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Floodplain Risk Management Plan Proposed Development at Meadow Views, Calderwood

for Illawarra Land Corp Pty Ltd

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Floodplain Risk Management Plan
Planning Proposal at Meadow Views, Calderwood

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1. INTRODUCTION

1.1. BACKGROUND AND PROPOSED DEVELOPMENT

The owners of the subject site seek to submit a Planning Proposal (PP) to Shellharbour City Council (SCC) to facilitate residential development on the land. The subject site comprises Lot 2 in DP 651377 and Lot A in DP 382471, and is located between Calderwood Road and Marshall Mount Creek. The subject site is currently used for grazing. Portions of the site are flood affected based on previous flood modelling and historic records. As such, Illawarra Land Corp Pty Ltd has engaged Rienco Consulting to prepare a suitably detailed Floodplain Risk Management Plan that addresses the requirements of the Section 9.1 Direction Clause 4.3, as further described in **Section 1.2**.

The proposed development consists of a residential subdivision, as summarised in **Figure 1.1-1** below. The proposal consists of a road network providing access to a series of lots of varying sizes. The proposal also involves the removal of an existing dam on the site, located 'online' in a minor tributary of Marshall Mount Creek.

Figure 1.1-1 Proposed Development Plan

Note: Plans supplied by Indesco. North is at the top of the figure.

1.2. PURPOSE OF THIS REPORT

The purpose of this report is to:

a) Review of existing flood information available for the site.
b) Prepare a detailed hydrologic and hydraulic model that determines peak flood levels at the subject site for a range of events up to and including the Probable Maximum Flood (PMF).

c) Determine the potential impacts of the proposed development, and the associated flood hazard categorisation.

d) Review the proposed development, together with the hydraulic model results, and assess it against:

   (a) Section 9.1 Directions relating to flooding, and

   (b) Clause 6.3 of the SLEP (2013, as amended).

e) Prepare a report summarising the above suitable for lodgement with SCC with the PP.

1.3. LIMITATIONS AND ASSUMPTIONS

This report has been strictly prepared for the purposes stated in this report for exclusive use by the client. No other warranty, expressed or implied, is made as to the advice included in this report. This study specifically focuses on the quantification of flood behaviour at the subject site, given current conditions. This study does not address flood behaviour for other sites within the overall catchment.

2. AVAILABLE DATA

2.1. SITE DESCRIPTION

The site is located in Calderwood, NSW and is a larger rural land holding. It is bounded to the north, east and west by rural lands, and tributaries of Macquarie Rivulet, being Marshall Mount Creek. The site is bounded to the south by Calderwood Road, and the Calderwood Urban Development Project. The site is currently used as grazing land. **Figure 2.1-1** presents an aerial image of the site and surrounds.

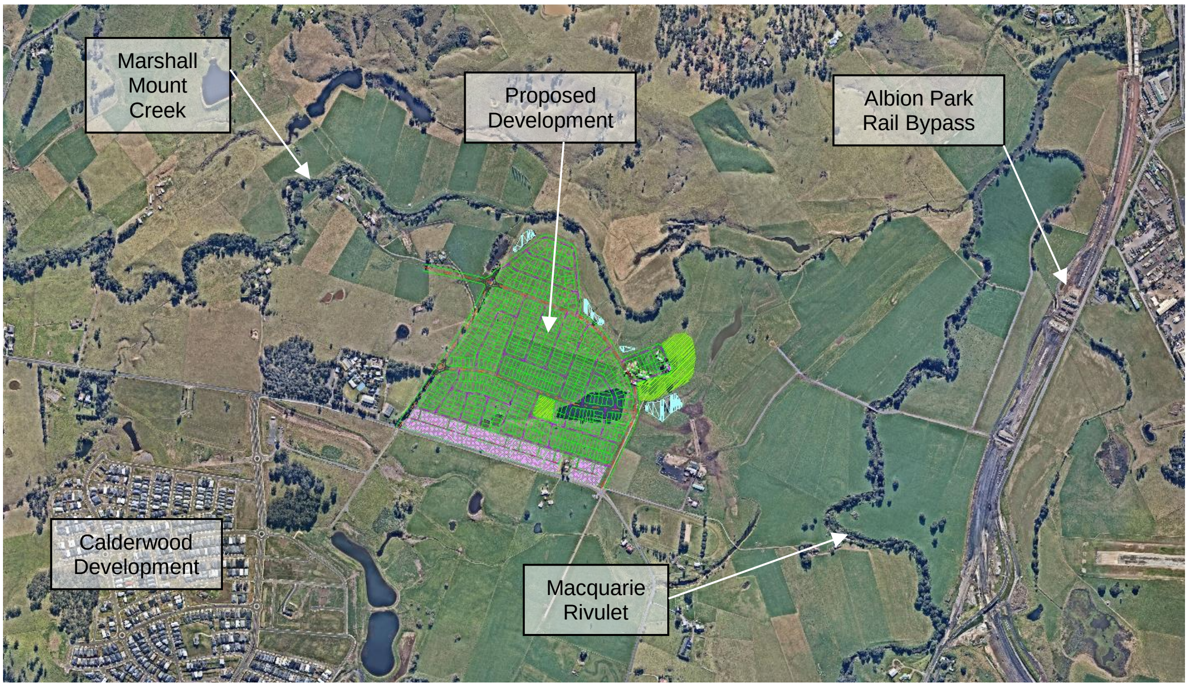

Figure 2.1-1 Subject Site

Note: Image sourced from NearMaps.

2.2. CATCHMENT DESCRIPTION

The catchment of Macquarie Rivulet lies within the Lake Illawarra sub-basin of the Wollongong Coastal Basin (#214). It drains 107 km^2 of mostly forested and rural lands and is located some 100 km to the south of Sydney on a thin band of coastal land between the Illawarra escarpment and the Tasman Sea. Macquarie Rivulet has its headwaters on the escarpment near Robertson, flowing east over the escarpment, to ultimately discharge into Lake Illawarra.

The drainage network of Macquarie Rivulet comprises three main arms:

- Macquarie Rivulet (the main arm draining the central portion of the catchment)
- Frazers Creek (a secondary arm draining the south-eastern sector)
- Marshall Mount Creek (a major arm draining the northern sector and the arm that passes through the subject site).

All three arms combine on the flood plain above the Princes Highway, to the immediate west of Albion Park airport. In large events, flows merge across the full width of the flood plain at this location to form a single near level pool of floodwater.

All three sub-catchments are predominantly rural with some existing urban development in the lower reaches of Frazers Creek and Macquarie Rivulet, around Albion Park. Areas to the west and south west of Albion Park are at present undergoing significant urban development.

Hazelton, Cooback and Yellow Rock Creeks are tributaries of Macquarie Rivulet, draining an area of mostly rural land to the south of the Illawarra Highway. The subject site has the potential to be affected by flooding from both Macquarie Rivulet and Marshall Mount Creek. A catchment plan for areas upstream of the subject site is included as **Appendix B**.

2.3. SURVEY DATA

Topographic information was also available, in the form of Airborne Laser Scan (ALS) data. The NSW Government's Land & Property Information department (LPI) have supplied a 1m DEM from the 2011 ALS dataset. Aerial imagery (2020) was also supplied for the subject site and surrounds via Nearmap.

2.4. SITE INSPECTION

A site inspection was undertaken by the author in September 2020. The site inspection confirmed the adequacy of the survey information used in this study.

2.5. PREVIOUS STUDIES

2.5.1. Flood Report on Macquarie Rivulet Below Sunnybank (Rienco, 2011)

This report was commissioned to quantify flood behaviour in Macquarie Rivulet as part of the environmental studies required to support the Calderwood development.

Modelling was undertaken to quantify existing flood behaviour in the Macquarie Rivulet system in the general vicinity of the junction of Macquarie Rivulet and Marshall Mount Creek where a residential development is currently proposed. The modelling involved data collection, construction, calibration and validation of hydrologic and hydraulic models and determination of existing flood discharges and levels in the vicinity of the proposed development for the 5yr and 100yr Average Recurrence Interval (ARI) events and the PMF.

Data collection included, aerial survey, creek and structure survey and the collection and collation of recorded rainfall, flood heights and lake level data for historic storms. Calibration of models was undertaken using the 11^{th} June 1991 flood event, with a high level of correlation between recorded and simulated peak flood discharges and levels.

Using this calibration and allowing for changes occurring in the catchment between the June 1991 event, and the present, flood behaviour in the study area was then modelled for the 5%, 1% AEP and PMF design flood events. It is noted that this 'design' event modelling incorporated consideration of blockage but did not consider the impact of future climate change. The modelling quantified flood levels, velocities, depth, unit flow (conveyance) and provisional hydraulic hazard through and in the vicinity of the proposed development site.

2.5.2. Albion Park Rail Bypass EIS Technical Paper 3 (Cardno/Hyder, 2015)

This report was prepared to inform the design of the APRB project, and enable an accurate assessment of the flood impacts that can be expected to result. The technical assessment was prepared to meet the following objectives:

- Document the existing environment with respect to the hydrology and flooding within the project area.

- Document the impacts that can be expected to result from the proposal on hydrology and flooding.
- Provide technical information to inform the project design and enable impacts of the project to be minimised through design.
- To fully address all elements of the Secretary's Environmental Assessment Requirements (SEARs) which are relevant to hydrology and flooding.

Within the context of the subject site, the report notes that increases in peak flood levels will be necessitated as a result of the APBR project. Specifically, it concludes that:

> *In general, the desired higher level of flood immunity for new roads is likely to cause flooding impacts within the flood affected areas, because the new roads act as a barrier to flows. For this project, increased flood levels within the Macquarie Rivulet catchment are predicted to extend over the floodplain between Tongarra Road, Marshall Mount Creek and the existing Princes Highway. These impacts are primarily due to additional fill within the floodplain.*

The predicted impacts from the concept design (as noted in the above report) were then later superseded by the SMEC report (2018) which documents the detailed design. The SMEC report is also summarised below.

2.5.3. Macquarie Rivulet Flood Study (WMA Water, 2017)

This report was prepared for Shellharbour Council as a catchment wide study prepared in accordance with the FPDM guidelines, detailing a calibrated and validated hydrology and hydraulic model, as well as design flood estimation. It was formally adopted in 2017.

The Study carried out a Flood Frequency Analysis (FFA) which was the first of its kind in the catchment. The Study notes that in terms of the design flood estimation:

> *….the results of the Flood Frequency Analysis were reconciled against both the ARR 1987 and BOM2013 rainfall data. It was found that neither set could be completely reconciled against the results of the Flood Frequency Analysis using reasonable hydrologic model parameters. Subsequent to discussion with Council and OEH it was recommended to adopt the ARR 1987 IFD and apply a reduction factor of 86% to allow flows to reconcile with flood frequency analysis. This reduction also includes the areal reduction factor.*

It is therefore interpreted that the ARR1987 design rainfall intensities were reduced by 86%, and the areal reduction factor (ARF) was left calculated as per the ARR1987 guidance, further reducing the rainfall depth contributing to runoff.

Whilst using slightly different approaches to calibration and validation, and also some more significantly different approach to design flood estimation, the results of the 2017 Study are markedly similar to Rienco (2011). Its results need to be considered in context, given the changes in the catchment that have occurred since the report was finalised.

2.5.4. Flooding and Scour Assessment, Albion Park Rail Bypass (SMEC, 2018)

The Flooding and Scour assessment report has been prepared to support the design verification process by providing supplementary information to demonstrate design compliance for detailed design. Materially, the report verified the flood-related performance of the detailed design of the Albion Park Rail Bypass, and carried out additional checks on the erosion and scour potential of the works in accordance with the consent conditions.

Figure 2.5-1 below is an extract from the 2018 report, summarising the peak flood surface level impacts generated by the APRB in the 1% AEP design flood. **Figure 2.5-2** is a similar extract for the Probable Maximum Flood (PMF) event. The 'impacts' are measured from the 'pre-development' scenario, which is materially the same peak flood level in Rienco (2011), Hyder/Cardno (2015) and WMA Water (2017).

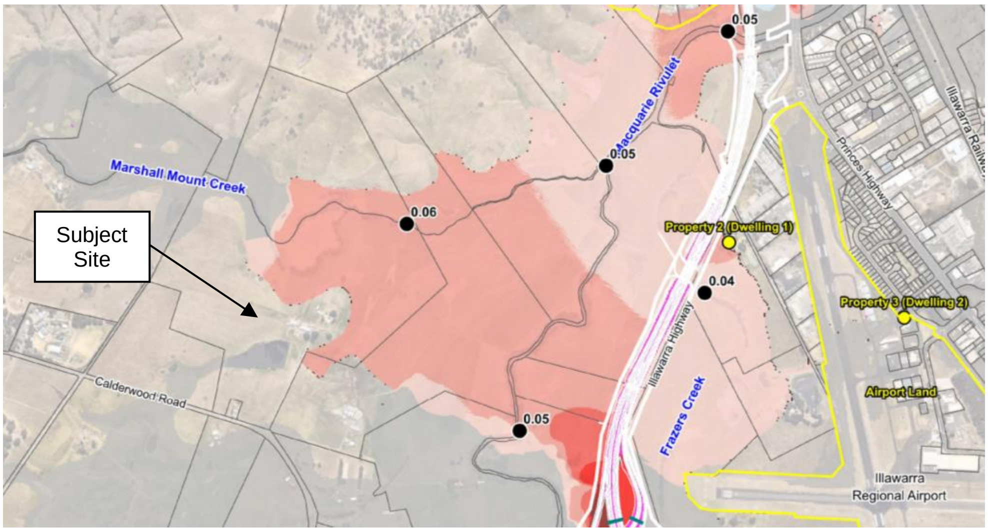

Figure 2.5-1 Albion Park Rail Bypass – Increases in 1% AEP Flood Levels

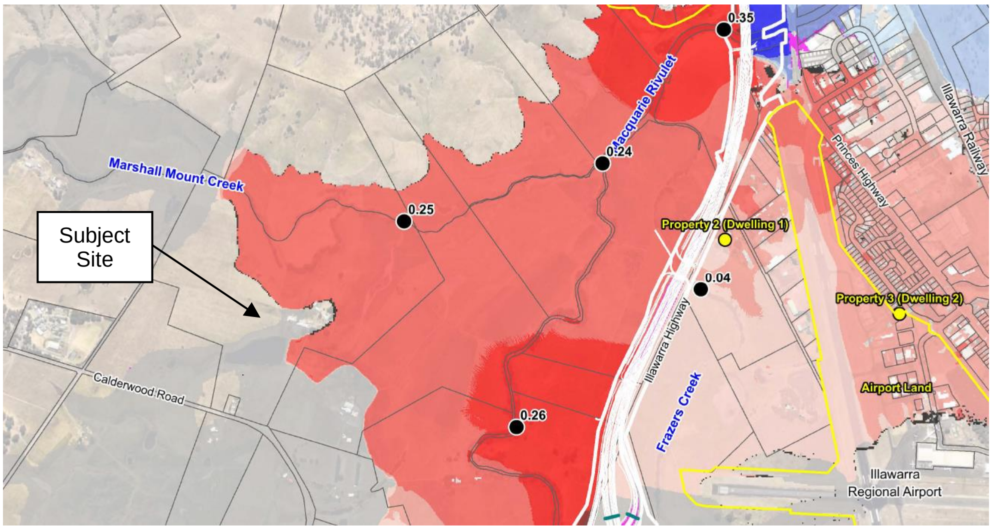

Figure 2.5-2 Albion Park Rail Bypass – Increases in PMF Levels

It can be seen that at the subject site, the APRB works have caused an increase in peak flood surface levels of 60 mm in the 1% AEP design flood, and 250 mm in the PMF. At the subject site, these increases are consistent with Hyder/Cardno (2015).

