MOORABOOL
SHIRE COUNCIL

ATTACHMENTS

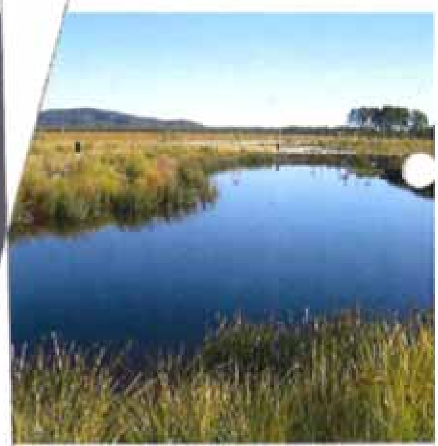
Ordinary Council Meeting
Under Separate Cover
Wednesday, 4 September 2019

Table of Contents

Peer Review

Moorabool Shire Flood Studies

V170467



Prepared for
Moorabool Shire Council

3 November 2017

Cardno
Shaping the Future

Attachment 1: Peer Review – Moorabool Shire Flood Studies

Contact Information

Cardno Victoria Pty Ltd
Cardno Victoria Pty Ltd
47 106 610 913

Level 4
501 Swanston Street
Melbourne 3000
Australia

www.cardno.com
Phone +61 3 8415 7777
Fax +61 3 8415 7788

Document Information

Prepared for	Moorabool Shire Council
Project Name	Moorabool Shire Flood Studies
File Reference	Document3
Job Reference	V170467
Date	3 November 2017
Version Number	Insert Version Number

Author(s):

Name Rob Swan
Principal Engineer

Effective Date 23/10/2017

Approved By:

Name Rob Swan
Manager, Water Engineering

Date Approved 23/10/2017

Document History

Version	Effective Date	Description of Revision	Prepared by:	Reviewed by:
0.1	28 July 2017	Initial draft	RCS	RCS
1	23 October 2017	Final Draft	RCS	RCS
2	2 November 2017	Final	RCS	RCS

Executive Summary

Mooroabool Shire Council, in conjuction with Melbourne Water, has prepared proposed Land Subject to Inundation and Special Building Overlays for potential inclusion into the Moorabool Planning Scheme. This peer review has investigated the technical methodology used to determine the location and shape of the proposed planning overlays.

In our view, the flood models used have delivered results that are suitable for inclusion in the Moorabool Planning Scheme. With the exception of the lower Lerderderg study area, the flood extents used in the draft planning overlays are considered appropriate. The proposed flood extents and the resulting Special Building Overlay (SBO) shapes for the lower Lerderderg study area should be recreated, based on the model results using appropriate filtering techniques, such as those described in Melbourne Water's 2016 technical specifications.

Once the lower Lerderderg flood mapping extent and resultant SBO shape is amended, it is recommended that the planning scheme amendment process be recommenced.

Table of Contents

Figures

Glossary of Terms

Airborne Laser Scanning (ALS)
A form of survey that uses a laser to scan the shape of an object or surface from a plane or other point. Also known as LiDAR

Average Exceedance Probability (AEP)
The chance of a given discharge or level value being exceeded in a given year. A 1% AEP flood event has a 1% chance of occurring in any year (and is equivalent to the 1 in 100 year ARI event).

The conversion from ARI to AEP is shown in the table below

ARI (years)	AEP (%)
1	63%
2	39%
5	18% (usually approximated as the 20% AEP)
10	10%
20	5%
50	2%
100	1%

Australian Height Datum (AHD)
A common national surface level datum approximately corresponding to mean sea level.

Australian Rainfall and Runoff (AR&R)
Australian Rainfall and Runoff is the industry standard resources for the estimation of flood flows in Australia.

Average Recurrence Interval (ARI)
The average or expected value of the period between exceedances of a given discharge or event. A 100-year ARI event would occur, on average, once every 100-years.

Catchment
The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.

Council
The Moorabool Shire Council

Design flood
A significant event to be considered in the design process; various works within the floodplain may have different design events. e.g. some roads may be designed to be overtopped in the 1 in 1 year or 100%AEP flood event.

Difference Plot
A map showing the difference in flood depth between two flood events.

Digital Elevation Model (DEM)
A digital elevation model is an electronic representation of the land surface, usually derived from a combination of data sources, including ALS and ground survey.

Discharge
The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.

Floodplain
Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.

HEC-RAS
A 1d hydraulic model, used to estimate water behaviour in rivers and creeks. HEC-RAS is freely available and is developed by the United State Army Core of Engineers.

Hydraulics
The term given to the study of water flow in a river, floodplain, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.

Hydrograph
A graph that shows how the discharge changes with time at any particular location.

Hydrology
The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.

Land Subject to Inundation Overlay (LSIO)	This is an overlay in the Moorabool planning scheme that provides for control of the development of land in areas subject to flooding from open watercourses
LIDAR	See Airborne Laser Scanning above
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Melbourne Water Corporation (MW)	The regional floodplain management and drainage authority.
Pluviograph	A recording of the rainfall depths over time. Typically this is recorded in millimetres at 6 minute intervals.
RORB	RORB is an industry standard hydrological model developed in Victoria at Monash University in the 1970's. It is freely available and widely used in Victoria
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In this report, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Runoff Coeffcient	The proportion of rainfall that becomes runoff, usually estimated in a hydrological model. Typically runoff coeffcients will increase as rainfall intensity and/or the proportion of hard surfaces increases.
Special Building Overlay (SBO)	This is an overlay in the Moorabool Planning Scheme that provides for control of the development of land in areas subject to flooding from formal drainage networks, including underground drains..
Topography	A surface which defines the ground level of a chosen area.
TUFLOW	A 1d2d hydraulic model used to predict the flow of water over land and through drainage infrastructure. TUFLOW is a commercially available model.

1 Introduction

The purpose of this peer review is to determine the suitability of the flood modelling and mapping processes in deriving the proposed Land Subject to Inundation Overlay (LSIO) and Special Building Overlay (SBO) for the Moorabool Planning Scheme Amendment C73. The key questions explored as part of the document are:

1. Was the data sufficient in quantity and quality to achieve fit for purpose flood risk modelling and mapping?
2. The LSIO and SBO maps were derived by using the hydrology model RORB and hydraulic models TUFLOW and HEC-RAS. Was the use of these models appropriate for the purpose of deriving planning scheme overlay maps?
3. Were the hydrology and hydraulic models set up with parameters that are within the normal range?
4. Have the hydrology results been incorporated correctly into the hydraulic model?
5. Are the model runs / results appropriate to produce fit for purpose flood extent mapping?
6. Have appropriate measures been used to produce the final flood extent mapping from the model results?

These questions can be answered through a thorough examination of the modelling processes used to derive the flood extents, a cross check of the methodology used to create the flood extents and assessment of the results against the community experience. We do note that for very severe flood events, especially around thunderstorm flooding, there may be no actual experience of this type of event.

1.1 Review procedure

The review has been completed to address the key queries above through the following methodology:

> Data Review

> Hydrological Modelling Review

> Hydraulic Modelling Review

> Flood Processing and Mapping Review.

For each section, any gaps and their expected impact in terms of accuracy of the overall flood shape and planning overlays have been highlighted

1.2 Projects Reviewed

There are a number of projects that form the inputs for the planning amendment. These projects utilised different hydraulic and hydrological modelling approaches and each will be assessed independently.

The three contributing flood mapping projects will for the main basis of the review plus additional mapping undertaken internally by Melbourne Water (known as the Planning Investigations studies.

The key documents to be reviewed as stated in the brief are:

- Report for Bacchus Marsh Area Floodplain Mapping (GHD, November 2010);
- Lower Lerderderg Catchments Flood Mapping Report (Engeny Water Management, December 2011);
- Ballan Township Flood Study, Final Report (Halcrow Pacific Pty Ltd, November 2011);
- Planning Investigations Methodology (Melbourne Water, 2015)
- Minutes of Special Meeting of Council – 22 June 2016; plus attachments to the agenda item.

The Planning Investigations Methodology is described in Appendix A.

2 Data Review

The three main projects that form the Overlay are:

- Bacchus Marsh Area Floodplain Mapping project (GHD, November 2010);
- Lower Lerderderg Catchments Flood Mapping project (Engeny Water Management, December 2011);
- Ballan Township Flood Study, (Halcrow Pacific Pty Ltd, November 2011);

These projects provide a detailed assessment of pre-existing data used for the purposes of the project. Cardno has undertaken a review of the datasets used in the derivation of the flood models to identify any gaps in the projects and their impact on flood mapping.

Melbourne Water's Planning Investigations team undertook flood analysis for a number of watercourses throughout the Moorabool Shire. The methodology and data used in these projects has been reviewed. These projects are collectively known as the Melbourne Water Planning Investigations models in this report.

2.1 Bacchus Marsh Area Floodplain Mapping Project

This project was undertaken by GHD after concerns were raised regarding the accuracy of an earlier study by WBM Oceanics Australia Pty Ltd (WBM), conducted for Council. The project used the following datasets:

> General MapInfo layers obtained from Melbourne Water during the course of the project:
  - Cadastral information (building footprints, properties, easements, road alignments);
  - Drainage data for Fisken St and Maddingley Park pipe drains;
  - 20 metre (m), 5 m, 1 m and 0.5 m contours of the Bacchus Marsh area;
  - Aerial photographs;
  - Bacchus Marsh Area flood extent (WBM Oceanics Australia Pty Ltd, 2006);
  - Bacchus Marsh Flood Risk Study (WBM Oceanics Australia Pty Ltd, 2006);
  - Data used to create the Digital Elevation Model (DEM) for the 2006 flood study, including surveyed cross-sections for the Werribee and Lerderderg Rivers;
  - TUFLOW model and GIS layers (WBM Oceanics Australia Pty Ltd, 2006);
  - RORB model and GIS layers(WBM Oceanics Australia Pty Ltd, 2006);
  - Thinned LiDAR data for the Bacchus Marsh area;
  - Survey drawings for bridges in the Bacchus Marsh Area; and
  - Benefit cost analysis model.

> Other data:
  - Bureau of Meteorology pluviograph data for stations 87017, 87039 and 87075;
  - Theiss flow data for stations 231200, 231201, 231204, 231211, 231213, 231222, 231230, 231234; and
  - Southern Rural Water (SRW) rating tables for Pykes Creek Reservoir, Melton Reservoir and Merrimu Reservoir.

Cardno has not identified any additional data sources that would be required to complete flood mapping for this project or that would increase the accuracy of the modelled flood results. GHD also undertook significant analysis and review of the previous WBM models of the area and appear to have an excellent understanding of the catchment area.

2.2 Lower Lerderderg Catchments Flood Mapping Project

This project was undertaken by Engeny Water Management and assessed the Melbourne Water main drains flowing into the lower Lerderderg River through Bacchus Marsh. Primarily, this project is for urban flood mapping, with the GHD Bacchus Marsh Area Floodplain Mapping project dealing with the main river and creek systems.

The project used the following data sources:

> Aerial photography;
> Pit and pipe data (Melbourne Water assets and Council assets);
> LiDAR terrain data;
> Main catchment boundaries;
> Contours;
> Planning zones;
> Cadastre boundaries;
> Previous reports; and
> Design data for the Cairns Drive retarding basin and other assets.

Cardno is of the view that the data sources listed are suitable for the development of urban flood models. It is noted that no calibration data is available from the historical flood events. This is not unusual for urban areas as the majority of data is collected along main rivers and creeks. In our view, the datasets used are suitable for the derivation of urban flooding.

2.3 Ballan Township Flood Study

This project was undertaken by Halcrow for the main drainage and creek lines through the Ballan Township area. Halcrow used the following data sources:

> Survey data (supplied by MW) – Existing Connell-Wagner site survey data included manhole and pit locations and levels, and terrain cross sections;
> LiDAR information (supplied by MW) – Received in comma separated value (CSV) format. This was used to create the digital terrain model (DTM) and this information supplemented the site survey where data was not available;
> GIS Melbourne Water asset data (supplied by MW) – Pipe locations with diameters, inverts and types. Pit locations were available but invert levels were not supplied;
> GIS Council asset data (supplied by Moorabool Council) – Pipe locations with diameter, inverts and type. Pit locations with inverts, entrance levels and type.
> Aerial photography (supplied by MW) – Covering all of Catchments A and B, and most of Catchment C. Site visit by Halcrow revealed the small area not covered by aerial photography was not significantly different from adjacent areas;
> Design storm data (procedure sourced from Australian Rainfall and Runoff (AR&R) Volume 1 (1998 reprint)
  - Intensity-Frequency-Duration (IFD) parameters for Ballan obtained from Australian Rainfall and Runoff, Volume 2 (1987), to develop the design storms used in the investigation;
> Probable Maximum Precipitation (PMP) design storm data (source -Generalised Short Duration Method (GSDM) 2003) – PMP parameter for the Ballan location obtained from the GSDM, to develop the design storms used in the investigation
> Hydrograph records of Werribee River (supplied by MW) - Flow gauge records, used to determine tailwater conditions.

Cardno is of the view that the data described above is suitable for the derivation of flood extents for the Ballan Township. Cardno is not aware of any additional data that would be useful for the Ballan Township modelling.

2.4 Melbourne Water Planning Investigations Models

These models were developed by Melbourne Water for the rural creeks in the Moorabool Shire. As the impacts of flooding on these creeks are usually limited to land inundation, they do not require the same level of information to develop reasonable flood extents for planning purposes. The Melbourne Water projects used the following information:

> Lidar Data to develop the model topography
> The existing Werribee River RORB model was used to derive overall catchments
> Land surface contours
> Melbourne Water Waterway alignment information.
> Storage information for major water storages including retarding basins and water reservoirs.

Cardno is of the view that these data sets are suitable for the derivation of indicative flood extents in rural areas of the Moorabool Shire.

2.5 Conclusions and recommendations

Based on our review, it is considered that the data used to derive the flood models in each project is suitable for the scale and type of project. Cardno is not aware of any additional data sources that would be required for accurate flood modelling of the Moorabool Shire.

3 Hydrological Modelling

Each project has used the RORB hydrological model to determine the catchment flows. RORB is an industry standard flood model developed in Victoria at Monash University in the 1970's. RORB is the most widely used hydrological model in Victoria and is the hydrological model required by Melbourne Water for flood mapping projects.

To estimate the expected catchment flows, RORB requires a number of inputs, including:

> Catchment and subcatchment sizes;

> The connectivity and flow lengths along streams, known as the model schematisation;

> An understanding of the river or stream form (stream, unlined channel,

> An empirical lag parameter, known as the k_c value, to modify how water is stored and routed through the model. It is important to note that this parameter is not determinable through the examination of the physical parameters of the catchment. K_c values can be determined by calibration and/or validation exercises or through the adoption of regional relationships;

> An estimate of the Fraction Impervious of each subcatchment.

The derivation of each of these parameters is discussed in the following sections for each project.

3.1 Catchment Delineation

For all projects, the catchment and subcatchment delineation has been undertaken based on land surface information. Cardno have reviewed the catchment delineation based on supplied catchment and subcatchment boundaries and available contour data.

For all models, the catchments used are consistient with the land surface contours and are appropriately sized for the nature of the project and the size of the catchments modelled. The subcatchment breakup is also appropriate. Some notes of importance include:

> The GHD model includes the entire Lerderderg River catchment. This is primarily a rural catchment and includes some significant storages.

> The model for the Lower Lerderderg area includes the Bacchus Marsh township. Subcatchment boundaries have been appropriately developed and are generally smaller than those used in the Bacchus Marsh Area Floodplain Mapping project. This allows a better definition of flows at the urban scale. Subcatchment boundaries are defined using appropriate topographical control, such as roads, railway lines and along property boundaries.

> The Ballan RORB model sub-catchments are appropriate. These catchments are generally relatively small in size, with clear delineation between existing rural and urban areas.

> The remaining rural area catchments, used by Melbourne Water to define rural stream flooding are subsets of the larger Werribee River model. These are considered to be appropriate for use.

Overall, Cardno considers the catchment and subcatchment delineation for all the RORB models is suitable for use in the derivation of floodway overlays and is consistent with best practice methods at the time of development.

3.2 RORB Model Schematisation

All the RORB models used in the project have been developed generally in accordance with Melbourne Water's technical specifications for flood mapping. Specifically:

> Reach types are consistent with on-ground conditions, including the use of natural, unlined, lined and drowned reaches.

> Diversions are appropriately considered

> Small farm dams are not specifically included in the model schematisations. This approach is considered to be conservative with regard to modelling and is consistent with normal flood modelling practice.

The schematisations of each model are suitable for the derivation of flood extents.

3.3 Derivation of Fraction Impervious Values

The fraction impervious value of a subcatchment is a measure of the hard surfaces that are directly connected to the drainage network as a proportion of the overall catchment area. This is one of the most important catchment characteristics in urban areas, as significantly more runoff is produced from impervious areas than from pervious areas. In general practice, the fraction imperviousness value of a subarea is based on the land use type, directly measured from aerial photography or a combination of these approaches.

Melbourne Water's technical specifications provide a guide for the expected fraction imperviousness value based on land use type. The values adopted in each project are shown in Table 3-1

Table 3-1 Fraction Impervious Values, Moorabool Shire Flood Projects

Land use	Bacchus Marsh	Lerderderg	Ballan	Melbourne Water
Residential Zones	0.5	0.5	Derived from Aerial photography indicatively 0.5	n/a
Road	0.6-0.7	0.6-0.7	0.6-0.7	0.6-0.7
Farm Zone	0.05	0.1	0.1	0.1
Schools	0.4-0.7 (site dependent)	0.7	0.5	n/a
Township Zones	0.3 (based on aerial photo)	0.2	0.3	0.2
Industrial/Commercial	0.9	0.9	0.9	n/a

Other areas were determined in all studies based on an examination of aerial photography. The values used in all studies are generally consistent and minor variations are to be expected. In our view, these values are consistent with the best practice approaches used at the time of the studies and are suitable for the derivation of flood extents.

3.4 Lag Parameter Kc

Each project has adopted a different method of determining the k_c factor, which is a lag parameter used in the model. This parameter accounts for local catchment storage and the speed of flow from the catchment. In general, for a catchment, lower k_c values means a fast response with a high peak flow, and higher k_c values indicate a slower catchment response with lower peak flows. The k_c parameter is also linked to the average flow length through a catchment, so a direct comparison of k_c values across catchments cannot be undertaken. K_c values are usually adopted based on calibration to known storm events, using regional methods based on a variety of catchments and/or comparison to other methods of flow estimation, usually the rational method.

3.4.1 Bacchus Marsh Flood Study

This project used recorded flow data for the Lerderderg and Werribee Rivers and recorded rainfall to estimate the k_c value based on real storm events. The model was assessed against three known storm events; November 1995, September 1993 and December 1987.

A good match was achieved for the recorded storm events and the model k_c was set based on these results. Validation was undertaken by running the design storm events for the model and comparing the results to a flood frequency analysis at each gauge using the design parameters. This approach is consistent with industry best practice.

3.4.2 Lower Lerderderg

The k_c parameter for the Lower Lerderderg RORB modelling was developed by estimating a peak flow rate using a rational method calculation and trialling k_c values until the flows at the catchment outlet in RORB matched. This approach is generally consistent with Melbourne Water's Flood Mapping Technical Specifications. The approach has been widely used in other studies across Melbourne. The k_c value was compared against the Dandenong Valley Authority Regional Method (which included Djerriwarrah Creek near Bacchus Marsh) and against the Department of Natural Resources and Environment (DNRE, now the Department of Environment, Land, Water and Planning) regression curves for catchments near the Great Dividing Range.

There are some minor issues with the approach adopted:

> Flow rates are only compared at the catchment outlet, however the hydraulic model area of interest starts well before the outlet. It would have been preferable to see some comparisons at the top of the Melbourne Water drainage network;

> The comparison to the DVA regional estimate is valid, although other estimates, such as Melbourne Water's Yarra values or the Victorian standard regional methods (e.g. Pearse, MAR <800, MAR >800) included in the RORB model may have been useful as a comparator.

> The models could have used a developed conditions case for the calculation of rational method flows, rather than a rural estimate.

Notwithstanding the above, the estimate of k_c is considered to be suitable for the development of the expected floodplain flows. It is possible that the flows estimated may be slightly lower than the actual 1% AEP flows based on the comparison with DNRE regional values.

3.4.3 Ballan Township

The k_c values in the Ballan Township RORB models were adopted by testing a range of regional methods for k_c generation and then comparing to a rational method calculation for each catchment. This provided a starting value for k_c. The method of Pearse was used as it provided the closest match to the 1% AEP flood event. The k_c value was then adjusted to provide the best match to this level, which included slightly increasing the estimate to lower the overall flow rates. As most of the catchments assessed in this study were rural, the comparison of RORB flows to the rational method is considered appropriate.

There are some minor issues with the analysis:

> Flow rates are only compared at the catchment outlet, however the hydraulic model area of interest starts well before the outlet. It would have been preferable to see some comparisons at the top of the Melbourne Water drainage network;

> It was noted that the RORB estimate of the critical storm event was much higher than that estimated by the rational method. This is likely due to the temporal pattern shapes of ARR 1987, where there are embedded bursts in the 9 hour pattern that are very close the those of the shorter durations. This is not an unexpected result.

> The adoption of runoff coefficients instead of continuous loss rates for rural catchments may also contribute to the longer storms being critical in RORB, but not in the estimates used in the Rational Method calculations. However, as the peak flow matches and the catchment flooding is not controlled by flood storage considerations this is considered minor.

Notwithstanding the above, the estimate of k_c is considered to be suitable for the development of the expected floodplain flows.

3.4.4 Melbourne Water Planning Investigations Models

The Melbourne Water RORB models have adopted k_c values based on the generalised regional equation found in the RORB manual. This is considered reasonable based on the rural nature of the catchments and tends to provide a higher value of k_c than some of the other regional methods. This would tend to result in a lower estimate of 1% AEP flows. The k_c values adopted are considered suitable for the assessment of floodplains in these rural areas.

3.5 Model Outputs

Each project has used the hydrograph outputs from the RORB model as inputs to their hydraulic model. This is standard practice in floodplain modelling. Our review indicates that model flows have been taken at appropriate locations in each hydrological model.

3.6 Conclusions

The hydrological modelling undertaken for each project in the Moorabool Shire is generally consistent with standard engineering practice for floodplain modelling. Our review has identified some potential minor issues with the assessment of RORB lag parameters in the Lower Lerderderg and Ballan model areas, however we consider that the impact on the results are very minor and would not lead to a significant change in the expected design flood hydrographs.

In our view, the hydrological models have been appropriately developed and are suitable for floodplain mapping in the Moorabool Shire.

4 Hydraulic Modelling and Flood Extents

In order to determine flood extents, hydraulic models are used. Hydraulic models calculate the water depth and flow velocity of water by solving the St Venant Equations for shallow water flow. The models used to determine the flood extents in the Moorabool Shire were:

> HEC-RAS – an industry standard one-dimensional (1D) hydraulic model developed by the US Army Core of Engineers. HEC-RAS is a well-established hydraulic model suitable for the analysis of flows in rivers and through floodplains where the flow direction is well understood (such as down a river valley). HEC-RAS can model both dynamic and steady state flows and mixed flow regimes. Branching flows are not allowed in standard versions of HEC-RAS
>
> HEC-RAS was used in all the projects undertaken by Melbourne Water's Investigations team and for two of the catchments in the Ballan Township Study where there were no underground drainage assets.

> XP-STORM – XP-STORM is a 1D hydraulic model developed by XP Software in Australia. XP-Storm is widely used for the analysis of drainage networks. In contrast to HEC-RAS, XP-STORM can model branched networks and include consideration of both piped underground drainage and overland flow paths simultaneously. The model is fully dynamic and can accurately calculate flood levels based on both storage and flow considerations
>
> XP-STORM was used in the Ballan Township Flood Mapping Project for catchment areas that included existing underground drainage networks

> TUFLOW (Including ESTRY1D) – The TUFLOW hydraulic model is widely used in Australia for the analysis of flood flows. TUFLOW is a two-dimensional (2D) model, meaning that the model calculates the flow directions based on the topography of the land surface, as opposed to a 1D model where the modeller must decide the flow direction. TUFLOW includes the ESTRY 1D model, allowing for the consideration of pipe and channel flows where the flow behaviour is inherently 1D in nature. This type of model represents industry best practice for the analysis of urban and rural floodplain flows. 2D models are particularly useful in the derivation of flood extents through complex flow areas, such as urban areas and branching floodplains.
>
> TUFLOW was used in the Bacchus Marsh and Lower Lerderderg flood mapping projects.

The models chosen are all used widely to derive floodplain flows. We have reviewed the overall schematisation of each flood model and found that they are generally well constructed and suitable for use. These models have been constructed in accordance with Melbourne Water's Technical Specification for Flood Mapping that was applicable at the time of each model being constructed. This specification is widely used around the Melbourne Metropolitan region and has been adopted by many municipalities as the standard specification for flood mapping. The specification ensures that all properties in the wider Melbourne area are treated equally in the provision of flood mapping services and that decisions made on the extent of the flood overlays are consistent.

Cardno has reviewed each model based on its schematisation, general model parameters, flow boundaries and downstream boundaries. This review has included the detailed examination of the model reporting and run files as appropriate.

4.1 Bacchus Marsh Flood Model

The Bacchus Marsh flood model is a large Tuflow model covering the riverine floodplains of the Lerderderg and Werribee Rivers, Parwan Creek and the floodplain of the Maddingley Park and Fisken Street Drains. The model did not include main drainage discharging to the Lerderderg River (covered by the Lower Lerderderg Flood Study).

We have reviewed the model and can advise that:

> It uses a topographic definition derived from LIDAR and river survey. The model adopted an 8m grid resolution, which is considered reasonable for the riverine flooding expected through the study area.

- The model included 1D sections for the main river channels and used a variety of structure types to represent channel features including bridges and weirs in the schematisation.
- The performance characteristics of some bridges were calculated using the HEC-RAS model and used in the TUFLOW model description. This is standard practice for some complex structure types.
- Mannings friction values are consistent with Melbourne Water's technical specification and are considered reasonable for the floodplain based on our experience. The model was calibrated to known storm events that provided some insight into the appropriate Mannings values
- Flows from upstream areas were introduced as hydrographs at appropriate locations. These matched the RORB output hydrographs.
- Where appropriate, local catchment inflows were introduced directly to the Melbourne Water Main Drains at each 'pit' along the length of the drain. This simulates the distribution inflow from local council drainage (that was not modelled) and is considered standard practice for these projects.
- Where there was no Melbourne Water drain, local inflows were introduced as 2D-sa boundaries. This type of boundary applies catchment flows to the lowest grid cells in an area specified by the modeller. The use of this boundary type is appropriate for the catchment.
- The model achieves a reasonable calibration to known storm events, especially adjacent to the township for both the Werribee and Lerderderg Rivers. The report provides valid examples of the errors in recorded data that can cause calibration to be a difficult process. In our view the calibration results appear to provide some certainty that the model is producing results that suitably replicate floodplain flows.
- An area not explored is the potential error in the gauging records. It is understood that the calibrated RORB model inflows are used in the input data. The accuracy of the gauged flow record, inferred from a rating curve) is not mentioned in the report. In our experience, the gauge records are often not well measured at very high stages. This may lead to some errors when calibrating as the modelled flow rates may not represent the actual flows at a certain stage. The effect of this is considered minor, as the calibration results are generally within 200 – 250 mm of the recorded levels at the key locations.
- The results from the 8m model grid were interpolated to provide a 1m resolution output. While this provides a smooth surface, the actual flood behaviour may not be representative at every location. This is considered a minor issue as the interpolation distance is short and the floodplain flow widths are relatively wide. This limitation is appropriately acknowledged in the report.
- Flood extents created from the results of the flood mapping project are consistent with the expected flood shapes based on the topography of the Bacchus Marsh area.

The Bacchus Marsh flood model and the flood extents created are considered to be suitable for the creation of planning scheme overlays.

4.2 Lower Lerderderg Catchments Flood Mapping Project

The Lower Lerderderg Catchments Flood Mapping project includes the urban drainage networks of Bacchus Marsh, including Melbourne Water main drains flowing into the lower Lerderderg River. The model area covers the following main drainage catchments:

- Robertsons Road Drain
- Cairns Drive Drain
- Grey Street Drain
- Masons Lane Drain
- Lerderderg Street Drain

Our review of the model indicates that:

- The model adopts a 3m topographic grid definition, and extends beyond the Melbourne Water drainage network, including some areas of Council drainage;
- The model includes consideration of the Dickson Street retarding basin explicitly in the model definition

> The drainage network includes a number of Council and Melbourne Water pipes and open channels. It was noted that in two locations, the invert levels used in the model appeared to be incorrect, resulting in an uphill grade to the pipe. In the 1% flood event, these pipes are flowing under head and the water level on the land surface will control the actual pipe flow. It is considered that these minor issues would not result in any significant change in the flood extent.

> The pipes that have the incorrect slope occur in the council network and the flood extents used in the SBO start at the Melbourne Water drainage network. This further lessens the impact of the uphill pipe slope as floodwaters can re-enter the network downstream as capacity allows.

> Pits have been modelled as side entry pits with a limited opening at street level. As all pits and pipe in the network are not modelled, this may lead to the flood extent being larger than if a free flow of water was allowed between the underground and overland flow networks. For a 1% storm event, where flows are introduced directly to the pipe network, this is likely to have little or no impact on the expected flood levels.

> Pit losses were included in the model using the Engelhund method. This is considered appropriate for the catchment.

> The model includes 3 main methods of introducing catchment flows into the model:

- Flow inputs at the upstream end of the models using 2d-sa boundaries.
- Flow input directly to the pipe network, distributed evenly into the pits on a subcatchment basis.
- Subcatchment flows in rural reaches, input to the model as direct rainfall boundaries.

> The flow boundaries for individual subcatchments are taken from the RORB model as unrouted flows. This means that no attenution of the flow is assumed prior to it being introduced to the hydraulic model, resulting in higher peak flows at each input location. In general, we would recommend that routed flows be used where subcatchment inflows are being introduced only to main drainage lines. This enables some attenuation to occur as would be expected as flows progress to the main drainage network.

To examine the effect this has on the proposed overlays, Cardno ran the 1% AEP, 60 minute storm event with routed hydrographs extracted from the RORB mode outputs for the Lower Lerderderg model. The results of the assessment are shown in Figure 4-1 below, with blue areas showing the exhibited flood extent and green areas showing the flood extent with flow routing included.

The effect of using the routed flows as input boundaries results in a small reduction in the overall flood extent in the 60 minute event. Our analysis indicated that out of approximately 450 impacted properties in the original flood extent, about 40 would no longer be considered flooded in this specific event. The original flood extent as exhibited could be considered a reasonable upper estimate of the 1% AEP flood extent as the differences are relatively minor. In some modelled catchments, there was no difference between the flood extents in this event. The effect of this change is expected to be less in longer storm events.

As such, it is considered that although the extents exhibited are slightly conservative, they provide a reasonable estimate of the 1% AEP flood.

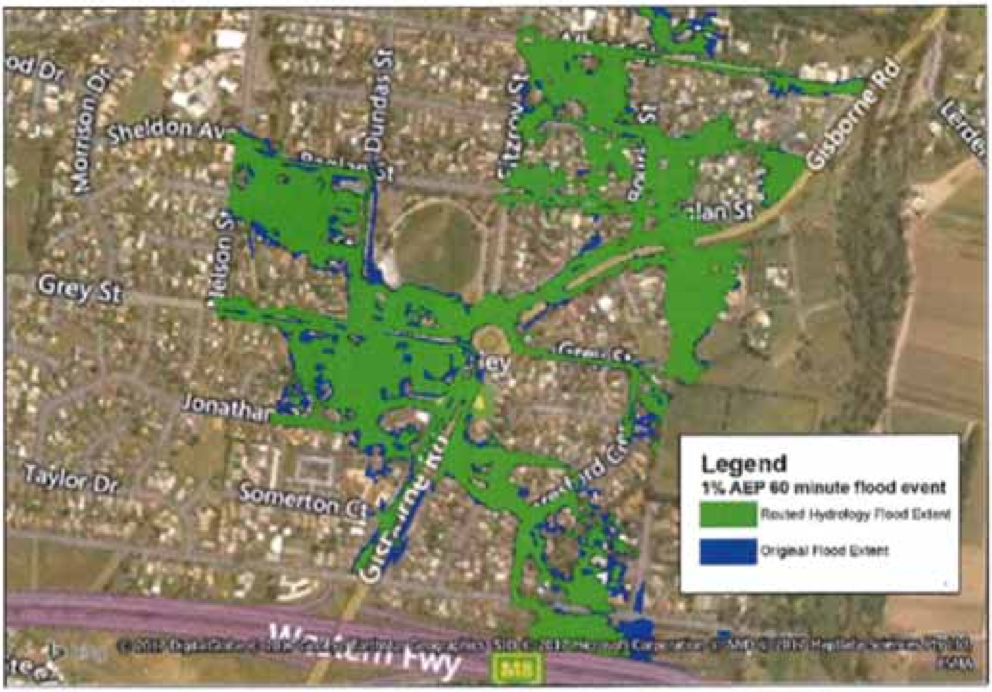


Figure 4-1 Flood Extent Comparison, Routed Hydrology inputs 1% AEP 60 minute flood event

> It was noted that the flood extent as exhibited, south of the Western Freeway, covers the entirety of the farming land between Mason's Lane and Lerderderg Street as shown in Figure 4-2. This flood shape does not match that shown in the Engeny report for this location (Figure 1 in the Engeny report, reproduced here as Figure 4-3). This is likely due to the flood extent in this area being created using a process that is now deprecated by Melbourne Water.

At the time of this project, Melbourne Water adopted a technique known as the 'point density method' to create flood extents based on the density of flooded areas predicted by a flood model. These extents did not appropriately take into account the actual hydraulic behaviour of the water and instead were used as they created a smooth boundary. As this location used a direct rainfall boundary, all grid cells in the area are 'wet' by the model and return a flow value. It appears that these shallow flood values were not appropriately filtered by Melbourne Water prior to creating the flood shape.

In our view, flood extents generated using the point density method should not be used in planning scheme overlays. It is recommended that the flood extents generated in the Lower Lerderderg catchments be re-examined and updated as necessary based on Melbourne Water's updated process to determine flood extents. The appropriate starting point would be the flood extents shown in the Lower Lerderderg Catchments Flood Mapping report, Figures 1 and 2.

It should be noted that this is not considered a modelling error but rather a data analysis error. We have noted other minor differences in the flood extents shown in the figures in the Lower Lerderderg report compared to the proposed SBO extent. This is likely due to the same issue.

Cardno considers that the proposed SBO extent does not appropriately reflect the results of the flood modelling for the Lower Lerderderg area. The proposed SBO should be modified to reflect the actual results of the flood modelling.

Figure 4-2 Exhibited SBO Extent, near Masons Lane

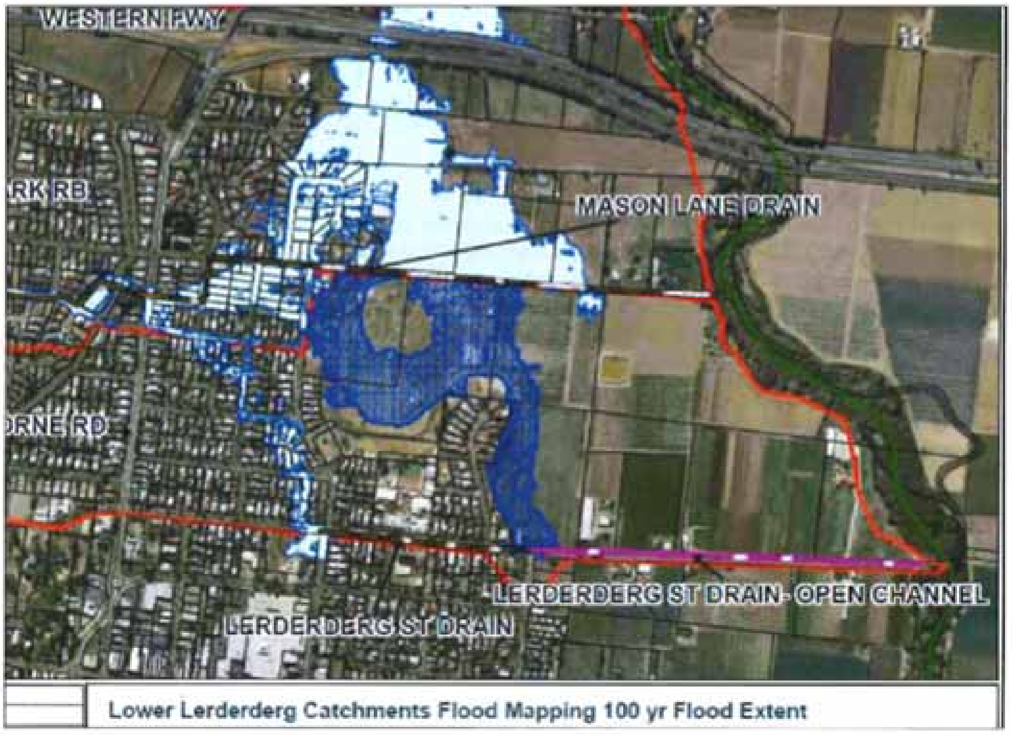


Figure 4-3 Model derived flood extent near Mason's Lane (after Engeny, 2011)

The modelling completed for the Lower Lerderderg study area likely provides a conservative flood extent, but is considered suitable for the derivation of flood extents for planning purposes. However, the exhibited shape does not appear to appropriately represent the results of the flood model, due to the algorithm adopted by Melbourne Water to smooth the flood extent. This algorithm is no longer used as it does not appropriately consider the hydraulic properties of the land. The flood extent needs to be recreated using the current Melbourne Water process.

4.3 Ballan Township Modelling

The Ballan township project used HEC-RAS and XP-STORM to model the flowpaths of three drainage catchments in the township. The catchments all ultimately drain to the Werribee River and primarily consist rural land with some township areas. Significant flow constrictions occur at road and rail formations, including the Western Highway and the Melbourne Ararat rail line.

Our review of the modelling indicates:

> For catchments A and C, modelling was completed using HEC-RAS. This model is considered to be suitable as there are no branching flowpaths and the floodplain is well defined by the creek valley.

> Catchment B uses the XP-STORM model as the catchment area includes the Gosling Street Drain and requires consideration of both underground and overland flow. The model chosen is suitable for the requirements of the project.

> In all models, the catchment cross sections are appropriately defined and are suitably spaced to define the flood behaviour. The extrapolation of cross sections using LIDAR is also considered appropriate as the ground survey contains the main creek channel, which can be difficult to capture using LIDAR. The floodplain shape will be well defined by the LIDAR data.

> The downstream boundary conditions adopted the 10% AEP river level for the Werribee River. This level provides a high tailwater condition without being too conservative. The use of the 10% AEP flood level as the downstream boundary is consistent with general industry practice.

> Manning's roughness values are consistent with industry standards for open channels and floodplains. The modelling has adopted the conservative approach of using the higher range of roughness values, thereby representing the maximum seasonal growth. This would raise the flood levels slightly compared to the average conditions, but is considered appropriate for large flood events.

> Flood extents were created by interpolating levels between model cross sections to develop a water surface. This surface was then intersected with the land surface to define the inundated area. This process is standard practice to derive flood extents from 1D flood models.

The models and flood extents produced in the Ballan Flood Study are suitable for use in planning scheme overlays.

4.4 Melbourne Water Planning Investigations

Melbourne Water's internal Planning Investigations team undertook HEC-RAS modelling of numerous creeks and rivers in the Moorabool Shire, including:

> Dale Creek

> Djerriwarah Creek

> Goodman Creek

> Korkuperrimul Creek

> The Lerderderg River (upstream of Bacchus Marsh)

> Myrniong Creek

> Stony Hut Creek

As part of this review we have not examined in detail every model provided by Melbourne Water. This is because the general methodology is consistent across the Melbourne Water projects.

