



Engineering | Surveying | Planning

# **MOLLERS LANE, LEOPOLD – REZONING AND SUBDIVISION**

## **SITE STORMWATER MANAGEMENT PLAN AND FLOOD IMPACT ASSESSMENT**

Revision 02

**TGM GROUP PTY. LTD.**

Level 1, 27-31 Myers Street

Geelong, Victoria 3220

Phone: (03) 5202 4600

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<b>Client Project Manager</b>	Peter Preece
<b>Author</b>	Mark Colegate
<b>Principal Contributors</b>	Luke Barber, Stephen Canton
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#### TGM Group Pty Ltd

27-31 Myers Street  
Geelong, VIC 3220  
Telephone – (03) 5202 4600  
Fax – (03) 5202 4691

### Document Location

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## EXECUTIVE SUMMARY

### Site Stormwater Management Plan

The following report provides empirical evidence that stormwater runoff generated within the proposed developed Mollers Lane site in Leopold can be mitigated to meet and exceed 'best-practice' reductions in stormwater contaminant loadings and achieve design requirements for site discharges for the full range of storm events.

An end-of-line wetland system is proposed to be constructed in the base of the detention basins to manage stormwater quality generated within the developed site.

The required dimensions of the wetland component are tabulated below in Table 0-1.

**Table 0-1: Wetland facilities – design parameters**

Wetland	Surface Area (m <sup>2</sup> )	Extended Detention Depth (m)
Northern (AB)	3,300	0.45
Southern (C)	1,900	0.4

The treatment efficiency of the wetland systems at each legal point of discharge (LPOD) is shown in Table 0-2.

**Table 0-2: Wetland treatment efficiency at designated LPOD**

Criteria	Reduction @ LPOD (%)	
	Northern (AB)	Southern (C)
Total Suspended Solids (kg/yr)	80.3	80.3
Total Phosphorus (kg/yr)	69.7	69.3
Total Nitrogen (kg/yr)	49.3	45.6
Gross Pollutants (kg/yr)	95.1	100

A detention basin facility was designed to mitigate stormwater runoff discharges from the developed site and ensure a 'no worsening' of predeveloped discharges for the full range of storm events.

The predeveloped discharge targets are shown in Table 0-3.

**Table 0-3:** Predeveloped Discharge at designated LPOD – All Events

Event		Discharge @ LPOD (m <sup>3</sup> /s)	
		Northern (AB)	Southern (C)
AEP	1%	0.65	0.54
	2%	0.54	0.45
	5%	0.41	0.38
	10%	0.30	0.32
EY	0.2	0.24	0.27
	0.5	0.15	0.20

The required detention volume is shown in Table 0-4.

**Table 0-4:** Detention basin facilities – 1% AEP design characteristics

Basin	Surface Area (m <sup>2</sup> )		Depth (m)	Volume (m <sup>3</sup> )	Discharge (m <sup>3</sup> /s)
	Base (I.L.)	T.W.L			
AB	3,510	~ 5,610	0.95	4,300	<b>0.65</b>
C	2,702	~ 4,370	0.79	2,657	<b>0.54</b>

## Flood Impact Assessment

The flood risk assessment identified that the developed site is not adversely affected by the regional flood for events up to and including the 1% AEP, demonstrating that the proposed developable land area is not subject to inundation during the analysed range of storm events.

The 1% AEP flood extent impacting the site under predeveloped conditions is shown in Figure 0-1.

The 1% AEP flood extent for the mitigated developed site is shown in Figure 0-2.

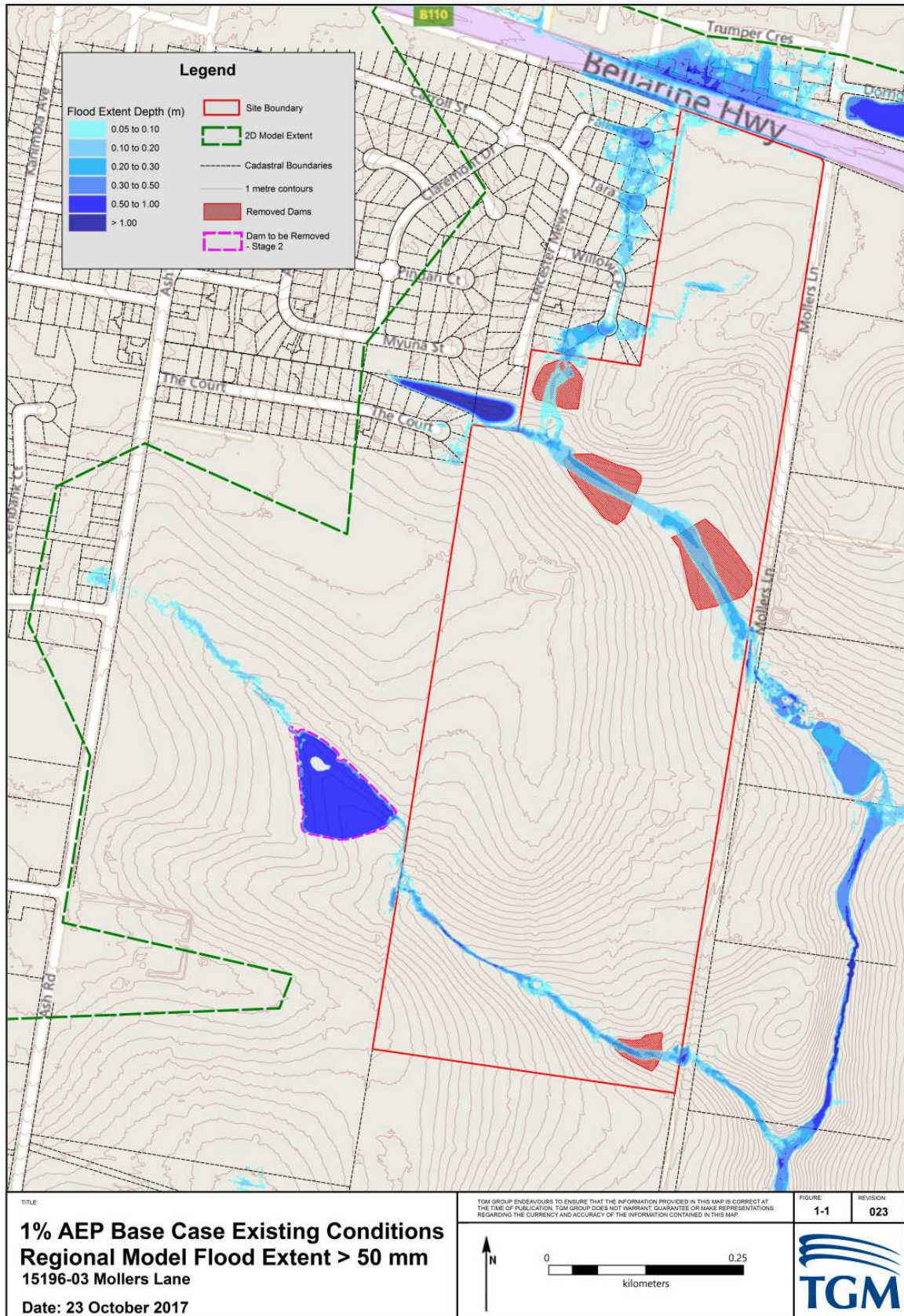


Figure 0-1: Predeveloped 1% AEP Flood Extent (depths  $\geq$  50 mm)

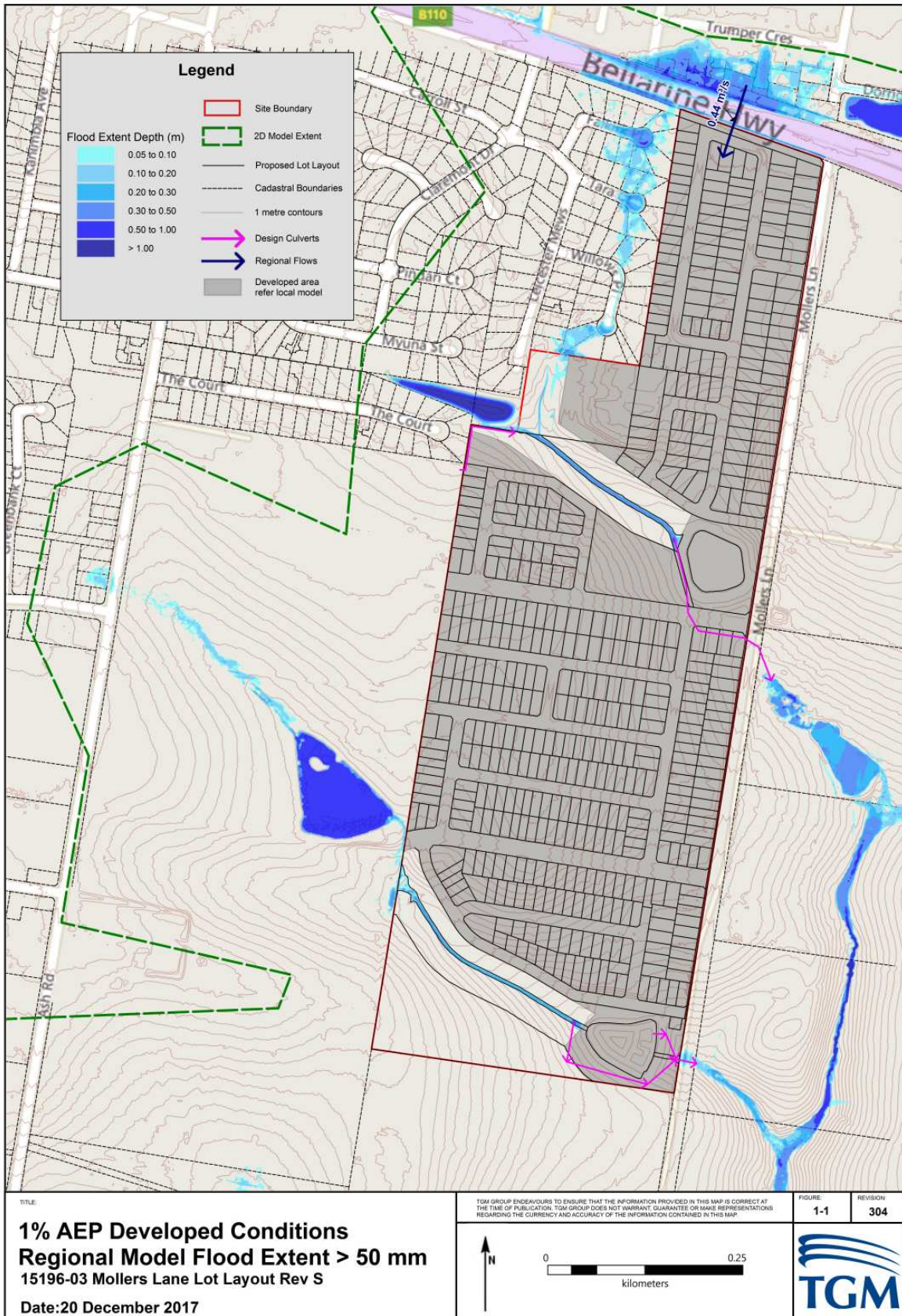


Figure 0-2: Developed 1% AEP Flood Extent (depths ≥ 50 mm)

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Flood risks, associated with safety hazards, are low as all 'unsafe' characteristics are contained within the existing waterway. Hazards associated with flooding are not prohibitive to the development site and will not present a danger to people or vehicle movement.

The overall hazard map for the developed site is shown in Figure 0-3 for the 1% AEP event.

The Flood Impact Assessment (FIA) identified no negative impacts resulting from the proposed development of the Mollers Lane site on the regional flood characteristics in the surrounding catchment.

The development results in a reduction in flood extents and/or no change to flood extents during all analysed events.

The flood impact 'change in flood' map can be seen in Figure 0-4 for the 1% AEP.

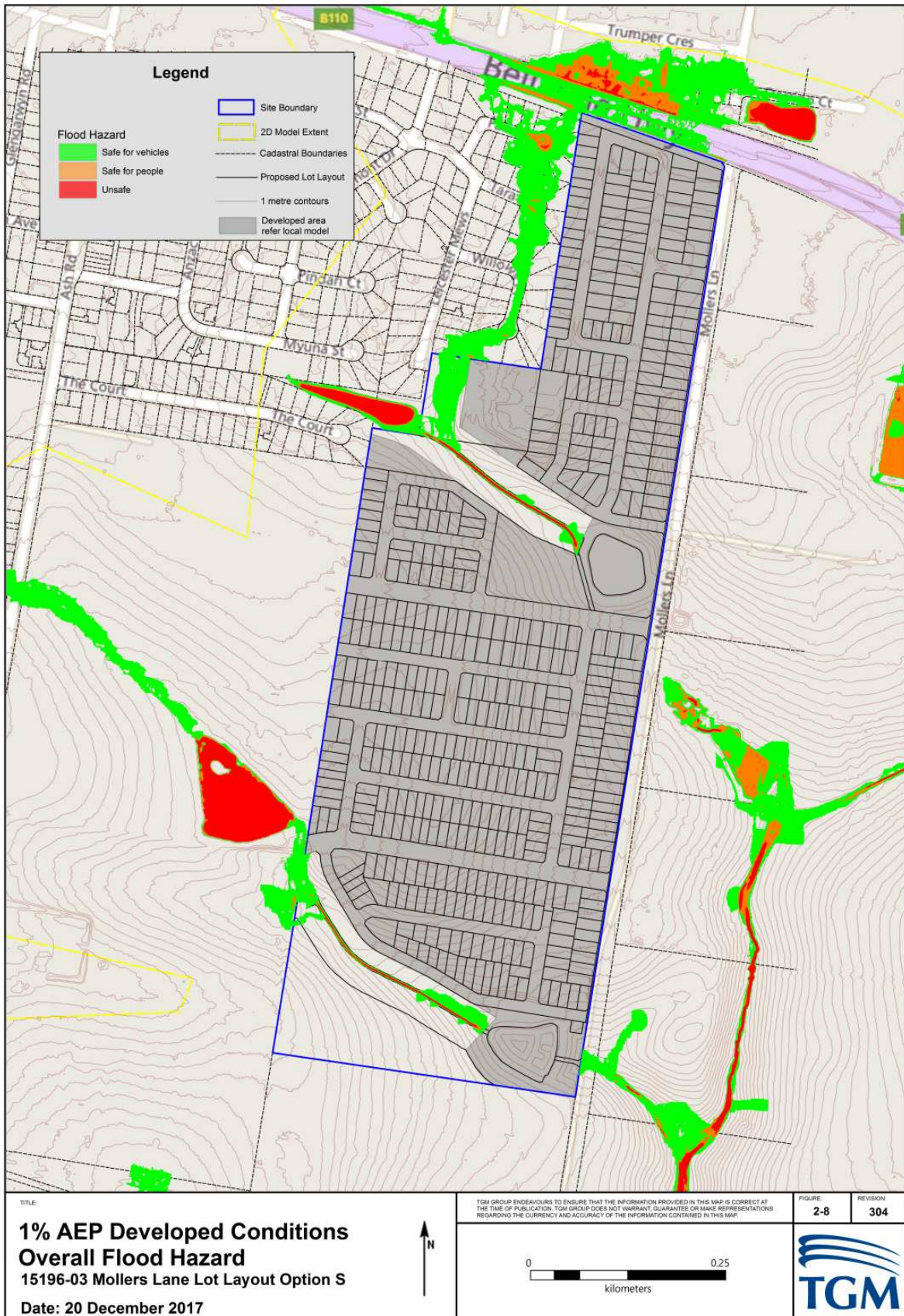


Figure 0-3: Developed 1% AEP Flood Extent

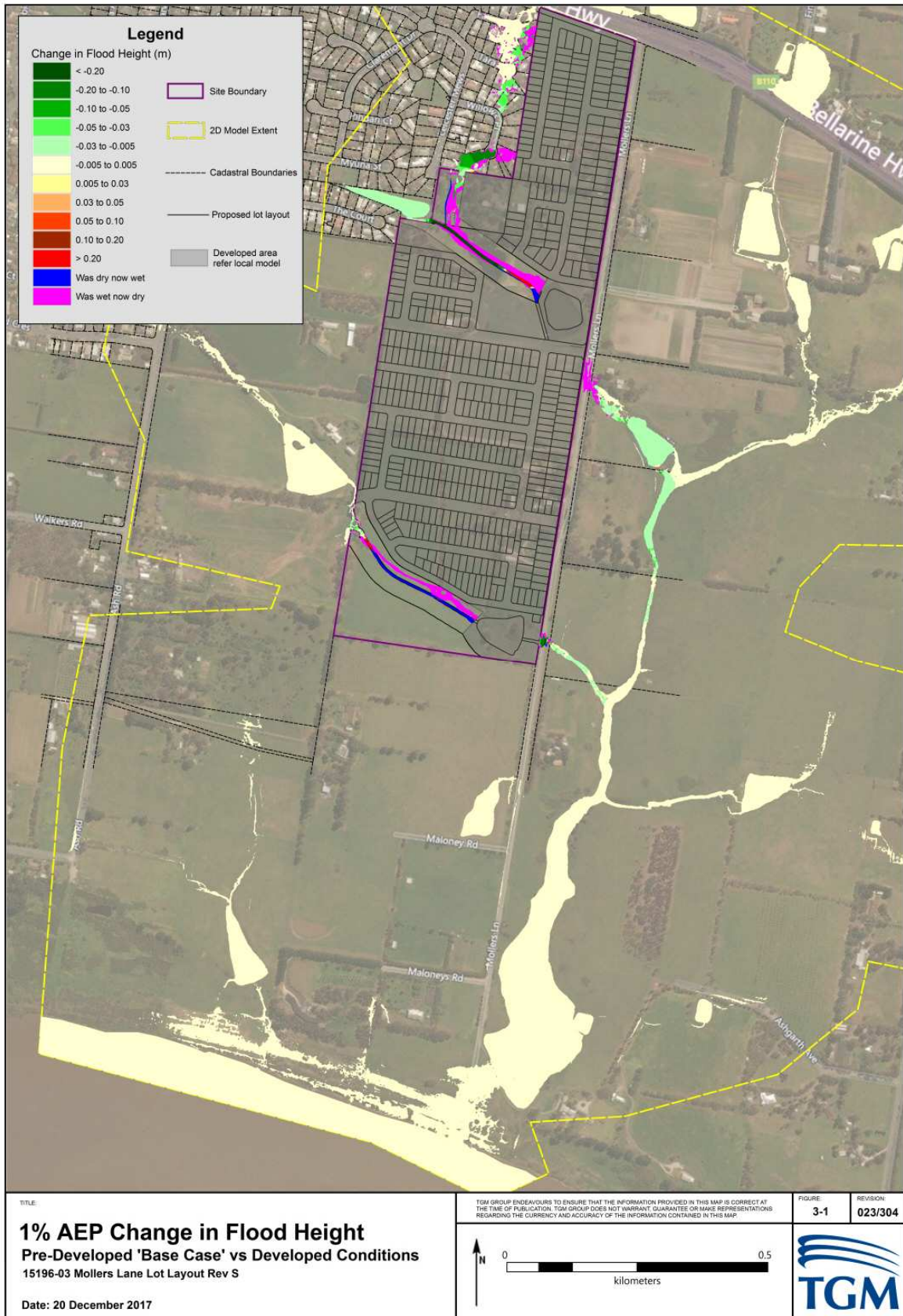


Figure 0-4: Change in Flooding – 1% AEP Impact Map (depths  $\geq$  50 mm)

## Contents

<b>Executive Summary</b> .....	<b>3</b>
Site Stormwater Management Plan .....	3
Flood Impact Assessment.....	4
<b>1. Background</b> .....	<b>14</b>
1.1 Inclusion Area (92-120 Mollers Lane, Leopold).....	14
<b>2. Study Area</b> .....	<b>16</b>
2.1 Existing Site Context.....	16
2.2 Regional Stormwater Catchments.....	16
2.3 Site Stormwater Catchments.....	18
2.3.1 Designated Waterways .....	19
2.4 Developed Site .....	19
4.3.1 Site Sub-Catchments .....	21
2.5 Lake Connewarre .....	23
<b>3. Study Objectives</b> .....	<b>25</b>
3.1 Existing Flooding Objectives .....	25
3.2 Site Stormwater Objectives .....	25
3.3 Regional Stormwater Objectives .....	25
<b>4. Modelled Scenarios</b> .....	<b>26</b>
4.1 Existing Conditions .....	26
4.2 Pre-developed Conditions - 'Base Case'.....	26
4.3 Developed Conditions.....	28
<b>5. Stormwater Mitigation Option</b> .....	<b>29</b>
<b>6. Study Methodology</b> .....	<b>35</b>
6.1 Topography – Light Detection And Ranging (LiDAR).....	35
6.2 Stormwater Catchments .....	39
6.2.1 Existing and Predeveloped Sub-Catchments .....	39
6.2.2 Developed Sub-Catchments .....	42
6.3 Geology.....	44
6.4 Hydrology.....	44
6.4.1 Model Description .....	44
6.4.2 Intensity Frequency Duration Data .....	45
6.4.3 Loss Parameters .....	46
6.4.4 Fraction Impervious .....	46
6.4.5 Calibration of Hydrology Model.....	46
6.4.6 Regional Flood Frequency Estimator (RFFE) Model.....	48
6.4.7 B <sub>x</sub> modification factor selection.....	51
6.4.8 Design Event Modelling .....	51
6.4.9 Critical Storm Duration .....	52
6.4.10 Calibration Summary .....	54
6.4.11 Predeveloped 'Base Case' Peak Discharge Targets.....	54
6.4.12 Developed Conditions – Detention Basin Design .....	55

6.5	Stormwater Quality .....	55
6.6	Hydraulic Modelling .....	56
6.6.1	2D Domain Analytical Grid .....	56
6.6.2	Manning's Coefficients .....	56
6.6.3	Boundary Conditions and Initial Water Levels .....	58
6.7	Hydraulic Sensitivity .....	60
6.7.1	Blockage .....	60
6.7.2	Tail Water Conditions .....	61
<b>7.</b>	<b>Results .....</b>	<b>63</b>
7.1	Stormwater Quality .....	63
7.1.1	Wetland Facility .....	63
7.2	Hydrologic Analysis – Detention Basin Facility .....	65
7.3	Hydraulic Analysis .....	68
7.3.1	Hydraulic Simulation .....	68
7.3.2	Existing Conditions .....	68
7.3.3	Predeveloped 'Base Case' Conditions .....	70
7.3.4	Developed Conditions .....	77
7.3.5	Change in Flood Mapping (Impact) .....	84
7.3.6	Hazard Mapping .....	91
<b>8.</b>	<b>Conclusion .....</b>	<b>95</b>
<b>9.</b>	<b>References .....</b>	<b>96</b>
	<b>Appendices .....</b>	<b>97</b>
	Hazard Mapping – Depth 1% AEP – Predeveloped and Developed .....	97
	Hazard Mapping – Velocity 1% AEP – Predeveloped and Developed .....	100
	Hazard Mapping – Velocity x Depth 1% AEP – Predeveloped and Developed .....	103

## List of Tables

Table 0-1: Wetland facilities – design parameters .....	3
Table 0-2: Wetland treatment efficiency at designated LPOD .....	3
Table 0-3: Predeveloped Discharge at designated LPOD – All Events .....	4
Table 0-4: Detention basin facilities – 1% AEP design characteristics .....	4
Table 2-1: Existing Mollers Lane study site stormwater catchment area .....	18
Table 2-2: Lower dam outlet characteristics .....	24
Table 6-1: Mollers Lane Sub-Catchment Characteristics .....	41
Table 6-2: Mollers Lane Developed Site Sub-Catchments .....	42
Table 6-3: Soil characteristics for Mollers Lane .....	44
Table 6-4: IFD (ARR87) data inputs for the St Leonards .....	45
Table 6-5: Hydrology Runoff parameters (COGG) .....	46
Table 6-6: Impervious fractions relative to land use .....	46
Table 6-7: RFFE derived peak discharge targets .....	51
Table 6-8: 1% AEP peak flows – Model calibration and existing conditions .....	54

Table 6-9: Predeveloped Discharge at designated LPOD – All Events .....	55
Table 6-10: Materials layer – Manning’s ‘n’ value .....	56
Table 6-11: Blockage Factors.....	61
Table 7-1: Wetland AB Parameters.....	63
Table 7-2: Wetland C Parameters.....	63
Table 7-3: Wetland AB treatment efficiency .....	64
Table 7-4: Wetland C treatment efficiency .....	64
Table 7-5: Mollers Lane site stormwater peak discharge objectives.....	65
Table 7-6: Mollers Lane developed stormwater peak discharge.....	66
Table 7-7: Detention basin characteristics – 1% AEP.....	68

## List of Figures

Figure 0-1: Predeveloped 1% AEP Flood Extent (depths ≥ 50 mm).....	5
Figure 0-2: Developed 1% AEP Flood Extent (depths ≥ 50 mm).....	6
Figure 0-3: Developed 1% AEP Flood Extent .....	8
Figure 0-4: Change in Flooding – 1% AEP Impact Map (depths ≥ 50 mm) .....	9
Figure 1-1: Leopold Structure Plan and Extents of Lot 92 – <i>Insert: Planning Maps Online</i> .....	15
Figure 2-1: Mollers Lane Study Area – site 1 metre contours.....	16
Figure 2-2: City of Greater Geelong Catchment Map – Catchment 14.....	17
Figure 2-3: Mollers Lane study site stormwater flowpaths .....	18
Figure 2-4: Mollers Lane - Overall Development Plan (14 December 2017).....	20
Figure 2-5: Mollers Lane subject site sub-catchments.....	22
Figure 2-6: Lake Connewarre locality plan – <i>Planning Maps Online (28 September 2016)</i> .....	23
Figure 2-7: Lower Dam at Lake Connewarre Interface .....	24
Figure 4-1: Proposed Dam Removal Plan.....	27
Figure 5-1: Concept Plan – Drainage Reserve Detention Basin and Wetlands.....	30
Figure 5-2: Concept Plan – ‘Green Corridor’.....	32
Figure 5-3: Linear Detention Typical wetland cross section.....	33
Figure 5-4: Indicative wetland and detention basin relationship cross section .....	33
Figure 5-5: Wetland Detention Facilities – Indicative Waterway Interface.....	34
Figure 6-1: Mollers Lane DEM – LiDAR 1 metre resolution .....	36
Figure 6-2: GIS Drainage Data ( <i>National Map: retrieved 6/10/2016</i> ).....	37
Figure 6-3: Field inspection photographs – culvert condition.....	38
Figure 6-4: Mollers Lane Analytical Sub-Catchments .....	40
Figure 6-5: Developed site sub-catchments.....	43
Figure 6-6: IFD Table (Mollers Lane) .....	45
Figure 6-7: RFFE (Mollers Lane).....	49
Figure 6-8: RFFE Parameters and Results .....	50
Figure 6-9: Australian Rainfall and Runoff Preferred Terminology .....	52
Figure 6-10: Catchment 14 storm duration hydrographs – 1% AEP (Calibration) .....	53
Figure 6-11: Catchment AB storm duration hydrographs – 1% AEP (Calibration) .....	53
Figure 6-12: Catchment C storm duration hydrographs – 1% AEP (Calibration).....	54
Figure 6-14: Boundary conditions and initial water levels .....	59
Figure 6-15: Lake Connewarre Tail Water Level – 2.30 m AHD.....	62
Figure 7-1: MUSIC network – Developed.....	64

Figure 7-2: Catchment AB Existing Site Discharge Hydrographs .....	65
Figure 7-3: Catchment C Existing Site Discharge Hydrographs .....	66
Figure 7-4: Catchment AB Developed Site Discharge Hydrographs .....	67
Figure 7-5: Catchment C Developed Site Discharge Hydrographs .....	67
Figure 7-6: Existing 1% AEP Flood Extent (depths $\geq$ 50 mm) .....	69
Figure 7-7: Predeveloped 1% AEP Flood Extent (depths $\geq$ 50 mm).....	71
Figure 7-8: Predeveloped 2% AEP Flood Extent (depths $\geq$ 50 mm).....	72
Figure 7-9: Predeveloped 5% AEP Flood Extent (depths $\geq$ 50 mm).....	73
Figure 7-10: Predeveloped 10% AEP Flood Extent (depths $\geq$ 50 mm).....	74
Figure 7-11: Predeveloped 0.2 EY Flood Extent (depths $\geq$ 50 mm) .....	75
Figure 7-12: Predeveloped 0.5 EY Flood Extent (depths $\geq$ 50 mm) .....	76
Figure 7-13: Mollers Lane Road Reserve – Typical Cross-Section Flow Path Detail.....	77
Figure 7-14: Developed 1% AEP Flood Extent (depths $\geq$ 50 mm).....	78
Figure 7-15: Developed 2% AEP Flood Extent (depths $\geq$ 50 mm).....	79
Figure 7-16: Developed 5% AEP Flood Extent (depths $\geq$ 50 mm).....	80
Figure 7-17: Developed 10% AEP Flood Extent (depths $\geq$ 50 mm).....	81
Figure 7-18: Developed 0.2 EY Flood Extent (depths $\geq$ 50 mm) .....	82
Figure 7-19: Developed 0.5 EY Flood Extent (depths $\geq$ 50 mm) .....	83
Figure 7-20: Change in Flooding 1% AEP Impact Map (depths $\geq$ 50 mm) .....	85
Figure 7-21: Change in Flooding 2% AEP Impact Map (depths $\geq$ 50 mm) .....	86
Figure 7-22: Change in Flooding 5% AEP Impact Map (depths $\geq$ 50 mm) .....	87
Figure 7-23: Change in Flooding 10% AEP Impact Map (depths $\geq$ 50 mm) .....	88
Figure 7-24: Change in Flooding 0.2 EY Impact Map (depths $\geq$ 50 mm).....	89
Figure 7-25: Change in Flooding 0.5 EY Impact Map (depths $\geq$ 50 mm).....	90
Figure 7-26: Predeveloped 1% AEP Hazard Envelope.....	92
Figure 7-27: Developed 1% AEP Hazard Envelope.....	93
Figure 0-1: Predeveloped 1% AEP Depth Hazard .....	98
Figure 0-2: Developed 1% AEP Depth Hazard .....	99
Figure 0-3: Predeveloped 1% AEP Velocity Hazard .....	101
Figure 0-4: Developed 1% AEP Velocity Hazard .....	102
Figure 0-5: Predeveloped 1% AEP Velocity x Depth Hazard.....	104
Figure 0-6: Developed 1% AEP Velocity x Depth Hazard.....	105

## 1. BACKGROUND

TGM Group has been engaged by Mollers Lane Developments Pty Ltd and Pamas Property Pty Ltd to prepare a combined Planning Scheme Amendment and Subdivision Application pursuant to Section 96A of the Planning and Environment Act 1987 for the rezoning and staged multi-lot subdivision of rural land situated to the west of Mollers Lane in Leopold.

The subject land is comprised of properties 2-20, 22-30, 32-40 and 32A, 42-90, and 92-120. The combined land parcels are currently zoned as Farming Zone (FZ) under the Greater Geelong Planning Scheme.

10 Willows Place, Leopold is also included in this study. It is already zoned General Residential Zone Schedule 1 (GRZ1) but is included in the study area of this report to provide stormwater management of the site.

Strategic planning support is established to provide the necessary strategic planning merit to validate a Planning Scheme Amendment application to rezone this land for residential subdivision and development in the short term.

The majority of the combined land is currently included in the Leopold Structure Plan adopted by the City of Greater Geelong in 2013. Map No. 11 – of the Leopold Structure Plan, identifies the subject land as an area to 'rezone residential 1'.

In June 2016 the City of Greater Geelong in consultation with landowners and referral agencies developed the South East Leopold Framework Plan to guide the future development of land generally located between Mollers Lane and Ash Road, Leopold. The Framework Plan included the subject land and the addition of the entire southern parcel at 92-120 Mollers Lane as the addition of this land provides improved drainage and servicing outcomes for the entire proposed development.

