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Providing Specialist Services in the Fields of Hydrology and Hydraulics

Floodplain Risk and Water Cycle Management Plan
Proposed Development at Cleveland Road, Cleveland

for Newquest Property Pty Ltd

Ref: 20054 Report 001 Rev 4 Flood Study.doc

Report title:

Floodplain Risk and Water Cycle Management Plan Planning Proposal at Cleveland Road, Cleveland

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Version History

Version	Released	Status	Author	Reviewer	Approval
0	28.04.20	Final Draft	AB	AB	AB
1	24.09.20	Final	AB	AB	AB
2	30.09.20	Final	AB	AB	AB
3	16.10.20	Final	AB	AB	AB
4	19.10.20	Final	AB	AB	AB

Issue History

Version	Issued	Copies	Format	Issued To	By
0	28.04.20	1	PDF	Client	AB
1	24.09.20	1	PDF	Client	AB
2	30.09.20	1	PDF	Client	AB
3	16.10.20	1	PDF	Client	AB
4	19.10.20	1	PDF	Client	AB

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1. INTRODUCTION

1.1. BACKGROUND

Cleveland Developments Pty Ltd have submitted a Planning Proposal (PP) to Wollongong City Council (WCC) for development on the subject site, which comprises a series of adjoining land-holdings totalling approximately 370 hectare. The subject site is known as the 'Cleveland Road North' and 'Cleveland Road South' precincts. Portions of the site are flood affected based on the results of WCC's catchment-wide *Mullet Creek Flood Model Update* (2018).

Various flood studies (incorporating a wider assessment of the water cycle) were submitted with the PP prepared by Cardno NSW in 2018 and 2019. WCC reviewed this study and a series of issues were raised with the reports. Subsequently, Cleveland Developments 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 1.3**.

This report also addresses comments made by WCC on the planning proposal, relating to the previous development layout and the Cardno reports. Some of the matters raised by WCC are addressed by virtue of the amended development proposal, however some of the issues have been addressed via further explanation and merit-based consideration. In preparing this report, and to address certain issues raised by WCC, discussions were held with the Natural Resources Access Regulator (NRAR) and where formal input was provided by NRAR, this input was directly incorporated into the proposal.

1.2. PURPOSE OF THIS REPORT

The purpose of this report is to:

a) Review the flood-related information currently submitted with the PP, including any assessment notes from WCC.
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 and risk precinct categorisation.
d) Review the proposed development, together with the hydraulic model results, and assess it against:
    i. The Section 9.1 Direction Clause 4.3 in relation to flooding.
    ii. Clause 7.3 of the WLEP (2009, as amended).
    iii. The assessment notes made by WCC during the assessment of this PP.
e) Prepare a report summarising the above suitable for lodgement with WCC 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 other than where explicitly provided for in this report.

The design flood estimation 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. Unfortunately, WCC mandate (via their DCP) that the obsolete procedures must be used, notwithstanding the NSW Land & Environment Court determining the 2019 procedure appropriate for use in Wollongong (see *RBFI Pty Limited v Wollongong City Council* [2019] NSWLEC 1312).

2. AVAILABLE DATA

2.1. SITE DESCRIPTION

The site is approximately 370 hectare in total, and is located in Cleveland, NSW. It consists of a number of adjoining landholdings. It is bounded to the north by existing residential development, namely Horsley and Brooks Reach. It is bounded to the east by Mullet Creek and existing residential development, as well as the Fowlers Road extension presently under construction. The site is bounded to the south by Mullet Creek and adjoining RU2 zoned land towards Avondale. The site is bounded to the west by a mix of R2 and RU2 zoned land that is currently used for grazing. **Figure 2.1-1** presents an aerial image of the site and surrounds.

Figure 2.1-1 Subject Site

Note: Image sourced from Nearmap. Subject site is shown as yellow line work.

2.2. SURVEY DATA

A detailed survey has been prepared by SDG (registered surveyors) in 2018, for the majority of the Cleveland Road South precinct. The survey is a detailed survey of the site, providing details on the site topography, all levels (in m AHD) across the site, existing vegetation and other topographic features. The survey also included numerous details on several culvert structures in and around the subject site. The site survey is included as **Appendix A**.

Additional survey was also made available in 3D format for the new bridge at Fairwater Drive and the channel areas immediately upstream of Fairwater Drive. This site survey is also included as **Appendix A**.

Additional 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 Digital Elevation Model (DEM) from the 2015 ALS dataset. Aerial imagery (2019) was also supplied for the subject site and surrounds via Nearmap.

2.3. SITE INSPECTION

A detailed site inspection was undertaken by the author in November 2019. The site inspection confirmed the adequacy of the survey information used in this study.

2.4. PREVIOUS STUDIES

1.1.1 Mullet and Brooks Creek Flood Study (2010)

The Mullet and Brooks Creeks Flood Study (denoted as MBCFS, 2010 in this report) has been developed for Wollongong City Council (WCC) by Bewsher Consulting. The hydrologic and hydraulic models were calibrated using data from the February 1984 and March 1975 flood events, and validated using the October 1999 flood event data. The study also estimates flood levels for design storm bursts up to and including the Probable Maximum Flood (PMF) event, and Provisional Hydraulic Hazard for events up to the 1% AEP flood.

It should be noted that the design flood estimation in this study is based on a hydraulic model geometry identical to that for the October 1999 flood. Therefore, changes to the floodplain between 1999 and 2010 (when the study was adopted) have not been reflected in the model.

1.1.2 Mullet and Brooks Creek Floodplain Risk Management Study and Plan (2010)

The Mullet and Brooks Creeks Floodplain Risk Management Study (denoted as MBCFRMSP, 2010 in this report) has been developed for Wollongong City Council (WCC) by Bewsher Consulting. The study was administered by the Mullet and Brooks Creeks Floodplain Management Committee, which comprised Councillors and staff from WCC, officers from the Department of Environment and Climate Change (DECC), the State Emergency Service (SES) and community representatives. This study reported on flood damages, flood mitigation works, recommended planning controls and other risk management matters.

1.1.3 Mullet Creek, West Dapto Extension of Flood Model Report (2011)

In 2011, WCC commissioned Bewsher Consulting Pty Ltd to carry out an extension of Mullet Creek Flood Model, primarily for the purposes of including the West Dapto Release Area. The study includes updated WBNM and TUFLOW modelling for the entire catchment. Throughout this process, Bewsher Consulting and WCC were unable to reconcile the 2011 results with the previous 2010 model results, in particular for land downstream of the Illawarra Railway Line.

In order to provide an equitable outcome for the community, the report states that *following a number of discussions with Council staff, <it was> adopted to preserve the existing flood behaviour results within downstream areas.* 'Downstream Areas' is defined in the study by a series of maps, but generally refers to land east of the Illawarra Railway Line. The subject site is located upstream of the transition zone.

1.1.4 Mullet Creek Flood Model Update (April, 2018)

This report is recently adopted and details the work undertaken to update existing flood models for Mullet Creek. The updated flood models have been utilised to re-establish design catchment flood conditions within the Mullet Creek catchment, and assess flood impacts due to the continued development of the West Dapto Urban Release area. The existing flood models were developed in 2010 and 2011 as described above. This work is essentially an update to the 2010 and 2011 studies. The 2018 report has been used to derive existing flood related information, as documented elsewhere in this report.

2.4.1. Water Cycle Management Study (Cardno, 2018)

Cardno NSW prepared the *Preliminary Water Cycle Management Study - Lot A DP156446, Lot 313 DP1188000 and Lot 1 DP194419 Cleveland Road* (for Cleveland Group Holdings Pty Ltd) dated 5th June 2018. This report covered what is essentially the Cleveland Road South precinct. This report supported an amendment to the development controls and associated mapping within the Wollongong Local Environmental Plan 2009 (LEP 2009) at West Dapto for a land along the north of Cleveland Rd (eastern end of Cleveland Road). The report addressed flooding, OSD and water quality issues associated with the proposal.

2.4.2. Water Cycle Management Study (Cardno, 2019)

Cardno NSW prepared the *Water Cycle Management Study - Cleveland Road Planning Proposal for Rezoning* (for Cavi Properties Pty Ltd) dated 5th March 2019. This report covered what is essentially the Cleveland Road North precinct. This report supported an amendment to the development controls and associated mapping within the Wollongong Local Environmental Plan 2009 (LEP 2009) at West Dapto for a land along the north of Cleveland Rd (eastern end of Cleveland Road). The report addressed flooding, OSD and water quality issues associated with the proposal.

3. HYDROLOGIC MODELLING

3.1. HYDROLOGY MODEL DEVELOPMENT

A WBNM model has been created for this study, to determine peak flows at the subject site for all 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.rienco.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.

It is not possible to use the *Mullet Creek Flood Model Update* (2018) hydrology model directly, because the location of the subareal boundaries does not align well enough with the flow input locations required in the subsequent hydraulic modelling for the proposed development. As such, a WBNM catchment plan was prepared specifically for use in this investigation. The model was established consistent with the information available in WCC's *Mullet Creek Flood Model Update* (2018).

Model parameters were as per **Table 3.1-1**. 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
Stream Routing Factor	1.0

Seven design rainfall gauges were used from the AR&R isohyetal datasets and incorporated into the model, located at RAI40, RAI43, RAJ42, RAK39, RAK41, RAN39 and RAN41. A detailed catchment plan is included as **Appendix B**.

3.2. HYDROLOGY MODEL CHECKS

Prior to using the model to establish design discharges, the model was checked in the following ways using a 2 hour, 1% AEP design rainfall burst.

- ***Overall volume conservation***. The total runoff volume (as calculated at the catchment outlet) was checked against total rainfall volume (i.e total amount of rain falling on the entire catchment surface). As expected from a correctly constructed model, these two values were the same once the volume of rainfall lost to groundwater and stored on the surface (and therefore not included in runoff at the outlet) were accounted for.

- ***Unit discharge – from local subareas.*** The unit discharge from each subarea was calculated by dividing the local runoff (sum of the pervious and impervious peak discharges) from each subarea by its area to give a discharge per hectare rate.

Unit discharge values should all lie within a typical range for a 1% AEP design storm of 2 hour burst duration in this area, of between 0.3 and 0.8 m^3/s/ha, with variation inside this range being due to spatial differences in rainfall and differences in area and impervious cover (larger sub-areas having lower unit discharges and more impervious sub-areas having higher unit discharges).

The predicted unit discharges from the Rienco model compare well to the predicted unit discharges from the *Mullet Creek Flood Model Update* (2018).

4. PRE-DEVELOPMENT HYDRAULIC MODELLING

4.1. HYDRAULIC MODEL DEVELOPMENT

4.1.1. Model Grid Construction

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

4.1.2. Model Topography Patches

Only one elevation patch was made in the model, being the patching of the full extent of ground survey as shown in **Appendix A** and **Appendix C**.

4.1.3. Model Boundary Conditions

In terms of inflow boundary conditions, inflow hydrographs were directly input from the WBNM model results. The inflow hydrographs were taken from WBNM and include all subareas upstream of, and within, the subject site. The downstream boundary condition is sufficiently downstream of the subject site to allow flood behaviour at the site to be satisfactorily determined, and is located well downstream of the Fairwater Drive Bridge.

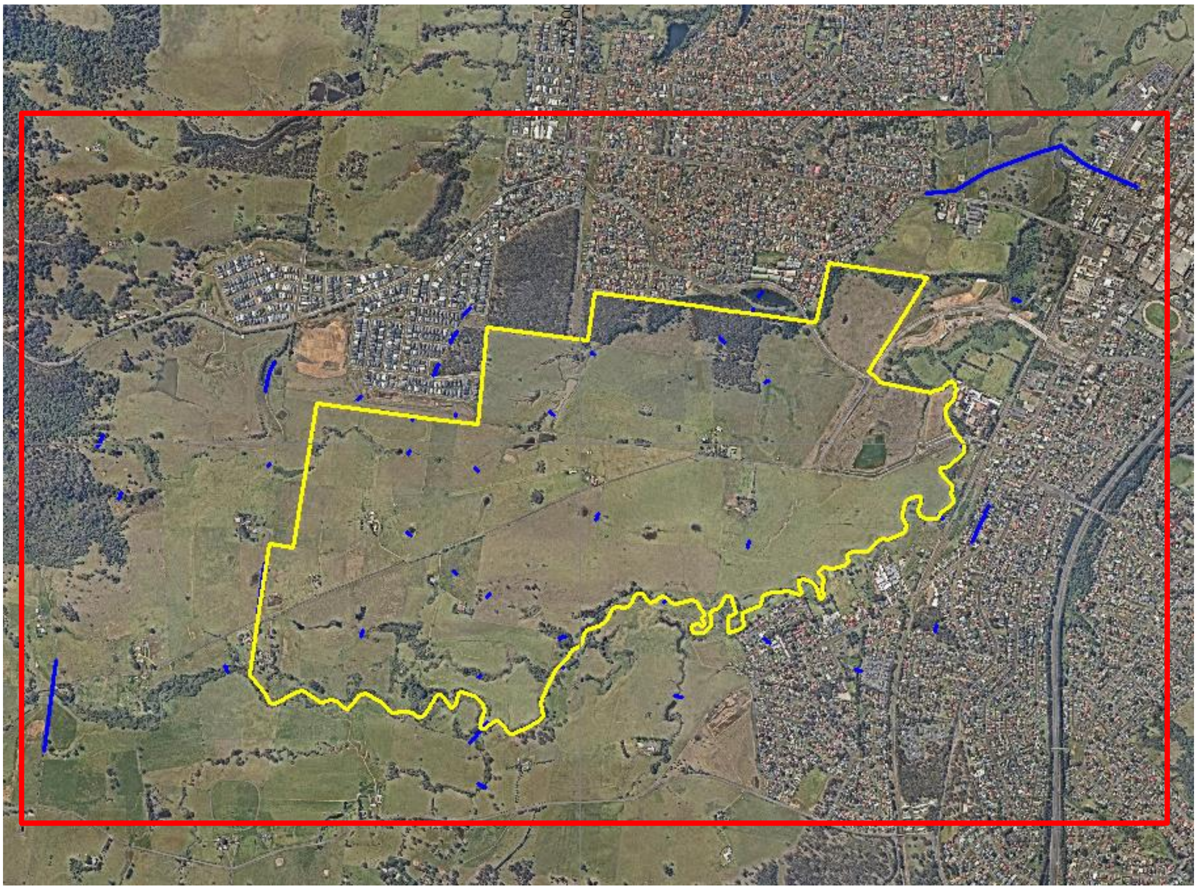


Figure 4.1-1 TUFLOW Grid and Boundary Condition Details

Note: TUFLOW 2m domain shown as red line. Inflow hydrograph BC's shown as blue lines. Subject site is shown indicatively in yellow.

4.1.4. Model Surface Roughness

Manning's surface roughness 'n' values were taken from a detailed site inspection and the typical roughness values associated with those surfaces. **Table 4.1-2** describes the surface characteristics and the associated roughness values. These values are generally consistent with the adopted *Mullet Creek Flood Model Update* (2018). The adopted *Mullet Creek Flood Model Update* (2018) includes some additional roughness mapping of (for example) Cleveland Road, however Cleveland Road is not inundated and as such there is no value in mapping tis roughness for this work.

Table 4.1-1 – Manning's Surface Roughness Values

Surface Description	Assigned 'n' value in TUFLOW
Pasture	0.050
Medium Density Vegetation	0.150

Figure 4.1-2 describes the surface roughness mapping, with the grid default value being Pasture.

