MELBOURNE WATER

Lower Lerderderg Catchments

Flood Mapping Report

December 2011

Job Number: V3000_004

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V3000_004 Lower Lerderderg Catchments – Flood Mapping Report					
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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.

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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**.

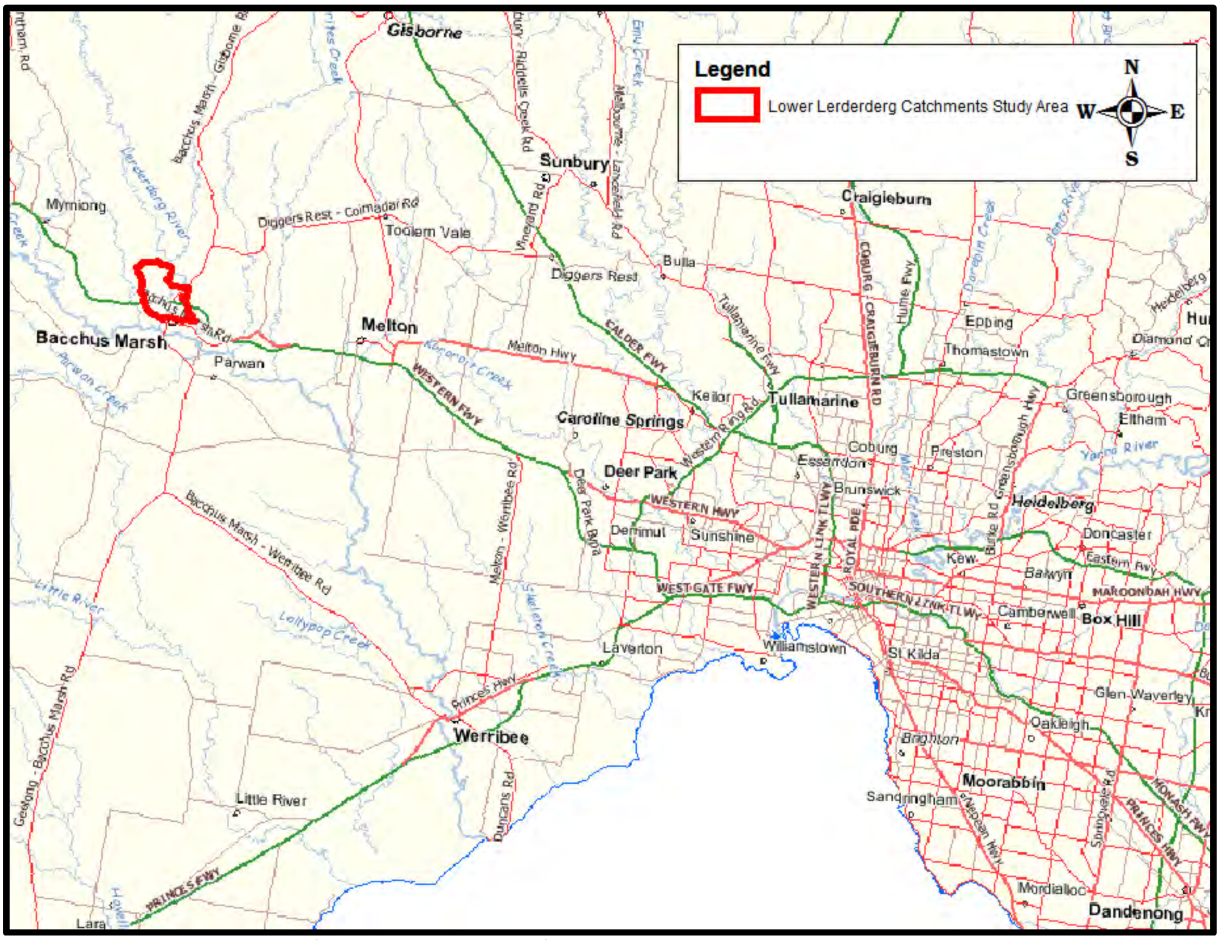

Figure 2.1 – Locality Plan of Lower Lerderderg Catchments

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.