This report addresses the inclusion of the outer southern area of Lot 92 – 100 Mollers Lane in the broader drainage strategy that effects this proposed development.

### 1.1 Inclusion Area (92-120 Mollers Lane, Leopold)

This report is based on an assessment of catchment impacts from the development of proposed residential land identified in the Leopold Structure Plan and the addition of the balance area of land at 92-120 Mollers lane.

This additional area is supported for inclusion in the South East Leopold Framework Plan and is 9.5 hectares in area and forms a continuous landform with land to the north and west. It also contains part of Designated Waterway 33-1-4-1-2 which flows through the South Leopold Urban Growth Area, immediately west of the site.

The inclusion of this land creates a new low point which is likely to reduce sewerage servicing costs and provide a more logical drainage strategy for the estate.

The inclusion of this land will also provide an ideal opportunity to rehabilitate the entire creek network west of Mollers Lane and provide a complimentary contiguous landscaped open space corridor throughout the Growth Area.

The study area and proposed inclusion area of property 92 – 100 Mollers Lane are identified in Figure 1-1.

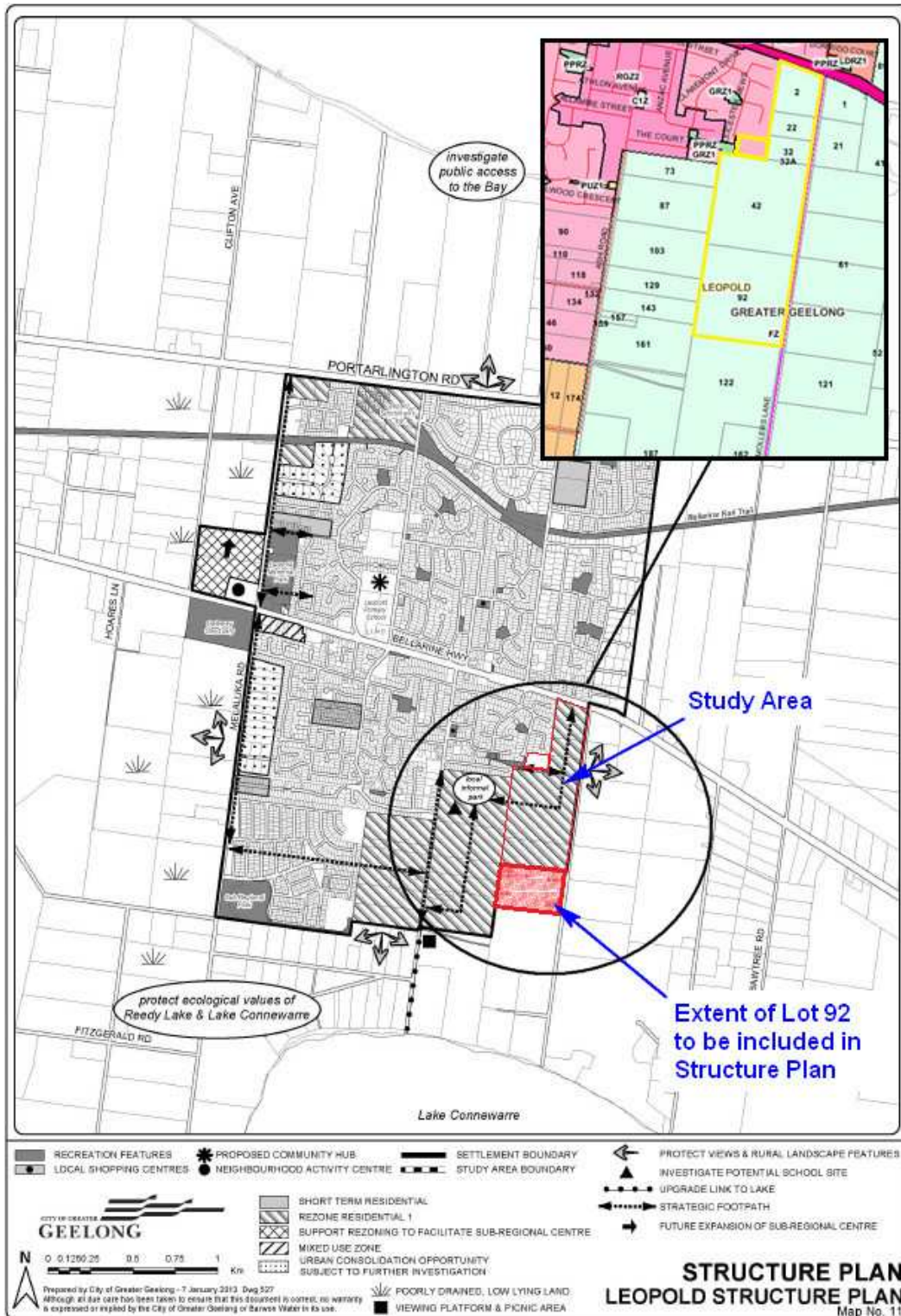


Figure 1-1: Leopold Structure Plan and Extents of Lot 92 – Insert: Planning Maps Online

The following combined Site Stormwater Management Plan (SSMP) and Flood Impact Assessment (FIA) has been prepared to inform and support the application to amend the Greater Geelong Planning Scheme and enable a rezoning of the subject land from the Farming Zone (FZ) to the General Residential Zone Schedule 1 (GRZ1) and staged multi lot subdivision.

## 2. STUDY AREA

### 2.1 Existing Site Context

The subject site currently comprises a significant rural holding of approximately 41 hectares (including the entire property at 92 Mollers Lane, Leopold) and is generally located to the south/east of the established urban development of Leopold.

The subject site has a frontage onto Bellarine Highway and Mollers Lane and provides a logical extension to the established residential zone located to the north and west.

The subject site has an elevation ranging from 49 m AHD in the north sector to 16 m AHD in the southern sector. There are two distinct gully's that collect and convey stormwater flows through the site in a south easterly direction.

The existing site contours can be seen in Figure 2-1.

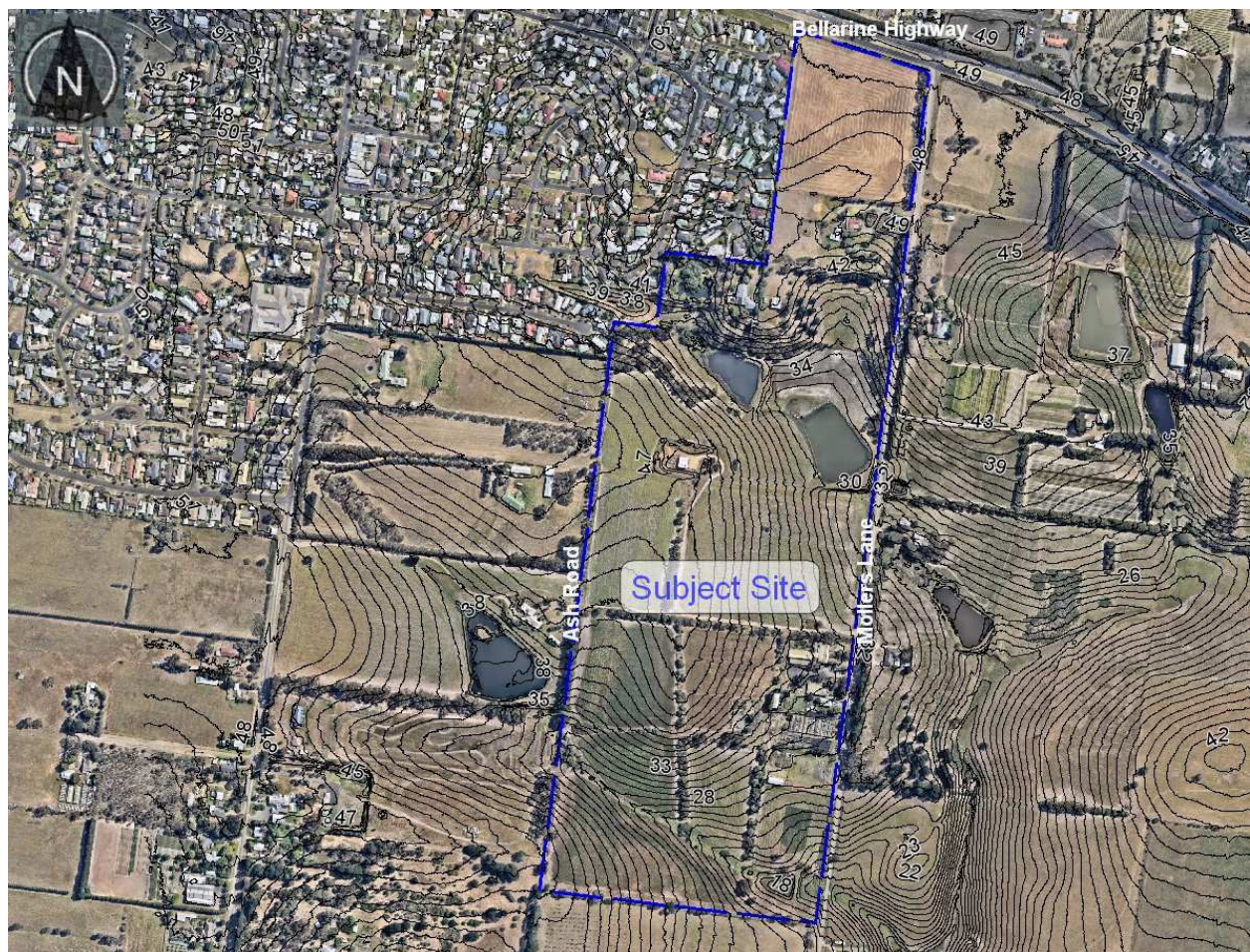
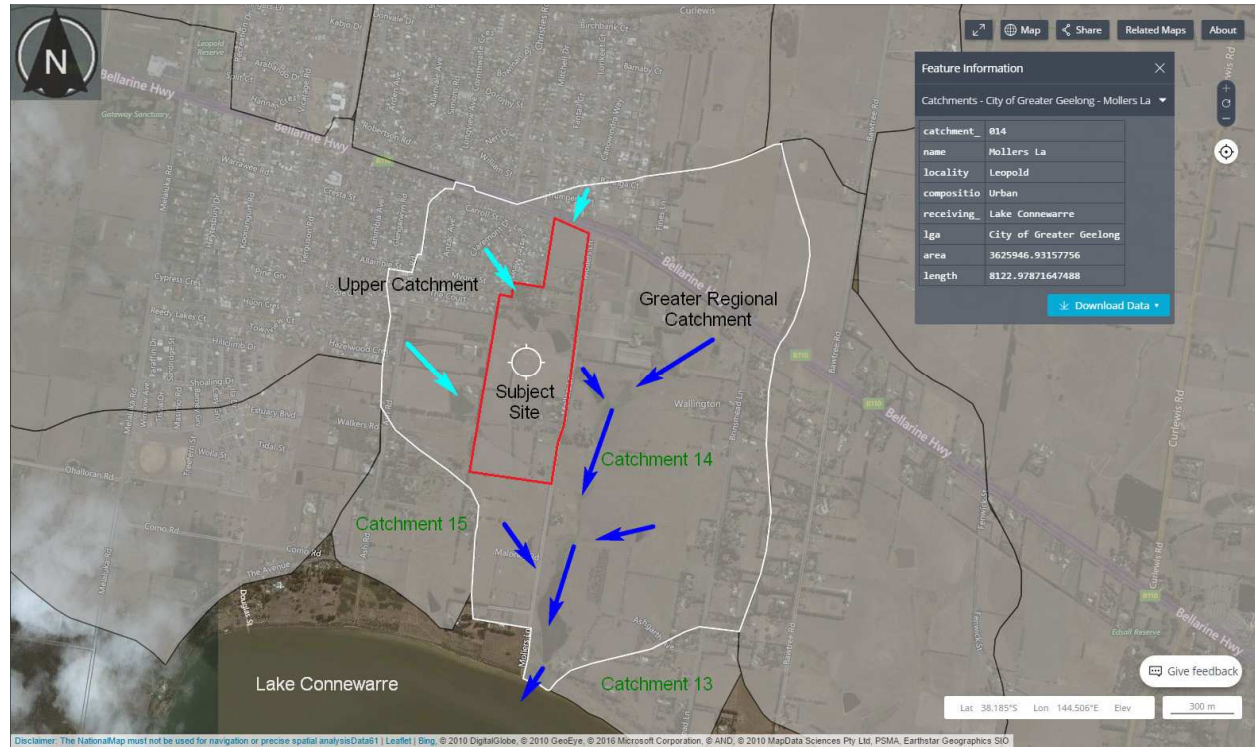


Figure 2-1: Mollers Lane Study Area – site 1 metre contours

### 2.2 Regional Stormwater Catchments

To provide an accurate definition of the site's hydrology and understand the volume of stormwater runoff impacting the site, the contributing regional catchment area was identified.

The study site is located within Catchment 14 as identified in the City of Greater Geelong catchment maps and shown in Figure 2-2.



**Figure 2-2:** City of Greater Geelong Catchment Map – Catchment 14 (source: <https://nationalmap.gov.au>)

A principle objective of this study is to assess the impact of the proposed development of the subject site on regional flood characteristics, Catchment 14 formed the extent of the study area.

The total regional stormwater catchment area (including subject site) is approximately **363 hectares**.

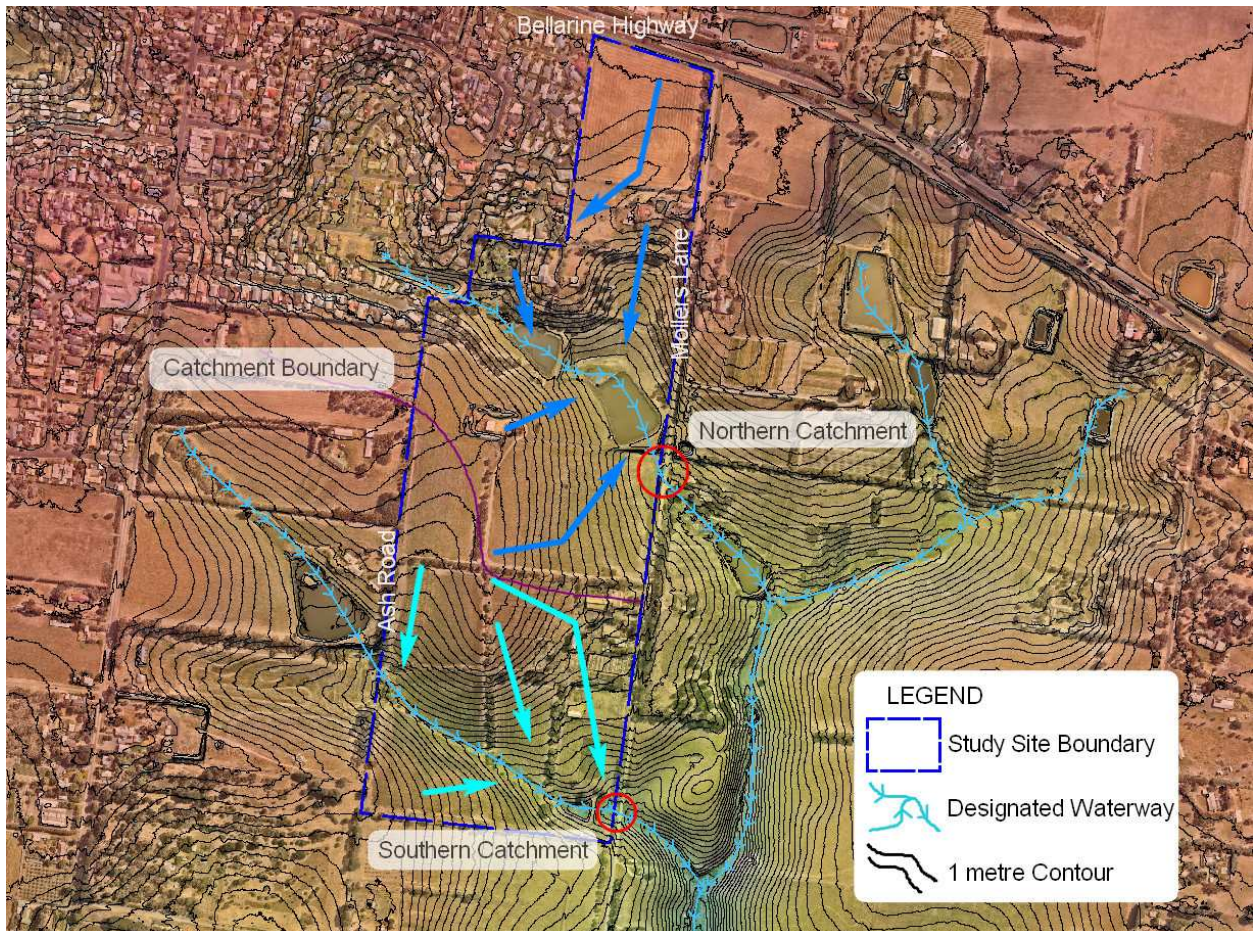
Approximately 66.2 hectares of the Catchment 14 generates stormwater flows that will pass through the subject site via one of the two (2) designated waterways. This forms the external 'upper catchment' area which includes the proposed development area along the eastern side of Ash Road.

The 'Upper Catchment' consists partially of General Residential (GRZ) and farmland (FZ), whereas the 'Greater Regional Catchment' is comprised largely of farmland (FZ) with smaller areas of rural residential (RLZ).

The downstream boundary condition for 'Catchment 14' is Lake Connewarre.

## 2.3 Site Stormwater Catchments

The study site has two distinct catchments, defined by local waterways which create a northern and southern catchment. The waterways traverse the site in a south-easterly direction and discharge via the eastern boundary at Mollers Lane as represented in Figure 2-3.



**Figure 2-3:** Mollers Lane study site stormwater flowpaths

The site catchment areas are shown in Table 2-1.

**Table 2-1:** Existing Mollers Lane study site stormwater catchment area

Catchment	Area (ha)
Northern Catchment	22
Southern Catchment	19

### 2.3.1 Designated Waterways

The subject site has two designated waterways<sup>1</sup> traversing the property as seen in Figure 2-3, above. The waterways have been identified as:

1. Designated Waterway No. 33-1-4-1
2. Designated Waterway No. 33-1-4-1-2

Stormwater runoff generated within the subject site is predominantly in the form of sheet flow that concentrates within the waterway alignments. Stormwater runoff generated in catchments upstream of the subject site is collected and conveyed (along with site runoff) through the site within the waterways, ultimately discharging to Lake Connewarre.

The Corangamite Catchment Management Authority (CCMA) has identified<sup>2</sup> the importance of the waterways and have stipulated the requirement for waterway buffers and management strategies.

The waterways will form the legal point of discharge (LPOD) for stormwater runoff from the developed site. Mitigation of stormwater flows from the developed site will be undertaken prior to discharge to the waterways.

## 2.4 Developed Site

The indicative development plan proposes creation of 494 conventional residential housing lots within the developable site. The overall development plan is shown in Figure 2-4.

The proposed subdivision will increase impervious surfaces within the developed site by approximately 70%.

The increase in impervious surfaces results in a decrease in stormwater infiltration and initial losses, creating an increase in the stormwater runoff volumes, velocities and pollutant loads generated within the site.

Stormwater mitigation measures will be designed to counteract the impact of development upon the downstream catchments and environmentally sensitive Lake Connewarre.

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<sup>1</sup> Water Act 1989 – Section 189. Designated waterways and designated land or waorks

<sup>2</sup> CCMA Flood Advice F-2015-0889. Leopold South Growth Area, Ash Road to Mollers Lane, Leopold. 14 December 2015



Figure 2-4: Mollers Lane - Overall Development Plan (14 December 2017)

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### 4.3.1 Site Sub-Catchments

The two (2) catchments will be broken down into smaller sub-catchments, reflecting the proposed developable area, legal points of discharge, waterway corridors and area remaining undeveloped. This will allow finer definition of the local hydrology and quantification of the permissible site discharge (PSD) which will be used as the design flow targets.

The site has three (3) developable sub-catchments. Two (2) sub-catchments - sub-catchment 'A/B' (17.73 ha) and sub-catchment 'C' (12.76 ha); are connected to the internal treatment train via the drainage network. The third sub-catchment (0.91 ha) is disconnected from the internal treatment train due to grade restrictions. The site sub-catchments used in this study are depicted in Figure 2-5.

Flows from the disconnected catchment will be conveyed through a separate drainage system and discharge unmitigated at a single LPOD with the proposed 1% AEP waterway pipe at Mollers Lane.

The proposed developable area within the site is approximately **32.4 hectares**.

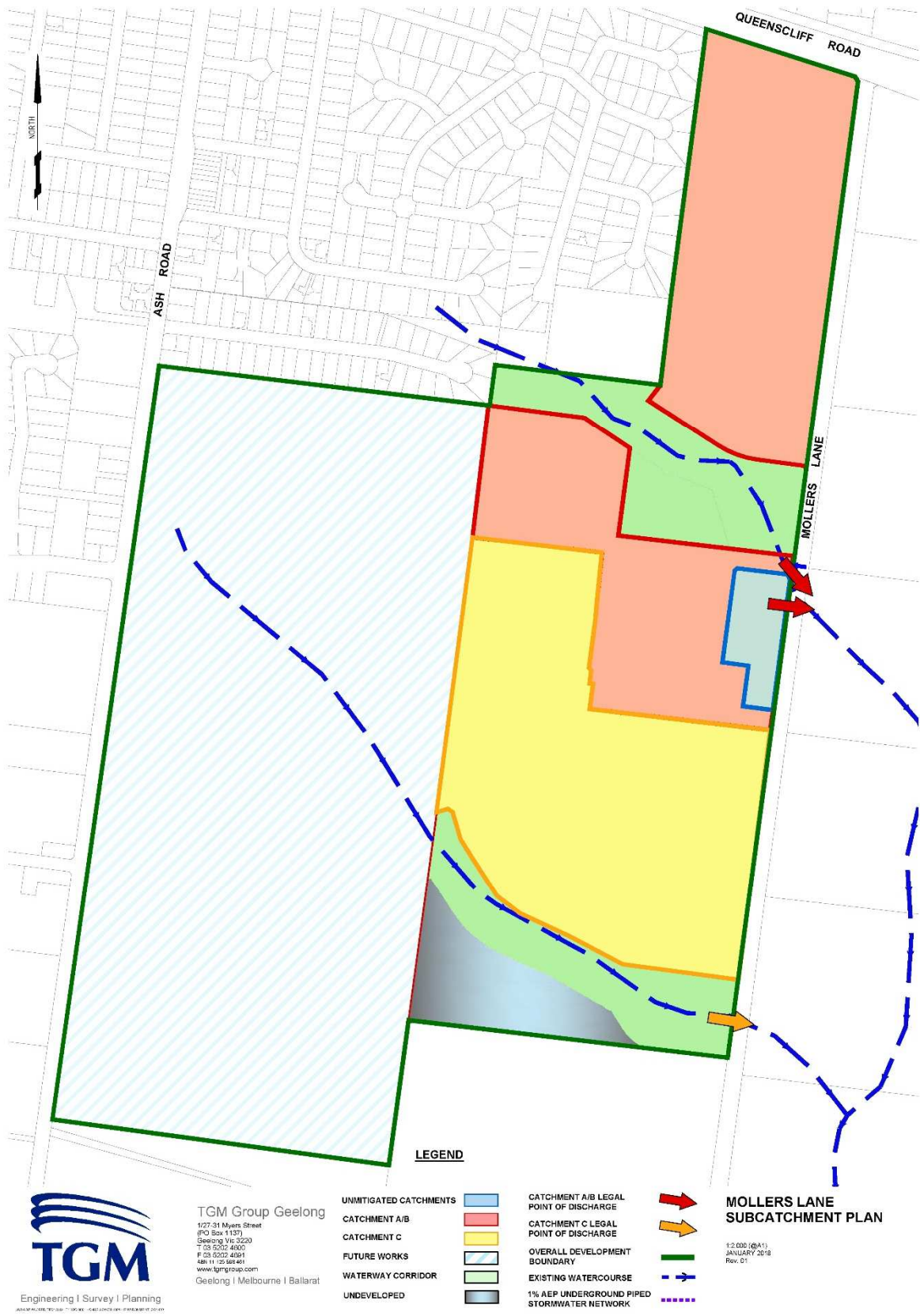


Figure 2-5: Mollers Lane subject site sub-catchments

## 2.5 Lake Connewarre

Lake Connewarre is a shallow estuarine lake located on the Barwon River. Covering approximately 880 hectares, Lake Connewarre is a classified RAMSAR<sup>3</sup> wetland and wildlife reserve.

A separate report and application has been prepared under the Environmental Protection and Biodiversity Act 1999 for discharge into Lake Connewarre – RAMSAR wetland.

Identified as Crown Parcel 2023, Lake Connewarre is situated around 1.0 km south of the Mollers Lane development area and ultimately receives stormwater runoff from the Mollers Lane and Leopold catchment area.

The Lakes proximity to the overall development site can be seen in Figure 2-6.

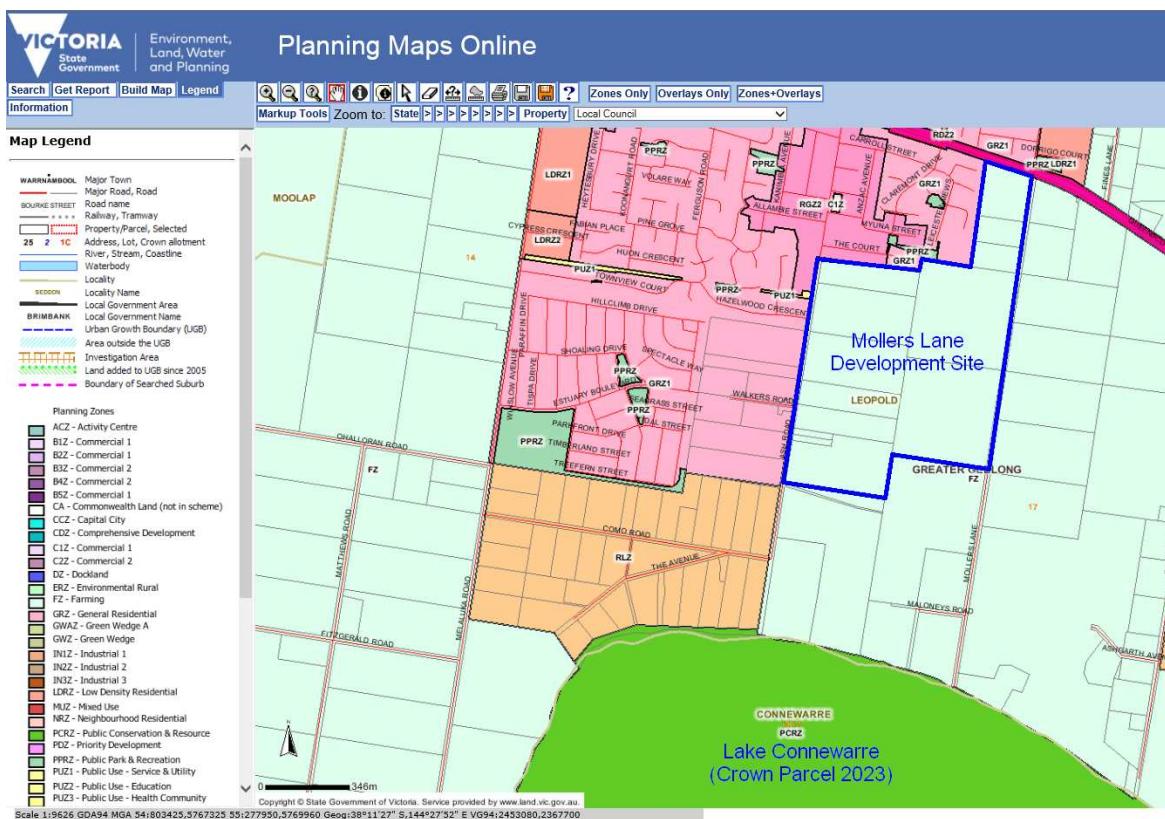


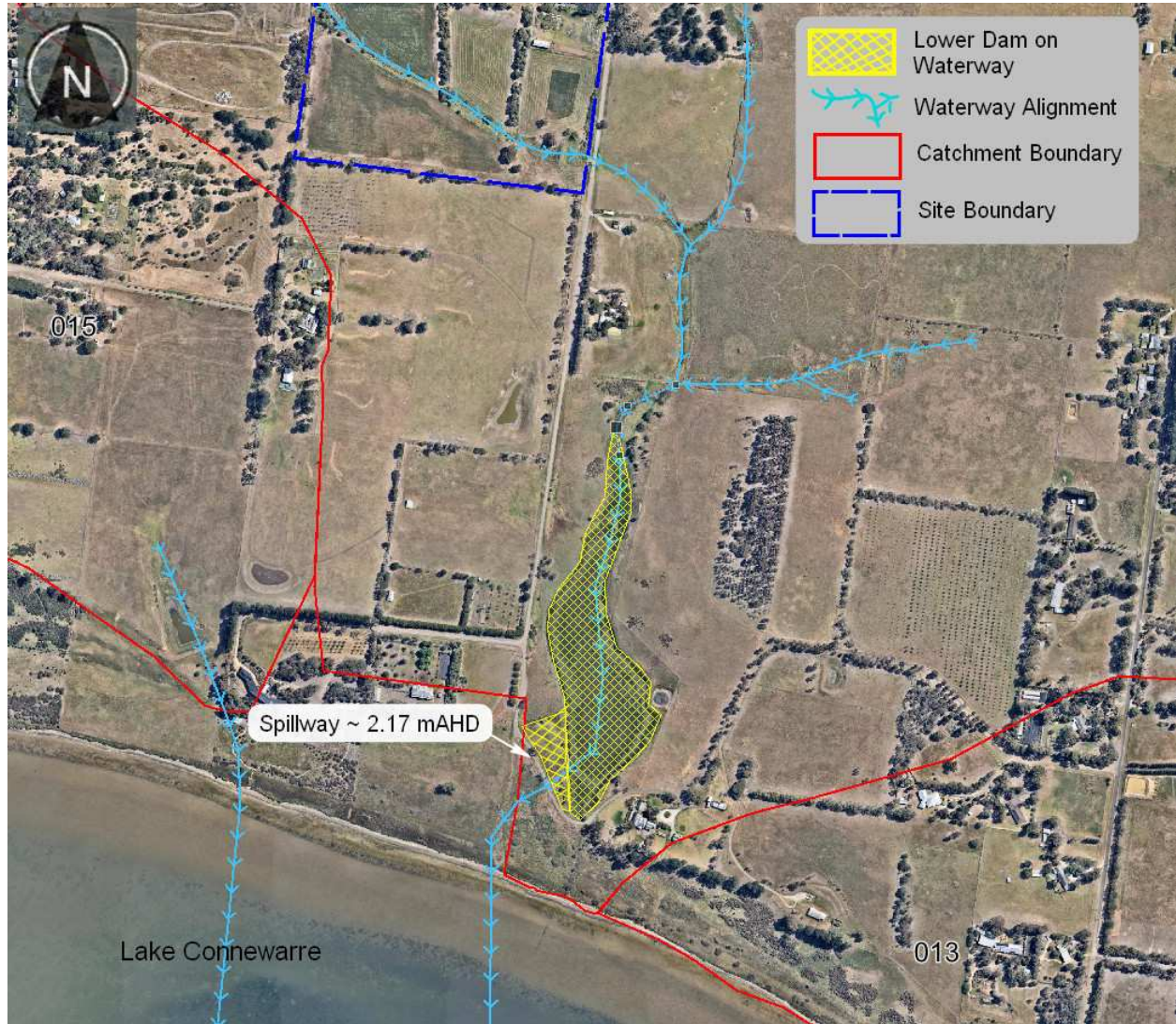
Figure 2-6: Lake Connewarre locality plan – Planning Maps Online (28 September 2016)

The environmental significance of Lake Connewarre has been flagged by the CCMA<sup>4</sup> and impacts created by changes in stormwater runoff must be integrated into design considerations.