Our review of the modelling indicates:

> For the majority of the models, floodplain cross sections were created using LIDAR data. This will generally provide a conservative flood extent as the invert detail of the creek channel may not be fully captured in the survey. As the areas mapped by Melbourne Water are mostly rural in nature, the effect of this is considered to be low. It is unlikely that any additional properties would be identified as being at risk of flooding as a result of the cross section definitions. Using LIDAR to define cross sections in rural areas is a reasonable approach for these projects.

> The Lerderderg River HEC-RAS model used surveyed cross sections captured on site by Melbourne Water. This included capture of bridges and other flow structures

> For smaller creeks catchments, such as Dale Creek, road crossings and culverts were included only where information was available detailing their size and shape. For smaller creeks, this approach will still identify land that may be subject to inundation in rural areas as the models effectively follow the valley line. The exact flood shape may be over or underestimated near individual crossings, depending on the assumptions made regarding that crossing.

> Flood extents have been created in a similar manner to those in Ballan Flood Study. This is considered appropriate for the type of flooding that is expected to occur.

In our view, the Melbourne Water Planning Investigations models and the flood extents derived from them are suitable for the derivation of planning overlays.

4.5 Conclusions

Cardno has drawn the following conclusions based on our review of the hydraulic models and the derivation of flood shapes:

> All the hydraulic models used in the derivation of the proposed Moorabool LSIO and SBO are considered to be suitable for the purpose of developing flood extents and are consistent with good flood mapping practice.

> For the Lower Lerderderg model, the method of introducing the hydrological model flows into the hydraulic model is likely to result in a conservative determination of flood levels. Indicatively, the change in the flood extent impacts less than 10% of the total number of properties identified as subject to inundation. It is considered that remodelling is not required as conservative flood shapes fulfil the requirements of the planning scheme and provide a reasonable estimate of the area subject to flooding

> For the Ballan models, the choice of the high roughness to simulate the maximum seasonal growth of vegetation is considered an appropriate assumption and in line with best practice for the derivation of lands that may be subject to inundation in a 1% AEP flood event.

> The Melbourne Water Planning Investigations models provide suitable definition of the expected flood extents in rural areas and appropriately identify land that may be subject to flooding.

> For the Lower Lerderderg model area, the flood shape proposed in the SBO appears to have been derived using Melbourne Water's 'Point Density Method'. The shape does not match that shown in the Lower Lerderderg Catchments Flood Mapping report. Flood shapes derived using the Point Density Method cannot be supported for use in planning scheme overlays as they do not define the flood shape based on hydraulic properties. As a matter of urgency, the flood shapes should be recreated, based on the current Melbourne Water guidelines adopting standard filtering and smoothing parameters. This change is likely to remove some properties from the flood shape and include others, however the magnitude of the change is expected to be small.

5 Conclusions and Recommendations

Based on Cardno's review of the models, the key questions posed in the introduction can be answered.

5.1 Was the data sufficient in quantity and quality to achieve fit for purpose flood risk modelling and mapping?

The data used in each project is sufficient in quantity and quality to achieve fit for purpose flood risk modelling and mapping. There were no major data sources identified that would have modified the results of the investigations.

5.2 The LSIO and SBO maps were derived by using the hydrology model RORB and hydraulic modes TUFLOW and HEC-RAS. Was the use of these models appropriate for the purpose of deriving planning scheme overlay maps?

The hydrological and hydraulic models used are suitable for the derivation of planning scheme overlay maps. The models chosen are widely used in Victoria for these purposes.

5.3 Were the hydrology and hydraulic models set up with parameters that are within the normal range?

All models were set up with parameters that are within the generally accepted ranges for models of this type in similar areas.

5.4 Have the hydrology results been incorporated correctly into the hydraulic model?

The hydrological model results have generally been incorporated correctly into the hydraulic models. Some subcatchment inflows in the Lower Lerderderg study area were incorporated into the hydraulic model without any routing, which may slightly overestimate the flood flows, however, they do not impact on flood volume. Cardno has tested adopting routed hydrographs in the Lower Lerderderg model area. For some subcatchments, this resulted in a slight reduction in the overall flood extent when compared to the results from the original project.

In a planning context, the model results from Lower Lerderderg Catchments Flood Planning project meet the objectives of the planning scheme and can be used to develop LSIO and SBO overlays. The results are considered to be a reasonable upper estimate of the likely flood extent.

5.5 Are the model runs / results appropriate to produce fit for purpose flood extent mapping?

The model runs and results in all hydraulic models are considered to be appropriate for the derivation of flood extent mapping

5.6 Have appropriate measures been used to produce the final flood extent mapping from the model results?

With the exception of the Lower Lerderderg study area, the flood extents used in the draft planning overlays are considered appropriate.

The flood extents created by Melbourne Water for Lower Lerderderg study area should not be used as the planning overlays. The proposed flood extents and the resulting SBO shapes in these areas should be recreated based on the model results using appropriate filtering techniques, such as those described in Melbourne Water's 2016 technical specifications.

5.7 Recommendations

In our view, the models used have delivered results that are suitable for inclusion in the Moorabool Planning Scheme. Once the Lower Lerderderg flood mapping extent and resultant SBO shape is amended, it is recommended that the planning scheme amendment process be recommenced.

Moorabool Shire Flood Studies

APPENDIX A

PLANNING INVESTIGATIONS METHODOLOGY

Cardno

Memo

To	Mike Kearney	From	Rushiru Kanakaratne
CC			
Date	19 February 2015	Subject	Werribee River Flood mapping

Dear Mike,

The flood mapping of Werribee River and its tributaries in the Moorabool Shire area was done using RORB and HEC-RAS models. The region was mapped using a series of these models in sequence; not a single large model what covered the whole area.

RORB

RORB models were used to estimate the flows for each of the mapping exercises. Werribee River had an existing RORB model that covered the entire catchment but smaller models were developed for the tributaries. The smaller models were necessary for better calibration. Lidar based surface contours were used to draw catchment boundaries and define reaches. All major storages (RBs and reservoirs) were included in these models but smaller storages (ponding upstream of road/rail embankments, farm dams) were not included.

HEC-RAS

The hydraulic modelling was done using HEC-RAS. The cross sections in HEC-RAS were generated from Lidar point data, not field survey. Crossings and culverts were included only where such information was available. Most crossings in this area are not modelled due to the lack of information. Downstream boundary levels were taken from exiting flood mapping.

Flood Extents

The results from HEC-RAS were used in conjunction with surface contours to generate the flood extents. Preliminary extents were generated using software such as 12d or Engage 3d and then refined manually.

In these models only the 100yr ARI flood event was considered.

Yours Sincerely

RUSHIRU KANAKARATNE
INVESTIGATIONS ENGINEER
FLOODPLAIN INVESTIGATIONS

Cardno Note: In many of the supplied Melbourne Water project files, there was additional model specific information provided. The general modelling approach was identical to that described in the Memo above.

Attachment 2: Responsibilities of Melbourne Water and Moorabool Shire Council

In Victoria, effective floodplain management is a responsibility of Melbourne Water and catchment management authorities (CMAs) in partnership with local government. For Moorabool Shire, the floodplain management authorities are Melbourne Water for the Port Phillip catchment area in the eastern half of the Shire, and Corangamite Catchment Management Authority for the western half of the Shire. This partnership is spelt out clearly in clause 13.2 of the Victorian Floodplain Management Strategy (DELWP, 2016) which states that *"the CMAs and Melbourne Water will work with LGAs to ensure that planning schemes use the planning controls that align with their flood risks"*.

Under Section 4(2) of the *Planning and Environment Act 1987*, one of the objectives of the planning framework established by the Act is *"to ensure sound, strategic planning and co-ordinated action at State, regional and municipal levels"*.

The State Planning Policy Framework (SPPF) of the Moorabool Planning Scheme includes a *'Floodplain Management'* policy under Clause 13.02-1, which has objectives for protecting life, property and community infrastructure, and for protecting natural flood carrying capacity, flood storage and floodplain areas of environmental significance. One of the strategies listed under Clause 13.02-1 is to *"identify land affected by flooding, including floodway areas, as verified by the relevant floodplain management authority, in planning scheme maps. Land affected by flooding is land inundate by the 1 in 100 year flood event or as determined by the floodplain management authority"*.

As a planning authority, Council has a legal obligation under Section 12(1) of the *Planning and Environment Act 1987* to implement the objectives of planning in Victoria. By introducing appropriate flood controls into the Moorabool Planning Scheme, Council would ensure that flood risk is considered in land development decisions, thereby implementing the following objectives of planning as set out under Section 4(1) of the Act:

- To provide for the fair, orderly, economic and sustainable use, and development of land;
- To provide for the protection of natural and man-made resources and the maintenance of ecological processes and genetic diversity;
- To secure a pleasant, efficient and safe working, living and recreational environment for all Victorians and visitors to Victoria; and
- To balance the present and future interests of all Victorians.

The above policies and statutory obligations provided the impetus for Melbourne Water to expend over $100,000 in modelling flood risk in Moorabool Shire, leading to the preparation of Amendment C73. Similar exercises were also carried out by Melbourne Water in partnership with City of Manningham (Amendment C109), City of Yarra (Amendment C201), City of Monee Valley (Amendment C151) and City of Port Phillip (Amendment C111) amongst others.

Attachment 3: Relevant Extracts from Moorabool Planning Scheme:

21.02 NATURAL ENVIRONMENT
10/11/2011
C57

21.02-1 Key Issues and Influences
26/02/2009
C34

Flood Management

- Large areas of the Moorabool Shire are prone to flooding as the Moorabool, Werribee, and Lerderderg Rivers flow through the Shire.

21.02-7 Implementation
[illegible]
C34

Zones and Overlays

Specific application of zones and overlays to achieve the strategic objectives includes:

- Apply relevant overlays (VPO or ESO) to reflect biodiversity mapping of the Shire when completed;
- Apply Erosion Management Overlay (EMO) and Salinity Management Overlays (SMO) to reflect land capability across the Shire;
- Apply Floodway Overlay (FO) and Land Subject to Inundation Overlays (LSIO) to reflect relevant Council flood studies;
- Apply Significant Landscape Overlay (SLO) to ridgelines, escarpments, and hilltops; and
- Apply Wildfire Management Overlay to areas of fire risk.

21.02-8 Further Strategic Work
16/11/2011
C57

- Complete the biodiversity mapping project.
- Undertake studies to further identify areas subject to flooding and areas subject to poor drainage.
- Undertake erosion studies to inform the incorporation of the Erosion Management Overlay.
- Undertake salinity mapping to inform the incorporation of the Salinity Management Overlay.
- Investigate an appropriate buffer zone around the Ballan and Parwan Waste Water Plants in conjunction with the relevant Water Authorities, and develop ESO's within these buffers in conjunction with the Water Authorities and the EPA.

Attachment 4: Why flood extent mapping is urgently required in the Moorabool Planning Scheme

1. The Victorian Floods Review found that land use planning and building controls were generally more cost effective than flood mitigation infrastructure, flood warning systems, education or emergency responses.

2. As discussed above, Council has a legal obligation under Section 12(1) of the *Planning and Environment Act 1987* to implement the objectives of planning in Victoria. Section 6(2)(e) of the Act also provides for *"planning schemes to regulate or prohibit any use or development in hazardous areas or in areas which are likely to become hazardous areas"*. Because it is possible to predict which land is likely to be flooded, it is prudent to regulate development and building in those areas to ensure any impacts are known and managed. In so doing, the aim is to avoid or minimise the increase in future flood risks.

3. Enhanced effort in municipal planning, supported by increased knowledge of flood hazards, will go a long way towards securing resilience to floods. Flood overlays need to be introduced or updated as soon as possible after new flood maps are produced to maximise the returns on investment in flood information and help manage risk.

4. The *Victorian Floodplain Management Strategy* (DELWP, 2016) sets the direction for floodplain management in Victoria. The Strategy supports communities by clarifying the roles and responsibilities of government, agencies and authorities involved in floodplain management for land use planning and infrastructure management. It also focuses on the development and sharing of high quality flood risk information that can be used for improved planning, flood warning and flood response. Key elements of the Strategy include:

   Policy 13c: *"LGAs with areas at risk of a 1% annual exceedance probability flood must ensure that their planning scheme contains:*
   - *the objectives and strategies for managing the risk in the Municipal Strategic Statement;*
   - *the appropriate zone and overlays."*

   Accountability 13a: *"LGAs are accountable for ensuring that their planning schemes correctly identify the areas at risk of a 1% annual exceedance probability flood, and contain the appropriate objectives and strategies to guide decisions in exercising land use controls in regard to flooding".*

5. Melbourne Water has legislative responsibilities as the floodplain management authority for the Port Phillip and Westernport catchments.

6. At present there is a lack of alignment between the planning scheme and building regulation system in Moorabool Shire. The Moorabool Planning Scheme currently does not contain any overlays to identify areas affected by flooding and overland drainage, despite State and local policies that suggest there should be flood extent mapping. Consequently, a planning permit is not required for many types of buildings and works and flood risk may not be identified until such time as the developer applies for a building permit.

Even if a planning permit is required for a particular development, without the appropriate flood overlays and permit triggers, flood risk may not be taken into consideration. Thus, there is currently potential for a planning permit to be issued for a development without due consideration of flood risk, and there have been cases where this has occurred. In such scenarios, the developer may subsequently have difficulty obtaining a building permit, or may be required to alter the design (e.g. reduce building footprint or raise floor levels). This may result in Council being accused of not fulfilling its duty as a planning authority or responsible authority under the *Planning and Environment Act 1987*. There is a high risk of litigation for building surveyors and Council staff, especially planners who may not even be aware of flood risk during pre-permit negotiations. Such risk would be alleviated if flood risk was identified and considered as early as possible in overall development concept design (i.e. the planning phase).

Upon application for a building permit or sale of property, Council issues a certificate under Regulation 326 of the Building Regulations 2006 (see Attachment 4), which requires identification of whether land is subject to flood risk. Council officers currently use the latest flood extent mapping prepared by Melbourne Water (i.e. the same mapping as exhibited under Amendment C73), to determine whether land is liable to flooding. Thus, the abandonment of Amendment C73 did not remove the mapping of flood risk or the obligation of landowners to comply with Melbourne Water requirements.

If the land is liable to flooding, a building permit applicant must obtain the 'report and consent' of Council prior to obtaining a permit. Council must not give its consent if it is of the opinion that there is likely to be a danger to the life, health or safety of the occupants of the building due to flooding of the site. In its report, Council may specify a minimum floor level for the building. Before specifying a floor level, Council *"must:*

a) consult with the floodplain management authority for that site; and
b) specify a level at least 300mm above any flood levels declared under the Water Act 1989 or otherwise determined by the floodplain management authority, unless the authority consents to a lower floor level."

7. Melbourne Water has no timeline or capital works programme to remove flooding risk from Bacchus Marsh, Ballan or other impacted areas. Melbourne Water is faced by many competing priorities – see point 1.

8. Reputation risk to Council in implementing M2041, all of which involves whole-of-government cooperation in data sharing, goal setting and infrastructure delivery. Land use planning starts with strategic planning which must consider threats from natural hazards such as bushfire and floods.

Attachment 5: **Revised flood extent mapping (SBO) for the lower Lerderderg study area**

Flood Related Planning Controls

Moorabool

V171804

Prepared for
Moorabool Shire Council & Melbourne Water

16 January 2018

Cardno

Contact Information

Cardno Victoria Pty Ltd
ABN 47 106 610 913

Level 4
501 Swanston Street
Melbourne 3000
Australia

www.cardno.com
Phone +61 3 8415 7777
Fax +61 3 8415 7788

Document Information

Prepared for	Moorabool Shire Council & Melbourne Water
Project Name	Moorabool
File Reference	V171604_R001_V001.docx
Job Reference	V171604
Date	16 January 2018
Version Number	001, Client Issue

Author(s):

Name Ailsa Veldema
Job title Senior Flood Analyst

Effective Date 16/01/2018

Approved By:

Name Ailsa Veldema
Job title Senior Flood Analyst

Date Approved 16/01/2018

Document History

Version	Effective Date	Description of Revision	Prepared by	Reviewed by
001	01/12/17	Client Issue	Ailsa Veldema	Ailsa Veldema
002	16/01/18	Final	Ailsa Veldema	Ailsa Veldema

Table of Contents

Figures

1 Introduction

This has been prepared to accompany the proposed Special Building Overlay (SBO) for Moorabool, December 2017. It provides a background, describes what information has been used in the development and provides details of the overlay.

2 Background

Melbourne Water (MW) and Moorabool Shire Council (Council) prepared flood related planning overlays for potential inclusion into the Moorabool Planning Scheme. The overlays consisted of proposed Land Subject to Inundation Overlays (LSIO) and Special Building Overlays (SBO). MW and Council engaged Cardno to undertake an independent review of the technical methodology used to determine the location and shape of the proposed planning overlays. The report 'Peer Review Moorabool Shire Flood Modelling' (V170467, November 2017) documents the review.

It was concluded that the flood model from the Lower Lerderderg Catchments Flood Mapping project was suitable for use. However, the methodology adopted to convert the outputs to a planning overlay should be modified and the overlays be amended accordingly.

3 Information used and Methodology

Hydraulic modelling results from the Lower Lerderderg Catchments Flood Mapping project were used as inputs into the flood overlay and the process below followed.

> Step 1: Filter flood results to remove areas with shallow (less than 0.05 m) flooding;

> Step 2: Combine the above results into a single shape and remove both wet "puddles" or dry "islands" if the area is less than 100 m².

> Step 3: Smooth the shape to remove the 'staircase' effect associated with modelling grid cells.

> Step 4: Split the shape into MW and Council controlled areas based on the splits adopted in the previous overlays and on the source of flooding (i.e. if inundation emanates from a MW asset then is classified as MW flooding). Remove the Council areas as the amendment is for MW controlled areas only.

> Step 5: Based on MW's document 'Finalising Flood Extents for Inclusion in Planning Schemes' review the overlay at the property scale. In summary, properties which had less than 2% of their total area inundated were considered for removal. If more than 25% of their frontage was affected or the area is considered at risk based on the various flood depths experienced, the overlay was retained on the property.

The draft overlay produced using the above process was supplied to MW for review. During this review an area (at Cairns Drive DS) was updated by MW to be more reflective of the topography which had recently been significantly modified as part of development works.

4 Overlays

The revised Special Building Overlay is shown on Figure 4-1 overleaf.

Figure 4-2 shows this proposed overlay alongside the previously exhibited overlay. Whilst there are a number of changes, the key area of change is in the rural land south of Masons Lane. The proposed overlay is significantly reduced from that which was previously exhibited.

It is recommended that the proposed SBO is adopted and the planning scheme amendment process be recommenced.

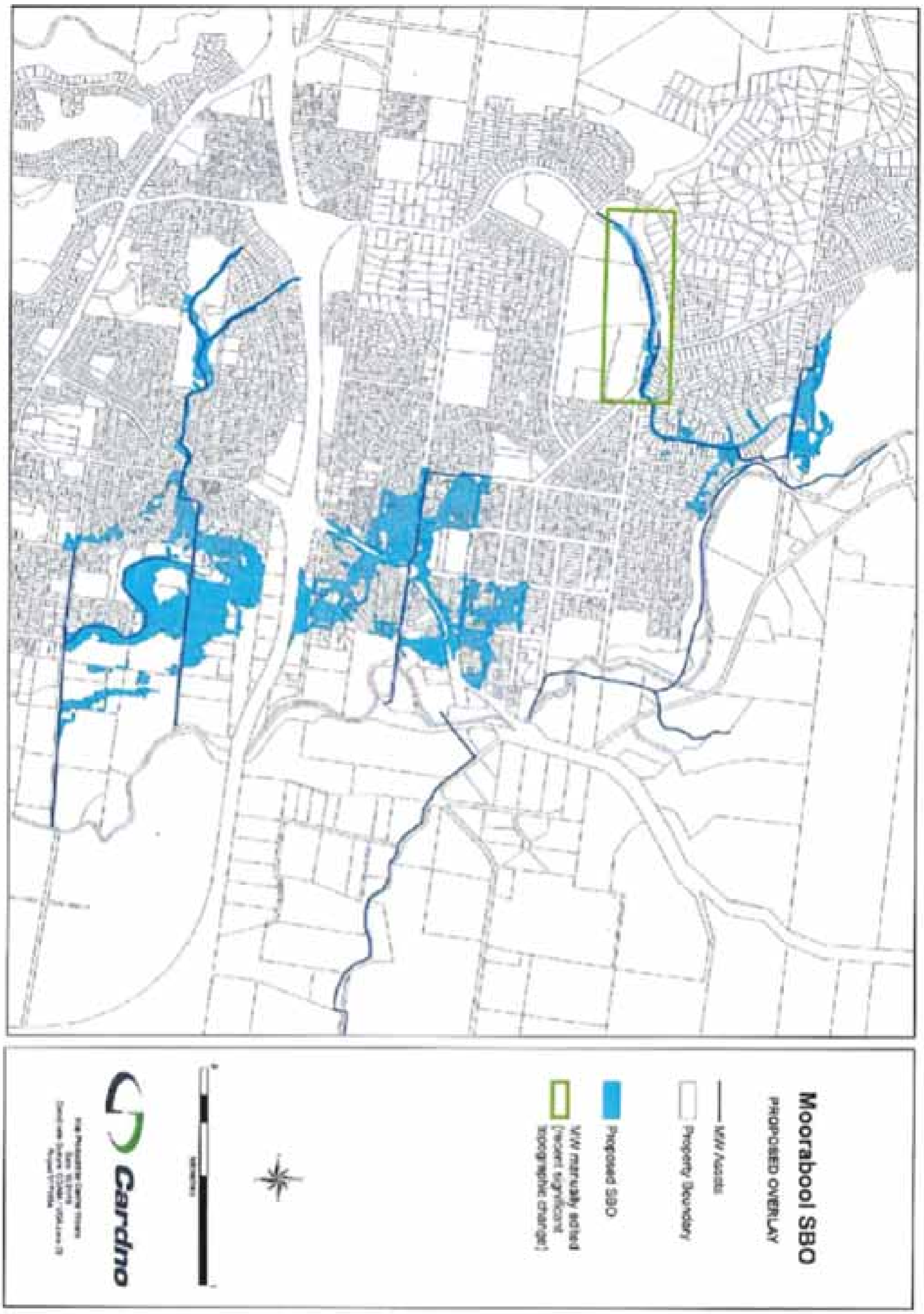
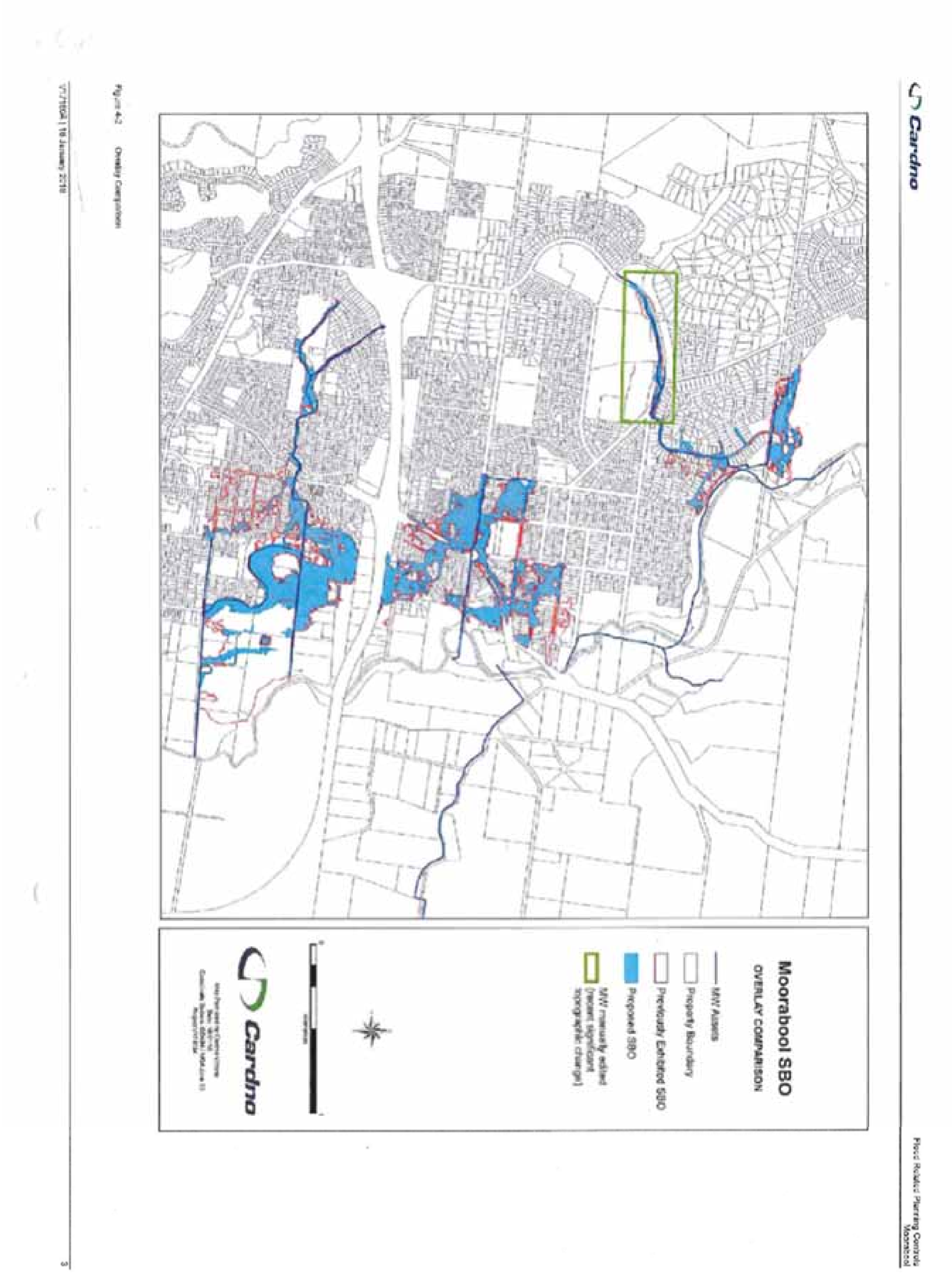


Figure 4-1 Proposed Overlay


Cardno
Moorabool SBO
OVERLAY COMPARISON
MW Assets
Property Boundary
Previously Exhibited SBO
Proposed SBO
MW manually edited (recent significant topographic change)
Cardno

MELBOURNE WATER

Lower Lerderderg Catchments Flood Mapping Report

December 2011

Job Number: V3000_004

www.engeny.com.au
P: 03 9877 1877 I F: 03 9877 3710
Suite 8C, 14 Albert St, Blackburn VIC 3130 I PO Box 218 Blackburn VIC 3130

DISCLAIMER

This report has been prepared on behalf of and for the exclusive use of Melbourne Water and is subject to and issued in accordance with Melbourne Water instruction to Engeny Management Pty Ltd (Engeny). The content of this report was based on previous information supplied by Melbourne Water.

Engeny accepts no liability or responsibility whatsoever for this report in respect of any use of or reliance upon this report by any third party. Copying this report without the permission of Melbourne Water or Engeny is not permitted.

V3000_004 Lower Lerderderg Catchments – Flood Mapping Report					
DOC PATH FILE					
REV	DESCRIPTION	AUTHOR	REVIEWER	APPROVED BY	DATE
0	Issued to Client	Glenn Ottrey	Scott Dunn	Andrew Prout	16th December 2011

EXECUTIVE SUMMARY

In 2007 Melbourne Water developed the Flood Management and Drainage Strategy for the Port Phillip and Westernport Region aimed at developing an action plan for flood management, planning and response. A key action item of this strategy was to undertake detailed flood mapping for the region to assist in the following key areas:

- Land use Planning Policy and Controls;
- Emergency Planning and Preparation; and
- Mitigation Priorities.

Engeny was commissioned by Melbourne Water to undertake the Lower Lerderderg Catchments Flood Mapping study as part of Melbourne Water's commitment to deliver upon the action plan. The key drivers for this project were to update Melbourne Water's flood mapping information and Flood Risk Assessment for each of the catchments.

The scope of works required to deliver the investigation were as follows:

- Develop RORB models for the Lower Lerderderg Catchments;
- Compile hydrographs for the full range of storm durations (15 minutes to 72 hours) for the specified ARI events, as per the Flood Mapping Brief (2010), under existing conditions and climate change conditions;
- Develop a TUFLOW hydraulic model to model overland flow and flow in existing Melbourne Water infrastructure for the existing level of development and climate change conditions;
- Determine flood extents and contours for all specified ARI events (flood mapping); and
- Assess and identify properties at risk of inundation.

Data Review

Engeny reviewed all available supplied information for the Lower Lerderderg Catchments. This information included the following:

- LiDAR elevation data;
- Pit information;
- Pipe information; and
- Surveyed cross-section data.

Site visits were also undertaken during the study to capture some information and verify outputs. The data review process enabled missing or inconsistent data to be determined thereby assisting in producing accurate and up to date hydrological and hydraulic modelling results.

Hydrological Analysis

The hydrological analysis determined design flood flow estimates for the Lower Lerderderg catchments at sub-catchment level for input to the hydraulic model. Design flood inflow hydrographs were determined for the full range of durations and ARI events using RORB hydrology modelling software. In the absence of gauged flow data the RORB routing parameter (k_c value) was determined through validation to Rural Rational Method Flow calculations for each of the catchments. The k_c values were adjusted to fit the Rural Rational Method Flow values whilst trying to closely match estimates of k_c from Dandenong Valley Authority (DVA) calibrated curves.

Hydraulic Analysis

The hydraulic modelling and analysis was undertaken through the use of TUFLOW software and has determined design flood levels and extents for the following range of events:

- 5, 10, 20, 50 and 100 year ARI for existing conditions; and
- 5, 20 and 100 year ARI events for the climate change scenario of increased rainfall intensity.

Whilst there is no gauged flow data or recorded flood levels within any of the catchments modelled it has not been possible to calibrate the generated TUFLOW model. Instead the flows and flood depths produced by the TUFLOW model were validated to ensure that they are reasonable. Any unexpectedly large or small flow results were investigated to understand whether or not they were reasonable. Knowledge gained through multiple site inspections within the catchments, especially Cairns Drive, was used when determining if flow magnitudes and paths appear reasonable.

Flood Mapping

Flood extents and contours have been generated for each of the design events specified above and delivered in MapInfo format. The standard Melbourne Water filter was used in generating the flood extents:

- Depth ≥ 50mm; AND/OR
- Hazard (depth x velocity) ≥ 0.008

Recommendations

It is proposed that the outputs from this study be used for the following purposes as anticipated:

- Land development advice;
- Planning scheme amendments;
- Updating of properties at risk of flooding; and
- Assessment of flood risk.

Whilst mitigation modelling and assessment has not been undertaken within this current study, options for flood mitigation within the Lower Lerderderg catchments can be assessed through use of the models generated from this study.

CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

APPENDICES

1. INTRODUCTION

Engeny was commissioned by Melbourne Water to undertake detailed flood mapping of the Lower Lerderderg Catchments. This report outlines and documents the investigations undertaken and the results obtained.

The key drivers for this project were to update Melbourne Water's flood mapping information and Flood Risk Assessment for each of the catchments. Major outcomes from this study include the review of existing catchment information, preparation of hydrologic and hydraulic flood models, and the completion of flood inundation and risk maps. The flood information produced by these investigations will aid Melbourne Water with

- Land development advice;
- Planning scheme amendments;
- Updating of properties at risk of flooding; and
- Assessment of flood risk.

Whilst mitigation modelling and assessment has not been undertaken within this current study, options for flood mitigation within the Lower Lerderderg catchments can be assessed through use of the models generated from this study.

Engeny has undertaken the flood mapping for five main drain catchments in Bacchus Marsh / Darley that all drain to the Lerderderg River. The five catchments mapped were:

- Robertsons Road Drain;
- Cairns Drive Drain;
- Grey Street Drain;
- Masons Lane Drain; and
- Lerderderg Street Drain.

In recent years the catchments have undergone significant development. Some of this development has placed pressure on the existing drainage infrastructure. The soil in this region is quite dispersive and as a result of ongoing construction exposed soil has been transported via runoff into the drainage network and contributed to localised flooding as a result of blocked pits and pipes. Moorabool Shire indicated that the Masons Lane catchment has experienced flooding in recent times in the location of the Masons Lane Retarding Basin.

The Lerderderg River which is the main receiving waterway for each of the study catchments experienced high flows and localised flooding in Janaury 2011 as shown below in Figure 1.1 and 1.2.

Figure 1.1 – Lerderderg River (http://www.flickr.com/photos/shaddsi/5357901751)

Figure 1.2 – Lerderderg River in Flood, January 2011 (http://commons.wikimedia.org)

The scope of works required to deliver the investigation were as follows:

- Develop RORB models for the Lower Lerderderg Catchments;
- Compile hydrographs for the full range of storm durations (15 minutes to 72 hours) for the specified ARI events, as per the Flood Mapping Brief (2010), under existing conditions and climate change conditions;
- Develop a TUFLOW hydraulic model to model existing Melbourne Water infrastructure for existing level of development and climate change conditions;
- Determine flood extents and contours for all specified ARI events (flood mapping); and
- Assess and identify properties at risk of inundation.

The aim of this project was to map the areas of the catchments that are inundated by flood events by a range of recurrence interval storm events. The results from this report will be used to assist with future development planning to ensure houses and buildings are built at appropriate levels to reduce the likelihood on inundation. It will also be used by Melbourne Water in their consultation with community and government stakeholders in determining if the flooding risks in the area require mitigation.

The structure of this report is as follows:

- Section 2 – details the background study information
- Section 3 – details the hydrological modelling phase
- Section 4 – outlines the hydraulic modelling approach
- Section 5 – summaries the hydraulic model development process
- Section 6 – provides details of the flood mapping process
- Section 7 – highlights the recommendations and conclusions from this study

2. BACKGROUND INFORMATION

2.1 Catchment Description

The study area contains parts of the suburbs of Bacchus Marsh and Darley within the Shire of Moorabool. A total of five Melbourne Water Main Drains fall within the catchments as listed below:

Table 2.1 – Lower Lerderderg Catchment Names and Areas

Drain Name	Catchment Area (Hectares)
Robertsons Road Drain	108
Cairns Drive Drain	176
Grey Street Drain	251
Masons Lane Drain	306
Lerderderg Street Drain	92

Each catchment is characterised by steep sloping terrain in the west, with as much as a 15% gradient, grading to very flat in the east where the catchments lie on the floodplain to the Lerderderg River. The catchments are bounded by the Lerderderg River to the east and by Korkuperrimul Creek to the west. The Lerderderg River flows into the Werribee River a short distance to the south of the Lower Lerderderg catchments.

The upper portions of the catchments are not developed due to the topography whilst the lower reaches are urbanised. The Western Freeway bisects the catchments through the middle in an east-west direction. The catchment drainage systems consist of a combination of underground drainage and open waterways and a number of retarding basins. Figure 2.1 shows a locality plan of the Lower Lerderderg Catchments, key features of the catchments can be seen in greater detail in **Appendix D**.

Figure 2.1 – Locality Plan of Lower Lerderderg Catchments

2.2 Available Data

Data for the Lower Lerderderg Catchments has been obtained from the following sources:

- Melbourne Water;
- Moorabool Shire;
- VicRoads; and
- Southern Rural Water.

This data has included the following:

- Aerial photography;
- Pit and pipe data (Melbourne Water assets and Council assets);
- LiDAR terrain data;
- Main catchment boundaries;
- Contours;
- Planning zones;
- Cadastre boundaries;
- Previous reports;

- Design data for the Cairns Drive retarding basin and other assets; and
- Other relevant data.

Upon review of the information provided it was evident that some relevant information was missing including some drainage details such as pipe sizes and open channel dimensions. Through identification of this missing data Melbourne Water was able to locate detailed drawings containing the necessary relevant information.

Several reaches of Council drainage have been used in this study to best represent flooding behaviour upstream of Melbourne Water assets.

2.3 Site Inspection

Engeny undertook site visits to the Lower Lerderderg Catchments at various stages throughout the project. The first visit was undertaken on 24th March 2011 to gain an understanding of the catchment and what the different land uses were. Several drainage features were also inspected to ensure GIS information was up to date. Details of our initial site visits and photographs can be found in **Appendix A – Site Inspection Report**. A second site visit was undertaken on 14th May 2011 to confirm dimensions and bridge details for the Lerderderg Street open channel. During this site visit preliminary hydraulic modelling results were inspected to ensure appropriateness.

3. HYDROLOGY

This section of the report documents the process undertaken by Engeny to develop RORB models for each of the Melbourne Water Main Drain Catchments.

The aim of catchment hydrology in this study is to produce accurate hydrographs for use in the TUFLOW, hydraulic model. It is a Melbourne Water requirement that a RORB model is used to determine flows in the catchments to be used in TUFLOW. Table 3.1 indicated the scenarios for which hydrographs have been determined.

Table 3.1 – Hydrological Modelling Scenarios

Scenario/ARI	5 Year	10 Year	20 Year	50 Year	100 Year
A (Base Case)	✓	✓	✓	✓	✓
D (Climate Change – Increase Rainfall Intensity	✓		✓		✓

3.1 Catchment Boundary Determination

Melbourne Water supplied Engeny with an existing catchment boundary along the western edge of the study area to match to the boundaries of the Lower Lerderderg Catchments. Along this western boundary the catchment boundaries have been edge matched in MapInfo. All of the other boundaries were determined by Engeny using the DEM generated from the supplied LiDAR contours (0.5 m resolution for most of the catchment), aerial photography and Council and Melbourne Water drainage asset locations. Where possible the catchment boundaries have been based on the predicted 100 year ARI overland flow paths, however there are some locations where this is not practical. Figure 3.1 and Figure 3.2 show examples of where the dominant direction of the overland flow path is different to the direction of flow of the underground drains. In these areas Engeny have tried to include the majority of the drainage network within the catchment boundary to ensure that all pipes will be contributing to the flow in the Melbourne Water Assets. At the edge of the flood mapping study area overland flow will be removed from the model by appropriate boundary conditions whilst between the different Melbourne Water Drain Catchments being modelled overland flow can continue into the neighbouring catchment in the TUFLOW model.

Engeny had previously completed a RORB model for the Cairns Drive Drain for Melbourne Water and it was agreed with Melbourne Water that the boundaries from this model would only be adjusted to edge match to the western boundary provided by Melbourne Water.