Figure 4.1-2 Pre-Development Manning's Surface Roughness Map

4.1.5. Model Structures

No structures were included in the pre-development hydraulic model except the newly constructed bridge at Fairwater Drive. This structure was included as a Layered Flow Constriction based on the deck and structure heights detailed on the ground survey. The Layered Flow also includes allowances for guard rails and losses associated with the supporting structure.

4.2. HYDRAULIC MODEL RESULTS

The model was run for the 1% AEP and PMF design events. The model simulates flood behaviour consistent with both the previous Rienco model (2010) and the WCC model (2011), albeit with the slightly lowered peak flood levels consistent with the blockage policy changes. 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**.

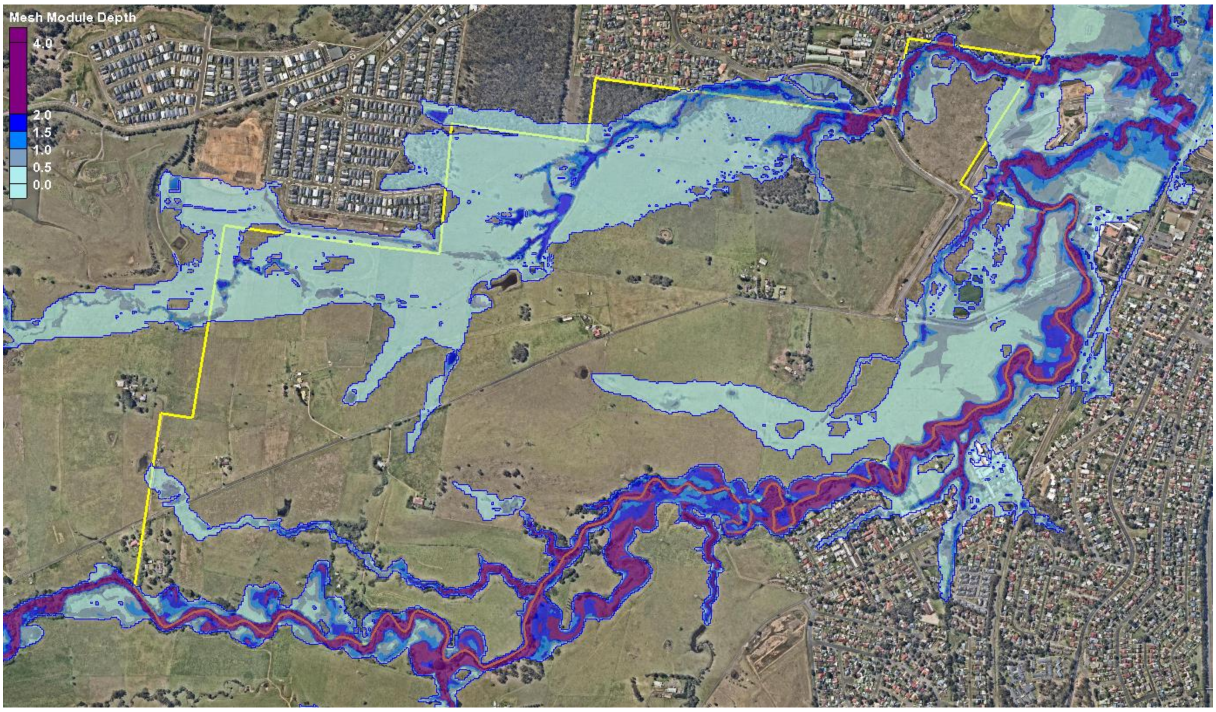


Figure 4.2-1 1% AEP Pre-Development Flood Extent and Depths

Note: Flood depths shaded 0mm (light blue) to 4,000mm (dark blue). All depths greater than 4,000mm are all shaded dark blue. Subject site shown in yellow.

As can be seen in **Figure 4.2-1**, the peak 1% AEP flood depths vary across the site. Through the northern areas of the site, peak flood depths are relatively shallow and broad, which reflects the underlying topography (i.e. little to no channel) and relatively small catchment size. Peak flood depths in the 1% AEP design flood, along the northern pasture areas, is well under 500mm. Conversely, the southern main arm of Mullet Creek has a highly incised channel and a much larger catchment area. There is very little shallow flood behaviour, with most flow contained within the bank or immediate overbank areas even in a 1% AEP design flood.

4.3. HYDRAULIC MODEL RESULTS – CHECK

Minimal historic concurrent rainfall and flood stage data was available for this catchment. As such the hydrologic and hydraulic models have been applied to this study without direct calibration or validation. To minimise the inherent uncertainty such modelling introduces, all modelling parameters have been selected from those found to best represent behaviour in other gauged regional catchments, and those values consistent with the *Mullet Creek Flood Model Update* (2018).

The hydraulic model was also checked in several other ways. As requested by WCC in their assessment notes on the planning proposal, the Rienco model results have been compared with the results of WCC's adopted *Mullet Creek Flood Model Update* (2018). To this end, **Figure 4.3-1** has been prepared to demonstrate the differences between the *Mullet Creek Flood Model Update* (2018) and the Rienco model results for the 1% AEP design flood.

The darker shaded areas are the 1% AEP extents based on the Rienco model. The lighter shaded areas are the results of the 1% AEP *Mullet Creek Flood Model Update* (2018). As can be seen, within the subject site, the Rienco model is materially indifferent to the results of the *Mullet Creek Flood Model Update* (2018). Where there are differences, the Rienco model is slightly more conservative than the *Mullet Creek Flood Model Update* (2018). This can be seen where the darker shading is a greater extent that the underlying lighter shading.

There are some other reasons for this. Firstly, the Rienco model uses ground survey in parts, as opposed to the use of ALS in the *Mullet Creek Flood Model Update* (2018). This will change the flood model results, in particular in areas where the flood depths are shallow. Further, the *Mullet Creek Flood Model Update* (2018) model results are post-processed results and may have been clipped to not show shallow flood depths. The Rienco model shows all flood depths.

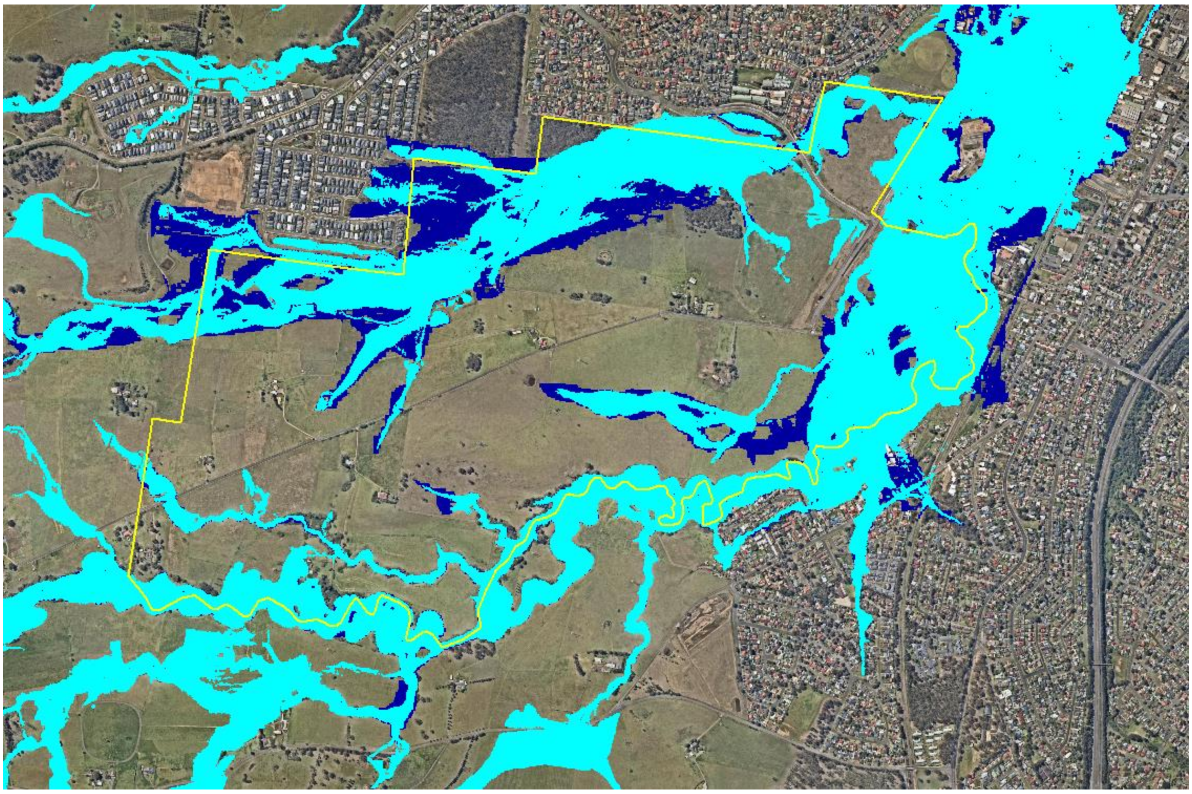


Figure 4.3-1 Comparison of Rienco vs WCC 1% AEP Flood Extents

Note: Flood extents are trimmed in WCC's model results to only show areas where flood depths are more than 150 mm.

As can be seen from **Figure 4.3-1** the current Rienco model replicates the results of the *Mullet Creek Flood Model Update* (2018) at a sufficient level of detail commensurate with the Planning Proposal.

5. POST-DEVELOPMENT HYDRAULIC MODELLING

5.1. HYDRAULIC MODEL DEVELOPMENT

The TUFLOW input files were modified to simulate the post-development scenario, as follows:

- The roughness values were modified, in particular around the proposed flood mitigation channel where a revegetated riparian corridor was applied (n = 0.100).
- Design TIN for the entire development proposal was applied as a 'Z' patch, in accordance with the civil design plans. A figure in **Appendix C** describes the extent of the post-development TIN patch.
- Several trunk drainage structures were also applied at major drainage crossings within the proposed development, to allow the model to function as per the design intent.

5.2. HYDRAULIC MODEL RESULTS – POST DEVELOPMENT

The model was 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**.

As can be seen in **Figure 5.2-1**, the peak 1% AEP flood is conveyed through the proposed development without inundation of any lot. The proposed open spaces throughout the development convey runoff that is contained within that particular open space. The several large waterway crossings in the northern precinct perform well in the 1% AEP design flood, with trafficable roads and no inundation of the adjoining lots.

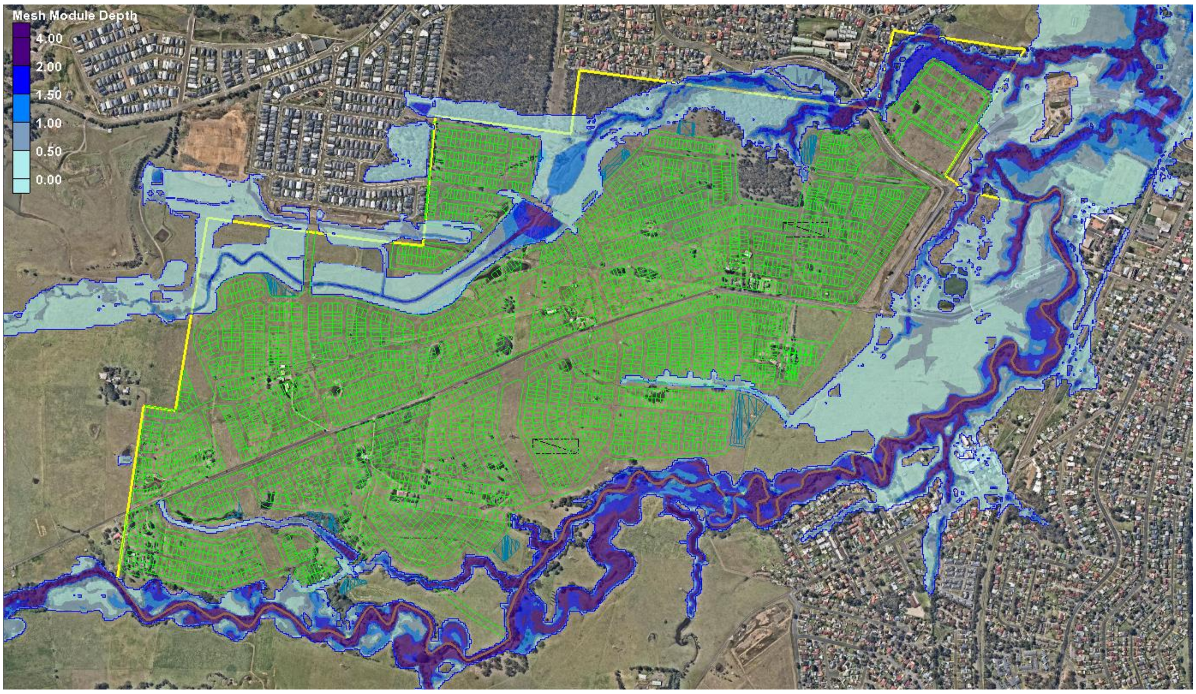


Figure 5.2-1 1% AEP Post-Development Flood Extent and Depths

Note: Flood depths shaded 0 mm (light blue) to 4,000 mm (dark blue). All depths greater than 2,000 mm are all shaded dark blue. Subject site shown in yellow.

6. DEVELOPMENT ASSESMENT USING COUNCILS POLICIES

6.1. FLOODWAYS

The methodology for delineating floodways, as stated in DCP 2009 (Chapter E13), is *where not mapped in an adopted Flood Study or FRMS, floodway areas may be defined using DPIE Floodway Definition Guidance (in Prep 2020), or using a velocity x depth product greater than 0.4m^2/s.*

Floodways are mapped in an adopted flood study, being the *Mullet Creek Flood Model Update* (2018). The floodway mapping in the *Mullet Creek Flood Model Update* (2018) is based on the findings of Howells (2003), where the floodway is defined as areas where:

- Velocity x depth greater than 0.25 m^2/s and velocity greater than 0.25 m/s; or
- Velocity greater than 1 m/s.

The Howells (2003) paper cautioned against using the technique, as it was a novel approach and had very limited application and needed further research to be validated. Nonetheless, Wollongong Council embraced the approach and have used it exclusively within their 2015 Study. Further, the DCP requirement determines that floodways are areas greater than 0.4 m^2/s, and the adopted flood study limits this to 0.25 m^2/s with other associated velocity limits. The differences in approach are considerable and do not relate well to the site setting or the proposal. For example, an existing water course flowing at >1 m/s is designated as a 'floodway', but if it's revegetated as part of the proposal and velocity is reduced, it's then not a floodway. It is either a floodway, or it isn't.

Moreover, the floodways in the *Mullet Creek Flood Model Update* (2018) are out-dated, due to the recent changes in the blockage policy. To this end, it is much more appropriate to consider a floodway in terms of the DCP requirement, noting that this is the benchmark that future residential development will be assessed against. **Figure 6.1-1** below describes the pre-development floodways and **Figure 6.1-2** below describes the post-development floodways.