<sup>3</sup> <https://www.environment.gov.au/water/wetlands/ramsar>

<sup>4</sup> CCMA Flood Advice F-2015-0889. Leopold South Growth Area, Ash Road to Mollers Lane, Leopold. 14 December 2015.

The waterways within Catchment 14 do not discharge directly to Lake Connewarre. The waterways converge into a single waterway within which a large (approximately 3.5 hectares) man made dam has been constructed, as shown in Figure 2-7.



**Figure 2-7: Lower Dam at Lake Connewarre Interface**

The dam has both high flow and low flow outlet controls. Low flows are discharge via a twin cell RCP culvert arrangement, whilst high flows discharge over a causeway which acts as a weir outlet. The dam creates a controlled interface between Catchment 14 and the RAMSAR wetland.

The crest of the causeway is approximately 2.15 - 2.17 m AHD, which overtops in events  $\geq 0.2$  EY

Characteristics of the dam outlet are shown in Table 2-2.

**Table 2-2: Lower dam outlet characteristics**

Outlet	Dimensions	Comment
Low Flow	Twin cell 525 mm RCP + 450 mm RCP. Invert Level ~ 1.4 to 1.5 m AHD. Discharge capacity ~ 0.7 m <sup>3</sup> /s	<ul style="list-style-type: none"> <li>Active during events <math>\geq 0.5</math> EY</li> <li>0.5 EY Inflow to dam ~ 0.4 m<sup>3</sup>/s</li> </ul>
High Flow	Crest ~ 2.15 -2.17 m AHD	<ul style="list-style-type: none"> <li>Activates during events <math>\geq 0.2</math> EY</li> </ul>

### 3. STUDY OBJECTIVES

Establishing the existing 1% AEP flood conditions will allow an understanding of the availability of developable land and identification of regional stormwater constraints associated with the development site. The defined predeveloped flood characteristics will form the 'base-case' for the analysis.

The objective of this Site Stormwater Management Plan is to demonstrate that the site can be developed using best practice stormwater management principles and techniques. This will enable the subdivision to meet the conditions and requirements set in the planning permit for stormwater management. The objectives will inform stormwater designs and ensure that stormwater quality and quantity targets are achieved and maintained.

Specific objectives are detailed below.

#### 3.1 Existing Flooding Objectives

The overriding objectives of the flood investigation are to –

- Prepare existing flood mapping for designated range of storm events
- Create Predeveloped 'Base Case' by removing (4 No.) existing dams within identified study area
- Establish the predeveloped 'base case' flood characteristics for the site
- Define waterway corridors and inform Overall Development Plan (ODP)
- Identify the associated flood risk

#### 3.2 Site Stormwater Objectives

The site stormwater objectives are:

1. Best Practice reductions for Water Quality
  - 80% reduction in Suspended solids (SS)
  - 45% reduction in total nitrogen (TN)
  - 45% reduction in total phosphorus (TP)
  - 70% reduction in gross pollutants (GP)
2. No-worsening stormwater peak discharges
  - Ensure pre-development flows are maintained

#### 3.3 Regional Stormwater Objectives

Development of the Mollers Lane site must not have an adverse impact on the surrounding area during the regional flood events up to and including an event with a 1% Annual Exceedance Probability (AEP).

The impact of the development will be assessed in regards to the following:

- Flood extents – No worsening of flood extents;
- Flood storage – No loss of waterway flood storage;
- Velocities and flow characteristics – Velocity-Depth product must not exceed safety limits for people and vehicle access;
- Duration – restrict change in flood durations in external properties; and
- Cumulative flooding impact – No worsening of overall flood impacts.

---

## 4. MODELLED SCENARIOS

For this study the following scenarios will be analysed.

### 4.1 Existing Conditions

To develop an understanding of the limitations and restraints associated with stormwater runoff characteristics within the study site catchment area a hydrologic and hydraulic assessment will be undertaken to define existing conditions.

Under existing conditions farm dams have been constructed along the alignment of the two waterways. These 'online' dams have altered the flow regime of the natural waterways and present potential hazards through structural failure.

It is proposed that existing dams within the development site shall be decommissioned and removed to allow restoration of the natural profile and flow regime of the waterways and remove risks associated with dams as defined in the ANCOLD guidelines on Risk Assessment.

### 4.2 Pre-developed Conditions - 'Base Case'

The pre-developed scenario will represent the existing conditions with dams removed. This will form the 'base case' for comparative analysis and enable the level of mitigation required for the developed site to be determined.

Dams identified for removal are shown in Figure 4-1. It is noted that removal of the dam (Ash Road Dam) situated between Ash Road and the West boundary of the site is not required for this study, but rather for Stage 2 works which entails proposed development of properties 7 to 13, as depicted in the ODP (Figure 2-4).

It is anticipated that the Ash Road Dam will remaining during development of the subject site, therefore, a dam break analysis was undertaken to ANCOLD Consequence Category criteria and has been detailed in the TGM report - *Mollers Lane, Leopold – Rezoning and Subdivision. Dam Break Assessment (June 2017)*.

*It is noted that this study does not allow for stormwater mitigation of runoff from the land east of Ash Road and west of the defined subject site. Development of the Ash Road site will require an individual SSMP and FIA to be undertaken at time of rezoning.*



Figure 4-1: Proposed Dam Removal Plan

---

Flow regimes, peak stormwater discharges, volumes and durations generated within the study area during events up to and including the 1% AEP will be defined in the Pre-developed scenario.

These characteristics will form the basis of comparison and design for the developed scenario.

### **4.3 Developed Conditions**

The developed conditions will reflect development of the Mollers Lane study site and proposed treatment train to manage stormwater discharges.

---

## 5. STORMWATER MITIGATION OPTION

Stormwater mitigation will be required to achieve the stormwater quality and quantity objectives detailed in Section 3. Mitigation facilities will be designed to ensure no-worsening of runoff characteristics from the proposed development.

The proposed mitigation option will consist of wetlands to manage stormwater quality and detention basin systems to manage stormwater discharge volumes generated within the development site.

Stormwater runoff from the developed site will be captured in wetland detention facilities for all events up to and including the 1% AEP and treated prior to discharge to the waterway and receiving environment.

Stormwater conveyance will be achieved via a combination of the underground drainage networks (minor flows) and overland flow paths along kerb and channel (major flows) where grades allow and via underground drainage with a 1% AEP capacity, where required.

The drainage system will convey flows to designated drainage reserves identified as Basin AB and Basin C as depicted in a concept layout in Figure 5-1, below.



**TGM**  
 Engineering | Survey | Planning  
 1/27-31 Myers Street  
 (PO Box 1137)  
 Geelong Vic 3220  
 T 03 5202 4800  
 F 03 5202 4891  
 488 11 25 668 461  
 www.tgmgroup.com  
 Geelong | Melbourne | Ballarat

Figure 5-1: Concept Plan – Drainage Reserve Detention Basin and Wetlands

---

Stormwater runoff from the majority of the upstream catchment area is conveyed within the two (2) waterway alignments. Although, a section of the Leopold urban area and Bellarine Highway reserve immediately north, enters the site across the northern boundary under existing conditions.

Stormwater runoff entering the site at the Bellarine Highway boundary will be collected in a cut off drain along the northern boundary and picked up in the developed road network where it will be conveyed, via the design drainage system, to the basin facility.

Clause 14.02-1 of the Victorian Planning Provisions defines a strategy to promote the retention of natural drainage corridors with vegetated buffer zones along each side of a waterway.

The 'Green Corridor' is an ecological corridor, consisting of encumbered and unencumbered public open space, which provides a buffer between the urban development and natural waterway.

Preferred corridor widths are defined according to waterway classification, in this case a 30 metre wide<sup>5</sup> corridor has been recommended.

Green Corridors will follow the existing waterway alignments, as depicted in Figure 5-2.

---

<sup>5</sup> CCMA Flood Advice F-2015-0889. Waterway Buffers. Pg 2, Leopold South Growth Area, Ash Road to Mollers Lane, Leopold. 14 December 2015



**Figure 5-2: Concept Plan – 'Green Corridor'**

The constructed wetlands will be designed to treat the low flow frequent events and the detention basins design for the high flow rarer events. The proposed design will integrate the wetland facility within the detention basin footprint, adjacent to the existing waterways.

A constructed wetland consists of two separate zones:

1. **Inlet Zone** – to remove coarse sediments, reducing scour and limiting nutrient build-up prior to entering the wetland proper; and a
2. **Macrophyte zone** – forming the biological wetland system, acting as a shallow vegetated area that allows the removal of fine particulates and the uptake of soluble pollutants. This system is designed primarily to remove stormwater pollutants associated with fine to colloidal particulates and dissolved contaminants.

A typical wetland cross-section is shown in Figure 5-3, below.

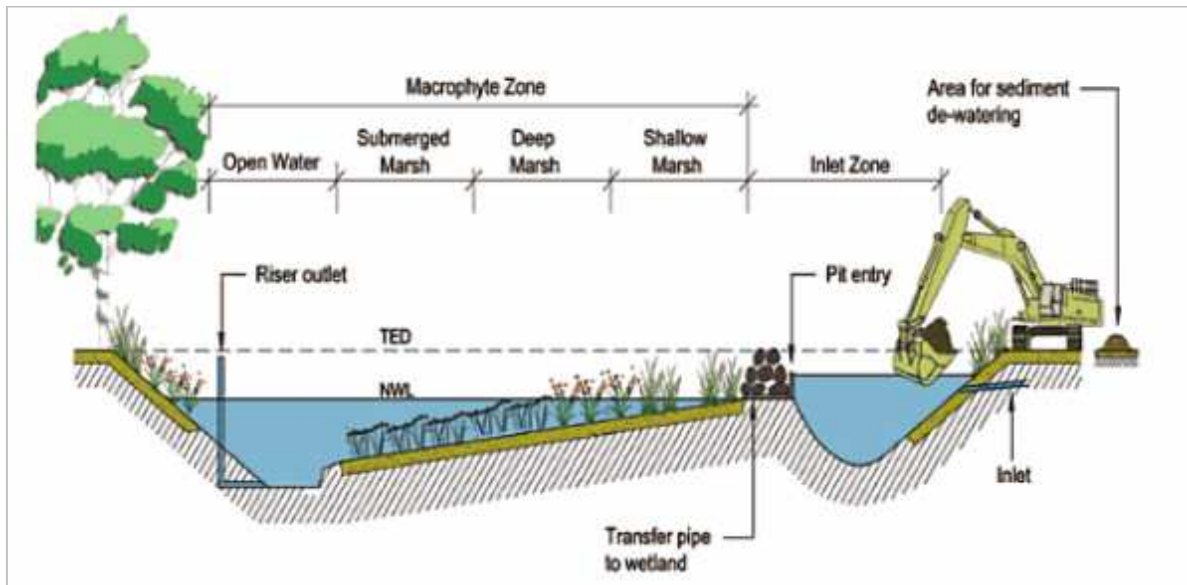


Figure 5-3: Linear Detention Typical wetland cross section<sup>6</sup>

Integration of the constructed wetland with the detention basin will assist in reducing the total footprint or land area, and maintenance requirements for both facilities. The detention basin is situated above the wetland with the required detention volume provided as additional storage above the total extended detention depth of the wetland; this can be seen in the typical cross-section profile in Figure 5-4.

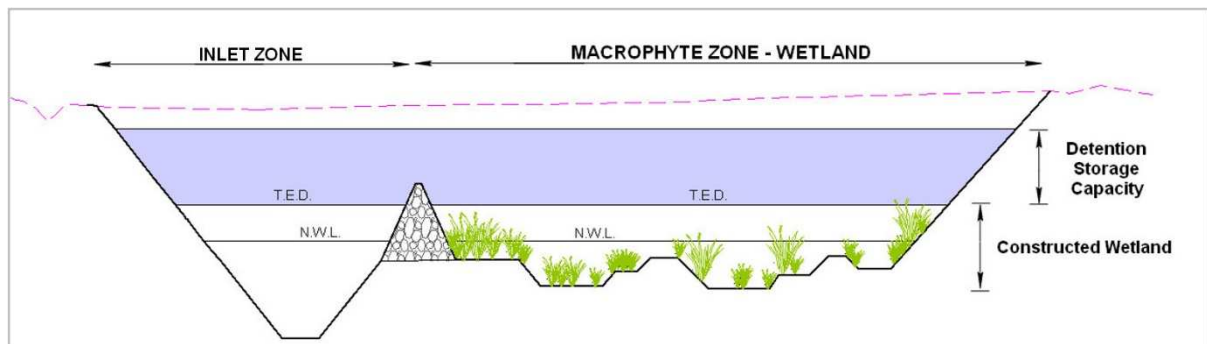


Figure 5-4: Indicative wetland and detention basin relationship cross section

The combined wetland detention basin facilities will be constructed within the designated waterways alignment traversing the site.

The wetland and detention basin treatment facilities will only receive runoff from the development site. Regional flows within the waterways will be conveyed around the treatment facilities in 1% AEP pipes to the downstream side of Mollers Lane.

<sup>6</sup> Melbourne Water (2005). WSUD Engineering Procedures: Stormwater, CSIRO Publishing, pp. 156.

The wetland detention facilities will create an interface between the urban area and the natural environment.

A typical interface can be seen in Figure 5-5, below.

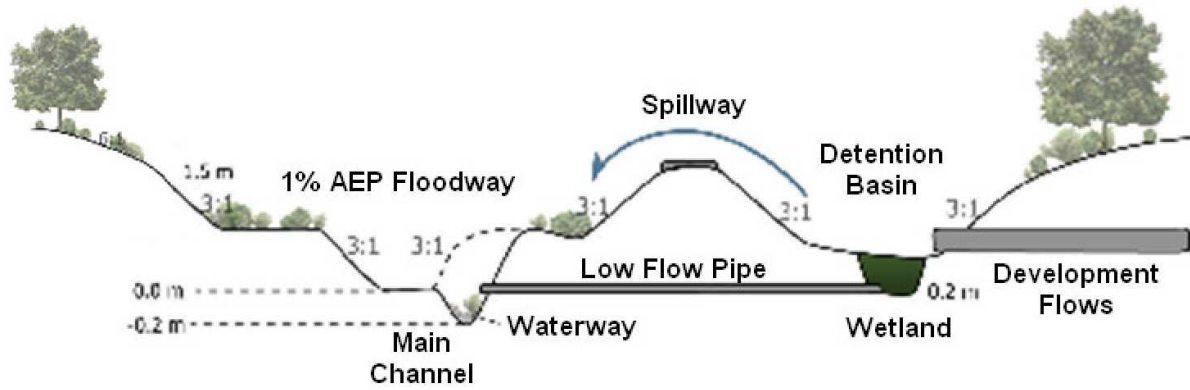


Figure 5-5: Wetland Detention Facilities – Indicative Waterway Interface

---

## 6. STUDY METHODOLOGY

Definition of the 1% AEP flood extent and development of a stormwater management plan (SSMP) for the Mollers Lane development site was undertaken using an integrated systems approach, enabling definition of regional hydrology and analysis of the performance of a range of stormwater and water cycle management options.

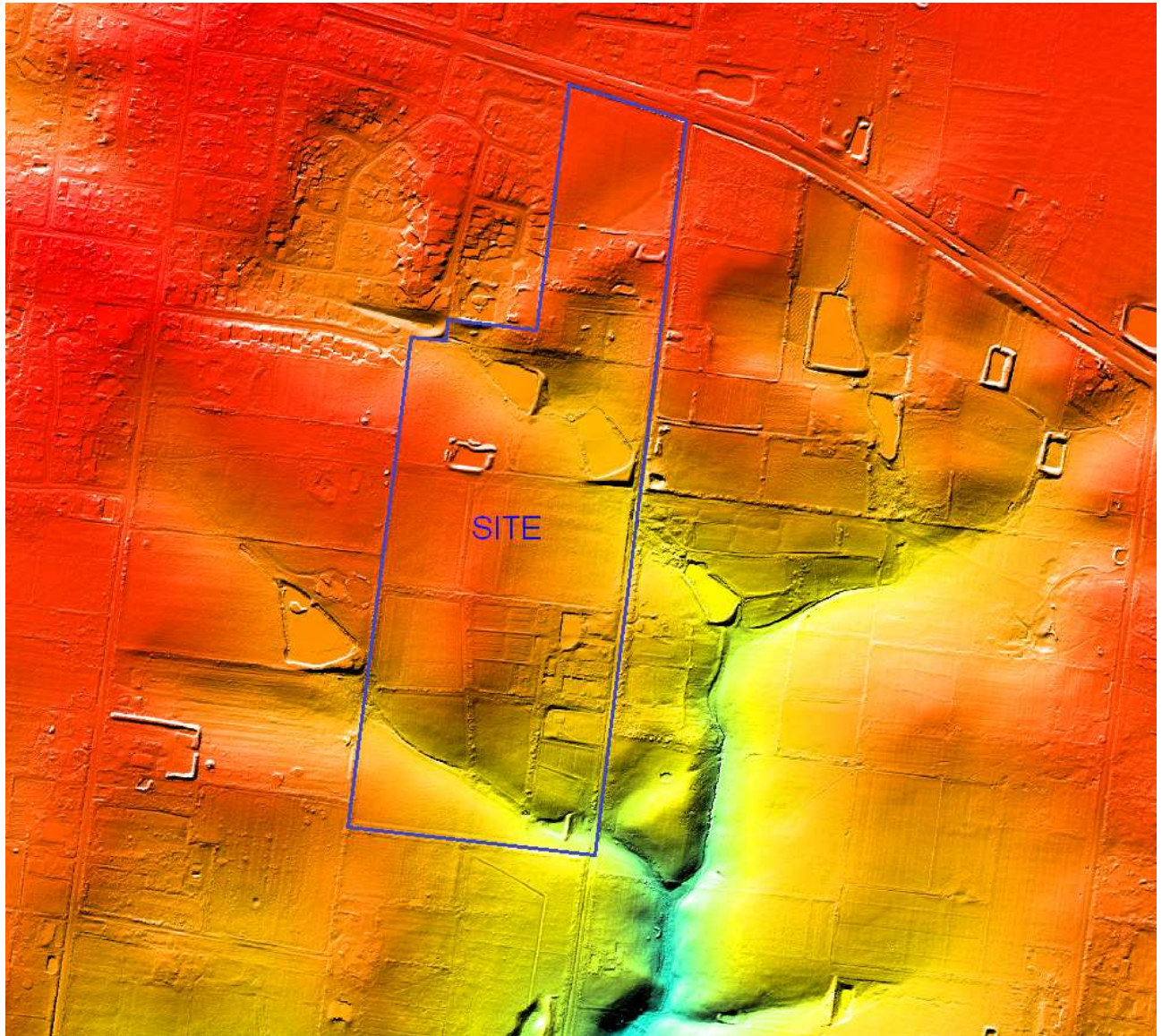
### 6.1 Topography – Light Detection And Ranging (LiDAR)

Site topography, Ramsar wetlands and contributing catchment area was identified and confirmed using a digital elevation model (DEM) generated from LiDAR with a 1.0 metre resolution.

The LiDAR data was commissioned by the Department of Environment, Land, Water and Planning (DELWP) and flown on 21 April 2007.

The LiDAR provided classification of the ground surface on a GDA94 datum, MGA55 projection to a vertical accuracy of +/- 10 cm. This enabled robust definition of the subject site and corresponding catchment area, and provided suitable definition for 2d analysis.

The level of detail can be seen the DEM in Figure 6-1, below.



**Figure 6-1:** Mollers Lane DEM – LiDAR 1 metre resolution

City of Greater Geelong GIS drainage tables were downloaded from the Australian Governments National Map website (see Figure 6-2) and used to identify underground drainage systems. Field inspections undertaken by TGM Group staff, confirmed relevant stormwater assets and identified assets not presented in the GIS data.



**Figure 6-2: GIS Drainage Data (National Map: retrieved 6/10/2016)**

The condition of relevant stormwater infrastructure assets (including assessment of blockage) and of overland flow paths were identified by TGM staff during onsite field inspections.

There is limited existing stormwater infrastructure within the study area and all are in relatively poor operational condition as seen in field inspection photographs in Figure 6-3.



**Figure 6-3:** Field inspection photographs – culvert condition

Pictured culverts (clockwise from top-left) –

- twin 850 mm RCP lower Mollers Lane – Southern waterway (identified in field inspections)
- 600 mm RCP middle Mollers Lane – Northern waterway (identified in field inspections)
- 525 mm inlet to 750 mm RCP North side of Bellarine Highway, west of Fines Lane
- 375 mm dia. RCP separated from headwall. Outlet from detention basin discharging to top of Northern waterway

The culverts have been modelled in hydraulic simulations as operating with various degrees of blockage that reflect observed conditions.

---

## 6.2 Stormwater Catchments

The identification and definition of hydrologic and hydraulic characteristics of the stormwater catchment (Catchment 14) interacting with the Mollers Lane site is crucial to understanding the volume, rate and quality of stormwater being generated and resulting flood extents.

The first step is to define the stormwater catchments and sub-catchments to be used in the analysis and ensure a suitable resolution is applied to provide an accurate detail of stormwater flows and flooding interacting with the study area.

### 6.2.1 Existing and Predeveloped Sub-Catchments

The undeveloped Mollers Lane site is subject to stormwater runoff from the rural and urban surrounding catchments. Due to the significance of the downstream RAMSAR wetlands, its contributing catchments have also been considered to allow for an accurate comparison. These include the smaller CoGG Catchments 13 and 15 (refer Figure 2-2 in Section 2).

Topographical data and urban drainage infrastructure enabled the identification of the current stormwater sub-catchments relative to the Mollers Lane subdivision site. The contributing stormwater sub-catchments for Mollers Lane development are shown in Figure 6-4, below.

Sub-catchment characteristics are shown in Table 6-1.



Figure 6-4: Mollers Lane Analytical Sub-Catchments

**Table 6-1:** Mollers Lane Sub-Catchment Characteristics

Catchment	Area (ha)	Land Use	Catchment	Area (ha)	Land Use
A1	0.9	Farming - Rural	14	7.0	Farming - Rural
A2	5.0	Farming - Rural	15	14.9	Farming - Rural
A3	4.2	Farming - Rural	16	2.8	Farming - Rural
B	8.7	Farming - Rural	17	14.1	Farming - Rural
C	13.4	Farming - Rural	18	2.3	Farming - Rural
D	3.3	Farming - Rural	19	3.3	Farming - Rural
E	9.0	Farming - Rural	20	2.4	Farming - Rural
F	13.4	Farming - Rural	21	4.0	Farming - Rural
G	9.2	Farming - Rural	22	4.1	Farming - Rural
NWW1	1.7	Waterway	23	19.5	Farming - Rural
NWW2	1.4	Waterway	24	12.7	Farming - Rural
UNDEV	2.9	Farming - Rural	25	1.8	Farming - Rural
SWW1	1.9	Waterway	26	0.7	Farming - Rural
SWW2	1.4	Waterway	27	16.7	Farming - Rural
SWW3	1.4	Waterway	28	6.9	Farming - Rural
SWW4	1.3	Waterway	29	17.1	Farming - Rural
1	20.1	Residential	30	9.9	Farming - Rural
2	5.2	Residential	31	12.5	Farming - Rural
3	3.9	Residential	32	21.6	Farming - Rural
4	4.9	Residential	33	3.4	Farming - Rural
5	0.8	Road	34	8.2	Farming - Rural
6	7.8	Residential	35	11.8	Farming - Rural
7	14.8	Farming - Rural	36	14.9	Farming - Rural
8	20.4	Farming - Rural	37	10.0	Farming - Rural
9	8.2	Farming - Rural	38	2.7	Farming - Rural
10	2.7	Farming - Rural	39	16.9	Farming - Rural
11	3.7	Farming - Rural	40	1.3	Farming - Rural
12	15.7	Farming - Rural	41	0.6	Farming - Rural
13	5.3	Farming - Rural	42	1.3	Farming - Rural

## 6.2.2 Developed Sub-Catchments

The developed sub-catchments have been delineated reflecting the proposed wetland detention basin catchment.

The developed sub-catchments are shown in Figure 6-5.

The sub-catchment areas, proportion of impervious surfaces and land use for the developed site shown in Table 6-2, were adopted for this study<sup>7</sup>.

**Table 6-2:** Mollers Lane Developed Site Sub-Catchments

Sub-catchment	Area (ha)	Impervious area (%)	Dominant land use
Basin A/B	17.73	70	Residential
Basin C	12.76	70	Residential
Unmitigated	0.91	70	Residential

<sup>7</sup> Melbourne Water. MUSIC Guidelines. Section 7 Fraction Impervious. (<http://www.melbournewater.com.au/planning-and-building/forms-guidelines-and-standard-drawings/documents/music-tool-guidelines.pdf>)



Figure 6-5: Developed site sub-catchments

## 6.3 Geology

An environmental assessment was undertaken by *Environmental Site Assessments Pty Ltd*<sup>8</sup> which included geological assessment and soil sampling throughout the study area. It was found that site geology is Moorabool Viaduct Sand (Nbm) – Neogene – Sedimentary (Marine) – Gravel, sand and silt.

Specific soil characteristics need to be detailed to guide calibration of rainfall runoff within the MUSIC water quality modelling process. Ideally, the relevant Council specifies soil parameters that are considered to reflect typical characteristics for the region. City of Greater Geelong MUSIC Modelling Guidelines<sup>9</sup> have been adopted for the subject site.

The soil parameters utilised are shown in Table 6-3, below.

**Table 6-3:** Soil characteristics for Mollers Lane

Parameter	Urban Residential
Rainfall Threshold (mm)	1
Soil Capacity (mm)	30
Initial Storage (%)	30
Field Capacity	20
Infiltration Capacity coefficient <i>a</i>	200
Infiltration Capacity coefficient <i>b</i>	1
Initial Depth (mm)	10
Daily Recharge Rate (%)	25
Daily Base flow Rate (%)	5
Daily Deep Seepage Rate (%)	0

## 6.4 Hydrology

It is an objective for this study that the development should not detrimentally affect stormwater runoff volume and discharge characteristics. The assessment of the stormwater runoff characteristics of the site in the existing and developed states was undertaken using the hydrological model XP-STORM developed by XP-Solutions.

### 6.4.1 Model Description

The XP-STORM program is a non-linear runoff routing model capable of using numerous routing methods. In this study the Laurenson routing procedure was used to produce stormwater runoff hydrographs from

<sup>8</sup> Environmental Assessments Group Pty LTD (2016). Environmental Assessment – 2 -120 Mollers Lane, Leopold

<sup>9</sup> City of Greater Geelong (2012). MUSIC Modelling Guidelines, No. 3

design storm events derived from Intensity-Frequency Duration data (based on the AR&R 1987 methodology).

## 6.4.2 Intensity Frequency Duration Data

The hydrology model applied design storm parameters from Australian Rainfall and Runoff<sup>10</sup>, to define the hydrology of the stormwater catchments in the study area. Design storms were generated for average exceedance probabilities (AEP's) using a regional skewness of 0.41 and temporal pattern region 1. The intensity frequency duration (IFD) climatic data used in the hydrology model was extracted from the Bureau of Meteorology (BOM) ARR87 generator at the centroid of the study area with a latitude and longitude of 38.2°S and 144.475°E, respectively. The IFD data shown in Table 6-4, below.

**Table 6-4:** IFD (ARR87) data inputs for the St Leonards

ARI (years)	Rainfall intensity (mm/hr) for a given duration (hours)		
	1	12	72
2	17.97	3.52	0.90
50	34.05	6.25	1.82

The generated IFD Table for this region is shown in Figure 6-6, below.

**Intensity-Frequency-Duration Table**

Location: 38.200S 144.475E NEAR.. Mollers Lane Issued: 6/9/2016

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

Duration	Average Recurrence Interval						
	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	45.0	59.9	81.6	96.5	117	146	170
6Mins	41.9	55.8	75.9	89.8	108	135	158
10Mins	34.1	45.3	61.0	71.7	86.2	107	124
20Mins	24.8	32.6	43.2	50.2	59.8	73.5	84.8
30Mins	20.0	26.3	34.4	39.8	47.2	57.7	66.3
1Hr	13.4	17.4	22.5	25.9	30.5	37.0	42.3
2Hrs	8.64	11.2	14.4	16.4	19.2	23.1	26.3
3Hrs	6.65	8.61	10.9	12.5	14.5	17.4	19.8
6Hrs	4.22	5.45	6.87	7.77	9.03	10.8	12.2
12Hrs	2.65	3.42	4.30	4.87	5.66	6.75	7.64
24Hrs	1.62	2.09	2.67	3.05	3.56	4.29	4.88
48Hrs	.940	1.23	1.61	1.86	2.20	2.69	3.10
72Hrs	.670	.880	1.16	1.35	1.61	1.98	2.29

(Raw data: 17.97, 3.52, 0.9, 34.05, 6.25, 1.82, skew=0.41, F2=4.28, F50=14.85) © Australian Government, Bureau of Meteorology

**Figure 6-6:** IFD Table (Mollers Lane)

<sup>10</sup> IEAust. (2001). Australian rainfall and runoff: a guide to flood estimation. Vols. 1 and 2. The Institution of Engineers, Australia.

### 6.4.3 Loss Parameters

This study has adopted the COGG initial and continual loss parameters used to define the catchment hydrology. These parameters are shown in Table 6-5, below.

**Table 6-5:** Hydrology Runoff parameters (COGG)

Surface Type	Initial Loss (IL)	Continuing Loss (CL)
Pervious	15 mm	2.5 mm/hr
Impervious	2.0 mm	0 mm/hr

XP-STORM allows each catchment to be split into five sub-areas that can be routed separately. For this analysis separate sub-areas were used to model the pervious and impervious area to enable application of the different loss parameters. The fraction impervious was calculated for each catchment.

### 6.4.4 Fraction Impervious

The fraction of impervious surfaces within a catchment is an integral input in hydrological modelling. The impervious area was ascertained from aerial and satellite images, field inspections, land use classifications<sup>11</sup> and proposed development plans.

The impervious fractions adopted are shown in Table 6-6.

**Table 6-6:** Impervious fractions relative to land use

Land Use	Impervious Fraction
Residential (Existing)	0.6
Residential (Developed)	0.7
Gravel Roads	0.7
Older Asphalt Roads	0.8
New/Resurfaced Roads	1
Ponds and Water Bodies	1
Public Open Space (Existing)	0.1

### 6.4.5 Calibration of Hydrology Model

An analysis of flooding in any region is subject to a range of variable influences that impact on hydrological assessment. Calibration of hydrological models to actual conditions is crucial to ensuring the accuracy of analysis.

<sup>11</sup> Melbourne Water. MUSIC Guidelines. Section 7 Fraction Impervious. (<http://www.melbournewater.com.au/planning-and-building/forms-guidelines-and-standard-drawings/documents/music-tool-guidelines.pdf>)

A key element of the calibration process is identification of the stormwater catchments that impact on the study area, the characteristics of those catchments and the configuration of waterways.

Factors such as availability of observed rainfall data, soil type, soil conditions, land use and local knowledge were considered in this investigation.

Due to the lack of historical rainfall runoff or stream flow data in catchments in and around the study area, calibration of the model to recorded data, using techniques such as flood frequency analysis (FFA), was not possible. Therefore, calibration of results from the hydrological model was undertaken using empirical methods.

Peak flows generated by the XP-STORM model selected catchments were compared to a peak discharge derived by application of the Regional Flood Frequency Estimator (RFFE)<sup>12,13</sup> model described in Australian Rainfall and Runoff (ARR) 2016 and available online at <http://arr.ga.gov.au/>.

Regional Flood Frequency Estimation (RFFE) is a data-driven approach, which attempts to transfer flood characteristics from a group of gauged catchments to ungauged locations of interest (where design floods need to be estimated).

The RFFE assumes runoff is generated within undeveloped rural catchments, therefore the urban areas within the study catchments were analysed as undeveloped for the calibration process.

The RFFE process is detailed in Section 6.4.6, below.

The Initial and Continual Loss factors, nominated in Table 6-5, were not capable of matching the predicted peak discharge generated by the RFFE calculations for each of the undeveloped contributing sub-catchments.