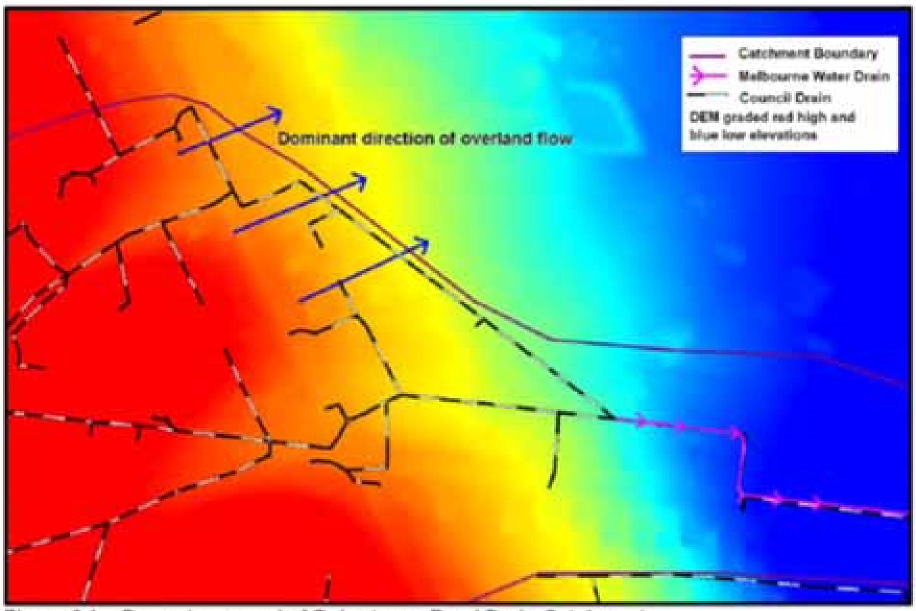


Figure 3.1 – Downstream end of Robertsons Road Drain Catchment

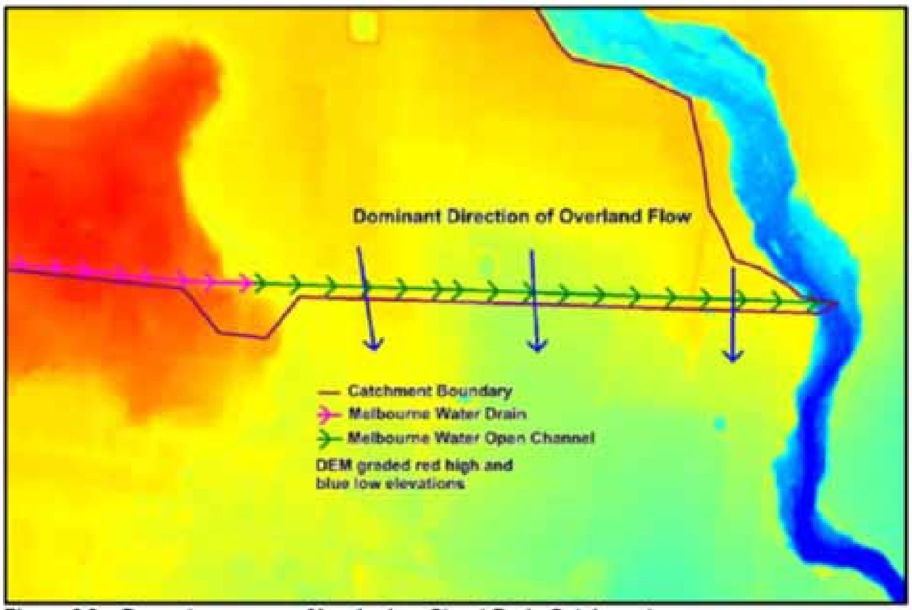


Figure 3.2 – Downstream area of Lerderderg Street Drain Catchment

3.1.1 Sub-Catchment Delineation

Once the individual catchment boundaries were determined, each of the individual catchments were broken down into sub-catchments. Sub-catchments were delineated as most appropriate for the 100 year ARI event and at a scale sufficient for use in the TUFLOW hydraulic model. MiRORB (MapInfo RORB) was used to draw sub-catchment boundaries for each catchment and generate the resultant RORB models.

3.2 Fraction Impervious Review

To determine the fraction impervious value for each of the individual sub-catchments, planning scheme information was used. A fraction impervious was assigned to each zone, with MiRORB merging the zones as necessary to give a single FI value for each of the sub-catchments. The initial fraction impervious values used in Table 3.2 below were from the Melbourne Water MUSIC fraction imperviousness guidelines. These values were reviewed against the aerial photographs provided by Melbourne Water and adjusted if necessary. Tables 3.3 and Table 3.4 show the fraction impervious values used in the final RORB models.

Table 3.2 – Fraction impervious for planning scheme zones

Planning Scheme Zone	Zone Code	Initial FI Value from MW MUSIC guidelines	Revised FI Value
Business Zone 1	B1Z	0.9	
Business Zone 2	B2Z	0.9	
Farm Zone	FZ	0.1	
Low Density Residential Zone	LDRZ	0.2	0.3
Mixed Use Zone	MUZ	0.7	
Public Park and Recreation Zone	PPRZ	0.1	
Service and Utility Zone	PUZ1	0.05	0.1
Education Zone	PUZ2	0.7	
Health and Community Zone	PUZ3	0.7	
Residential Zone 1	R1Z	0.45	0.5
Road Category 1 Zone (freeways and major roads)	RDZ1	0.7	0.5
Road Category 2 Zone (secondary and local roads)	RDZ2	0.6	
Special Use Zone 3 (golf course)	SUZ3	0.1	

Table 3.3 – Fraction Impervious for each sub-catchment

Sub-catchment	Robertsons Road	Grey Street	Masons Lane	Lerderderg Street
A	0.188	0.374	0.503	0.462
B	0.266	0.539	0.389	0.354
C	0.300	0.477	0.504	0.484
D	0.343	0.497	0.500	0.486
E	0.454	0.390	0.428	0.194
F	0.364	0.498	0.484	0.100
G	-	0.495	0.493	0.246
H	-	0.510	0.495	-
I	-	0.498	0.493	-
J	-	0.481	0.484	-
K	-	0.481	0.413	-
L	-	0.232	0.473	-
M	-	0.445	0.278	-
N	-	0.516	0.502	-
O	-	0.463	0.474	-
P	-	-	0.108	-

Table 3.4 – Cairns Drive Fraction Impervious values

Sub-catchment	Fraction Impervious	Sub-catchment	Fraction Impervious	Sub-catchment	Fraction Impervious
A	0.3	Q	0.498	AG	0.5
B	0.442	R	0.5	AH	0.581
C	0.5	S	0.5	AI	0.1
D	0.57	T	0.548	AJ	0.492
E	0.625	U	0.101	AK	0.5
F	0.126	V	0.3	AL	0.5
G	0.3	W	0.226	AM	0.485
H	0.299	X	0.281	AN	0.483
I	0.5	Y	0.3	AO	0.495
J	0.232	Z	0.302	AP	0.5
K	0.457	AA	0.249	AQ	0.483
L	0.5	AB	0.118	AR	0.435
M	0.42	AC	0.104	AS	0.296
N	0.3	AD	0.5	AT	0.327
O	0.307	AE	0.524	AU	0.495
P	0.5	AF	0.5	AV	0.375

3.3 Intensity-Frequency-Duration (IFD) Data

Intensity-Frequency-Duration (IFD) data for Bacchus Marsh was sourced from the Bureau of Meteorology using the online IFD request tool. The coordinates entered were S 37°37'48", and E 144°26'05". These coordinates yielded the IFD variable shown in Table 3.5 below. The resultant IFD factors are shown in Table 3.66 below.

Table 3.5 – Intensity-Duration-Frequency (IFD) parameters

Variable	Value
Intensity - 1 hour duration, ARI = 2 years ($^{2}I_{1}$)	18.13
Intensity - 12 hour duration, ARI = 2 years ($^{2}I_{12}$)	3.74
Intensity - 72 hour duration, ARI = 2 years ($^{2}I_{72}$)	1.01
Intensity - 1 hour duration, ARI = 50 years ($^{50}I_{1}$)	40.36
Intensity - 12 hour duration, ARI = 50 years ($^{50}I_{12}$)	7.53
Intensity - 72 hour duration, ARI = 50 years ($^{50}I_{72}$)	2.11
Skew (G)	0.35
F_2	4.31
F_{50}	14.9

Table 3.6 – Intensity-Duration-Frequency (IFD) Table

DURATION	1 Year	2 years	5 years	10 years	20 years	50 years	100 years
5Mins	45.2	60.8	85.8	103	126	161	189
6Mins	42.2	56.7	80	96.2	118	149	176
10Mins	34.2	46	64.6	77.4	94.6	120	141
20Mins	24.6	33	46	55	66.9	84.3	98.9
30Mins	19.8	26.5	36.8	43.9	53.3	67.1	78.5
1Hr	13.2	17.6	24.3	28.9	34.9	43.7	51.1
2Hrs	8.63	11.5	15.6	18.4	22.2	27.6	32.1
3Hrs	6.69	8.86	12	14.1	16.9	20.9	24.2
6Hrs	4.32	5.69	7.6	8.88	10.6	13	15
12Hrs	2.76	3.63	4.81	5.59	6.64	8.11	9.32
24Hrs	1.73	2.28	3.02	3.5	4.16	5.09	5.85
48Hrs	1.04	1.37	1.83	2.13	2.54	3.13	3.61
72Hrs	0.751	0.991	1.32	1.55	1.85	2.28	2.63

3.3.1 Climate Change Scenario

To model Melbourne Water's climate change scenario (Scenario D), the intensity variables used to generate the IFD data have been increased by 32%. The result is an increase in the rainfall intensity by 32% as per Melbourne Water's guidelines for climate change scenarios.

Table 3.77 shows the IFD parameters that were used in RORB to determine the climate change flows for the 5, 20 and 100 year ARI events.

Table 3.7 – Climate Change Intensity-Duration-Frequency (IFD) Parameters

Variable	Value
Intensity - 1 hour duration, ARI = 2 years (${}^{2}I_{1}$)	23.93
Intensity - 12 hour duration, ARI = 2 years (${}^{2}I_{12}$)	4.94
Intensity - 72 hour duration, ARI = 2 years (${}^{2}I_{72}$)	1.33
Intensity - 1 hour duration, ARI = 50 years (${}^{50}I_{1}$)	53.28
Intensity - 12 hour duration, ARI = 50 years (${}^{50}I_{12}$)	9.94
Intensity - 72 hour duration, ARI = 50 years (${}^{50}I_{72}$)	2.79
Skew (G)	0.35
F_2	4.43
F_{50}	16.64

3.4 RORB Modelling

3.4.1 Existing Cairns Drive RORB Model

Melbourne Water did not provide any existing RORB models in the Lower Lerderderg group of catchments for use on this project, however Engeny had previously created a diverted RORB model of the Cairns Drive Drain catchment for the Waterway Development Planning Group of Melbourne Water. It was agreed with Melbourne Water that this existing RORB model would be used with the only modification being to edge match the MiRORB model to the existing catchment boundary provided by Melbourne Water for the current study and to update the sub-catchment areas in RORB. The existing k_c value and calibration details were used in the model for the current study.

Engeny's Cairns Drive RORB model had been used to investigate options for main drains and retarding basins in the catchment and the latest version of the development and retarding basin were adopted for this study.

Figure 3.3 shows the extent of changes that were required for the Cairns Drive model along the western boundary which as can be seen are minimal.

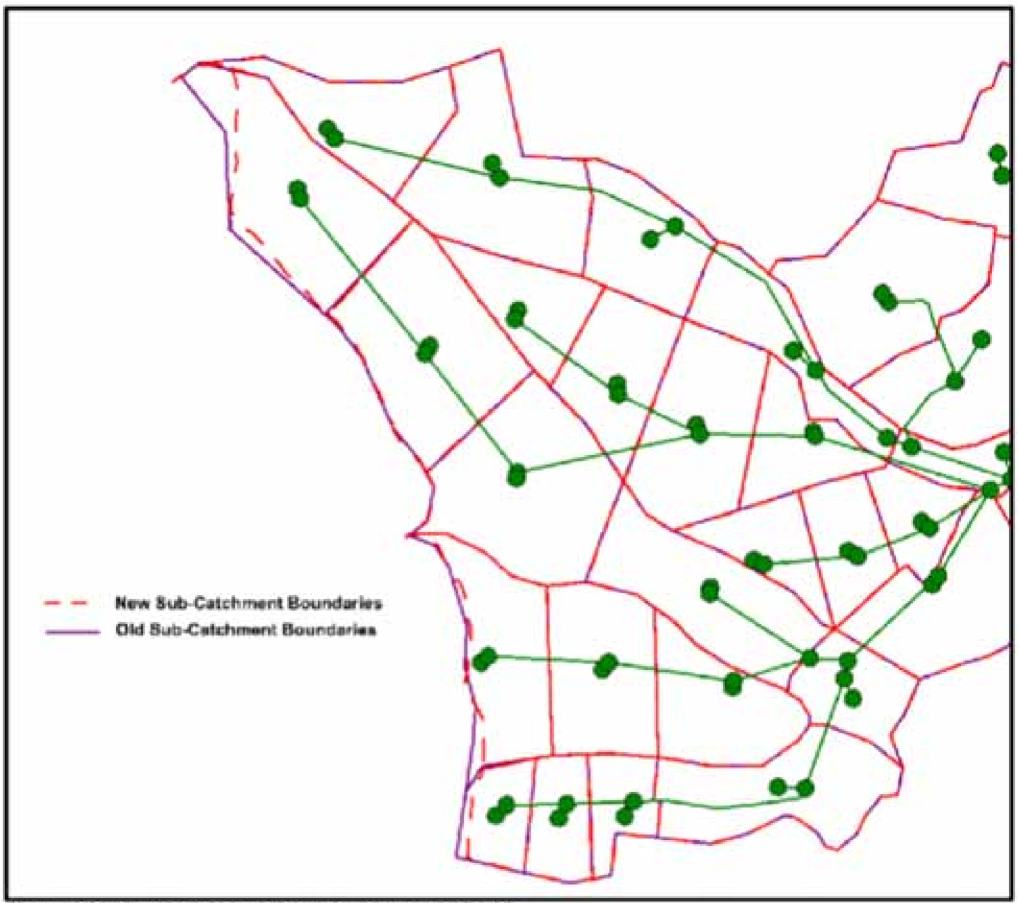


Figure 3.3 – Revised Cairns Drive Catchment MiRORB

3.4.2 New RORB Models

The remaining four Lower Lerderderg Catchments have been modelled in the following way:

- Robertsons Road – undiverted
- Grey Street – undiverted
- Lerderderg Street – undiverted
- Masons Lane – partially diverted

Figure 3.4 below shows the Masons Lane Drain Catchment. Masons Lane Catchment grades generally downhill from the northwest to the east. The upper part of the catchment is separated from the rest of the catchment by the Western Freeway and contains no Melbourne Water assets. Given that the piped and overland flow paths are in the same alignment and that there are no Melbourne Water assets in the upper part of the catchment, this portion of the catchment has been modelled as a diverted RORB model. In the subsequent TUFLOW model inflow points were placed at the downstream ends of the two diverted flow paths for the upper part of the catchment, immediately upstream of the Western Freeway, shown in Figure 3.4 below. The result of this approach is that the culverts beneath the Western Freeway have been modelled to determine if they restrict the upstream flow reaching the downstream parts of the catchment. The diversions in the RORB model convey the piped flow, with the main reaches conveying the overland flows. The capacity of the pipes in each sub-catchment has been estimated from council GIS pipe data where available. Where pipe data is not available it has been assumed that the piped system is sized for the 5 year ARI and the capacity of the diversion pipes have been set at the 5 year ARI sub-catchment peak flow rate as determined by RORB. The rest of the Mason Lane Catchment has used the undiverted hydrographs from the RORB model in the TUFLOW model, TUFLOW being used to rout the flows in the parts of the catchment south of the Western Freeway.

Figure 3.4 – Masons Lane Catchment MiRORB Layout

3.4.3 Calibration / Validation

For each of the RORB models that Engeny has created, calibration and validation of the flows have been performed. In the absence of gauged flow data a rural RORB model was generated and a rural rational method calculation was performed for each catchment. The flows from the rural Rational Method calculations can be seen below in Table 3.88. The time of concentration was calculated using Adam's method as described in Australian Rainfall and Runoff (t_c=0.76$A^{0.38}$). The average velocity for each catchment was also determined based on the time of concentration and flow path length. These velocities seem reasonable given that the upper parts of most of the catchments are fairly steep, while the lower parts of most of the catchments are relatively flatter.

Table 3.8 – Rural Rational Method Calculations

	Robertsons Road	Grey Street	Masons Lane	Lerderderg Street	Cairns Drive
Area (ha)	85.4	229.2	265.5	122.2	184.7
t_c (min)	42.9	62.5	66.1	49.2	58
C_{10}	0.18	0.18	0.18	0.18	0.18
I_{100} (mm/hr)	64.0	50.0	48.0	58.1	52.2
Rational Q_{100} (m^3/s)	3.56	7.45	8.28	4.62	6.35
Average Velocity (m/s)	0.9	0.8	0.9	1.2	0.8

The rural RORB models have then been adjusted to the flow produced by the rural Rational Method calculation by adjusting the k_c value. This k_c value has then been used in the urban or main RORB model to extract the hydrographs for use in TUFLOW to model the existing catchment. The Rural RORB models used a fraction impervious value of 0.10, consistent with the Melbourne Water guidelines.

Table 3.9 shows the comparison between the calculated rural RORB model peak flow rates and those calculated from the rural Rational Method. Engeny have also compared the k_c values used in the RORB model with a calibration determined by the Dandenong Valley Authority (DVA) using catchments in the Melbourne area which relates catchment area to k_c. The DVA k_c graph (see **Appendix B**) includes a catchment in the Djerriwarrh Creek catchment which is located nearby to Bacchus Marsh.

As Table 3.9 shows, the adopted k_c values are close to the DVA relationship between k_c and area. As a further validation check the rural Rational Method calculation and rural RORB flows were compared to a regression of flood flows versus catchment area in Victoria for rural catchments adjacent to the Great Dividing Range carried out by the DNRE in June 1997 (see **Appendix B**). The comparison of the DNRE regression curves to the calculated values from RORB and the rational method shows the regression curve values are consistently higher than the rational and RORB values. An explanation for this could be that the Lower Lerderderg Catchments areas are all significantly smaller than any of the catchments on which the regression is based. This means that the values obtained from the regression curve is an extrapolation outside of the main data set and may be subject to more variation. What the comparison does suggest is that the rural Rational Method flow is of the right order of magnitude given that the flows are generally comparable. In the absence of any gauged data to compare the flows with Engeny believes that they are reasonable estimates suitable for flood modelling.

Table 3.9 – RORB Validation

	Robertsons Road	Grey Street	Masons Lane	Lerderderg Street	Cairns Drive
Rural Rational Q_{100} (m^3/s)	3.56	7.45	8.28	4.62	6.35
Rural RORB Q_{100} (m^3/s)	3.57	7.46	8.28	4.62	6.36
Rural Regression Q_{100} (m^3/s)	4.14	8.79	9.84	5.44	7.5
Adopted k_c	1.46	2.46	2.82	1.65	2.0
DVA k_c	1.40	2.41	2.62	1.71	2.14

3.4.4 RORB Model Parameters

The RORB model created by Engeny used a runoff coefficient model with Filtered Temporal patterns and uniform areal patterns. The areal reduction factor was in accordance with Australian Rainfall and Runoff 1987 (Book 2 figures 1.6 and 1.7). The following parameter specification was used to run the RORB models:

- m = 0.8
- Initial Loss (rural models) = 15 mm
- Initial Loss (final models) = 10 mm
- 5 year ARI Runoff Coefficient = 0.25
- 10 year ARI Runoff Coefficient = 0.35
- 20 year ARI Runoff Coefficient = 0.45
- 50 year ARI Runoff Coefficient = 0.55
- 100 year ARI Runoff Coefficient = 0.60
- k_c as determined in the calibration process (Table 6)

RORB model catchment layouts for each of the catchments are attached in **Appendix C**.

4. HYDRAULIC MODELLING APPROACH

4.1 Objective

The objective of creating a hydraulic model for the Lower Lerderderg Catchments was to provide a flood risk assessment of the catchment and produce flood maps that can be incorporated into the planning scheme for the 100 year ARI event. TUFLOW was the hydraulic model used to undertake this work. The extents of flooding were determined for a range of recurrence intervals for the existing extent of development. Hydraulic modelling allowed for:

- Identification of properties at risk of flooding;
- Mapping flood extents and depths for a range of flood events; and
- Mapping flood hazard categories for the 100 year ARI event.

4.2 Methodology

The following steps outline the tasks undertaken to develop the TUFLOW model and to obtain results and outputs which were used for flood mapping:

- Generate DEM;
- Compile hydrographs for full range of storm durations (from 10 mins to 72 hours) for 5, 10, 20, 50, and 100 year ARI rainfall events for existing levels of development and for climate change scenario of increased rainfall intensity (from RORB model);
- Input surface roughness's (materials layer);
- Input and verify data for the 1-D network;
- Set 1-D and 2-D boundary conditions;
- Run TUFLOW for the full range of storm durations (from 15 mins to 12 hours) for 5, 10, 20, 50, and 100 ARI conditions for existing development scenarios;
- Prepare floodplain maps from the model results;
- Prepare flooding database of properties and buildings flooded; and
- Prepare flood Hazard maps.

5. TUFLOW MODEL DEVELOPMENT

5.1 2-D Model Domain

5.1.1 Digital Elevation Model (DEM)

Melbourne Water supplied Fugro (2009) Light Detection and Ranging (LiDAR) data for this investigation. A DEM (with resolution of 1m) was generated for the entire catchment from the LiDAR data. From the DEM, levels were allocated to points within the 2d_zpt layer which was utilised directly by TUFLOW. Figure 5.1 shows the DEM generated for the Lower Lerderderg catchments. The orange areas indicate the greatest elevation whilst the blue areas designate the lower elevations.

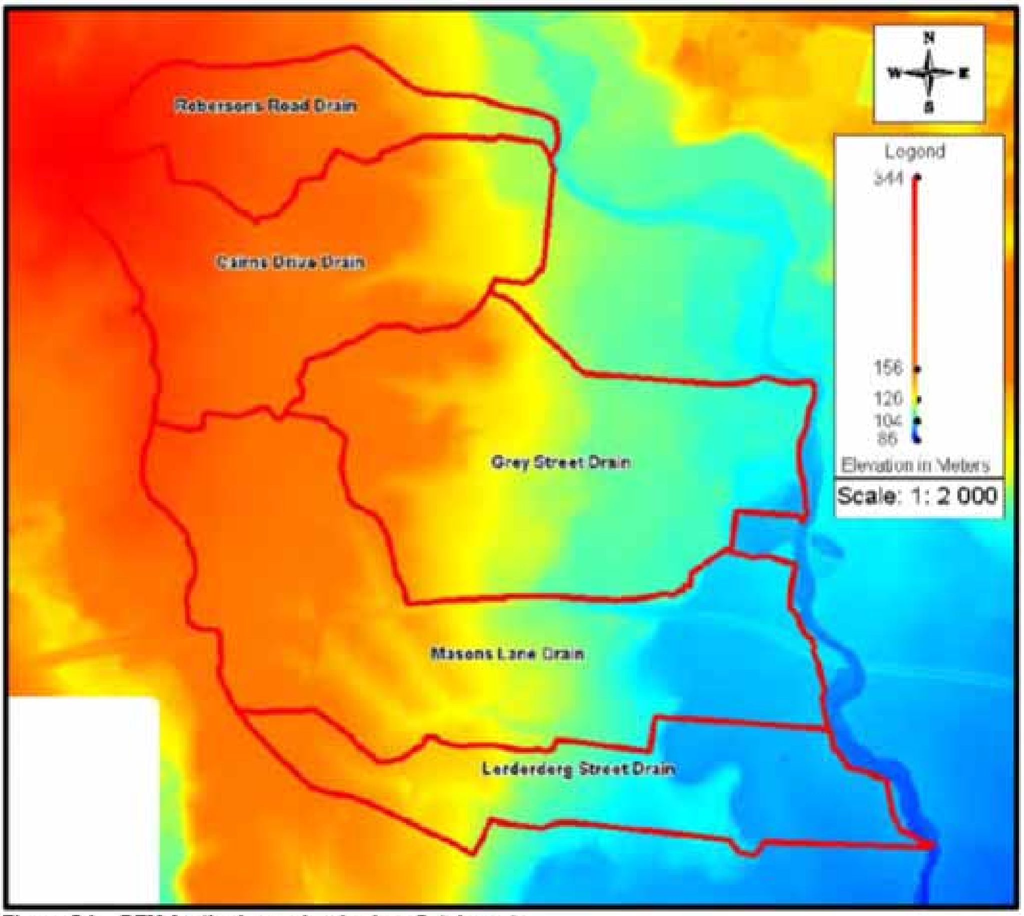


Figure 5.1 – DEM for the Lower Lerderderg Catchments

5.1.2 2-D Z Points

A 3m grid size was selected as per the Melbourne Water specifications to accurately model urban surface flows in TUFLOW. The Melbourne Water 2D Modelling Guidelines (March 2011) require a grid size of 2-5m for urban flood modelling. Such a cell size is sufficiently small to enable the effects of raised roadside verges and medians to be modelled while at the same time provided reasonable model run times. The grid was aligned north-south as there was no dominant direction of flow within the catchment with regards to an aligned road network.

5.1.3 Retarding Basins

There are currently known flooding issues in Dickson Street possibly associated with the Dickson Street Retarding Basin. As such it was important that the basin was modelled accurately. A drainage layout of the retarding basin is shown in Figure 5.2. The inverts and sizes of the pits were not contained within the data provided by Melbourne Water, however as constructed drawings of the retarding basin were obtained from Moorabool Shire Council with the data being used in the TUFLOW model.

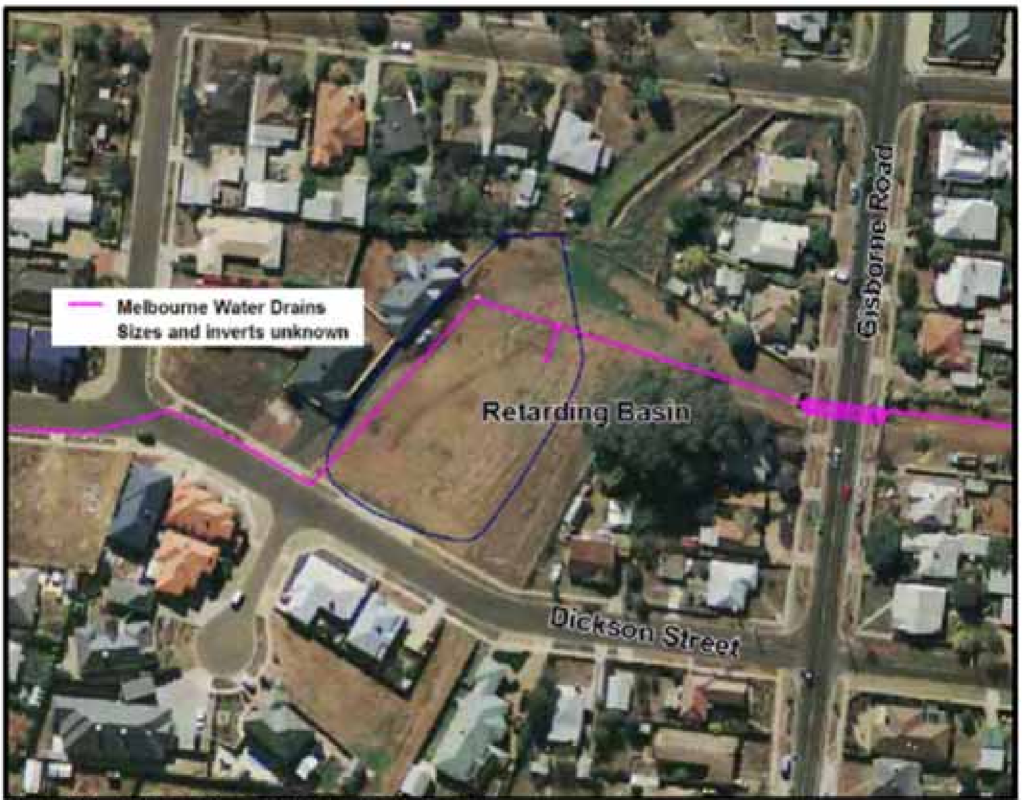


Figure 5.2 – Dickson Street Retarding Basin Layout

There are two other retarding basins that have not yet been constructed which have been modelled, based on current design plans. One is located in the Cairns Drive Catchment beside the future Halletts Way alignment. Paroissien Grant and Associates Pty Ltd undertook this design and provided Engeny with a functional design which has been used for this modelling project. Engeny had previously developed the RORB model for Melbourne Water that was used for the Paroissien Grant basin design. The second basin is located in the Masons Lane Catchment upstream of the Dickson Street Retarding Basin. It is being designed by Urban Design and Management who provided a concept design to Engeny which has also been used for this modelling project. Both of these designs are subject to change and Engeny cannot guarantee that the final basin constructed will match what has been modelled.

There are also Council maintained retarding basins near Silverdale Road, east of Halletts Way south of the freeway and south west of the Western Freeway Interchange with Gisborne Road. These basins were also modelled to ensure accurate routing of flows to the Melbourne Water assets.

5.2 1-D Network Data

5.2.1 Melbourne Water Underground Drainage

GIS data of the existing Melbourne Water stormwater network was provided to Engeny. This data was imported into MapInfo for verification and manipulation to ensure consistency throughout the entire pipe network within the catchment. There were several instances of missing data, including missing diameter and invert data. The majority of these data gaps were filled by interpolating off nearby assets or using data provided by Moorabool Shire Council. Moorabool Shire Council was able to provide some as-constructed drawings for parts of the network for which Melbourne Water had no information, the retarding Basin in Masons Lane being an example.

A section of pipe shown as being a Melbourne Water asset in the Cairns Drive Catchment was believed to be in a non-operational state. From previous work completed in the Cairns Drive catchment by Engeny and communication with Melbourne Water's Darren Coughlan suggest that the pipe was a 900-1200 diameter HDPE pipe which was set on fire and has partially collapsed as a result. Engeny believes that the flow is now conveyed via overland flow paths as the HDPE pipe has not been replaced or repaired. Parts of this catchment are zoned for residential development and there are currently several developments in the final stages of design. As a result this area of the catchment was modelled using the drainage infrastructure, including retarding basins, which will be in place once the developments in the area are constructed. Figure 5.3 shows the pipes that were affected by fire and the damaged pipes shown in red in this figure have not been modelled.

Figure 5.3 – Length of non-operational pipe in Cairns Drive

5.2.2 Open Channels

Within the catchment two open channels exist:

- Melbourne Water open channel, Lerderderg Street; and
- Southern Rural Water Irrigation Channel.

The Lerderderg Street open channel was modelled using the 1-D network layer (1d_nwke) to define the centreline as the channel definition provided by the 2-D grid was not considered adequate due to the narrow nature of the channel. Cross section data obtained from a Melbourne Water survey of the channel has been used in a 1-D cross section (1d_xs) layer to define the shape and inverts of the channel.

The Southern Rural Water Irrigation Channel was not modelled, although it is partially evident in the 2-D grid. The definition provided by the 2-D grid indicates that the channel is unable to "flow" for long distances, as the channel is too narrow relative to the grid size. Engeny believe it is conservative not to model flows in the channel as there are no guarantees that the channel will be empty when a large storm event occurs and so the capacity provided by the channel to mitigate flood effects could not be relied upon. Discussion held with Southern Rural Water also indicate that in the future the channel may be replaced with a pipe to reduce the risk of having an open irrigation channel running through a catchment which is now predominantly residential rather than rural as it was when the channel was built.

5.2.3 Council Drainage

Some areas of the Council drainage network were included in the 1-D model to ensure that flows are accurately distributed to the Melbourne Water drains. This information was sourced from Council design drawings and GIS data provided by Melbourne Water. In locations where the Council drainage pipes run in a different direction to the major overland flow path the main trunk of the Council drainage network was modelled to ensure that the flows were correctly diverted by the pipes.

5.2.4 Pits

Pits were modelled on both the Melbourne Water pipes and Council pipes. It was assumed that all pits are 900 mm by 1200 mm side entry pits, with a 150 mm by 1200 mm opening at street level, unless other information was available. Where other information was available it has been included.

5.2.5 Culverts

There are a number of culverts which cross under the Western Freeway which were modelled in TUFLOW. These range in size from 300 mm diameter circular culverts up to a box culvert which is 2.4 m high by 3.0 m wide (a pedestrian underpass). The size and inverts of these culverts were obtained from VicRoads design drawings of the Freeway.

Melbourne Water drainage infrastructure also includes some culverts in the Masons Lane Catchment.

5.2.6 Pit and Pipe Losses

The 2010 release of TUFLOW includes a new way of computing pit losses. A manhole layer can be either automatically or manually created and used to apply the losses to the nodes created in the 1 dimensional network layers in a variety of different ways. A combination of manual and automatic manhole layers, applying losses using the Engelhund method was used. This method recalculates losses at each time step using the angle of the entry and exit culverts, water levels, manhole widths and flow distributions. A combination of a manual manhole layer and automatic manholes were used as the automatic manhole layer was producing losses that were considered too high for some of the pipes. The manual manhole layer was used to model all manholes on Melbourne Water pipes as data was provided on the sizes for the majority of Melbourne Water manholes. The default TUFLOW K_e values for circular and rectangular manholes were changed from 0.25 and 0.5 respectively to 0.2. The K_e value represents the entry loss of the water entering the pipe from the manhole. Additional losses are also applied by TUFLOW depending on the angle and number of pipes entering and exiting the manhole.

In instances where additional pipe losses were needed, for example pipes which curved around a corner without a pit, additional form losses were applied to the pipes. These losses were calculated using figure 7.16.13 from the Queensland Urban Drainage Manual.

5.3 Surface Roughness

Within TUFLOW, a land use (materials) layer was utilised to import surface roughness information into the model. A materials layer for the catchment was constructed by utilising cadastre data in conjunction with aerial photography. The following Manning's 'n' values were used based on those considered 'reasonable' in the MW technical specifications:

- 0.2 (Low Density Residential);
- 0.35 (High Density Residential);
- 0.5 (Industrial/Commercial Buildings)
- 0.03 (Roads/ Car parks);
- 0.016 (Concrete Lined Channels)
- 0.035 (Open Space with minimal vegetation);
- 0.045 (Open Space with moderate vegetation)
- 0.09 (Open Space with heavy vegetation); and
- 0.05 (Future Development Zone)

The future development zone roughness value was applied in areas which were zoned R1Z (Residential Zone 1) and LDRZ (Low Density Residential) but were not yet developed. This was done to ensure a consistent approach between hydrologic and hydraulic modelling, as all areas zoned for future development have been assigned a developed fraction impervious, which created a greater amount of runoff than a predevelopment fraction impervious value. The aim of using 0.05 as a roughness value was to simulate overland flow through one or two properties, which would normally be assigned a value between 0.2 and 0.35, and then along a designated floodway or road (Mannings n range of 0.018-0.045). The majority of the flow length would be expected to be along the floodway or road, hence a value closer to the floodway roughness than house lot roughness has been used. The roughness value of 0.05 was discussed with and agreed by Rod Watkinson from Melbourne Water.

To construct the materials layer, a default roughness of 0.35 was applied to cadastre blocks throughout the catchment as it was predominantly high density residential (over 50% of block covered by buildings on aerial photograph). Values were changed for those allotments where the land use was different according to a visual inspection of the aerial photography.

To help improve the stability of the model a depth variable Mannings value was used for each of the open space categories and the future development category. When the flow is less than 10 mm deep the Mannings n value of 0.3 was used. Between 10 mm and 15 mm depth the Mannings value transitioned from 0.3 to the values listed above. When the depth was greater than 15 mm the Mannings values above applied. The use of the depth variable Mannings values helped to improve the stability particularly in the steeper areas of the catchment which were experiencing shallow sheet flow.

5.4 Boundary Conditions

5.4.1 1-D Boundary Conditions (downstream boundary)

Within the study catchments, 1-D boundary conditions were required at each of the pipe outlets where the Melbourne Water drains discharge into the Lerderderg River. A head over time (HT) boundary was applied at the downstream end to represent the water level at the point where the pipe discharged into the river. Water levels were supplied by Melbourne Water for 10 year ARI event in the Lerderderg River and were used in the TUFLOW hydraulic model for all modelling events including climate change events.

The 1-D boundary condition layer (1d_bc) were also be used to read in each of the RORB inflow hydrographs for the individual sub-catchments. The sub-catchments polygons created for the hydrological model were inputted into this layer, which allowed the inlet pits within an individual sub-catchment to have the total hydrograph split equally across the pits.

5.4.2 2-D Boundary Conditions

To model the 1-D open channel, a series of 2-D boundary conditions were included to model and map the interaction of flow between the 1-D channel and the 2-D surface. HX lines (Water Level (**H**ead) from an e**X**ternal Source (ie. a 1-D model)) were drawn at the top of bank to define where the flow would interact between the 1-D channel and the 2-D floodplain. CN lines were drawn to connect the HX lines to the 1-D channel.

As part of the 1-D network, 2-D SX (source of flow from a 1D model) boundaries were assigned to the pits to allow discharge of water from the pipe network to the 2-D surface. 2-D SX boundaries were also applied at the entrance and exits to culverts throughout the catchment.

2-D HQ (Head versus Flow) boundaries were also used at the model boundaries where overland flow exits to the study catchments. 2-D HT boundaries were also used at the downstream ends of the model to set constant water levels. HT boundaries were used where possible as it was believed that the HQ boundaries were contributing to the slightly unstable dV pattern which was evident in some run log files.

5.4.3 Initial water surface levels

Initial water surface levels were specified at some points in the model, mainly near boundary conditions which specify a fixed water level, such as at the downstream end of the model. In these instances the initial water levels were set to the same level as the boundary condition (assuming a fixed elevation boundary condition was being used). Applying the initial water levels helped to prevent any "backflow wave" from the boundary condition filling up pipes or low lying areas that are below the elevation specified at the boundary, which can result in mass balance errors. An initial water level was also used to fill an old water supply dam in the upper part of the Lerderderg Street Catchment. The basin was filled as it was not known what the operating conditions of the basin were, and so a conservative approach was to assume that the basin was full when a storm event occurred.

5.5 Complete TUFLOW Model

A layout depicting the key TUFLOW layers is shown in **Appendix D**. The TUFLOW model and key model information has also been supplied in electronic format.

5.6 TUFLOW Parameters

5.6.1 Time Step

A time step of 0.5 seconds was used for both the 1-D and 2-D elements of the model. This time step is below Melbourne Water guidelines which specify that the time step should not be smaller than one quarter of the grid size. Given the gird size of 3 m this would allow for a time step of 0.75 seconds. A 0.5 second time step was chosen as it allows for rounded outputs on each whole second. A 1 second time step could not be used as the upper parts of the catchment are very steep with grades of up to 5:1 (H:V) resulting in unstable flow patterns and high 2-D errors.

5.6.2 Durations Modelled

All storm durations from 10 minutes to 36 hour for the 100 year event were initially modelled. As the run times for the model are roughly two times real time (one hour of simulation takes two hours) an investigation was undertaken to determine if the longer runs were contributing to the final mapping outputs or not. It was determined that 99.6% of all critical durations for the model were from the 12 hour duration or less. Of the points which were critical in durations above the 12 hour run, many of them were contained in trapped low points such as dams, in areas not being mapped. As this was the case it was decided to only model all durations up to and including the 12 hour storm but not beyond. The size of the catchments suggests that shorter runs should make up the majority of the critical durations for the catchments.

5.6.3 Model Log File

The TUFLOW log file provides a summary of key information while the model is running. Two items that are reported in the log file are percentage error and change in volume of water in the model (dV). Engeny have been able to keep the 1-D, 2-D and cumulative error below 1% in all runs for the entire duration of all runs. In all runs the 1-D error is 0% for the duration of the runs.

The target for the dV values is to have a smooth series of numbers, indicating that water is entering and leaving the model with as few "wobbles" or fluctuations as possible. Fluctuations can indicate instabilities or areas of the model which require improvement. All of the runs which Engeny completed included dV values with a level of fluctuation. The causes of these fluctuations were investigated and it is believed that they are related to the HQ boundaries which have been used to remove flow from the model. To ensure that these fluctuations do not impact on the mapping of Melbourne Water assets the boundaries for the model have been moved at least 50 – 100 m from the areas to be mapped. The use of HQ boundaries was limited where possible to reduce the influence that the boundary conditions can have, however not all locations were suitable for HT boundaries to be used.

5.6.4 Warnings and Errors

Melbourne Water request that all warnings and errors be explained or justified. Prior to the simulation commencing two warnings were recorded in all of the runs undertaken.