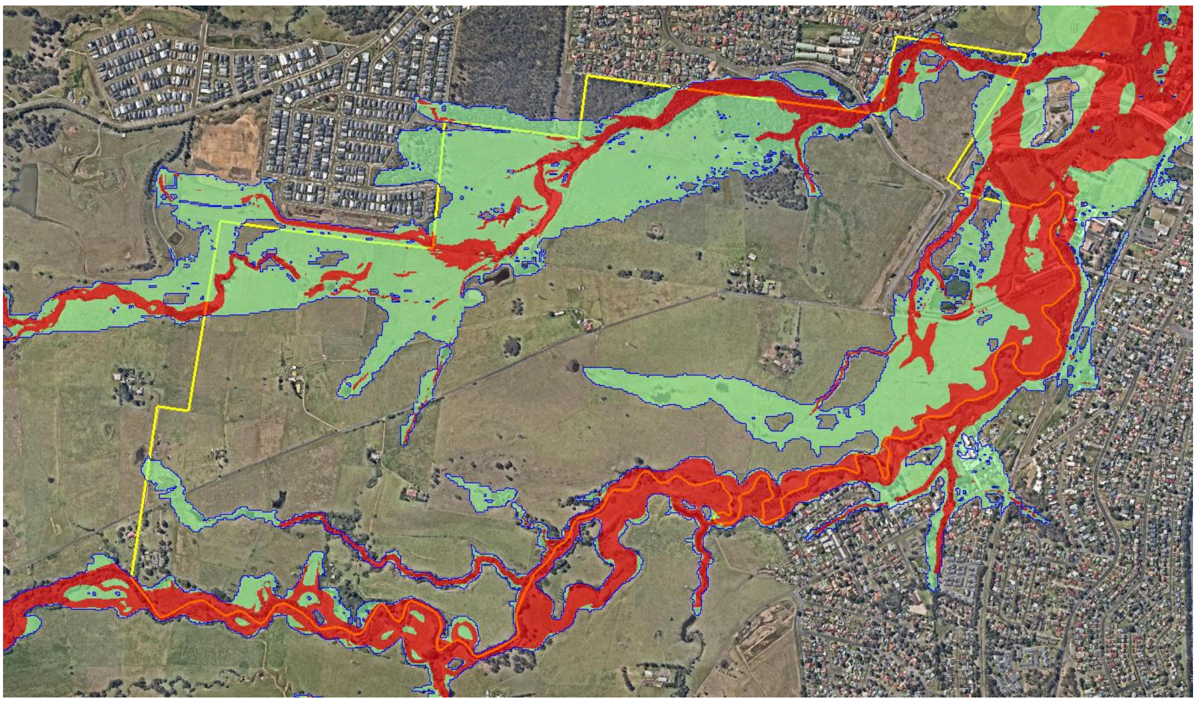


Figure 6.1-1 1% AEP Pre-Development Floodway Categorisation by WCC

As can be seen, the floodway areas (shown in red) make up the bulk of the flooded extent in the southern portion of the site. Conversely, in the norther precinct, very little floodway exists except areas directly over the existing watercourses. It is concluded that the floodway's are predominantly confined to areas within the existing channels (which is a logical progression of the concept of a floodway).

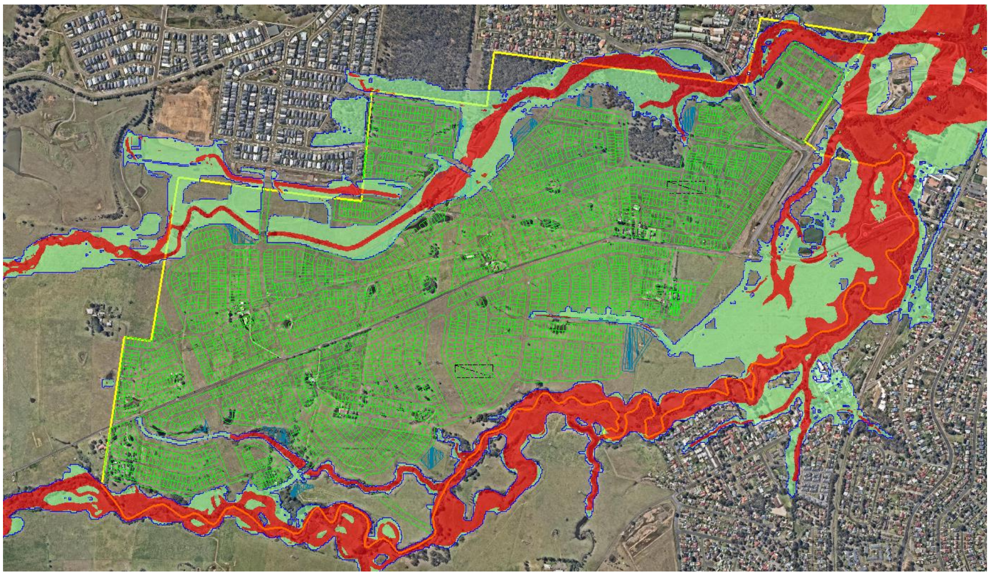


Figure 6.1-2 1% AEP Post-Development Floodway Categorisation by Rienco

As can be seen, there is no proposed residential development contained within a floodway. The proposal has reconfigured the existing floodway in the northern precinct to integrate into the urban form. This is considered essential; the existing riparian areas and informal farm dams are untenable and needed to be removed at some point.

6.2. DEVELOPMENT RELATED IMPACTS ON FLOOD BEHAVIOUR

Figure 6.2-1 describes the impacts on peak flood surface levels in the 1% AEP event, in terms of increases and decreases to peak flood surface levels. A detailed map of these impacts is included in **Appendix C**. The impacts resulting from the proposed development are generally isolated to the subject site. The small impacts seen upstream of the site in the NW corner of the development (i.e. upslope of Brooks Reach) are attributable to works outside the scope of the Planning Proposal. The proposed development TIN applied to the model includes works already approved on that particular site. The TIN was applied to this site to ensure flow in the post-development scenario was applied realistically, however the impacts are not associated with this Planning Proposal.

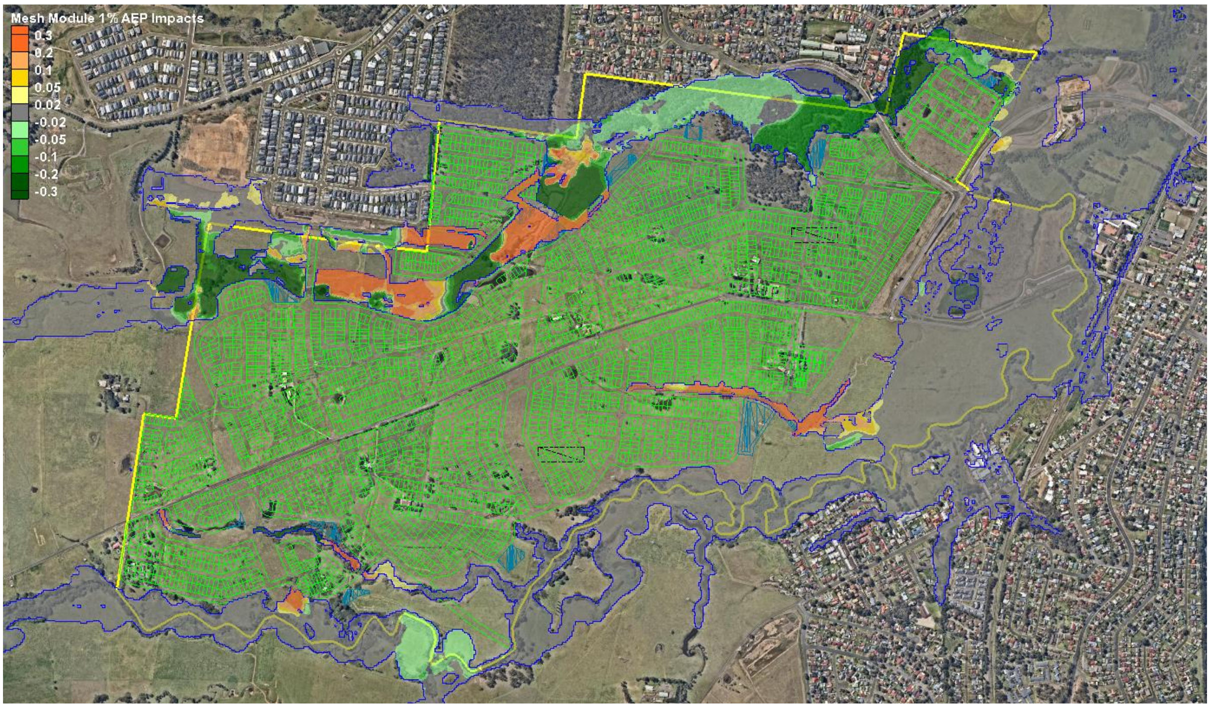


Figure 6.2-1 1% AEP Peak Flood Surface Level Impacts

In terms of flood storage, there are minor reductions in flood storage as a result of the proposal. In the 1% AEP design flood, at the peak of the flood, there is a 2% decrease in flood storage, and a ~1% reduction in flood storage in the PMF. Such reductions are close to the volume tolerance of the model, which is reported at 0.5%. Notwithstanding that such minor reductions in flood storage have no effect on flood behaviour downstream of the site, there is ample opportunity to provide additional storage during detailed design for DA and CC would it be determined by WCC that such storage is required.

6.3. FLOOD RISK PRECINCTS

Flood risk precincts are areas where certain flood-related planning controls apply. They are only of relevance within the DCP, and therefore only applicable at the DA stage. In particular, the High Flood Risk Precinct requires very detailed survey of the top of creek bank to determine, information that is not warranted at the Planning Proposal phase.

There are a multitude of examples in West Dapto where WCC have zoned entire parcels of land as R2 or R3 that contain floodway's and watercourses (i.e. High Flood Risk Precinct's). The finer detail of each precinct for each DA can be determined and readily complied with. All lots are flood-free in the 1% AEP design flood, and there remains no impediment to the rezoning of the land based on the information contained in this report.

6.4. REQUIREMENTS OF SECTION 9.1 DIRECTION

As the subject site is susceptible to 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 6.4-1** 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 6.4-1 – Section 9.1 Direction Requirements

Section 9.1 Objective	How the Proposal Addresses the Objective
(1a) To ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and	This report contains guidance on how the proposed development will be consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005.
(1b) To ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.	This report quantifies flood hazard and the extent of flood prone land, and considers the compatibility of the proposal with the pre- and post-development flood hazard. This report provides full consideration of the potential flood impacts both on and off the subject land, as required by the Floodplain Development Manual and WCC's DCP 2009 Chapter E13.
Section 9.1 Requirements	**How the Proposal Addresses the Requirement**
(4) 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.
(5) 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.	The planning proposal does seek to do this, which it is permitted as long as 9 (a) or (b) of Clause 4.3 of the Section 9.1 Directions is met. See further discussion below.
(6) 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 Section 9.1 Directions are met. See further discussion below.
(7) A planning proposal must not impose flood related development controls above the	The planning proposal does <u>not</u> impose flood related development controls above the

residential flood planning level for residential 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).	residential flood planning level, except where required in order to comply with WCC's DCP (Chapter E13) which does impose flood related development controls above the residential flood planning level.
Consistency (9) 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 6.4-1** that the proposed development can readily meet the requirements of the Section 9.1 direction.

6.5. REQUIREMENTS OF THE FLOODPLAIN DEVELOPMENT MANUAL

The primary documents used when assessing any development proposal, are in order of weight, the LEP and then the DCP. WCC states that its DCP 2009 (Chapter E13) contains objectives, design principles and prescriptive controls that are wholly in accordance with the NSW Government's Floodplain Development Manual (2005). As such, compliance with the DCP (as described elsewhere in this report) means compliance with the aims and objectives of the Floodplain Development Manual. As such, there are no additional measures contained within the Floodplain Development Manual that require addressing, beyond those contained within the DCP.

6.6. ADDRESSING WOLLONGONG LEP CLAUSE 7.3

WCC's Local Environment Plan (LEP) 2009 sets forth its requirements for land for which the LEP applies (i.e. the subject site). **Table 6.6-1** describes each LEP clause and commentary on how future residential development can readily meet the requirements of the LEP.

Table 6.6-1 – LEP Requirements Addressed for Proposed Development

LEP Requirement	How Future Residential Development Can Readily Meet the Requirement
All habitable floors of the development will be above the flood planning level.	Future residential development can readily meet this requirement. All lots are above the 1% AEP design flood.
The development will not adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties.	The proposed development does not *adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties*, as quantified by the detailed modelling and impact assessment undertaken in this report.

The development will not significantly alter flow distributions and velocities to the detriment of other properties or the environment of the floodplain.	The proposed development does not *significantly alter flow distributions and velocities to the detriment of other properties or the environment of the floodplain*, as quantified by the detailed modelling and impact assessment undertaken in this report.
The development will not affect evacuation from the land.	The development will not affect evacuation from the land.
The development will not significantly detrimentally affect the floodplain environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	There are no such environmental effects caused by the proposed development, as quantified by the detailed modelling undertaken in this report. During the construction phase, the site will operate under an approved Soil & Water Management Plan.
Development will not result in unsustainable social and economic costs to the community as a consequence of flooding.	The development will not result in unsustainable social and economic costs to the community as a consequence of flooding. This is controlled by habitable floors levels set above the Flood Planning Level, and the use of flood compatible materials as per WCC's DCP.
If located in a floodway area – the development will not be incompatible with the flow conveyance function of, or increase a flood hazard, in the floodway area.	The proposed future residential development is not located within a floodway, as an essential component of the proposal is to relocate minor floodway's around the proposed development.

It can be seen from **Table 6.6-1** that the proposed development meets or exceeds WCC's LEP requirements.

6.7. FLOOD PLANNING AREA

The methodology for delineating Flood Planning Area is determining the 1% AEP flood extents and adding 500 mm to it. This process is computationally intensive and is completed in vastly different approaches by various different software. Nonetheless, **Figure 6.7-1** below describes the pre-development Flood Planning Area, as shown by the pink shading.

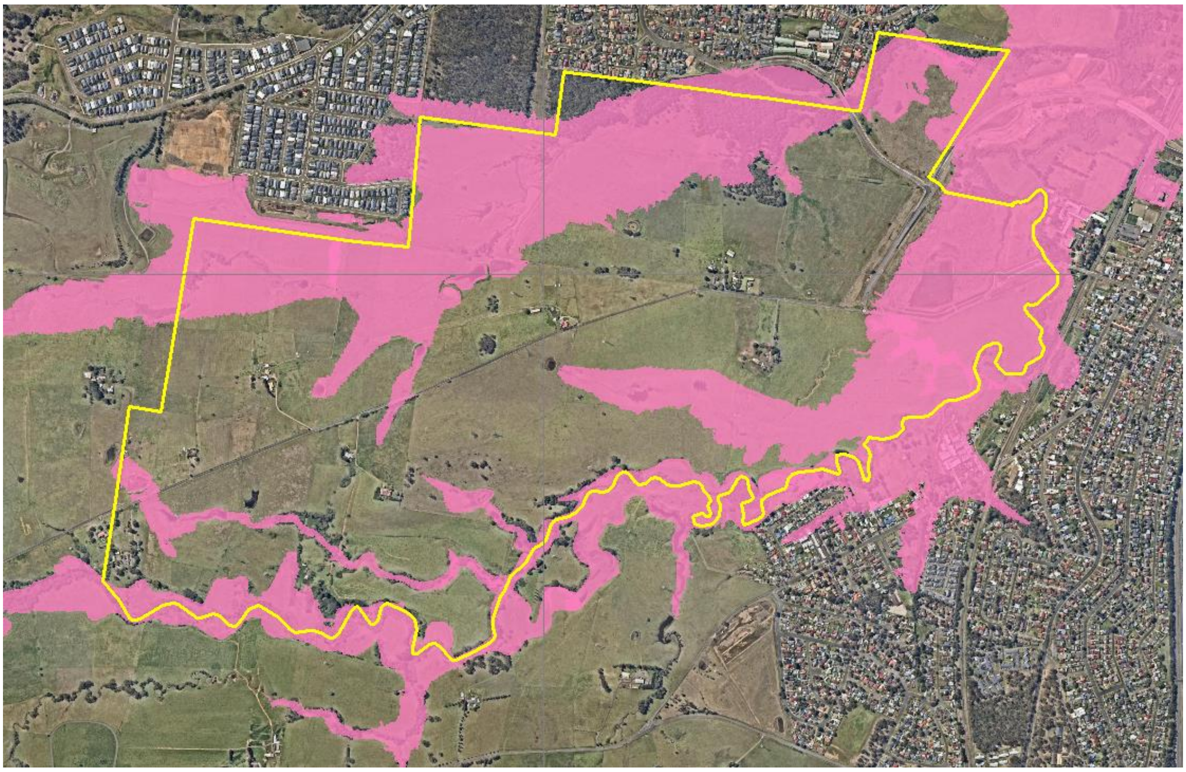


Figure 6.7-1 1% AEP Pre-Development Flood Planning Area

7. STORMWATER QUALITY MANAGEMENT

7.1. WOLLONGONG CITY COUNCIL REQUIREMENTS

Wollongong City Council (WCC) provide the required development controls for water quality via their Development Control Plan, 2009. Chapter E15 is titled *Water Sensitive Urban Design* and is the focal point of the suitable requirements for this development. **Table 7.1-1** below describes the WCC requirements for the proposed development.