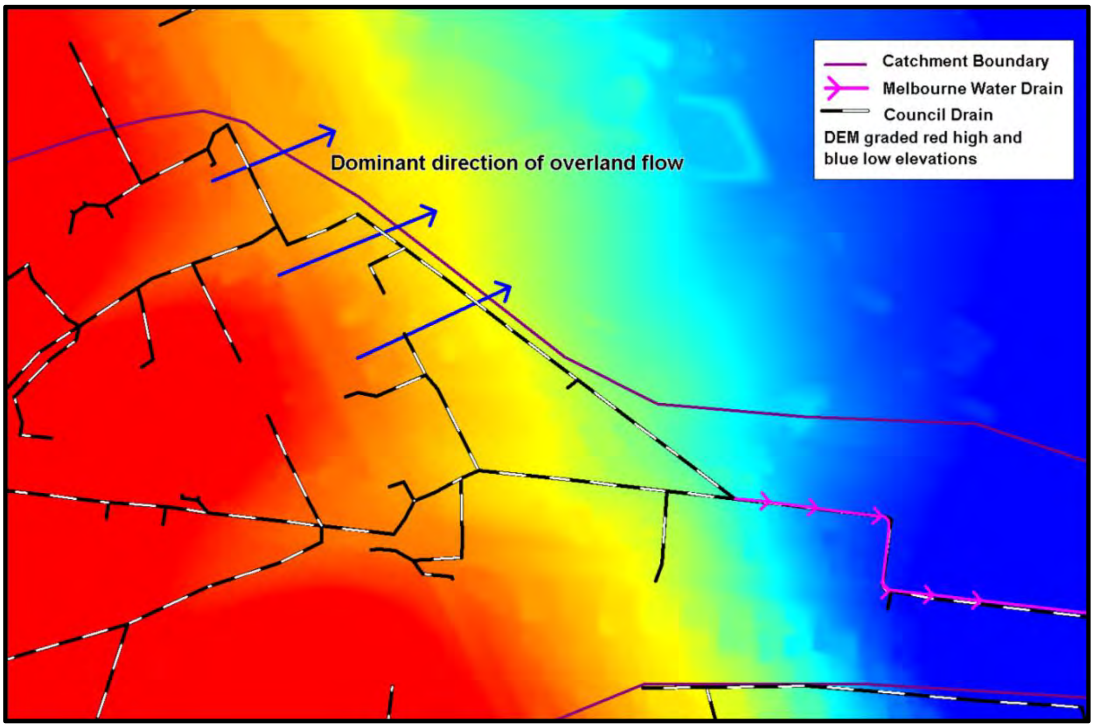

Figure 3.1 – Downstream end of Robertsons Road Drain Catchment

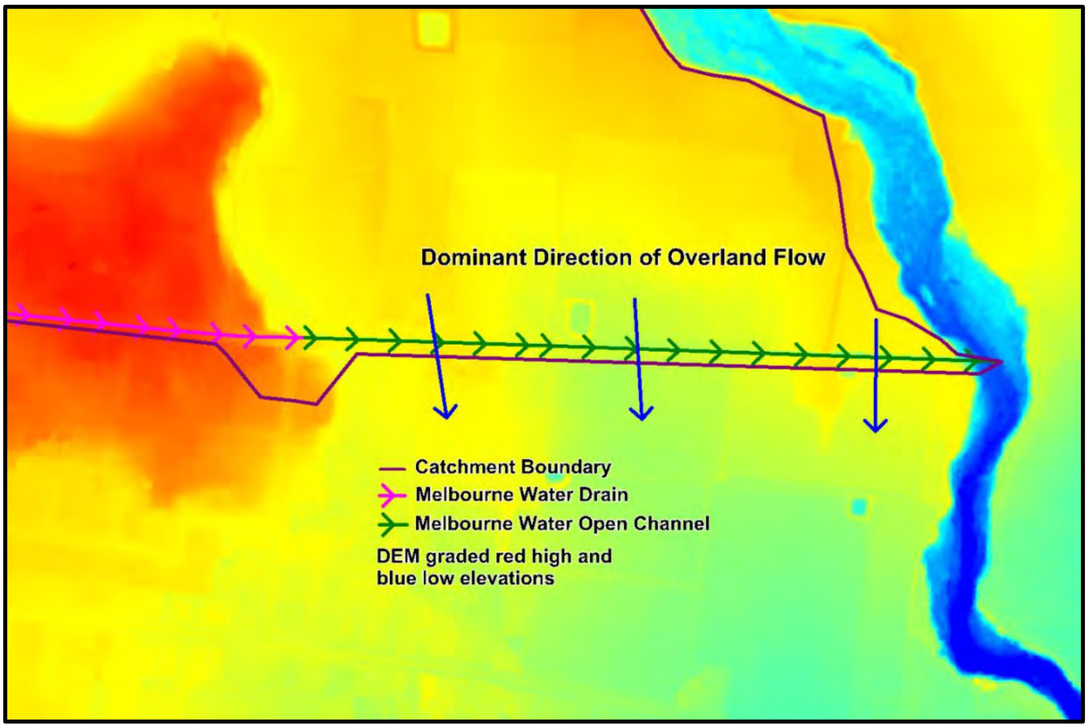

Figure 3.2 – Downstream area of Lerderderg Street Drain Catchment

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.