2.5.5. Watercycle and Flood Management Strategy Updates (JWP, 2018)

The Watercycle and Flood Management Strategy Updates report was published for the Calderwood Urban Development Project Section 75W Application on 13 July, 2018 by J. Wyndham Prince (JWP).

This report was an update to the Watercycle and Flood Management Strategy previously prepared to support the Calderwood C oncept Plan Approval (MP09_0082) for the Calderwood Urban Development Project (CUDP). It accompanied an Environmental Assessment Report

(EAR) for a proposed S75W Modification Application to the approved Concept Plan, which seeks to increase the total number of dwellings within CUDP from approximately 4800 to approximately 6500.

This Study documents the intended 'post-development' landform for the CUDP, which includes some landform modifications that modify the cross catchment diversion that occurs between Macquarie Rivulet and Marshall Mount Creek. This is important the subject site, because the current cross-catchment diversion occurs through the subject site and therefore the construction of the CUDP creates a significant flood behaviour reduction on the subject site.

The flood model results show that for the 1% AEP design flood, the cross-catchment diversion is eliminated. In the PMF, the cross-catchment diversion is modified, and flows around some of the CUDP fill platforms. This accentuates the PMF across the subject site in places, which can be adequately managed via a minor amount of filling on the subject site adjacent to Calderwood Road. This is discussed elsewhere in this report.

3. HYDROLOGIC MODELLING

3.1. HYDROLOGY MODEL DEVELOPMENT

A WBNM model has been utilised for this study, to determine peak flows at the subject site for events up to and including the PMF. WBNM is an advanced storage-routing model that allows simulation of complex catchment behaviour. Further details of the models capabilities are available in the Research & Development section of www.wbnm.com.au. This particular model was considered most appropriate to the task of modelling the study area, given its ability to simulate a wide range of catchment characteristics and its extensive use in the region. The model allowed flows to be established at various locations of interest throughout the model domain.

The model was established consistent with Rienco (2011). The hydrologic model was developed by Rienco (2011) as part of a calibrated and validated hydrology and hydraulic model suite, which also carried out various design flood estimations. Model parameters were as per **Table 3.1-1**, and peak flow estimates were as per **Table 3.1-2**. Model parameters used in WBNM are consistent with locally derived parameters in calibrated and validated WBNM models, and are deemed appropriate for use in this study.

Table 3.1-1 – Summary of WBNM Model Parameters

Parameter	Adopted Value
Initial loss (pervious surface)	0 mm
Continuing loss (pervious surface)	2.5 mm/hr
C (Lag parameter)	1.3

Three design rainfall gauge were used from the AR&R isohyetal datasets and incorporated into the model, consistent with Rienco (2011). A detailed catchment plan is included as **Appendix B**.

3.2. HYDROLOGY MODEL RESULTS

The WBNM model was then run for a full range of durations for the 1% AEP and PMF events. **Table 3.2-1** below describes the peak flow estimates from the WBNM modelling for each of the critical sub-areas. At the subject site, the critical duration design storm for the 1% AEP event is 120 minutes, and 60 minutes for the PMF, consistent with previous estimates (Rienco, 2011).

Table 3.2-1 – Summary of Peak Flow Estimates at Various Locations

Location	1% AEP Peak Flows 120 min. Critical Duration	PMF Peak Flows 60 min. Critical Duration
Marshall Mount Creek – Upstream Site Boundary (Approximate WBNM Sub MarsG)	358 m^3/s	796 m^3/s
Marshall Mount Creek – Downstream Site Boundary (Approximate WBNM Sub MarsH)	386 m^3/s	859 m^3/s

In terms of the models reported critical duration, the results are consistent with Rienco (2011) and WMA Water (2017). WMA Water (2017) note that:

> *The nine-hour storm was found to produce the highest flows and levels across the majority of the catchment. However, the two-hour storm was found to produce the highest flows and levels across Frazers Creek and Albion Park. As such, the envelope of the two-hour and nine-hour storms was derived to define the peak flood behaviour in the catchment.*

The 2 hour design rainfall event also produces the highest peak discharges through the subject site in Marshall Mount Creek. In terms of overall consistency with the WMA Water (2017) Study, we form the view that our results are conservative at the subject site because:

1. We have used an Areal Reduction Factor (ARF) of 1.0, thus not reducing the design rainfall in a manner that the WMA Water (2017) report suggests.
2. We have not reduced our design rainfall intensities by 14%, in a manner that the WMA Water (2017) report suggests.

We further consider that our hydrologic model results are additionally conservative, because the Design Flood Estimation (DFE) carried out in this report has been performed under the obsolete procures contained in Australian Rainfall and Runoff (1987). The most appropriate design flood estimation procedure to be used by practitioners in Australia is found under the updated version of Australian Rainfall and Runoff (2019). The updated 2019 version, when used with the latest design rainfall data produced by the Bureau of Meteorology, corrects a number of known errors in the 1987 procedure, particularly in Wollongong.

At this time, Shellharbour Council are not allowing the updated ARR19 procedure to be used within the LGA, and mandate that the obsolete ARR87 procedure be maintained. Whilst we do not agree with this principal, we have prepared this report consistent with SCC's desired procedures at this time.

4. HYDRAULIC MODELLING – PRE DEVELOPMENT

4.1. HYDRAULIC MODEL DEVELOPMENT

The model grid was established as a 5m grid across the entire model domain. The 2011 ALS data was used exclusively to extract elevation data to the TUFLOW grid, which is described in **Figure 4.1-1**.

In terms of inflow boundary conditions, inflow hydrographs were directly input from the WBNM model results. The downstream boundary condition was set to a fixed water surface level, derived from Rienco (2011) and modified to suit SMEC (2018). The downstream boundary condition is sufficiently downstream of the subject site to allow flood behaviour at the site to be satisfactorily determined. Downstream boundary condition details are presented in **Table 4.1-1**.

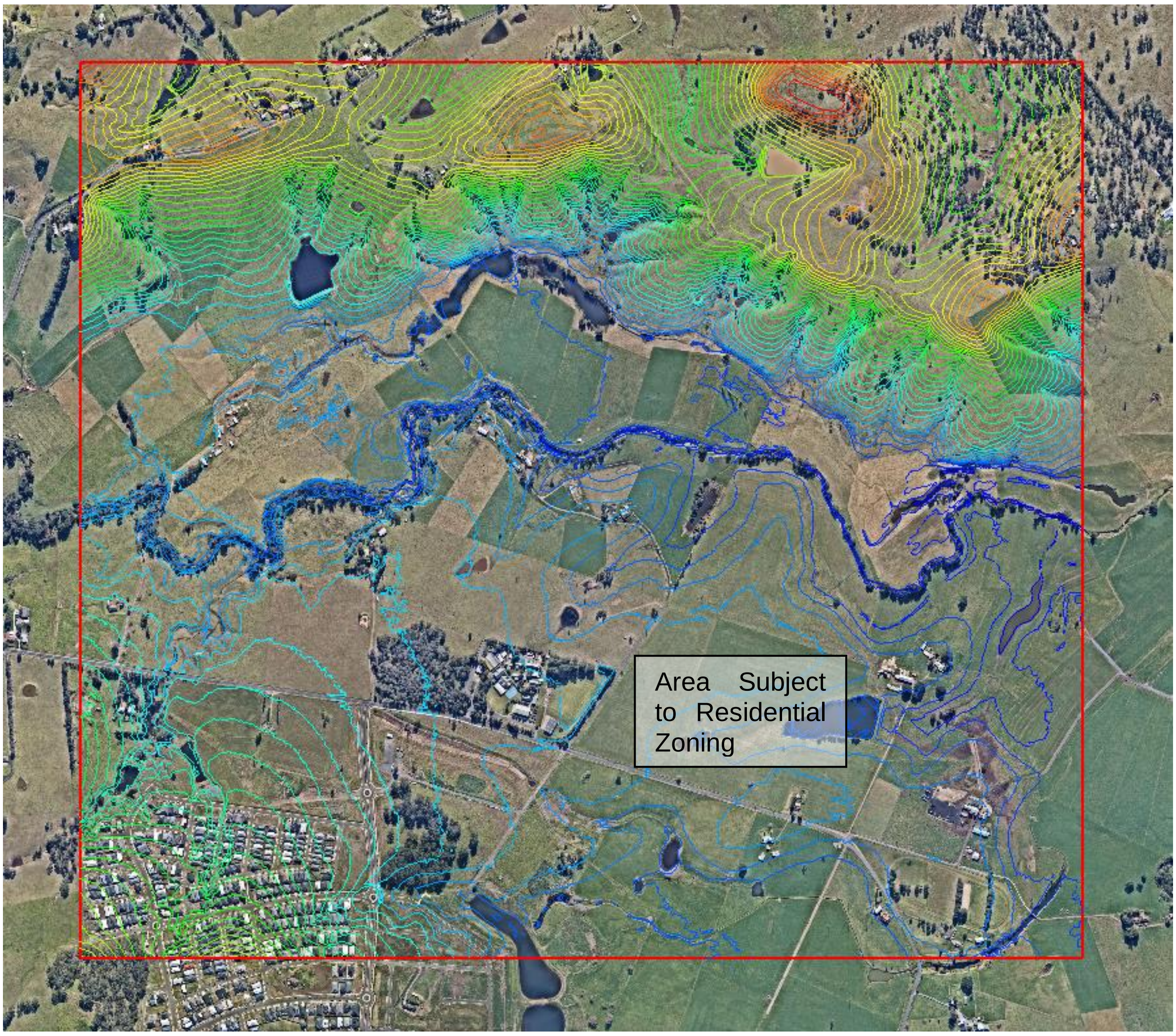

Figure 4.1-1 TUFLOW Grid and Boundary Condition Details

Note: TUFLOW 5m domain shown as red line. Subject site is shown indicatively.

Manning's surface roughness 'n' values were categorised and mapped, with each of the roughness zones then ascribed roughness characteristics. The values initially used for model establishment were derived from consideration of various industry recommendations (including Chow (1959), Hicks *et al* (1991) and Arcement *et al* (1984)), further adjusted to account for local conditions and Rienco's experience in previous 2D modelling in the Illawarra. All roughness values are consistent with those in the calibrated and validated Rienco model (2011). **Figure 4.1-2** describes the surface roughness mapping.

Table 4.1-1 – Adopted Downstream Boundary Condition Levels

Event	Peak Flood Surface Level at Site Boundary (Before APR)	Peak Flood Surface Level at Site Boundary (After APR)
1% AEP	RL +6.65m AHD	RL +6.71m AHD
PMF	RL +8.49m AHD	RL +8.74m AHD

There is a known diversion of runoff across Calderwood Road, from Macquarie Rivulet into Marshall Mount Creek through the subject site. The peak flood depths across Calderwood Road are approximately 270 mm in the 1% AEP event and approximately 850 mm in the PMF. However, this diversion of flow has not been included in the hydraulic modelling in the 1% AEP design flood, because the proposed Calderwood Urban Development Project (CUDP) modelling shows that the filling proposed by the CUDP on the southern side of Calderwood Road removes the diversion.

In the PMF, the CUDP filling doesn't prevent the flow diversion, but it does impact the nature and behaviour of the diversion. As such, the CUDP flood behaviour for the PMF has been used as an inflow into our modelling. This is considered reasonable given the relative timing between the CUDP project (already rezoned and under construction) and the proposed project (preliminary stages of the Planning Proposal). In other words, by the time this subject site is rezoned, it is reasonable to anticipate that the CUDP filling would be in place.

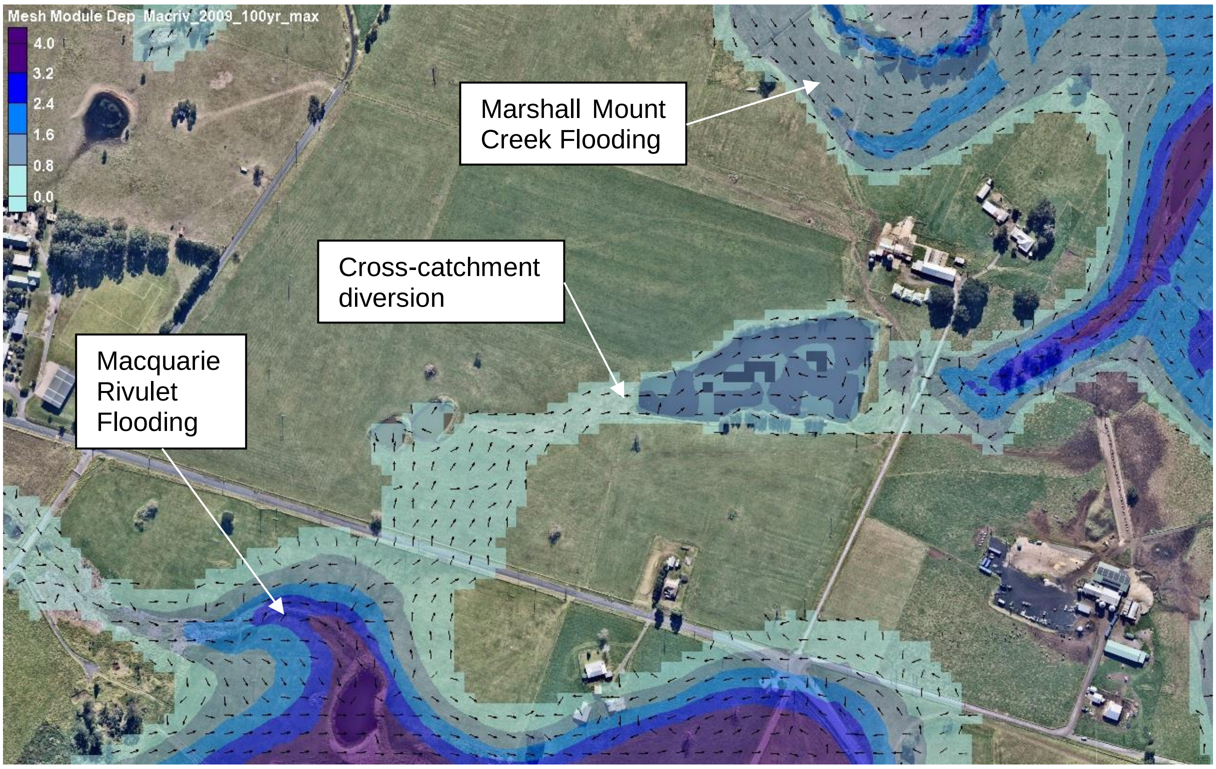

Figure 4.1-2 Cross Catchment Diversion of Flow

Note: Model results taken from Rienco (2011).