Table 7.1-1 – WCC Required Stormwater Pollutant Load Reduction

Pollutant	% post development average annual load reduction
Gross Pollutants	**90**
Total Suspended Solids	**85**
Total Phosphorus	**60**
Total Nitrogen	**45**

These load reductions have been applied throughout this study.

7.2. WSUD COMPONENTS

Several WSUD measures have been evaluated for their considered effectiveness and suitability for integration into the proposed development. **Table 7.2-1** summaries these measures and provides commentary on their anticipated suitability.

Table 7.2-1 – Potential WSUD Measures

WSUD Component	Specific Measure	Considered Applicable to Development?
Stormwater management	Gross Pollutant Traps (GPTs)	Yes. GPT's (proprietary litter/sediment traps) should be provided at locations where the piped drainage system discharges into the existing Mullet Creek watercourse.
	Inline treatment devices (i.e. sand filters)	No. These are typically used for infill development scenarios and are not the best choice for master-planned release areas such as this site, where other WSUD measures can be deigned into the proposal.
	Water quality control ponds/ artificial wetlands	Yes, these devices offer performance and have been used extensively in the region.
	Bio-retention basins	Yes, these devices offer performance and have been used extensively in the region.
	Detention storage	Yes, On Site Detention is recommended for this development, and would be required under WCC's DCP 2009 (Chapter E14).
	Rainwater tanks to collect roof runoff	Yes, and this can be readily implemented in accordance with the requirements of BASIX.

Water supply management	Demand management	Yes. Promote use of water efficient showerheads & dishwashers, and tap aerators. Provide native landscaping with a lower water demand than traditional urban planting regimes.
	Aquifer recharge	No. Not considered relevant given the minor nature of the development.

As can be seen from **Table 7.2-1**, WSUD measures considered most appropriate to the proposed development are in the areas of stormwater quality control. Options relating to stormwater quality control and groundwater management are discussed in **Section 7.3** below.

7.3. STORMWATER QUALITY MANAGEMENT

For stormwater quality management a combination of proprietary litter/sediment traps and inline filtration treatment are proposed.

An important aspect of modern WSUD is recognising that rainfall patterns are inherently variable and that a pollutant removal system should be designed with variable treatment mechanisms. These must perform across a range of pollutant concentrations (generally governed by the duration of the inter-event period), and for a range of hydraulic loadings (a function of rainfall intensity during any given storm event). For this reason a treatment 'train' commencing at an early stage in the runoff cycle is advocated.

The proposed water quality treatment system for this project takes account of this recent research by incorporation of a range of physical and chemical/biological mechanisms occurring at different locations within the treatment train and which provide optimum performance at different pollutant and hydraulic loadings. The expected performance of the various components in the proposed treatment system is described in **Table 7.3-1** below.

Table 7.3-1 – Proposed Treatment Train

Treatment Measure	Purpose	Comment
GPTs	• Removal of coarse pollutants and letter	Selection of such devices to recognise maintenance issues. Some devices (such as the CDS units) rely on wet well storage of captured gross pollutants and require servicing with a suction truck, whereas dry-type units (eg, Baramy traps) can be serviced with more conventional maintenance equipment and are potentially cheaper to maintain, although they are less efficient at trapping sediment. The optimal arrangement may thus be a combination of different type GPTs, confirmed during detailed design.
Inline Treatment Device	• Sediment and Nutrient Removal	At this stage, we nominate bio-retention basins. However, during detailed design, wetlands could also be used.
OSD	• Ensure peak flows are retarded to pre-development rates.	OSD should be provided as per WCC's OSD policy in Chapter E14 of DCP 2009.

Now that a treatment train has been developed commensurate with the opportunities and constraints of the subject site, **Section 7.4** describes the modelling of the performance of that treatment train.

7.4. WSUD PERFORMANCE MODELLING

7.4.1. Modelling Approach

The water quality software package MUSIC v6.20 (Model for Urban Stormwater Improvement Conceptualisation) was to optimise the configuration of the various WSUD measures identified above and to ensure water quality objectives are met. The model is designed to evaluate conceptual stormwater treatment designs by simulating the performance of stormwater quality improvement measures and allowing comparison with water quality targets.

MUSIC was used to predict pollutant loads under both pre-development and post-development conditions, based on a range of project-specific input data including daily rainfall, monthly evapo-transpiration rates and sub-catchment characteristics.

Once the complete suite of input data was entered (refer **Section 7.4-2** below for further detail), the model was run for a near 100-year continuous simulation period. It is noted that 100 years of data represents a substantial record set. Continuous simulation over such a period given increased confidence in modelling output, and reduces the effects of assumed starting water levels and allows wetland performance to be predicted over a range of climatic conditions.

7.4.2. Modelling Parameters and Inputs

A total of approximately 117 years of daily rainfall data (July 1892 to November 2009) from the Bureau of Meteorology gauging station No 068000 at Albion Park Post Office was used for continuous simulation purposes. The Albion Park Post Office is within a reasonable proximity to the subject site, and so provides an accurate meteorological template on which to model the proposed system. Monthly average evapo-transpiration data input to the model was taken from Bureau of Meteorology mapping for the region. **Figure 7.4-1** describes the rainfall and evapo-transpiration data series.

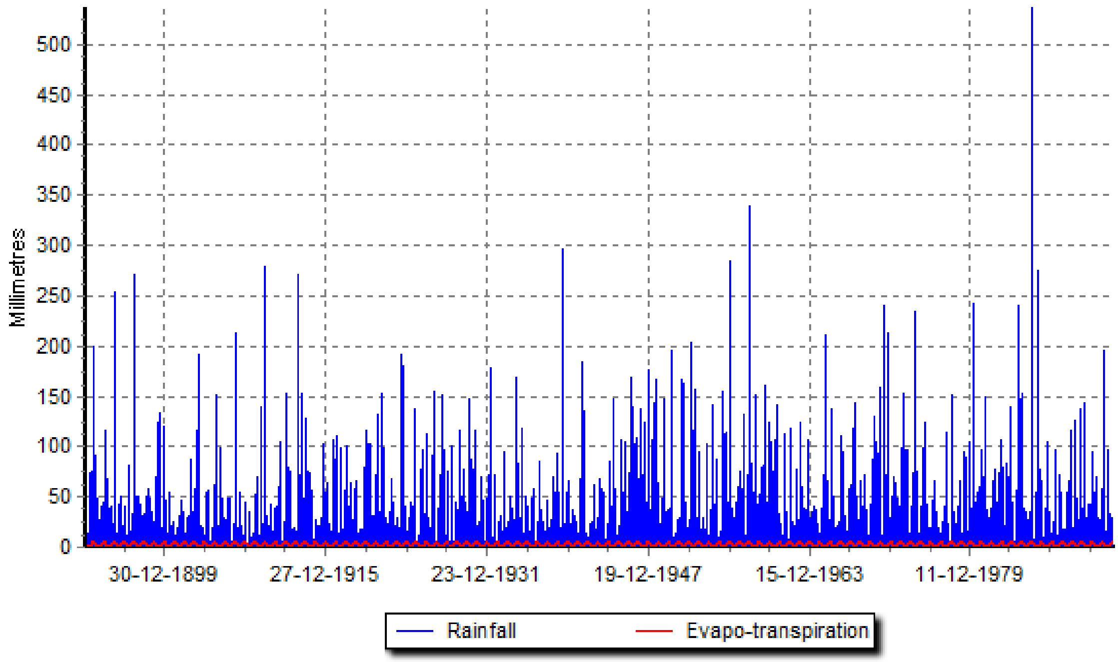


Figure 7.4-1 MUSIC Rainfall and Evapotranspiration Data

Note: Data supplied by Bureau of Meteorology, graph extracted from MUSIC model.

The overall catchment areas were derived from the WSUD catchment plan, which has been developed generally in accordance with the proposed layout. The impervious area was assessed based on land use and proposed 'vegetated' areas (including open space and nature strips). The adopted impervious percentages for the overall 'urban' areas was 60%.

7.4.3. Model Results

MUSIC modelling results are presented in **Table 7.4-1**.

Table 7.4-1 – MUSIC Model Results

Target Pollutants	Post Development Source Loads	Residual Loads	% Reduction	*Council Reduction Targets*
Total Suspended Solids (kg/yr)	277,000	13,800	**95%**	*85%*
Total Phosphorus (kg/yr)	475	190	**60%**	*60%*
Total Nitrogen (kg/yr)	3480	1370	**60%**	*45%*
Gross Pollutants (kg/yr)	34700	1.54	**100%**	*90%*

These results show that the proposed treatment train is readily capable of reducing the mean pollutant loads to those required by WCC's DCP. The final design or the treatment train can be determined once a final Stormwater Concept Plan has been developed for each stage, and more details are confirmed through detailed design during DA and CC. Importantly, the MUSIC modelling carried out in this report is highly conservative, as it achieves the desired water quality outcomes without any consideration of GPT's and rainwater tanks. This demonstrates the robustness of the planning proposal in that there is undoubtedly adequate land provisions made for WSUD measures.

As stated previously in this report, the WSUD measures proposed have been developed to sufficient detail to convey the design intent only. Further detailed design will be required prior to Development Application, in particular once more detailed geotechnical and stormwater design information can be made available. During detailed design, the proposed WSUD measures may require some changes to suit detailed local issues. It is not anticipated however that significant changes will be required to the physical parameters which govern WSUD measure performance.

Nonetheless, it can be seen that given the specific details of the proposed development, the proposed land use and its integrated controls can readily meet the water quality targets described in WCC's DCP (Chapter E15). This report simply describes only one of those solutions, which is entirely appropriate at the rezoning stage.

7.5. STORMWATER QUANTITY

Specifically, for the southern precinct, Cardno (2019) demonstrated that the development of the Cleveland Road South precinct made no difference to mainstream design flood behaviour. However, WCC have still requested that On Site Detention (OSD) is provided of the entire development.

The proposal for OSD is to integrate additional storage into the WSUD measures. These WSUD measures are currently proposed as bio-retention basins, however would function just as efficiently as wetlands. In any case, extended detention is feasible in either WSUD measure.

Runoff rates and volumes were determined from each of the nine WSUD catchments using WBNM. The total catchment area for each of the nine WSUD areas was used, together with the existing (zero) and proposed (60%) impervious areas. Differences in peak flows were reported when comparing pre- and post-development scenarios, and nine storages were configured to endure that post-development peak flows were equal to or less than the pre-development peak flows.

The high-level WBNM modelling shows that for this to be achieved, a typical OSD rate in the 1% AEP of 300 m^3/ha needs to be allowed for. This can be typically configured into the bio-retention swales as additional storage of less than 1 metre. It is noted that through detailed design, regional storage rates of 100 m^3/ha can be achieved, and it is anticipated that the rates nominated in this report would be reduced with additional detailed design at the DA stage.

A check on all subareas for peak discharge control in the 20% AEP was also carried out, and both the 20% AEP and 1% AEP design discharges are reduced in the post-development scenario.

8. OTHER MATTERS

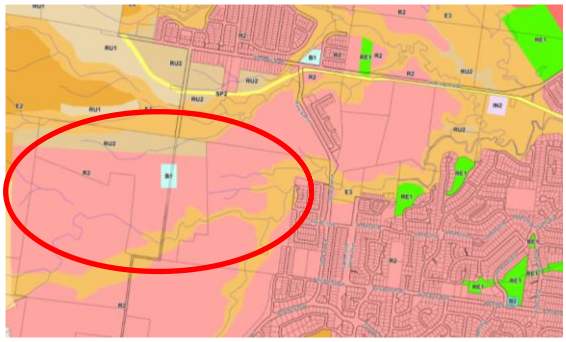
8.1. ADDRESSING PRELIMINARY ASSESSMENT NOTES ON PP

WCC's stormwater assessment officers made comment on the PP after a review of the previously submitted Cardno reports (Cardno 2018, Cardno 2019). These assessment notes were made available to the applicant, and they have been forwarded to Rienco. **Table 8.1-1** describes each comment made in the assessment notes in relation to stormwater and flooding, and includes comments on how the PP responds to the issue, in either this report, or by the project as a whole.

Table 8.1-1 – Summary of Assessment Notes and Responses

Matter Raised in WCC's Current Assessment of the Proposal	How the Matter has been integrated into this report / the proposal
A number of watercourses/floodways within the planning proposal site have been excluded from the WCMS. The WCMS shall be amended to include all watercourse/floodways within the full extent of the planning proposal site that were modelled in Council's adopted Mullet Creek Review Flood Study (2018).	The modelling has been updated to include all areas modelled in Council's adopted Mullet Creek Review Flood Study (2018).
The WBNM model parameters used by Cardno in the WCMS are inconsistent with those used in Council's adopted Mullet Creek Flood Study Review dated 2018. The WCMS and modelling shall be amended such that all input parameters are consistent with those used in Council's model.	The WBNM parameters used are consistent with the published research underpinning the WBNM model.
A plan is required showing a comparison between the modelled flood levels and the flood levels from Council's adopted study for the 1% AEP and PMF events for the entire model extent. This information must demonstrate that the flood levels being predicted by the Cardno WCMS are consistent with Council's adopted study.	This is provided in **Figure 4.3-1** of this report for the 1% AEP design flood.
Clarification of batter slopes used in basins is required.	Typically 4(H):1(V) have been applied.
The WCMS shall be amended to include plans showing the existing Flood Planning Area (FPA) and risk precincts etc.	The Flood Planning Area is shown in **Figure 6.7-1** of this report.
The planning proposal is inconsistent with Ministerial Direction Section 9.1 Direction 4.3(5). The planning proposal rezones land within the flood planning area from rural to a residential zone.	Noted. The Section 9.1 Direction allows for proposals to be inconsistent with this part of the Direction, as long as 9 (a) or (b) of Clause 4.3 of the S117 Directions are met.
The planning proposal is inconsistent with Ministerial Direction Section 9.1 Direction 4.3(6)(a), (b), (c) and (d). The planning proposal would permit a range of development uses (ie those permitted within the Zone R2 and	The PP relies on engineering works to modify the location of the existing floodway and High Flood Risk Precinct. We would agree with WCC if the proposal was being put forth without the associated engineering works.