The global storage multiplication factor was adjusted, using B modification factor in XP-RAFTS, until peak stormwater discharges generated by the hydrology model were comparable to peak discharges derived using RFFE calculations. The storage multiplication factor is discussed below.

#### **Storage Coefficient Multiplication Factor**

*During calibration of a gauged catchment the Storage Coefficient Multiplication Factor ( $B_x$ ) may be used to modify the calculated storage time delay coefficient ( $B$ ). The Storage Coefficient Multiplication Factor uniformly modifies all sub catchment Storage Time Delay Coefficient values previously computed or determined from the default equation. This process has been applied to enable validation of the hydrology model.*

The  $B_x$  modification factor selection process is discussed in Section 6.4.6, below.

<sup>12</sup> Rahman, A, et al (2013). New Regional Flood Frequency Estimation (RFFE) Method for the whole of Australia: Overview of progress. Paper. Flood plain conference 2013.

<sup>13</sup> Rahman, A, Haddad, K, Kuczera, G and Weinmann, E, 2016, Peak Flow Estimation, Chapter 3 Book 3 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia

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It is noted that City of Greater Geelong's stormwater detention storage design notes<sup>14</sup> state that for estimation of rural or pre-development discharge the runoff-routing model (XP-STORM) must be validated against the VicRoads Method of the Probabilistic Rational Method (PRM) for rural discharge and may be adjusted  $\pm 30\%$  to reflect catchment conditions.

However, the more simplistic Rational Method calculations were not employed in this study for purpose of calibration because this type of method does not account for the volumes of rainfall in storm events or the range of variable initial conditions that impact on stormwater runoff in defined catchments.

The VicRoads PRM was only used as a 'ball-park' figure for the XP-STORM calibration process as assessments such as these transition from ARR87 processes to ARR2016 techniques. The calibration process was undertaken for every sub-catchment and at key routing locations within the hydrological model.

#### **6.4.6 Regional Flood Frequency Estimator (RFFE) Model**

The RFFE model used at Mollers Lane can be seen in Figure 6-7, below.

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<sup>14</sup> City of Greater Geelong (2012). Stormwater Detention Storage Design, No. 2

**Regional Flood Frequency Estimation Model (DRAFT)**  
Draft Version of the Regional Flood Frequency Estimation Model for the 4th edition of Australian Rainfall and Runoff.

**Input Data**

Basic  Advanced

**Catchment Name**

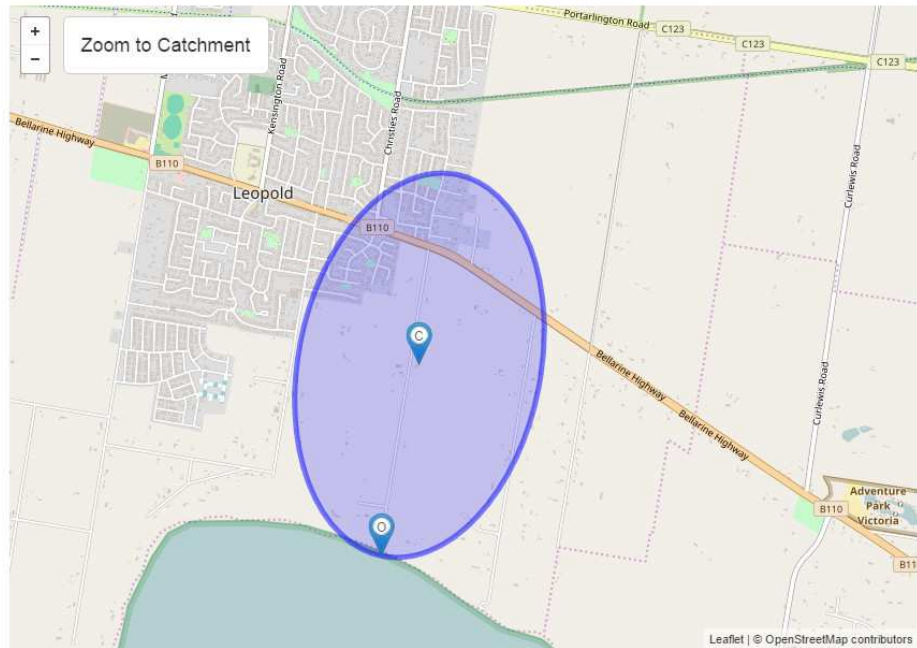
**Catchment Outlet Latitude**

**Catchment Outlet Longitude**

**Catchment Centroid Latitude**

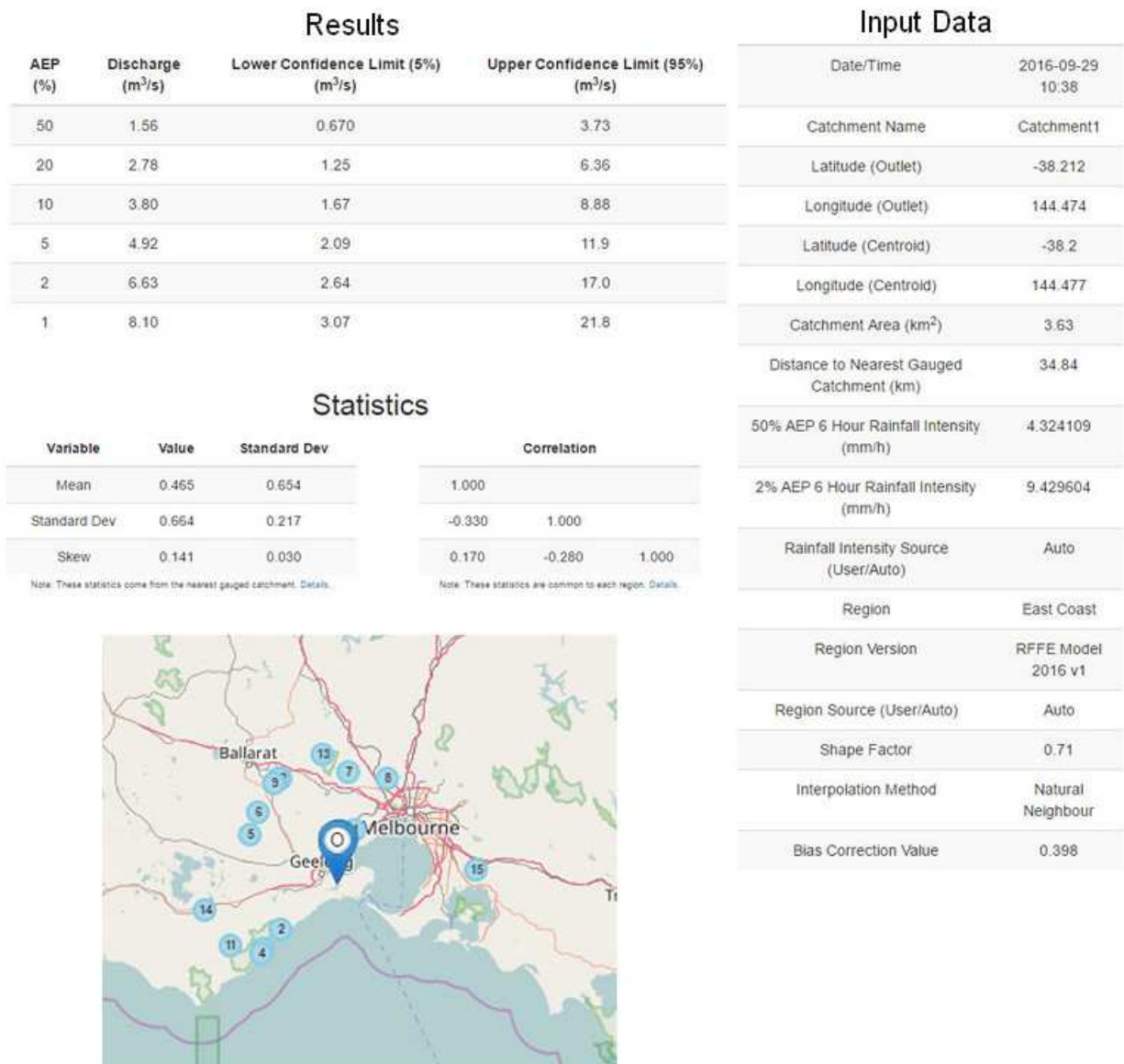
**Catchment Centroid Longitude**

**Catchment Area (km<sup>2</sup>)**



**Figure 6-7: RFFE (Mollers Lane)**

The data inputs, statistical parameters and resulting discharges are shown in Figure 6-8.



**Figure 6-8: RFFE Parameters and Results**

There were 15 gauged regional catchments which made up the sample group for the statistical analysis used in the Mollers Lane RFFE model.

The peak discharge used to calibrate the XP-STORM model are shown in Table 6-7 for the range of events.

**Table 6-7:** RFFE derived peak discharge targets

Event	Discharge (m <sup>3</sup> /s)
1% AEP	8.10
2% AEP	6.63
5% AEP	4.92
10% AEP	3.80
0.2 EY	2.78
0.5 EY	1.56

#### 6.4.7 $B_x$ modification factor selection

Selection of a suitable global storage modification factor ( $B_x$ ) was achieved through a ‘trial and error’ process to match the rural XP-STORM catchments to the calculated RFFE discharges.

The calibrated XP-STORM model was then adapted to current conditions by applying the effect of urbanisation in the form of impervious surfaces. Urbanisation of a catchment can have a dramatic effect on peak discharges and catchment hydrology.

The hydrological model was used to define the current climate existing conditions, proposed design conditions and quantify the level of mitigation required to produce a ‘no-worsening’ of stormwater peak discharges, for storm events up to and including the 1% AEP, to protect waterways from erosion and sedimentation and reduce risks to people and property for a range of events.

#### 6.4.8 Design Event Modelling

ARR design storm events were simulated in the XP-STORM hydrological model. Hydrological analysis was undertaken for the 1%, 2%, 5%, 10% AEP, 0.2 and 0.5 EY design storm events.

This study adopts the new terminology for the classification of storm events as shown in Figure 6-9. This terminology is recommended by ARR 2016<sup>15</sup> and is in-line with the National Committee on Water Engineering.

15 Ball, J, Babister, M, Retallick, M, Weinmann, E, 2016, Scope and Philosophy, Chapter 2 Book 1 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia

Frequency Descriptor	EY	AEP (%)	AEP	ARI
			(1 in x)	
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
Rare	0.11	10	10	9.49
	0.05	5	20	20
	0.02	2	50	50
Very Rare	0.01	1	100	100
	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
Extreme	0.0002	0.02	5000	5000
			↓	
			PMP/ PMPDF	

Figure 6-9: Australian Rainfall and Runoff Preferred Terminology

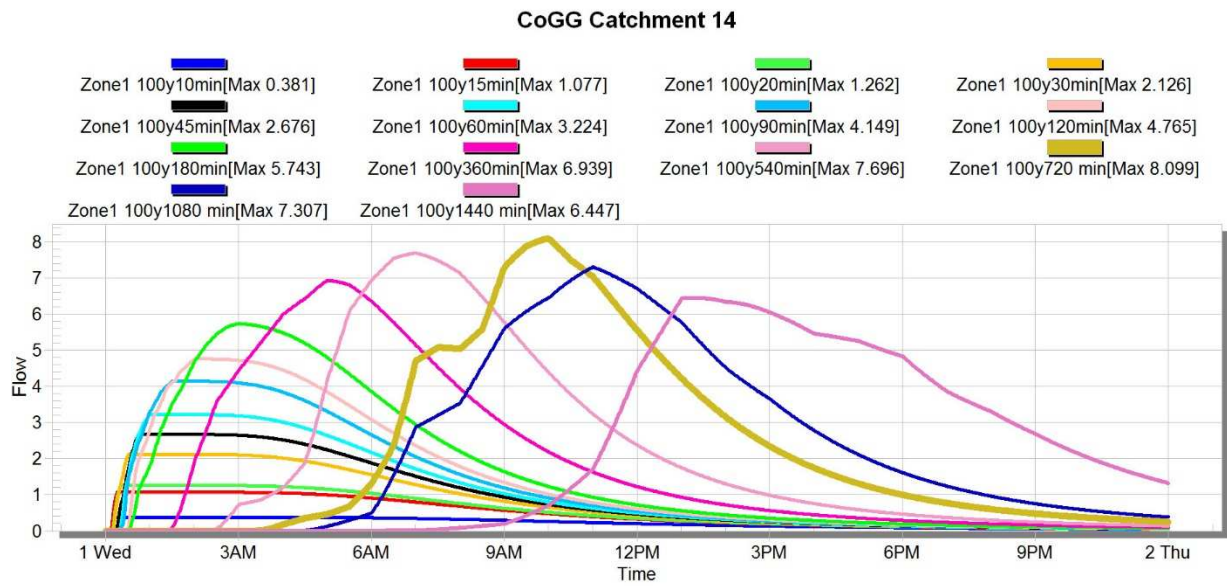
The resulting output hydrographs were used to define the internal and external boundary conditions to the TUFLOW hydraulic model.

### 6.4.9 Critical Storm Duration

The critical duration for each design event probability and each sub-catchment may vary depending on a number of conditions. Therefore, consideration of a number of storm durations is important to ascertain the critical storm duration impacting the site and study area.

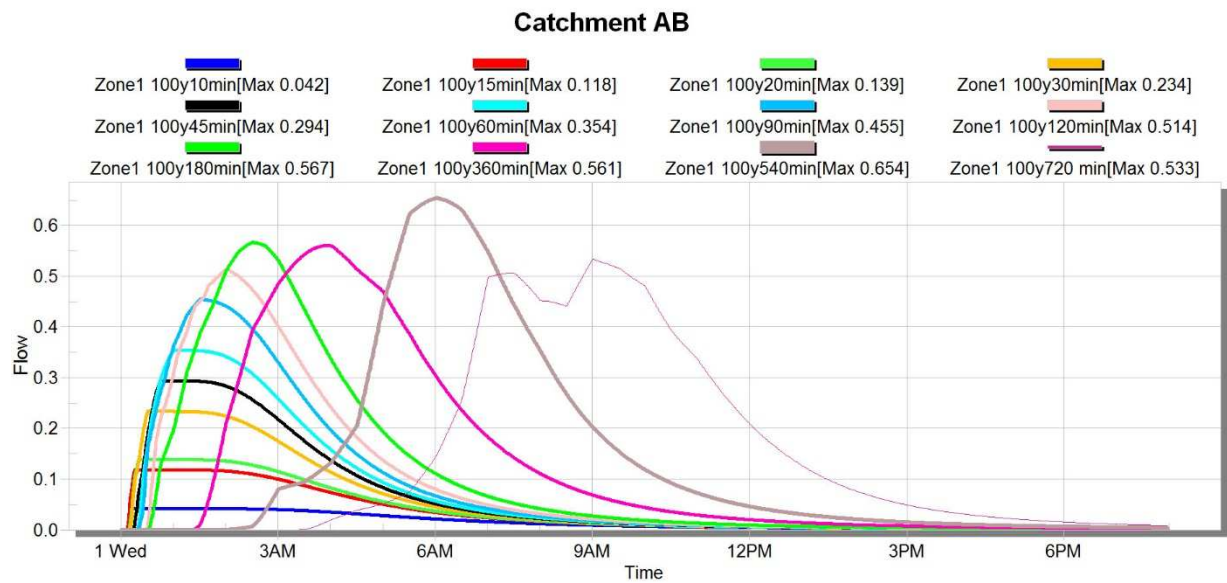
The upstream contributing catchment consist of the existing Leopold urban area and will typically be driven by the smaller event durations; whereas the rural undeveloped area within the site and lower catchments generate its peak discharge in the larger duration events.

The critical storm for the regional flood event within Catchment 14 was identified as being the **720 minute** (12 hour) duration for the 1% AEP event. This is seen in Figure 6-10.



**Figure 6-10:** Catchment 14 storm duration hydrographs – 1% AEP (Calibration)

However, the critical duration for the smaller sub-catchments applied in this study were **540 minutes** (9 hour) and can be seen in Figure 6-11 and Figure 6-12 for sub-catchment AB and C, respectively.



**Figure 6-11:** Catchment AB storm duration hydrographs – 1% AEP (Calibration)

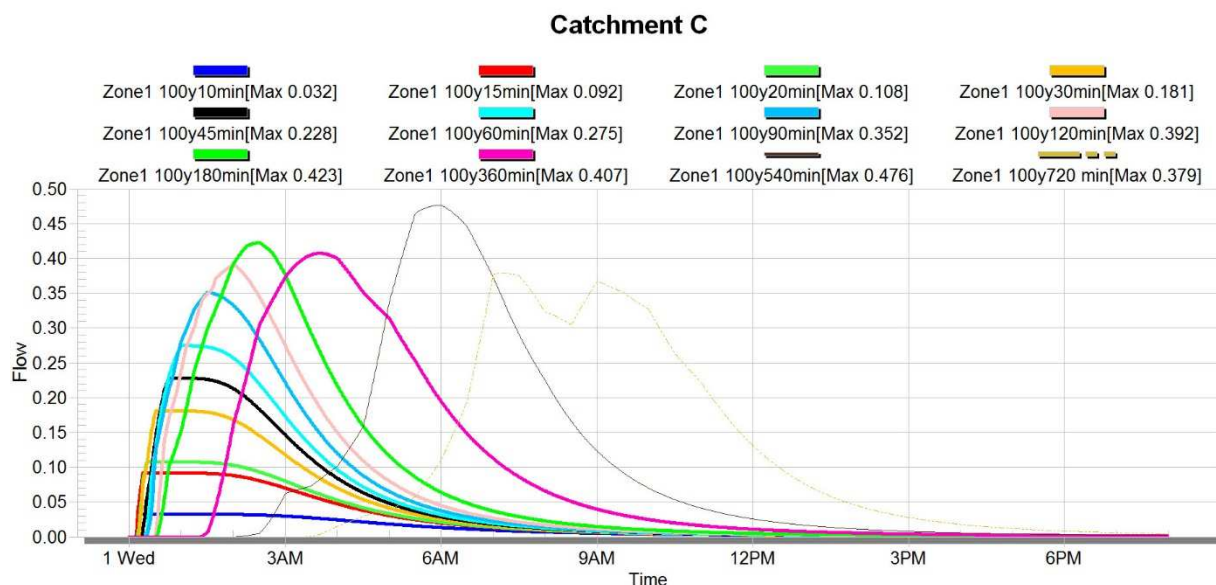


Figure 6-12: Catchment C storm duration hydrographs – 1% AEP (Calibration)

TGM adopted the **540 minute (9 hour)** event durations for this analysis.

### 6.4.10 Calibration Summary

The XP-STORM *Bx* factor was determined for the whole of Catchment 14 area. The *Bx* factor was then applied to the sub-catchment areas and checked against the VicRoads PRM.

The calibration summary table is shown below.

Table 6-8: 1% AEP peak flows – Model calibration and existing conditions

Catchment	Area (ha)	Validation Method Peak Discharge (m³/s)			XP-STORM Peak Discharge (m³/s) for Bx=2.66	
		RFFE	PRM	CoGG ± 30% range	Validation	Existing Conditions
CoGG Cat 14	363.0	8.10	-	-	8.10	-
AB	19.19	-	0.55	0.39 - 0.72	0.65	0.65
C	13.15	-	0.39	0.28 - 0.51	0.48	0.54

### 6.4.11 Predeveloped ‘Base Case’ Peak Discharge Targets

The design discharge targets defined by the predeveloped rates at each LPOD are shown in Table 6-9.

**Table 6-9:** Predeveloped Discharge at designated LPOD – All Events

Event		LPOD AB	LPOD C
AEP	1%	0.65	0.54
	2%	0.54	0.45
	5%	0.41	0.38
	10%	0.30	0.32
EY	0.2	0.24	0.27
	0.5	0.15	0.20

#### 6.4.12 Developed Conditions – Detention Basin Design

A detention basin stage-storage-discharge relationship was calculated to ensure a ‘no worsening’ of discharges from the developed site was achieved for the full range of storm events. The basin parameters were input into the XP-STORM program using the ‘Storage’ feature in the hydraulics model and applying the Stepwise Linear Storage method.

The XP-STORM model was used to optimise detention basin performance and design. The functional design of the detention basins was undertaken by TGM Civil as part of the design optimisation process.

### 6.5 Stormwater Quality

A comparative analysis of stormwater quality at the point of discharge from the Mollers Lane subdivision site was integrated with the hydrological simulations. Discussions with authorities have identified the existing waterways traversing the site as the legal point of discharge for stormwater runoff from the proposed development, prior to entering Lake Connearre; therefore each existing waterway was identified as a key reference location for assessment of stormwater quality targets.

Analysis of the impacts of urban development on receiving waterway ecosystem health was conducted using the continuous simulation model MUSIC from eWater CRC and the hydrological model. The MUSIC model was used to analyse the efficiency of the proposed stormwater system:

- Stormwater quality:
  - Total Suspended Solids;
  - Total Phosphorus;
  - Total Nitrogen;
  - Gross Pollutants;
  - Average annual runoff volumes; and
  - Frequency of stormwater runoff as indicated by average annual runoff days.

Stormwater quality measures were designed using MUSIC to meet “best practice” targets as described in Section 3. These design parameters serve the dual purpose of protecting waterway health and improving the amenity of waterways.

## 6.6 Hydraulic Modelling

The hydraulic analysis was undertaken using the fully 2D, TUFLOW (Build 2012-05-AE-iDP-w64) hydraulic modelling package. TUFLOW is a fully 2D hydraulic modelling package with the ability to dynamically integrate 1D elements.

Overland flow paths, obstructions and storages were modelled in the 2D domain, whilst underground drainage systems were represented as 1D elements linked to the 2D domain. The TUFLOW model was run in unsteady state.

### 6.6.1 2D Domain Analytical Grid

The 2D domain was analysed using a 1 metre grid mesh. This enabled accurate definition of the variable terrain topography, road obstructions and defined waterways. This grid size was determined to be of optimum size so as to accurately define the terrain and not adversely affect the simulation run times.

### 6.6.2 Manning's Coefficients

The TUFLOW hydraulic model assumed a Manning's roughness coefficient of 0.035 (pasture) for the majority of the catchment, with variation in roughness to reflect the vegetated waterway, urban development, gravel and bitumen road networks and existing water bodies. The relevant roughness coefficients adopted are shown in Table 6-10, below.

**Table 6-10:** Materials layer – Manning's 'n' value

Surface Description	Manning's 'n' value
Pasture	0.035
Asphalt Roads	0.018
Gravel Roads	0.029
Urban Residential (buildings)	0.200
Ponds and Water bodies	0.030
Light brush/scrub	0.050
Vegetated Waterway	0.080

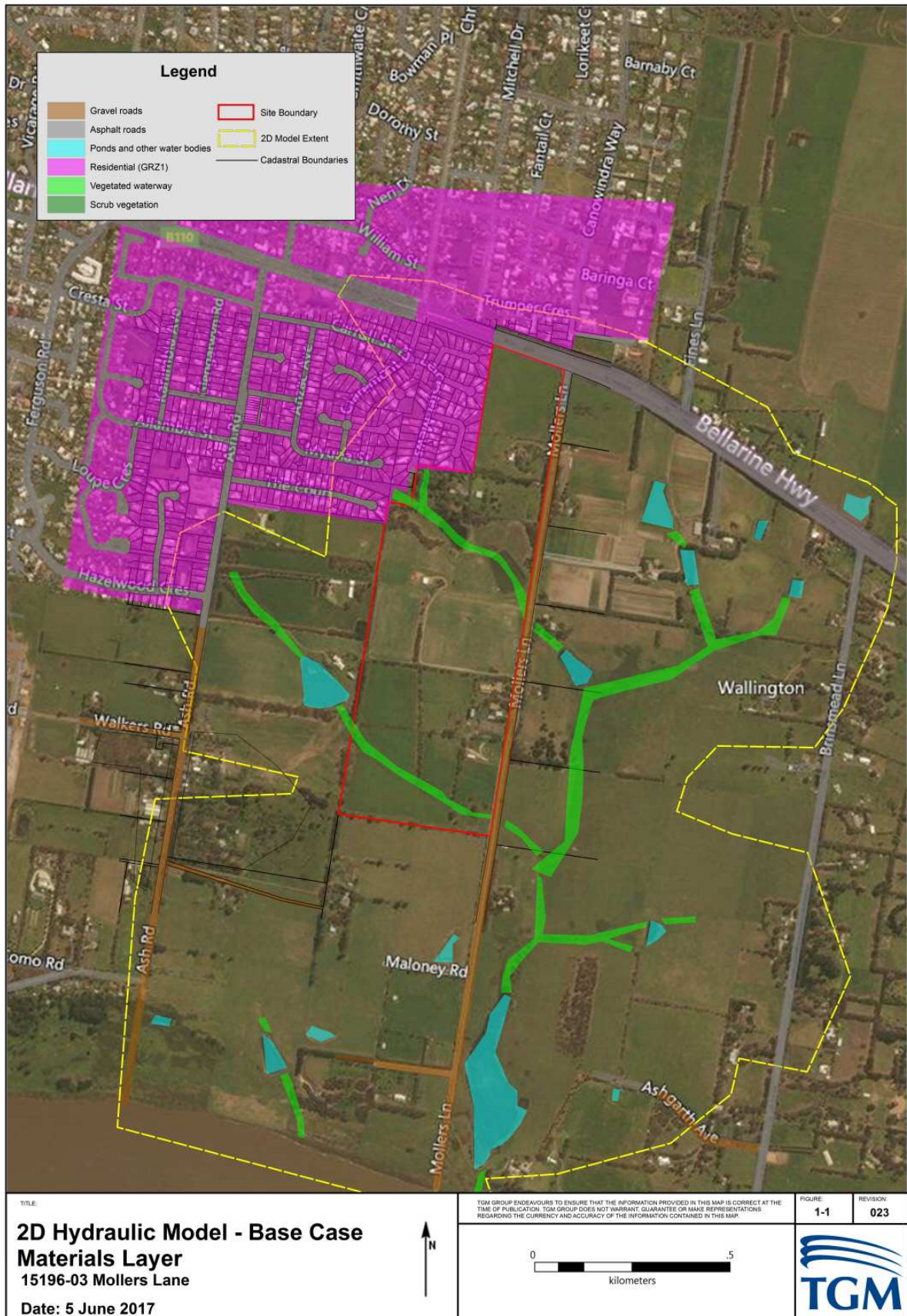


Figure 6-13: Variation in Landuse Materials Layer – Study Catchment

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### 6.6.3 Boundary Conditions and Initial Water Levels

The inflow hydrographs extracted from the hydrology model were distributed within the hydraulic model using the 2d\_bc and 2d\_sa functions in TUFLOW as inflow boundary conditions.

The 2d\_sa inputs were used to apply internal catchment inflows to the 2d model. Model outlet conditions adopted a head vs flow (HQ) boundary condition at Lake Connewarre.

The initial water levels (IWL) of waterbodies and farm dams was applied using the 2d\_iwl function in TUFLOW to reflect full dams prior to event. The IWL for each waterbody was set according to individual outlet conditions identified by TGM staff during field inspections.

The boundary conditions and identified initial water level locations are shown in Figure 6-14.



Figure 6-14: Boundary conditions and initial water levels

## 6.7 Hydraulic Sensitivity

A sensitivity analysis was undertaken to assess how the variation in the hydrologic and hydraulic inputs and boundary conditions impact the output of the model. Reasons for undertaking a sensitivity analysis on this study are:

- To identify the factors which have the most influence on model output;
- To identify factors that are insignificant to model output and can be eliminated from further analysis;
- To identify which, if any, factors or groups of factors interact with each other;
- To establish whether model predictions are robust to plausible variations in input factors or, on the other hand, are strongly dependent on fragile assumptions.

The sensitivity analysis assessed physical hydraulic variations in the form of:

- Blockage to stormwater infrastructure; and
- Tail water conditions of Lake Connewarre.

Each scenario is described below.

### 6.7.1 Blockage

Blockage factors have been applied to the limited number of culverts and pits within the study area as part of the sensitivity analysis. The inclusion of blockage in the analysis of hydraulic structures is an important part of understanding the impact and severity of a flood event should the drainage system fail to operate as designed. It is important, however, to ensure the blockage factor estimations applied are not over-estimated or under-estimated as this can dramatically influence the performance of the total system.

For this study current best practice procedures referenced in Book 6, Chapter 6 of ARR 2016, 'Blockage of Hydraulic Structures' were adopted, for the selection of design blockage factors.

Design blockage is the blockage condition most likely to occur during a given design storm. It is an “average” of conditions to ensure that the calculated design flood levels should be appropriate for the defined probability.

This is necessary as the assumption of a higher level of blockage than appropriate would result in the calculated design flood level upstream of the structure being higher than would be appropriate for the defined probability. Downstream flood levels would be lower because of the additional flood storage upstream of the structure.

On the other hand, an assumed lower level of blockage would result in lower flood levels upstream and higher flood levels downstream.

It is also noted that actual blockage levels vary greatly from event to event with a potential spread from “all clear” to “fully blocked” even in floods of comparable magnitude.

The blockage factors for this study were derived by assessing the following mechanisms of blockage in the contributing catchment:

- Debris availability;
- Debris mobility; and
- Debris transportability.

The contributing catchment consists urban residential and agricultural farmland and has been observed to result in high sediment loadings in stormwater runoff and conveyance of debris. The debris and sediment collects in the drainage culverts and pits. This has resulted in extensive plant growth and blockages in all locations as shown earlier in Figure 6-3.

Assessment of the contributing catchment area has led to the analysis of the following blockage factors for existing infrastructure:

**Table 6-11: Blockage Factors**

Blockage Conditions	
Design Blockage	Severe Blockage
20%	100%

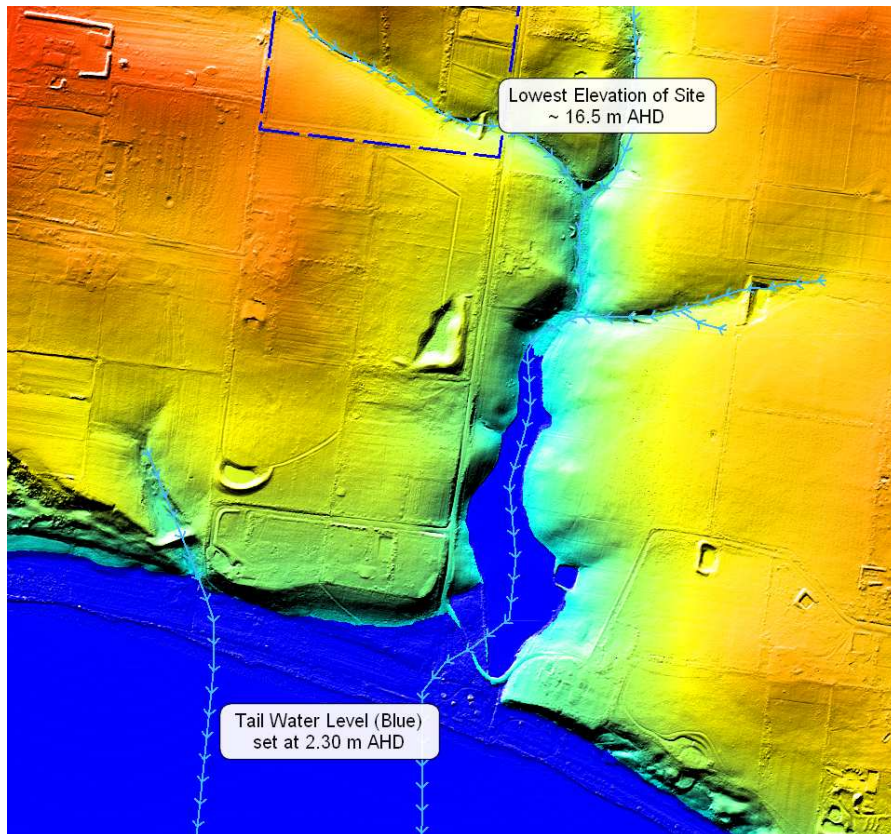
It was found, due to the marked lack of stormwater infrastructure, defined flow paths and steep terrain; that variation in blockage did not prove sensitive to the regional flood extent.