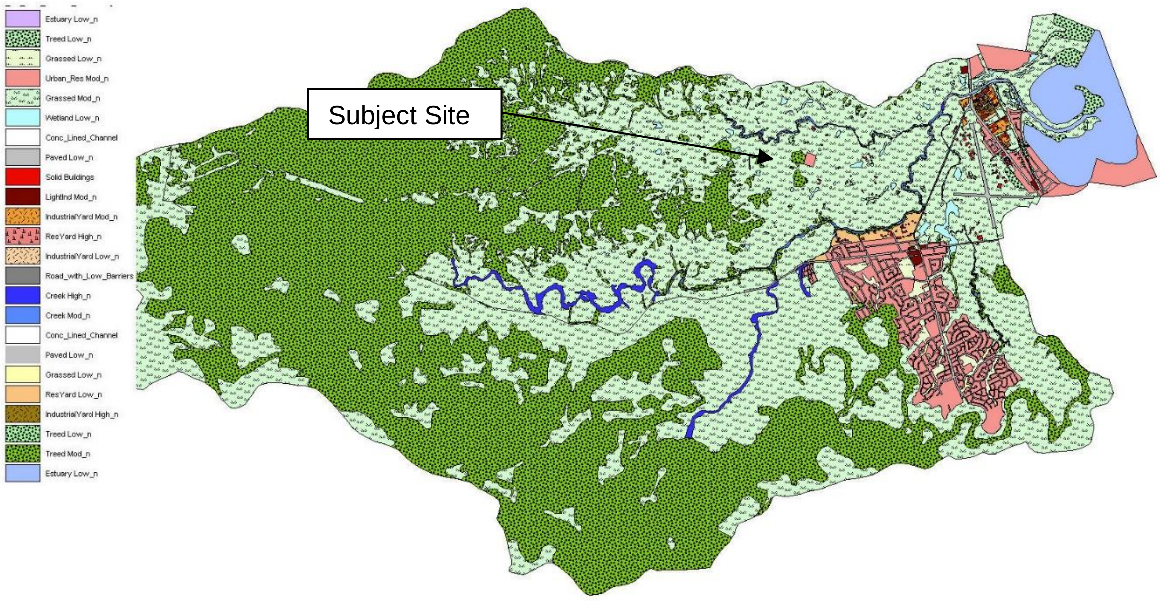

Figure 4.1-3 TUFLOW Surface Roughness Zones

4.2. HYDRAULIC MODEL RESULTS

The model was run for the 1% AEP and PMF design events. A summary of the model results is described below in **Figure 4.2-1**. A full detailed set of model results is included as **Appendix C**. As can be seen in **Figure 4.2-1**, the peak 1% AEP flood depths vary across the site but are however relatively shallow in the vicinity of the proposed residential rezoning. Flooding is confined to the riparian and watercourse areas, which is expected given the incised nature of the watercourses and valley flanks through the subject site. A large portion of the site earmarked for future residential development is already well above the PMF.

Figure 4.2-1 1% AEP Pre-Development Flood Extent and Depths

Note: Flood depths shaded 0 mm (light blue) to 6,000 mm (dark blue). All depths greater than 6,000 mm are all shaded dark blue.

5. HYDRAULIC MODELLING - POST DEVELOPMENT

5.1. HYDRAULIC MODEL DEVELOPMENT

The TUFLOW input files were modified to simulate the post-development scenario. A small amount of fill was added to the model around the development fringes, which simulates the eventual design profile of the proposed access road. No other changes were made to the model.

5.2. HYDRAULIC MODEL RESULTS

The model was re-run for the 1% AEP and PMF design events. A summary of the model results is described below in **Figure 5.2-1**. A full detailed set of model results is included as **Appendix C**.

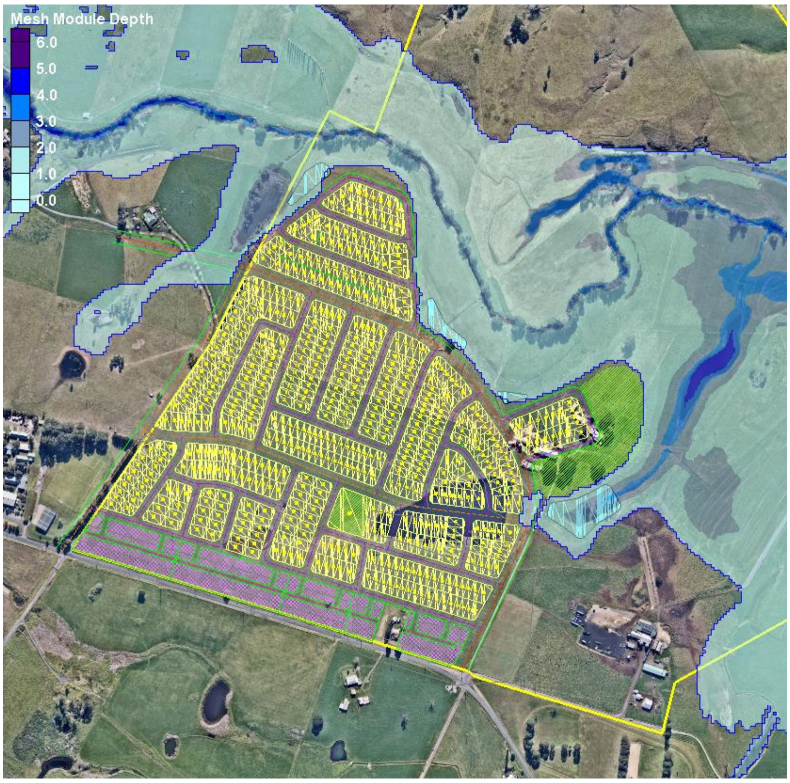

Figure 5.2-1 1% AEP Post-Development Flood Extent and Depths

Note: Flood depths shaded 0 mm (light blue) to 6,000 mm (dark blue). All depths greater than 6,000 mm are all shaded dark blue.

None of the proposed building envelopes are affected by mainstream flooding in the 1% AEP. All residential lots are above the Flood Planning Level. This is an important conclusion from the model results, and underscores the suitability of the proposal with regard to flooding. A minor incursion of the PMF occurs in the NW corner of the site, which is acceptable under the provisions of SCC's DCP.

5.3. DEVELOPMENT RELATED IMPACTS ON FLOOD BEHAVIOUR

Figure 5.3-1 describes the impacts on peak flood surface levels in the 1% AEP event. A detailed map of these impacts is included in **Appendix C**. There are no impacts resulting from the proposed development in the 1% AEP design flood.

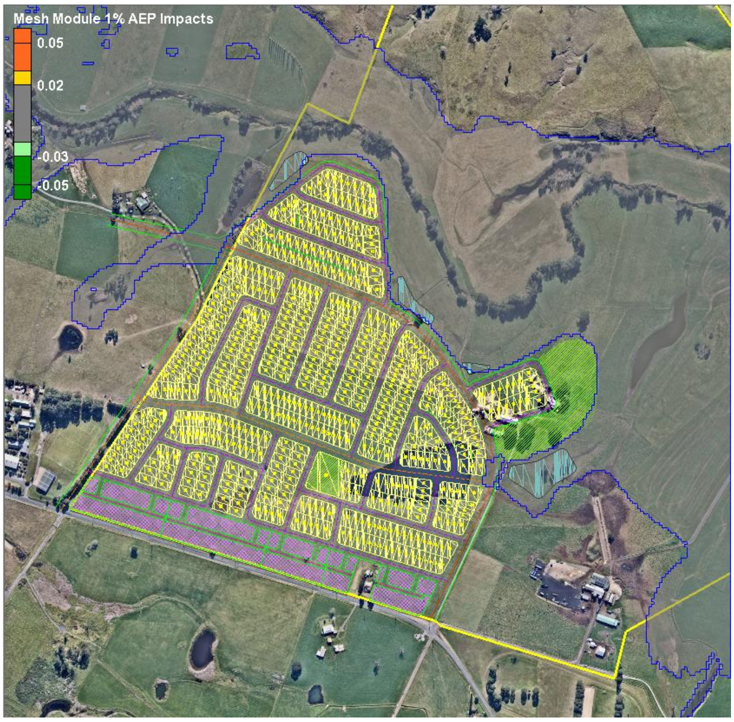

Figure 5.3-1 1% AEP Peak Flood Surface Level Increases

Note: There are no flood impacts +/- 20mm within the modelling

5.4. PROVISIONAL HYDRAULIC HAZARD

The existing site is affected by the 1% AEP and is classified as a mix of Low and High Provisional Hydraulic Hazard (PHH) for the 1% AEP flood event, when assessed under the NSW Government's Floodplain Development Manual (Figure L-2). **Figure 5.4-1** below describes the pre-development PHH and **Figure 5.4-2** below describes the post-development PHH. As can be seen, all of the proposed residential lots are flood-free in the 1% AEP event and are therefore not subject to any hydraulic hazard.

In both the figures, dark blue shading denotes High Provisional Hydraulic Hazard, and light blue shading denotes Low Provisional Hydraulic Hazard, in accordance with the Floodplain Development Manual (Figure L-2).

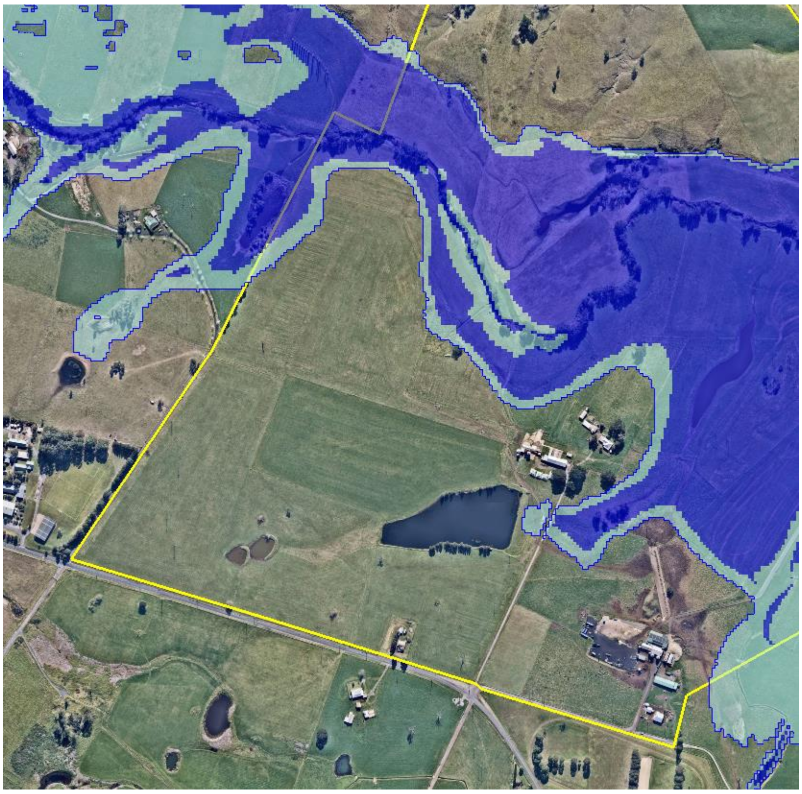

Figure 5.4-1 1% AEP Pre-Development Provisional Hydraulic Hazard

Note: Provisional Hydraulic Hazard designated by TUFLOW in accordance with NSW Government's Floodplain Development Manual Figure L-2 (2005).

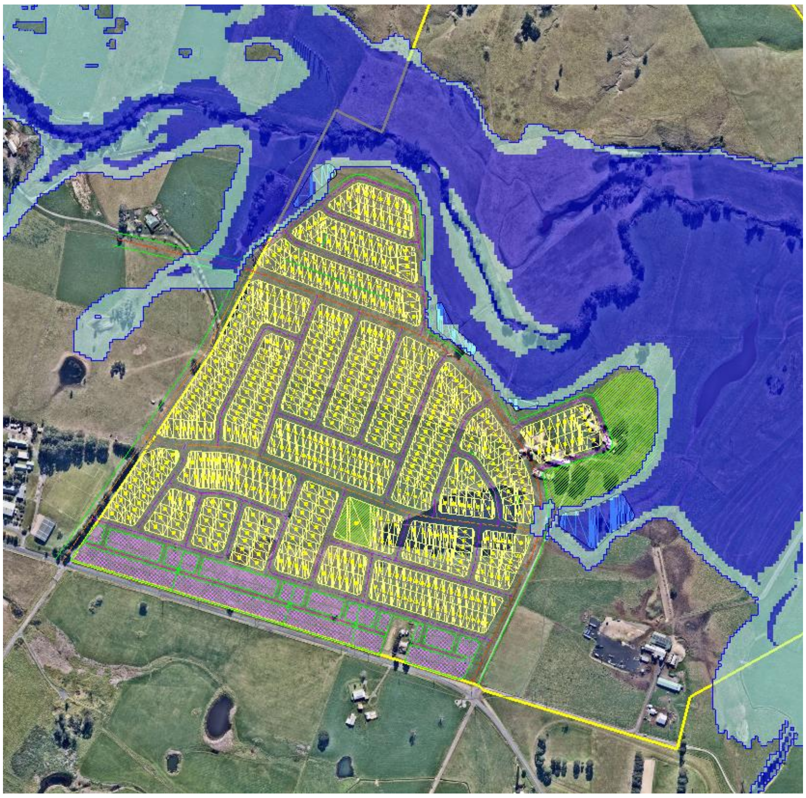

Figure 5.4-2 1% AEP Post-Development Provisional Hydraulic Hazard

Note: Provisional Hydraulic Hazard designated by TUFLOW in accordance with NSW Government's Floodplain Development Manual Figure L-2 (2005).

6. PLANNING REQUIREMENTS

6.1. REQUIREMENTS OF SECTION 117 DIRECTION

As the subject site is susceptible to flood events more frequent than the PMF event, it is defined under NSW legislation as 'Flood Prone Land'. This definition is consistent with the NSW Government's Floodplain Development Manual (2005). As the site is defined as Flood Prone Land, the Section 9.1 Direction (Section 4.3) applies to development on the subject site.

The Ministerial Section 9.1 Direction provides certain objectives and direction on what a relevant planning authority must do if this direction applies. **Table 6.1-1** describes each aspect of the Section 9.1 direction, and advice on how the proposed development already complies, or what design aspects can be incorporated into the development to ensure compliance with the Section 9.1 direction.

Table 6.1-1 – Section 9.1 Direction Requirements

Section 9.1 Requirements	How the Proposal Addresses the Requirement
A planning proposal must include provisions that give effect to, and are consistent with, the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas).	This report constitutes the provisions within the Planning Proposal that give effect to, and are consistent with, the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005.
A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.	If it is considered that the planning proposal does seek to do this, this is permitted as long as 9 (a) or (b) of Clause 4.3 of the S9.1 Directions is met. See further discussion below.
A planning proposal must not contain provisions that apply to the flood planning areas which: (a) permit development in floodway areas, (b) permit development that will result in significant flood impacts to other properties, (c) permit a significant increase in the development of that land, (d) are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or (e) permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodway's or high hazard areas), roads or exempt development.	The planning proposal does not propose: • Development in floodway areas. • Development that will result in significant flood impacts to other properties. • A development which will result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services. • Development to be carried out without development consent. The planning proposal does propose: • Significant increase in the development of that land, The planning proposal can propose a significant increase in the development of the land, as long as 9 (a) or (b) of Clause 4.3 of the S9.1 Directions are met. See further discussion below.
A planning proposal must not impose flood related development controls above the residential flood planning level for residential	The planning proposal does <u>not</u> impose flood related development controls above the residential flood planning level.

development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).	
A planning proposal may be inconsistent with this direction only if the relevant planning authority can satisfy the Director-General (or an officer of the Department nominated by the Director-General) that: (a) the planning proposal is in accordance with a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or (b) the provisions of the planning proposal that are inconsistent are of minor significance.	This report constitutes *a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005,* and the planning proposal is in accordance with it.