RE1) within a floodway area, and permit a significant increase in the development of the land that is within a floodway area, high flood hazard, and Flood Planning Area. The planning proposal may also result in a substantially increased requirement for government spending on flood mitigation measures, due to inappropriate development within floodway areas..	But it is not true to say that the PP seeks to rezone land that is a floodway, because inherent in the PP is the engineering works to modify the land and relocate the floodway.
In order to be consistent with the Section 9.1 directions, the proposal will need to be amended such that there is no rezoning of land within the flood planning area.	This is incorrect. The Section 9.1 Direction allows for proposals to be inconsistent with this part of the Direction, as long as 9 (a) or (b) of Clause 4.3 of the Section 9.1 Directions are met.
Should Council's strategic planning officers be of the view that a proposal that is inconsistent with the Section 9.1 Ministerial Directions should be supported in this instance, then it is strongly recommended that any such proposal not be supported until after it has been clearly demonstrated how the future development would be undertaken in a way that satisfies Council's DCP and LEP.	All proposed lots are flood free in the 1% AEP design flood. There is no reason why future development could not readily comply with Council's DCP and LEP.
It is proposed to rezone land (to R2 and RE1) within an existing floodway area as mapped in Council's adopted Mullet Creek Flood Study Review (2018). The majority of the permitted uses within the R2 and RE1 zones are uses that are not compatible with the flow conveyance function or flood hazard of a floodway area. The proposal as described and shown in the WCMS and general arrangement plan indicates filling, roads, residential lots, car parking areas, and earth berms within the existing watercourse channels and mapped floodway areas. These uses are also not compatible with the flow conveyance function and flood hazard of the floodway areas. In this regard the proposal is contrary to objectives 1(a), (c), (d) and (e) of Clause 7.3 of the Wollongong LEP (2009) and is therefore not supported. The planning proposal shall be amended to ensure that uses not compatible with the flow conveyance function and flood hazard will not be permitted within the floodway area.	These comments mischaracterise the proposal. The proposed R2 zones are not located within areas of proposed floodway. The floodway is being augmented such that all lots are flood free in the 1% AEP design flood. Council's comments relate to an overlay of the existing floodway and the proposed development. This is disingenuous and does not reflect the proposal or the associated flood risk.
It is proposed to rezone land that is within High Hydraulic Hazard areas and land that is within 10 metres from the top of bank of the creeks/watercourses. These are categorised as High Flood Risk Precincts as per Section 6.3 of Chapter E13 of the Wollongong DCP (2009). It is also proposed to rezone land that is within existing floodway areas. Intensification of use within the High Flood Risk Precinct and floodway areas is contrary to the objectives in Chapter E13 of the Wollongong DCP and is therefore not supported. As per Objective 6.4.1(d) the planning proposal shall be	The land is being modified, such that future residential development can readily comply with the DCP. The DCP is not a guide to the development of a Planning Proposal; this is not the purpose of a DCP as defined by the NSW EP&A Act Section 3.42.

amended to allow for the conversion of the High Flood Risk Precinct and floodway areas to natural waterway corridors.	
The submitted WCMS and general arrangement plan indicates future development of the rezoned areas would require filling within the floodplain, however insufficient information has been provided to demonstrate whether this could be achieved in compliance with the requirements of Clause 7.3 of the Wollongong LEP. The following additional information is required: • Conceptual cut/fill plans • Finished surface level contours • Details and location of compensatory earthworks to maintain existing flood storage • Detailed cut/fill volume and storage calculations • Pre- and post-development modelling and impact mapping It should be noted that it is not acceptable to rely on increased flood levels due to elevated manning's 'n' values (i.e. revegetation) and/or blockage of hydraulic structures to provide compensatory flood storage. The compensatory flood storage volume shall be achieved via excavation to ensure no net removal of existing capacity as required by Clause 6.3.4(4) of Chapter D16 of DCP 2009. Must be demonstrated for 1, 2, 5, 10, 20, 50, 100yr ARI and PMF events).	Earthworks plans are provided by Craig and Rhodes, showing finished surface level contours. These plans also document the earthworks that provide the offset in flood storage. Pre- and post-development modelling and impact mapping is provided in this report. Clause 6.3.4(4) of Chapter D16 of DCP 2009 is mischaracterised by WCC. This clause does discuss offsetting flood storage by revegetation, but does not discuss offsetting flood storage by blockage of hydraulic structures to provide compensatory flood storage. Clearly, applying Council's blockage policy does have a tremendous influence over flood storage.
The future development intended to be facilitated by the planning proposal involves filling of existing watercourse channels, which is contrary to the requirements of Section 10.3.7 of Chapter E14 of DCP 2009. Modifications to watercourses are generally not permitted as they adversely impact on a number of watercourse functions. Reduction in development potential as a result of not modifying a watercourse is not considered justification for such modifications. The planning proposal shall be amended such that filling of watercourses will not be required to develop the rezoned land.	There are a myriad of examples in West Dapto where Council rezoned land to R2 or R3, where an existing watercourse is located. See example below:  To require that *the planning proposal be amended such that filling of watercourses will not be required to develop the rezoned land* is inappropriate and inconsistent with other major PP's (i.e. West Dapto, Tullimbar, Calderwood, Sandon Point and Corrimal Cokeworks).
The proposal to pipe/fill the watercourses is also not supported from an asset management point of view. Council is not supportive of	There are a myriad of examples in West Dapto where Council rezoned land to R2 or R3, where an existing watercourse is located. This requires

inheriting the significantly sized public underground stormwater infrastructure that is required to drain catchments of this size. The planning proposal shall be amended to maintain open channel conveyance in existing watercourse areas.	future development to utilise all manner of adopted urban stormwater management techniques. These can be determined at the time of DA and future detailed design. The zoning does not preclude, or mandate, and one particular form. The required underground stormwater infrastructure may only be, for example, a 600mm diameter pipe. This is hardly unorthodox or outside of the usual range of underground stormwater infrastructure maintained in many other newly developed precincts. Formal discussions with, and feedback from, NRAR demonstrate that NRAR is supportive of the piping of the nominated watercourses.
An excessive number of detention basins are proposed. The lot layout and stormwater concept plan shall be amended to enable consolidation of detention basins to as few as possible and allow multi-purpose use of the detention storages where possible, to ensure good planning and open space outcomes.	Each detention basin caters for ~250 lots. This is not excessive. Further, it is not possible to refine them further, and still comply with Council's note below. For example, if natural drainage paths are to be maintained, then the number of basins cannot be optimised (because you need to change natural drainage paths to do so).
The conceptual road layout does not appear to enable natural drainage paths to be maintained without significant changes to landform. The concept layout needs to be amended to avoid a situation where there will be road sags where stormwater overflows into the adjacent private lots.	The proposed current road layout does maintain natural drainage paths
The conceptual OSD design calculations appear to rely on segregation and diversion of significant upslope catchment areas from urban development within the low point of those catchments. This is unlikely to be achieved in a way that is acceptable to Council/. The calculations and conceptual OSD sizing shall be amended based on allowance for the full upslope catchment areas to drain into the detention storages.	The current OSD strategy caters of the proposed lots only. There is no requirement for the OSD basins on this site to be *based on allowance for the full upslope catchment areas to drain into the detention storages*. This is the antithesis of WCC's OSD policy. The OSD strategy proposed in this report caters for the entire land that is the subject of the rezoning, which is appropriate. The only 'upslope catchment areas' that are not subject to OSD is runoff from those areas that are already within the stream. WCC's OSD policy has no requirement for online stream flow retardation, or OSD.

9. CONCLUSIONS AND RECOMMENDATIONS

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

- The subject site is a combination of the Cleveland Road North and Cleveland Road South planning precincts. Portions of these precincts are flood affected.
- WCC adopted its catchment-wide flood study titled *Mullet Creek Flood Model Update* (2018). Its results are directly applicable to the subject site for quantifying flood behaviour in the pre-development scenario.
- A WBNM hydrologic model has been used to determine design flood estimates at the subject site and surrounds. This model is consistent with the *Mullet Creek Flood Model Update* (2018).
- A detailed 2D TUFLOW model has been updated for the subject site and surrounds.
- Flood behaviour for a range of design floods has been determined for the subject site and surrounds. This flood behaviour is consistent with Rienco's previous model results and those within WCC's adopted catchment-wide flood study.
- Design flood behaviour has been determined for both the pre- and post-development scenarios, and is quantified in detail in this report.
- The Flood Planning Level for the site is difficult to specify as one level, given the flood gradient across the site. In any case, the Flood Planning Level is determined by the 1% AEP peak flood surface levels in this report plus 500 mm.
- 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.
- Future residential development can readily meet the requirements of Wollongong Council's LEP (2009) Clause 7.3.
- In an extreme flood event, such as the PMF, future occupants will be safe via their flood free refuge in their homes, and will also have a substantially accessible road network available within the precinct (noting PMF free access is not available to West Dapto).

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

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Managing Director

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)
WCC	Wollongong City Council; name of the council with jurisdiction over the Wollongong 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

GENERAL NOTES:–

1. THIS SURVEY IS NOT A 'LAND SURVEY' AS DEFINED BY THE SURVEYING AND SPATIAL INFORMATION ACT, 2002.
2. EXISTING VEGETATION IS NOT SHOWN ON THIS PLAN AND MAY REQUIRE ADDITIONAL SURVEY WHERE CRITICAL TO DESIGN.
3. CONTOURS AND SPOT LEVELS ARE INDICATIVE OF GROUND FORM ONLY.
4. LEVELS ARE ON AUSTRALIAN HEIGHT DATUM (A.H.D.)
5. THE CONTOUR INTERVAL IS 1m
6. ALL SETOUT LEVELS MUST BE REFERRED TO THE BENCH MARK SHOWN ON THIS PLAN.
7. THIS PLAN IS FOR DEVELOPMENT APPLICATION PURPOSES ONLY. FURTHER DETAILED ENGINEERING PLANS MAY BE REQUIRED FOR THE PURPOSE OF OBTAINING A CONSTRUCTION CERTIFICATE.

BOUNDARY NOTES:–

8. THE BOUNDARIES OF THE LAND HAVE NOT BEEN SURVEYED. THE RELATIONSHIP BETWEEN THE BOUNDARIES SHOWN AND FEATURES SURVEYED ARE APPROXIMATE AND SUITABLE FOR PLOTTING PURPOSES ONLY.
9. BOUNDARIES HAVE NOT BEEN MARKED.

SURVEY INFORMATION NOTES:–

10. THE ORIGIN OF COORDINATESCOMES FROM PM76645 CLASS A ORDER 1 ADOPTED FROM SCIMS DATED 20/05/2018.
11. THE ORIGIN OF LEVELS COMES FROM PM76645 RL16.367 CLASS LB ORDER L2 ADOPTED FROM SCIMS DATED 20/05/2018.
12. THE ORIENTATION OF THIS PLAN IS MGA NORTH. THE VARIATION FROM MGA NORTH TO TRUE NORTH IS APPROXIMATELY 1°15'.

SERVICES NOTES:–

13. NO UNDERGROUND OR ABOVEGROUND SERVICES SEARCH HAS BEEN UNDERTAKEN. THERE MAY BE ADDITIONAL SERVICES WITHIN THE SURVEY AREA.
14. UNDERGROUND SERVICES HAVE BEEN PLOTTED FROM 'DIAL–BEFORE'YOU–DIG' PLANS AND ARE QUALITY LEVEL D AS DEFINED BY AS 5488–2013. SEE DWG FILE.
15. ALL RELEVANT AUTHORITIES MUST BE CONTRACTED TO DETERMINE THE FULL EXTENT OF SERVICES PRIOR TO ANY PLANNING OR WORKS NEAR THE SITE.

CERTIFICATE OF TITLE NOTES:–

16. THE FOLLOWING INFORMATION IS FROM THE CERTIFICATES OF TITLE DATED 07/05/2018.
17. LOT 313 IN DP1188000 IS AFFECTED BY:
   - EASEMENT FOR TRANSMISSION LINE 30.48 WIDE (GOV. GAZ. 19/11/1943 FOLIOS 2015–16) (11543–3000)
   - EASEMENT FOR TRANSMISSION LINE 18.29 WIDE (GOV. GAZ. 07/04/1961 FOLIOS 1032–35) (18019–3000)
   - EASEMENT FOR PIPELINE 20 WIDE (8351968 VIDE DP1016609)
   - EASEMENT FOR TRANSMISSION LINE 36.58 WIDE (GOV. GAZ. 13/05/1966 FOLIOS 1916–18) (20935–3000)
   - EASEMENT FOR TRANSMISSION LINE VARIABLE WIDTH (GOV. GAZ. 28/08/1964 FOLIOS 2759–60)
18. LOT A IN DP156446 IS AFFECTED BY:
   - EASEMENT FOR TRANSMISSION LINE 30.48 WIDE (GOV. GAZ. 19/11/1943 FOLIOS 2015–16) (11543–3000)
   - EASEMENT FOR TRANSMISSION LINE 18.29 WIDE (GOV. GAZ. 07/04/1961 FOLIOS 1032–35) (18019–3000)
   - EASEMENT FOR TRANSMISSION LINE 60.96 WIDE (GOV. GAZ. 16/07/1965 FOLIO 2253) (BK. 2869 NO. 11)
   - EASEMENT FOR TRANSMISSION LINE 30.48 WIDE (BK. 2713 NO. 29)
   - EASEMENT FOR TRANSMISSION LINE 5.03 WIDE AND VARIABLE WIDTH (BK. 2817 NO. 640)
   - EASEMENT FOR TRANSMISSION LINE (BK. 2932 NO. 929) (19872–3000)
   - EASEMENT FOR PIPELINE 20 WIDE (DP1016609)
19. LOT 1 IN DP194419 IS AFFECTED BY:
   - EASEMENT FOR TRANSMISSION LINE (GOV. GAZ. 02/04/1965 FOLIO 1119)
   - EASEMENT FOR TRANSMISSION LINE 60.96 WIDE (GOV. GAZ. 16/07/1965 FOLIO 2253) (BK. 2869 NO. 11)
20. COVENANTS AND RESTRICTIONS NOTED ON THE TITLE HAVE NOT BEEN INVESTIGATED. THESE SHOULD BE INVESTIGATED PRIOR TO DESIGN TO ENSURE ANY FUTURE DEVELOPMENT COM

CONTOURS ARE BASED ON LIDAR SURVEY BY MEASURE AUTRALIA REF. 5086MA. THE ORIGIN OF COORDINATES AND LEVELS IS BASED ON GPS AND HAS NOT BEEN VERIFIED BY SDG.

21. LIMI PRC REGISTRATION OF A PLAN OF DEFINITION AT DEPARTMENT OF LANDS NSW. THEREFORE, THE LOCATION OF THE BOUNDARIES SHOWN IS APPROXIMATE ONLY AND NO RESPONSIBILITY CAN BE ACCEPTED FOR ANY FUTURE CHANGES IN BOUNDARY LOCATIONS WHICH MAY RESULT FROM RE–SURVEY OF ADJOINING LANDS OR SUBSEQUENT REGISTRATION OF NEW SURVEY PLAN.

LEGEND:–

CKG denotes CONCRETE KERB AND GUTTER
COM denotes COMMUNICATIONS PIT
FCE denotes FENCE
FL denotes FLOOR LEVEL
IL denotes INVERT LEVEL
LIP denotes LIP LINE
PP denotes POWER POLE
TB denotes TOP OF BANK
TK denotes TOP OF KERB

ALL FENCES SHOWN ARE TIMBER POST AND WIRE FENCES.