1. WARNING 1316 - Total flow width of inlet culverts exceeds R manhole flow width. Manhole Flow Width = 1.25; Total Inlet Flow Width = 2.40
2. WARNING 1313 - No outlet culvert connected to Manhole "289.2". Manhole not used/applied.

Warning 1 is referring to a pit just downstream of the outlet of the Dickson Street retarding basin in the Masons Lane Catchment. The two pipes entering this pit are both 1.2 m in diameter each, while the pipe exiting the pit is 0.375 m in diameter. Given that the function of this pit is to spill water into the swale above, the losses at this pit will be high intentionally. The 0.375 m outlet pipe was checked and is flowing full in both peak 5 year and 100 year ARI events.

Warning 2 is stating that there is a node with two pipes coming together but no manhole is being applied. This location is the Cairns Drive outfall, where a council network pipe is also outfalling to the Lerderderg River. It is correct that there is no manhole applied to this location. The reason that the warning is created is that TUFLOW was run using the automatic manhole creation command. This will try to create a manhole at any location where two pipes meet, however in this instance two pipes enter and none leave, which prompts TUFLOW to create the warning.

During the simulation 7 of the runs created warnings:

- 100 year 270 minute;
- 20 year 720 minute;
- 10 year 270 minute;
- 5 year 540 minute;
- 100 year climate change, 25 and 360 minute runs; and
- 5 year climate change 120 minute.

The warnings in each of these models were similar to the one listed below:

WARNING 1991 - 1:25:49: Negative depth at Node 40020: y = -0.80 Bed = 115.71 Iter =1

The warnings were recorded in two locations only, one at the connection between two Melbourne Water pipes on the Cairns Drive Main Drain (100 year 270 min, 100 year CC 25 min, 100 year CC 360 min and 5 year CC 120 min) and the other at the connection between two pipes on the Grey Street Main Drain (20 year 720 min, 10 year 270 min and 5 year 540 min). The critical storm durations were checked at each of the locations where the errors occurred to see if the the errors occurred during the critical event at that location. Only the errors from the 5 year 540 minute (9 hour) event were occurring at a location where the 540 minute event was also the critical duration of the overland flow flood depths. Further interrogation of the results revealed that the peak water levels were recorded later in the run than when the errors occurred. The errors occurred at 3.5 hours into the simulation, at which time there was no surface flow, while the peak water surface level occurred at approximately 6.5 hours into the simulation.

The largest total number of negative depth warnings was 6 in any one run. As these warnings have had no effect on the mapped results Engeny believe that they are acceptable.

5.6.5 Checks

There are a number of checks which the model issues. Most of these relate to the manual manholes layer and the SX links on culverts and pits. The manhole checks are created as a result of using a manual manhole layer and an automatic manhole layer – the manual layer overrides the automatic layer creating the check. The SX links are also adjusted so that the Z point values match the pipe invert or pit opening. The largest change in elevation at SX links were obtained at the ends of culverts, normally on the upstream end. This was expected as the LiDAR data often does not pick-up the low point before a culvert goes under the road.

The model also issues a check file relating to the use of centre cross sections over 1-D channels used in the model. These occur at all of the bridges and also at the most upstream cross section in the Lerderderg Street Catchment. These have been checked and are correct.

5.7 Model Calibration/Validation

As there is no gauged flow data within any of the catchments modelled it has not been possible to calibrate the model. Instead Engeny have tried to validate that the flows and water depths being produced by the TUFLOW model are reasonable. Any unexpectedly large or small flow results have been investigated to understand whether or not they were reasonable. Knowledge gained through multiple site inspections within the catchments, especially Cairns Drive has been applied when determining if flow magnitudes and paths appear reasonable.

Results files such as the 1-D capacity check (ccA), time series (TS) and time series loss (TSL) were investigated for some of the runs from each event. These files were used to check that pipes are flowing full in the 5 year event and if not flowing full then to confirm that the level of overland flow was minor. The pipe flow in the 100 year event was also checked to ensure that the network was modelled correctly and that there were no "brick walls" where pipes had not been correctly connected to the next pipe downstream.

The developed TUFLOW model was internally checked by independent people multiple times throughout its development to ensure that it is as accurate as possible.

5.8 TUFLOW Model Results

A table listing the TUFLOW discharges at agreed locations is contained in **Appendix E.**

Details of the flood mapping process are documented in Section 6.

6. FLOOD MAPPING

The 'raw' TULFOW model results were interrogated in MapInfo to produce the following output files as required by Melbourne Water's Guidelines and Technical Specifications (2010):The flood mapping has been trimmed to the appropriate level to depict Melbourne Water asset flooding only

The following information has been provided to Melbourne Water in MapInfo electronic format:

- Flood Extents
- Flood Contours
- Mapping Limits
- 1m Grid Point Tables
- Flow Values; and
- Safety Risk in Roads.

All results tables have been trimmed to an appropriate level to depict flooding that relates to Melbourne Water drainage assets only.

The standard Melbourne Water flood mapping filter was used in generating the flood extents and contours:

- Depth ≥ 50mm; AND/OR
- Hazard (depth x velocity) ≥ 0.008

Plots showing the final flood mapping results for all events and scenarios modelled are contained in **Appendix F**.

7. CONCLUSIONS AND RECOMMENDATIONS

Engeny has undertaken flood mapping for the Melbourne Water drainage system for the following five catchments in Bacchus Marsh / Darley:

- Robertsons Road Drain;
- Cairns Drive Drain;
- Grey Street Drain;
- Masons Lane Drain; and
- Lerderderg Street Drain.

The study developed detailed hydrological models and a hydraulic model for the Lower Lerderderg catchments. In the absence of gauged flow data the RORB routing parameter (k_c value) was determined through validation to Rural Rational Method Flow calculations for each of the catchments. The k_c values were adjusted to fit the Rural Rational Method Flow values whilst trying to closely match estimates of k_c from Dandenong Valley Authority (DVA) calibrated curves. The flows and flood depths produced by the TUFLOW model were also validated to ensure that they are reasonable. Any unexpectedly large or small flow results were investigated to understand whether or not they were reasonable. Knowledge gained through multiple site inspections within the catchments, especially Cairns Drive, was used when determining if flow magnitudes and paths appear reasonable.

Flood mapping was completed for a range of storm events for existing conditions and for a climate change scenario of increased rainfall intensity as specified by Melbourne Water.

The outputs from this project include:

- Flood Extents
- Flood Contours
- Mapping Limits
- 1m Grid Point Tables
- Flow Values; and
- Safety Risk in Roads.

Potential uses for these outputs include:

- Update properties at risk of flooding;
- Assessment of flood risk;
- Planning scheme amendments, to control future development in flood risk areas;
- Declare flood levels;
- Undertake a Flood Management Plan, if not already undertaken, to understand local flooding in greater details; and
- Investigate flood mitigation options by undertaking floor level surveys, modelling flood damages, rating the flood risk for each catchment, developing flood mitigation options and assessing the economic and social benefits of the flood mitigation options.

8. REFERENCES

Guidelines and Technical Specifications – Flood Mapping Projects (Melbourne Water, November 2010)

Bureau of Meteorology (BoM), 2011, Intensity Frequency Duration Table, http://www.bom.gov.au/hydrao/has/cdirswebx/cdirswebx.shtml

TUFLOW User Manual (BMT WBM, 2010)

Australian Rainfall and Runoff – A Guide to Flood Estimate, Volumes 1 and 2 (The Institution of Engineers, Australia, 1987)

Queensland Urban Drainage Manual, Volume 1 Second Edition (Department of Natural Resources and Water, 2007)

APPENDIX A

Engeny Site Inspection Report

MELBOURNE WATER

Lower Lerderderg Catchments

Site Inspection Report

Date: 25th March 2011

Job Number: V3000-004

www.engeny.com.au
P: 03 9877 1877 | F: 03 9877 3710
Suite 8C, 14 Albert St, Blackburn VIC 3130 | PO Box 218 Blackburn VIC 3130

ENGENY
WATER MANAGEMENT

DISCLAIMER

This report has been prepared on behalf of and for the exclusive use of Melbourne Water and is subject to and issued in accordance with Melbourne Water instruction to Engeny Management Pty Ltd (Engeny). The content of this report were based on previous information supplied by Melbourne Water.

Engeny accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this report by any third party. Copying this report without the permission of Melbourne Water or Engeny is not permitted.

V3000-004 Lower Lerderderg Catchments – Site Inspection Report					
DOC PATH FILE					
REV	**DESCRIPTION**	**AUTHOR**	**REVIEWER**	**APPROVED BY**	**DATE**
1	Client Issue	Scott Dunn	Andrew Prout	Andrew Prout	25th March 2011

LOWER LERDERDERG CATCHMENTS – SITE INSPECTION REPORT

Thursday 24th March

Attendees: Fathaha Khanam – Melbourne Water

Scott Dunn – Engeny

Glenn Ottrey - Engeny

A site inspection was carried out on the Lower Lerderderg Catchments to inspect catchment boundaries and identify inputs for the hydraulic model to undertake floodplain mapping of the catchment. The inspection captured a number of key issues with regards to hydraulic modeling of the Catchments including:

- Roadway culverts;
- Pedestrian underpass beneath Western Freeway;
- Drainage outlets;
- Southern Rural Water Irrigation Channel; and
- Retarding Basins.

Roadway Culverts

A number of roadway culverts were inspected and measured to validate supplied GIS information. It is essential that these culverts are modeled accurately in the hydraulic TUFLOW model.

Pedestrian Underpass

The dimensions of the pedestrian underpass beneath the Western Freeway were noted. Whilst it is not expected to provide significant transfer of overland flow it is essential that this it is inputted into TUFLOW to represent reality.

Drainage Outlets

The outlets of the major drains were inspected to analyse their interaction with their outfall which in all instances is the Lerderderg River.

Southern Rural Water Irrigation Channel

The Southern Rural Water Irrigation Channel was inspected to determine how it operates and where it outfalls. It was determined that the Channel outfalls to the Lerderderg River which was different to our initial impressions. Measurements of the channel were taken for input into the TUFLOW model. Given that the channel is relatively narrow and it expected that TUFLOW will be modelled with a 4m 2-D grid, the channel will need to be modelled as part of the 1-D network.

Retarding Basins

The retarding basin on the Masons Lane Drain was inspected to determine its design intent and note its inlets and outlets. Several measurements were undertaken to validate supplied GIS information of the drains. It was noted that the capacity of this retarding basin is going to be relatively small given the shaping of the side slopes (approximately less 300mm in some areas), this will be validated against the developed Digital Elevation Model (DEM).

A dam/potential retarding basin built on Southern Rural Water land was not able to be inspected given that it is on private land, contact will be made with Southern Rural Water to determine the design intent for this body of water.

MELBOURNE WATER
LOWER LERDERDERG CATCHMENTS – SITE INSPECTION

Photo 1: Holts Lane Culvert near Halletts Way

Photo 2: Pedestrian Underpass at Western Freeway from Holts Lane

Job No. V3000-004 Page 3

Photo 3: Cairns Drive Outlet and Robertsons Road Outlet

Photo 4: Robertsons Road Outlet

Photo 5: Cairns Drive Outlet

Photo 6: Cairns Drive Outlet looking towards Lerderderg River

Photo 7: Lerderderg River looking Upstream from Robertsons Rd/Cairns Drive Outlets

Photo 8: Lerderderg River looking Downstream from Robertsons Rd/Cairns Drive Outlets

Photo 9: Southern Rural Water Irrigation Channel Outfall at Lerderderg River

Photo 10: Southern Rural Water Irrigation Channel Outfall at Lerderderg River

Photo 11: Southern Rural Water Irrigation Channel looking upstream

Photo 12: Masons Lane Outlet

Photo 13: Masons Lane Outlet looking towards Lerderderg River

Photo 14: Retarding Basin on Masons Lane Drain

Photo 15: Retarding Basin on Masons Lane Drain

Photo 16: Downstream of Retarding Basin on Masons Lane Drain

Photo 17: Culverts Downstream of Retarding Basin on Masons Lane Drain

Photo 18: Masons Lane Waterway looking upstream from Dickson Street

Photo 19: Masons Lane Waterway looking upstream from western end of Clifton Drive

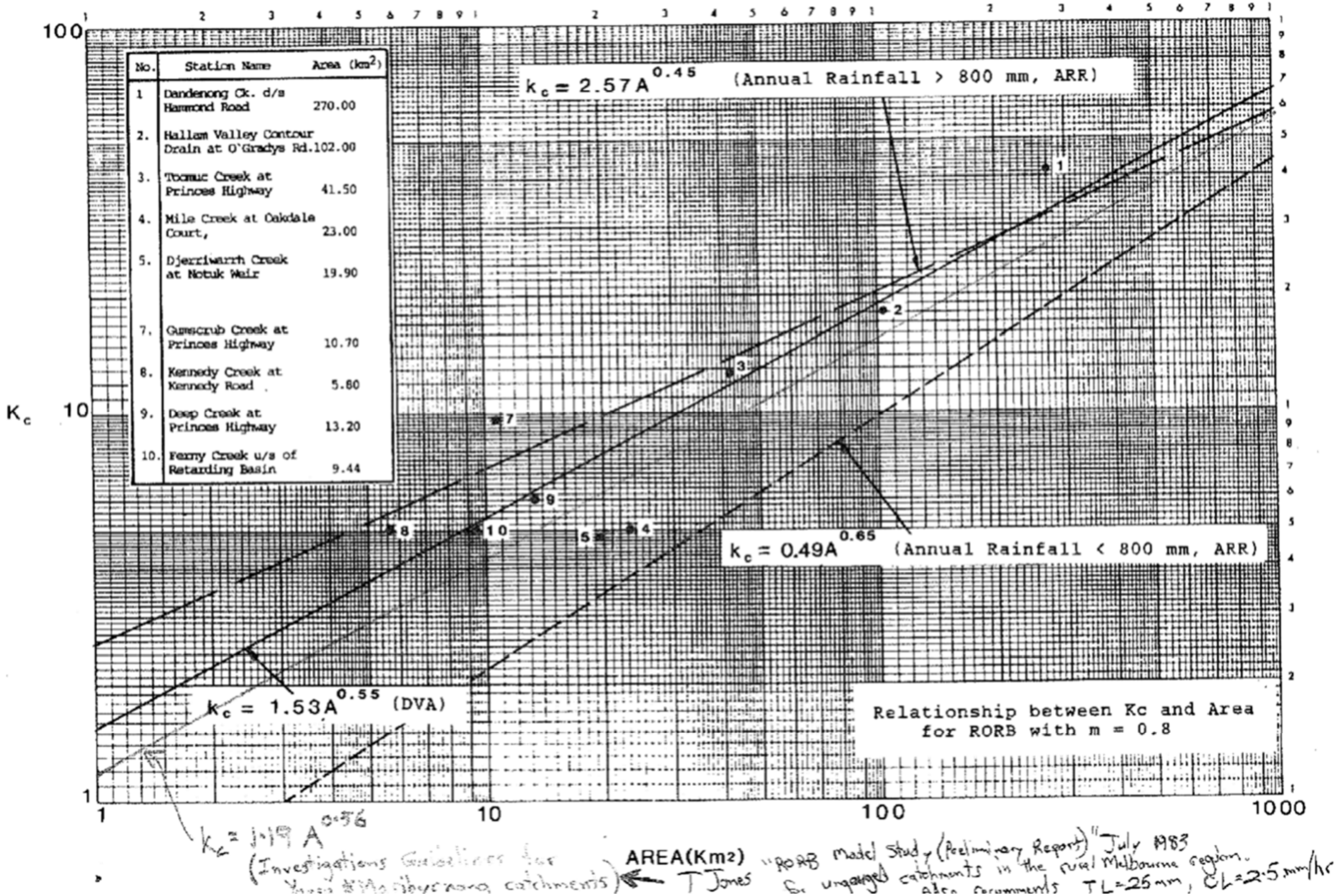
Photo 20: Masons Lane Waterway looking downstream from Clifton Drive

Photo 21: Masons Lane Waterway looking upstream from south of Western Freeway

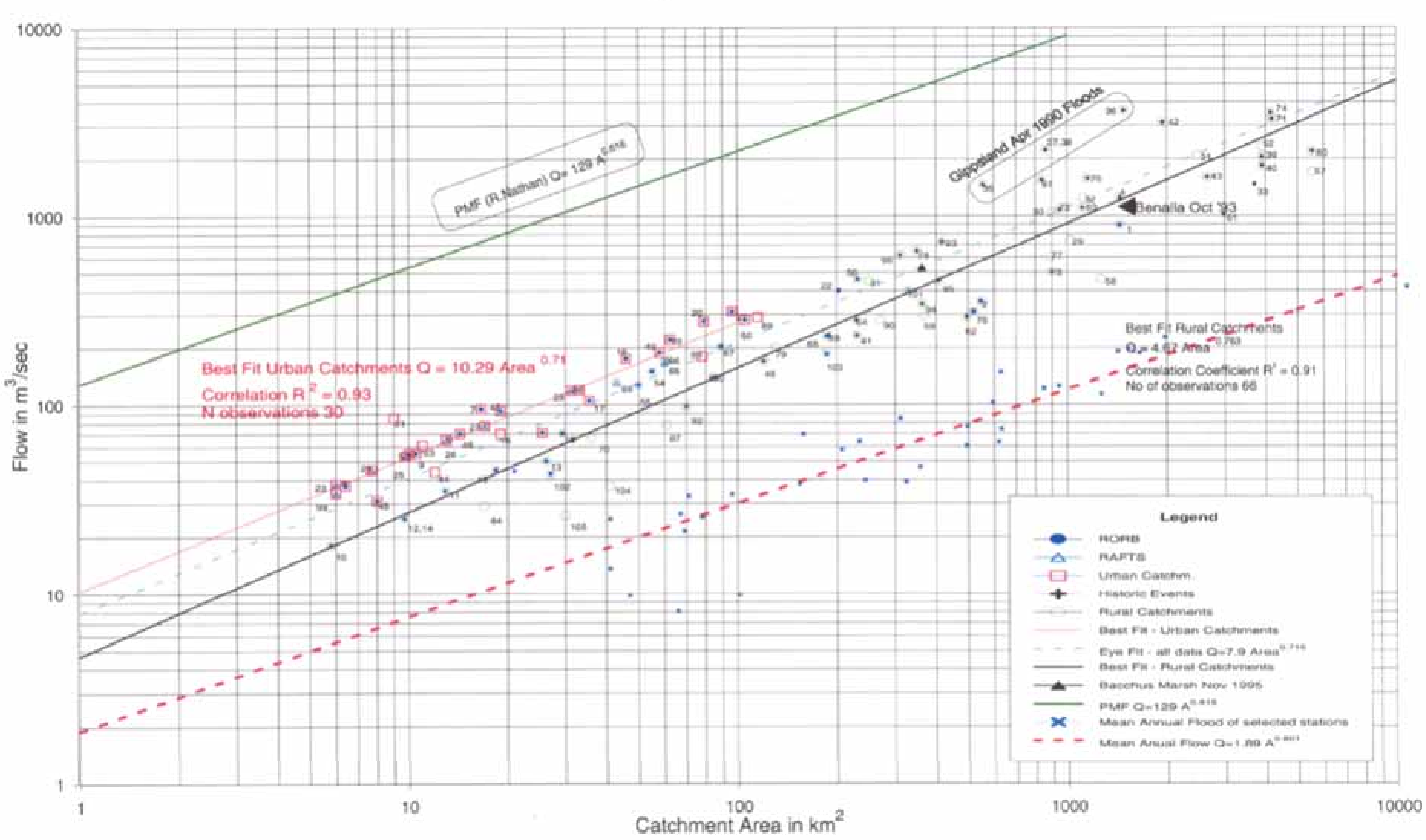
Photo 22: Masons Lane Waterway looking downstream from south of Western Freeway

APPENDIX B

RORB k_c and Regression Curves


No. | Station Name | Area (km²)
1 Dandenong Ck. d/s Hammond Road 270.00
2. Hallam Valley Contour Drain at O'Gradys Rd. 102.00
3. Toomuc Creek at Princes Highway 41.50
4. Mile Creek at Oakdale Court, 23.00
5. Djerriwarrh Creek at Notuk Weir 19.90
7. Gumscrub Creek at Princes Highway 10.70
8. Kennedy Creek at Kennedy Road 5.80
9. Deep Creek at Princes Highway 13.20
10. Ferny Creek u/s of Retarding Basin 9.44
k_c = 2.57 A^0.45 (Annual Rainfall > 800 mm, ARR)
k_c = 0.49A^0.65 (Annual Rainfall < 800 mm, ARR)
k_c = 1.53A^0.55 (DVA)
Relationship between Kc and Area for RORB with m = 0.8
K_c
AREA(Km2)
100
10
1
1000
T Jones
July 1983
TL=25mm, CL=2.5mm/hr

Regression of Flood Flows versus Catchment Areas in Victoria for urban and rural catchments along and adjacent to the Great Dividing Range.
Source: Flood Studies and Large Historic Events



Designed: Nick Nikolaou & Roel von't Steen
Floodplain Management DNRE -Revised June 1997

APPENDIX C

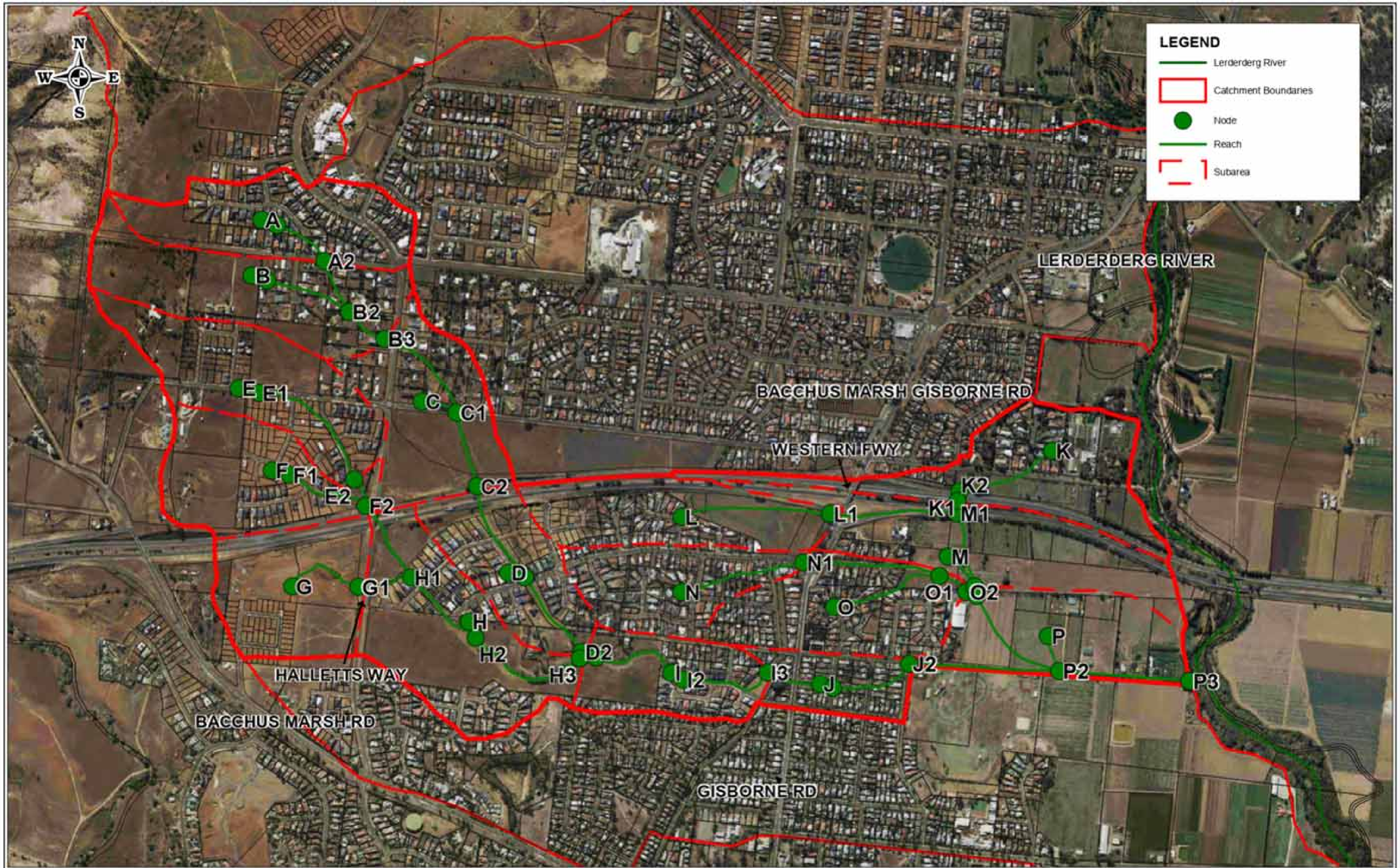
RORB Model Catchment Layouts

ENGENY WATER MANAGEMENT

Melbourne Water

Scale 1: 10 000	
Date: 14/12/2011	
By: CM	
Checked By: GO	
Job No. V3000_004	
Revision: 0	

Lower Lerderderg Catchments Flood Mapping
RORB Subcatchment Plan Lerderderg St Drain
Melways Map Ref: M327, M328, M333, M334
Figure 1



ENGENY WATER MANAGEMENT

www.engeny.com.au

Melbourne Water

Scale 1: 10 000	
Date: 14/12/2011	
By: CM	
Checked By: GO	
Job No. V3000_004	
Revision: 0	

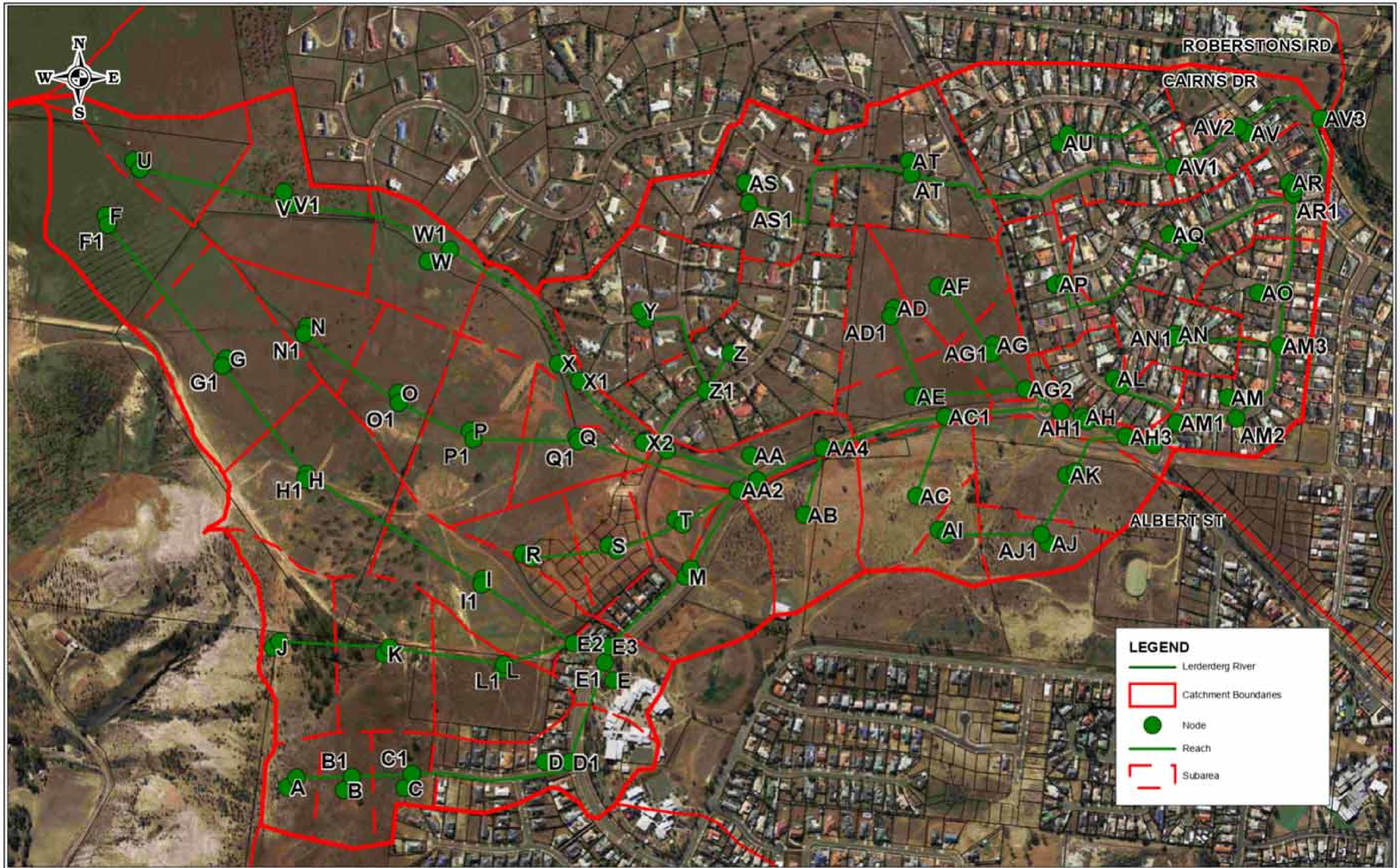
Lower Lerderderg Catchments Flood Mapping
RORB Subcatchment Plan Masons Ln Drain
Melways Map Ref: M327, M328, M333, M334
Figure 2

ENGENY WATER MANAGEMENT

Melbourne Water

Scale 1: 10 000	
Date: 14/12/2011	
By: CM	
Checked By: GO	
Job No. V3000_004	
Revision: 0	

Lower Lerderderg Catchments Flood Mapping
RORB Subcatchment Plan Grey St Drain
Melways Map Ref: M327, M328, M333, M334
Figure 3



ENGENY WATER MANAGEMENT

Melbourne Water

Scale 1: 6 000	
Date: 14/12/2011	
By: CM	
Checked By: GO	
Job No. V3000_004	
Revision: 0	

Lower Lerderderg Catchments Flood Mapping
RORB Subcatchment Plan Cairns Dr Drain
Melways Map Ref: M327, M328, M333, M334
Figure 4

ENGENY WATER MANAGEMENT

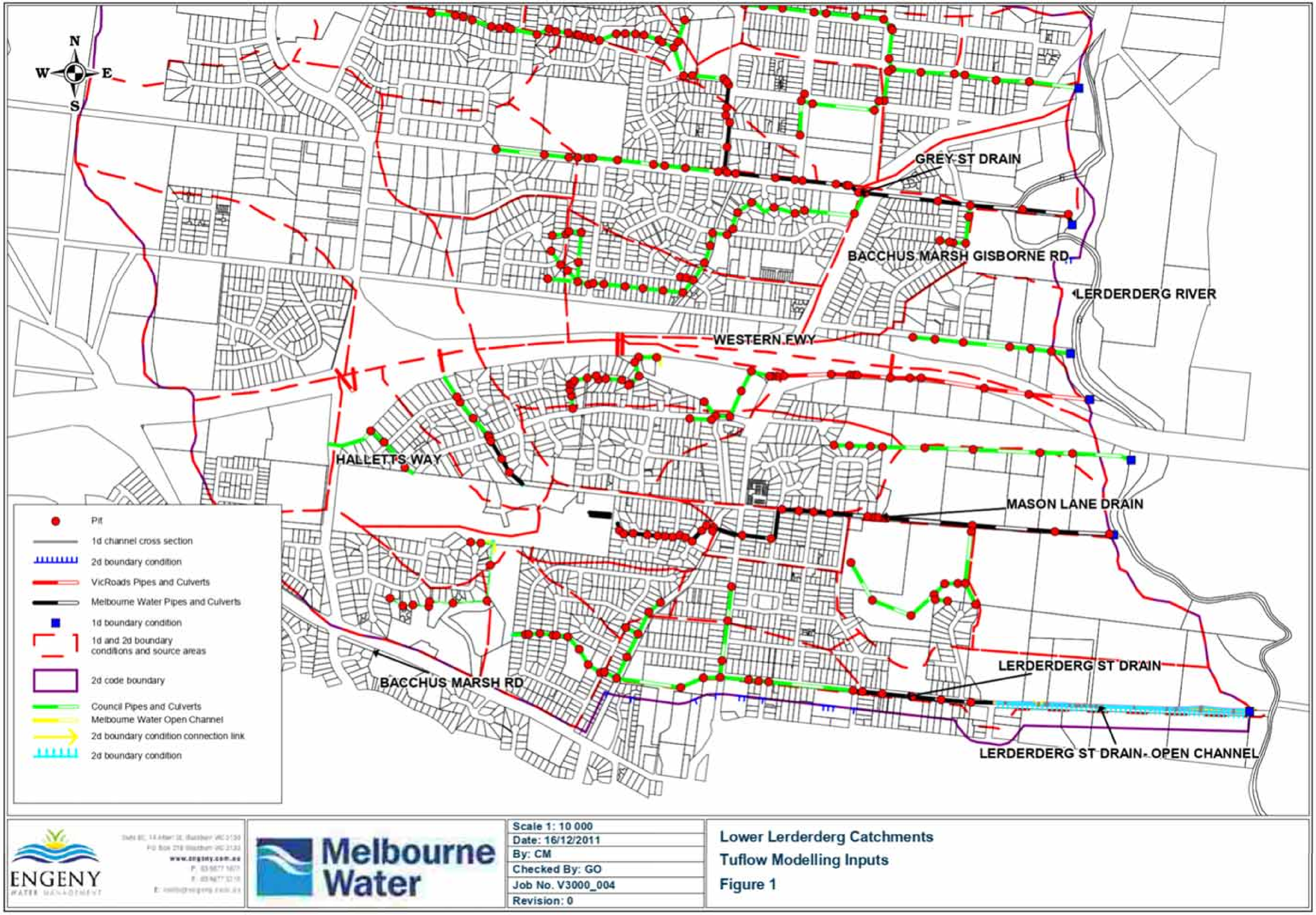
www.engeny.com.au

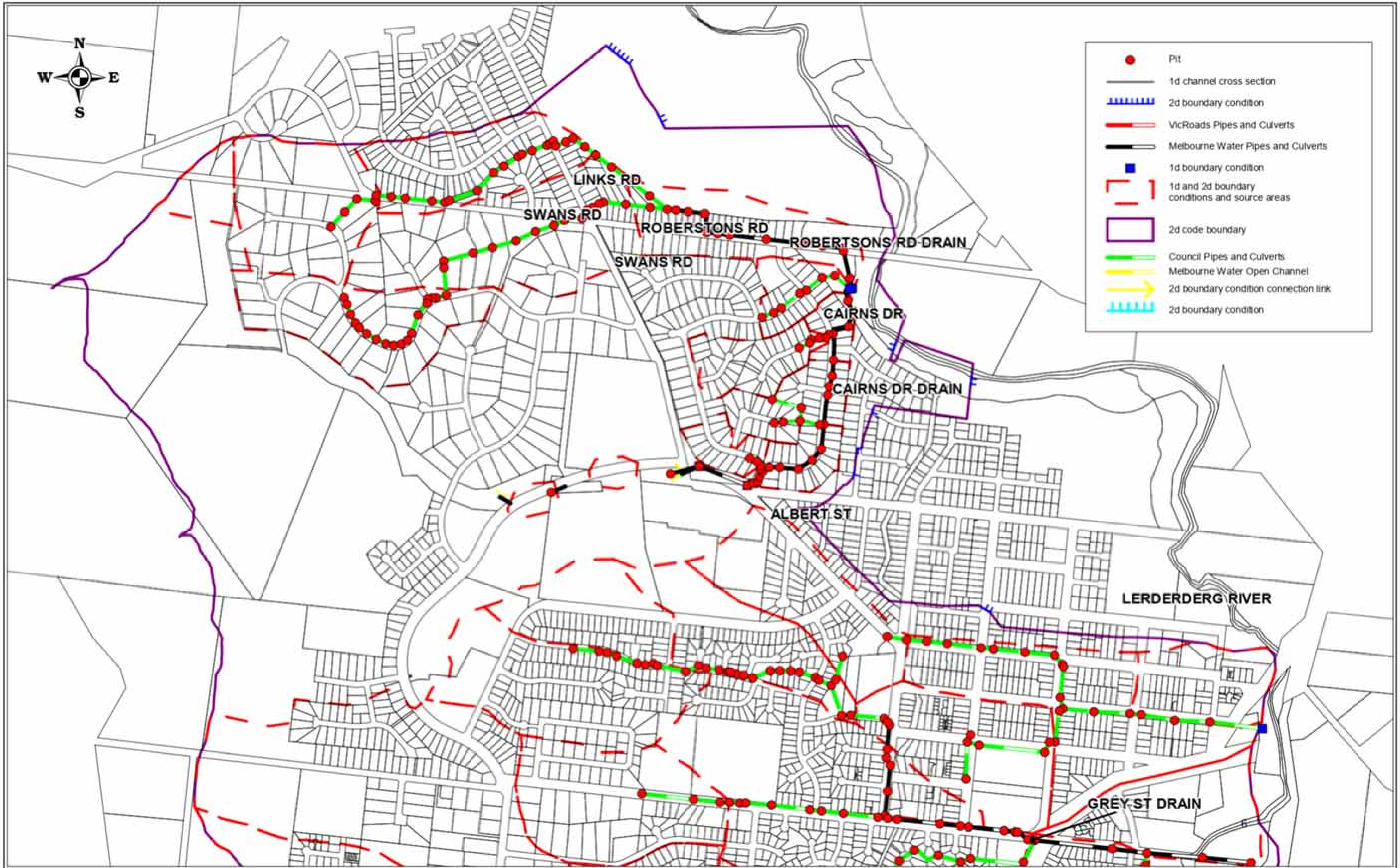
Melbourne Water

Scale 1: 6 000
Date: 14/12/2011
By: CM
Checked By: GO
Job No. V3000_004
Revision: 0

Lower Lerderderg Catchments Flood Mapping
RORB Subcatchment Plan Robertson Rd Drain
Melways Map Ref: M327, M328, M333, M334
Figure 5

APPENDIX D
Hydraulic Model Layout


N
W
E
S
GREY ST DRAIN
BACCHUS MARSH GISBORNE RD
LERDERDERG RIVER
WESTERN FWY
HALLETTS WAY
MASON LANE DRAIN
LERDERDERG ST DRAIN
BACCHUS MARSH RD
LERDERDERG ST DRAIN- OPEN CHANNEL
Pit
1d channel cross section
2d boundary condition
VicRoads Pipes and Culverts
Melbourne Water Pipes and Culverts
1d boundary condition
1d and 2d boundary conditions and source areas
2d code boundary
Council Pipes and Culverts
Melbourne Water Open Channel
2d boundary condition connection link
2d boundary condition
ENGENY
Melbourne Water
Scale 1: 10 000
Date: 16/12/2011
By: CM
Checked By: GO
Job No. V3000_004
Revision: 0
Lower Lerderderg Catchments
Tuflow Modelling Inputs
Figure 1



ENGENY WATER MANAGEMENT

Melbourne Water

Scale 1: 10 000
Date: 16/12/2011
By: CM
Checked By: GO
Job No. V3000_004
Revision: 0