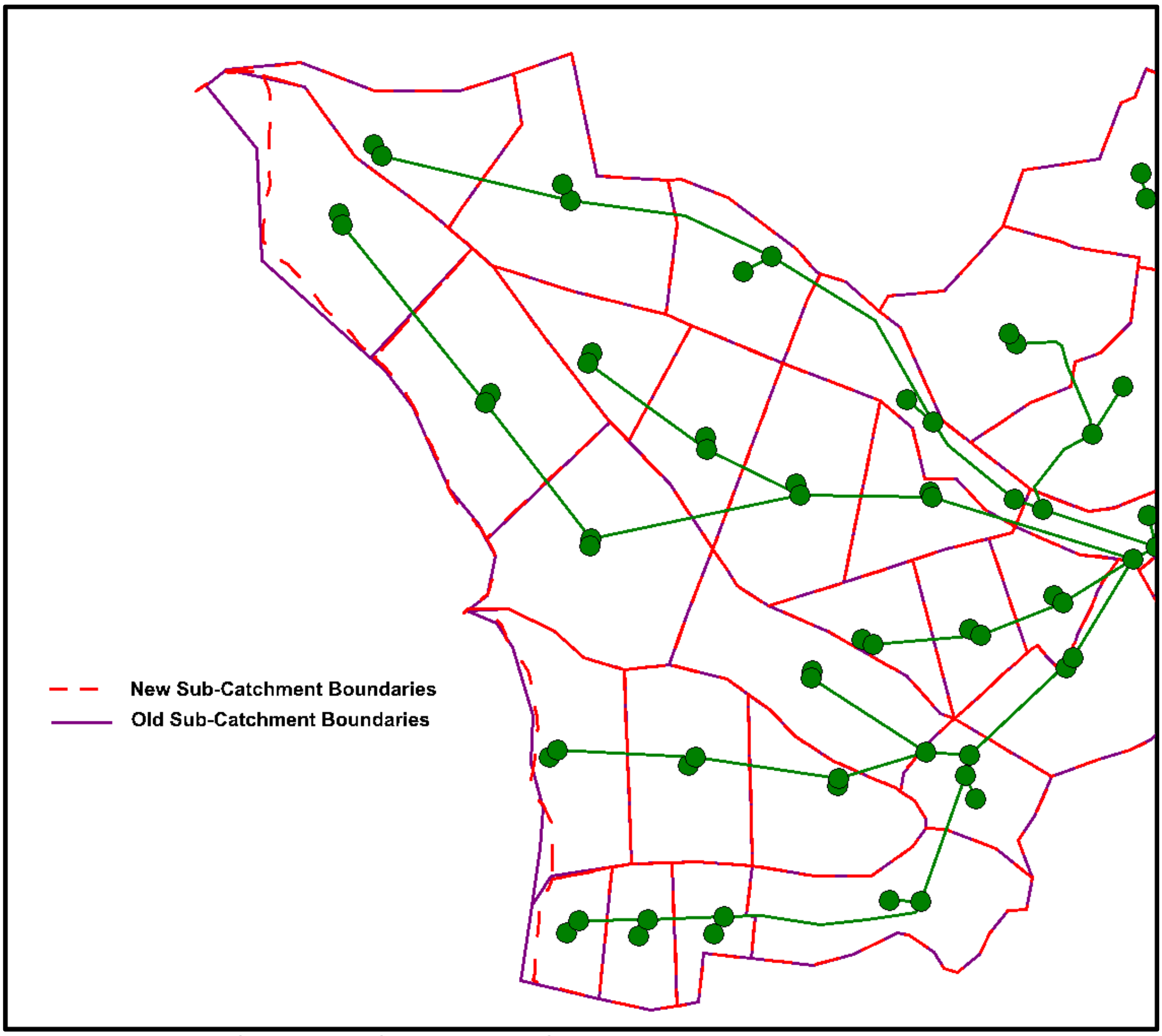

Figure 3.3 – Revised Cairns Drive Catchment MiRORB

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.