It can be seen from **Table 6.1-1** that the proposed development can readily meet the requirements of the Section 9.1 direction.

6.2. ADDRESSING SHELLHARBOUR LEP CLAUSE 6.3

SCC's Local Environment Plan (LEP) 2013 sets forth its requirements for land for which the LEP applies (i.e. the subject site). **Table 6.2-1** describes each LEP clause and commentary on how the proposed development relates to the requirements of the LEP.

Table 6.2-1 – LEP Requirements Addressed for Proposed Development

LEP Requirement	How the Proposal Addresses the Requirement
The development… is compatible with the flood hazard of the land	The proposed development is entirely compatible with the flood hazard of the land. All lots proposed for residential development are above the flood planning level, and the majority of lots are above the PMF. This can be seen in **Figure C4.1**.
The development… will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties,	The proposed development will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties. This is demonstrated by the detailed hydraulic modelling carried out in this report.
The development… incorporates appropriate measures to manage risk to life from flood	The proposed development does incorporate the optimum measure to manage risk to life from flooding, as all lots proposed for residential development are above the flood planning level, and the majority of lots are above the PMF.
The development… will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses,	The model results show that the those aspects of the project that have the potential to *significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability*

	of river banks or watercourses can be readily managed through detailed design.
The development… is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.	The proposed development will not result in unsustainable social and economic costs to the community as a consequence of flooding, as all lots proposed for residential development are above the flood planning level, and the majority of lots are above the PMF.

It can be seen from **Table 6.2-1** that the proposed development meets or exceeds SCC's LEP requirements. In other words, if the land was suitably zoned for the proposed development to be permissible today, the proposed development already meets the requirements of the SLEP (2013).

Whilst SCC's Local Environment Plan (LEP) 2013 states that a proposal *must incorporate appropriate measures to manage risk to life from flood,* it does not require any explicit consideration of evacuation issues in relation to flooding. Nonetheless, whilst the entire extent of proposed residentially zoned land meets the evacuation requirements of Council's DCP, an alternative flood-free access is provided via the section of Calderwood Road west of the proposed within the CUDP and Escarpment Drive (once constructed).

6.3. ADDRESSING CLIMATE CHANGE

SCC's Local Environment Plan (LEP) 2013 nor the S9.1 Directions require any explicit consideration of climate changes impacts on design flood behaviour. Nonetheless, as it has the potential to be considered a matter of public interest, consideration of climate change issues through the rezoning phase is considered thorough.

Helpfully, Shellharbour Council have already investigated the potential impacts of climate change on design flood behaviour through the subject site. WMA Water (2017) includes a sensitivity analysis on flood modelling using increases of 10%, 20% and 30% to ARR 1987 rainfall intensities. WMA Water (2017) found that such increases in design rainfall intensity increases 1% AEP flood levels between 7 and 19 mm at Marshall Mount Creek (near 453 Marshall Mount Road being 500m upstream of Meadow Views).

WMA Water (2017) also found that the sensitivity analysis shows for the lower reaches of Marshall Mount Creek (where Meadow Views is located), the land is relatively insensitive to climate-changed increases in rainfall intensity and well within the 0.5m freeboard for Flood Planning Levels.

It is therefore concluded that there is no climate change flood-related impediment to the rezoning of the land.

7. CONCLUSIONS AND RECOMMENDATIONS

Based on the information contained within this report, it can be concluded that:

- The subject site is located in Calderwood and is affected by mainstream flooding from Macquarie Rivulet and Marshall Mount Creek.
- SCC adopted its catchment-wide flood study in 2017, titled *Macquarie Rivulet Flood Study.* Its results are largely applicable to the subject site for quantifying flood behaviour in the pre-development scenario, except where recent works at the Calderwood Urban Development Project (CUDP) and the Albion Park Rail Bypass (APRB) supersede the 2017 Study.
- A WBNM hydrologic model has been used to determine design flood estimates at the subject site and surrounds. This model uses data for its construction that is consistent with Rienco (2011) and the *Macquarie Rivulet Flood Study (2017).*
- A detailed 2D TUFLOW model has been prepared for the subject site and surrounds. The model was run for the 1% AEP and Probable Maximum Floods (PMF).
- Flood behaviour for a range of design floods has been determined for the subject site and surrounds. This flood behaviour is consistent with the *Macquarie Rivulet Flood Study (2017)* model results and those within Rienco's previous work in the catchment.
- The flood model results and subsequent conclusions reached in this report take into account the additional flood-related impacts on the land caused by the construction of the Albion Park Rail Bypass.
- The Flood Planning Level for the site is difficult to specify as one level, given the flood gradient across the site. In any case, none of the proposed building envelopes are affected by mainstream flooding for all events up to the 1% AEP, and all proposed lots are above the Flood Planning Level.
- The proposal meets the requirement of the NSW Governments Section 9.1 Direction Clause 4.3. Where the proposal is inconsistent with this Direction, as per Clause 9 of the Section 9.1 Direction these inconsistencies are supported by this Floodplain Risk Management Plan.
- The proposal meets the requirement of Shellharbour Council's LEP (2013) Clause 6.3.
- There is no climate change flood-related impediment to the rezoning of the land.
- The requirements of the NSW Government's Floodplain Development Manual (2005) have been considered. There are no specific additional requirements stemming from the application of the Floodplain Development Manual, as the S9.1 Directions and SCC's LEP (Clause 6.3) are consistent with the Floodplain Development Manual.

Based on the information contained within this report, it is recommended this report is included in the submission to SCC for the proposed development.

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Managing Director

8. REFERENCES AND BIBLIOGRAPHY

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Abbreviations

	Abbreviation Description
AEP	Annual Exceedance Probability; The probability of a rainfall or flood event of given magnitude being equalled or exceeded in any one year.
AHD	Australian Height Datum: National reference datum for level
ALS	Air-borne Laser Scanning; aerial survey technique used for definition of ground height
ARI	Average Recurrence Interval; The expected or average interval of time between exceedances of a rainfall or flood event of given magnitude.
AR&R	Australian Rainfall and Runoff; National Code of Practice for Drainage published by Institution of Engineers, Australia, 1987.
EDS	Embedded Design Storm; synthesised design storm involving embedment of an AR&R design burst within a second design burst of much longer duration
FPDM	Floodplain Development Manual; Guidelines for Development in Floodplains published by N.S.W. State Government, 2005.
FSL	Flood Surface Level;
GIS	Geographic Information Systems; A system of software and procedures designed to support management, manipulation, analysis and display of spatially referenced data.
IFD	Intensity-Frequency-Duration; parameters describing rainfall at a particular location.
ISG	Integrated Survey Grid; ISG: The rectangular co-ordinate system designed for integrated surveys in New South Wales. A Transverse Mercator projection with zones 2 degrees wide (Now largely replaced by the MGA).
LEP	Local Environment Plan; plan produced by Council defining areas where different development controls apply (e.g. residential vs industrial)
LGA	Local Government Area; political boundary area under management by a given local council. Council jurisdiction broadly involves provision of services such as planning, recreational facilities, maintenance of local road infrastructure and services such as waste disposal.
MGA	Mapping Grid of Australia; This is a standard 6° Universal Transverse Mercator (UTM) projection and is now used by all states and territories across Australia.
MHI	Maximum Height Indicator; measuring equipment used to record flood levels
PMF	Probable Maximum Flood; Flood calculated to be the maximum physically possible.
PMP	Probable Maximum Precipitation; Rainfall calculated to be the maximum physically possible.
RCP	Reinforced Concrete Pipe;
km	Kilometre; (Distance = 1,000m)
m	Metre; (Basic unit of length)
m^2	Square Metre; (Basic unit of area)
ha	Hectare; (Area =10,000 m2)
m^3	Cubic Metre; (Basic unit of volume)
m/s	Metres/Second; (Velocity)
m^3/s	Cubic Metre per Second; (Flowrate)
s	Second; (basic unit of time)
SCC	Shellharbour City Council; name of the council with jurisdiction over the Shellharbour LGA

Technical Terms

Term	Description
Alluvium	Material eroded, transported and deposited by streams.
Antecedent	Pre-existing (conditions e.g. wetness of soils).
Catchment	Area draining into a particular creek system, typically bounded by higher ground around its perimeter.
Critical Flow	Water flowing at a Froude No. of one.
Culvert	An enclosed conduit (typically pipe or box) that conveys stormwater below a road or embankment.
Discharge	The flowrate of water.
Escarpment	A cliff or steep slope, of some extent, generally separating two level or gently sloping areas.
Flood	A relatively high stream flow which overtops the stream banks.
Flood storages	Those parts of the floodplain important for the storage of floodwaters during the passage of a flood.
Floodways	Those areas where a significant volume of water flows during floods. They are often aligned with obvious naturally defined channels and are areas which, if partly blocked, would cause a significant redistribution of flow.
Flood Fringes	Those parts of the floodplain left after floodways and flood storages have been abstracted.
Froude No.	A measure of flow instability. Below a value of one, flow is tranquil and smooth, above one flow tends to be rough and undulating (as in rapids).
Geotechnical	Relating to Engineering and the materials of the earth’s crust.
Gradient	Slope or rate of fall of land/pipe/stream.
Headwall	Wall constructed around inlet or outlet of a culvert.
Hydraulic	A term given to the study of water flow, as relates to the evaluation of flow depths, levels and velocities.
Hydrodynamic	The variation in water flow, depth, level and velocity with time
Hydrology	A term given to the study of the rainfall and runoff process.
Hydrograph	A graph of flood flow against time.
Hyetograph	A graph of rainfall intensity against time.
Isohyets	Lines joining points of equal rainfall on a plan.
Manning’s n	A measure of channel or pipe roughness.
Orographic	Pertaining to changes in relief, mountains.
Orthophoto	Aerial photograph with contours, boundaries or grids added.
Pluviograph	An instrument which continuously records rain collected
Runoff	Water running off a catchment during a storm.
Scour	Rapid erosion of soil in the banks or bed of a creek, typically occurring in areas of high flow velocities and turbulence.
Siltation	The filling or raising up of the bed of a watercourse or channel by deposited silt.
Stratigraphy	The sequence of deposition of soils/rocks in layers.
Surcharge	Flow unable to enter a culvert or exiting from a pit as a result of inadequate capacity or overload.
Topography	The natural surface features of a region.
Urbanisation	The change in land usage from a natural to developed state.
Watercourse	A small stream or creek.

APPENDIX A – SITE SURVEY

Figure A1.1: ALS Survey Levels at Subject Site

APPENDIX B – WBNM CATCHMENT PLAN

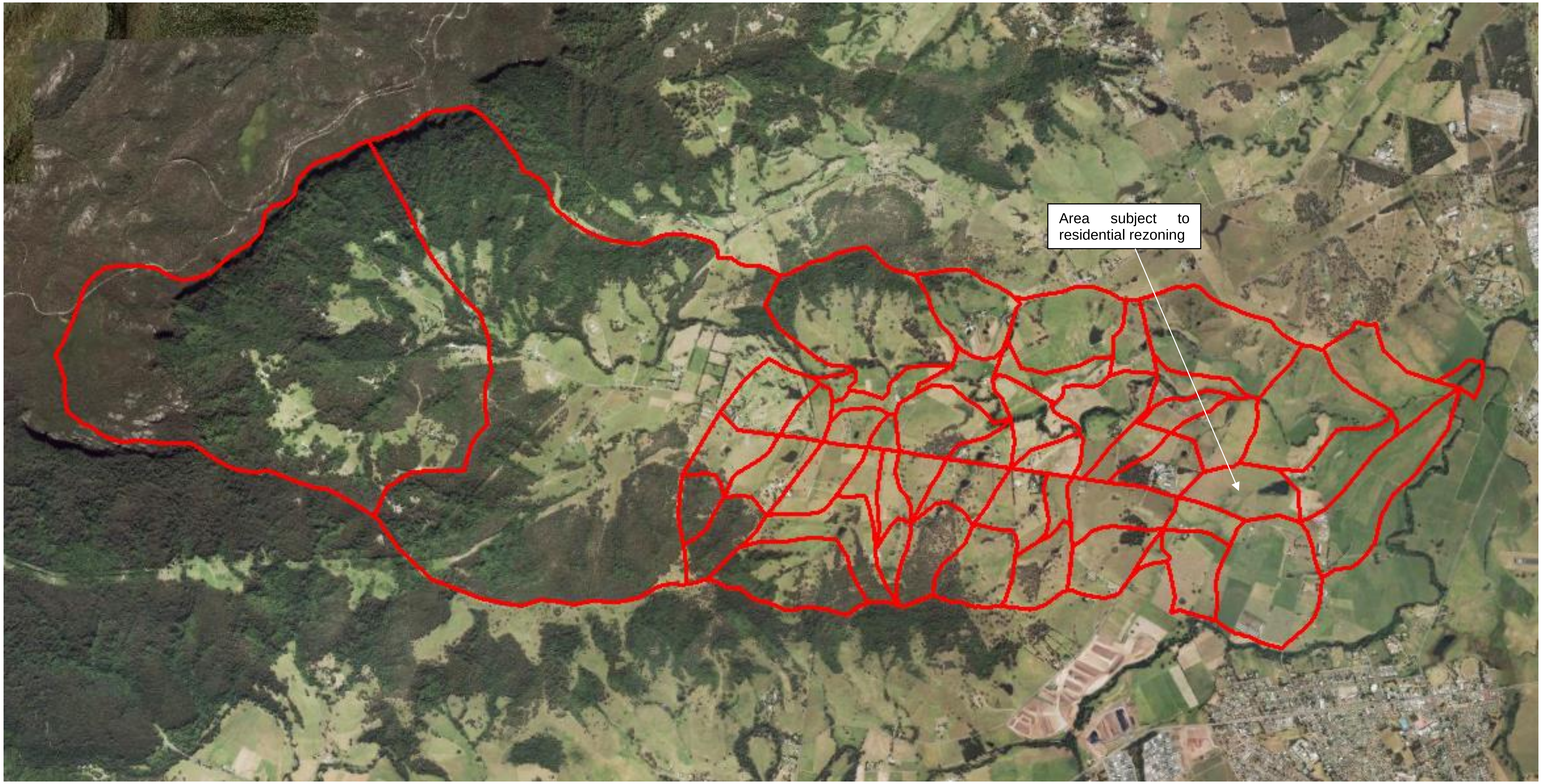

Figure B1.1: WBNM Catchment Plan

Note: Diagrammatic only, as catchment plan too detailed to describe subareal attributes, where considered important an electronic version can be supplied to Council.