Lower Lerderderg Catchments
Tuflow Modelling Inputs
Figure 2

APPENDIX E
TUFLOW Results Table

APPENDIX E – TULFOW Results Table

Flow Point Number	Flow 100yr (m^3/s)	Asset flow 100yr (m^3/s)	Overland flow 100y (m^3/s)r	Flow 50yr (m^3/s)	Asset flow 50yr (m^3/s)	Overland flow 50yr (m^3/s)	Flow 20yr (m^3/s)	Asset flow 20yr (m^3/s)	Overland flow 20yr (m^3/s)	Flow 10yr (m^3/s)	Asset flow 10yr (m^3/s)	Overland flow 10yr (m^3/s)	Flow 5yr (m^3/s)	Asset flow 5yr (m^3/s)	Overland flow 5yr (m^3/s)
Q 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q 2	3.34	0	3.34	1.61	0	1.61	1	0	1	0.69	0	0.69	0.39	0	0.39
Q 3	3.19	0	3.19	1.94	0	1.94	1.27	0	1.27	0.88	0	0.88	0.69	0	0.69
Q 4	0.17	0	0.17	0.11	0	0.11	0.04	0	0.04	0.02	0	0.02	0.01	0	0.01
Q 5	6.68	2.92	3.76	5.78	2.88	2.9	4.64	2.47	2.17	3.92	2.43	1.49	3.16	2.24	0.92
Q 6	8.24	5.01	3.23	7.06	4.77	2.29	5.45	3.82	1.63	4.09	3	1.09	3.17	2.6	0.57
Q 7	0.2	0	0.2	0.12	0	0.12	0.07	0	0.07	0.04	0	0.04	0.03	0	0.03
Q 8	6.74	3.41	3.33	5.95	3.27	2.68	4.81	2.81	2	3.98	2.63	1.35	3.16	2.42	0.74
Q 9	5.21	0	5.21	4.13	0	4.13	2.99	0	2.99	1.89	0	1.89	1.27	0	1.27
Q 10	6.36	2.01	4.35	5.72	1.99	3.73	4.34	1.51	2.83	3.98	1.59	2.39	3.44	1.34	2.1
Q 11	3.24	2.77	0.47	3.02	2.68	0.34	2.77	2.57	0.2	2.38	2.24	0.14	2.25	2.14	0.11
Q 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q 13	2.51	0	2.51	2.4	0	2.4	2.22	0	2.22	2.13	0	2.13	1.97	0	1.97
Q 14	5.18	0	5.18	4.62	0	4.62	4.06	0	4.06	3.23	0	3.23	2.76	0	2.76
Q 15	8.65	0	8.65	6.88	0	6.88	5.64	0	5.64	4.7	0	4.7	3.87	0	3.87
Q 16	6.07	0	6.07	5.07	0	5.07	4.28	0	4.28	3.56	0	3.56	3.06	0	3.06
Q 17	6.96	1.86	5.1	4.7	1.86	2.84	4.4	1.85	2.55	3.91	1.85	2.06	3.55	1.85	1.7
Q 18	4.01	0	4.01	3.86	0	3.86	3.47	0	3.47	3.1	0	3.1	2.86	0	2.86
Q 19	1.09	0	1.09	0	0	0	0	0	0	0	0	0	0	0	0
Q 20	2.64	0	2.64	2.17	0	2.17	1.26	0	1.26	0.37	0	0.37	0.31	0	0.31
Q 21	7.14	0.36	6.78	4.99	0.36	4.63	4.64	0.36	4.28	4.17	0.35	3.82	3.79	0.35	3.44
Q 22	6.84	2.74	4.1	4.93	2.69	2.24	4.56	2.66	1.9	4.12	2.64	1.48	3.74	2.62	1.12
Q 23	0.45	0	0.45	0.11	0	0.11	0.09	0	0.09	0.08	0	0.08	0.03	0	0.03
Q 24	0.69	0	0.69	0.41	0	0.41	0.37	0	0.37	0.13	0	0.13	0.14	0	0.14
Q 25	6.03	0	6.03	3.92	0	3.92	1.84	0	1.84	0.06	0	0.06	0	0	0

Flow Point Number	Flow 100yr (m^3/s)	Asset flow 100yr (m^3/s)	Overland flow 100y (m^3/s)r	Flow 50yr (m^3/s)	Asset flow 50yr (m^3/s)	Overland flow 50yr (m^3/s)	Flow 20yr (m^3/s)	Asset flow 20yr (m^3/s)	Overland flow 20yr (m^3/s)	Flow 10yr (m^3/s)	Asset flow 10yr (m^3/s)	Overland flow 10yr (m^3/s)	Flow 5yr (m^3/s)	Asset flow 5yr (m^3/s)	Overland flow 5yr (m^3/s)
Q 26	1.07	0	1.07	0.81	0	0.81	0.49	0	0.49	0.25	0	0.25	0.02	0	0.02
Q 27	3.94	3.79	0.15	3.67	3.62	0.05	3	3	0	2.72	2.72	0	2.53	2.53	0
Q 28	1.78	0	1.78	1.35	0	1.35	0.77	0	0.77	0.4	0	0.4	0.28	0	0.28
Q 29	4.47	0	4.47	3.43	0	3.43	2.38	0	2.38	1.37	0	1.37	0.76	0	0.76
Q 30	3.04	0.61	2.43	2.36	0.6	1.76	1.87	0.61	1.26	1.52	0.6	0.92	1.33	0.6	0.73
Q 31	2.96	0	2.96	2.07	0	2.07	1.34	0	1.34	0.91	0	0.91	0.73	0	0.73
Q 32	4.36	0	4.36	3.32	0	3.32	2.37	0	2.37	1.69	0	1.69	1.24	0	1.24
Q 33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q 34	0.2	0	0.2	0.05	0	0.05	0	0	0	0	0	0	0	0	0
Q 35	3.53	0	3.53	2.31	0	2.31	1.62	0	1.62	0.93	0	0.93	0.41	0	0.41
Q 36	0.66	0	0.66	0.57	0	0.57	0.39	0	0.39	0.26	0	0.26	0.2	0	0.2
Q 37	0.53	0	0.53	0.24	0	0.24	0.03	0	0.03	0.01	0	0.01	0.01	0	0.01
Q 38	0.96	0	0.96	0.79	0	0.79	0.47	0	0.47	0.28	0	0.28	0.27	0	0.27
Q 39	1.97	0	1.97	0.75	0	0.75	0.05	0	0.05	0.02	0	0.02	0	0	0
Q 40	3.25	0	3.25	2.1	0	2.1	1.57	0	1.57	0.66	0	0.66	0.41	0	0.41
Q 41	4.13	0	4.13	3.35	0	3.35	2.1	0	2.1	1.48	0	1.48	0.87	0	0.87
Q 42	2.07	0	2.07	1.68	0	1.68	1.09	0	1.09	0.74	0	0.74	0.42	0	0.42
Q 43	3.94	0	3.94	3.07	0	3.07	2.18	0	2.18	1.22	0	1.22	0.77	0	0.77
Q 44	0.04	0	0.04	0.01	0	0.01	0	0	0	0	0	0	0	0	0
Q 45	4.4	0	4.4	4.17	0	4.17	3.61	0	3.61	3.26	0	3.26	2.82	0	2.82
Q 46	2.27	1.5	0.77	2.01	1.42	0.59	1.66	1.3	0.36	1.33	1.05	0.28	0.91	0.73	0.18
Q 47	5.6	0.85	4.75	4.46	0.85	3.61	3	0.85	2.15	2.12	0.85	1.27	1.87	0.85	1.02
Q 48	3.84	1.64	2.2	3.21	1.53	1.68	2.49	1.4	1.09	1.95	1.21	0.74	1.55	1.05	0.5
Q 49	3.66	1.68	1.98	3.11	1.63	1.48	2.53	1.54	0.99	2.02	1.37	0.65	1.54	1.14	0.4
Q 50	0.33	0	0.33	0.22	0	0.22	0.12	0	0.12	0.09	0	0.09	0.05	0	0.05
Q 51	0.17	0	0.17	0.1	0	0.1	0.03	0	0.03	0.01	0	0.01	0.01	0	0.01

Flow Point Number	Flow 100yr (m^3/s)	Asset flow 100yr (m^3/s)	Overland flow 100y (m^3/s)r	Flow 50yr (m^3/s)	Asset flow 50yr (m^3/s)	Overland flow 50yr (m^3/s)	Flow 20yr (m^3/s)	Asset flow 20yr (m^3/s)	Overland flow 20yr (m^3/s)	Flow 10yr (m^3/s)	Asset flow 10yr (m^3/s)	Overland flow 10yr (m^3/s)	Flow 5yr (m^3/s)	Asset flow 5yr (m^3/s)	Overland flow 5yr (m^3/s)
Q 52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q 53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q 54	3.31	0	3.31	2.61	0	2.61	2.06	0	2.06	1.77	0	1.77	1.47	0	1.47
Q 55	0.52	0	0.52	0.28	0	0.28	0.14	0	0.14	0.05	0	0.05	0.03	0	0.03
Q 56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q 57	6.99	3.18	3.81	5.4	2.91	2.49	4.73	2.57	2.16	4.16	2.46	1.7	3.78	2.41	1.37
Q 58	3.94	3.54	0.4	3.28	3.14	0.14	2.77	2.67	0.1	2.6	2.53	0.07	2.49	2.45	0.04
Q 59	2.31	0	2.31	1.7	0	1.7	1.08	0	1.08	0.64	0	0.64	0.36	0	0.36
Q 60	3.86	0	3.86	2.84	0	2.84	2.06	0	2.06	1.74	0	1.74	1.42	0	1.42
Q 61	0.41	0	0.41	0.12	0	0.12	0.02	0	0.02	0	0	0	0	0	0
Q 62	0.72	0	0.72	0.38	0	0.38	0.16	0	0.16	0.01	0	0.01	0	0	0
Q 63	0.13	0	0.13	0.09	0	0.09	0.03	0	0.03	0.01	0	0.01	0.01	0	0.01
Q 64	0.78	0	0.78	0.53	0	0.53	0.29	0	0.29	0.2	0	0.2	0.12	0	0.12
Q 65	3.11	2.2	0.91	2.58	2.32	0.26	2.28	2.02	0.26	2.04	1.8	0.24	1.91	1.67	0.24
Q 66	1.71	0	1.71	0.74	0	0.74	0.05	0	0.05	0.01	0	0.01	0	0	0
Q 67	0.02	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0
Q 68	0.04	0	0.04	0.01	0	0.01	0	0	0	0	0	0	0	0	0
Q 69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q 70	6.02	0	6.02	4	0	4	1.8	0	1.8	0.1	0	0.1	0.04	0	0.04
Q 71	5.58	0	5.58	4.28	0	4.28	2.64	0	2.64	1.38	0	1.38	0.08	0	0.08
Q 72	6.76	0	6.76	5.11	0	5.11	3.49	0	3.49	2.47	0	2.47	1.7	0	1.7
Q 73	1.41	0	1.41	0.84	0	0.84	0.31	0	0.31	0.03	0	0.03	0	0	0
Q 74	2.01	0	2.01	1.61	0	1.61	1.13	0	1.13	0.7	0	0.7	0.42	0	0.42
Q 75	1.46	0	1.46	1.13	0	1.13	0.78	0	0.78	0.49	0	0.49	0.23	0	0.23
Q 76	0.25	0	0.25	0.19	0	0.19	0.12	0	0.12	0.09	0	0.09	0.06	0	0.06
Q 77	4.43	3.48	0.95	4.01	3.38	0.63	3.57	3.19	0.38	3.15	2.92	0.23	2.86	2.72	0.14

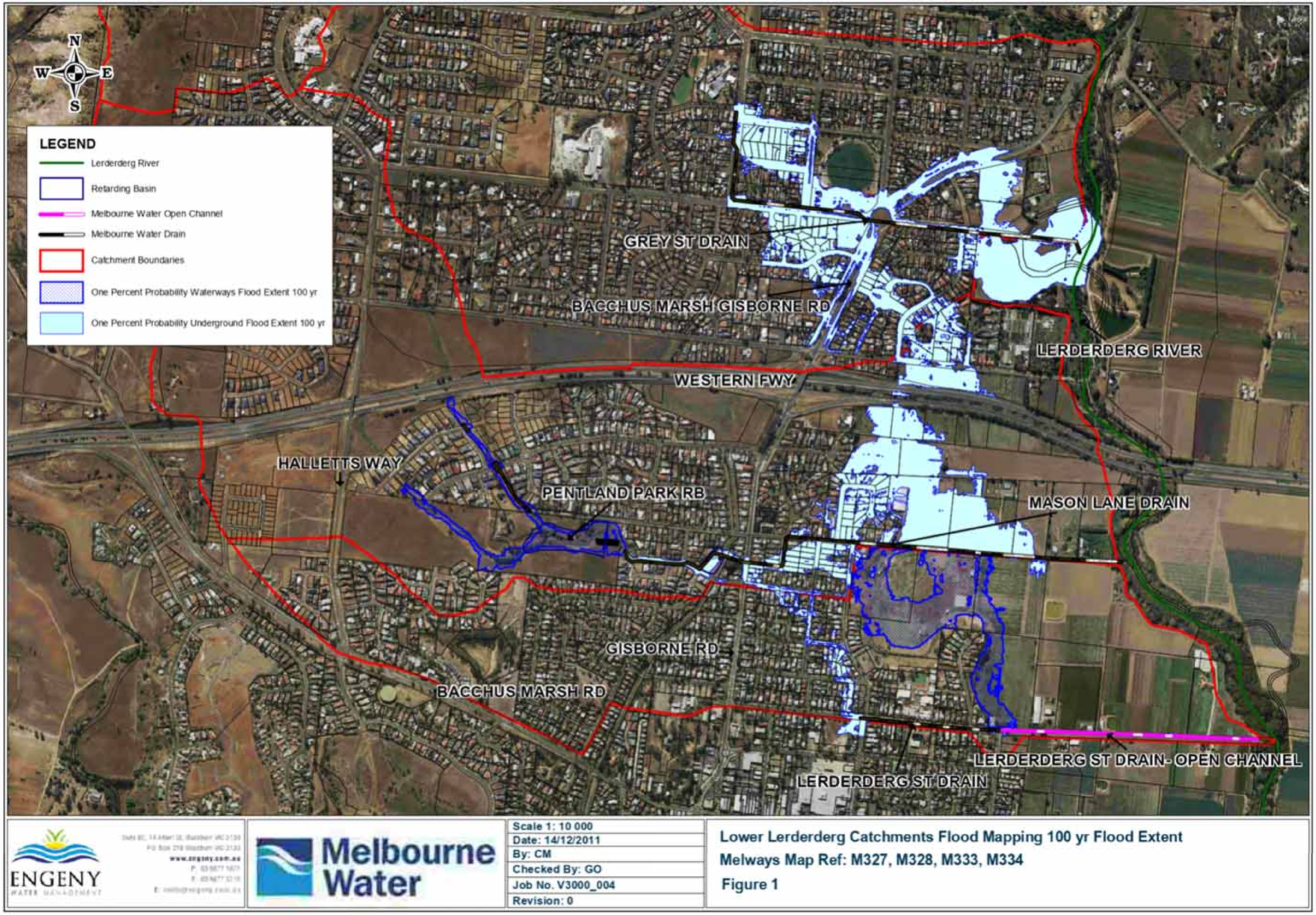
Climate Change Flow Values Table

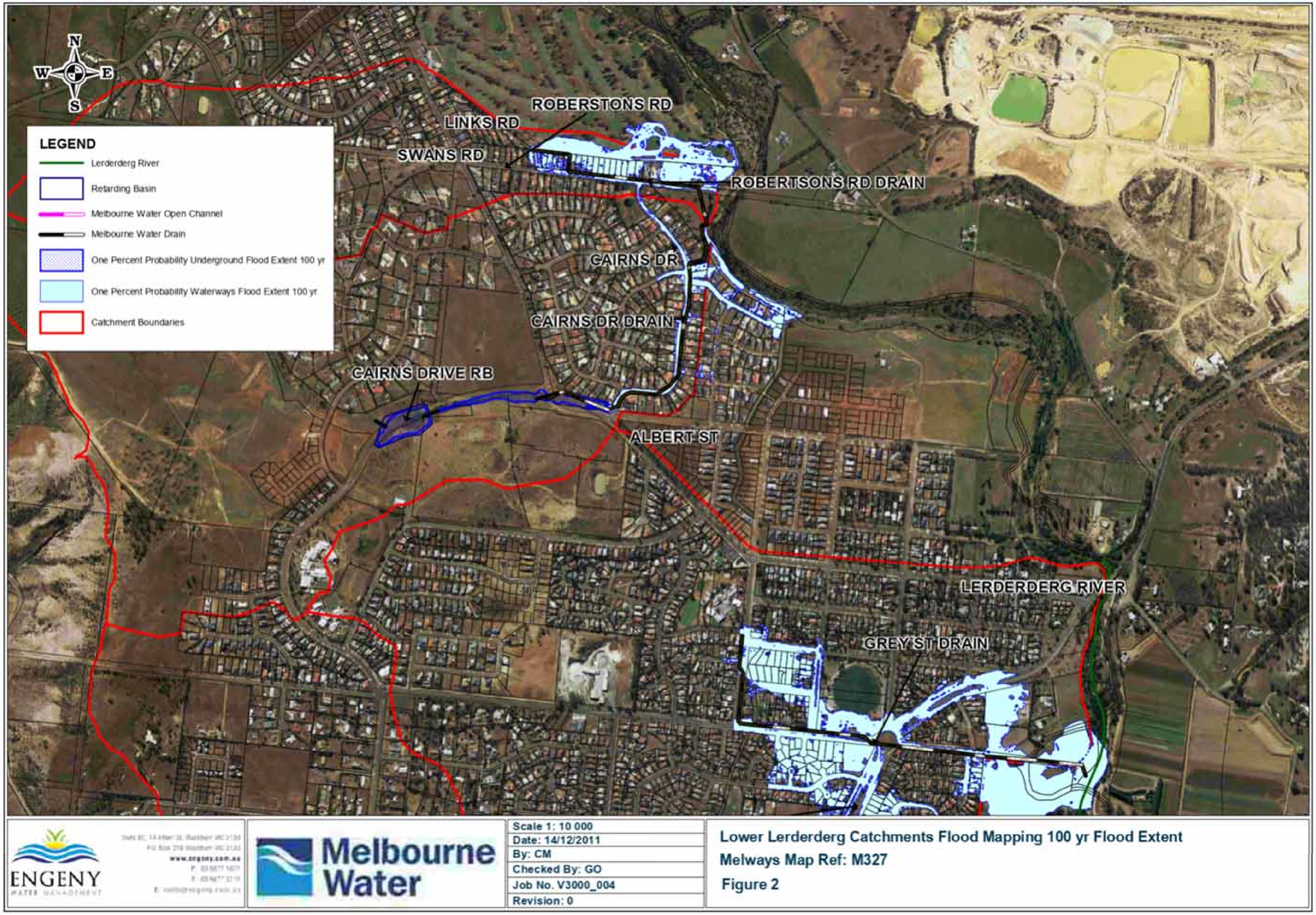
Flow Point Number	Flow 100yr (m^3/s)	Asset flow 100yr (m^3/s)	Overland flow 100y (m^3/s)r	Flow 20yr (m^3/s)	Asset flow 20yr (m^3/s)	Overland flow 20yr (m^3/s)	Flow 5yr (m^3/s)	Asset flow 5yr (m^3/s)	Overland flow 5yr (m^3/s)
Q 1	0	0	0	0	0	0	0	0	0
Q 2	5.93	0	5.93	1.54	0	1.54	0.4	0	0.4
Q 3	4.37	0	4.37	2.03	0	2.03	0.56	0	0.56
Q 4	0.36	0	0.36	0.13	0	0.13	0.36	0	0.36
Q 5	9.18	3.02	6.16	5.72	2.87	2.85	3.94	2.46	1.48
Q 6	11.05	5.68	5.37	7.1	4.58	2.52	4.19	3.02	1.17
Q 7	0.33	0	0.33	0.12	0	0.12	0.03	0	0.03
Q 8	9.57	3.76	5.81	5.94	3.16	2.78	4.07	2.67	1.4
Q 9	7.43	0	7.43	4.19	0	4.19	1.95	0	1.95
Q 10	7.75	1.81	5.94	5.6	1.91	3.69	4.25	1.51	2.74
Q 11	3.63	2.82	0.81	3.07	2.72	0.35	2.42	2.27	0.15
Q 12	0	0	0	0	0	0	0	0	0
Q 13	2.66	0	2.66	2.4	0	2.4	2.13	0	2.13
Q 14	5.88	0	5.88	4.75	0	4.75	3.45	0	3.45
Q 15	10.27	0	10.27	7.46	0	7.46	4.88	0	4.88
Q 16	7.2	0	7.2	5.41	0	5.41	3.7	0	3.7
Q 17	10.61	1.86	8.75	4.76	1.86	2.9	3.96	1.85	2.11
Q 18	4.16	0	4.16	3.85	0	3.85	3.16	0	3.16
Q 19	4.3	0	4.3	0	0	0	0	0	0
Q 20	2.89	0	2.89	1.17	0	1.17	0.51	0	0.51
Q 21	10.74	0.36	10.38	5	0.36	4.64	4.23	0.35	3.88
Q 22	10.04	2.97	7.07	4.99	2.74	2.25	4.19	2.65	1.54
Q 23	1.9	0	1.9	0.13	0	0.13	0.07	0	0.07
Q 24	2.61	0	2.61	0.42	0	0.42	0.11	0	0.11
Q 25	11.67	0	11.67	3.76	0	3.76	0.07	0	0.07

Flow Point Number	Flow 100yr (m³/s)	Asset flow 100yr (m³/s)	Overland flow 100y (m³/s)r	Flow 20yr (m³/s)	Asset flow 20yr (m³/s)	Overland flow 20yr (m³/s)	Flow 5yr (m³/s)	Asset flow 5yr (m³/s)	Overland flow 5yr (m³/s)
Q 26	1.78	0	1.78	0.83	0	0.83	0.28	0	0.28
Q 27	4.79	4.21	0.58	3.65	3.59	0.06	2.73	2.73	0
Q 28	2.48	0	2.48	1.51	0	1.51	0.58	0	0.58
Q 29	6.31	0	6.31	3.48	0	3.48	1.6	0	1.6
Q 30	4.2	0.64	3.56	2.44	0.61	1.83	1.76	0.77	0.99
Q 31	4.43	0	4.43	2.19	0	2.19	1	0	1
Q 32	6.19	0	6.19	3.43	0	3.43	1.77	0	1.77
Q 33	0.01	0	0.01	0	0	0	0	0	0
Q 34	0.56	0	0.56	0.06	0	0.06	0	0	0
Q 35	5.28	0	5.28	2.48	0	2.48	0.38	0	0.38
Q 36	1.1	0	1.1	0.53	0	0.53	0.2	0	0.2
Q 37	1.08	0	1.08	0.34	0	0.34	0	0	0
Q 38	1.21	0	1.21	0.81	0	0.81	0.16	0	0.16
Q 39	3.81	0	3.81	0.11	0	0.11	0.02	0	0.02
Q 40	5.51	0	5.51	1.75	0	1.75	0.92	0	0.92
Q 41	5.47	0	5.47	3.31	0	3.31	1.55	0	1.55
Q 42	4.31	0	4.31	1.66	0	1.66	0.77	0	0.77
Q 43	6.12	0	6.12	3.38	0	3.38	1.4	0	1.4
Q 44	0.14	0	0.14	0.01	0	0.01	0	0	0
Q 45	4.81	0	4.81	4.01	0	4.01	3.24	0	3.24
Q 46	2.61	1.58	1.03	1.99	1.44	0.55	1.32	1.03	0.29
Q 47	7.6	0.85	6.75	4.58	0.85	3.73	1.73	0.85	0.88
Q 48	4.56	1.68	2.88	3.28	1.63	1.65	1.56	1.06	0.5
Q 49	4.45	1.78	2.67	3.06	1.63	1.43	1.56	1.16	0.4
Q 50	0.61	0	0.61	0.25	0	0.25	0.05	0	0.05
Q 51	0.26	0	0.26	0.12	0	0.12	0.01	0	0.01

Flow Point Number	Flow 100yr (m^3/s)	Asset flow 100yr (m^3/s)	Overland flow 100y (m^3/s)r	Flow 20yr (m^3/s)	Asset flow 20yr (m^3/s)	Overland flow 20yr (m^3/s)	Flow 5yr (m^3/s)	Asset flow 5yr (m^3/s)	Overland flow 5yr (m^3/s)
Q 52	0	0	0	0	0	0	0	0	0
Q 53	0	0	0	0	0	0	0	0	0
Q 54	4.95	0	4.95	2.67	0	2.67	1.84	0	1.84
Q 55	0.74	0	0.74	0.31	0	0.31	0.05	0	0.05
Q 56	0	0	0	0	0	0	0	0	0
Q 57	9.63	3.39	6.24	5.55	2.92	2.63	4.24	2.48	1.76
Q 58	4.91	3.79	1.12	3.3	3.16	0.14	2.63	2.56	0.07
Q 59	3.91	0	3.91	1.69	0	1.69	0.72	0	0.72
Q 60	6.04	0	6.04	2.78	0	2.78	1.95	0	1.95
Q 61	1.38	0	1.38	0.15	0	0.15	0	0	0
Q 62	1.32	0	1.32	0.37	0	0.37	0.01	0	0.01
Q 63	0.19	0	0.19	0.11	0	0.11	0.02	0	0.02
Q 64	1.15	0	1.15	0.29	0	0.29	0.17	0	0.17
Q 65	3.07	2.24	0.83	2.63	2.33	0.3	2.02	1.79	0.23
Q 66	4.06	0	4.06	1.01	0	1.01	0.01	0	0.01
Q 67	0.06	0	0.06	0	0	0	0	0	0
Q 68	0.23	0	0.23	0.01	0	0.01	0	0	0
Q 69	0	0	0	0	0	0	0	0	0
Q 70	11.53	0	11.53	3.77	0	3.77	0.11	0	0.11
Q 71	8.85	0	8.85	4.44	0	4.44	1.56	0	1.56
Q 72	10.37	0	10.37	5.04	0	5.04	2.57	0	2.57
Q 73	2.55	0	2.55	0.82	0	0.82	0.06	0	0.06
Q 74	2.71	0	2.71	1.6	0	1.6	0.78	0	0.78
Q 75	2.37	0	2.37	1.13	0	1.13	0.5	0	0.5
Q 76	0.45	0	0.45	0.2	0	0.2	0.09	0	0.09
Q 77	5.38	3.68	1.7	3.99	3.37	0.62	3.18	2.93	0.25

APPENDIX F
Flood Mapping Results


N
W
E
S
LEGEND
Lerderderg River
Retarding Basin
Melbourne Water Open Channel
Melbourne Water Drain
Catchment Boundaries
One Percent Probability Waterways Flood Extent 100 yr
One Percent Probability Underground Flood Extent 100 yr
GREY ST DRAIN
BACCHUS MARSH GISBORNE RD
LERDERDERG RIVER
WESTERN FWY
HALLETTS WAY
PENTLAND PARK RB
MASON LANE DRAIN
GISBORNE RD
BACCHUS MARSH RD
LERDERDERG ST DRAIN- OPEN CHANNEL
LERDERDERG ST DRAIN
ENGENY
WATER MANAGEMENT
Melbourne Water
Scale 1: 10 000
Date: 14/12/2011
By: CM
Checked By: GO
Job No. V3000_004
Revision: 0
Lower Lerderderg Catchments Flood Mapping 100 yr Flood Extent
Melways Map Ref: M327, M328, M333, M334
Figure 1


N
S
W
E
LEGEND
Lerderderg River
Retarding Basin
Melbourne Water Open Channel
Melbourne Water Drain
One Percent Probability Underground Flood Extent 100 yr
One Percent Probability Waterways Flood Extent 100 yr
Catchment Boundaries
ROBERSTONS RD
LINKS RD
SWANS RD
ROBERTSONS RD DRAIN
CAIRNS DR
CAIRNS DR DRAIN
CAIRNS DRIVE RB
ALBERT ST
LERDERDERG RIVER
GREY ST DRAIN
ENGENY
Melbourne Water
Scale 1: 10 000
Date: 14/12/2011
By: CM
Checked By: GO
Job No. V3000_004
Revision: 0
Lower Lerderderg Catchments Flood Mapping 100 yr Flood Extent
Melways Map Ref: M327
Figure 2

ENGENY WATER MANAGEMENT

www.engeny.com.au

Melbourne Water

Scale 1: 10 000	Lower Lerderderg Catchments Flood Mapping 50 yr Flood Extent
Date: 14/12/2011	Melways Map Ref: M327, M328, M333, M334
By: CM	Figure 3
Checked By: GO	
Job No. V3000_004	
Revision: 0	

ENGENY WATER MANAGEMENT

Melbourne Water

Scale 1: 10 000	
Date: 14/12/2011	
By: CM	
Checked By: GO	
Job No. V3000_004	
Revision: 0	

Lower Lerderderg Catchments Flood Mapping 50 yr Flood Extent

Melways Map Ref: M327

Figure 4

ENGENY WATER MANAGEMENT

Melbourne Water

Scale 1: 10 000	Lower Lerderderg Catchments Flood Mapping 20 yr Flood Extent
Date: 14/12/2011	Melways Map Ref: M327, M328, M333, M334
By: CM	Figure 5
Checked By: GO	
Job No. V3000_004	
Revision: 0	

ENGENY WATER MANAGEMENT

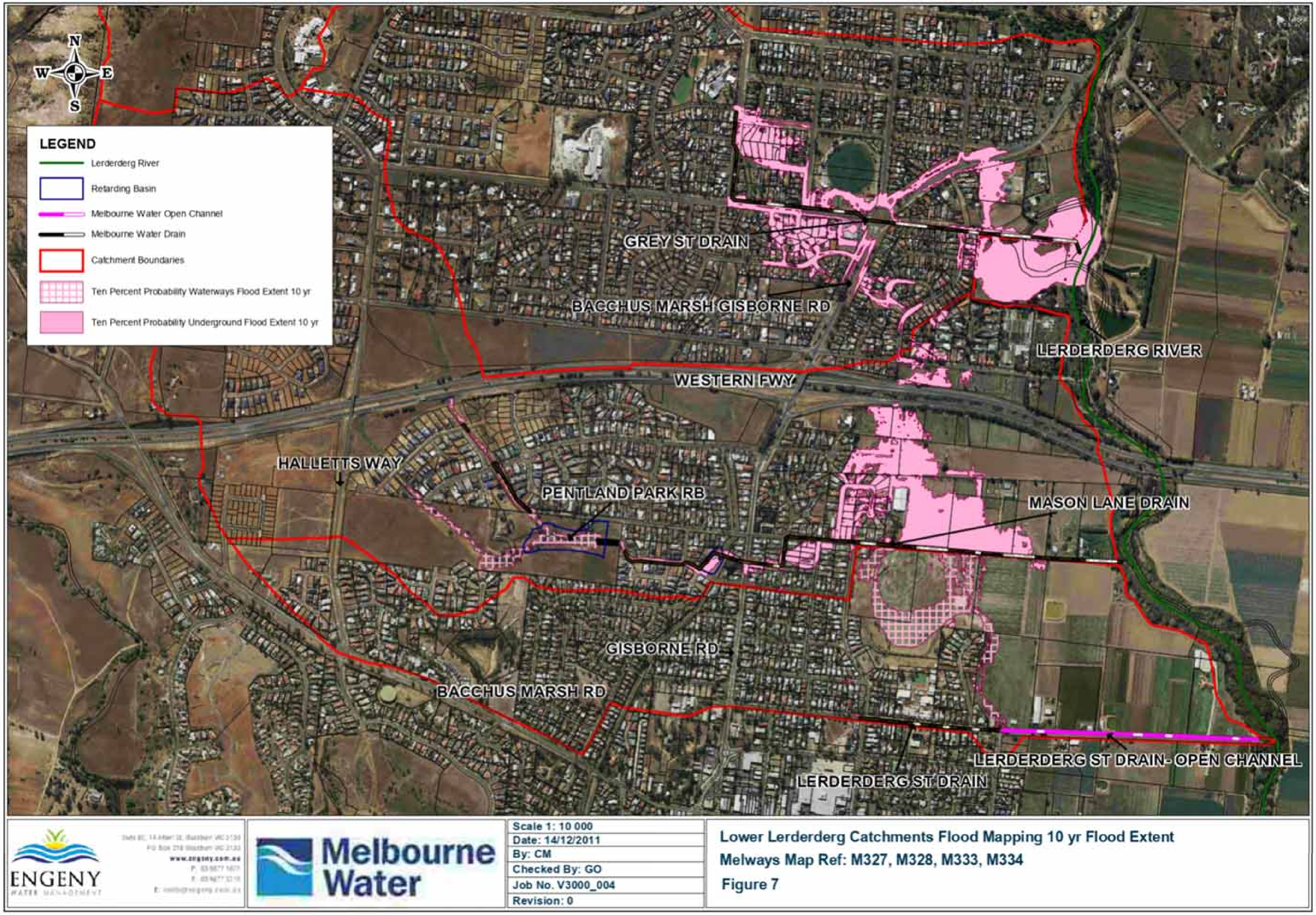
Melbourne Water

Scale 1: 10 000	
Date: 14/12/2011	
By: CM	
Checked By: GO	
Job No. V3000_004	
Revision: 0	

Lower Lerderderg Catchments Flood Mapping 20 yr Flood Extent

Melways Map Ref: M327

Figure 6


N
E
S
W
LEGEND
Lerderderg River
Retarding Basin
Melbourne Water Open Channel
Melbourne Water Drain
Catchment Boundaries
Ten Percent Probability Waterways Flood Extent 10 yr
Ten Percent Probability Underground Flood Extent 10 yr
GREY ST DRAIN
BACCHUS MARSH GISBORNE RD
LERDERDERG RIVER
WESTERN FWY
HALLETTS WAY
PENTLAND PARK RB
MASON LANE DRAIN
GISBORNE RD
BACCHUS MARSH RD
LERDERDERG ST DRAIN- OPEN CHANNEL
LERDERDERG ST DRAIN
ENGENY
Melbourne Water
Scale 1: 10 000
Date: 14/12/2011
By: CM
Checked By: GO
Job No. V3000_004
Revision: 0
Lower Lerderderg Catchments Flood Mapping 10 yr Flood Extent
Melways Map Ref: M327, M328, M333, M334
Figure 7

ENGENY WATER MANAGEMENT

Melbourne Water

Scale 1: 10 000	
Date: 14/12/2011	
By: CM	
Checked By: GO	
Job No. V3000_004	
Revision: 0	

Lower Lerderderg Catchments Flood Mapping 10 yr Flood Extent
Melways Map Ref: M327
Figure 8

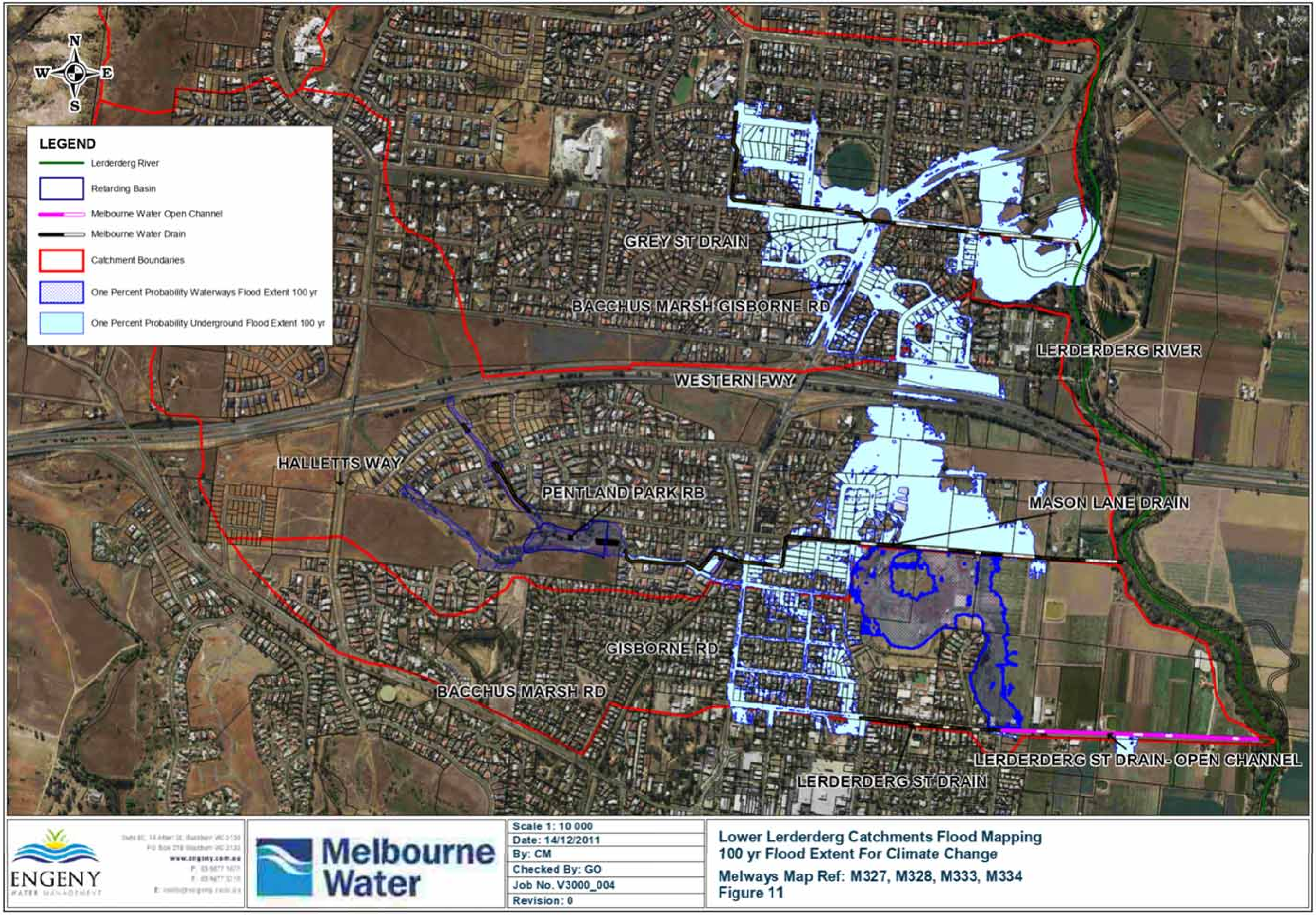
ENGENY WATER MANAGEMENT

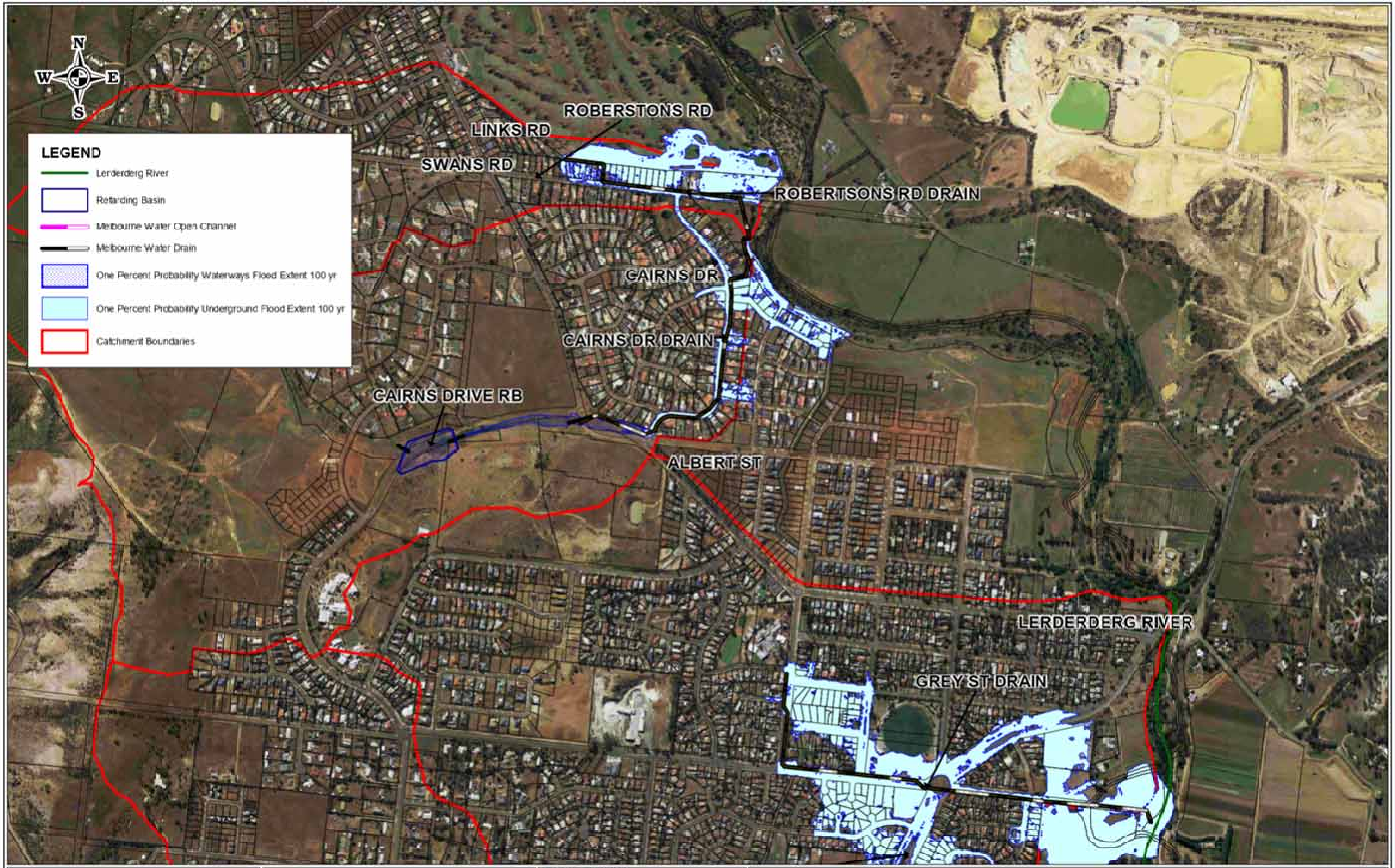
Melbourne Water

Scale 1: 10 000
Date: 14/12/2011
By: CM
Checked By: GO
Job No. V3000_004
Revision: 0