### 6.7.2 Tail Water Conditions

The variation of the water level in Lake Connewarre were assessed to analyse the sensitivity of tail water conditions with the extent of flooding within the development site.

Variation of water levels within Lake Connewarre are principally driven by flooding within the Barwon River system. The Barwon River under extreme recorded flooding has a level of 2.30 m AHD at the Sheepwash Road gauge approximately 4 km south of the site on the opposite side of Lake Connewarre.

The 2.30 m AHD tail water level representing the Barwon River flood is depicted in Figure 6-15.



**Figure 6-15:** Lake Connewarre Tail Water Level – 2.30 m AHD

The change in elevation between the site and Lake Connewarre at 2.30 m AHD is approximately 14.2 metres. An increased tail water level in Lake Connewarre does not have an impact on the hydraulic sensitive of flooding within, or around, the site and had no bearing on this study.

## 7. RESULTS

The results of the stormwater hydrology and water quality analysis are shown in this section. The design has been undertaken to meet stormwater quality 'best practice' standards and to ensure that peak discharges for events up to and including the 1% AEP do not exceed predeveloped conditions and/or create a negative impact to neighbouring properties and receiving ecosystems.

### 7.1 Stormwater Quality

The ability of development to meet stormwater quality 'best practice' standards and the performance of the treatment system was continuously simulated using MUSIC.

#### 7.1.1 Wetland Facility

An end-of-line wetland system is proposed to be constructed in the base of the detention basin to manage stormwater quality generated within the developed site.

The wetland dimensions, required to meet best practice reductions, will dictate the size and footprint of the stormwater detention basin facility. The required dimensions of the wetland component are tabulated below.

**Table 7-1: Wetland AB Parameters**

Parameter	Dimension
Area	3,300 m <sup>2</sup>
EDD	0.45 m

**Table 7-2: Wetland C Parameters**

Parameter	Dimension
Area	1,900 m <sup>2</sup>
EDD	0.40 m

The MUSIC network is shown in Figure 7-1.



**Figure 7-1: MUSIC network – Developed**

The treatment efficiency of the wetland systems at each legal point of discharge is shown in Table 7-3 and Table 7-4 for Catchment AB and Catchment C, respectively.

**Table 7-3: Wetland AB treatment efficiency**

Criteria	Sources	Residual Load	Reduction (%)
Total Suspended Solids (kg/yr)	11,700	2320	80.3
Total Phosphorus (kg/yr)	24	7.28	69.7
Total Nitrogen (kg/yr)	167	84.9	49.3
Gross Pollutants (kg/yr)	2,580	126	95.1

**Table 7-4: Wetland C treatment efficiency**

Criteria	Sources	Residual Load	Reduction (%)
Total Suspended Solids (kg/yr)	8,380	1,670	80.1
Total Phosphorus (kg/yr)	17.0	5.11	69.9
Total Nitrogen (kg/yr)	118	61.2	48
Gross Pollutants (kg/yr)	1,820	0	100

It is noted that the wetland designs exceed best practice reductions noted in Section 3.

## 7.2 Hydrologic Analysis – Detention Basin Facility

The hydrologic analysis compared peak flow rates and runoff volumes from the mitigated developed site with those of the predeveloped site.

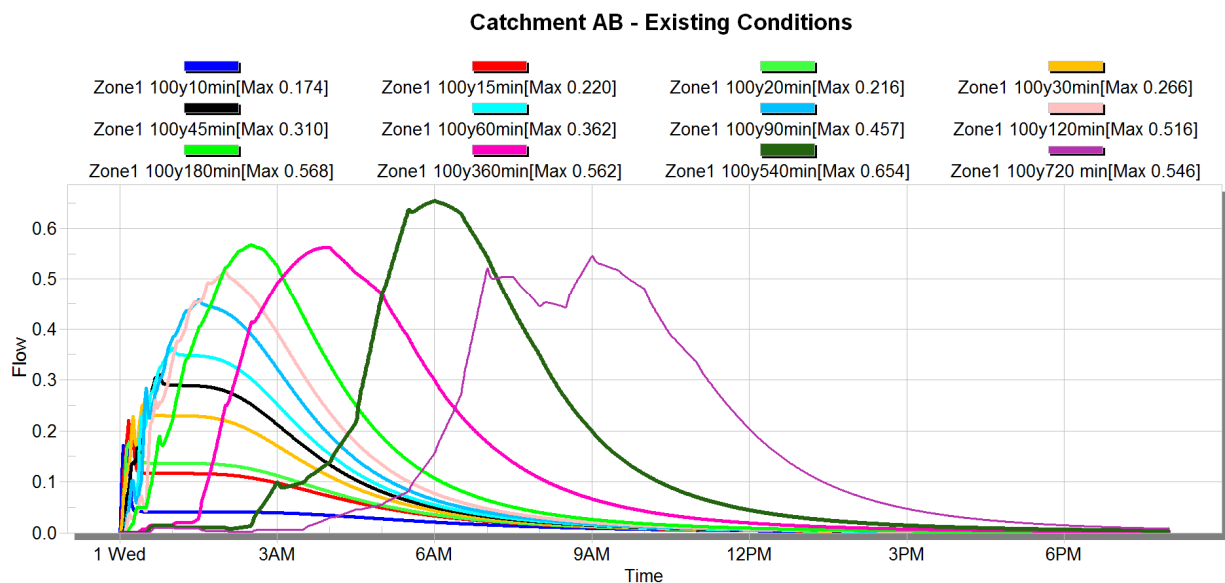
Analysis of the undeveloped 'base case' condition of the proposed development site highlights that peak discharge occurs at 9 hour storm duration. Developed conditions indicate a peak discharge at 15 minute storm duration from the proposed development.

The peak discharge generated for predeveloped conditions set the target objective for the developed scenario and is shown in Table 7-5.

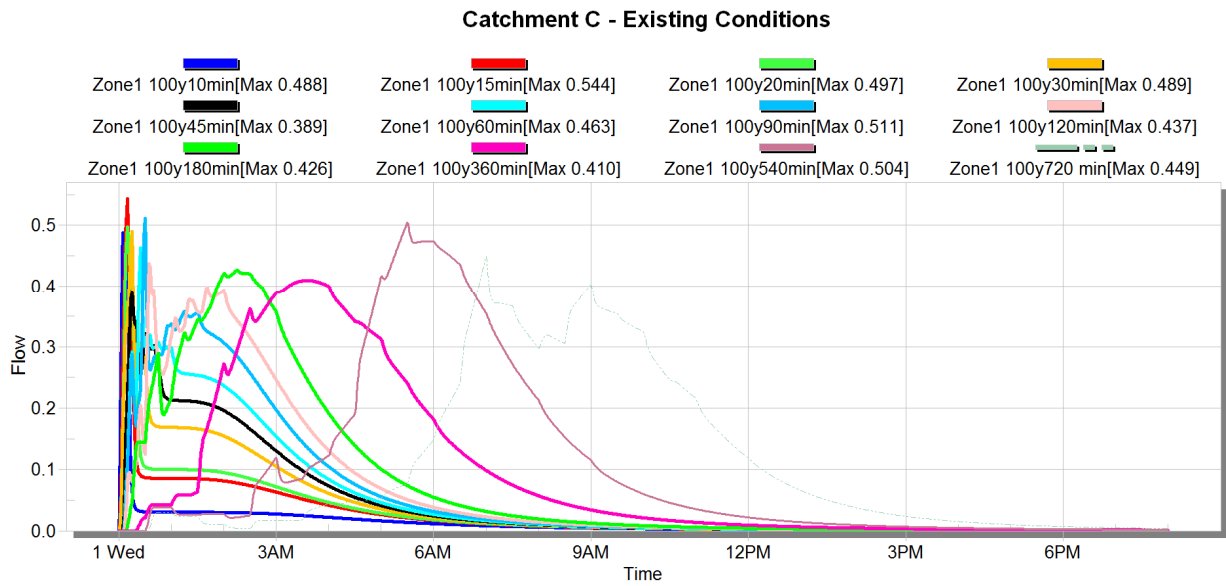
**Table 7-5: Mollers Lane site stormwater peak discharge objectives**

Catchment	Predeveloped 'base case' discharge
AB	0.65 m <sup>3</sup> /s
C	0.54 m <sup>3</sup> /s

The predeveloped (existing) conditions runoff hydrographs are shown in Figure 7-2 and Figure 7-3 for catchments AB and C, respectively.



**Figure 7-2: Catchment AB Existing Site Discharge Hydrographs**



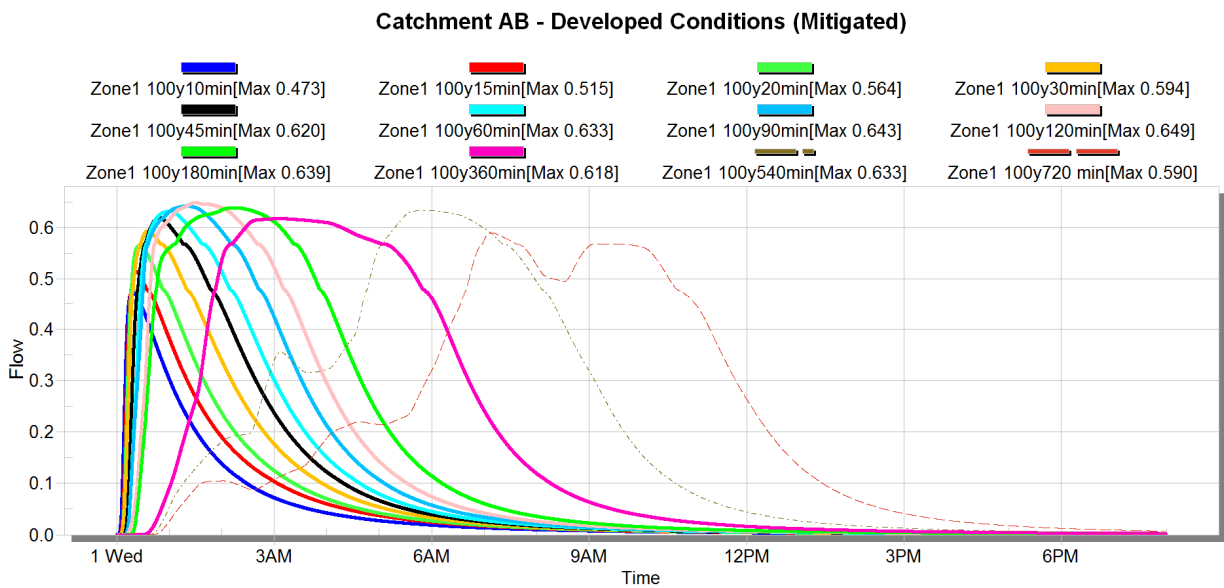
**Figure 7-3: Catchment C Existing Site Discharge Hydrographs**

The developed site peak discharges are shown in Table 7-5 for both the unmitigated and mitigated scenarios.

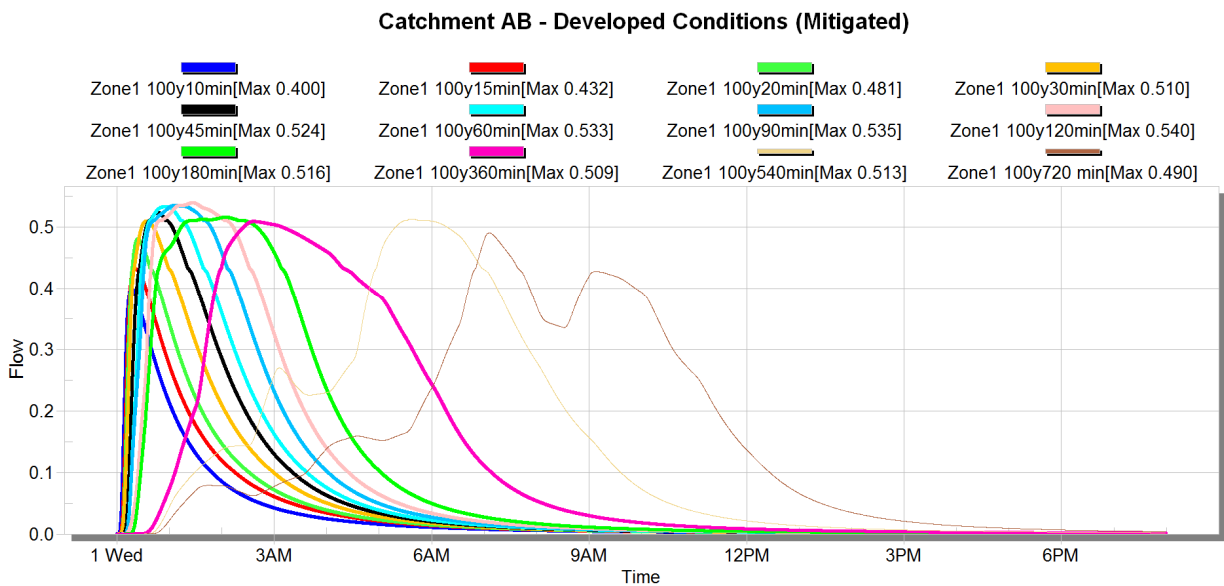
**Table 7-6: Mollers Lane developed stormwater peak discharge**

Catchment	Developed Site (Unmitigated)	Developed Site (Mitigated)
AB	5.05 m <sup>3</sup> /s	<b>0.65 m<sup>3</sup>/s</b>
C	3.52 m <sup>3</sup> /s	<b>0.54 m<sup>3</sup>/s</b>

The discharge hydrographs for the mitigated solution is shown in Figure 7-4 and Figure 7-5.



**Figure 7-4: Catchment AB Developed Site Discharge Hydrographs**



**Figure 7-5: Catchment C Developed Site Discharge Hydrographs**

There is an increase in stormwater runoff volumes and peak discharges as a result of the increase in impervious surfaces within the developed site, resulting in a shorter duration and more intense runoff.

The proposed development at Mollers Lane will generate an increase in the peak stormwater discharges from catchments AB and C (unmitigated) of 5.05 m<sup>3</sup>/s and 3.52 m<sup>3</sup>/s, respectively.

The significant increase is largely due to the hydrological and topographical nature of the existing site and the characteristic change to developed/residential land use.

The stormwater peak discharge was mitigated using a detention basin to ensure no-worsening compared to existing conditions. The required detention volume is shown in Table 7-7.

**Table 7-7:** Detention basin characteristics – 1% AEP

Basin	Surface Area (m <sup>2</sup> )		Depth (m)	Volume (m <sup>3</sup> )	Discharge (m <sup>3</sup> /s)
	Base (I.L.)	T.W.L			
AB	3,510	~ 5,610	0.95	4,300	0.65 m <sup>3</sup> /s
C	2,702	~ 4,370	0.79	2,657	0.54 m <sup>3</sup> /s

### 7.3 Hydraulic Analysis

The ability for the development to mitigate the impact of development on the regional flood extents is depicted in this section.

#### 7.3.1 Hydraulic Simulation

The simulated existing ‘base case’ model returned a mass error (ME) of -0.89% - recommended mass balance error range for a healthy model is between +1% and -1%.

To maintain an acceptable courant number the model was run at a 0.25 second time step which is a quarter the grid cell size. TUFLOW manual recommends a 2D model time step  $\frac{1}{2}$  to  $\frac{1}{5}$  of the grid cell size.

#### 7.3.2 Existing Conditions

The existing conditions 1% AEP flood extent is depicted in Figure 7-6, below.

The existing conditions shows the existing dams within waterway alignments that are nominated for removal.

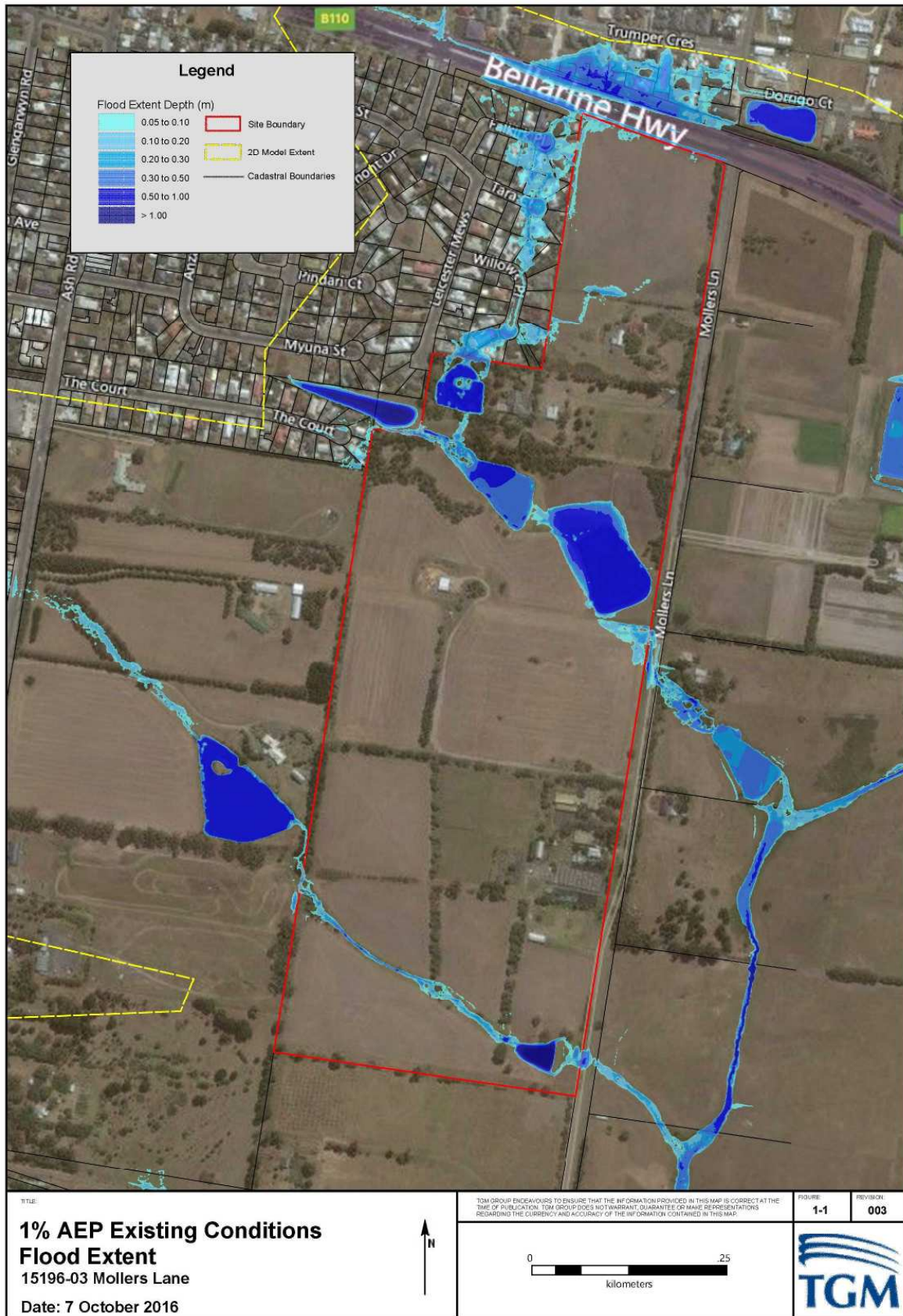


Figure 7-6: Existing 1% AEP Flood Extent (depths ≥ 50 mm)

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### 7.3.3 Predeveloped 'Base Case' Conditions

The predeveloped 'base case' conditions flood extents are depicted below for storm events up to and including the 1% AEP.

Predeveloped conditions feature removal of 4 No. existing dams within waterway alignments within the site as identified in Figure 4-1 in Section 4, above.

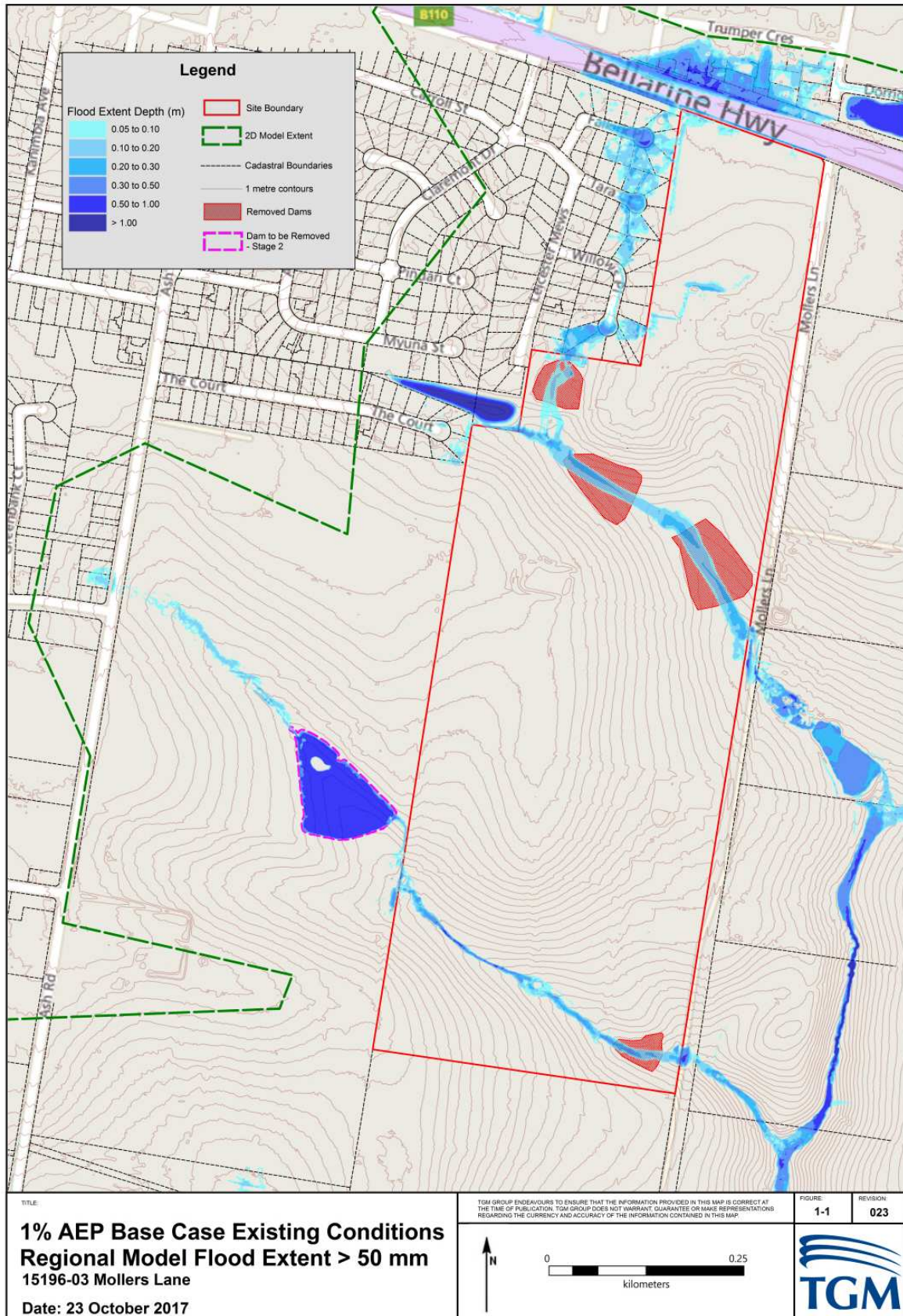


Figure 7-7: Predeveloped 1% AEP Flood Extent (depths  $\geq$  50 mm)

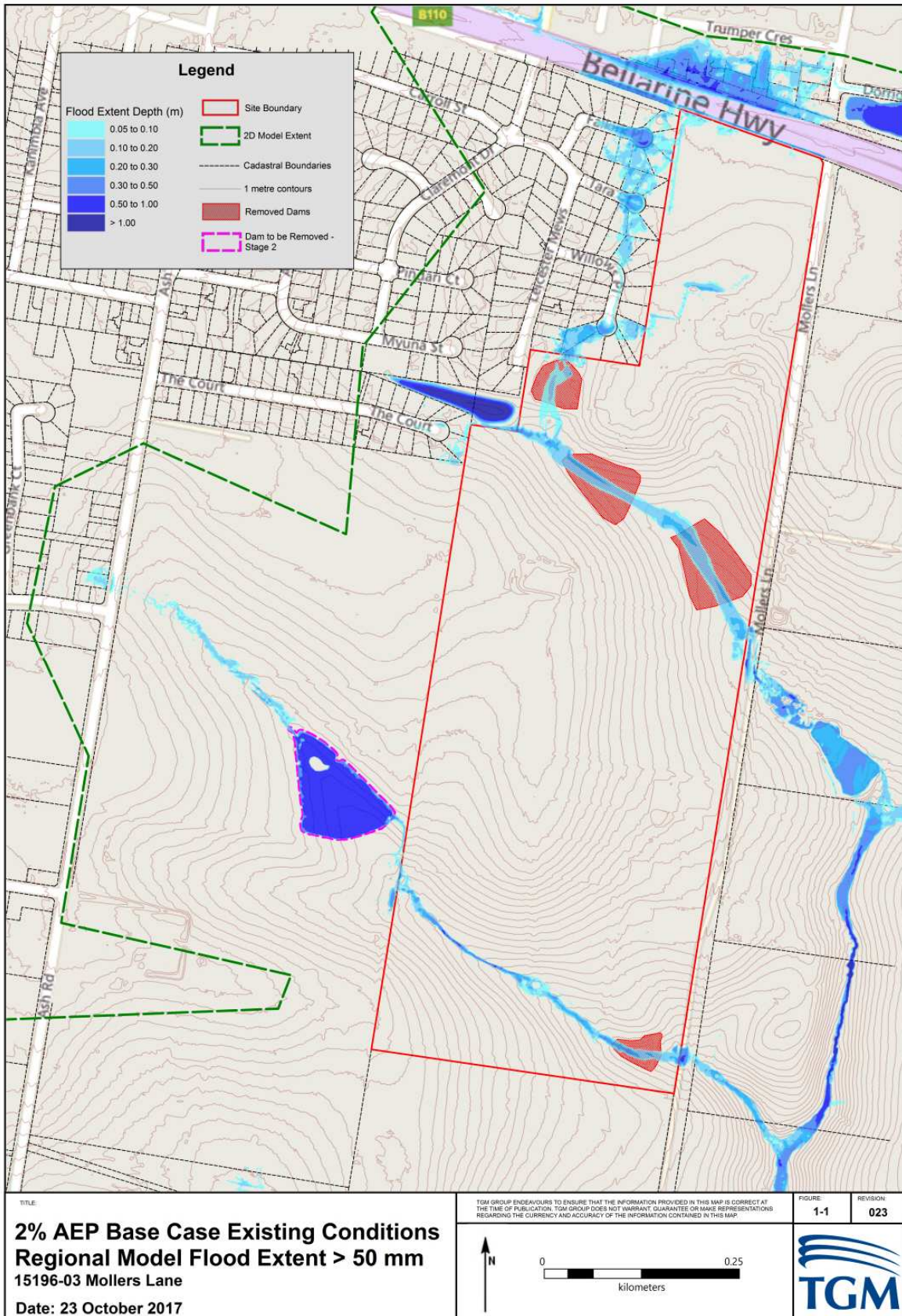


Figure 7-8: Predeveloped 2% AEP Flood Extent (depths ≥ 50 mm)

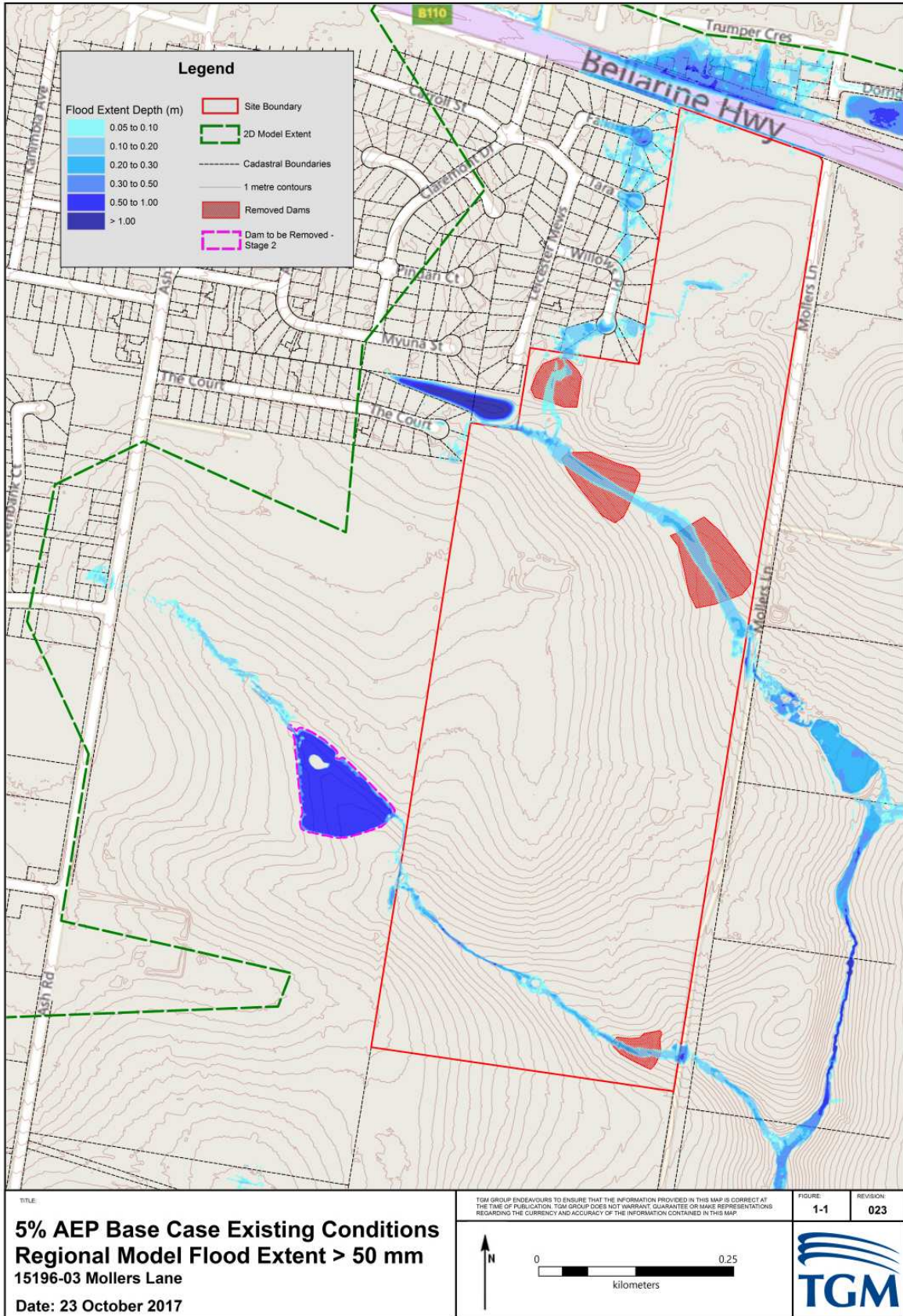


Figure 7-9: Predeveloped 5% AEP Flood Extent (depths  $\geq$  50 mm)