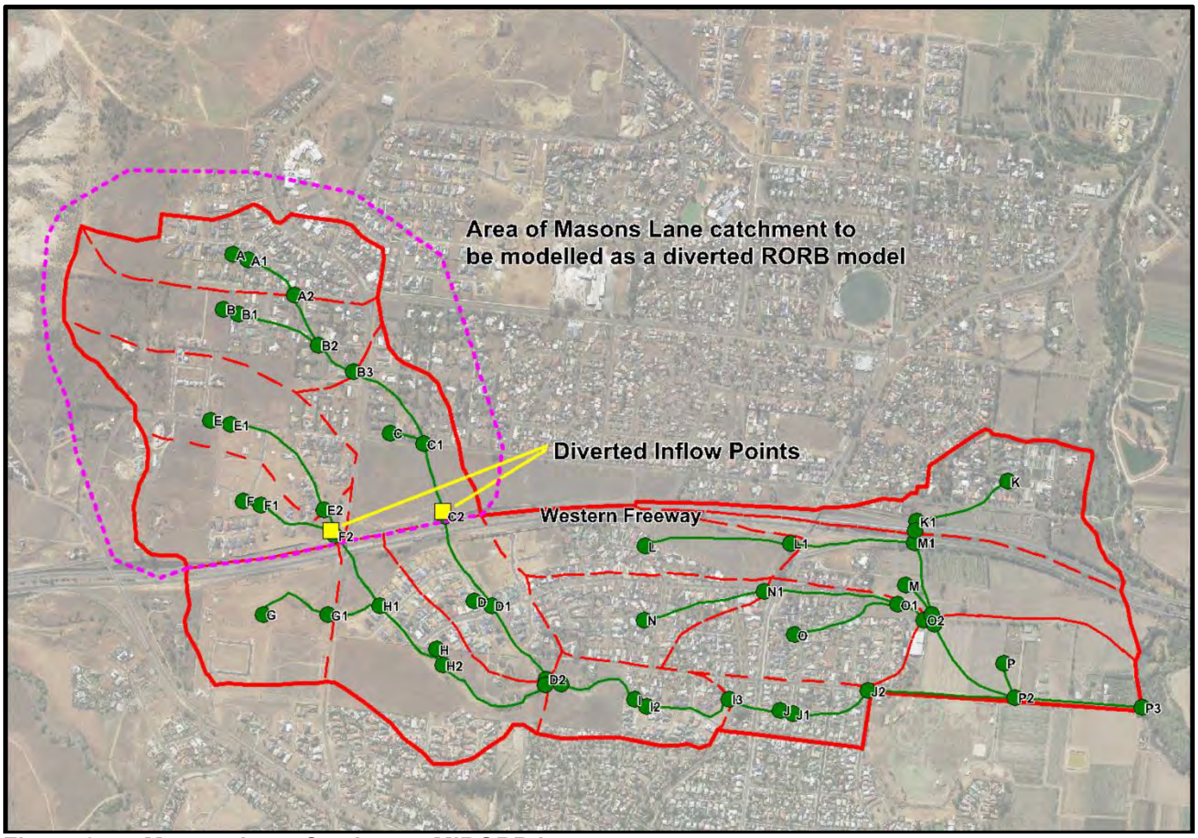

Figure 3.4 – Masons Lane Catchment MiRORB Layout

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=0.76A$^{0.38}$). 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.