Lower Lerderderg Catchments Flood Mapping 5 yr Flood Extent
Melways Map Ref: M327, M328, M333, M334
Figure 9


N
W
E
S
LEGEND
Lerderderg River
Retarding Basin
Melbourne Water Open Channel
Melbourne Water Drain
Catchment Boundaries
Twenty Percent Probability Waterways Flood Extent 5 yr
Twenty Percent Probability Underground Flood Extent 5 yr
ROBERSTONS RD
LINKS RD
SWANS RD
ROBERTSONS RD DRAIN
CAIRNS DR
CAIRNS DR DRAIN
CAIRNS DRIVE RB
ALBERT ST
LERDERDERG RIVER
GREY ST DRAIN
ENGENY
www.engeny.com.au
Melbourne Water
Scale 1: 10 000
Date: 14/12/2011
By: CM
Checked By: GO
Job No. V3000_004
Revision: 0
Lower Lerderderg Catchments Flood Mapping 5 yr Flood Extent
Melways Map Ref: M327
Figure 10


LEGEND
Lerderderg River
Retarding Basin
Melbourne Water Open Channel
Melbourne Water Drain
Catchment Boundaries
One Percent Probability Waterways Flood Extent 100 yr
One Percent Probability Underground Flood Extent 100 yr
GREY ST DRAIN
BACCHUS MARSH GISBORNE RD
LERDERDERG RIVER
WESTERN FWY
HALLETTS WAY
PENTLAND PARK RB
MASON LANE DRAIN
GISBORNE RD
BACCHUS MARSH RD
LERDERDERG ST DRAIN - OPEN CHANNEL
LERDERDERG ST DRAIN
ENGENY
Melbourne Water
Scale 1: 10 000
Date: 14/12/2011
By: CM
Checked By: GO
Job No. V3000_004
Revision: 0
Lower Lerderderg Catchments Flood Mapping
100 yr Flood Extent For Climate Change
Melways Map Ref: M327, M328, M333, M334
Figure 11

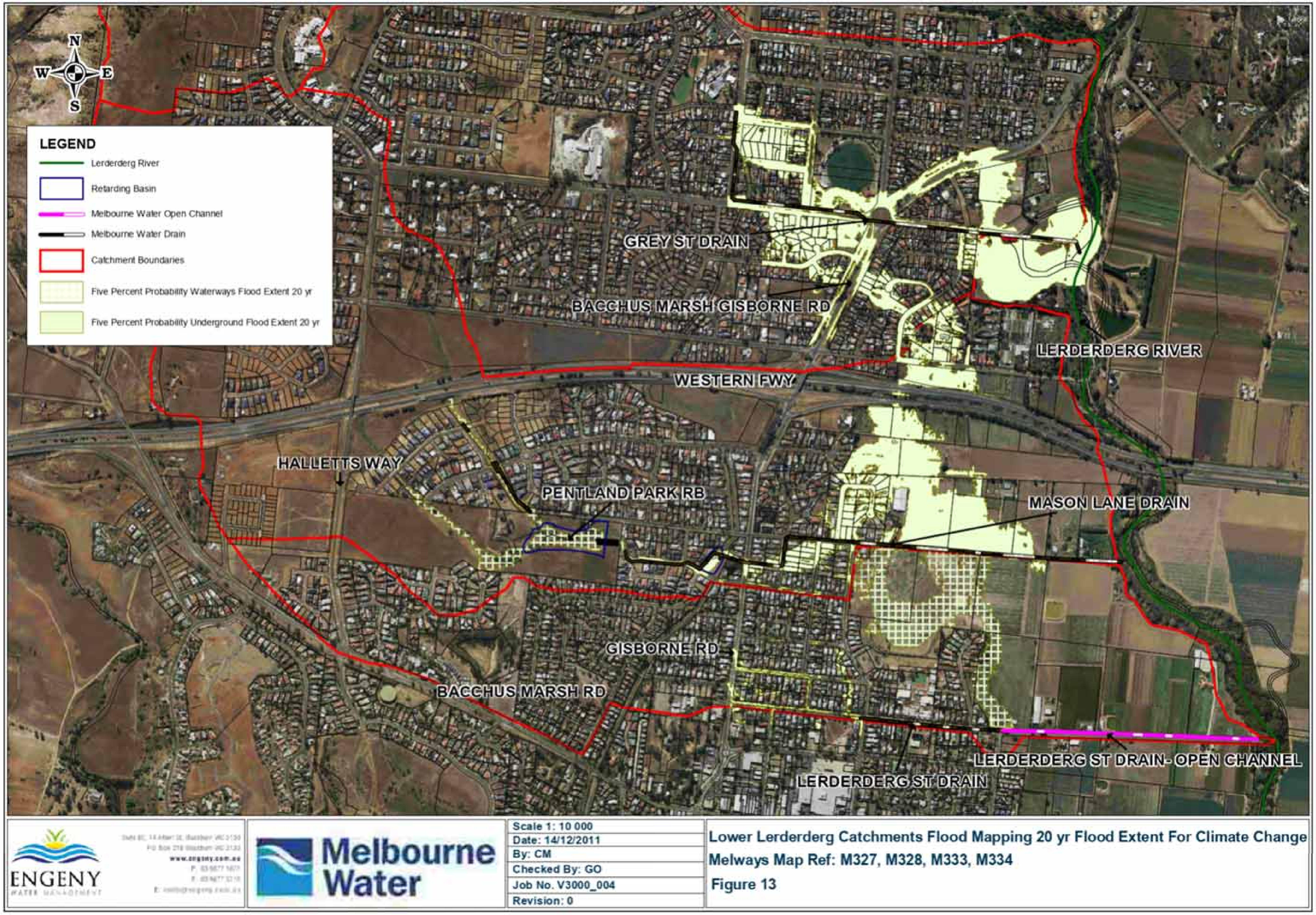


ENGENY WATER MANAGEMENT

Melbourne Water

Scale 1: 10 000
Date: 14/12/2011
By: CM
Checked By: GO
Job No. V3000_004
Revision: 0

Lower Lerderderg Catchments Flood Mapping
100 yr Flood Extent For Climate Change
Melways Map Ref: M327
Figure 12


N
W
E
S
LEGEND
Lerderderg River
Retarding Basin
Melbourne Water Open Channel
Melbourne Water Drain
Catchment Boundaries
Five Percent Probability Waterways Flood Extent 20 yr
Five Percent Probability Underground Flood Extent 20 yr
GREY ST DRAIN
BACCHUS MARSH GISBORNE RD
LERDERDERG RIVER
WESTERN FWY
HALLETTS WAY
PENTLAND PARK RB
MASON LANE DRAIN
GISBORNE RD
BACCHUS MARSH RD
LERDERDERG ST DRAIN- OPEN CHANNEL
LERDERDERG ST DRAIN
ENGENY
WATER MANAGEMENT
www.engeny.com.au
Melbourne Water
Scale 1: 10 000
Date: 14/12/2011
By: CM
Checked By: GO
Job No. V3000_004
Revision: 0
Lower Lerderderg Catchments Flood Mapping 20 yr Flood Extent For Climate Change
Melways Map Ref: M327, M328, M333, M334
Figure 13

ENGENY WATER MANAGEMENT

Melbourne Water

Scale 1: 10 000	
Date: 14/12/2011	
By: CM	
Checked By: GO	
Job No. V3000_004	
Revision: 0	

Lower Lerderderg Catchments Flood Mapping 20 yr Flood Extent For Climate Change

Melways Map Ref: M327

Figure 14

ENGENY WATER MANAGEMENT

Melbourne Water

Scale 1: 10 000	**Lower Lerderderg Catchments Flood Mapping 5 yr Flood Extent For Climate Change**
Date: 14/12/2011	**Melways Map Ref: M327, M328, M333, M334**
By: CM	**Figure 15**
Checked By: GO	
Job No. V3000_004	
Revision: 0	

ENGENY WATER MANAGEMENT

Melbourne Water

Scale 1: 10 000	Lower Lerderderg Catchments Flood Mapping 5 yr Flood Extent Climate Change
Date: 14/12/2011	Melways Map Ref: M327
By: CM	Figure 16
Checked By: GO	
Job No. V3000_004	
Revision: 0	

21.02 NATURAL ENVIRONMENT

06/12/2018
C81 Proposed C91

21.02-1 Key Issues and Influences

06/12/2018
C81
Proposed C91

Non Urban Landscapes

- Moorabool Shire's natural environment, towns, rural landscapes, and forested areas are important elements of the Shire's character.

Water and Catchment Management

- Large areas of Moorabool Shire are in Special Water Supply Catchments providing potable water for local and regional populations.
- For public health reasons, prospects for population growth and investment are minimal for small towns and settlements that reside within a Special Water Supply Catchment and lack reticulated sewerage.
- Much of the Special Water Supply Catchment areas contain towns, communities, and productive farms that have a legitimate expectation to grow and prosper.
- There is a combined responsibility for water quality by the Shire, Water Authorities and Catchment Management Authorities.

Biodiversity

- Lerderderg State Park, the Brisbane Ranges National Park, Wombat State Forest, Werribee Gorge State Park, Long Forrest Nature Conservation Reserve and other bushland areas in the Shire are highly significant natural resources with nationally important flora, fauna habitat values. These values are also valuable attractors of recreation and tourism.
- Human activity particularly the impacts of population growth, urban growth, and agricultural activity have contributed to the decline in biodiversity, quality and quantity of native vegetation and waterway condition.
- Roadside vegetation is of great value to the Moorabool Shire as it provides for flora and fauna movement corridors between State and National Parks or Forests and supports the rural character of the area.
- Pest and environmental weed control are important issues within the Shire as is the revegetation of native flora along waterways.

Bushfire

- Large areas of the Shire are at risk of bushfire particularly forested areas on steep inclines.

Environmentally Sustainable Development

- Planning for development in Moorabool Shire must give deliberate consideration to environmentally sustainable development principals that will maintain and enhance the quality of the environment and natural resource base.

Flood Management

- Large areas of ~~the~~ Moorabool Shire are prone to flooding ~~as~~ from waterways including the Moorabool, Werribee, ~~and~~ Lerderderg and Little Rivers and their tributaries ~~flow through the Shire~~.

- Some urban areas are prone to inundation by overland flows from the urban drainage system.

21.02-2 Objective—Non Urban Landscapes

06/12/2018
C81

- To maintain and enhance the natural environment and the Shire's rural identity and character.

Strategies

- Maintain the open rural landscape between the Shire's eastern boundary and Bacchus Marsh as a visual buffer.
- Recognise and protect the national, state and regional values of Werribee George State Park, Bungal State Forest, Long Forest nature Reserve, Lal Lal State Forest, Lal Lal Falls, Brisbane Ranges Lerderderg State Park, and Wombat State Forest.
- Protect the landscape and scenic qualities of forested hill slopes, rural landscapes, and bushland setting of the Shire's rural and urban areas.
- Minimise visual impacts on high quality landscapes by only supporting well designed appropriate development on hilltops and ridgelines.

21.02-3 Objective—Water and Catchment Management

06/12/2018
C81

- To protect the quality and quantity of water within the Moorabool Shire.

Strategies

- Promote the installation of reticulated sewerage within Bungaree, Dunnstown, Wallace and Myrniong subject to a viable business case to support provision.
- Promote land use and development compatible with the Shire's natural environment, native vegetation, and places of environmental significance.
- Ensure that the removal of all stormwater and effluent associated with new development is undertaken in a way which is not to the detriment of the quality or quantity of water in local watercourses and limits downstream effects.
- Ensure the retention, protection, and revegetation of the riparian area along watercourses.

21.02-4 Objective—Biodiversity

10/11/2011
C57

- To positively enhance biodiversity in the Moorabool Shire.

Strategies

- Support the implementation of the appropriate Regional Catchment Management Strategy
- Require land use change and development to retain native vegetation and to minimise topsoil disturbance.
- Require an increase in sustainable rural land management practices (in particular weed and pest management) when supporting land use change or development within rural areas.
- Maintain protect, and enhance the biodiversity values of important roadsides, particularly those within the surrounds of the state and national parks or forests.
- Maintain, protect and enhance the River Red Gum (Eucalyptus Camaldulensis) Population within the Bacchus Marsh Valley.

21.02-5 Objective—Bushfire

31/05/2018
C78

- To minimise risk of bushfire damage.

Strategies

- Apply the Moorabool Fire Management Plan.

21.02-6 06/12/2018 C81 **Objective—Environmentally Sustainable Development**

- To manage land use in an environmentally sustainable manner, to assist in reducing the ecological footprint of land within Moorabool Shire.

Strategies

- Ensure that the natural drainage functions are retained in the development of land for residential purposes.
- Ensure that new dams in the rural zones consider stream flow, catchment, landscape, environmental and land degradation issues.
- Encourage the principals of energy efficient building design and site layout to be considered for new developments, to reduce reliance on artificial heating and cooling and therefore subsequently reducing green house gas emissions.
- Ensure Best Practice Water Sensitive Urban Design principals are applied to all new development within the Moorabool Shire.

21.02-7 Objective-Flood Management

_/_/20_ Proposed C81

- To recognise the constraints of floodplains and overland flow paths on the use and development of land.

Strategies

- Ensure that new development maintains the free passage and temporary storage of floodwater, integrates with the local drainage conditions, and minimises soil erosion, sedimentation and silting.

21.02-78 06/12/2018 C81 Proposed C81 **Implementation**

Zones and Overlays

Specific application of zones and overlays to achieve the strategic objectives includes:

- Apply relevant overlays (VPO or ESO) to reflect biodiversity mapping of the Shire when completed;
- Apply Erosion Management Overlay (EMO) and Salinity Management Overlays (SMO) to reflect land capability across the Shire;
- Apply Floodway Overlay (FO) and Land Subject to Inundation Overlays (LSIO) to reflect relevant Council flood studies;
- Apply Significant Landscape Overlay (SLO) to ridgelines, escarpments, and hilltops; and
- Apply bushfire Management Overlay to areas of fire risk.

21.02-89 06/12/2018 C81 Proposed C81 **Further Strategic Work**

- Complete the biodiversity mapping project.
- Undertake studies to further identify areas subject to flooding and areas subject to poor drainage.
- Undertake erosion studies to inform the incorporation of the Erosion Management Overlay.

- Undertake salinity mapping to inform the incorporation of the Salinity Management Overlay.
- Investigate an appropriate buffer zone around the Ballan and Parwan Waste Water Plants in conjunction with the relevant Water Authorities, and develop ESO's within these buffers in conjunction with the Water Authorities and the EPA.
- Revise Environmental Significance Overlay Schedule 2 (ESO2 Waterway Protection) to incorporate floodway management.
- Extend and update the Bushfire Management Overlay (WMO) based on CFA mapping for bushfire prone areas.
- Review, update, and implement the Moorabool Shire Council Roadside Management Plan, 2001, including the application of a Vegetation Protection Overlay along roadsides with vegetation of significance.

21.02-910 Other Actions

06/12/2018
C81
Proposed C91

- Work with and encourage other land managers and authorities to ensure a consistent and proactive approach to land and biodiversity conservation and enhancement.
- Encourage greater land owner awareness, involvement, and responsibility towards protecting their land and property from the threat of bushfire and flooding.
- Support the introduction of Stream Flow Management Plans.
- Work with the State Government to monitor the impact of domestic and stock dams on river flows and ground water quality and quantity.
- Work with Water Authorities to review planning controls relating to development in Special Water Supply Catchments.

21.11 REFERENCE DOCUMENTS

06/12/2018
C81
Proposed C81

- Bacchus Marsh District Urban Growth Framework, 2017.
- Bacchus Marsh Heritage Study, 1995.
- Bacchus Marsh Integrated Transport Strategy, 2015.
- Bacchus Marsh Tracks and Trails Master Plan 2004-2005.
- Ballan Township Flood Study, Final Report, November 2011.
- Housing Bacchus Marsh to 2041, 2016
- Lower Lerderderg Catchments Flood Mapping Report, December 2011.
- Moorabool Fire Management Plan.
- Moorabool Industrial Areas Strategy, 2015.
- Moorabool Municipal Fire Prevention Plan.
- Moorabool Shire Council Retail Strategy 2041, 2016.
- Moorabool Shire Council Roadside Management Plan, 2001.
- Moorabool Shire Economic Development Strategy, 2015.
- Moorabool Shire Small Towns and Settlements Strategy, 2016.
- Moorabool Social Infrastructure Plan 2007.
- Report for Bacchus Marsh Area Floodplain Mapping, November 2010.
- River Red Gums in the Bacchus Marsh Valley, December 2008

44.04 LAND SUBJECT TO INUNDATION OVERLAY

31/07/2018
VC148

Shown on the planning scheme map as **LSIO** with a number (if shown).

Purpose

To implement the Municipal Planning Strategy and the Planning Policy Framework.

To identify land in a flood storage or flood fringe area affected by the 1 in 100 year flood or any other area determined by the floodplain management authority.

To ensure that development maintains the free passage and temporary storage of floodwaters, minimises flood damage, is compatible with the flood hazard and local drainage conditions and will not cause any significant rise in flood level or flow velocity.

To reflect any declaration under Division 4 of Part 10 of the *Water Act, 1989* where a declaration has been made.

To protect water quality in accordance with the provisions of relevant State Environment Protection Policies, particularly in accordance with Clauses 33 and 35 of the State Environment Protection Policy (Waters of Victoria).

To ensure that development maintains or improves river and wetland health, waterway protection and flood plain health.

44.04-1 Land subject to inunadation objectives and statement of risk

31/07/2018
VC148

A schedule to this overlay may contain:

- Land subject to inundation management objectives to be achieved.
- A statement of risk.

44.04-2 Buildings and works

31/07/2018
VC148

A permit is required to construct a building or to construct or carry out works, including:

- A fence.
- Roadworks, if the water flow path is redirected or obstructed.
- Bicycle pathways and trails.
- Public toilets.
- A domestic swimming pool or spa and associated mechanical and safety equipment if associated with one dwelling on a lot.
- Rainwater tank with a capacity of not more than 10,000 litres.
- A pergola or verandah, including an open-sided pergola or verandah to a dwelling with a finished floor level not more than 800mm above ground level and a maximum building height of 3 metres above ground level.
- A deck, including a deck to a dwelling with a finished floor level not more than 800mm above ground level.
- A non-domestic disabled access ramp.
- A dependent person's unit.

This does not apply:

- If a schedule to this overlay specifically states that a permit is not required.
- To flood mitigation works carried out by the responsible authority or floodplain management authority.

- To the following works in accordance with plans prepared to the satisfaction of the responsible authority:
  - The laying of underground sewerage, water and gas mains, oil pipelines, underground telephone lines and underground power lines provided they do not alter the topography of the land.
  - The erection of telephone or power lines provided they do not involve the construction of towers or poles.
- To post and wire and post and rail fencing.

44.04-3 Subdivision

31/07/2018
VC148

A permit is required to subdivide land.

44.04-4 Application requirements

31/07/2018
VC148

An application must be accompanied by any information specified in a schedule to this overlay.

44.04-5 Local floodplain development plan

31/07/2018
VC148

If a local floodplain development plan has been developed for the area and has been incorporated into this scheme, an application must be consistent with the plan.

44.04-6 Exemption from notice and review

31/07/2018
VC148

An application under this overlay is exempt from the notice requirements of section 52(1)(a), (b) and (d), the decision requirements of section 64(1), (2) and (3) and the review rights of section 82(1) of the Act.

44.04-7 Referral of applications

31/07/2018
VC148

An application must be referred to the relevant floodplain management authority under Section 55 of the Act unless in the opinion of the responsible authority, the proposal satisfies requirements or conditions previously agreed in writing between the responsible authority and the floodplain management authority.

44.04-8 Decision guidelines

31/07/2018
VC148

Before deciding on an application, in addition to the decision guidelines in Clause 65, the responsible authority must consider, as appropriate:

- The Municipal Planning Strategy and the Planning Policy Framework .
- Any local floodplain development plan.
- Any comments from the relevant floodplain management authority.
- The existing use and development of the land.
- Whether the proposed use or development could be located on flood-free land or land with a lesser flood hazard outside this overlay.
- The susceptibility of the development to flooding and flood damage.
- The potential flood risk to life, health and safety associated with the development. Flood risk factors to consider include:
  - The frequency, duration, extent, depth and velocity of flooding of the site and accessway.
  - The flood warning time available.

- The danger to the occupants of the development, other floodplain residents and emergency personnel if the site or accessway is flooded.

- The effect of the development on redirecting or obstructing floodwater, stormwater or drainage water and the effect of the development on reducing flood storage and increasing flood levels and flow velocities.
- The effect of the development on river health values including wetlands, natural habitat, stream stability, erosion, environmental flows, water quality and sites of scientific significance.
- Any other matters specified in a schedule to this overlay.

--/--/20--
C91

SCHEDULE 1 TO CLAUSE 44.04 LAND SUBJECT TO INUNDATION OVERLAY

Shown on the planning scheme map as **LSIO1**

WERRIBEE RIVER, LERDERDERG RIVER AND

LITTLE RIVER CATCHMENTS

1.0 Land subject to inundation objectives to be achieved

--/--/20--
C91

None specified.

2.0 Statement of risk

--/--/20--
C91

- Damage to assets due to flooding.
- Increased flood damage due to reduced storage of floodwaters as a result of development.
- Risk to life and property due to flooding.
- Waterway and floodplain protection.

3.0 Permit requirement

--/--/20--
C91

A permit is not required for the following:

- A dependent person's unit with the written consent of the relevant floodplain management authority.
- A fence that is 50 per cent permeable.
- An open building or structure with no walls.
- A domestic in-ground swimming pool or spa and associated mechanical and safety equipment.
- Upper storey extensions or alterations to existing dwellings.
- An out-building (including replacement of an existing building) if the out-building is less than 20 square metres in floor area and constructed to at least 300mm above the flood level or the relevant floodplain management authority has agreed in writing that the flowpath is not obstructed.
- A non-domestic disabled access ramp.
- Public toilets with the written consent of the relevant floodplain management authority.
- Construction of a pergola or verandah.
- Construction of a deck with unenclosed foundations.
- Construction of a tennis court.
- Replacement fencing constructed of identical type and material as the existing fence.
- A mast, antenna, satellite dish, power pole, light pole, or telecommunication tower.
- An outdoor advertising sign/structure, provided that it does not alter flood flows or floodplain storage capacity.
- Carrying out of works if the relevant floodplain management authority has agreed in writing that the flowpath is not obstructed.

4.0 Application requirements

--/--/20--
C91

The following application requirements apply to an application for a permit under Clause 44.05, in addition to those specified in Clause 44.05 and elsewhere in the scheme and must accompany an application, as appropriate, to the satisfaction of the responsible authority:

- The boundaries and dimensions of the site.
- Relevant ground levels, to Australian Height Datum, taken by a licensed surveyor.
- The layout of existing and proposed buildings and works.
- Floor levels of any existing and proposed buildings, to Australian Height Datum, taken by a licensed surveyor

5.0 Decision guidelines

--/--/20--
C91

The following decision guidelines apply to an application for a permit under Clause 44.05, in addition to those specified in Clause 44.04 and elsewhere in the scheme which must be considered, as appropriate, by the responsible authority.

- The DELWP *Guidelines for Development in Flood-Affected Areas*
- Melbourne Water's Healthy *Waterways Strategy*
- Melbourne Water's *Flood Management Strategy* – Port Phillip and Westernport

44.05 SPECIAL BUILDING OVERLAY

31/07/2018
VC148

Shown on the planning scheme map as **SBO** with a number (if shown).

Purpose

To implement the Municipal Planning Strategy and the Planning Policy Framework.

To identify land in urban areas liable to inundation by overland flows from the urban drainage system as determined by, or in consultation with, the floodplain management authority.

To ensure that development maintains the free passage and temporary storage of floodwaters, minimises flood damage, is compatible with the flood hazard and local drainage conditions and will not cause any significant rise in flood level or flow velocity.

To protect water quality in accordance with the provisions of relevant State Environment Protection Policies, particularly in accordance with Clauses 33 and 35 of the State Environment Protection Policy (Waters of Victoria).

44.05-1 Flooding management objectives and statement of risk

31/07/2018
VC148

A schedule to this overlay may contain:

- Flooding management objectives to be achieved.
- A statement of risk.

44.05-2 Buildings and works

31/07/2018
VC148

A permit is required to construct a building or to construct or carry out works, including:

- A fence.
- Roadworks, if the water flow path is redirected or obstructed.
- Bicycle pathways and trails.
- Public toilets.
- A domestic swimming pool or spa and associated mechanical and safety equipment if associated with one dwelling on a lot.
- A rainwater tank with a capacity of not more than 10,000 litres.
- A pergola or verandah, including an open-sided pergola or verandah to a dwelling with a finished floor level not more than 800mm above ground level and a maximum building height of 3 metres above ground level.
- A deck, including a deck to a dwelling with a finished floor level not more than 800mm above ground level.
- A non-domestic disabled access ramp.
- A dependent person's unit.

This does not apply:

- If a schedule to this overlay specifically states that a permit is not required.
- To flood mitigation works carried out by the responsible authority or floodplain management authority.
- To the following works in accordance with plans prepared to the satisfaction of the responsible authority:
  - The laying of underground sewerage, water and gas mains, oil pipelines, underground telephone lines and underground power lines provided they do not alter the topography of the land.

- The erection of telephone or power lines provided they do not involve the construction of towers or poles designed to operate at more than 66,000 volts.

- To landscaping, driveways, vehicle cross overs, footpaths or bicycle paths if there is no significant change to existing surface levels, or if the relevant floodplain management authority has agreed in writing that the flowpath is not obstructed.
- To an extension of less than 20 square metres in floor area to an existing building (not including an out-building), where the floor levels are constructed to at least 300mm above the flood level or if the relevant floodplain management authority has agreed in writing that the flowpath is not obstructed.
- To an upper storey extension to an existing building.
- To an alteration to an existing building where the original building footprint remains the same and floor levels are constructed to at least 300mm above flood level.
- To an out-building (including replacement of an existing building) if the out-building is less than 10 square metres in floor area and constructed to at least 150mm above the flood level or the relevant floodplain management authority has agreed in writing that the flowpath is not obstructed.
- To a replacement building (not including an out-building) if it is constructed to at least 300mm above the flood level and the original building footprint remains the same. The responsible authority may require evidence of the existing building envelope.
- To fencing with at least 25% openings and with the plinth at least 300mm above the flood level.
- To a replacement fence in the same location and of the same type and materials as the existing fence.
- To a pergola or an open deck area with unenclosed foundations.
- To a carport constructed over an existing carspace.
- To an in-ground swimming pool and associated security fencing, where the perimeter edging of the pool is constructed at natural surface levels and excavated material is removed from the flowpath.
- To a tennis court at existing surface level with fencing designed to minimise obstruction to flows.
- To an aviary or other enclosure for a domestic animal if it is less than 10 square metres in floor area at ground level.
- To open sided verandahs, open sided picnic shelters, barbeques and park furniture (excluding playground equipment) if there is less than 30mm change to existing surface levels.
- To radio masts, light poles or signs on posts or attached to buildings.

VicSmart applications

Subject to Clause 71.06, an application under this clause for a development specified in Column 1 is a class of VicSmart application and must be assessed against the provision specified in Column 2.

Class of application	Information requirements and decision guidelines
Construct a building or construct or carry out works.	Clause 59.08

44.05-3 Subdivision

31/07/2018
VC148

A permit is required to subdivide land.

VicSmart applications

Subject to Clause 71.06, an application under this clause for a development specified in Column 1 is a class of VicSmart application and must be assessed against the provision specified in Column 2.

Class of application	Information requirements and decision guidelines
Any of the following classes of subdivision: • Subdivide land to realign the common boundary between 2 lots where the area of either lot is reduced by less than 15 percent and the general direction of the common boundary does not change. • Subdivide land into lots each containing an existing building or car parking space where: - The buildings or car parking spaces have been constructed in accordance with the provisions of this scheme or a permit issued under this scheme. - An occupancy permit or a certificate of final inspection has been issued under the Building Regulations in relation to the buildings within 5 years prior to the application for a permit for subdivision. • Subdivide land into 2 lots if: - The construction of a building or the construction or carrying out of works on the land is approved under this scheme or by a permit issued under this scheme and the permit has not expired. - The construction or carrying out of the approved building or works on the land has started lawfully. - The subdivision does not create a vacant lot.	Clause 59.08

44.05-4 Application requirements

31/07/2018
VC148

Unless otherwise agreed in writing by the relevant floodplain management authority, an application to construct a building or construct or carry out works must be accompanied by a site plan which shows, as appropriate:

- The boundaries and dimensions of the site.
- Relevant existing and proposed ground levels, to Australian Height Datum, taken by or under the direction or supervision of a licensed land surveyor.
- The layout, size and use of existing and proposed buildings and works, including vehicle parking areas.
- Floor levels of any existing and proposed buildings to Australian Height Datum.
- Cross sectional details of any basement entry ramps and other basement entries to Australian Height Datum, showing floor levels of entry and exit areas and drainage details.
- Any other application requirements specified in a schedule to this overlay.

Local floodplain development plan

If a local floodplain development plan has been developed for the area and has been incorporated into this scheme, an application must be consistent with the plan.

44.05-5 Exemption from notice and review

31/07/2018
VC148

An application under this overlay is exempt from the notice requirements of section 52(1)(a), (b) and (d), the decision requirements of section 64(1), (2) and (3) and the review rights of section 82(1) of the Act.

44.05-6 Referral of applications

31/07/2018
VC148

An application must be referred to the relevant floodplain management authority under Section 55 of the Act unless in the opinion of the responsible authority, the proposal satisfies requirements or conditions previously agreed to in writing between the responsible authority and the floodplain management authority.

44.05-7 Decision guidelines

31/07/2018
VC148

Before deciding on an application, in addition to the decision guidelines in Clause 65, the responsible authority must consider, as appropriate:

- The Municipal Planning Strategy and the Planning Policy Framework.
- Any local floodplain development plan.
- Any comments from the relevant floodplain management authority.
- The existing use and development of the land.
- Whether the proposed use or development could be located on flood-free land or land with a lesser flood hazard outside this overlay.
- The susceptibility of the development to flooding and flood damage.
- Flood risk factors to consider include:
  - The frequency, duration, extent, depth and velocity of flooding of the site and accessway.
  - The flood warning time available.
  - The danger to the occupants of the development, other floodplain residents and emergency personnel if the site or accessway is flooded.
- The effect of the development on redirecting or obstructing floodwater, stormwater or drainage water and the effect of the development on reducing flood storage and increasing flood levels and flow velocities.
- Any other matters specified in a schedule to this overlay.

--/--/20--
C91

SCHEDULE 1 TO CLAUSE 44.05 SPECIAL BUILDING OVERLAY

Shown on the planning scheme map as **SBO1.**

WERRIBEE RIVER AND LERDERDERG RIVER

CATCHMENTS

1.0 Flooding management objectives to be achieved

--/--/20--
C91

None specified.

2.0 Statement of risk

--/--/20--
C91

- Damage to assets due to flooding.
- Increase in off-site flooding impacts.
- Risk to life and property due to flooding.

3.0 Permit requirement

--/--/20--
C91

A permit is not required to construct a building or construct or carry out works for:

- A dependent person's unit with the written consent of the relevant floodplain management authority.
- A fence that is 50 per cent permeable.
- An open building or structure with no walls.
- A domestic in-ground swimming pool or spa and associated mechanical and safety equipment.
- To an out-building (including replacement of an existing building) if the out-building is less than 20 square metres in floor area and constructed to at least 150mm above the flood level or the relevant floodplain management authority has agreed in writing that the flowpath is not obstructed.
- A non-domestic disabled access ramp.
- Public toilets with the written consent of the relevant floodplain management authority.
- Construction of a tennis court.
- A mast, antenna, satellite dish, power pole, light pole, or telecommunication tower.
- An outdoor advertising sign/structure, provided that it does not alter flood flows or floodplain storage capacity.
- Carrying out of works if the relevant floodplain management authority has agreed in writing that the flowpath is not obstructed.

4.0 Application requirements

--/--/20--
C91

The following application requirements apply to an application for a permit under Clause 44.05, in addition to those specified in Clause 44.05 and elsewhere in the scheme and must accompany an application, as appropriate, to the satisfaction of the responsible authority:

- The boundaries and dimensions of the site.
- Relevant ground levels, to Australian Height Datum, taken by a licensed surveyor.
- The layout of existing and proposed buildings and works.
- Floor levels of any existing and proposed buildings to Australian Height Datum, taken by a licensed surveyor.

5.0 Decision guidelines

--/--/20--
C91

The following decision guidelines apply to an application for a permit under Clause 44.05, in addition to those specified in Clause 44.05 and elsewhere in the scheme which must be considered, as appropriate, by the responsible authority.

- The DELWP *Guidelines for Development in Flood-Affected Areas*
- Melbourne Water's Healthy *Waterways Strategy*
- Melbourne Water's *Flood Management Strategy* – Port Phillip and Westernport

31/07/2018
VC148
Proposed C81

SCHEDULE TO CLAUSE 72.03 WHAT DOES THIS PLANNING SCHEME CONSIST OF?