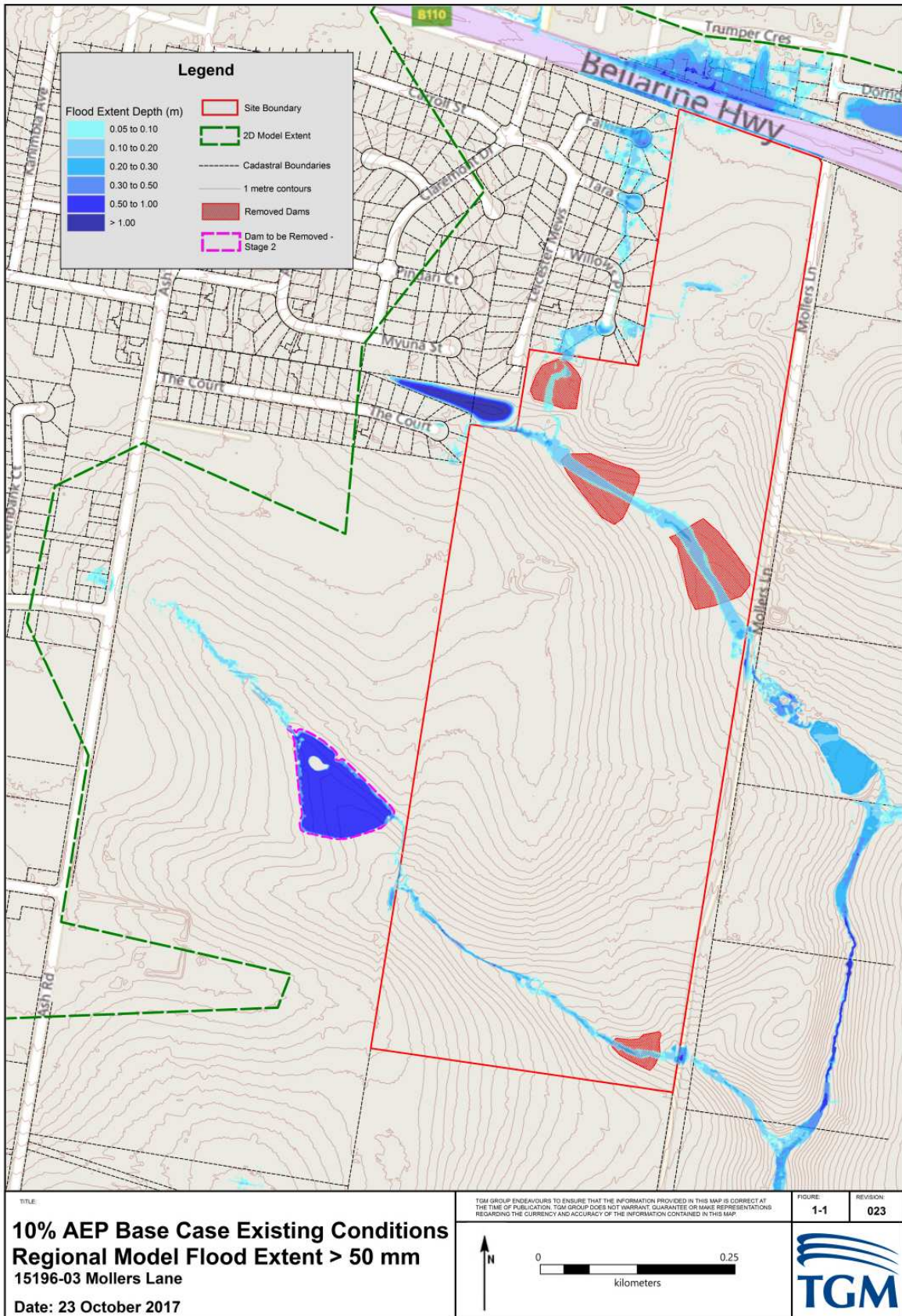


Figure 7-10: Predeveloped 10% AEP Flood Extent (depths ≥ 50 mm)

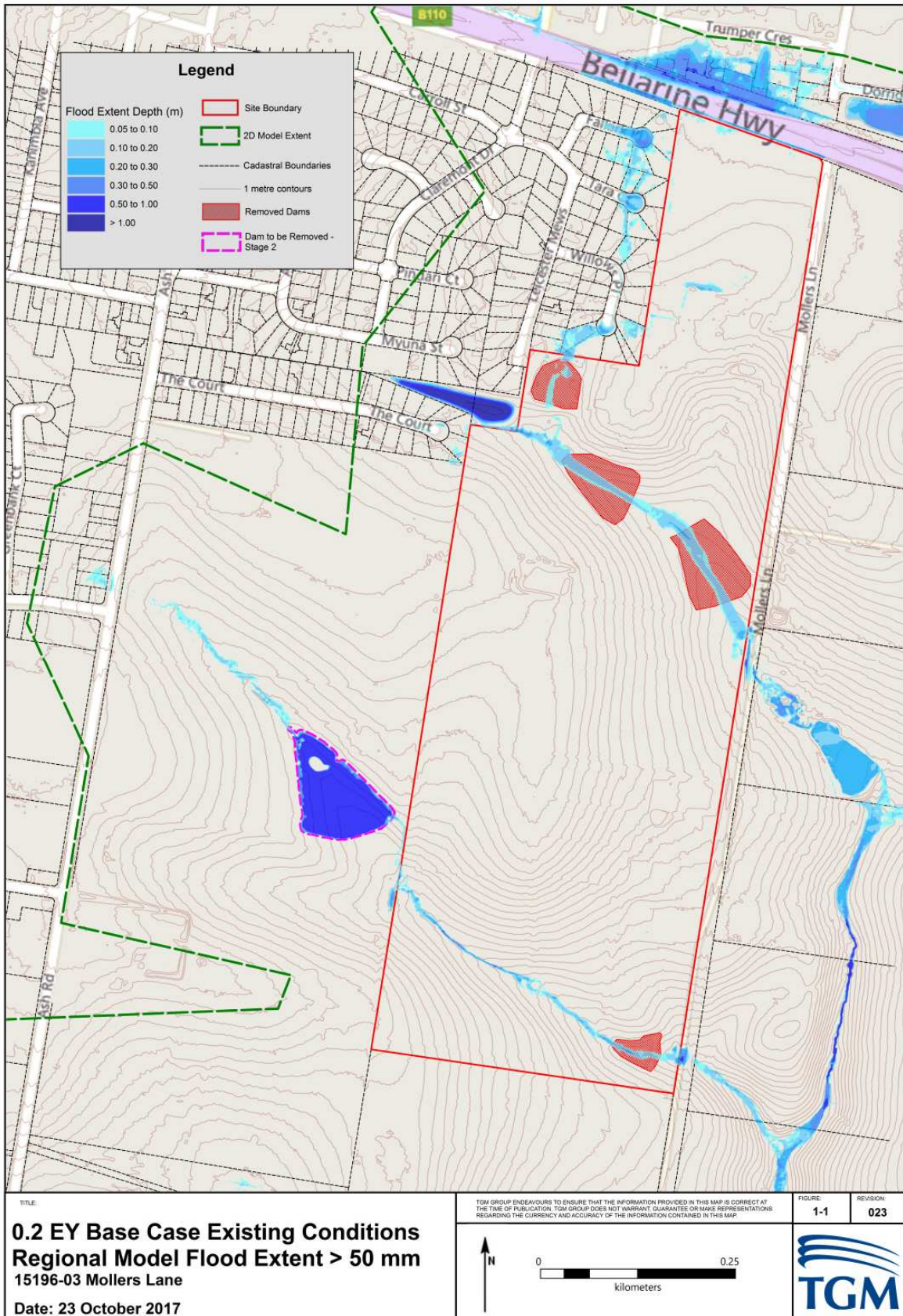


Figure 7-11: Predeveloped 0.2 EY Flood Extent (depths ≥ 50 mm)

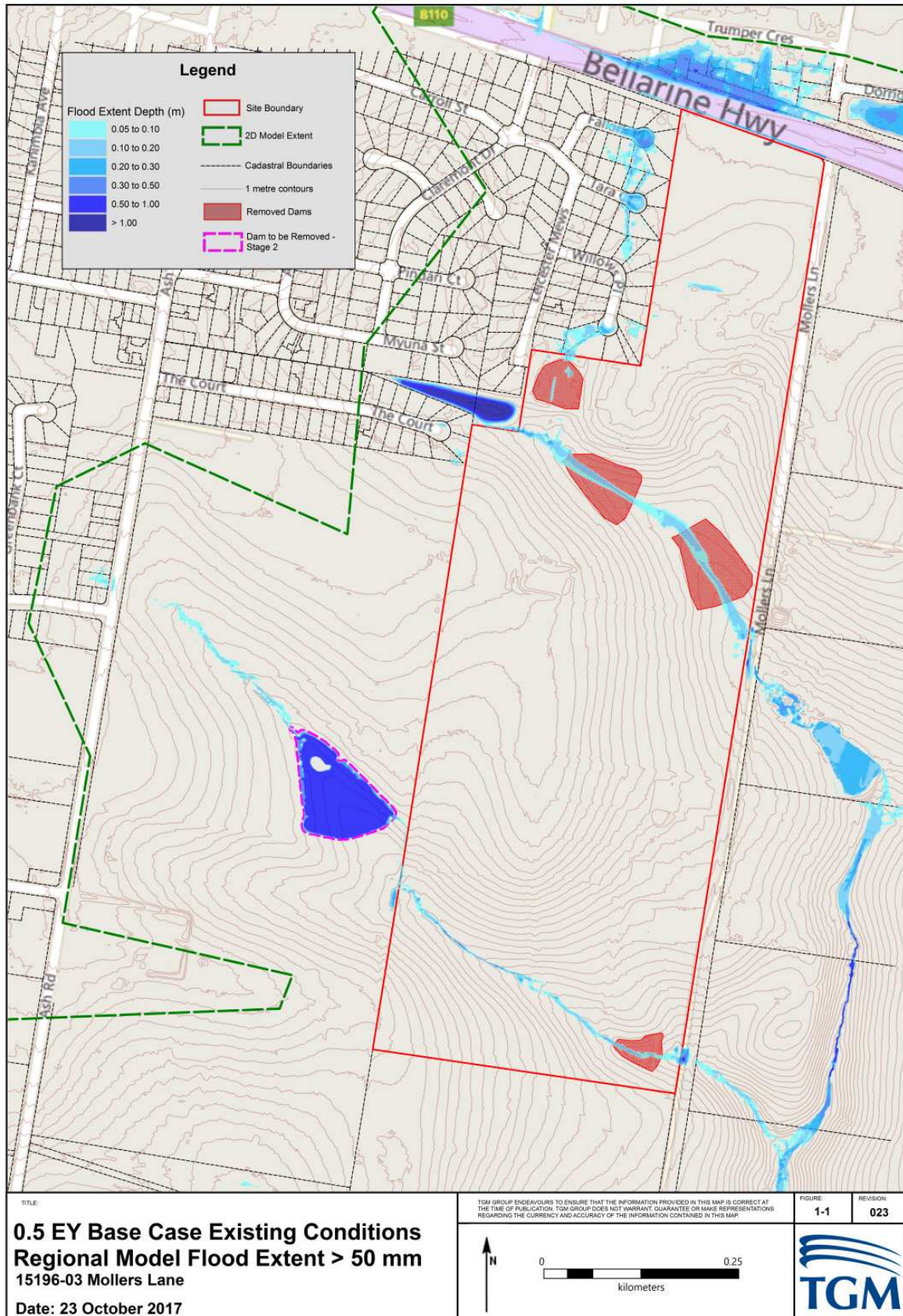


Figure 7-12: Predeveloped 0.5 EY Flood Extent (depths ≥ 50 mm)

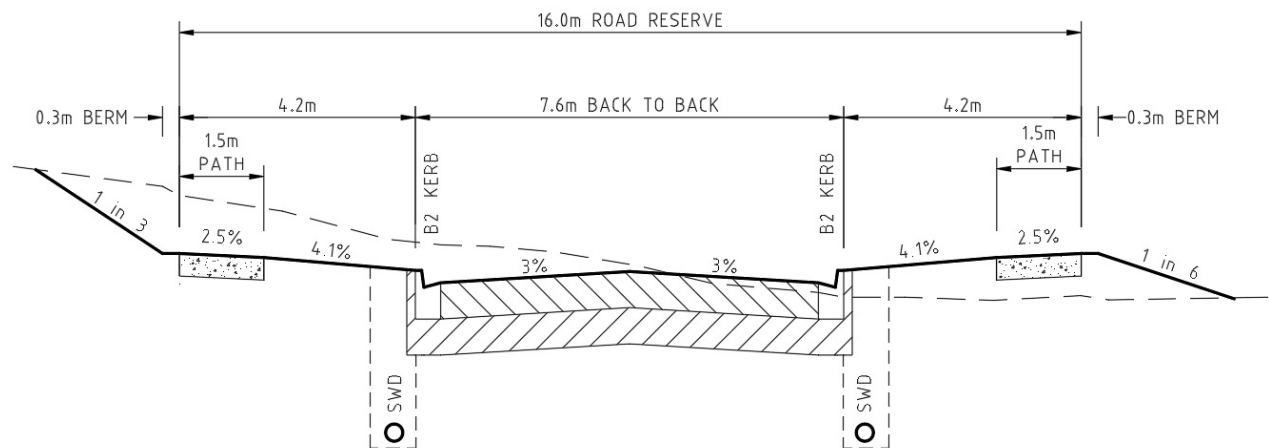
### 7.3.4 Developed Conditions

The developed conditions flood extent for the specified range of AEP's are shown in this section.

Stormwater flow enters the developed site predominantly within the two (2) waterway alignments, however, as seen in the 'Predeveloped' mapping, flood waters enter the site at the northern boundary along Bellarine Highway traversing the site (largely as shallow (< 50 mm) sheet flow however deeper in sections) in a south westerly direction, flowing through property on Willows Place and ultimately entering the northern waterway via the existing dam at 10 Willows Place, Leopold.

Under developed conditions, these flows will be collected in cut off swales along Bellarine Highway and directed to the internal road reserves for conveyance to the wetland basin facility AB.

The road reserve has a capacity of 10.2 m<sup>3</sup>/s. The typical cross section detail for the design road is shown in Figure 7-13.



**Figure 7-13: Mollers Lane Road Reserve – Typical Cross-Section Flow Path Detail**

The 1% AEP peak runoff from the developed site discharging to basin facility A/B is 2.75 m<sup>3</sup>/s which occurs during the 15 minute event. The timing of the peak 1% AEP flows (0.44 m<sup>3</sup>/s) from the external catchment occurs at 5.6 hours during the 540 minute event.

The road has the capacity to allow conveyance of stormwater flows generated within the developed site as well as external flows entering the site via the northern boundary.

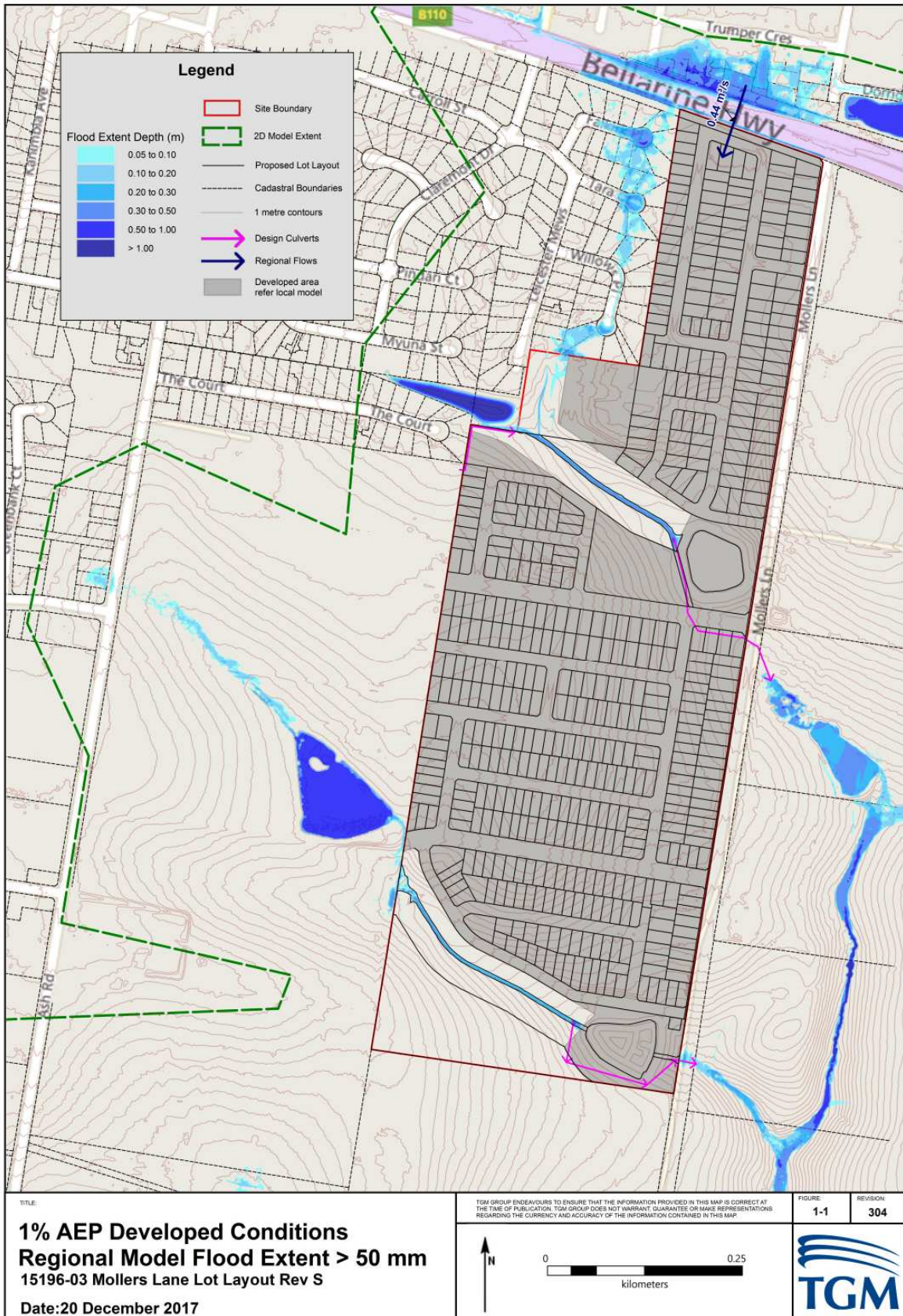


Figure 7-14: Developed 1% AEP Flood Extent (depths  $\geq$  50 mm)

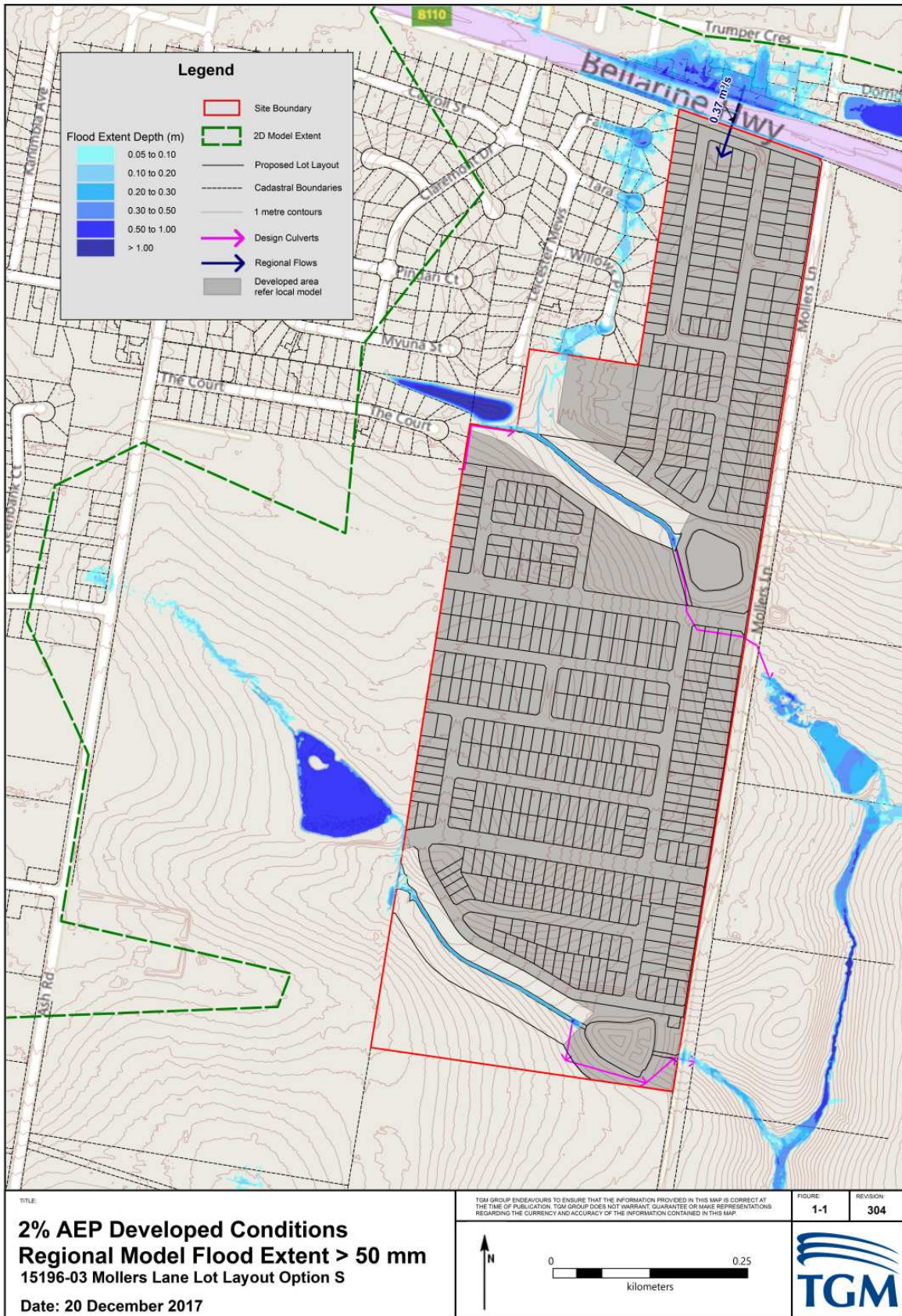


Figure 7-15: Developed 2% AEP Flood Extent (depths  $\geq$  50 mm)

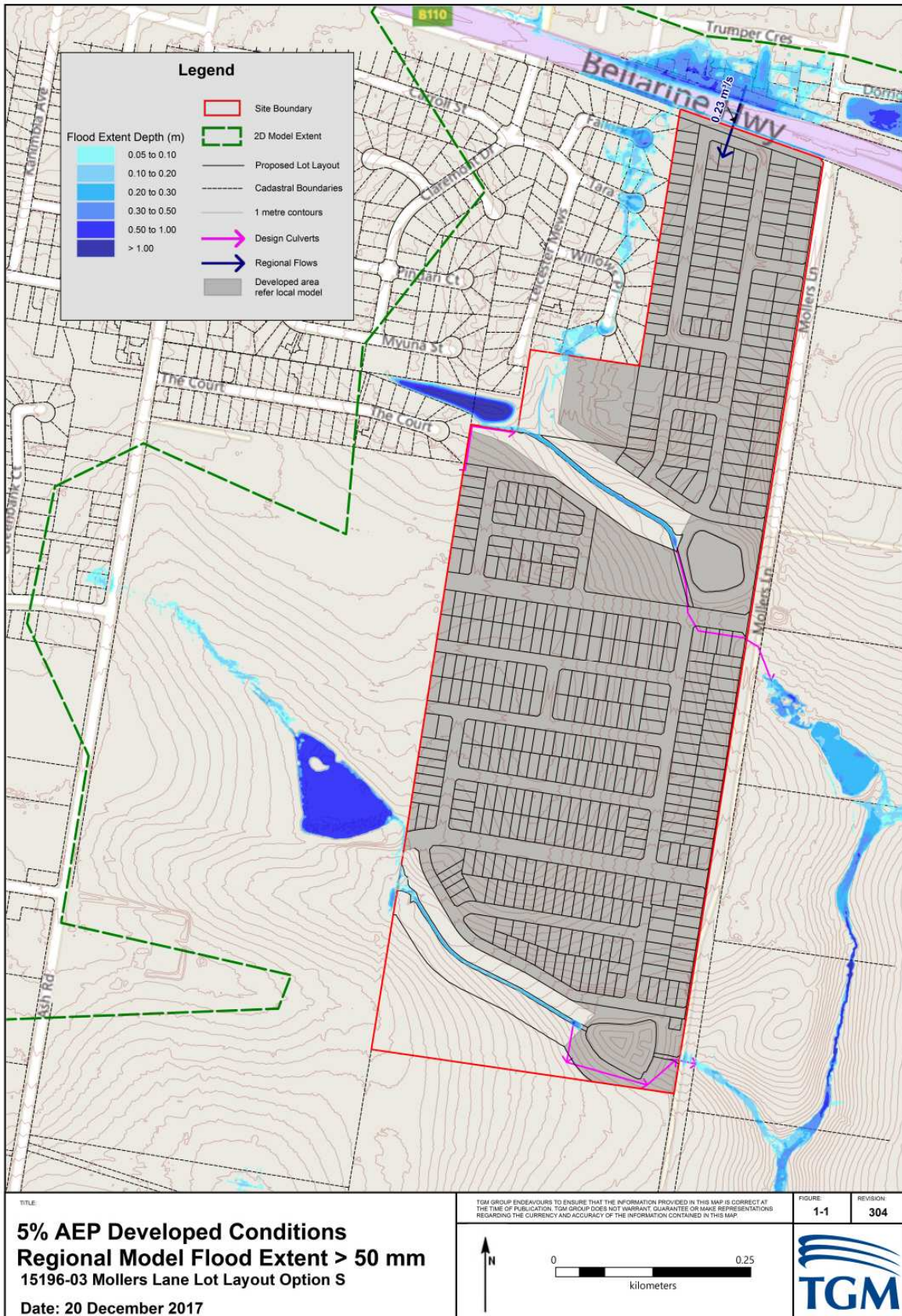


Figure 7-16: Developed 5% AEP Flood Extent (depths  $\geq$  50 mm)

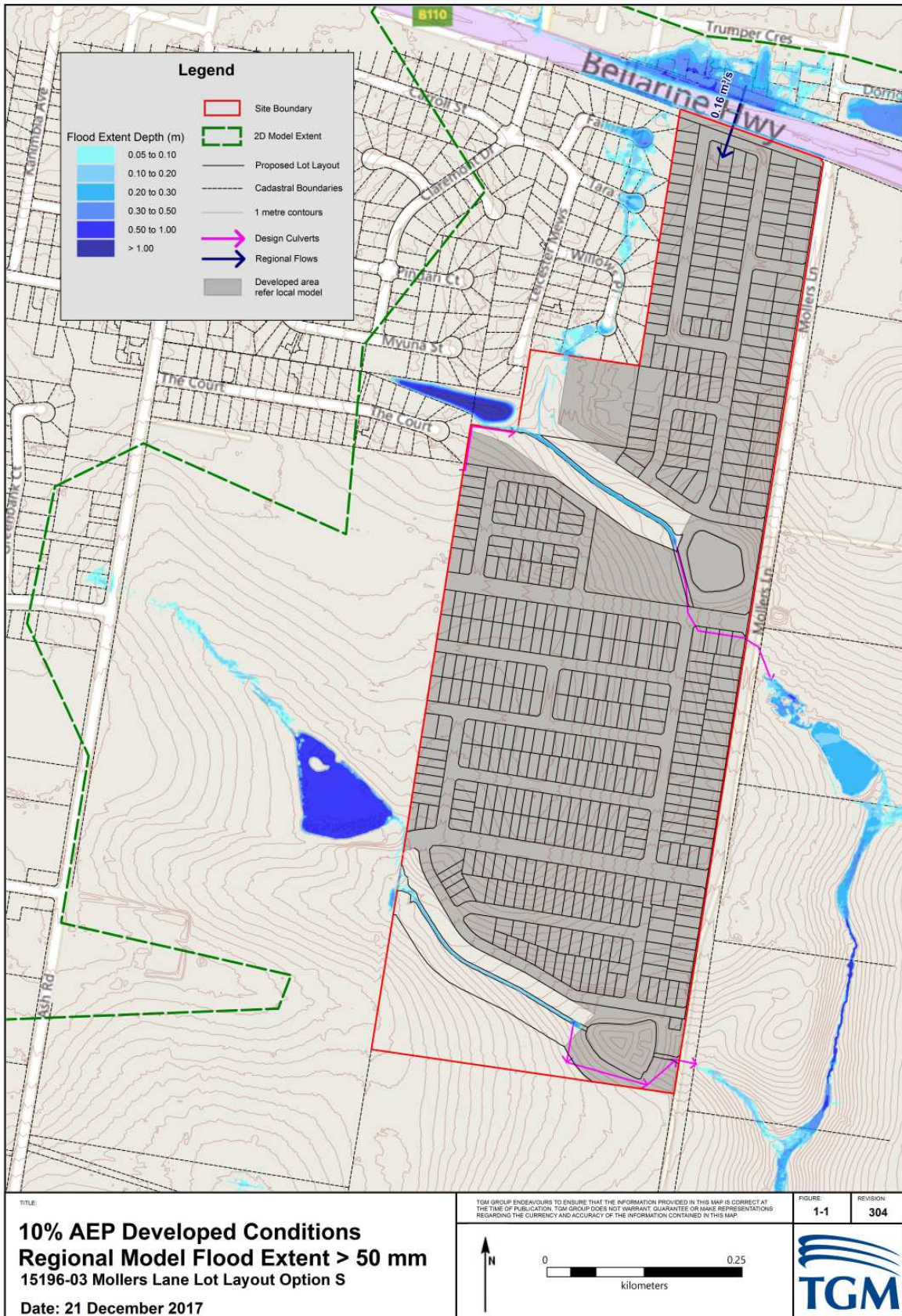


Figure 7-17: Developed 10% AEP Flood Extent (depths ≥ 50 mm)

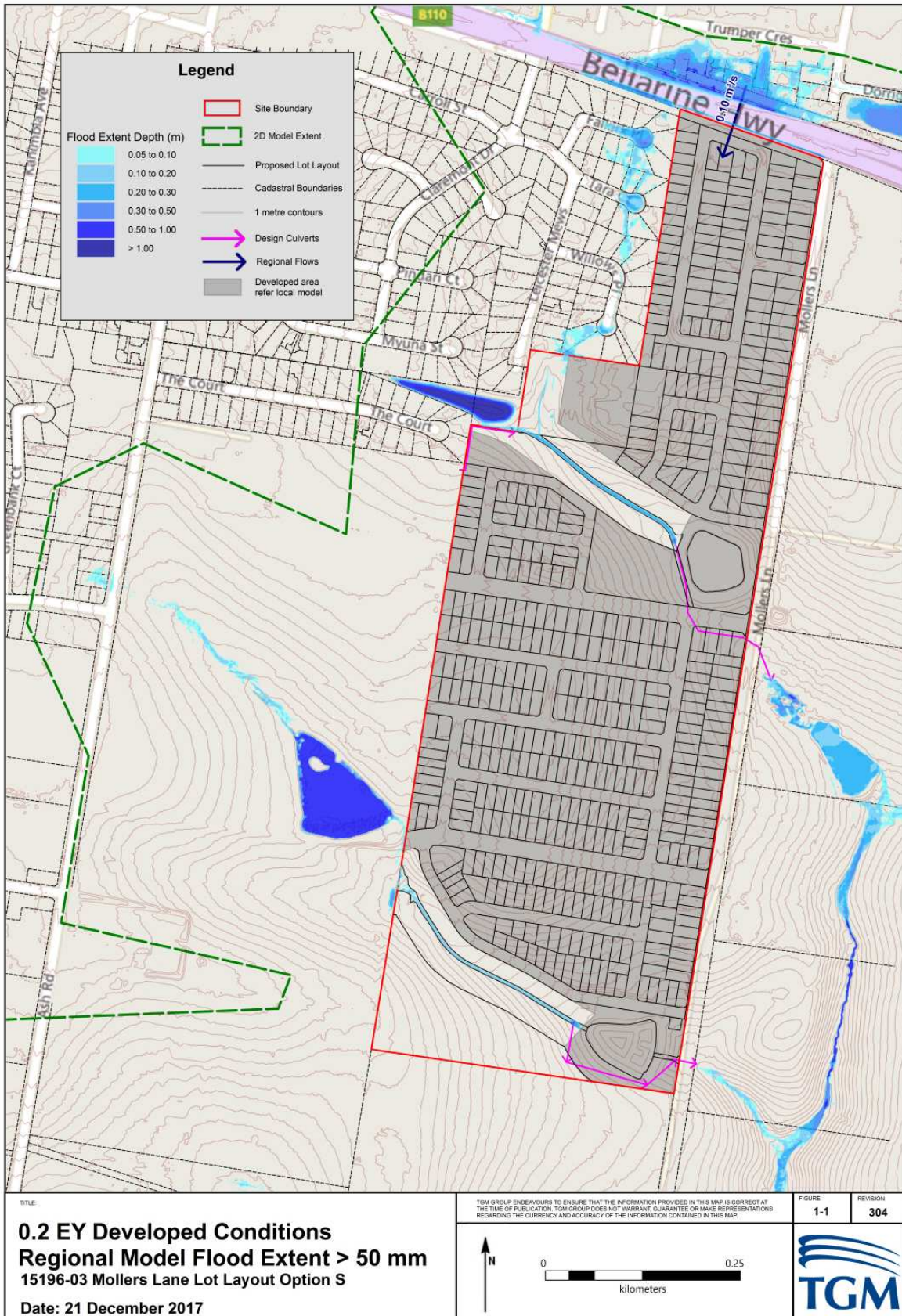


Figure 7-18: Developed 0.2 EY Flood Extent (depths ≥ 50 mm)