WBNM MODEL INPUT FILE

```
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#####END_PREAMBLE_BLOCK############|###########|###########|###########|


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#####END_STATUS_BLOCK##############|###########|###########|###########|


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      none
      0.00       0.00       0.00       0.00       0.00       0.00
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#####START_TOPOLOGY_BLOCK##########|###########|###########|###########|
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CaldA         293270.00  6172742.00   293379.00  6172590.00 CaldB
CaldB         293511.00  6172664.00   293710.00  6172643.00 CaldC
CaldC         293774.00  6172927.00   294049.00  6173252.00 CaldD
CaldC(1)A     293694.00  6173384.00   293908.00  6173330.00 CaldC(1)B
CaldC(1)B     293922.00  6173313.00   294049.00  6173252.00 CaldD
CaldD         294244.00  6173161.00   294484.00  6173365.00 CaldE
CaldD(1)A     293783.00  6173605.00   294099.00  6173607.00 CaldD(1)B
CaldD(1)B     294304.00  6173585.00   294484.00  6173365.00 CaldE
CaldE         294758.00  6173105.00   295108.00  6173176.00 CaldF
CaldF         295446.00  6173678.00   296254.00  6174646.00 MacRivY
MarsH(1)A     294565.00  6173734.00   294964.00  6173730.00 MarsH(1)B
MarsH(1)B     295228.00  6173914.00   295609.00  6174315.00 MarsI
MarsC(2)A     292645.00  6174983.00   292550.00  6174615.00 MarsD
MarsB(1)(1)A  290948.00  6173401.00   291131.00  6173696.00 MarsB(1)(1)B
MarsB(1)(1)B  291293.00  6173851.00   291485.00  6174112.00 MarsB(1)(1)C
MarsB(1)(1)C  291514.00  6174305.00   291631.00  6174502.00 MarsB(1)D
MarsB(1)D     291713.00  6174490.00   291848.00  6174606.00 MarsC
MarsA         287790.00  6174881.00   289302.00  6174749.00 MarsB
MarsB         290146.00  6174687.00   291848.00  6174606.00 MarsC
MarsB(1)A     290787.00  6173619.00   290871.00  6173862.00 MarsB(1)B
MarsB(1)B     290977.00  6173837.00   291192.00  6174149.00 MarsB(1)C
MarsB(1)C     291268.00  6174401.00   291848.00  6174606.00 MarsC
MarsC         291902.00  6174920.00   292550.00  6174615.00 MarsD
MarsC(1)(1)A  291594.00  6173831.00   291824.00  6174065.00 MarsC(1)(1)B
MarsC(1)(1)B  291864.00  6174190.00   292090.00  6174285.00 MarsC(1)E
MarsC(1)(2)A  292128.00  6173247.00   292161.00  6173552.00 MarsC(1)(2)B
MarsC(1)(2)B  292128.00  6173688.00   292058.00  6174003.00 MarsC(1)D
MarsC(1)A     291386.00  6173148.00   291731.00  6173405.00 MarsC(1)B
MarsC(1)B     291893.00  6173325.00   291924.00  6173710.00 MarsC(1)C
MarsC(1)C     291990.00  6173496.00   292058.00  6174003.00 MarsC(1)D
MarsC(1)D     292059.00  6174153.00   292090.00  6174285.00 MarsC(1)E
MarsC(1)E     292117.00  6174429.00   292550.00  6174615.00 MarsD
MarsD         292581.00  6174634.00   292936.00  6174247.00 MarsE
MarsD(1)A     292318.00  6173767.00   292315.00  6173995.00 MarsD(1)B
MarsD(1)B     292539.00  6174221.00   292936.00  6174247.00 MarsE
MarsD(2)A     292418.00  6173298.00   292505.00  6173656.00 MarsD(2)B
MarsD(2)B     292602.00  6173716.00   292704.00  6173941.00 MarsD(2)C
MarsD(2)C     292737.00  6174069.00   292936.00  6174247.00 MarsE
```

```
MarsE         293158.00  6174155.00   293432.00  6174154.00 MarsF
MarsE(1)(1)A   293131.00  6173227.00   293320.00  6173534.00 MarsE(1)(1)B
MarsE(1)(1)B   293227.00  6173459.00   293182.00  6173766.00 MarsE(1)C
MarsE(1)A      292702.00  6173243.00   292950.00  6173473.00 MarsE(1)B
MarsE(1)B      292976.00  6173590.00   293182.00  6173766.00 MarsE(1)C
MarsE(1)C      293211.00  6173988.00   293432.00  6174154.00 MarsF
MarsF         293601.00  6174183.00   293971.00  6174555.00 MarsG
MarsF(1)A      293294.00  6174770.00   293667.00  6174684.00 MarsF(1)B
MarsF(1)(1)A   292992.00  6174583.00   293667.00  6174684.00 MarsF(1)B
MarsF(1)B      293804.00  6174818.00   293971.00  6174555.00 MarsG
MarsG         294227.00  6174471.00   294631.00  6174389.00 MarsH
MarsG(3)A      293765.00  6174017.00   293990.00  6174178.00 MarsG(3)B
MarsG(3)B      294184.00  6174301.00   295609.00  6174315.00 MarsH
MarsG(1)A      293969.00  6173926.00   294236.00  6174099.00 MarsG(1)B
MarsG(1)B      294381.00  6174136.00   294631.00  6174389.00 MarsH
MarsG(2)A      294416.00  6174788.00   295609.00  6174315.00 MarsH
MarsH         294906.00  6174148.00   295609.00  6174315.00 MarsI
MarsI         295602.00  6174552.00   296093.00  6174473.00 MacRivY
MacRivY       296092.00  6174523.00   296757.00  6174973.00 SINK
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     -99.90
CaldA          22.050      0.0      1.30      0.10
CaldB           9.030      0.0      1.30      0.10
CaldC          22.480      0.0      1.30      0.10
CaldC(1)A      21.790      0.0      1.30      0.10
CaldC(1)B       2.510      0.0      1.30      0.10
CaldD          20.500      0.0      1.30      0.10
CaldD(1)A      23.200      0.0      1.30      0.10
CaldD(1)B       9.600      1.0      1.30      0.10
CaldE          52.780      1.0      1.30      0.10
CaldF          44.380      1.0      1.30      0.10
MarsH(1)A      23.530      0.0      1.30      0.10
MarsH(1)B      23.290      1.0      1.30      0.10
MarsC(2)A      28.130      0.0      1.30      0.10
MarsB(1)(1)A   18.420      0.0      1.30      0.10
MarsB(1)(1)B   16.930      0.0      1.30      0.10
MarsB(1)(1)C    9.030      0.0      1.30      0.10
MarsB(1)D       3.180      0.0      1.30      0.10
MarsA         467.960      0.0      1.30      0.10
MarsB         575.280      0.0      1.30      0.10
MarsB(1)A      11.040      0.0      1.30      0.10
MarsB(1)B      16.350      0.0      1.30      0.10
MarsB(1)C      21.360      0.0      1.30      0.10
MarsC          83.540      0.0      1.30      0.10
MarsC(1)(1)A   17.910      0.0      1.30      0.10
MarsC(1)(1)B    8.280      0.0      1.30      0.10
MarsC(1)(2)A    7.800      0.0      1.30      0.10
MarsC(1)(2)B    9.160      0.0      1.30      0.10
MarsC(1)A      39.920      0.0      1.30      0.10
MarsC(1)B      27.360      0.0      1.30      0.10
MarsC(1)C       7.840      0.0      1.30      0.10
MarsC(1)D       3.670      0.0      1.30      0.10
MarsC(1)E      10.130      0.0      1.30      0.10
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MarsD(1)B	25.280	0.0	1.30	0.10
MarsD(2)A	21.570	0.0	1.30	0.10
MarsD(2)B	15.960	0.0	1.30	0.10
MarsD(2)C	8.360	0.0	1.30	0.10
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MarsE(1)(1)B	6.150	0.0	1.30	0.10
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MarsE(1)B	18.280	0.0	1.30	0.10
MarsE(1)C	8.810	0.0	1.30	0.10
MarsF	26.990	0.0	1.30	0.10
MarsF(1)A	38.240	0.0	1.30	0.10
MarsF(1)(1)A	13.110	0.0	1.30	0.10
MarsF(1)B	10.660	0.0	1.30	0.10
MarsG	9.940	1.0	1.30	0.10
MarsG(3)A	10.540	0.0	1.30	0.10
MarsG(3)B	8.910	1.0	1.30	0.10
MarsG(1)A	16.020	14.0	1.30	0.10
MarsG(1)B	18.600	0.0	1.30	0.10
MarsG(2)A	52.540	0.0	1.30	0.10
MarsH	47.680	0.0	1.30	0.10
MarsI	29.050	0.0	1.30	0.10
MacRivY	4.400	0.0	1.30	0.10

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CaldB
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CaldC
#####ROUTING
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CaldD
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1.00
CaldD(1)B
#####ROUTING
1.00
CaldE
#####ROUTING
1.00
CaldF
#####ROUTING
1.00
MarsH(1)B
#####ROUTING
1.00
MarsB(1)(1)B
#####ROUTING
1.00

MarsB(1)(1)C
#####ROUTING
1.00
MarsB(1)D
#####ROUTING
1.00
MarsB
#####ROUTING
1.00
MarsB(1)B
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MarsB(1)C
#####ROUTING
1.00
MarsC
#####ROUTING
1.00
MarsC(1)(1)B
#####ROUTING
1.00
MarsC(1)(2)B
#####ROUTING
1.00
MarsC(1)B
#####ROUTING
1.00
MarsC(1)C
#####ROUTING
1.00
MarsC(1)D
#####ROUTING
1.00
MarsC(1)E
#####ROUTING
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MarsD
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MarsD(1)B
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MarsD(2)B
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1.00
MarsD(2)C
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MarsE
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1.00
MarsE(1)(1)B
#####ROUTING
1.00
MarsE(1)B
#####ROUTING
1.00

```
MarsE(1)C
#####ROUTING
       1.00
MarsF
#####ROUTING
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MarsF(1)B
#####ROUTING
       1.00
MarsG
#####ROUTING
       1.00
MarsG(3)B
#####ROUTING
       1.00
MarsG(1)B
#####ROUTING
       1.00
MarsH
#####ROUTING
       1.00
MarsI
#####ROUTING
       1.00
MacRivY
#####ROUTING
       1.00
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#####END_LOCAL_STRUCTURES_BLOCK####|###########|###########|##########
#|


#####START_OUTLET_STRUCTURES_BLOCK#|###########|###########|##########
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#####END_OUTLET_STRUCTURES_BLOCK###|###########|###########|##########
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100 Year ARI 120 Mins Duration DESIGN STORM
       1.00
       1.00
#####START_DESIGN_RAIN
        100        120       1.00
IFD_COEFFS_IN_IFD_FILE
C:\Users\Anthony Barthelmess\Desktop\DesignMGA.ifd
          3
MACQRIV#1
MACQRIV#2
```

MACQRIV#3
#####END_DESIGN_RAIN
#####START_CALC_RAINGAUGE_WEIGHTS
#####END_CALC_RAINGAUGE_WEIGHTS
#####START_LOSS_RATES

CaldA	0.00	2.50	0.00
CaldB	0.00	2.50	0.00
CaldC	0.00	2.50	0.00
CaldC(1)A	0.00	2.50	0.00
CaldC(1)B	0.00	2.50	0.00
CaldD	0.00	2.50	0.00
CaldD(1)A	0.00	2.50	0.00
CaldD(1)B	0.00	2.50	0.00
CaldE	0.00	2.50	0.00
CaldF	0.00	2.50	0.00
MarsH(1)A	0.00	2.50	0.00
MarsH(1)B	0.00	2.50	0.00
MarsC(2)A	0.00	2.50	0.00
MarsB(1)(1)A	0.00	2.50	0.00
MarsB(1)(1)B	0.00	2.50	0.00
MarsB(1)(1)C	0.00	2.50	0.00
MarsB(1)D	0.00	2.50	0.00
MarsA	0.00	2.50	0.00
MarsB	0.00	2.50	0.00
MarsB(1)A	0.00	2.50	0.00
MarsB(1)B	0.00	2.50	0.00
MarsB(1)C	0.00	2.50	0.00
MarsC	0.00	2.50	0.00
MarsC(1)(1)A	0.00	2.50	0.00
MarsC(1)(1)B	0.00	2.50	0.00
MarsC(1)(2)A	0.00	2.50	0.00
MarsC(1)(2)B	0.00	2.50	0.00
MarsC(1)A	0.00	2.50	0.00
MarsC(1)B	0.00	2.50	0.00
MarsC(1)C	0.00	2.50	0.00
MarsC(1)D	0.00	2.50	0.00
MarsC(1)E	0.00	2.50	0.00
MarsD	0.00	2.50	0.00
MarsD(1)A	0.00	2.50	0.00
MarsD(1)B	0.00	2.50	0.00
MarsD(2)A	0.00	2.50	0.00
MarsD(2)B	0.00	2.50	0.00
MarsD(2)C	0.00	2.50	0.00
MarsE	0.00	2.50	0.00
MarsE(1)(1)A	0.00	2.50	0.00
MarsE(1)(1)B	0.00	2.50	0.00
MarsE(1)A	0.00	2.50	0.00
MarsE(1)B	0.00	2.50	0.00
MarsE(1)C	0.00	2.50	0.00
MarsF	0.00	2.50	0.00
MarsF(1)A	0.00	2.50	0.00
MarsF(1)(1)A	0.00	2.50	0.00
MarsF(1)B	0.00	2.50	0.00
MarsG	0.00	2.50	0.00
MarsG(3)A	0.00	2.50	0.00
MarsG(3)B	0.00	2.50	0.00
MarsG(1)A	0.00	2.50	0.00

```
MarsG(1)B         0.00       2.50       0.00
MarsG(2)A         0.00       2.50       0.00
MarsH           0.00       2.50       0.00
MarsI           0.00       2.50       0.00
MacRivY         0.00       2.50       0.00
#####END_LOSS_RATES
#####START_RECORDED_HYDROGRAPHS
         0
#####END_RECORDED_HYDROGRAPHS
#####START_IMPORTED_HYDROGRAPHS
         0
#####END_IMPORTED_HYDROGRAPHS
#####END_STORM#1
#####START_STORM#2
9999 Year ARI 60 Mins Duration DESIGN STORM
       1.00
       1.00
#####START_DESIGN_RAIN
       9999        60       1.00
IFD_COEFFS_IN_IFD_FILE
C:\Users\Anthony Barthelmess\Desktop\DesignMGA.ifd
         3
MACQRIV#1
MACQRIV#2
MACQRIV#3
#####END_DESIGN_RAIN
#####START_CALC_RAINGAUGE_WEIGHTS
#####END_CALC_RAINGAUGE_WEIGHTS
#####START_LOSS_RATES
CaldA           0.00       2.50       0.00
CaldB           0.00       2.50       0.00
CaldC           0.00       2.50       0.00
CaldC(1)A         0.00       2.50       0.00
CaldC(1)B         0.00       2.50       0.00
CaldD           0.00       2.50       0.00
CaldD(1)A         0.00       2.50       0.00
CaldD(1)B         0.00       2.50       0.00
CaldE           0.00       2.50       0.00
CaldF           0.00       2.50       0.00
MarsH(1)A         0.00       2.50       0.00
MarsH(1)B         0.00       2.50       0.00
MarsC(2)A         0.00       2.50       0.00
MarsB(1)(1)A       0.00       2.50       0.00
MarsB(1)(1)B       0.00       2.50       0.00
MarsB(1)(1)C       0.00       2.50       0.00
MarsB(1)D         0.00       2.50       0.00
MarsA           0.00       2.50       0.00
MarsB           0.00       2.50       0.00
MarsB(1)A         0.00       2.50       0.00
MarsB(1)B         0.00       2.50       0.00
MarsB(1)C         0.00       2.50       0.00
MarsC           0.00       2.50       0.00
MarsC(1)(1)A       0.00       2.50       0.00
MarsC(1)(1)B       0.00       2.50       0.00
MarsC(1)(2)A       0.00       2.50       0.00
MarsC(1)(2)B       0.00       2.50       0.00
MarsC(1)A         0.00       2.50       0.00
```