UNDERGROUND SERVICES LEGEND – QUALITY LEVEL D (AS 5488–2013)

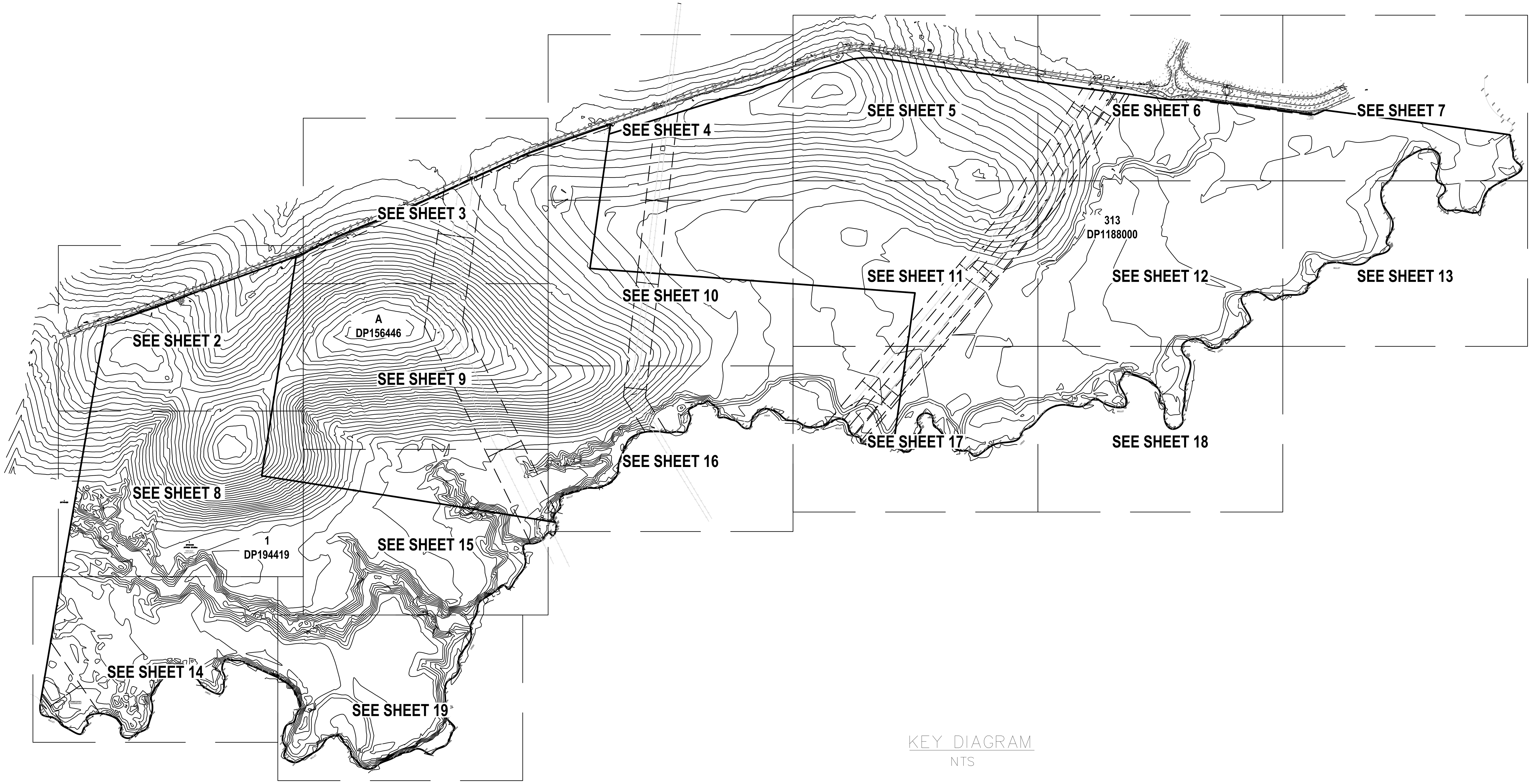
W POTABLE WATER MAIN
R RECYED WATER MAIN
D STORMWATER PIPE
S SEWER MAIN
C COMMUNICATIONS CABLES
E ELECTRICITY CABLES
G GAS MAIN
U UNIDENTIFIED SERVICES
OVERHEAD POWER LINES

CAUTION: FIBRE OPTIC CABLES ARE PRESENT IN THIS AREA

APPROXIMATE POSITION ONLY VIDE 'DIAL–BEFORE–YOU–DIG' PLANS JOB No.14492449. SEE DWG FILE. WHERE CRITICAL TO DESIGN, UNDERGROUND SERVICES SHOULD BE LOCATED BY MORE ACCURATE METHODS.

MGA

Schedule of Easements & Restrictions	
No	Description
(A)	EASEMENT FOR TRANSMISSION LINE 30.48 WIDE (GOV. GAZ. 19/11/1943 FOLIOS 2015-16) (11543-3000)
(B)	EASEMENT FOR TRANSMISSION LINE 18.29 WIDE (GOV. GAZ. 07/04/1961 FOLIOS 1032-35) (18019-3000)
(C)	EASEMENT FOR PIPELINE 20 WIDE (8351968 VIDE DP1016609)
(D)	EASEMENT FOR TRANSMISSION LINE VARIABLE WIDTH (GOV. GAZ. 28/08/1964 FOLIOS 2759-60)
(E)	EASEMENT FOR TRANSMISSION LINE 36.58 WIDE (GOV. GAZ. 13/05/1966 FOLIOS 1916-18) (20935-3000)
(F)	EASEMENT FOR TRANSMISSION LINE 30.48 WIDE (DEED BOOK 2713 NO 29)
(G)	EASEMENT FOR TRANSMISSION LINE 60.96 WIDE (GOV. GAZ. 16/07/1965 FOLIOS 2253) (BOOK 2869 NO 11)
(H)	EASEMENT FOR TRANSMISSION LINE 5.03 WIDE AND VARIABLE (DEED BOOK 2817 NO 640)
(I)	EASEMENT FOR TRANSMISSION LINE 36.58 WIDE (DEED BOOK 2932 NO 929) (19872-3000)
(J)	EASEMENT FOR TRANSMISSION LINE 60.96 WIDE (GOV. GAZ. 02/04/1965 FOLIO 1119) (APPROX.)



KEY DIAGRAM
NTS

PRELIMINARY

ISSUE	DATE	AMENDMENT	SURV/CHK	ISSUE	DATE	AMENDMENT	SURV/CHK
A	29/06/18	ORIGINAL ISSUE	NN/VT				

CLIENT: CLEVELAND GROUP HOLDINGS
ROB AZAR

ORIGIN OF LEVELS: PM76645 RL16.367
DATUM: A.H.D.

SCALE: NTS
ORIGIN OF COORDINATES: PM76645
DATUM: M.G.A

REF: 7668
DATE: 09/07/2018
SURV/CHK: NN/VT
SHEET 1 OF 19 SHEETS

PLAN A1
ISSUE A

DETAIL AND LEVEL SURVEY OF LOT 313 IN DP1188000, LOT A IN DP156446 & LOT 1 IN DP194419
CLEVELAND ROAD, CLEVELAND

SDG™
LAND DEVELOPMENT SOLUTIONS
A.B.N. 85 213 523 621
Suite 1 3 Railway Street
BAULKHAM HILLS 2153
P.O.Box 2572
NORTH PARRAMATTA 1750
t: (02) 9630 7955
e: office@sdg.net.au
w: www.sdg.net.au

.\AL\DIAL BEFORE YOU DIG.jpg

APPENDIX B – WBNM CATCHMENT PLAN

WBNM CATCHMENT PLAN - MULLET CREEK UPSTREAM OF SUBJECT SITE

ISSUE:	DESCRIPTION:	DATE:	BY:
A	ISSUED FOR COORDINATION	APR '20	AB

RIENCO CONSULTING
Providing Specialist Services in Hydrology and Hydraulics
PO BOX 3094, AUSTINMER NSW 2515
www.rienco.com.au

TITLE: MULLET CREEK CATCHMENT PLAN

CLIENT:	LOCATION:
NewQuest Property	Cleveland Road, Cleveland

DRG No:	SCALE:	DRAWN BY:	REVISION:
1001	1 : 5,000	AB	A

APPENDIX C – DETAILED MODEL RESULTS

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

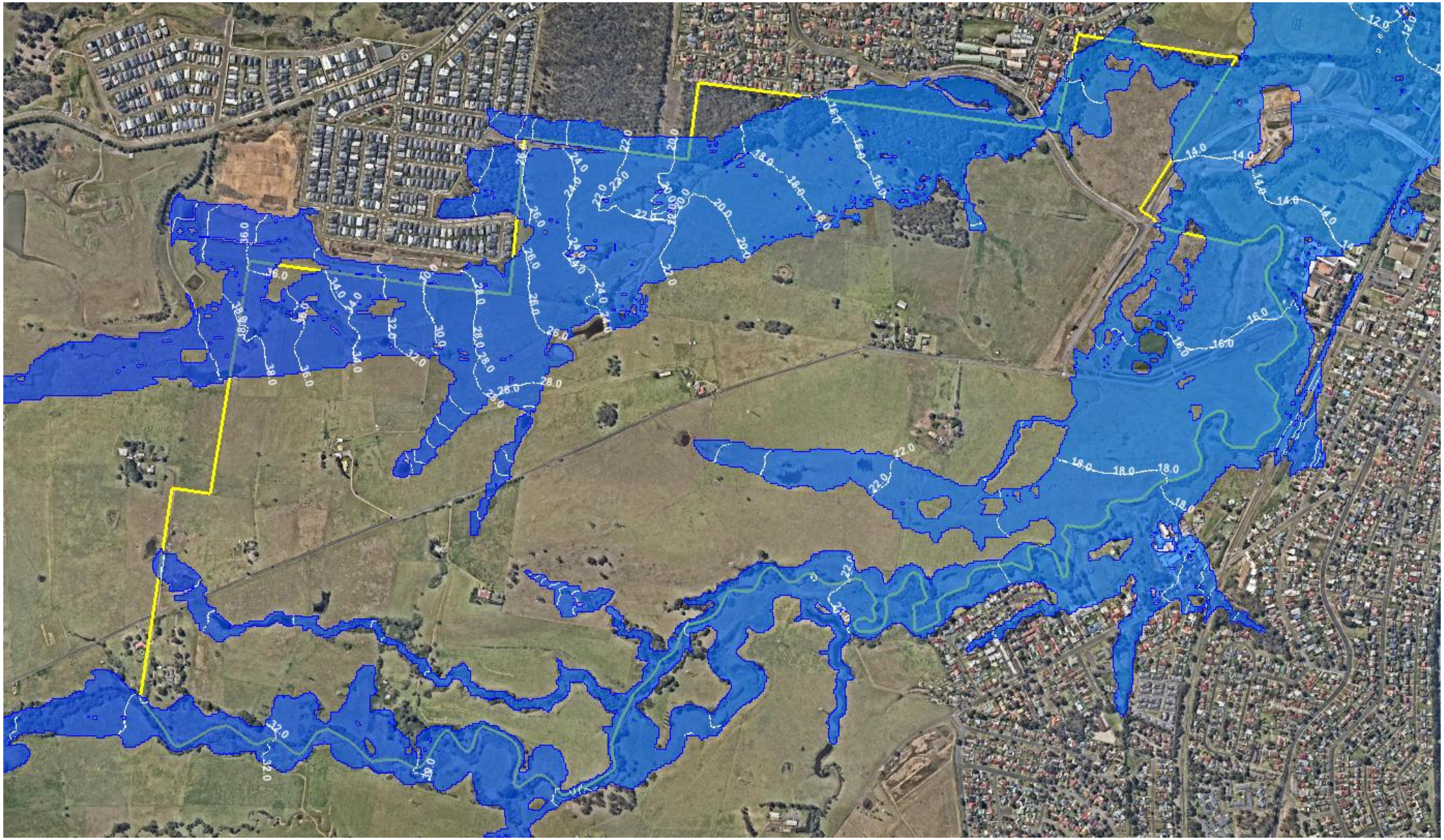


Figure C1.1: 1% AEP Flood Levels – Pre-Development

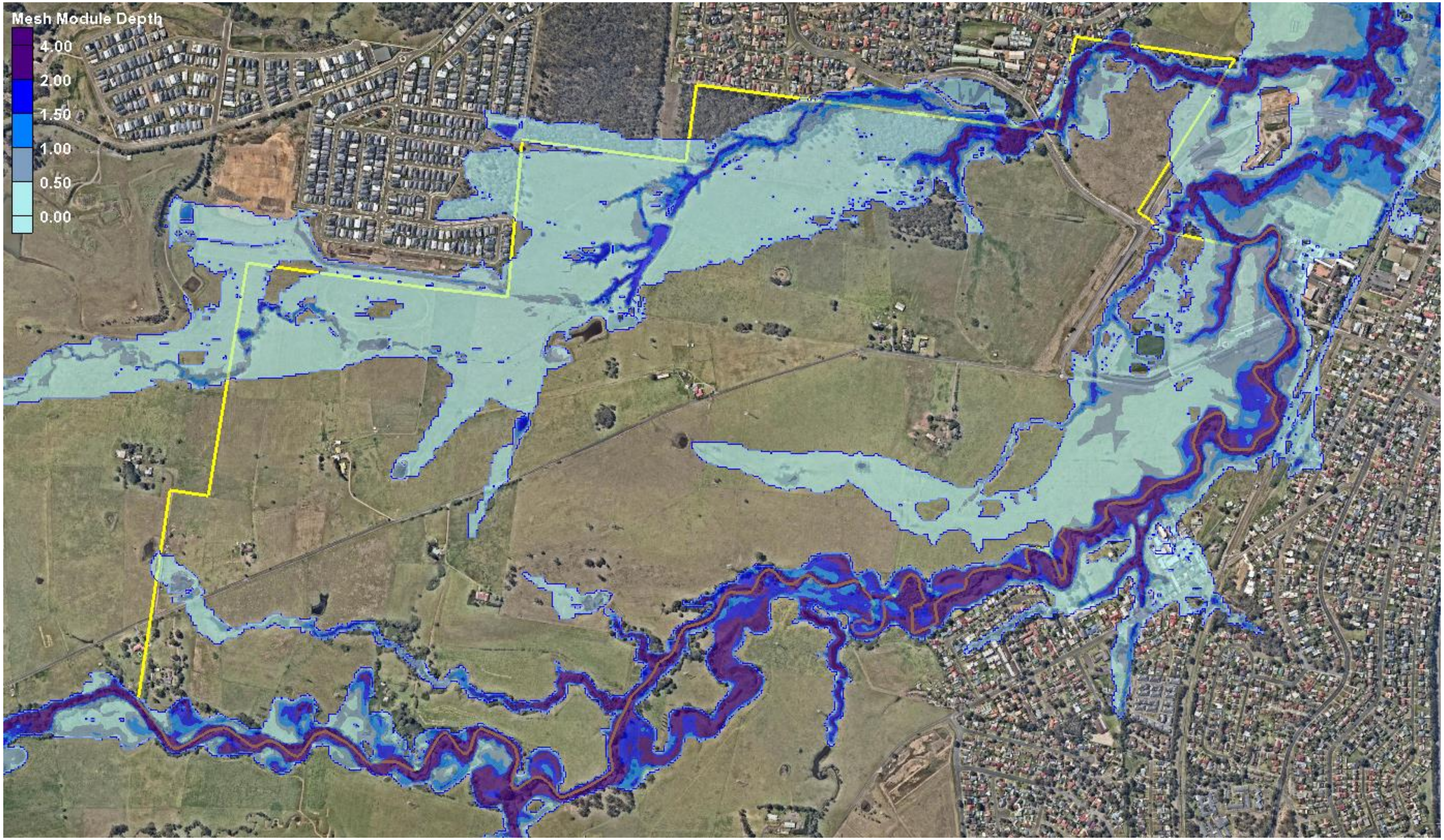


Figure C1.2: 1% AEP Flood Depths – Pre-Development

Note: Flood depths shaded from 0m (light blue) to 4.0m (dark blue). All depths over 2.0m shaded dark blue.