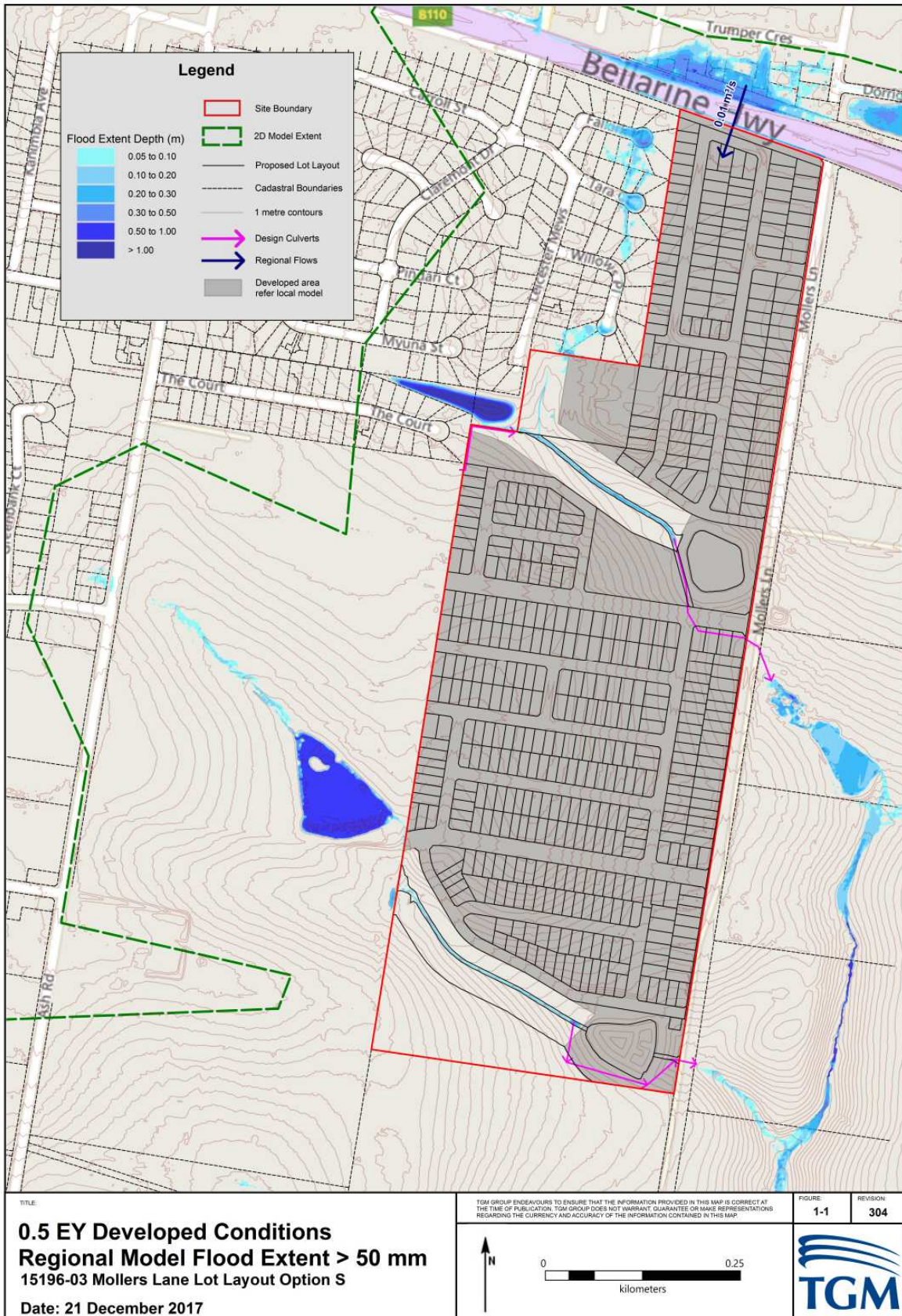


Figure 7-19: Developed 0.5 EY Flood Extent (depths ≥ 50 mm)

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### 7.3.5 Change in Flood Mapping (Impact)

The impacts of developing the Mollers Lane subject site on regional flooding has been shown in this section to a 'no change' tolerance of  $\pm 5$  mm.

The impact mapping shows increases in flood level and/or "was dry now wet" within the waterway channels upstream of the.... These are not real impacts but are an artefact of the model boundary conditions. In these areas the boundary condition type is called a source-area which means that the runoff is distributed evenly to all wet cells in the model; at the start of the simulation when the area is fully dry the boundary initially distributes to the low point until more of the model gets wet. In these areas the flood extent has changed in the developed case because of the reductions in flood level caused by the development. This means that the model boundary distributes the runoff slightly differently between the existing and developed case, which is not a real effect.

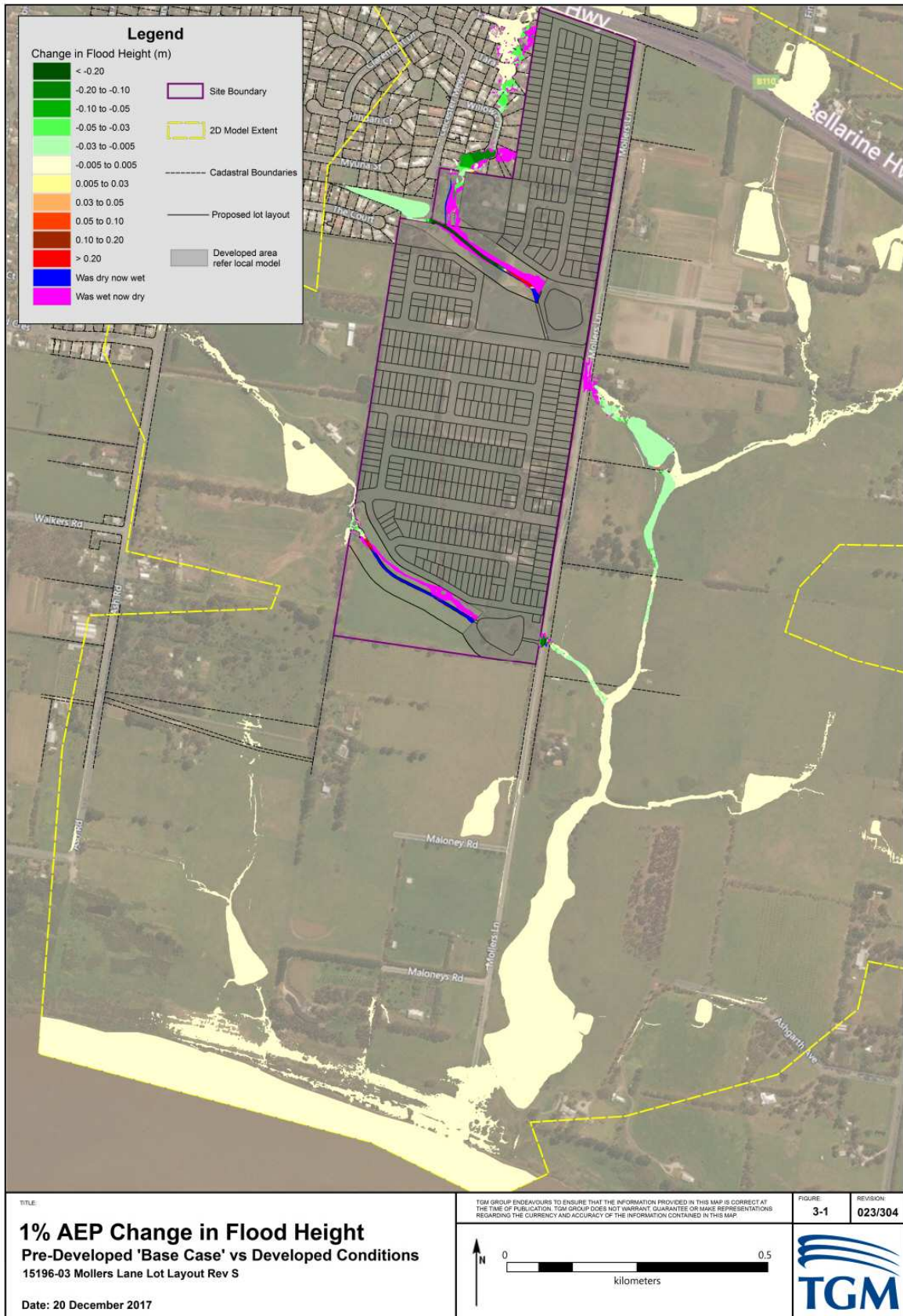


Figure 7-20: Change in Flooding 1% AEP Impact Map (depths ≥ 50 mm)

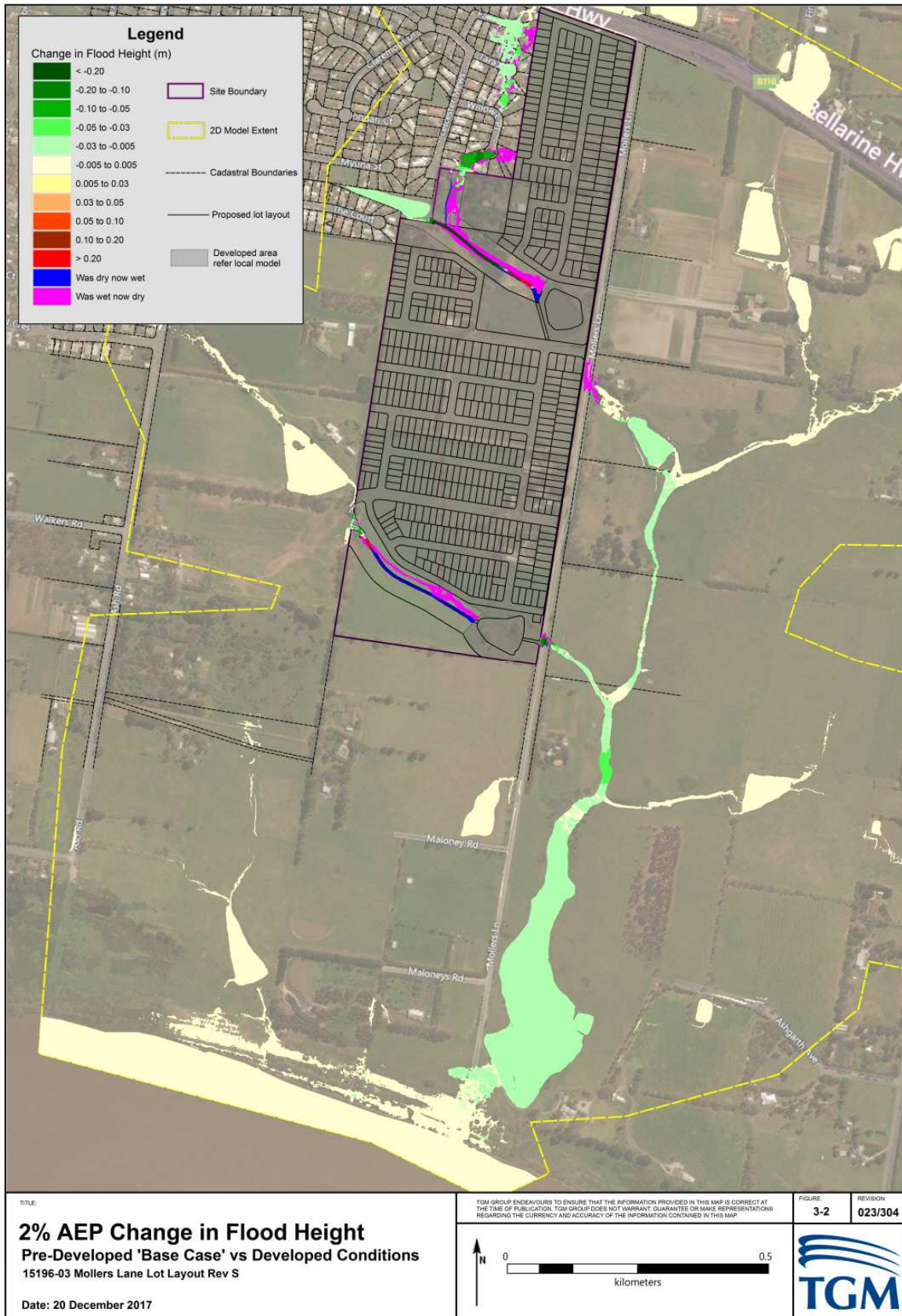


Figure 7-21: Change in Flooding 2% AEP Impact Map (depths  $\geq$  50 mm)

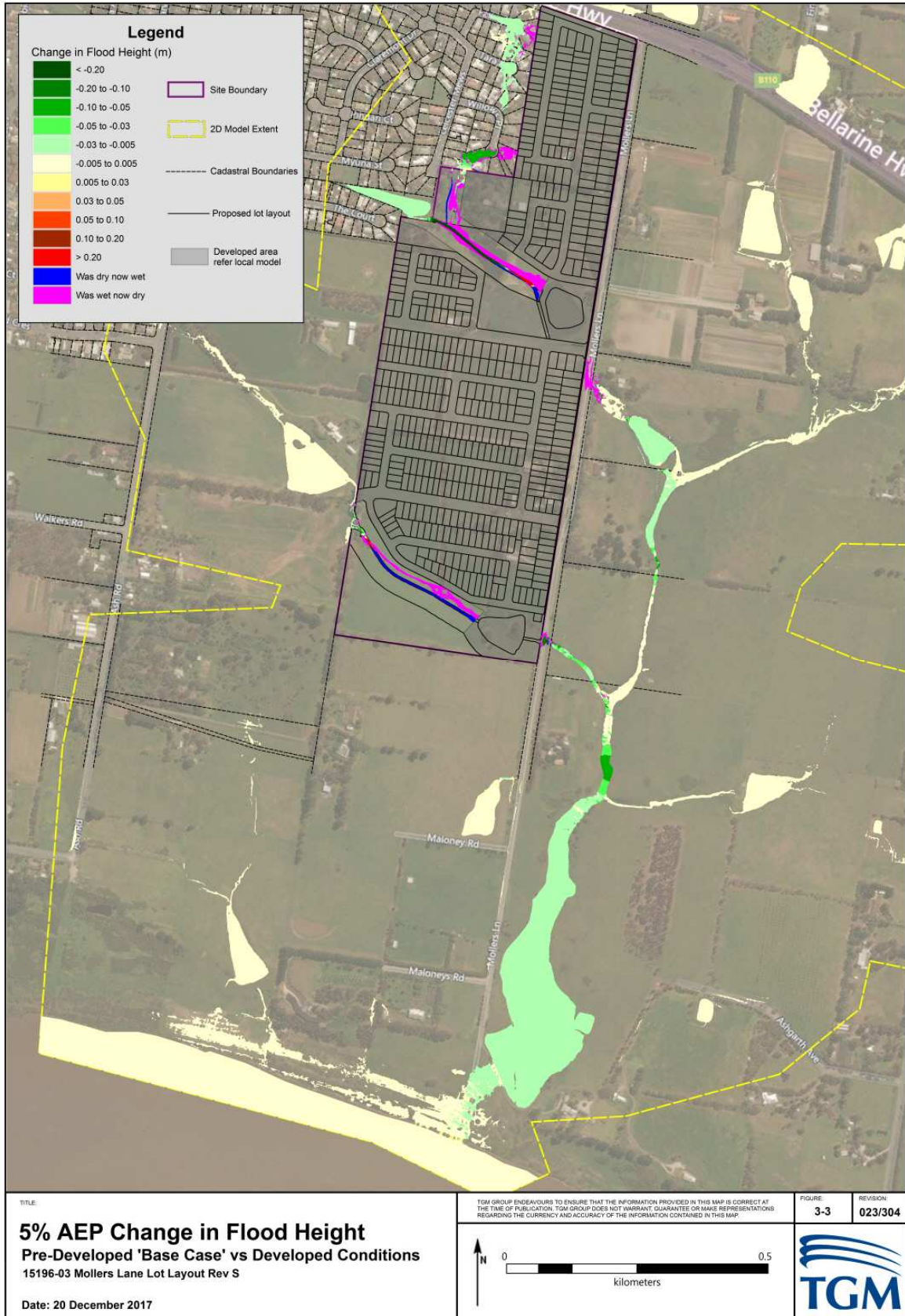


Figure 7-22: Change in Flooding 5% AEP Impact Map (depths  $\geq$  50 mm)

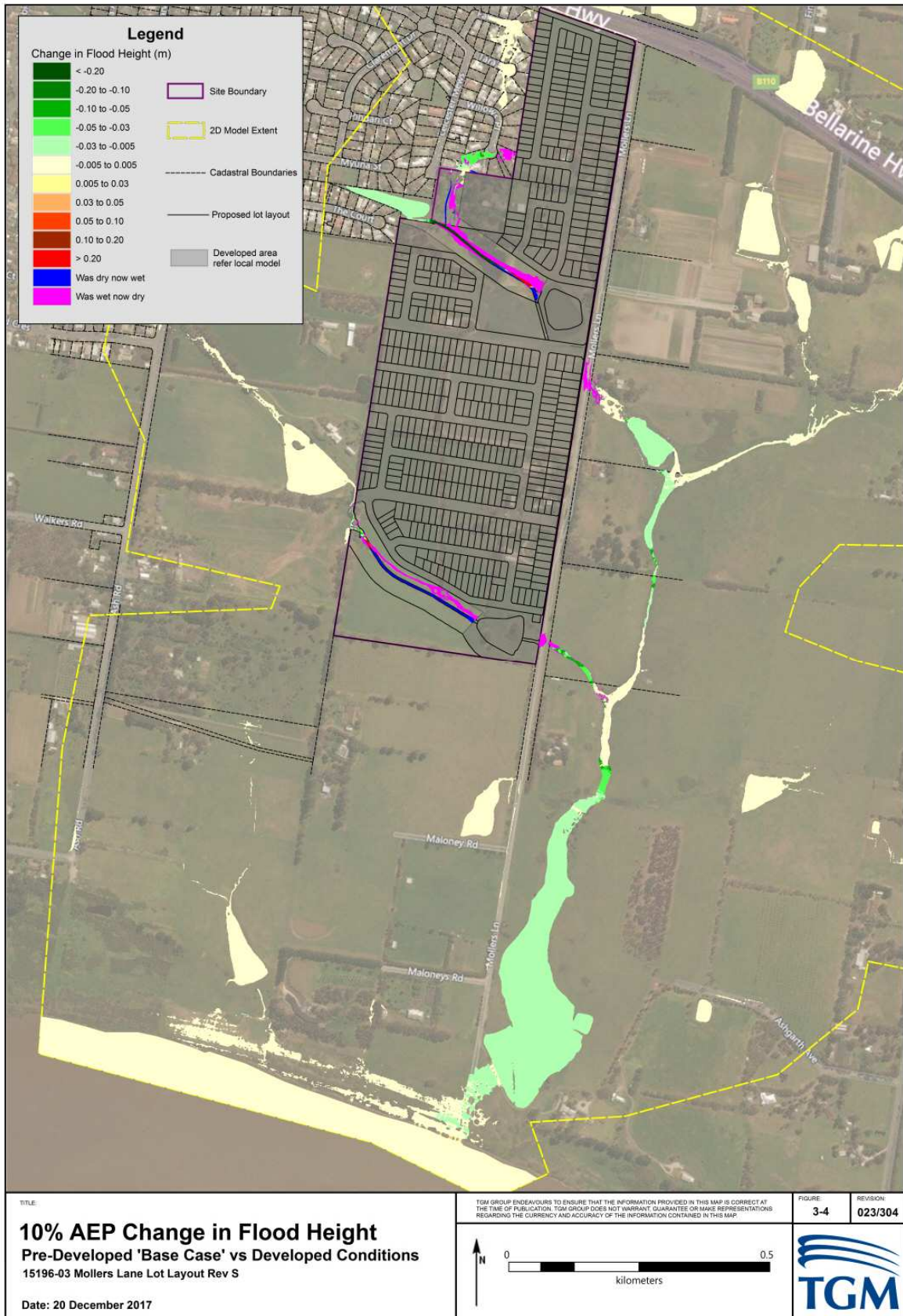


Figure 7-23: Change in Flooding 10% AEP Impact Map (depths  $\geq$  50 mm)

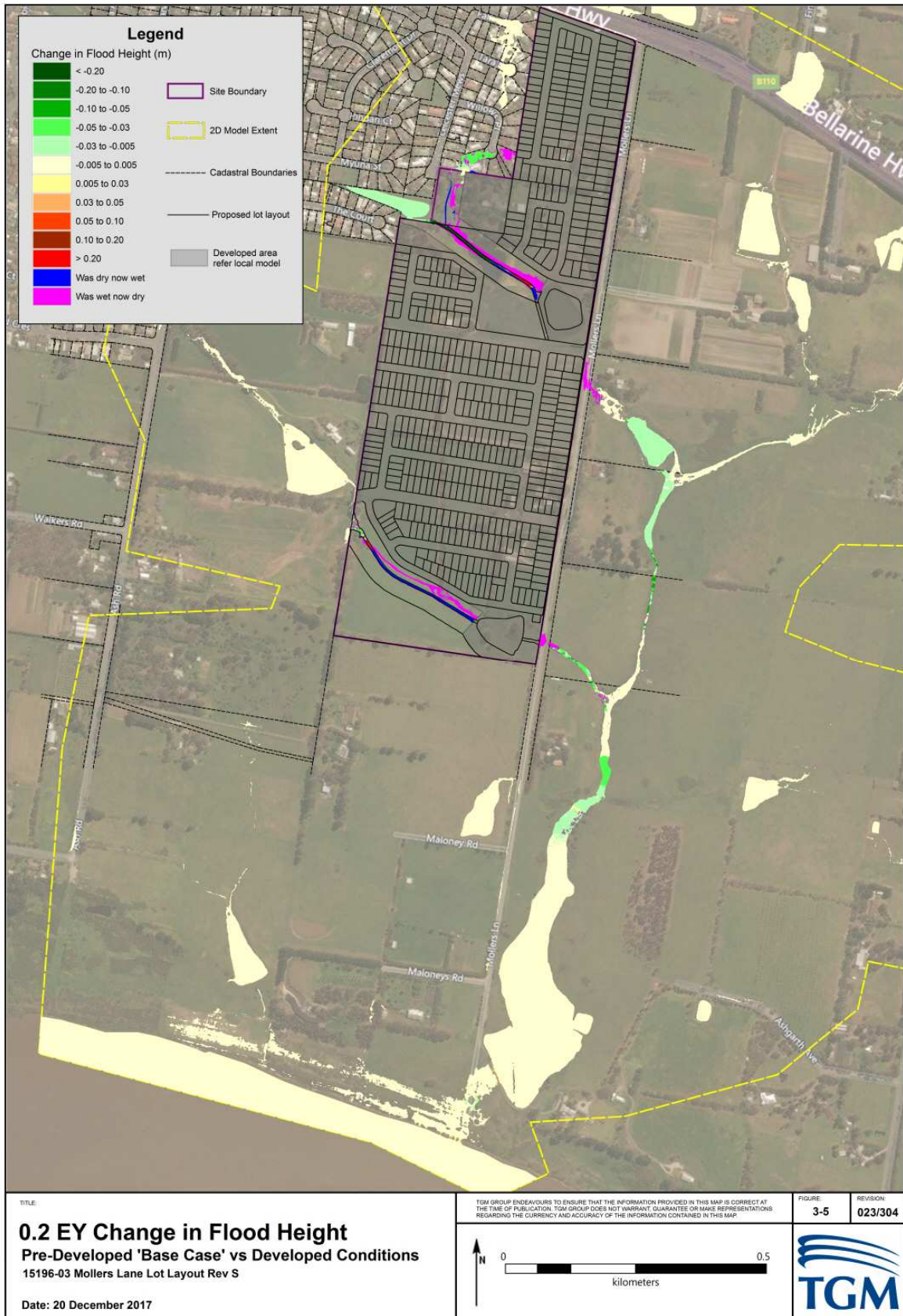


Figure 7-24: Change in Flooding 0.2 EY Impact Map (depths  $\geq$  50 mm)

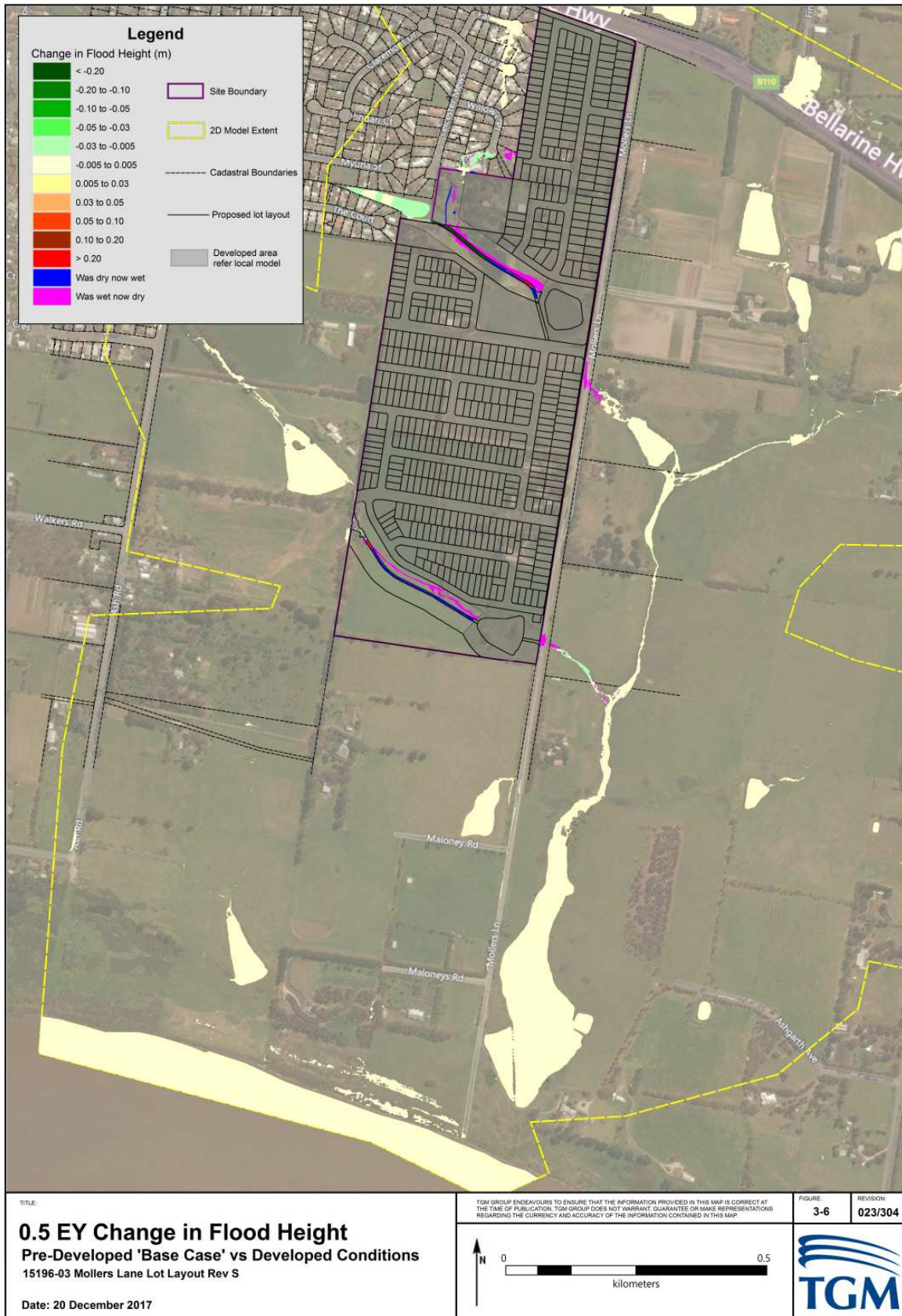


Figure 7-25: Change in Flooding 0.5 EY Impact Map (depths ≥ 50 mm)

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### 7.3.6 Hazard Mapping

The hazard mapping was undertaken using the methodology in ARR 2016, Book 6, and Chapter 7 – ‘Safety Design Criteria’. The hazard analysis is used to determine whether it is safe for people and vehicles to move during a flood event.

Development should not occur where depth and flow of flood water on a property will be hazardous. Safety is defined in terms of the depth, velocity and the product of the depth multiplied by velocity.

Safety criteria during a 1% AEP flood event are:

**1. For People**

- Depth must be no greater than or equal to 0.5 metres;
- Velocity must be no greater than or equal to 3.0 m/s; and
- The product of depth by velocity must be no greater than or equal to 0.4 m<sup>2</sup>/s.

**2. For Vehicles**

- Depth must be no greater than or equal to 0.3 metres;
- Velocity must be no greater than or equal to 3.0 m/s; and
- The product of depth by velocity must be no greater than or equal to 0.3 m<sup>2</sup>/s.

The Hazard Mapping shows the depth, velocity, velocity depth product and the overall hazard envelope for the range of events up to and including the 1% AEP.