```
MarsC(1)B        0.00       2.50       0.00
MarsC(1)C        0.00       2.50       0.00
MarsC(1)D        0.00       2.50       0.00
MarsC(1)E        0.00       2.50       0.00
MarsD            0.00       2.50       0.00
MarsD(1)A        0.00       2.50       0.00
MarsD(1)B        0.00       2.50       0.00
MarsD(2)A        0.00       2.50       0.00
MarsD(2)B        0.00       2.50       0.00
MarsD(2)C        0.00       2.50       0.00
MarsE            0.00       2.50       0.00
MarsE(1)(1)A     0.00       2.50       0.00
MarsE(1)(1)B     0.00       2.50       0.00
MarsE(1)A        0.00       2.50       0.00
MarsE(1)B        0.00       2.50       0.00
MarsE(1)C        0.00       2.50       0.00
MarsF            0.00       2.50       0.00
MarsF(1)A        0.00       2.50       0.00
MarsF(1)(1)A     0.00       2.50       0.00
MarsF(1)B        0.00       2.50       0.00
MarsG            0.00       2.50       0.00
MarsG(3)A        0.00       2.50       0.00
MarsG(3)B        0.00       2.50       0.00
MarsG(1)A        0.00       2.50       0.00
MarsG(1)B        0.00       2.50       0.00
MarsG(2)A        0.00       2.50       0.00
MarsH            0.00       2.50       0.00
MarsI            0.00       2.50       0.00
MacRivY          0.00       2.50       0.00
#####END_LOSS_RATES
#####START_RECORDED_HYDROGRAPHS