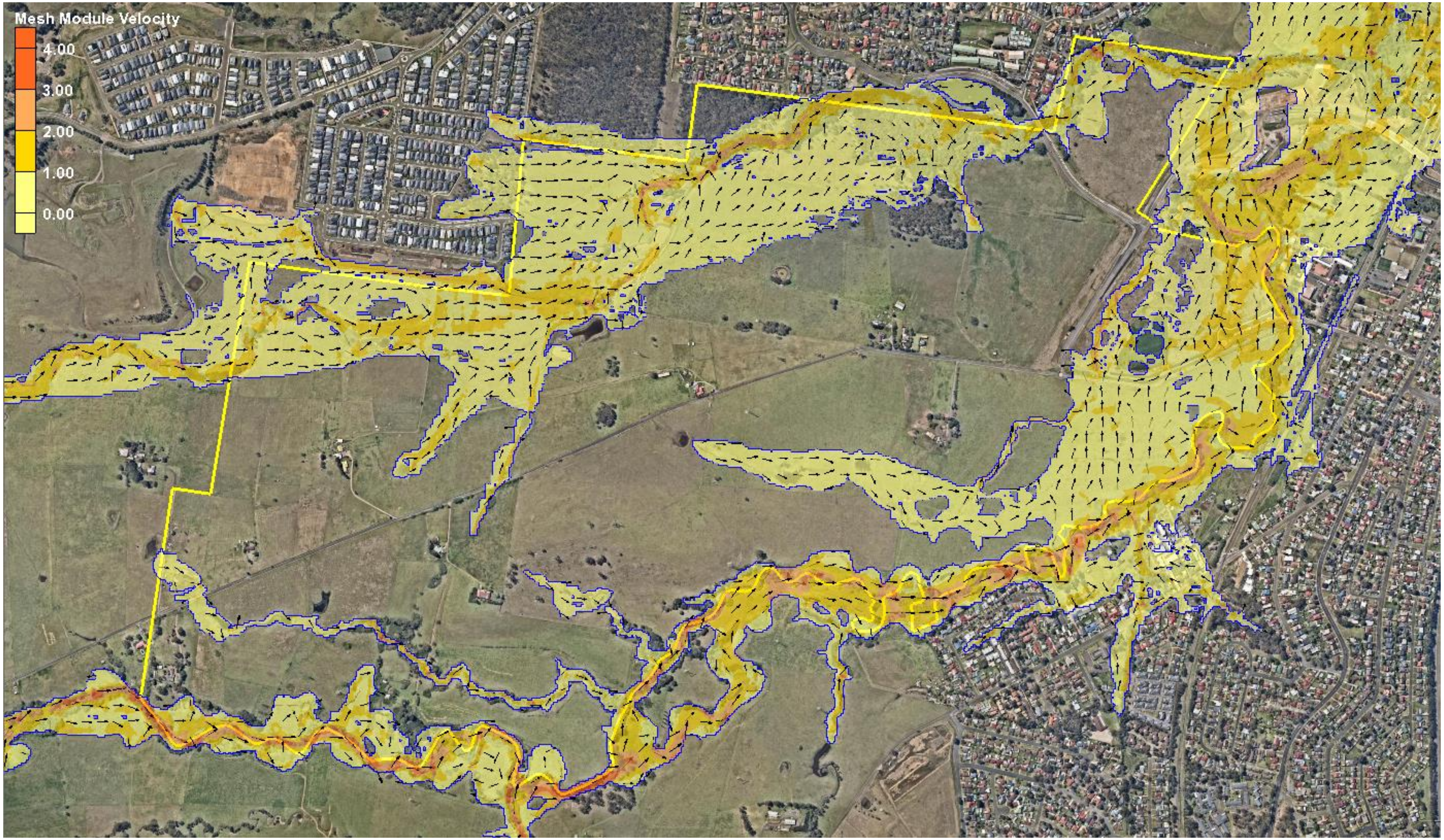


Figure C1.3: 1% AEP Flood Velocity – Pre-Development

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

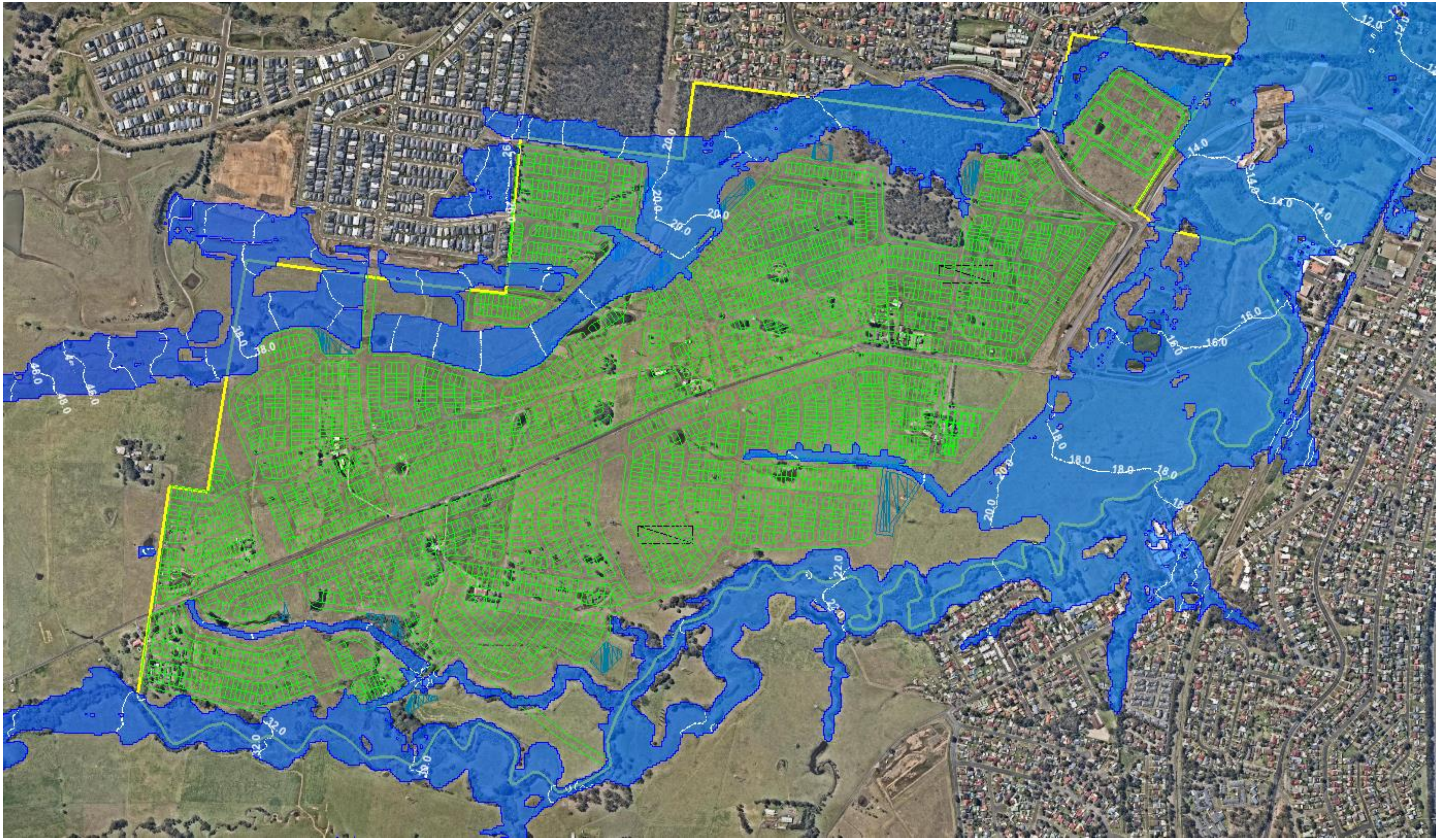


Figure C2.1: 1% AEP Flood Levels – Post-Development

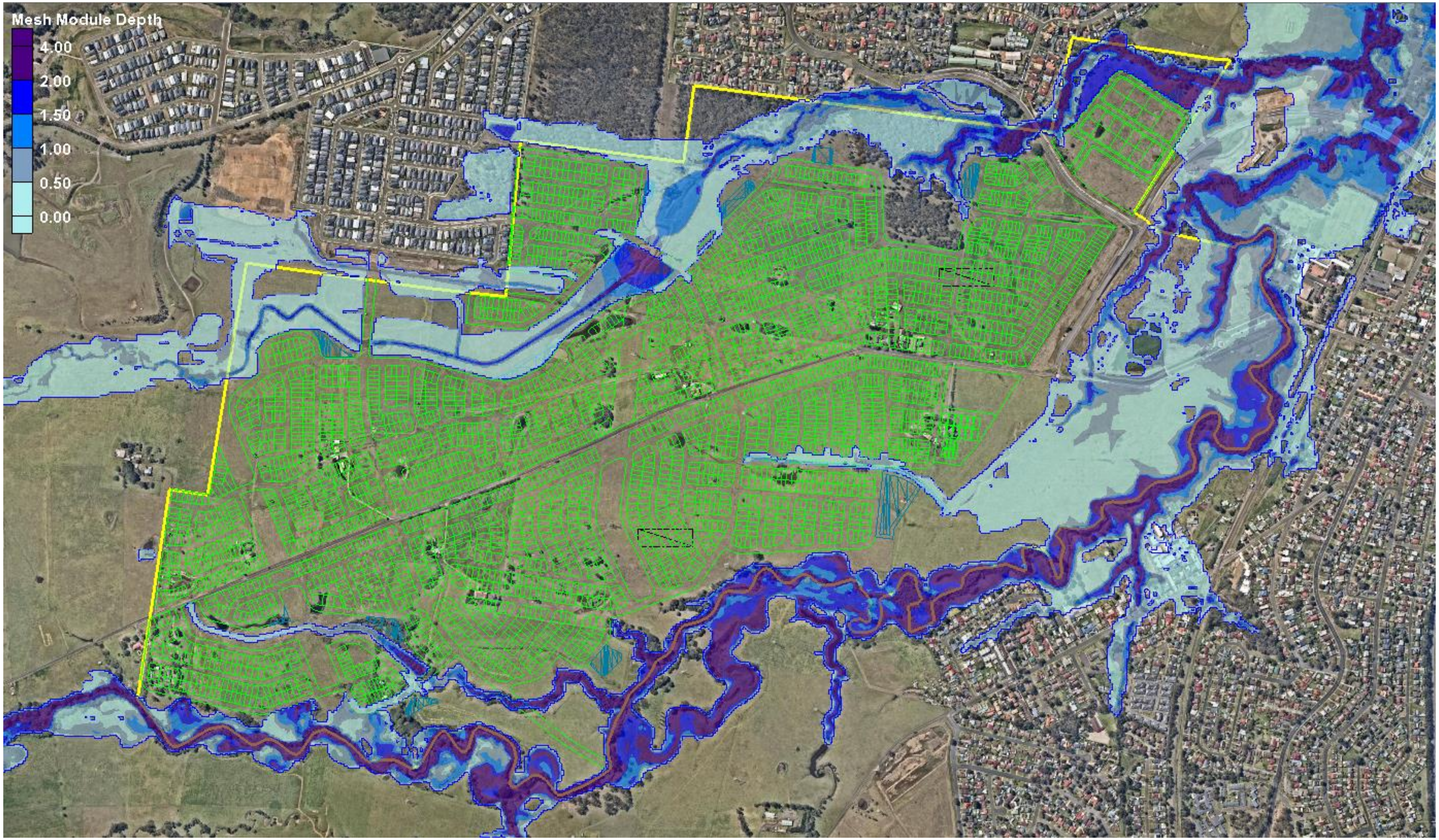


Figure C2.2: 1% AEP Flood Depths – Post-Development

Note: Flood depths shaded from 0m (light blue) to 4.0m (dark blue). All depths over 2.0m shaded dark blue.