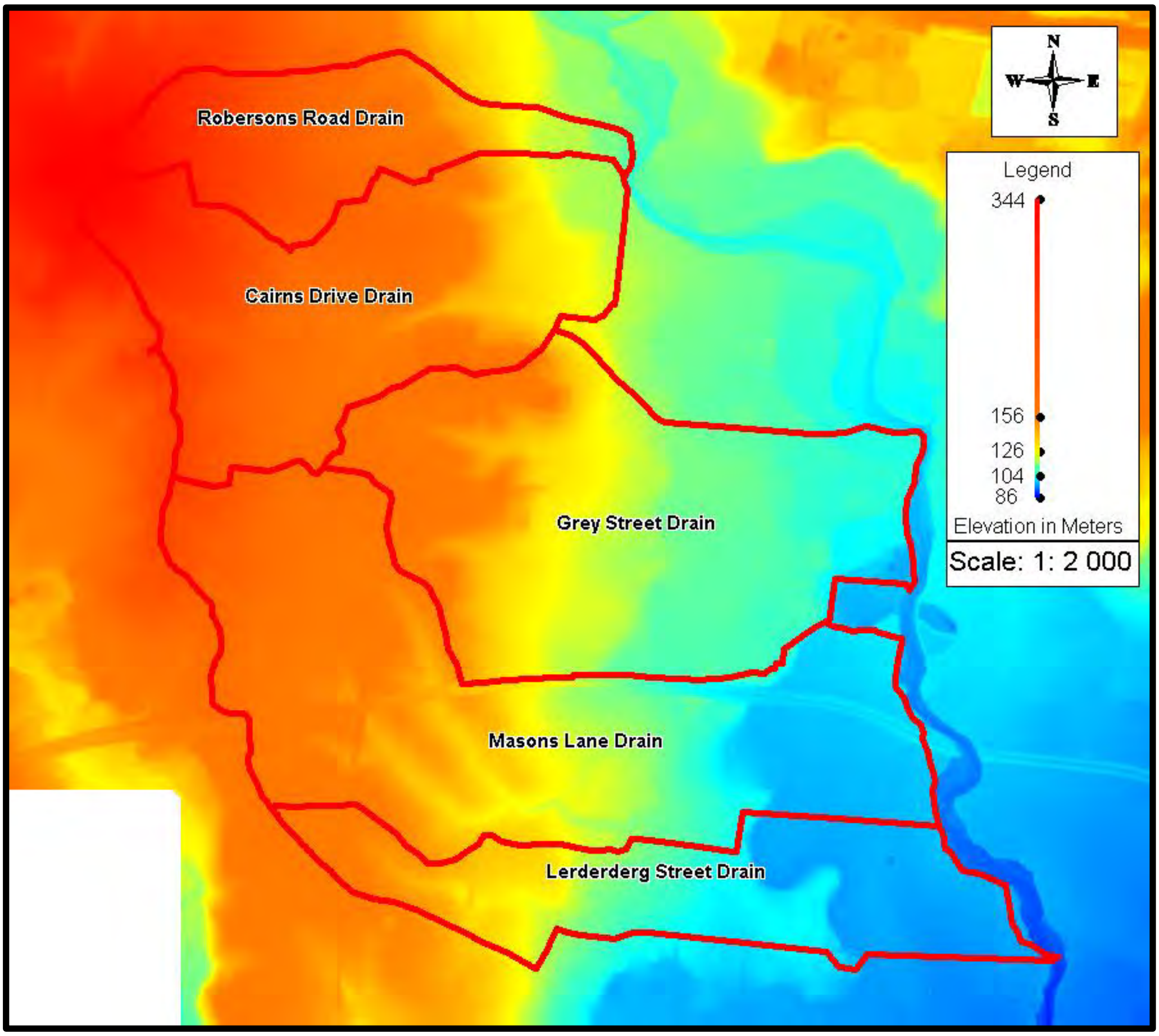

Figure 5.1 – DEM for the Lower Lerderderg Catchments

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.