The overall hazard envelope maps are shown for predeveloped and developed conditions below. The mapping for Depth, Velocity and Velocity x Depth can be seen in Appendices

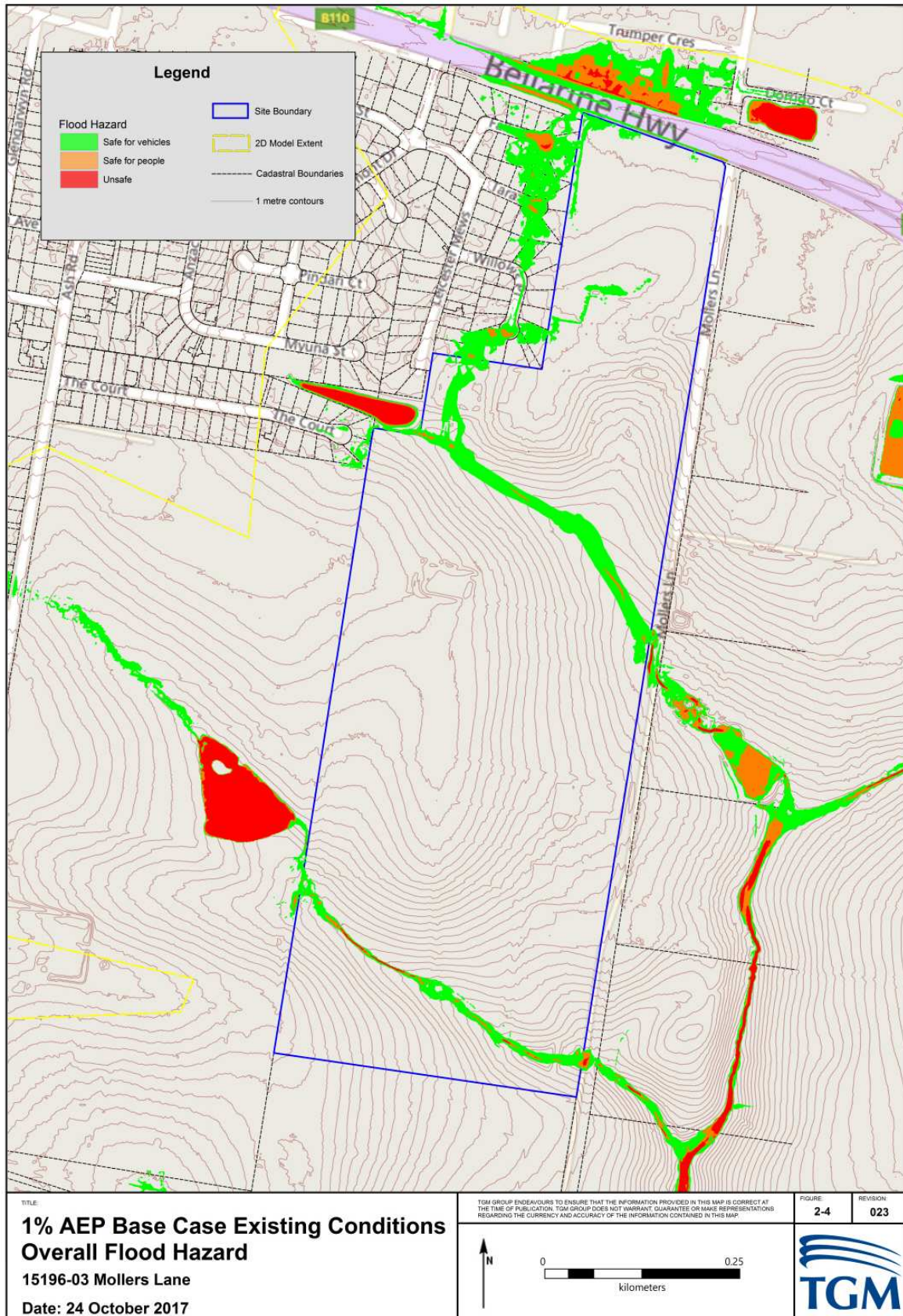


Figure 7-26: Predeveloped 1% AEP Hazard Envelope

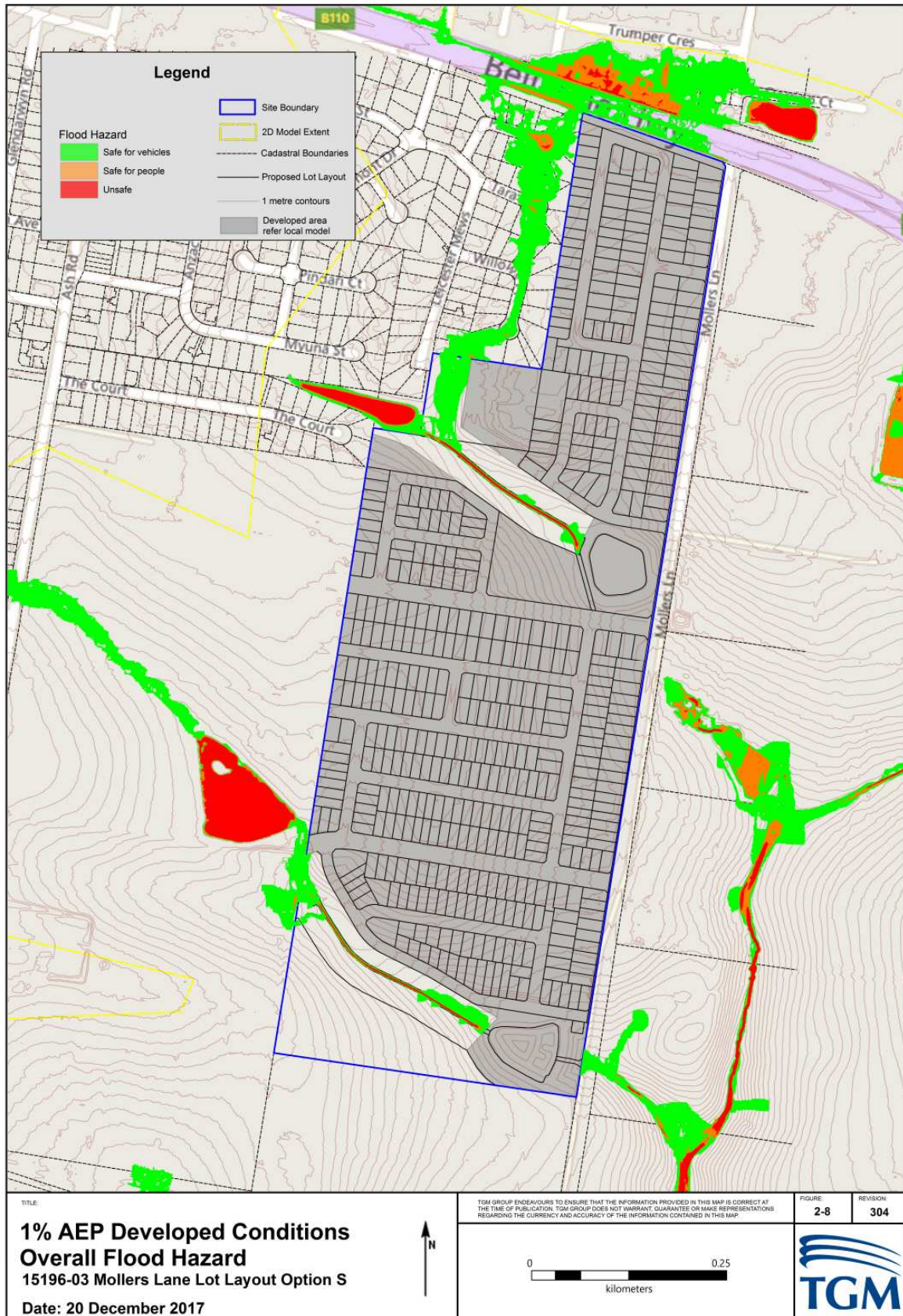


Figure 7-27: Developed 1% AEP Hazard Envelope

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Figure 7-27 does not indicate the presence of hazards related to the safety of people and vehicles or prohibit access/egress from the developed site to Mollers Lane or Bellarine Highway during the 1% AEP flood event.

Comparison of hazards shown in Figure 7-27 (developed) and Figure 7-26 (predeveloped) show that existing hazards are not exasperated as a result of the development of the subject site.

## 8. CONCLUSION

The stormwater management section of the report proves that stormwater runoff generated within the developed Mollers Lane site in Leopold can be mitigated to exceed 'best-practice' reductions in stormwater contaminant loadings and achieve design requirements for site discharges for the full range of storm events.

The continuous simulation model MUSIC was used to design and confirm the mitigation required to meet water quality discharge objectives. Water quantity mitigation was designed using XP-STORM.

A full and proper hydrological and hydraulic flood investigation was undertaken applying the latest analytical techniques, research and science described in Australian Rainfall and Runoff 2016 to define the regional flood event for CoGG catchments 13, 14 and 15.

A fully two-dimensional TUFLOW model was developed, applying hydrological inputs from XP-STORM to define the regional flooding for a range of events, to ensure that the proposed residential development at Mollers Lane, Leopold has no adverse impacts on flood characteristics external to the site and to ensure that the development meets specific objectives for safety and egress during floods.

The flood risk assessment identified that the development site is not adversely affected by the regional flood for events up to and including the 1% AEP. This study has demonstrated that the proposed developable land area is not subject to inundation during the analysed range of storm events.

Flood risks, associated with safety hazards, are relatively low as the 'unsafe' characteristics are contained within the existing waterway.

The flood impact assessment identified no negative impacts resulting from the proposed development of the Mollers Lane site on the regional flood characteristics. The development results in reduction in flood extents and/or no change to flood extents during the analysed events.

Conveyance of stormwater flow through the site will be achieved by underground drainage systems and overland flow path within the road reserves to the wetland detention basin facilities.

Stormwater conveyance through the developed site was not modelled in 2d. To undertake a 2d analysis of the developed site requires a design surface. Given local topography it was not deemed necessary to undertake a 2d analysis of the site at this stage. The ability of the proposed subdivision drainage system to convey stormwater flows, for events up to and including the 1% AEP, through the site will be investigated during the projects detailed design phase.

Clearly defined flow paths and steep terrain will easily accommodate the proposed developed site drainage system. A functional design surface will be developed during the detailed design stage of the project.

The analysis undertaken in this study has demonstrated that the proposed development can be constructed and meet the requirements and objectives for site stormwater management, through assessment of the flood impact and safety performance of the development during regional flood events.

This study did not allow for stormwater mitigation of runoff from the land east of Ash Road and west of the defined subject site. Development of the Ash Road site will require an individual SSMP and FIA to be undertaken at time of rezoning.

## 9. REFERENCES

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- CCMA Flood Advice F-2015-0889. Leopold South Growth Area, Ash Road to Mollers Lane, Leopold. 14 December 2015

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## **APPENDICES**

### **Hazard Mapping – Depth 1% AEP – Predeveloped and Developed**

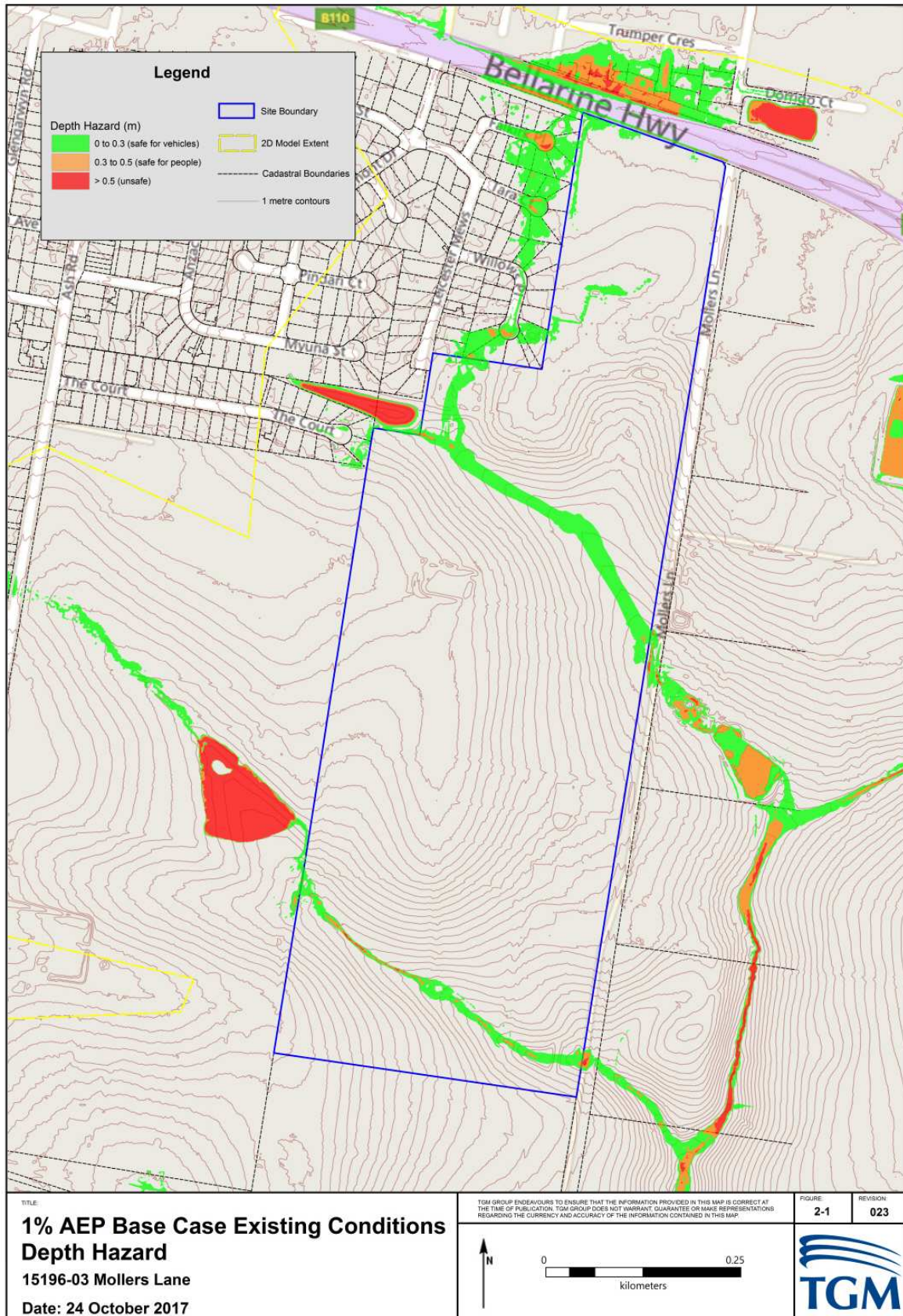


Figure 0-1: Predeveloped 1% AEP Depth Hazard

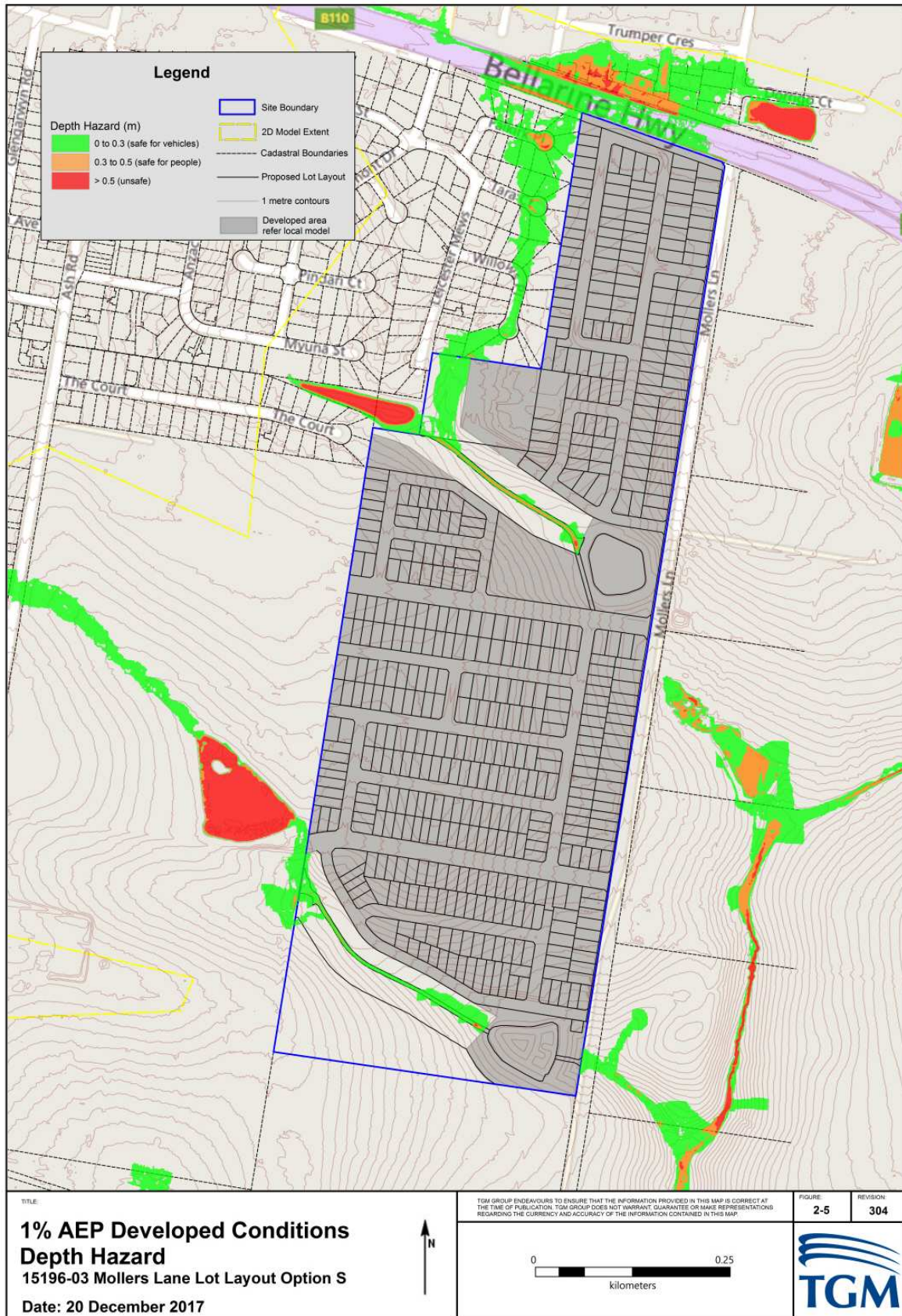


Figure 0-2: Developed 1% AEP Depth Hazard

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## **Hazard Mapping – Velocity 1% AEP – Predeveloped and Developed**

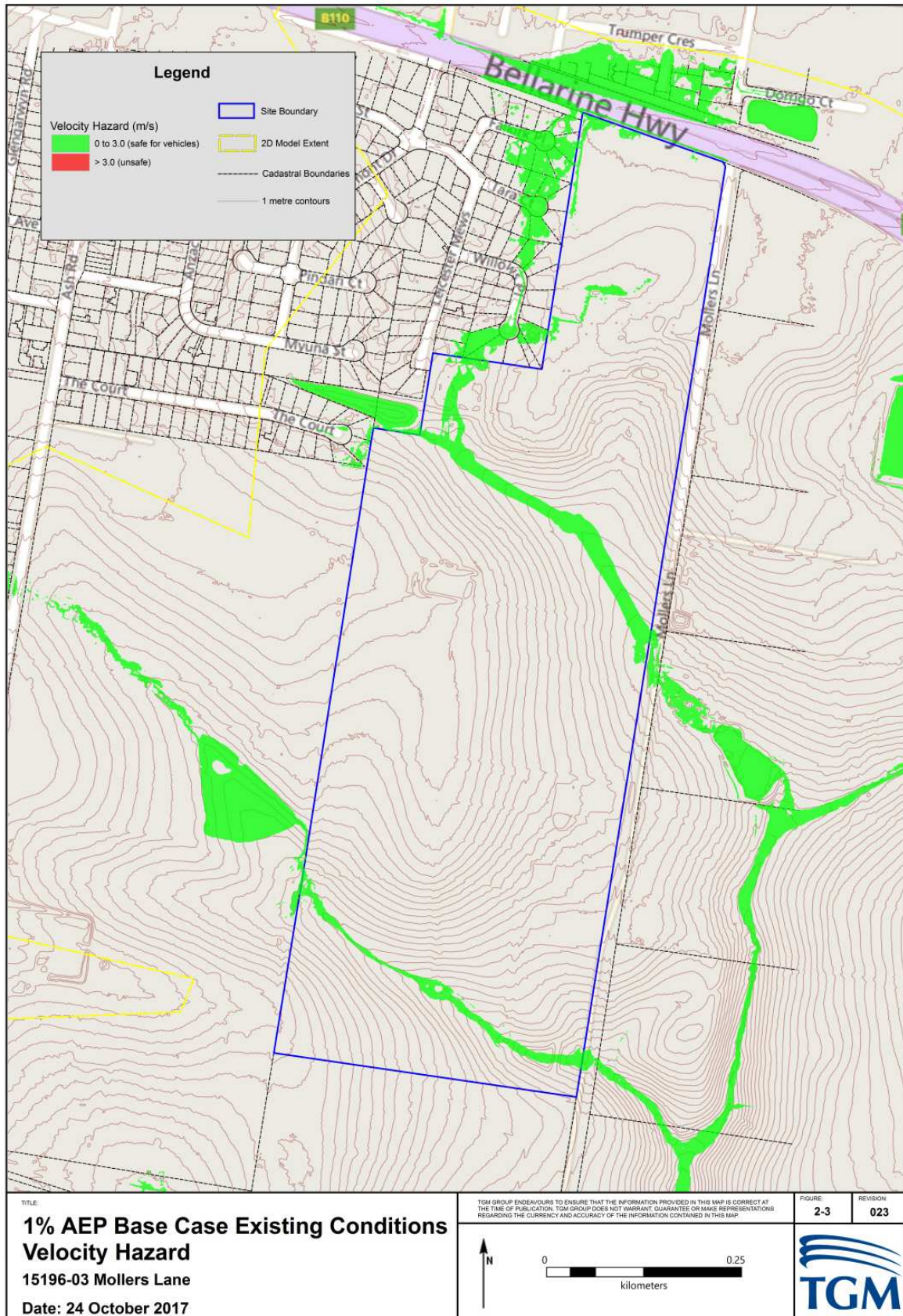


Figure 0-3: Predeveloped 1% AEP Velocity Hazard

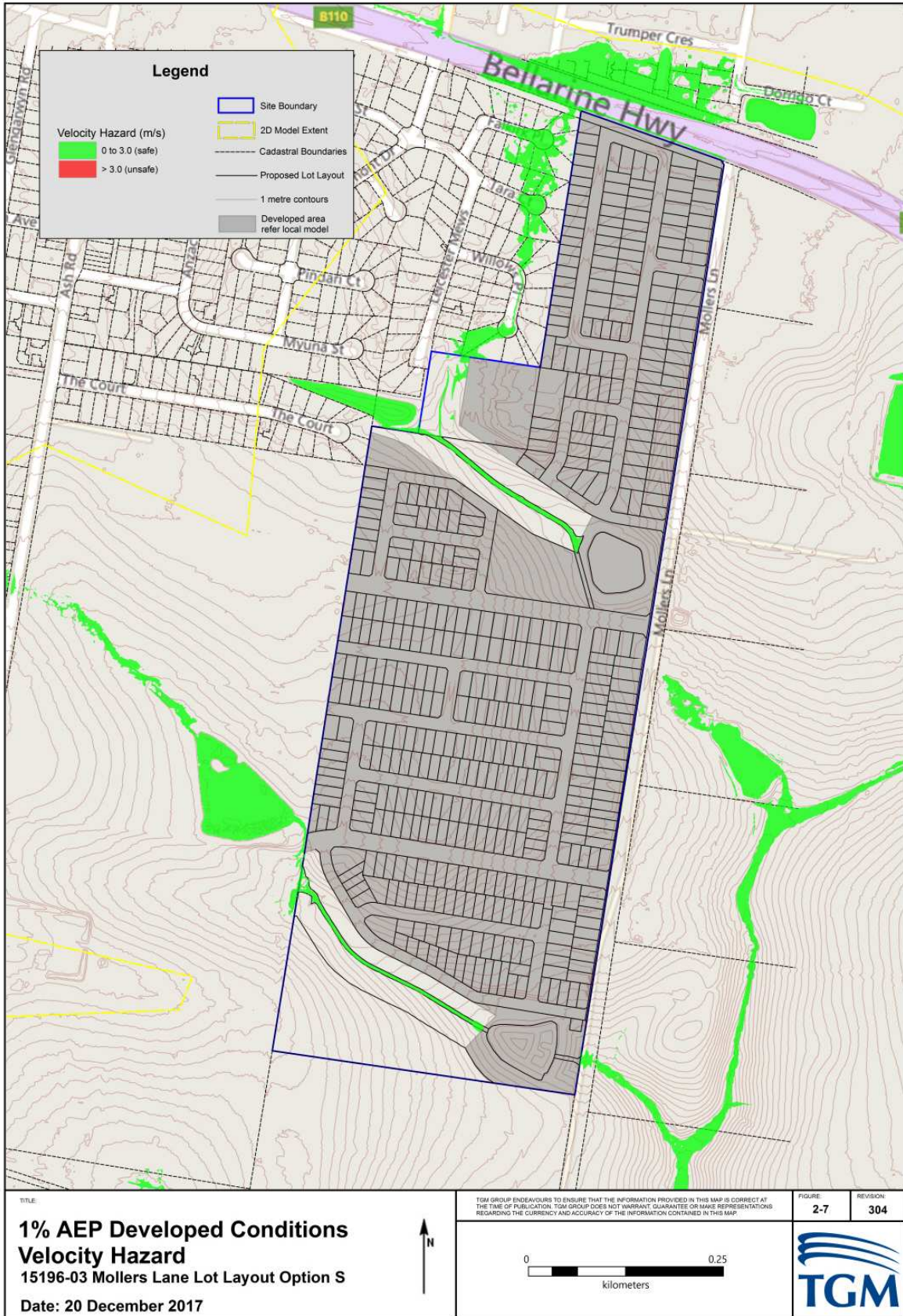


Figure 0-4: Developed 1% AEP Velocity Hazard

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## **Hazard Mapping – Velocity x Depth 1% AEP – Predeveloped and Developed**

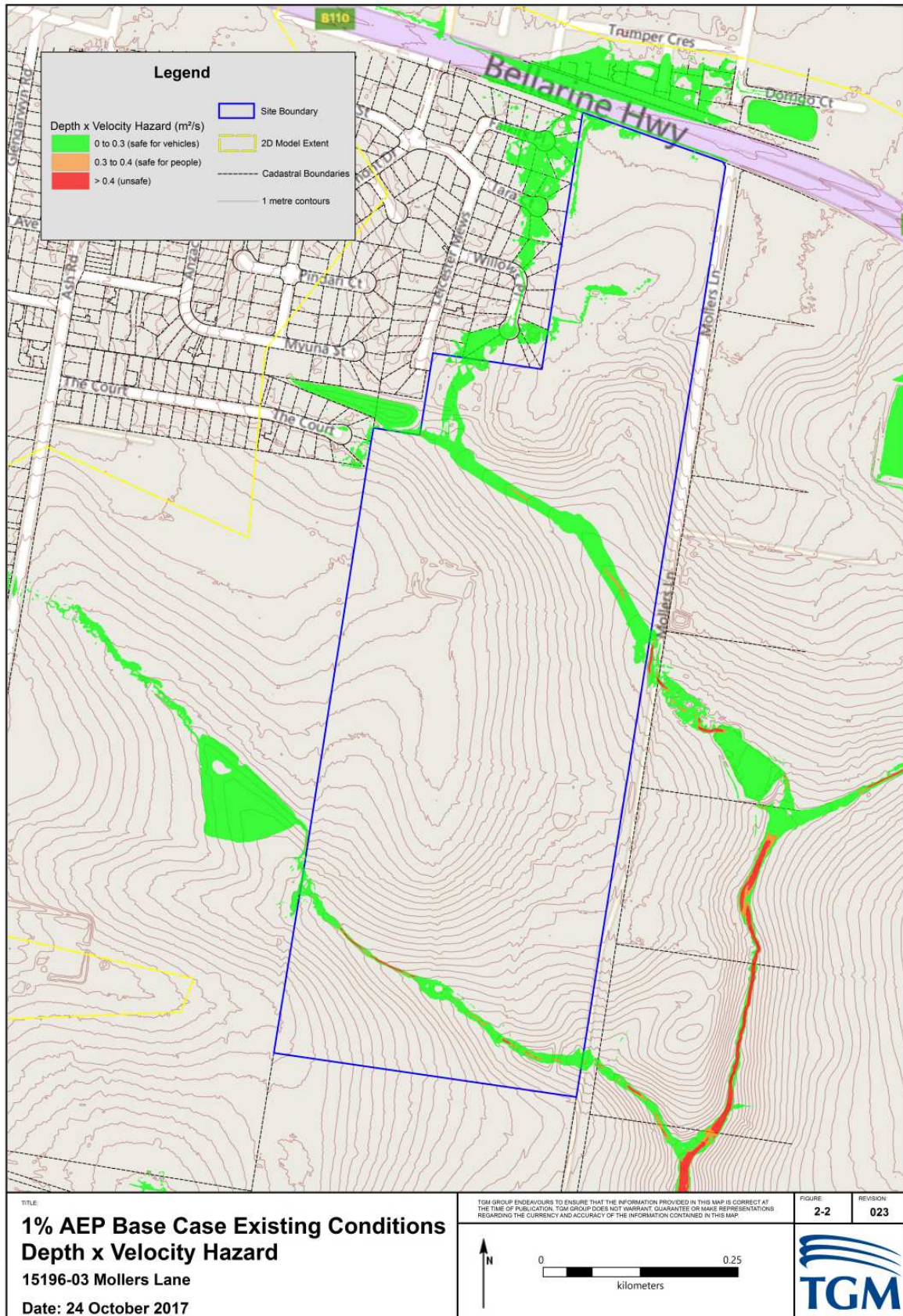


Figure 0-5: Predeveloped 1% AEP Velocity x Depth Hazard

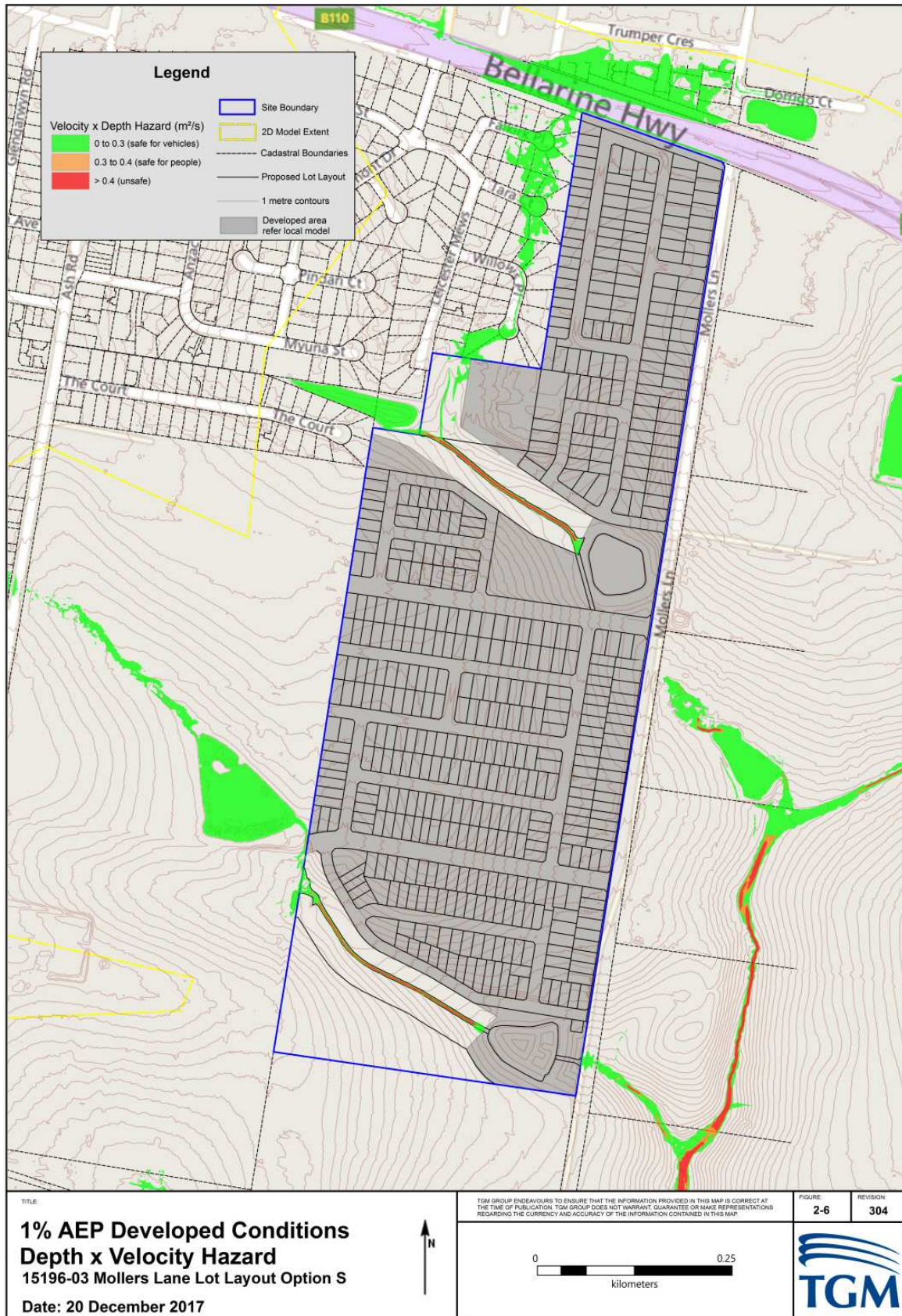


Figure 0-6: Developed 1% AEP Velocity x Depth Hazard