1.0 Maps comprising part of this planning scheme:

31/07/2018
VC148
Proposed C81

Zoning maps 1 to 55 inclusive

Overlay maps

- 1DDO, 1ESO, 1BMO
- 2DDO, 2ESO, 2BMO,
- 3DDO, 3ESO, 3HO, 3BMO
- 4DDO, 4ESO, 4HO, 4LSIO, 4BMO
- 5DDO, 5ESO, 5HO, 5LSIO, 5VPO, 5BMO
- 6DDO, 6ESO, 6HO, 6LSIO, 6VPO, 6BMO
- 7DDO, 7ESO, 7LSIO, 7BMO
- 8BMO, 8LSIO
- 9DDO, 9ESO, 9PAO, 9BMO
- 10DDO, 10ESO, 10PAO, 10BMO
- 11DDO, 11ESO, 11RO, 11RXO, 11BMO
- 12DDO 12ESO
- 13DDO, 13ESO, 13LSIO, 13RO, 13BMO
- 14DDO, 14ESO, 14HO, 14LSIO, 14RO, 14BMO
- 15DDO, 15ESO, 15HO, 15LSIO, 15BMO
- 16DDO, 16ESO, 16HO, 16LSIO, 16BMO
- 17DDO, 17ESO, 17HO, 17LSIO, 17BMO
- 18DDO, 18ESO, 18BMO
- 19DDO, 19ESO, 19HO, 19PAO, 19BMO
- 20DDO, 20ESO, 20HO, 20BMO
- 21DDO, 21ESO, 21BMO
- 22DDO, 22ESO, 22HO, 22BMO
- 23DDO, 23ESO, 23SLO, 23BMO
- 24DDO, 24ESO, 24BMO
- 25DDO, 25ESO, 25HO, 25SLO, 25BMO
- 26DDO, 26ESO, 26HO, 26LSIO, 26SBO, 26BMO
- 27DDO, 27ESO, 27HO, 27LSIO, 27SBO
- 28DDO, 28ESO, 28HO, 28LSIO, 28SBO, 28BMO
- 29DDO, 29ESO, 29HO, 29LSIO, 29BMO
- 30DDO, 30ESO, 30HO, 30LSIO
- 31DDO, 31DPO, 31ESO, 31HO, 31LSIO, 31PAO, 31SBO, 31SLO, 31BMO
- 32DDO, 32ESO, 32HO, 32LSIO, 32SBO, 32SLO, 32BMO
- 33DDO, 33ESO, 33HO, 33LSIO, 33SBO, 33BMO
- 34DDO, 34DPO, 34ESO, 34HO, 34LSIO, 34SBO, 34SLO
- 35DDO, 35DPO, 35EAO, 35ESO, 35HO, 35LSIO, 35PAO, 35SBO
- 36DDO, 36DPO, 36ESO, 36HO, 36LSIO
- 37DDO, 37DPO, 37EAO, 37ESO, 37HO, 37LSIO, 37PAO
- 38DDO, 38DPO, 38ESO, 38HO, 38LSIO, 38PAO, 38SLO, 38BMO

- 39DDO, 39BMO
- 40DDO, 40ESO, 40HO, 40BMO
- 41DDO, 41ESO, 41HO, 41BMO
- 42DDO, 42ESO, 42HO, 42BMO
- 43DDO, 43ESO, 43HO, 43BMO
- 44DDO, 44ESO, 44HO, 44LSIO, 44BMO
- 45DDO, 45ESO, 45HO, 45LSIO, 45RO, 45BMO
- 46AEO, 46DDO, 46DPO, 46ESO, 46HO, 46LSIO, 46SLO, 46RO
- 47DDO, 47DPO, 47ESO, 47HO, 47LSIO, 47SLO
- 48DDO, 48ESO, 48BMO
- 49DDO, 49ESO, 49BMO
- 50DDO, 50ESO, 50RO, 50RXO, 50BMO
- 51DDO, 51ESO, 51HO, 51BMO
- 52DDO, 52ESO, 52LSIO, 52BMO
- 53DDO, 53ESO, 53HO, 53LSIO, 53BMO
- 54DDO, 54ESO, 54HO, 54LSIO, 54PAO
- 55DDO, 55ESO, 55LSIO, 55PAO

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

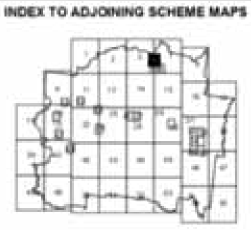
NORTH

Planning Group

Printed: 21/03/2019

Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS



LAND SUBJECT TO INUNDATION OVERLAY **MAP No 4LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY **MAP No 5LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

NORTH

Planning Group

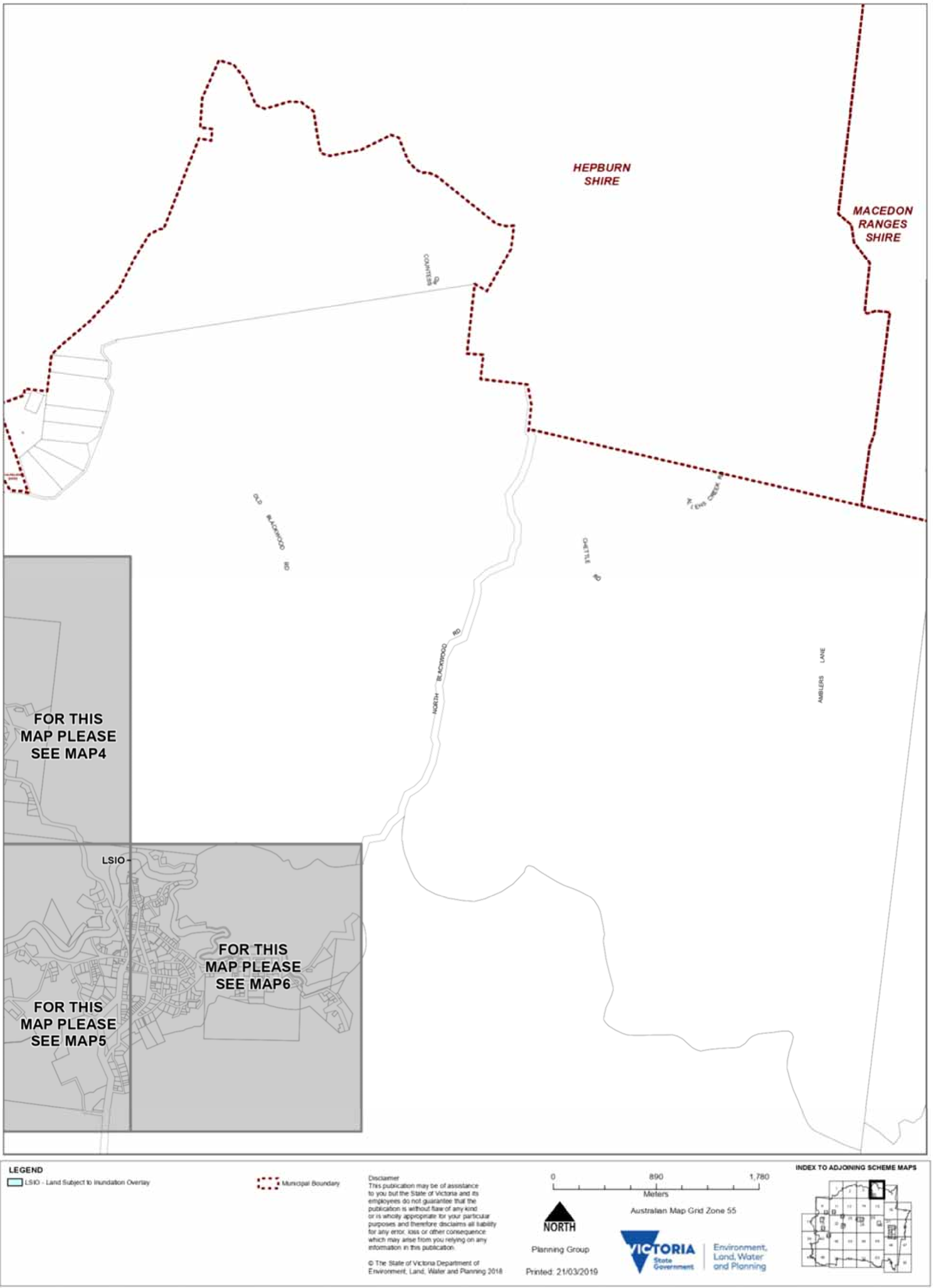
Printed: 21/03/2019

VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY **MAP No 6LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION
AMENDMENT C91

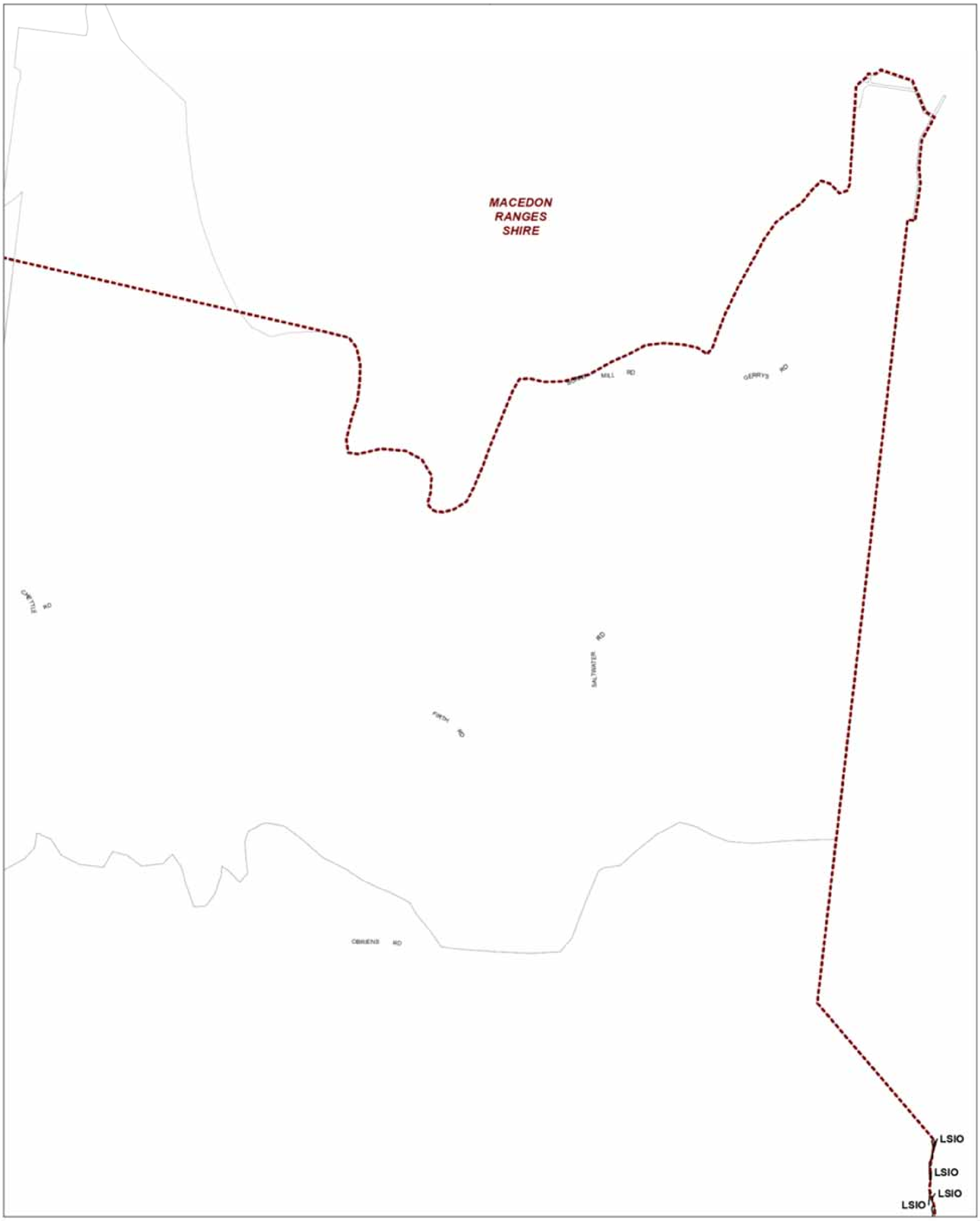


Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

LAND SUBJECT TO INUNDATION OVERLAY **MAP No 7LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

Australian Map Grid Zone 55

NORTH

Planning Group

Printed: 21/03/2019

Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY

MAP No 8LSIO

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

NORTH

Australian Map Grid Zone 55

Planning Group

Printed: 21/03/2019

Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY **MAP No 13LSIO**

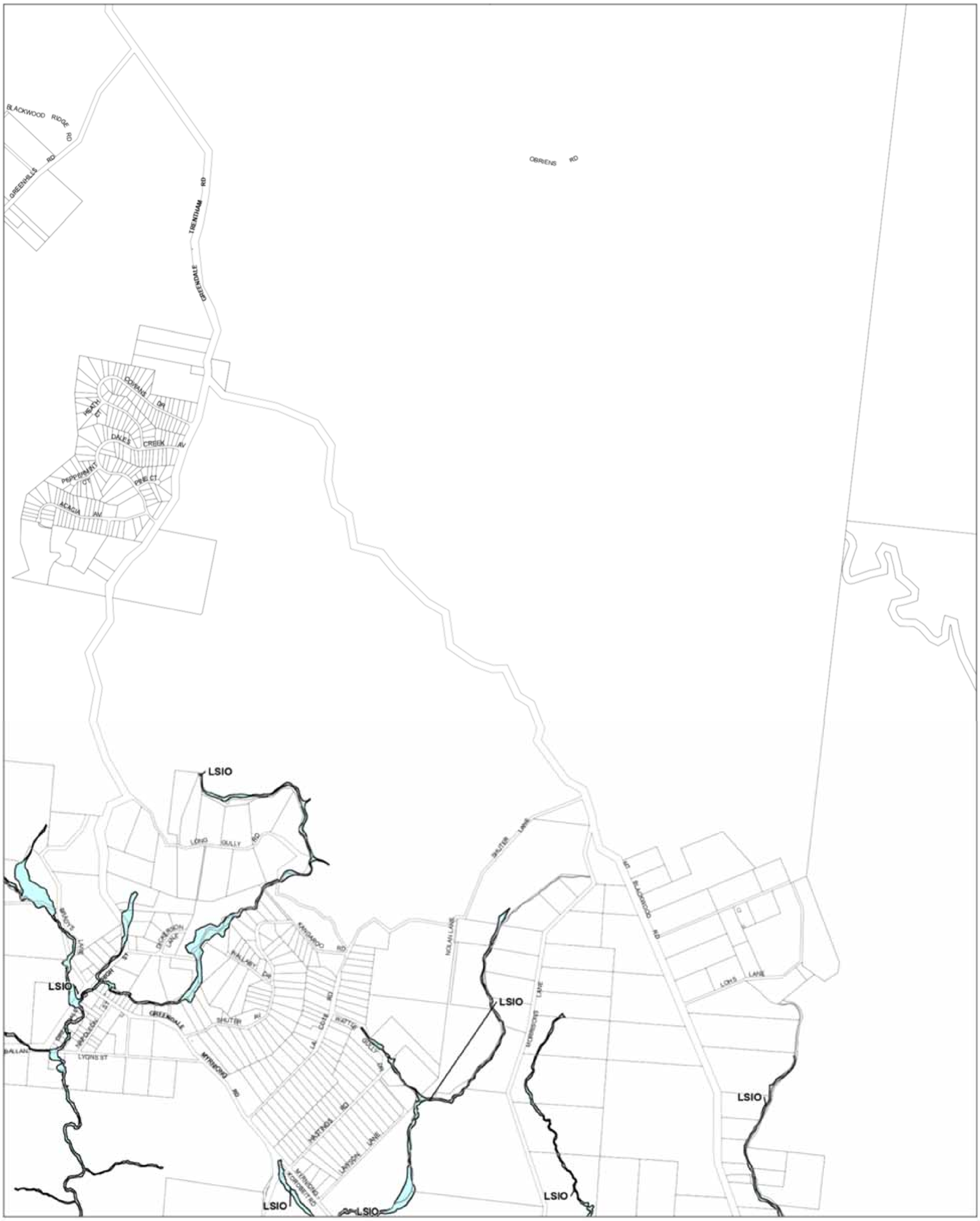
MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LAND SUBJECT TO INUNDATION OVERLAY **MAP No 14LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

NORTH

Australian Map Grid Zone 55

Planning Group

Printed: 21/03/2019

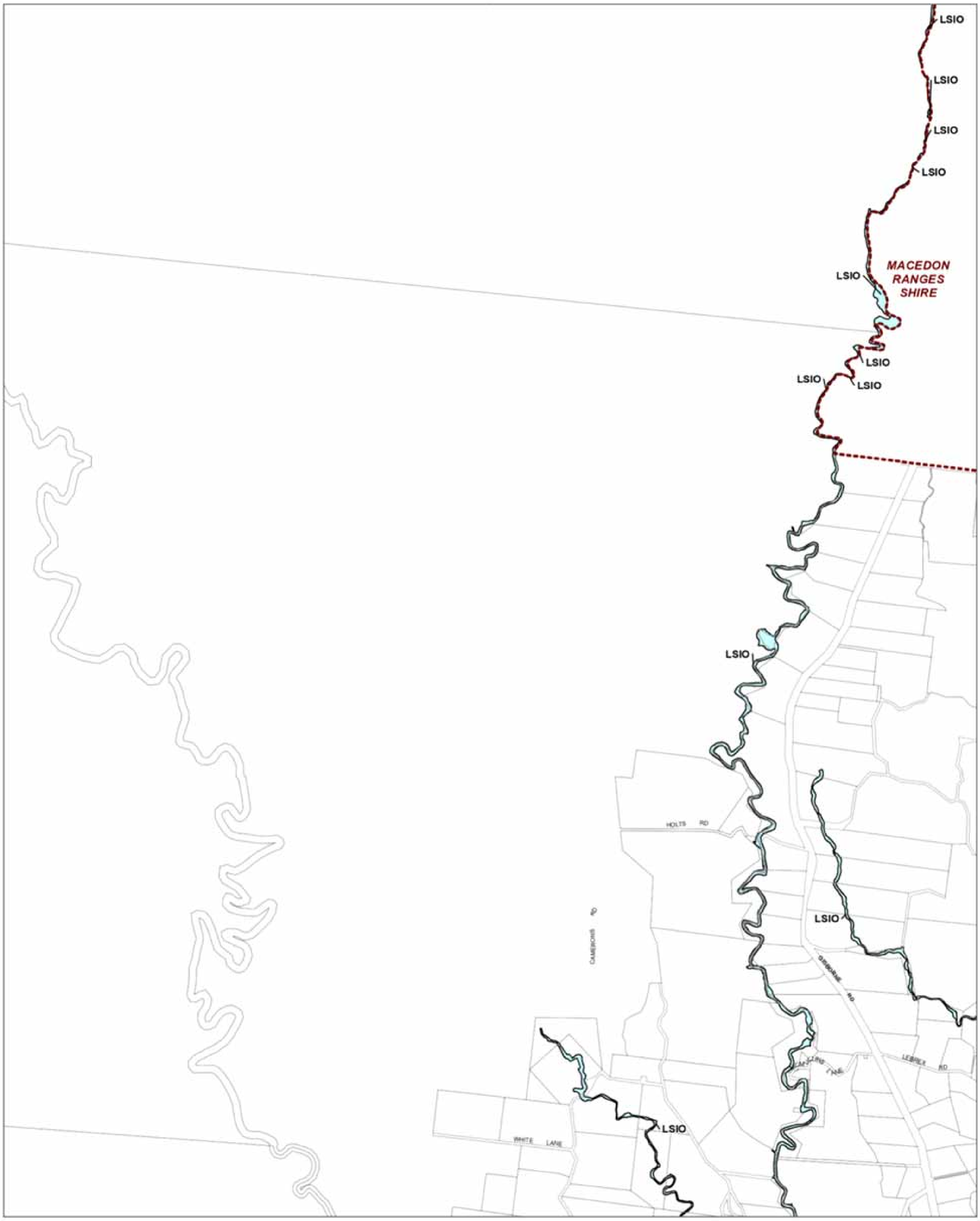
VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY **MAP No 15LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

NORTH

Australian Map Grid Zone 55

Planning Group

Printed: 21/03/2019

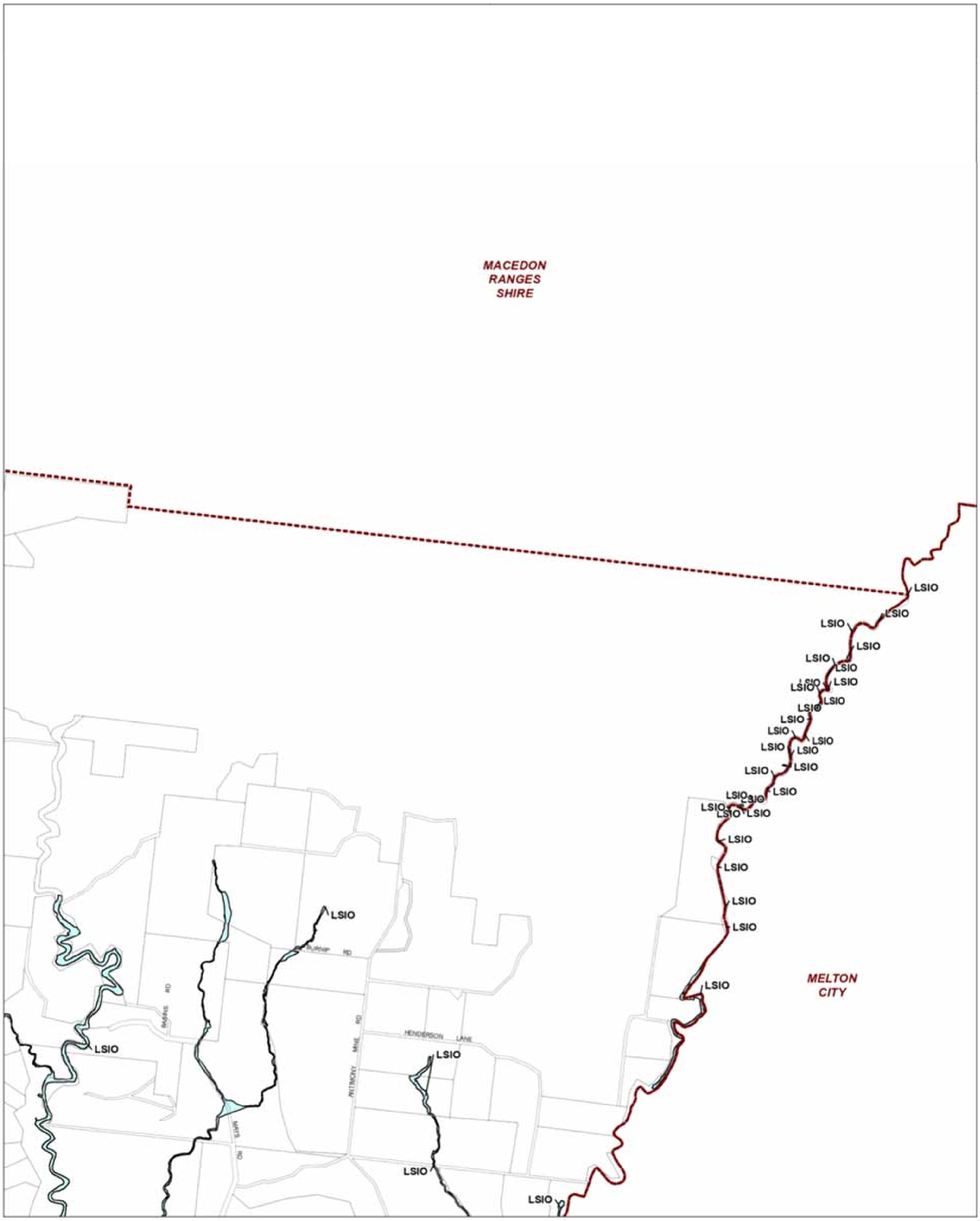
VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY **MAP No 16LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

Australian Map Grid Zone 55

NORTH

Planning Group

Printed: 21/03/2019

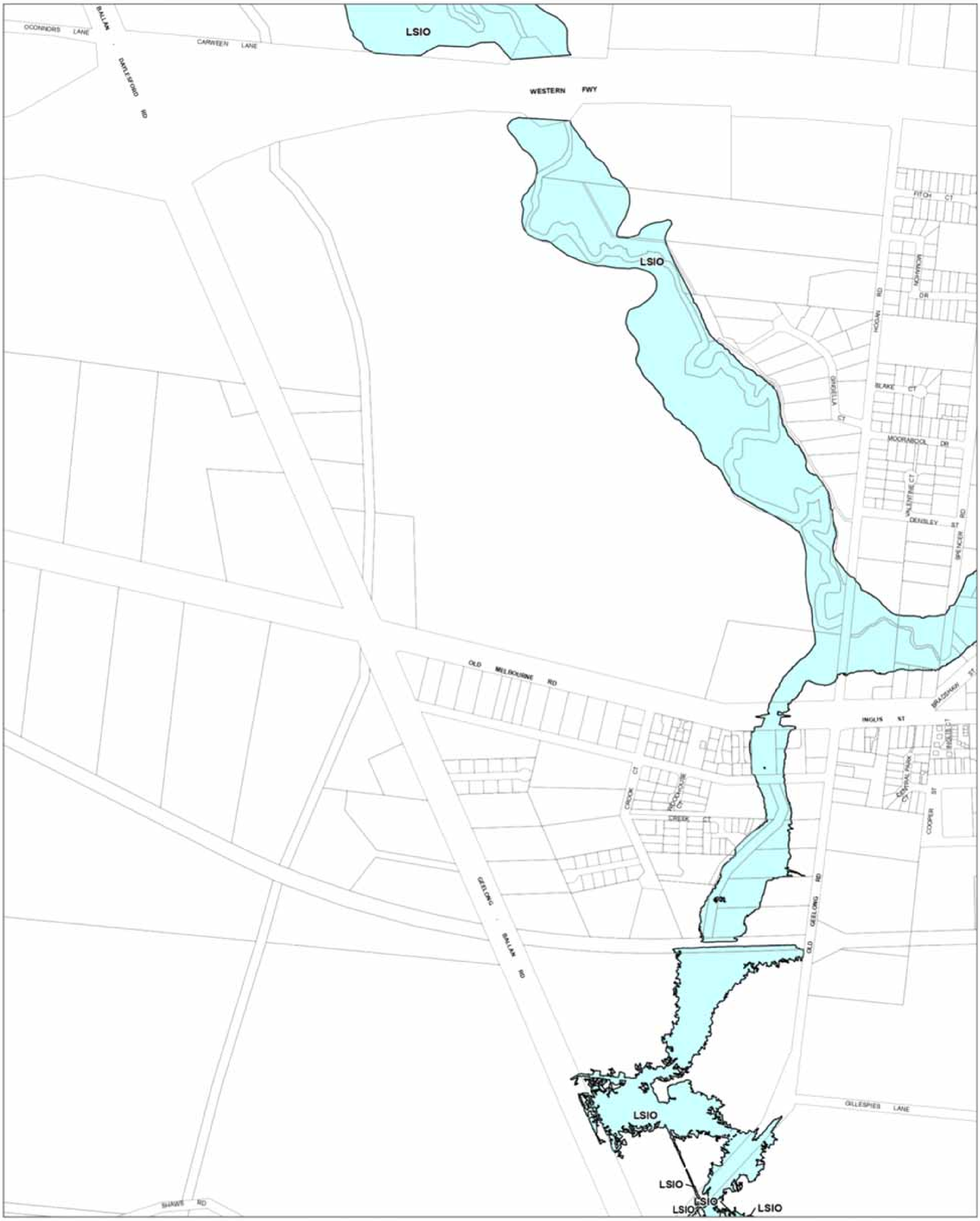
VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY **MAP No 17LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY

MAP No 26LSIO

MOORABOOL PLANNING SCHEME - LOCAL PROVISION
AMENDMENT C91

LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

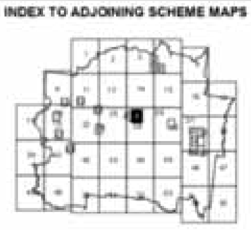
NORTH

Planning Group

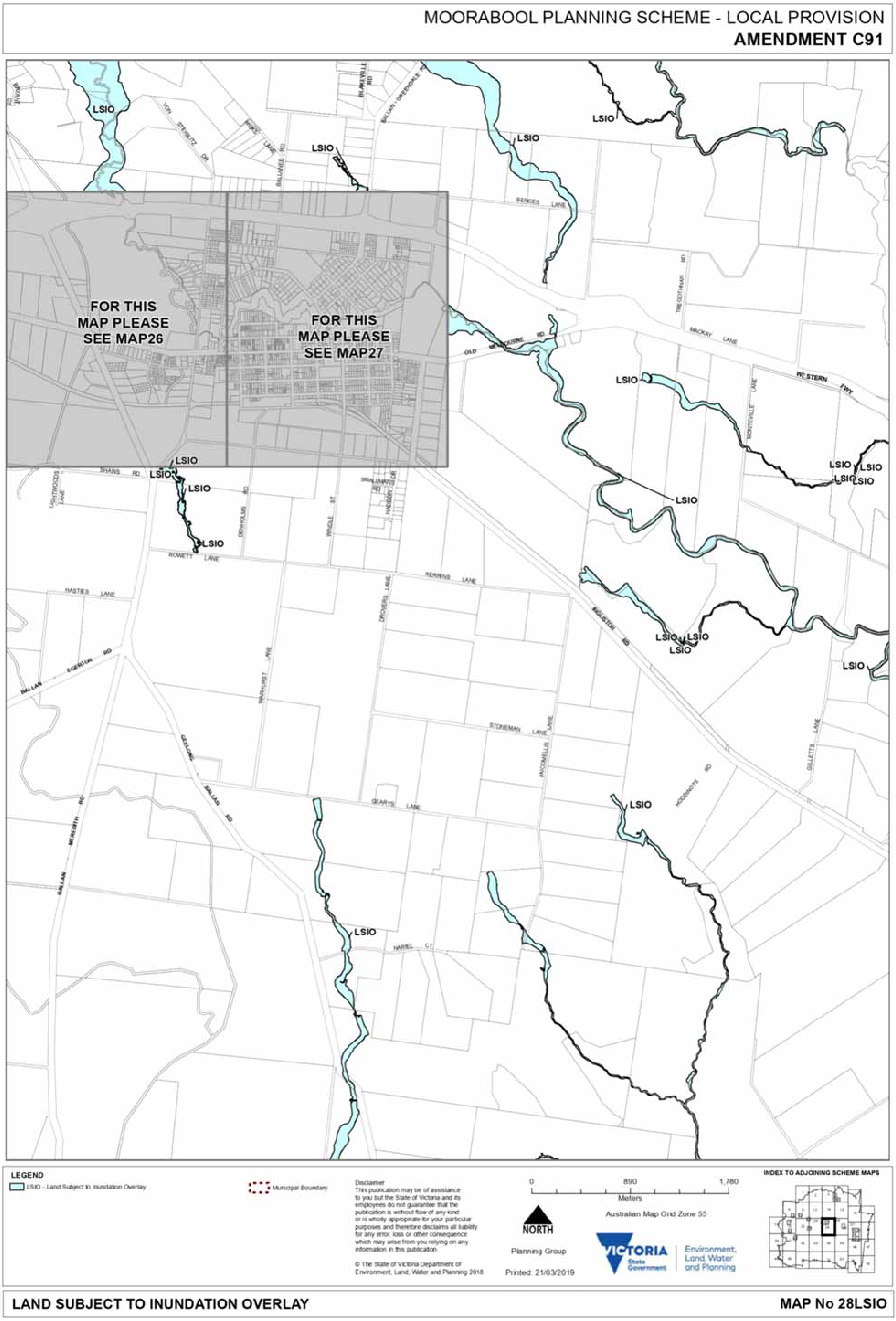
Printed: 21/03/2019

VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS



LAND SUBJECT TO INUNDATION OVERLAY **MAP No 27LSIO**


MOORABOOL PLANNING SCHEME - LOCAL PROVISION
AMENDMENT C91
FOR THIS MAP PLEASE SEE MAP26
FOR THIS MAP PLEASE SEE MAP27
LSIO
LEGEND
LSIO - Land Subject to Inundation Overlay
Municipal Boundary
Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.
© The State of Victoria Department of Environment, Land, Water and Planning 2018
0
890
1,780
Meters
Australian Map Grid Zone 55
NORTH
Planning Group
Printed: 21/03/2019
VICTORIA State Government
Environment, Land, Water and Planning
INDEX TO ADJOINING SCHEME MAPS
LAND SUBJECT TO INUNDATION OVERLAY
MAP No 28LSIO

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

Australian Map Grid Zone 55

NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government | Environment, Land, Water and Planning

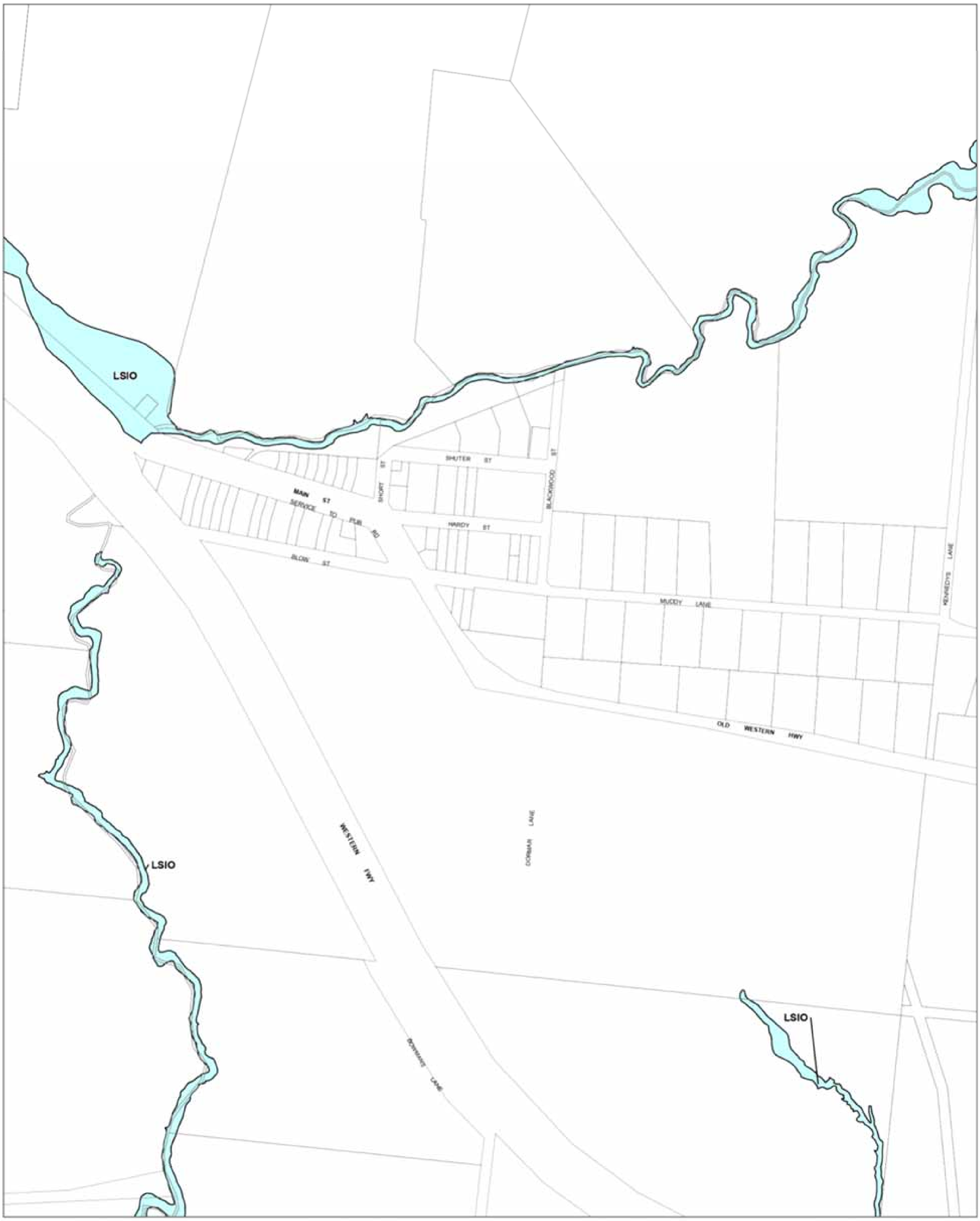
INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY

MAP No 29LSIO

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

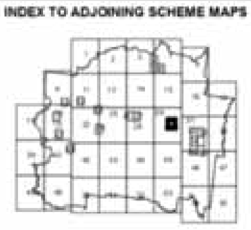
NORTH

Planning Group

Printed: 21/03/2019

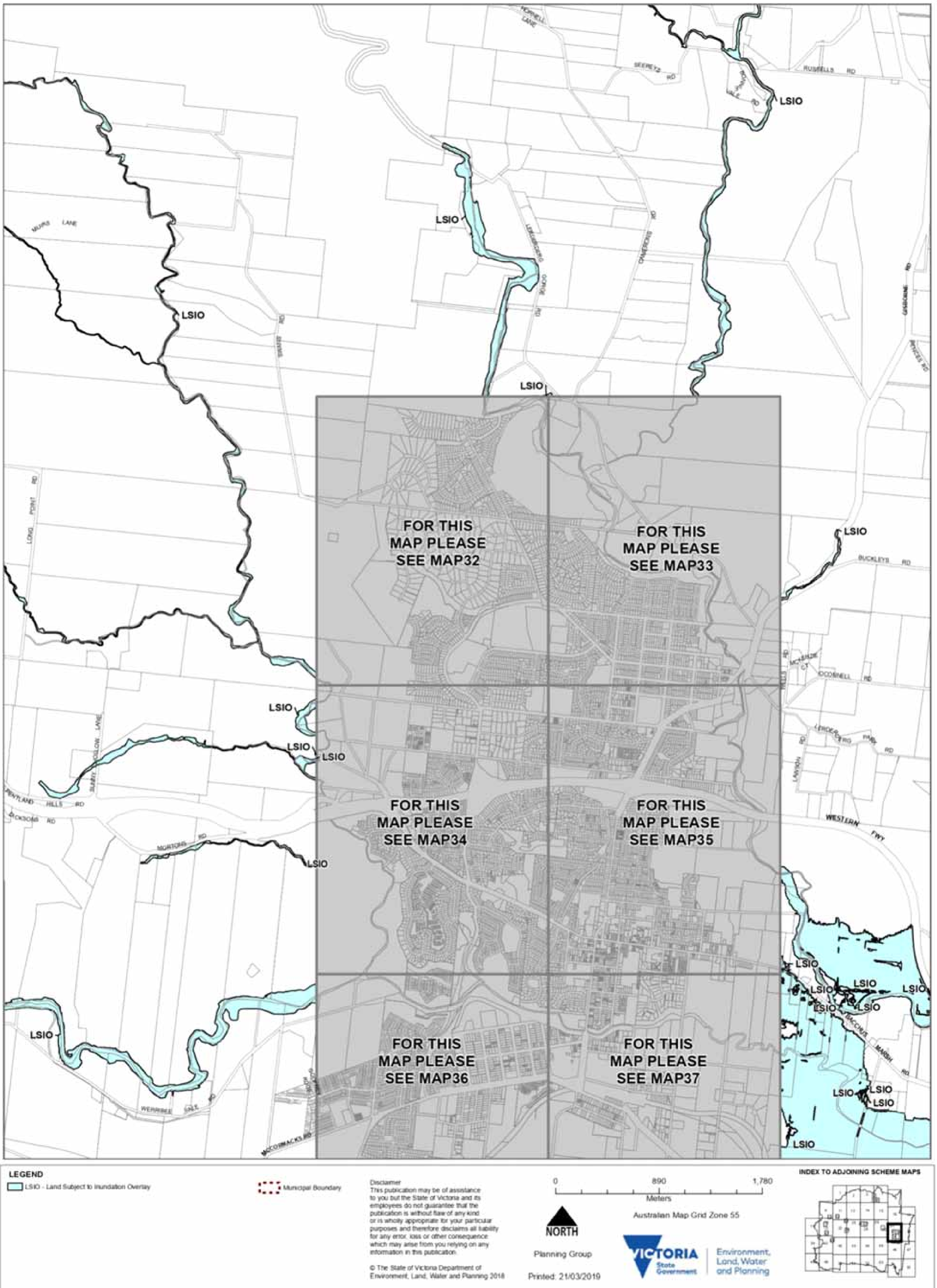
VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS



LAND SUBJECT TO INUNDATION OVERLAY **MAP No 30LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION
AMENDMENT C91



LAND SUBJECT TO INUNDATION OVERLAY **MAP No 31LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

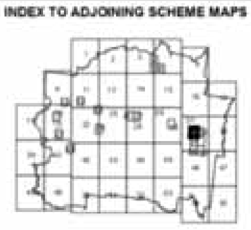
NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government — Environment, Land, Water and Planning

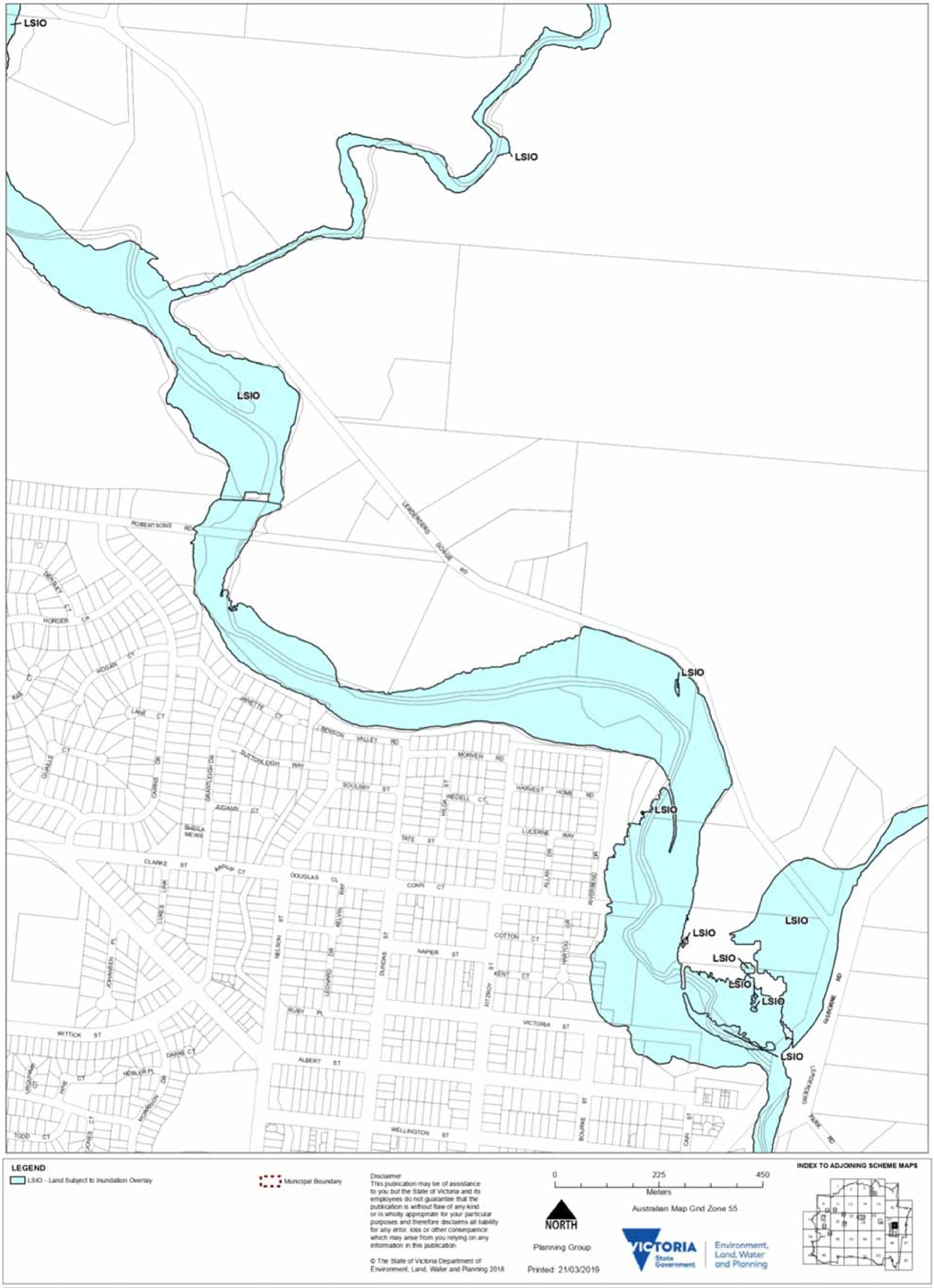
INDEX TO ADJOINING SCHEME MAPS



LAND SUBJECT TO INUNDATION OVERLAY **MAP No 32LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LAND SUBJECT TO INUNDATION OVERLAY