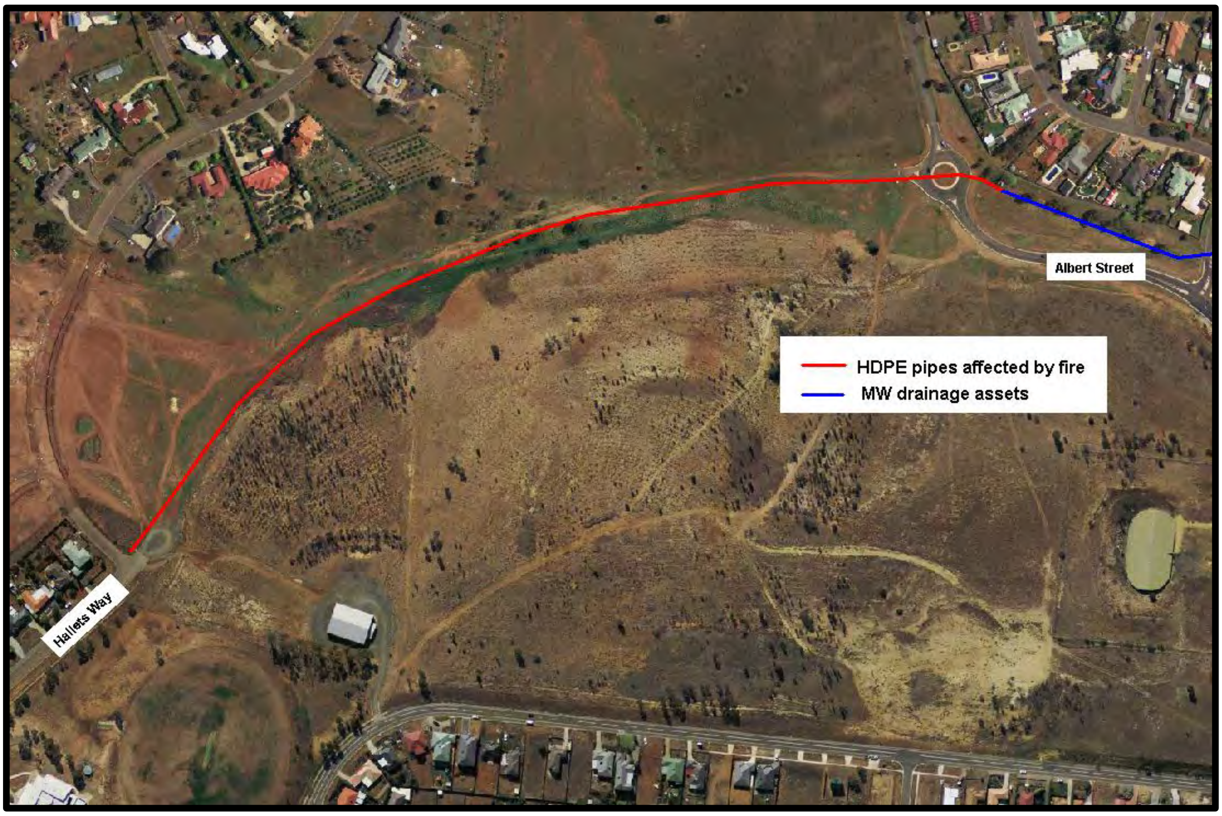

Figure 5.3 – Length of non-operational pipe in Cairns Drive

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