         0
#####END_RECORDED_HYDROGRAPHS
#####START_IMPORTED_HYDROGRAPHS
         0
#####END_IMPORTED_HYDROGRAPHS
#####END_STORM#2
#####END_STORM_BLOCK###############|###########|###########|###########|
```

APPENDIX C – DETAILED MODEL RESULTS

APPENDIX C1 – 1% AEP MODEL RESULTS – PRE-DEVELOPMENT

Figure C1.1: 1% AEP Flood Levels – Pre-Development

Figure C1.2: 1% AEP Flood Depths – Pre-Development

Note: Flood depths shaded from 0m (light blue) to 1.0m (dark blue). All depths over 1.0m shaded dark blue.

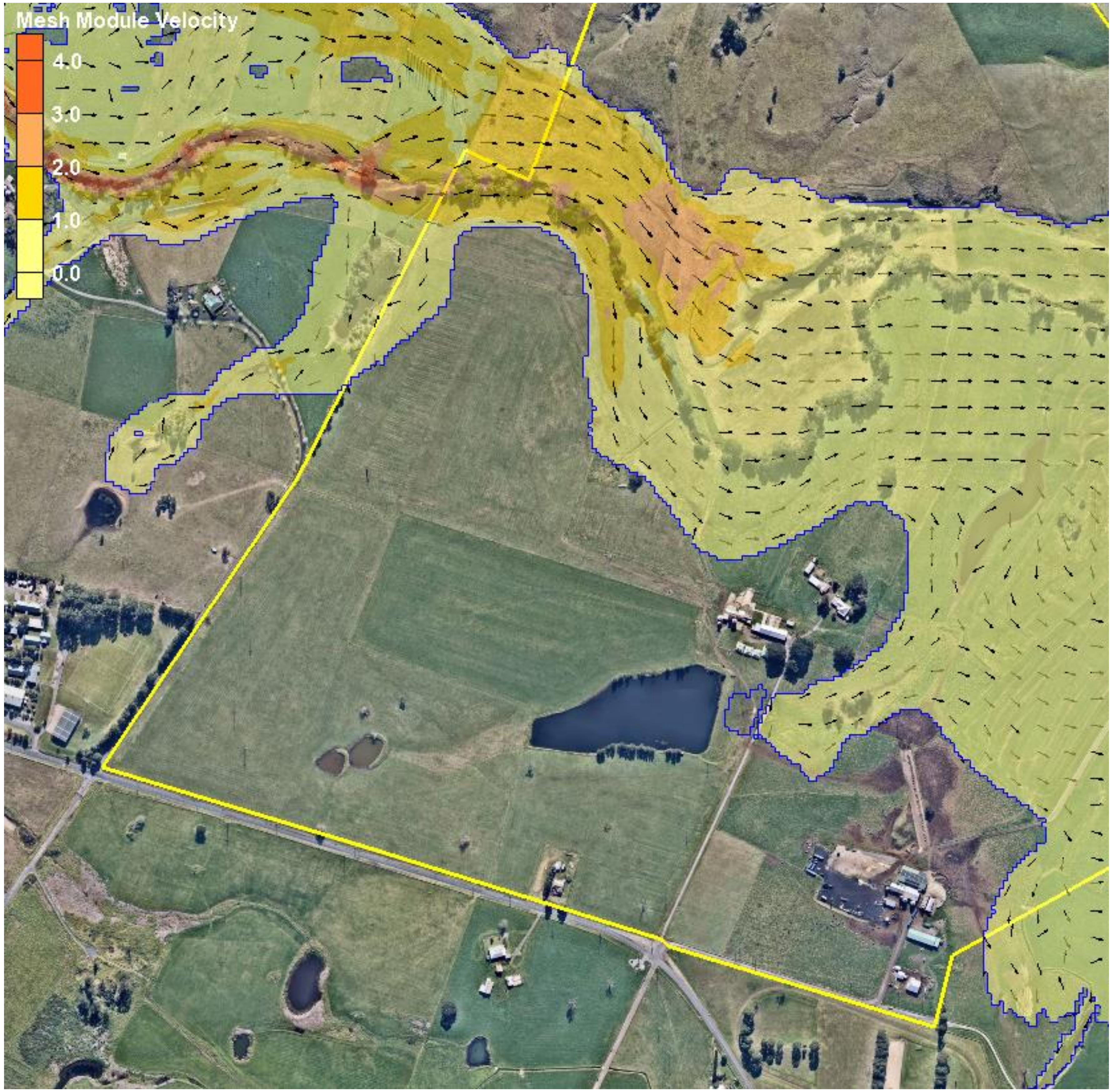

Figure C1.3: 1% AEP Flood Velocity – Pre-Development

Note: Flood velocity shaded from 0 m/s (yellow) to 4.0 m/s (orange). All velocity over 4.0 m/s shaded orange.

APPENDIX C2 – 1% AEP MODEL RESULTS – POST-DEVELOPMENT

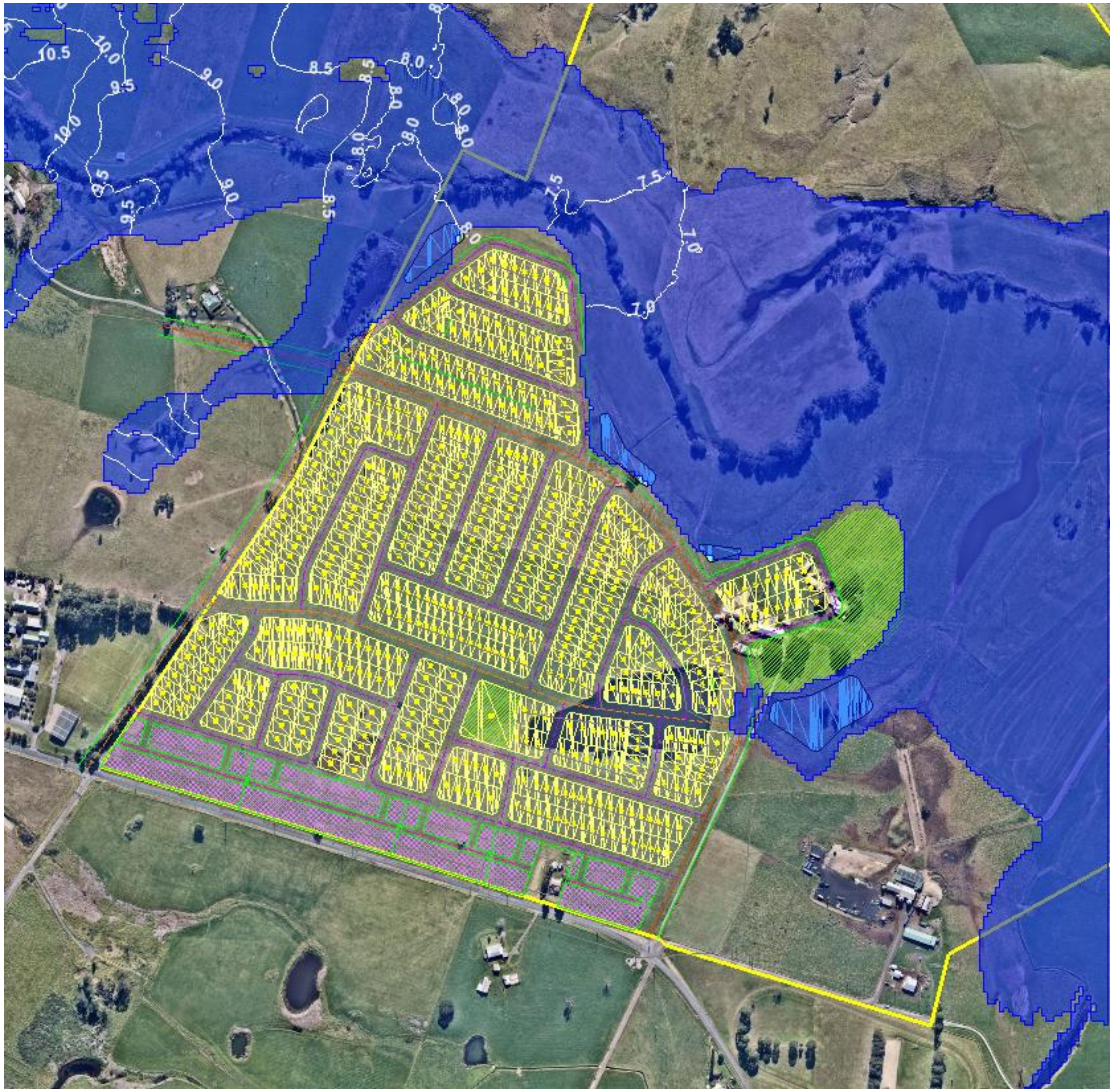

Figure C2.1: 1% AEP Flood Levels – Post-Development

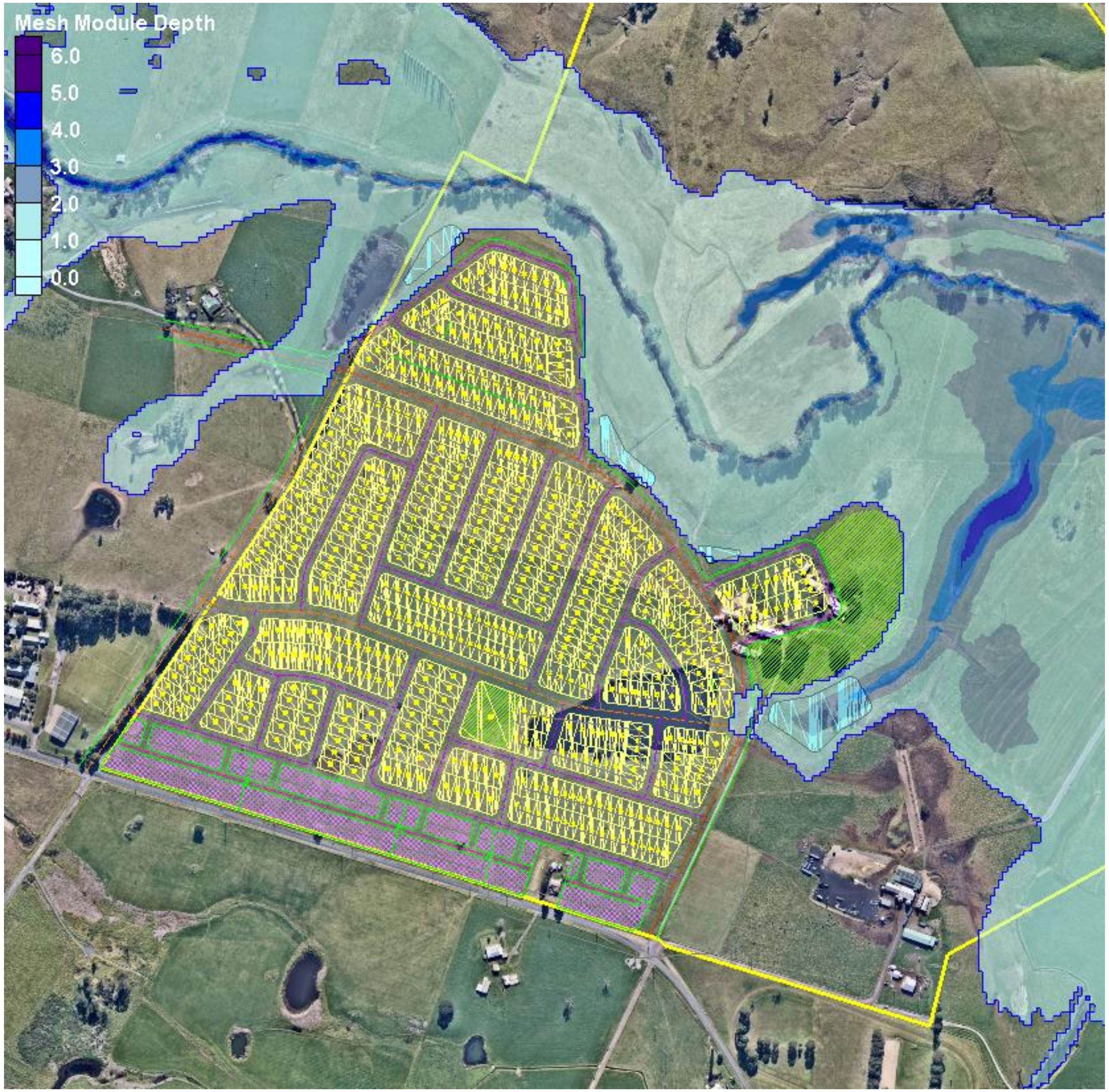

Figure C2.2: 1% AEP Flood Depths – Post-Development

Note: Flood depths shaded from 0m (light blue) to 1.0m (dark blue). All depths over 1.0m shaded dark blue.

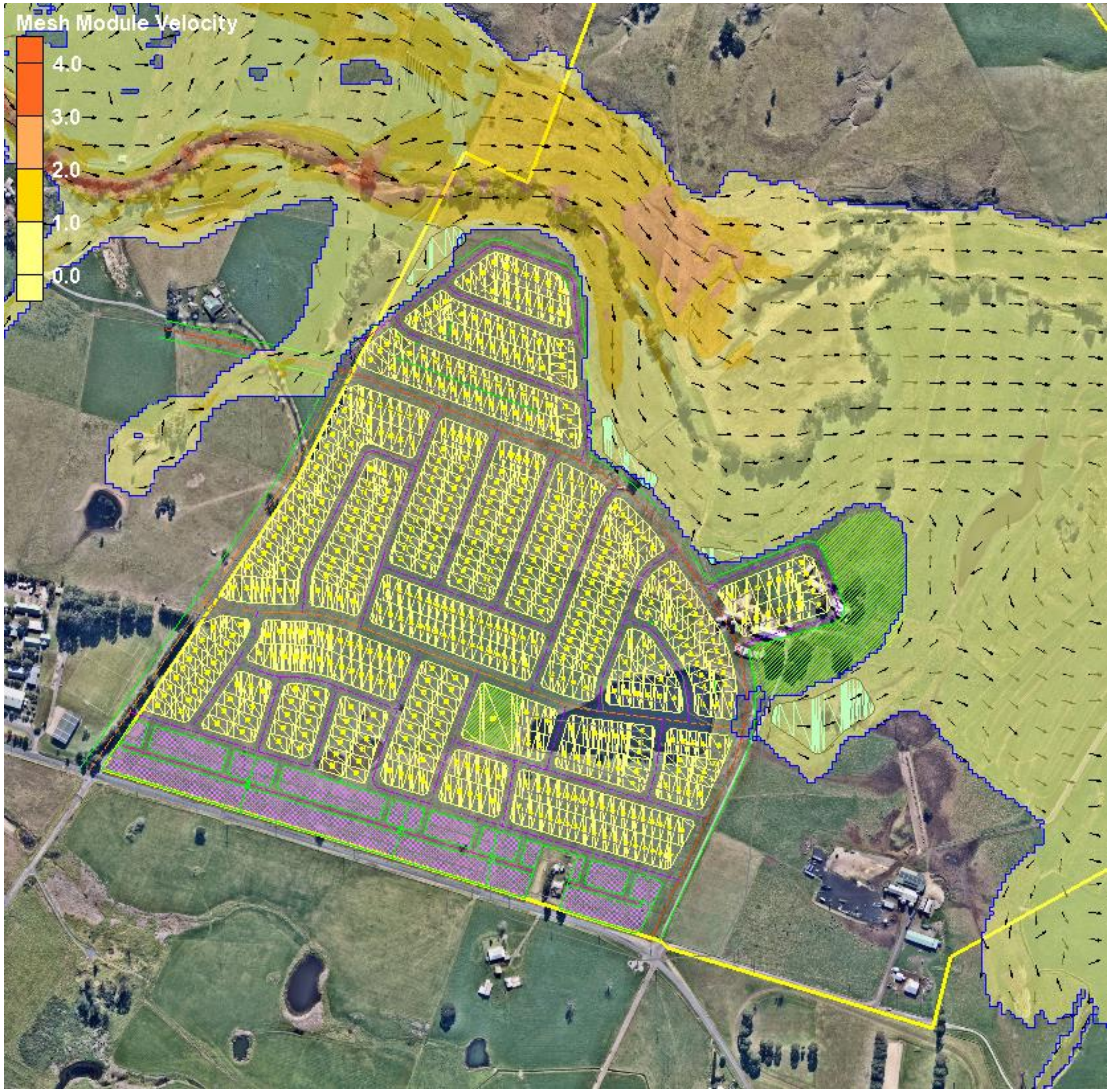

Figure C2.3: 1% AEP Flood Velocity – Post-Development

Note: Flood velocity shaded from 0 m/s (yellow) to 4.0 m/s (orange). All velocity over 4.0 m/s shaded orange.

APPENDIX C3 – PMF MODEL RESULTS – PRE-DEVELOPMENT