MAP No 33LSIO

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government — Environment, Land, Water and Planning

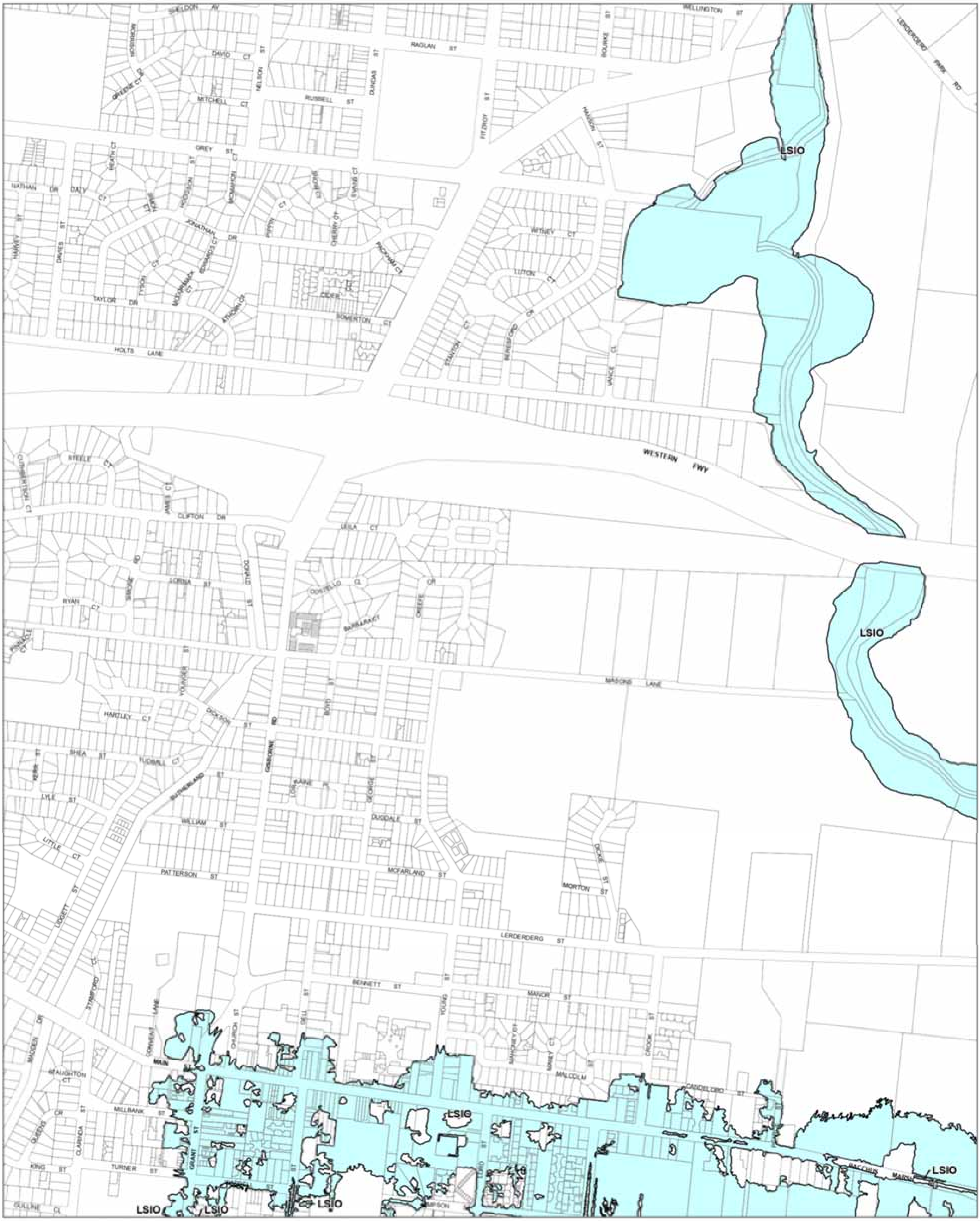
INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY

MAP No 34LSIO

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY **MAP No 35LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

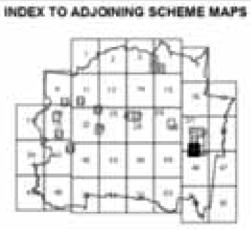
NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

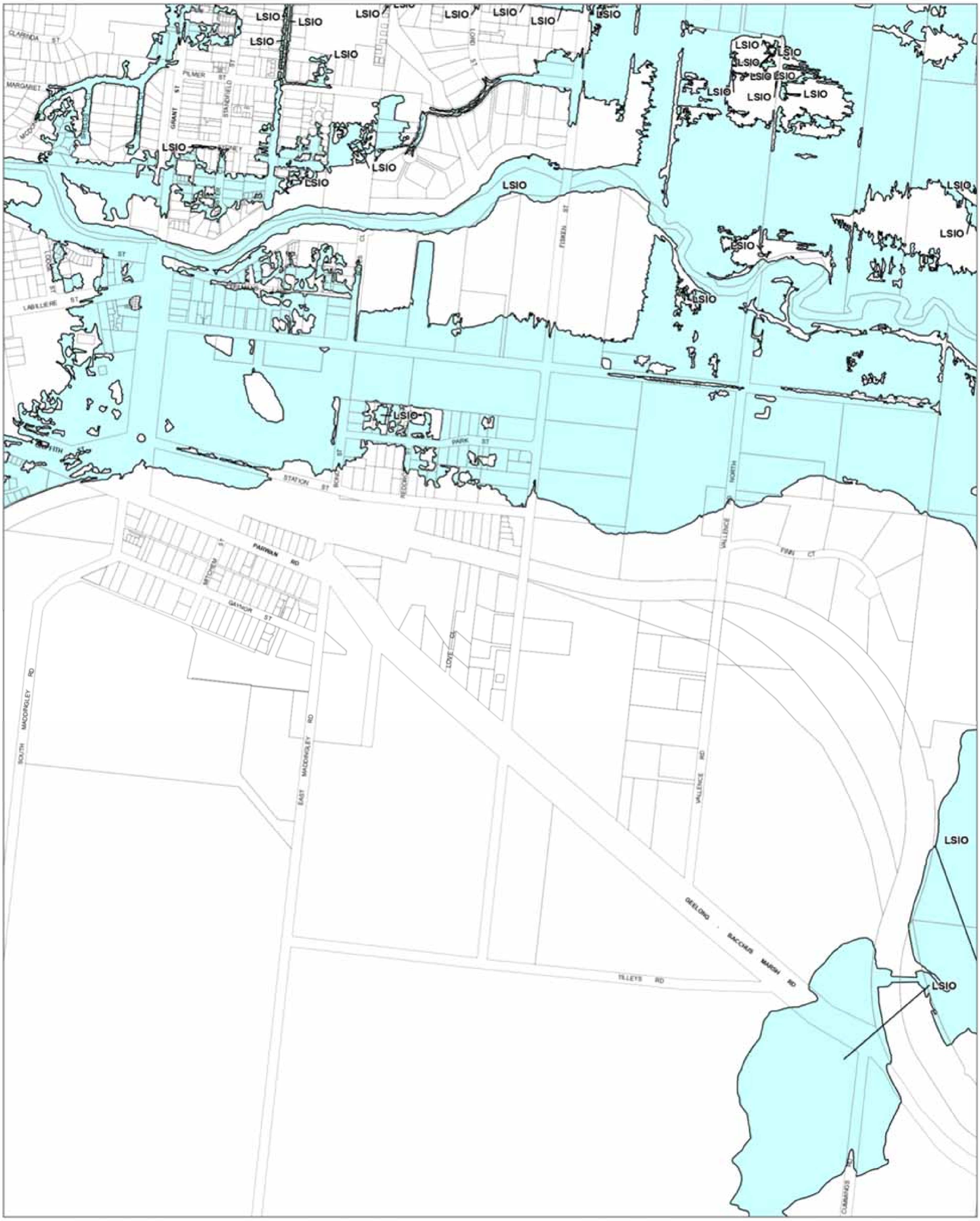


LAND SUBJECT TO INUNDATION OVERLAY

MAP No 36LSIO

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

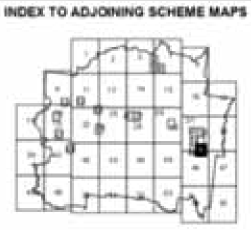
NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS



LAND SUBJECT TO INUNDATION OVERLAY **MAP No 37LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

NORTH

Australian Map Grid Zone 55

Planning Group

Printed: 21/03/2019

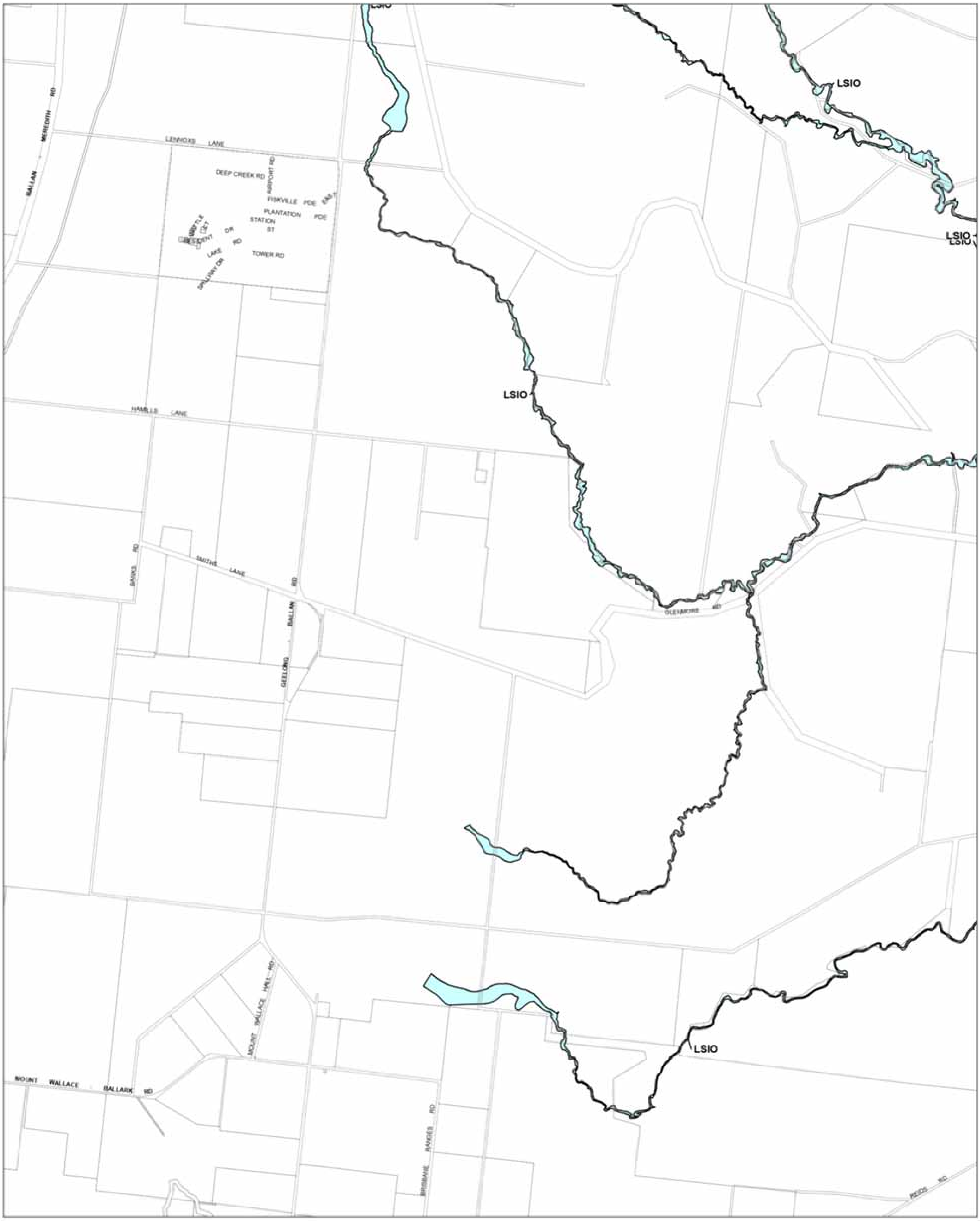
VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY **MAP No 38LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

Australian Map Grid Zone 55

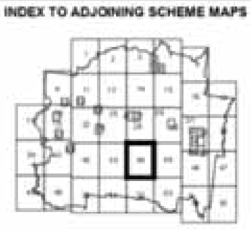
NORTH

Planning Group

Printed: 21/03/2019

Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS



LAND SUBJECT TO INUNDATION OVERLAY **MAP No 44LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

Australian Map Grid Zone 55

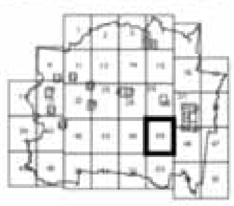
NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS



LAND SUBJECT TO INUNDATION OVERLAY **MAP No 45LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

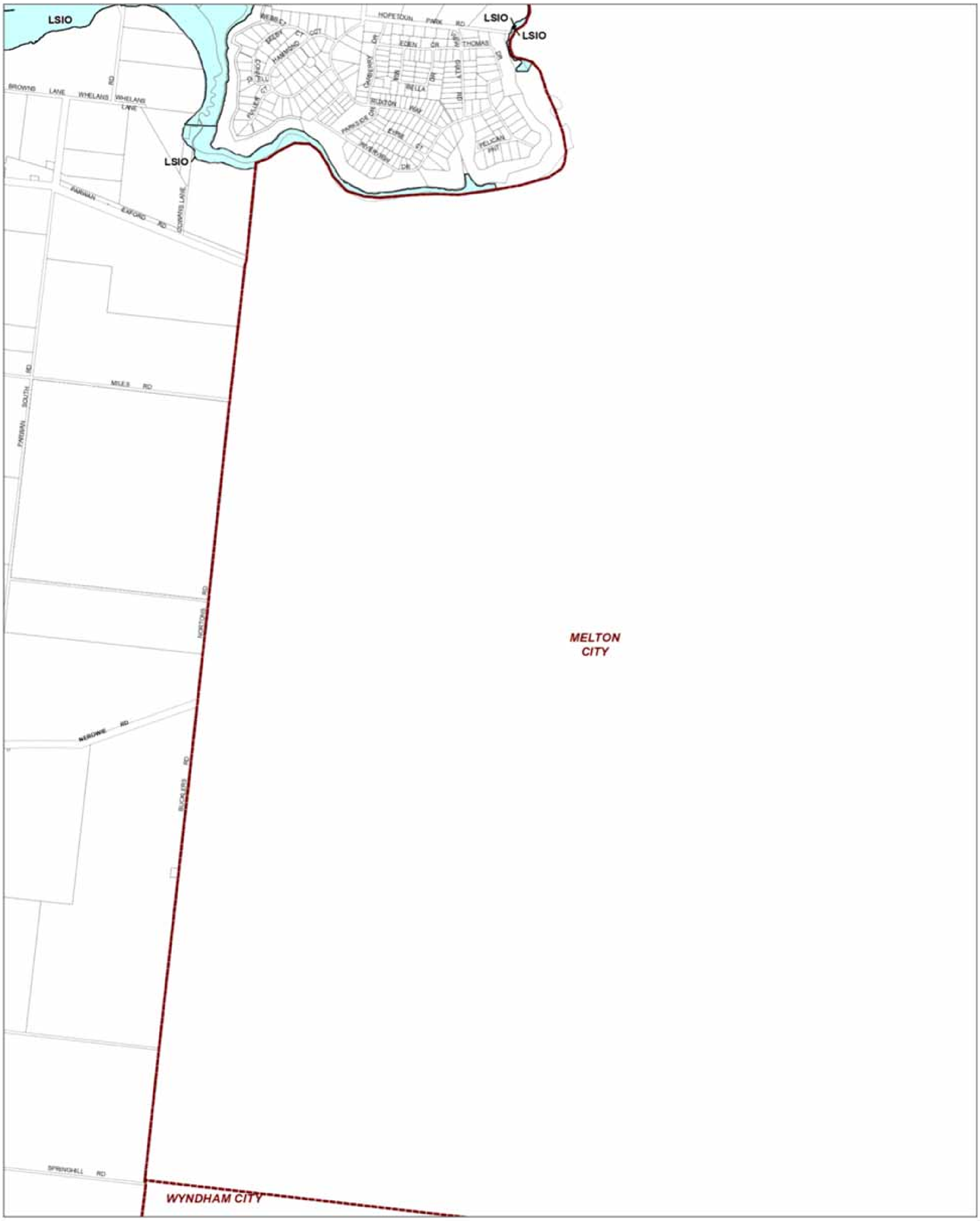
AMENDMENT C91

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

LAND SUBJECT TO INUNDATION OVERLAY **MAP No 46LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

Australian Map Grid Zone 55

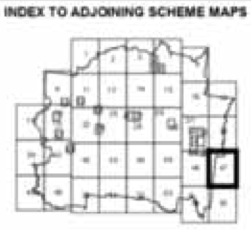
NORTH

Planning Group

Printed: 21/03/2019

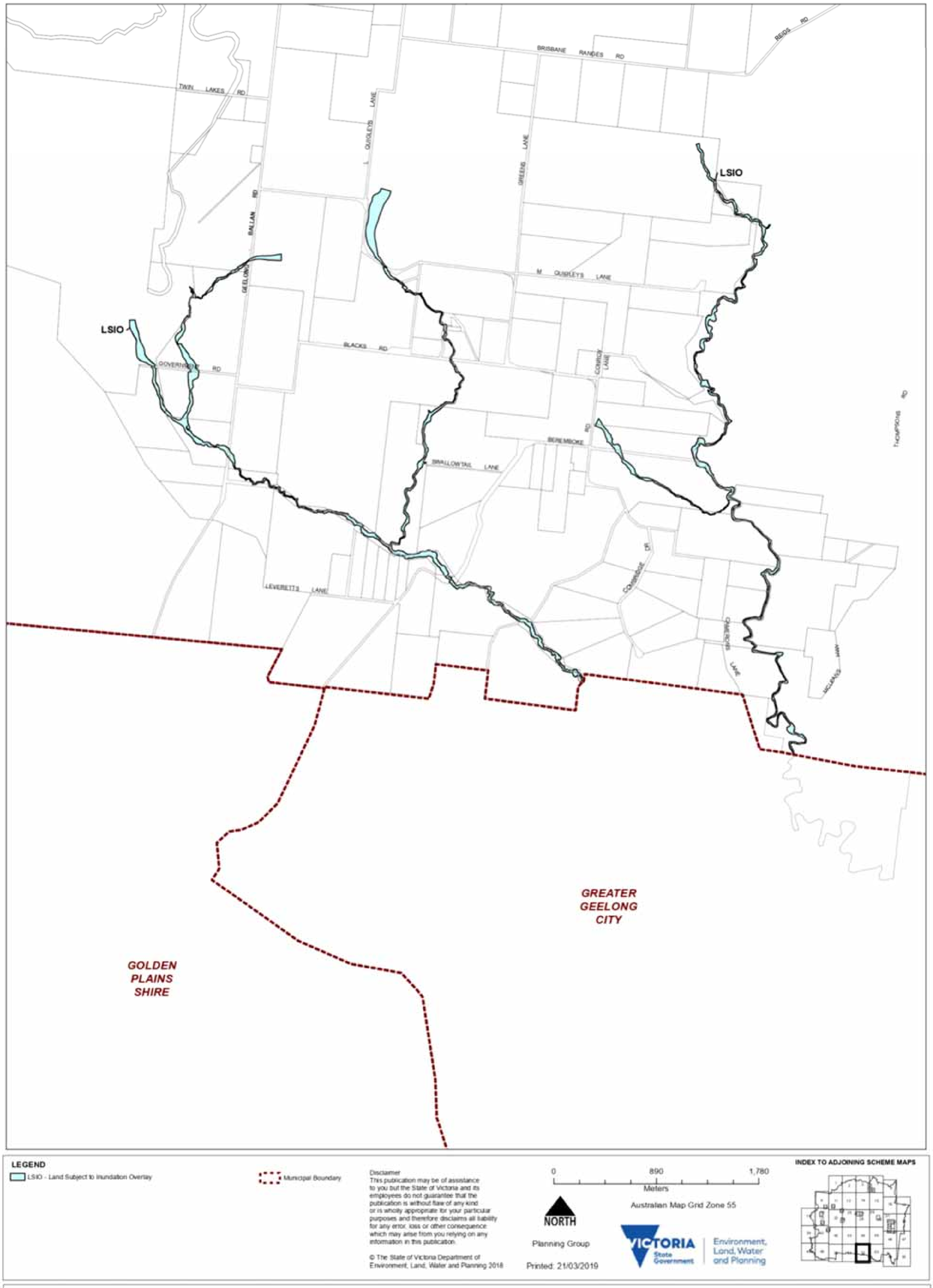
VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS



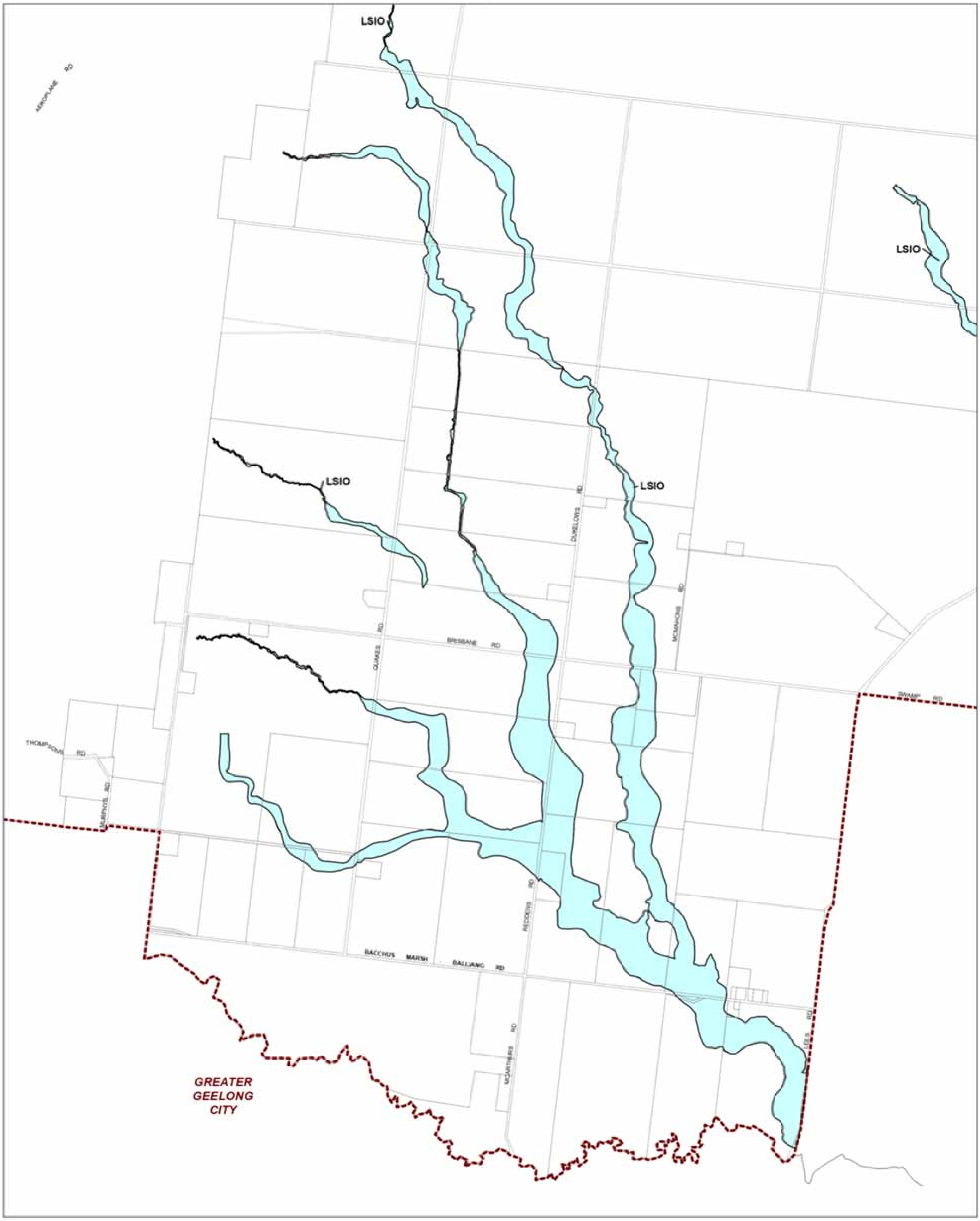
LAND SUBJECT TO INUNDATION OVERLAY **MAP No 47LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION
AMENDMENT C91



LAND SUBJECT TO INUNDATION OVERLAY **MAP No 52LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION
AMENDMENT C91



LEGEND
LSIO - Land Subject to Inundation Overlay
Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters
Australian Map Grid Zone 55
NORTH
Planning Group
Printed: 21/03/2019
VICTORIA State Government | Environment, Land, Water and Planning
INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY **MAP No 53LSIO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

LSIO - Land Subject to Inundation Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

Australian Map Grid Zone 55

NORTH

Planning Group

Printed: 21/03/2019

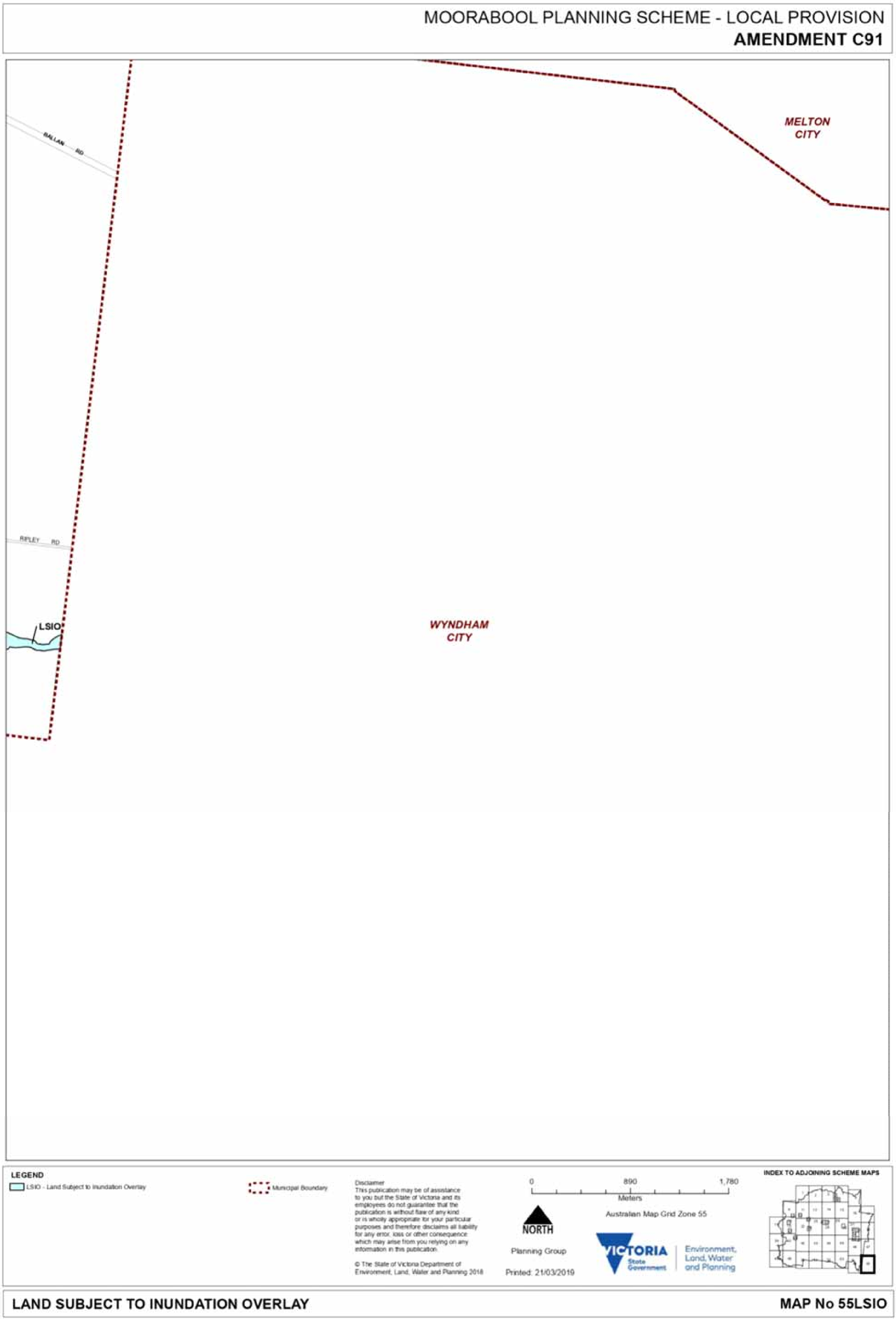
VICTORIA State Government

Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

LAND SUBJECT TO INUNDATION OVERLAY

MAP No 54LSIO


MOORABOOL PLANNING SCHEME - LOCAL PROVISION
AMENDMENT C91
BALLAN RD
MELTON CITY
RIPLEY RD
LSIO
WYNDHAM CITY
LEGEND
LSIO - Land Subject to Inundation Overlay
Municipal Boundary
Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.
© The State of Victoria Department of Environment, Land, Water and Planning 2018
0
890
1,780
Meters
Australian Map Grid Zone 55
NORTH
Planning Group
Printed: 21/03/2019
VICTORIA State Government
Environment, Land, Water and Planning
INDEX TO ADJOINING SCHEME MAPS
LAND SUBJECT TO INUNDATION OVERLAY
MAP No 55LSIO

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

SBO - Special Building Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government

Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

SPECIAL BUILDING OVERLAY **MAP No 26SBO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

SBO - Special Building Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

Australian Map Grid Zone 55

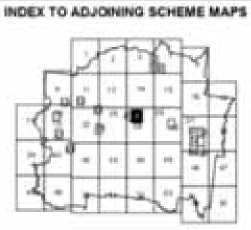
NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS



SPECIAL BUILDING OVERLAY

MAP No 27SBO

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

SBO - Special Building Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

Australian Map Grid Zone 55

NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government — Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

SPECIAL BUILDING OVERLAY **MAP No 28SBO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

SBO - Special Building Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 890 1,780
Meters

Australian Map Grid Zone 55

NORTH

Planning Group

Printed: 21/03/2019

VICTORIA State Government — Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

SPECIAL BUILDING OVERLAY **MAP No 31SBO**

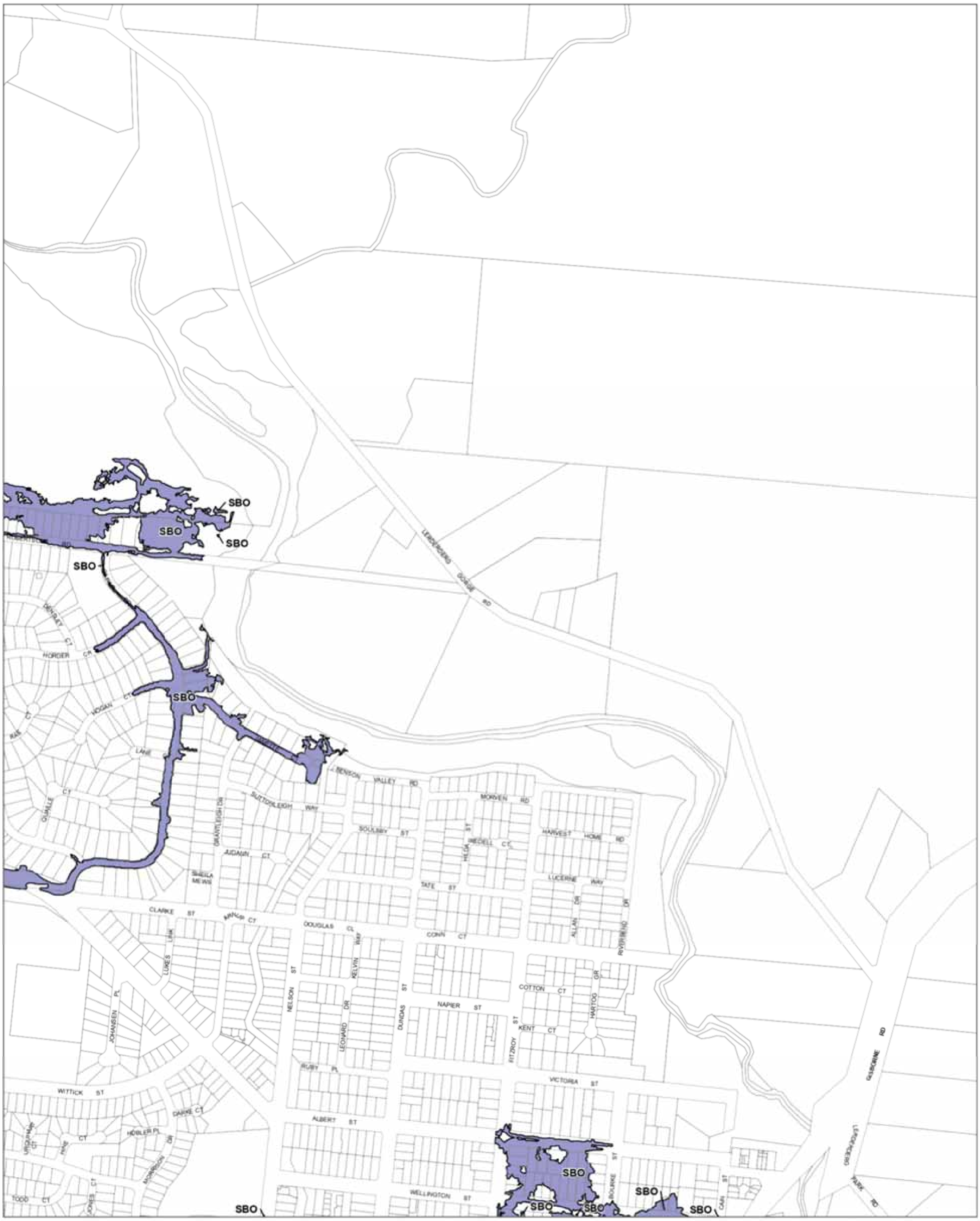
MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

SPECIAL BUILDING OVERLAY **MAP No 32SBO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LEGEND

SBO - Special Building Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450
Meters

NORTH

Planning Group

Printed: 21/03/2019

Australian Map Grid Zone 55

VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

SPECIAL BUILDING OVERLAY **MAP No 33SBO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91

LEGEND

SBO - Special Building Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

NORTH

0 225 450
Meters

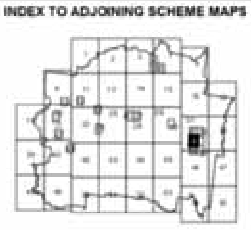
Australian Map Grid Zone 55

Planning Group

Printed: 21/03/2019

VICTORIA State Government | Environment, Land, Water and Planning

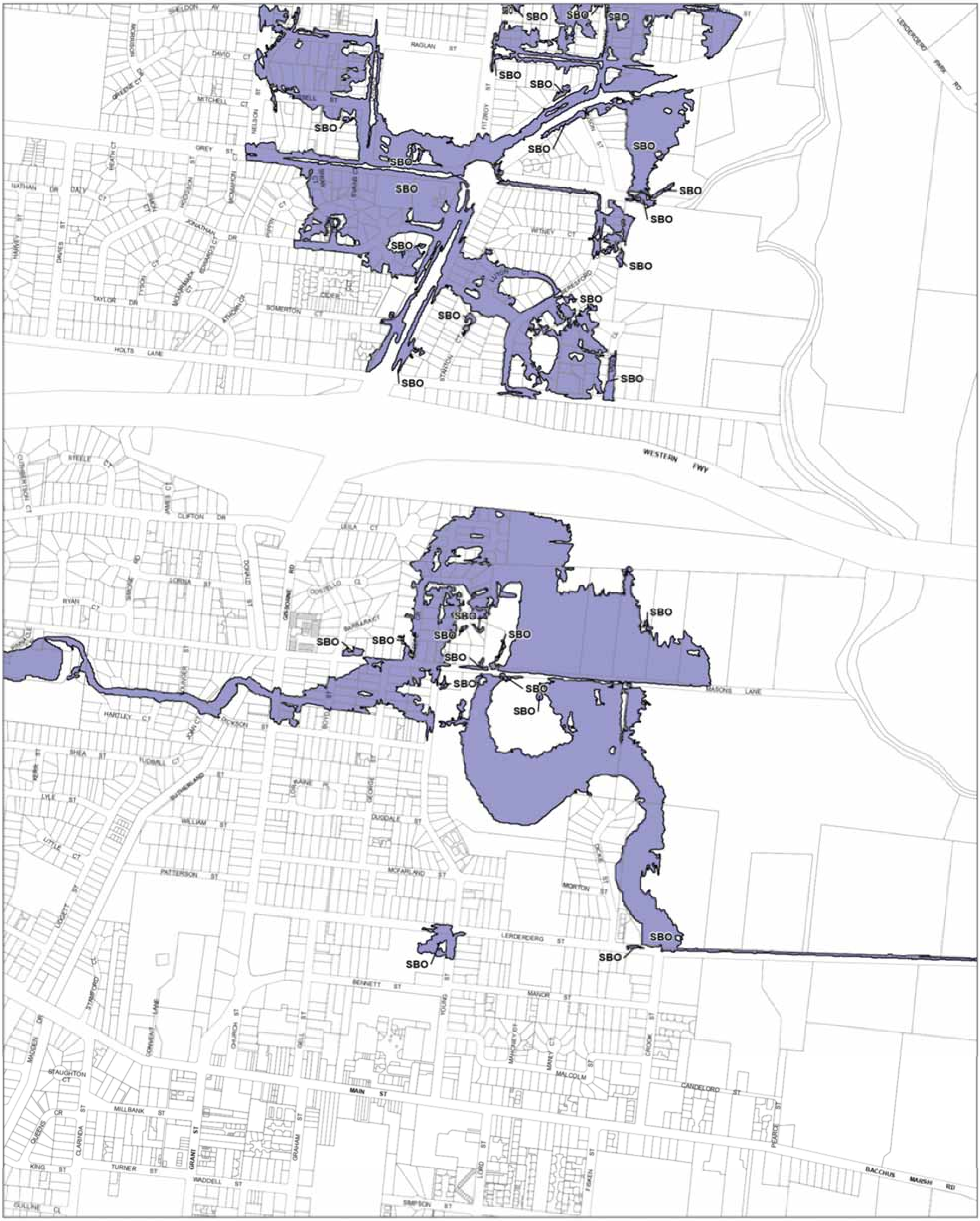
INDEX TO ADJOINING SCHEME MAPS



SPECIAL BUILDING OVERLAY **MAP No 34SBO**

MOORABOOL PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C91



LEGEND

SBO - Special Building Overlay

Municipal Boundary

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

0 225 450 Meters

Australian Map Grid Zone 55

NORTH

Planning Group

Printed: 21/03/2019

INDEX TO ADJOINING SCHEME MAPS

SPECIAL BUILDING OVERLAY **MAP No 35SBO**