Figure C3.1: PMF Flood Levels – Pre-Development

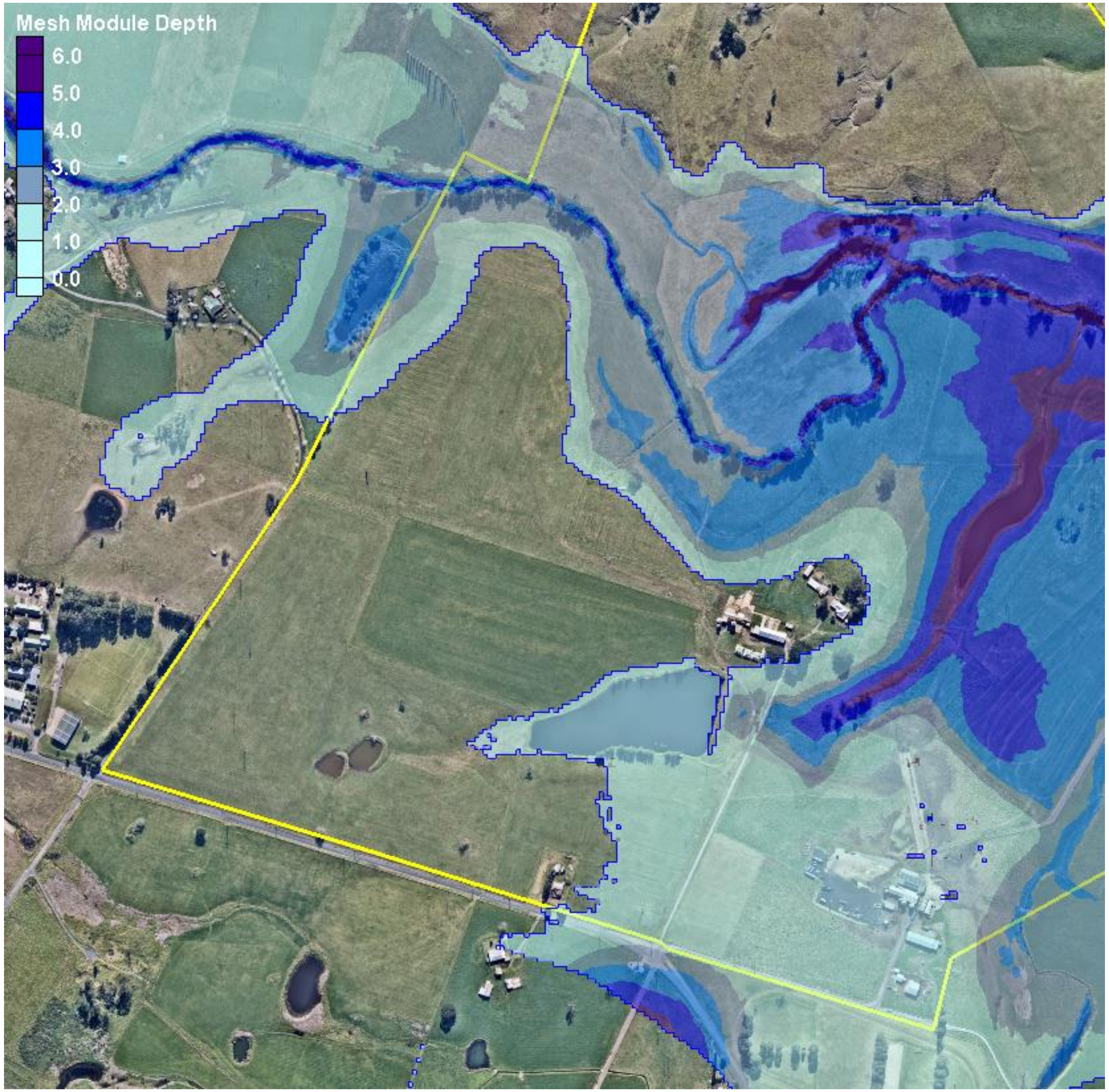

Figure C3.2: PMF Flood Depths - Pre-Development

Note: Flood depths shaded from 0m (light blue) to 1.0m (dark blue). All depths over 1.0m shaded dark blue

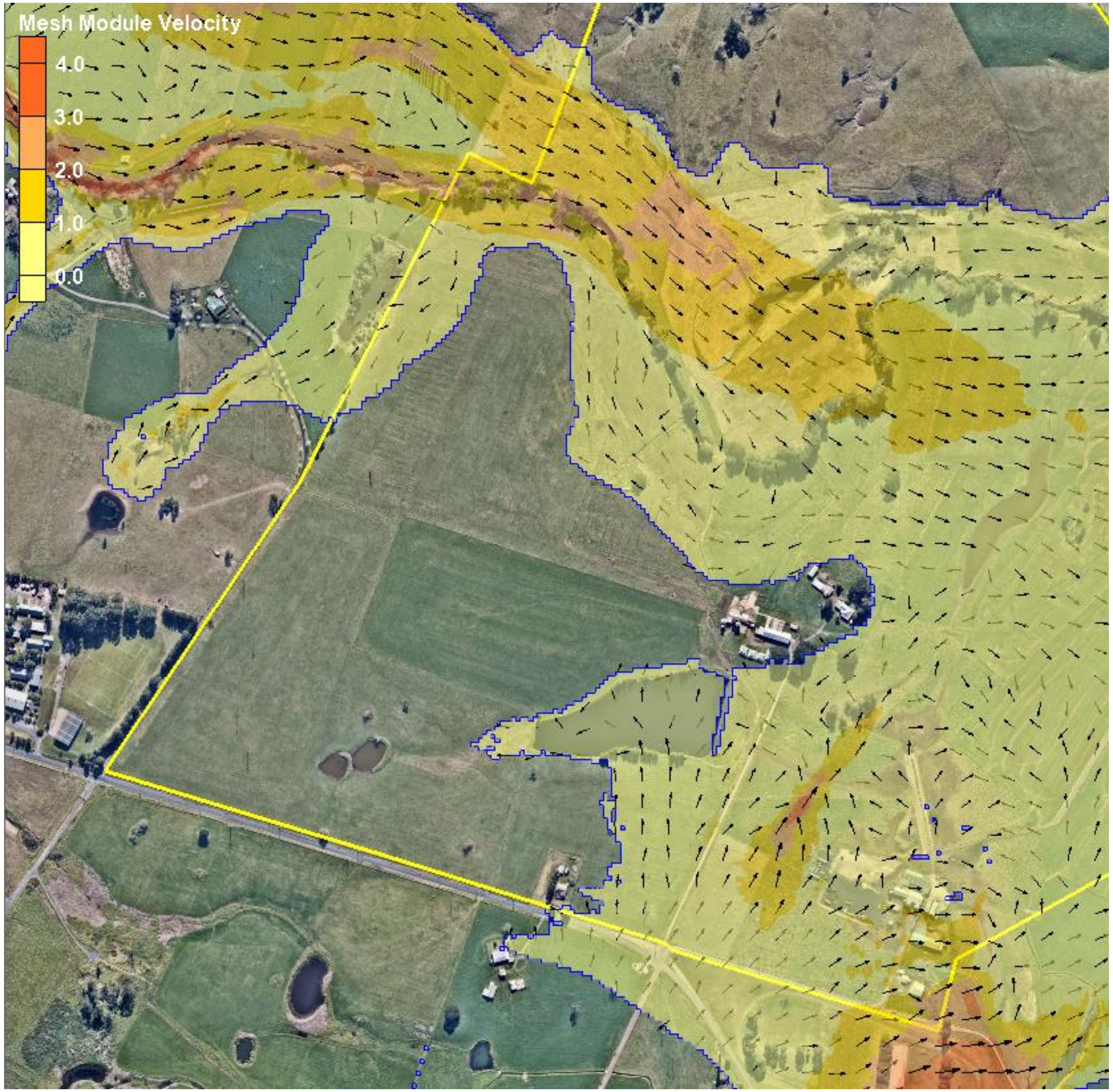

Figure C3.3: PMF Flood Velocity - Pre-Development

Note: Flood velocity shaded from 0 m/s (yellow) to 4.0 m/s (orange). All velocity over 4.0 m/s shaded orange

APPENDIX C4 – PMF MODEL RESULTS – POST-DEVELOPMENT

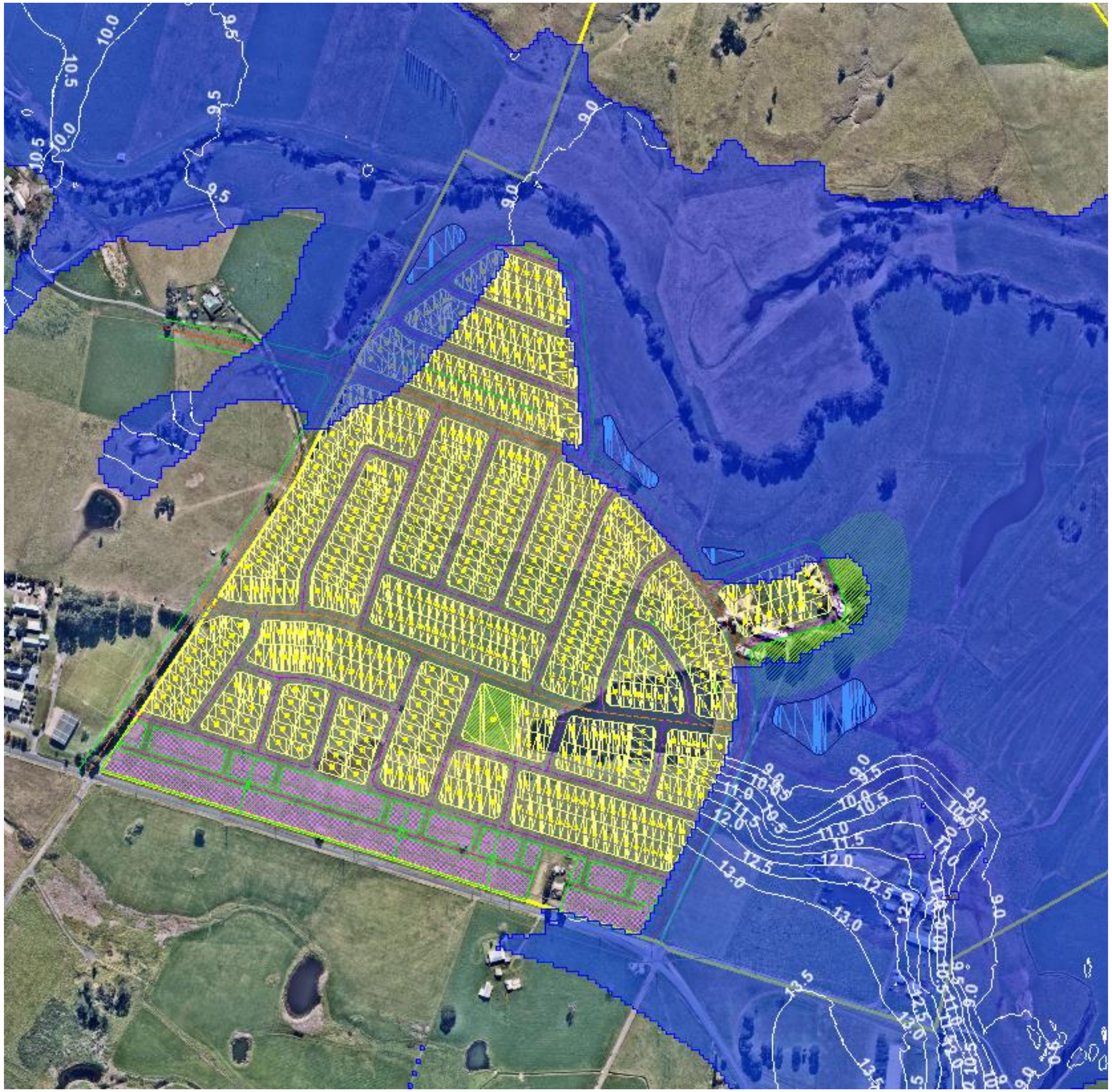

Figure C4.1: PMF Flood Levels - Post-Development

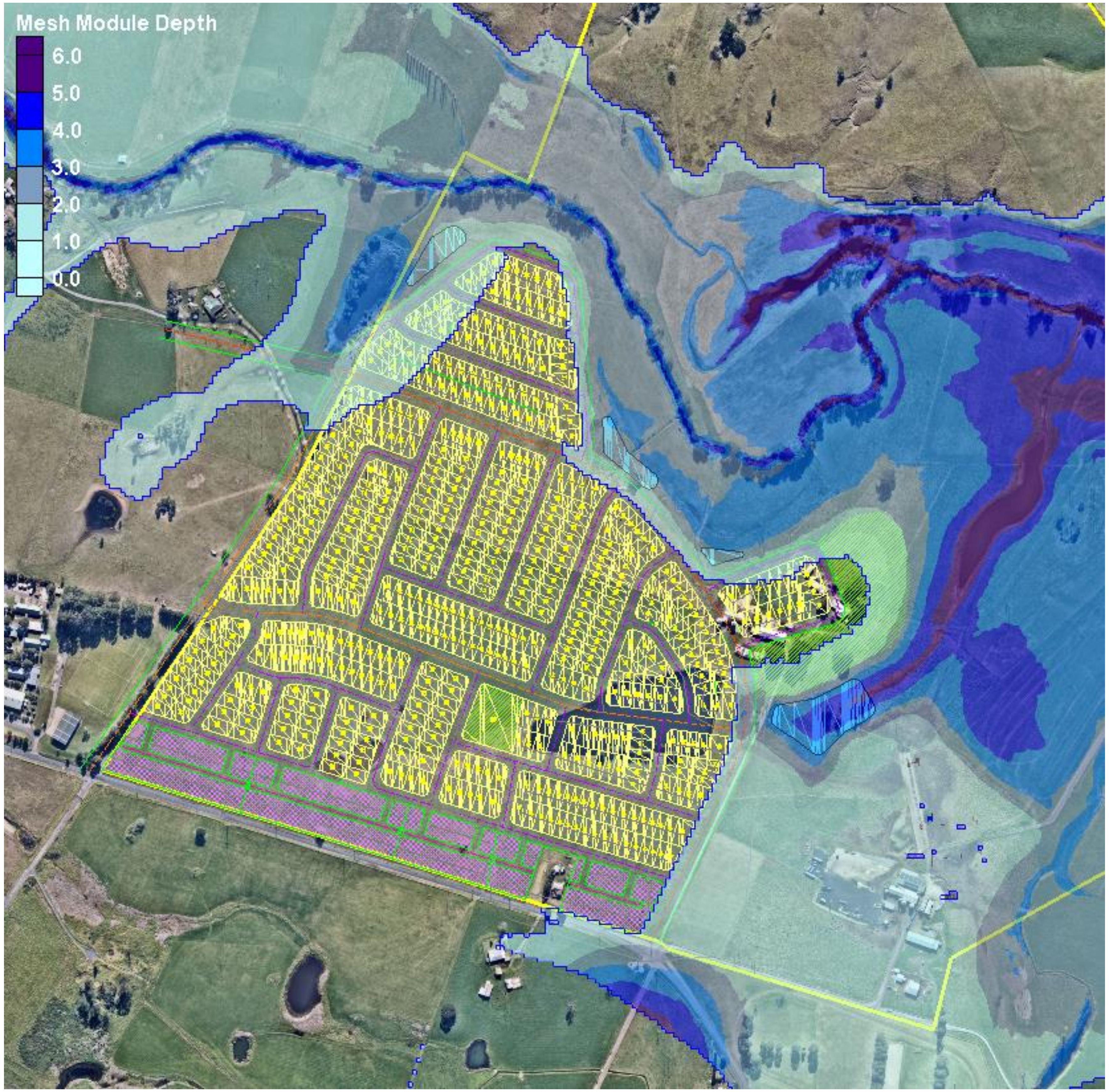

Figure C4.2: PMF Flood Depths - Post-Development

Note: Flood depths shaded from 0m (light blue) to 1.0m (dark blue). All depths over 1.0m shaded dark blue

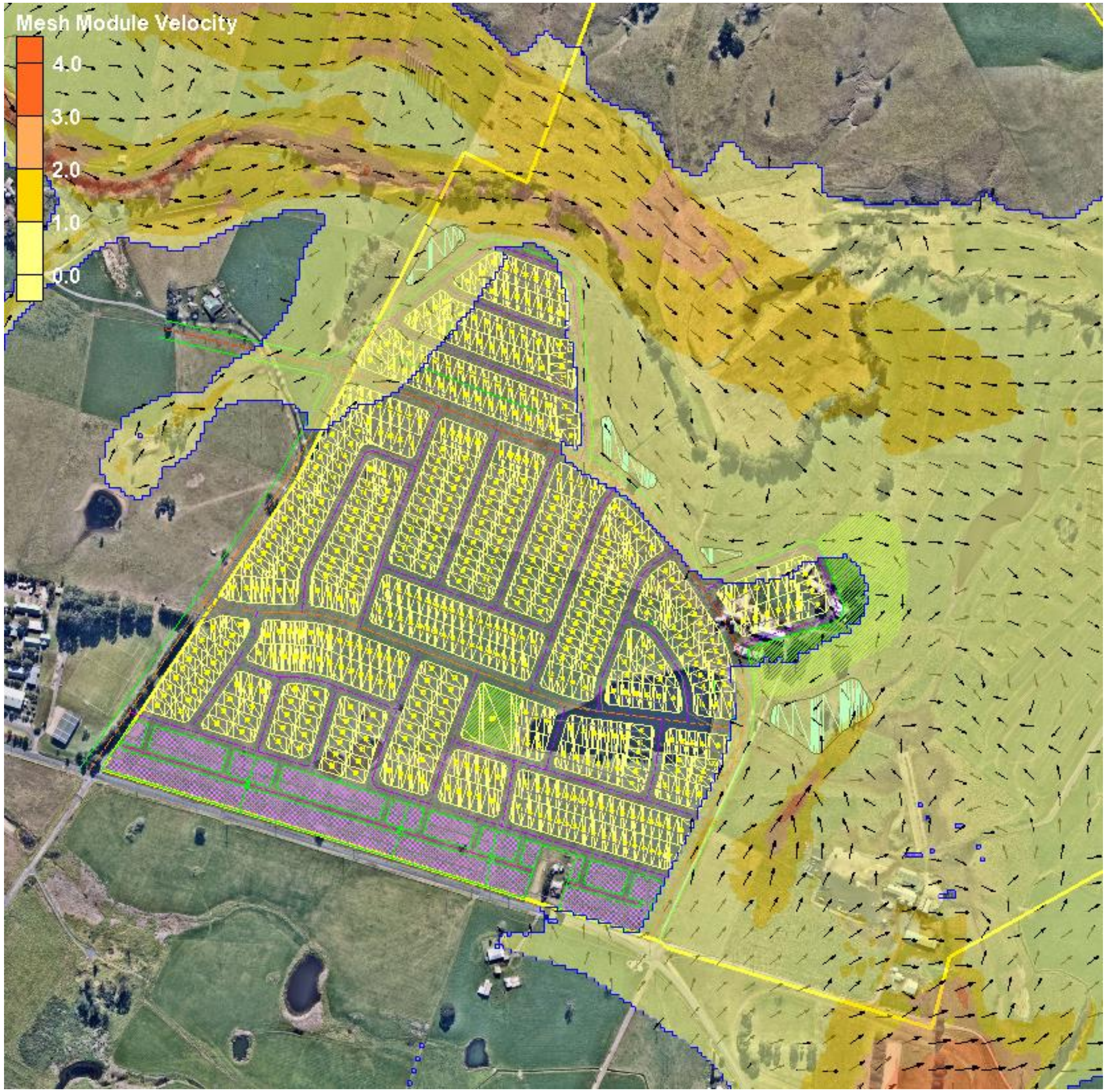

Figure C4.3: PMF Flood Velocity - Post-Development

Note: Flood velocity shaded from 0 m/s (yellow) to 4.0 m/s (orange). All velocity over 4.0 m/s shaded orange

APPENDIX 5 – IMPACT MAPS

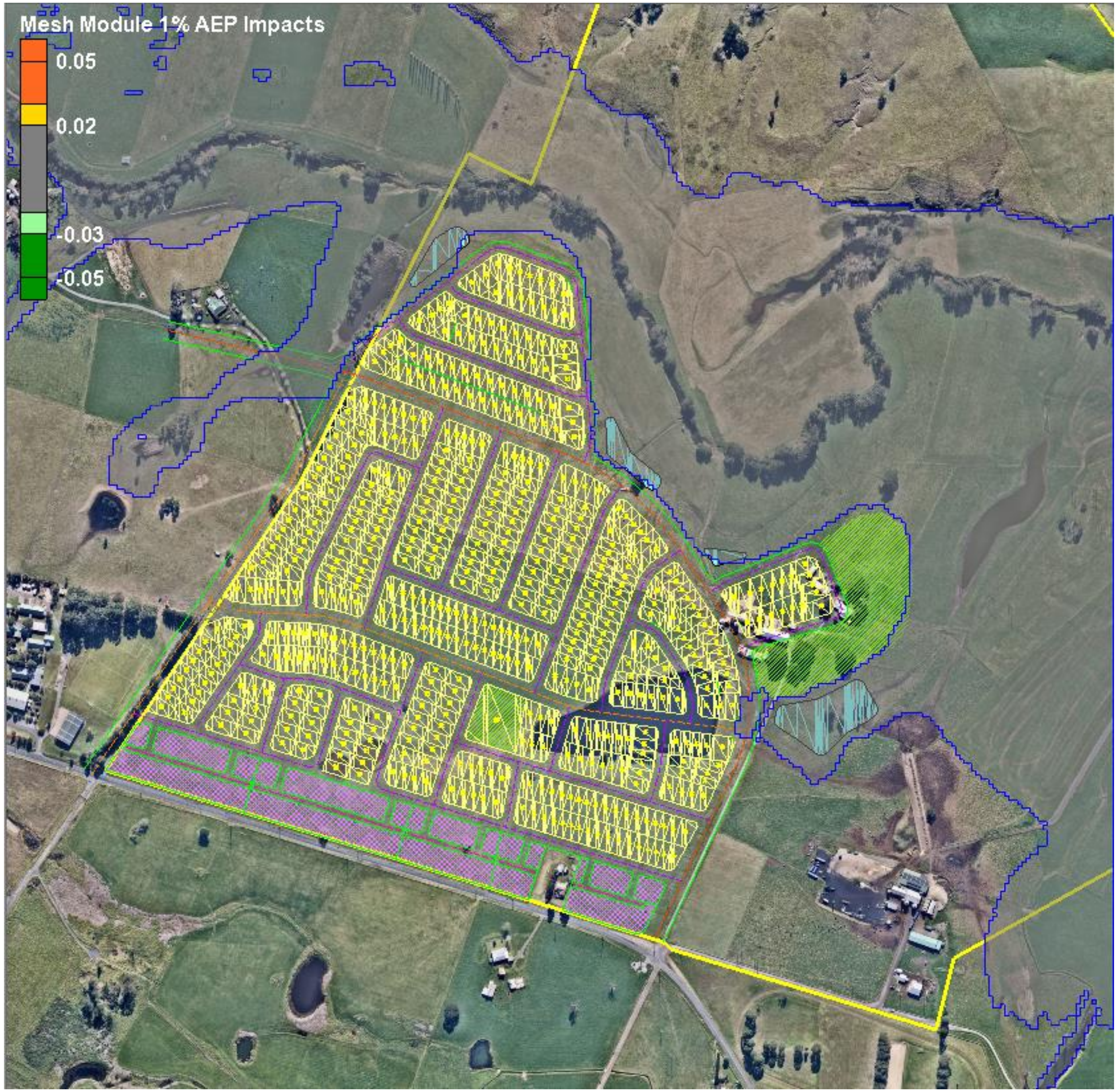

Figure C5.1: 1% AEP Development Related Impacts to Peak Flood Surface Levels under Post-Development Conditions

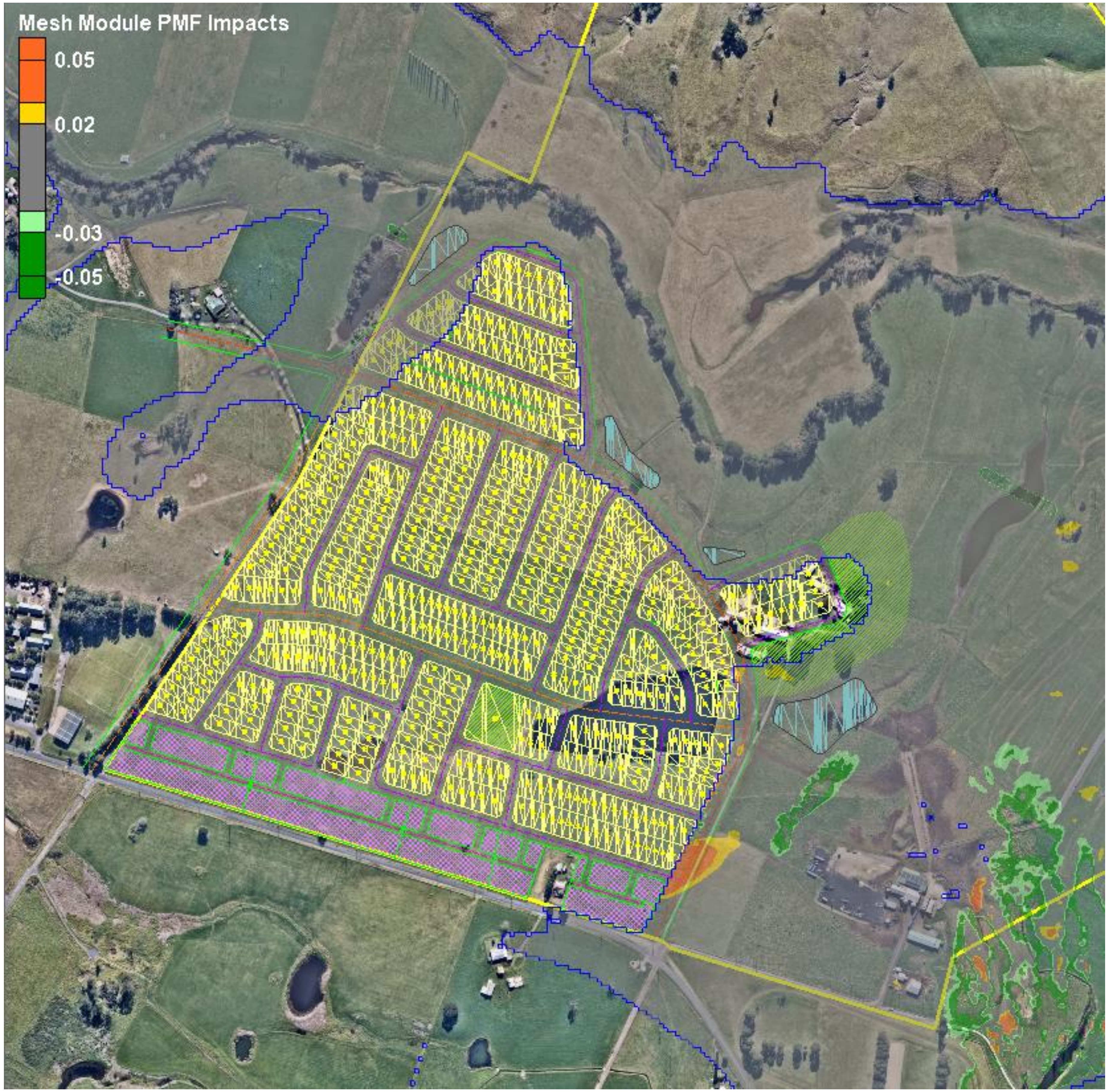

Figure C5.2: PMF Development Related Impacts to Peak Flood Surface Levels under Post-Development Conditions