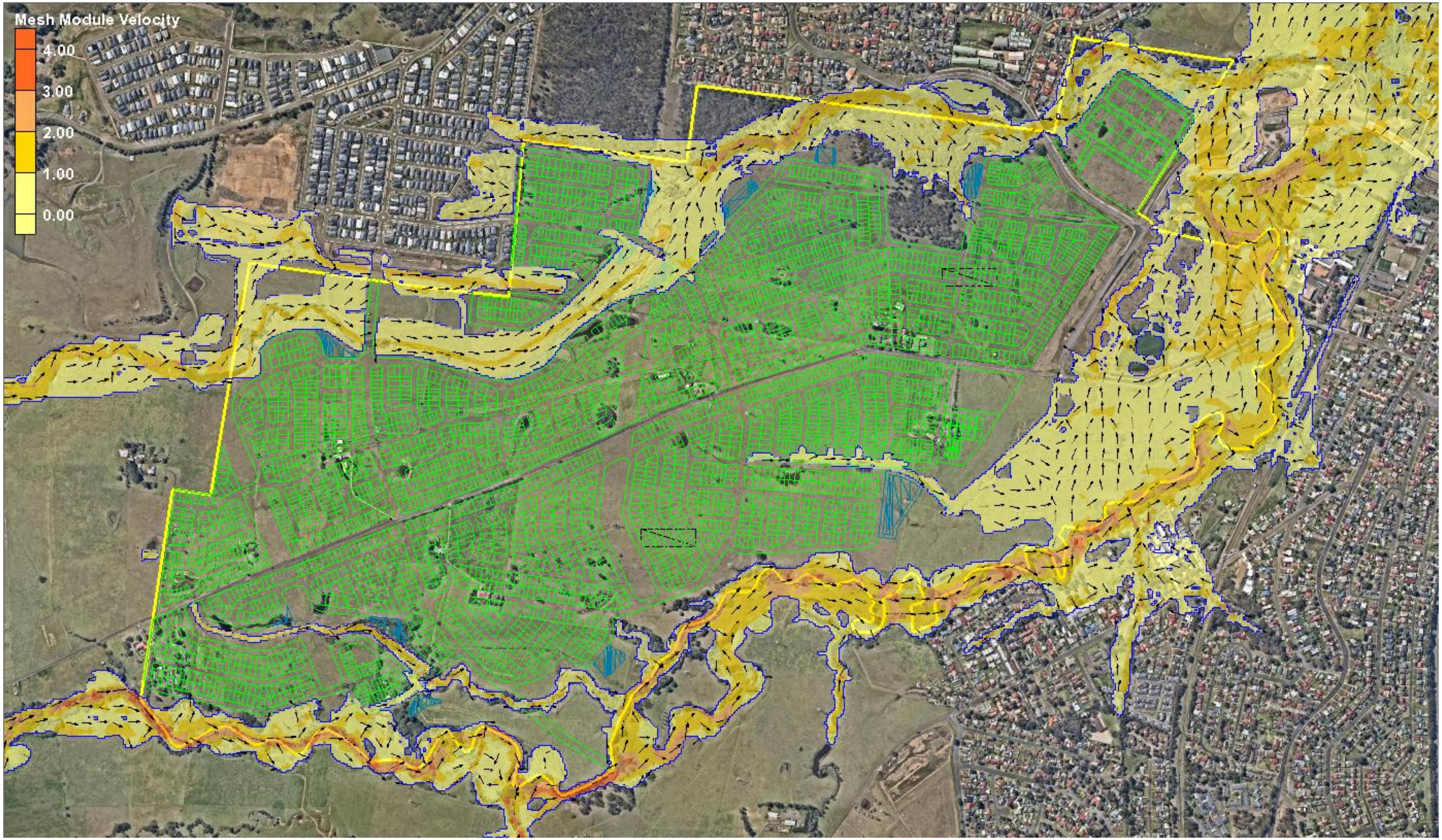


Figure C2.3: 1% AEP Flood Velocity – Post-Development

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

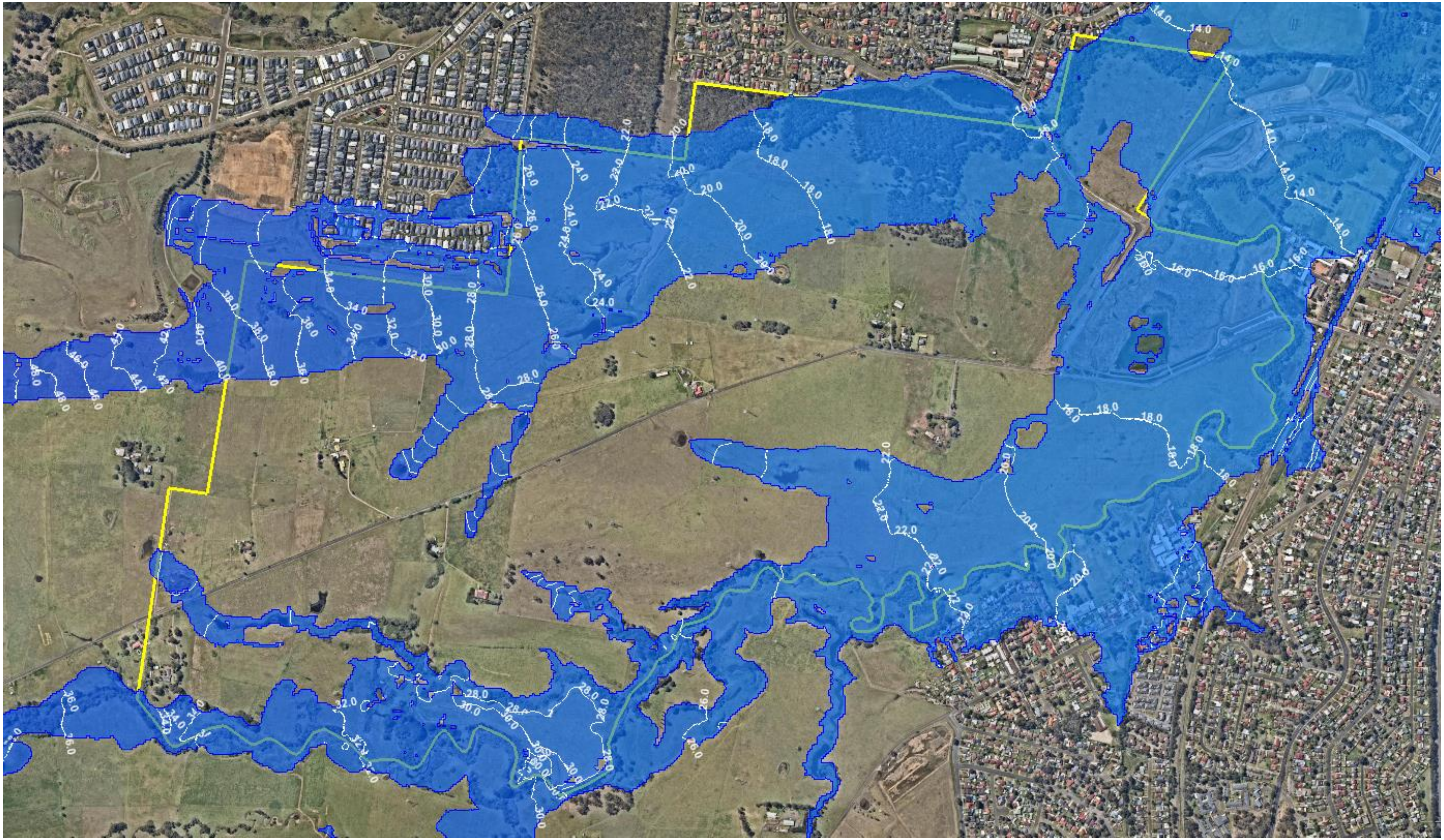


Figure C3.1: PMF Flood Levels – Pre-Development

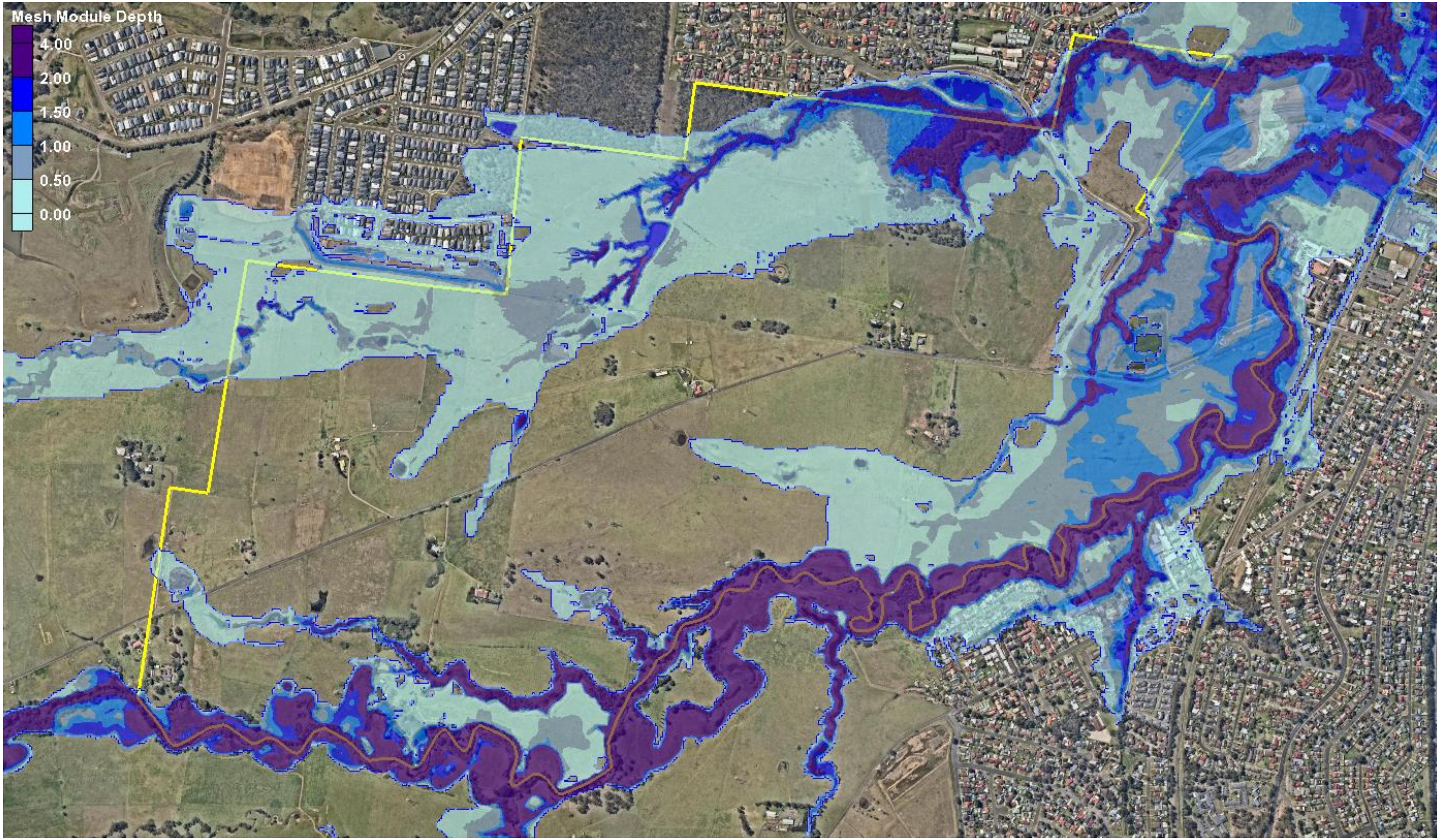


Figure C3.2: PMF Flood Depths - Pre-Development

Note: Flood depths shaded from 0m (light blue) to 4.0m (dark blue). All depths over 2.0m shaded dark blue

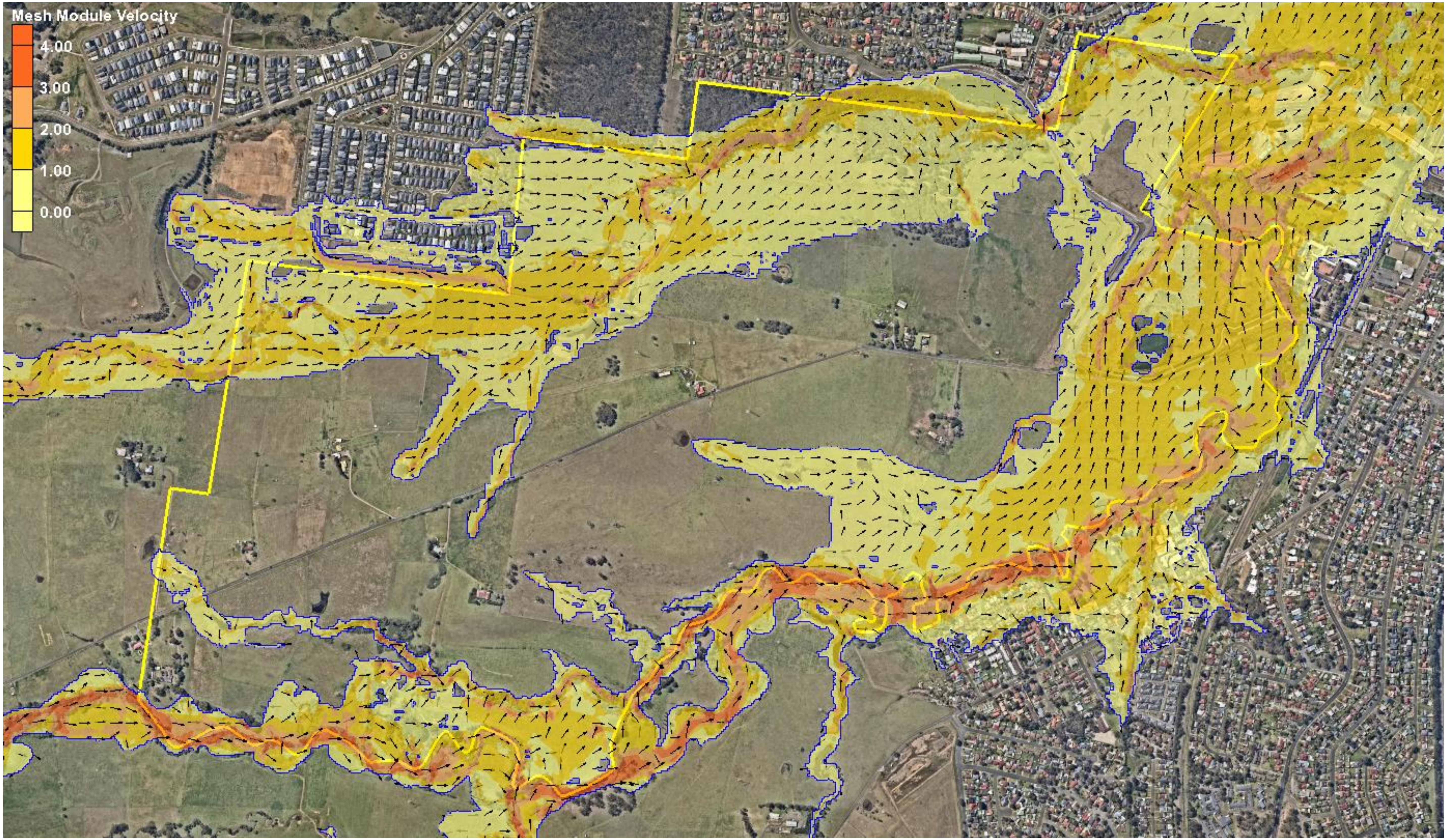


Figure C3.3: PMF Flood Velocity - Pre-Development

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

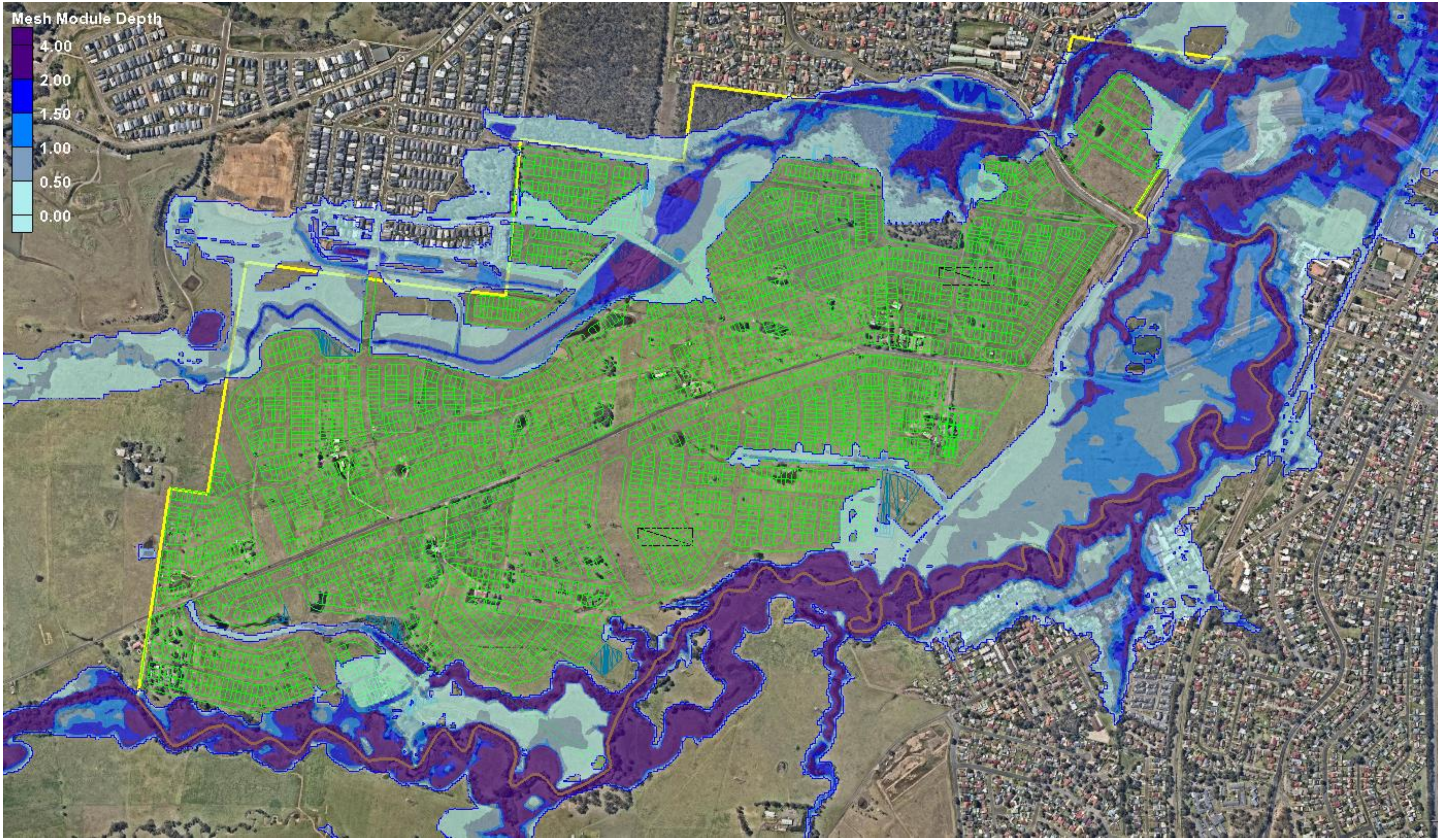


Figure C4.2: PMF Flood Depths - Post-Development

Note: Flood depths shaded from 0m (light blue) to 4.0m (dark blue). All depths over 2.0m shaded dark blue

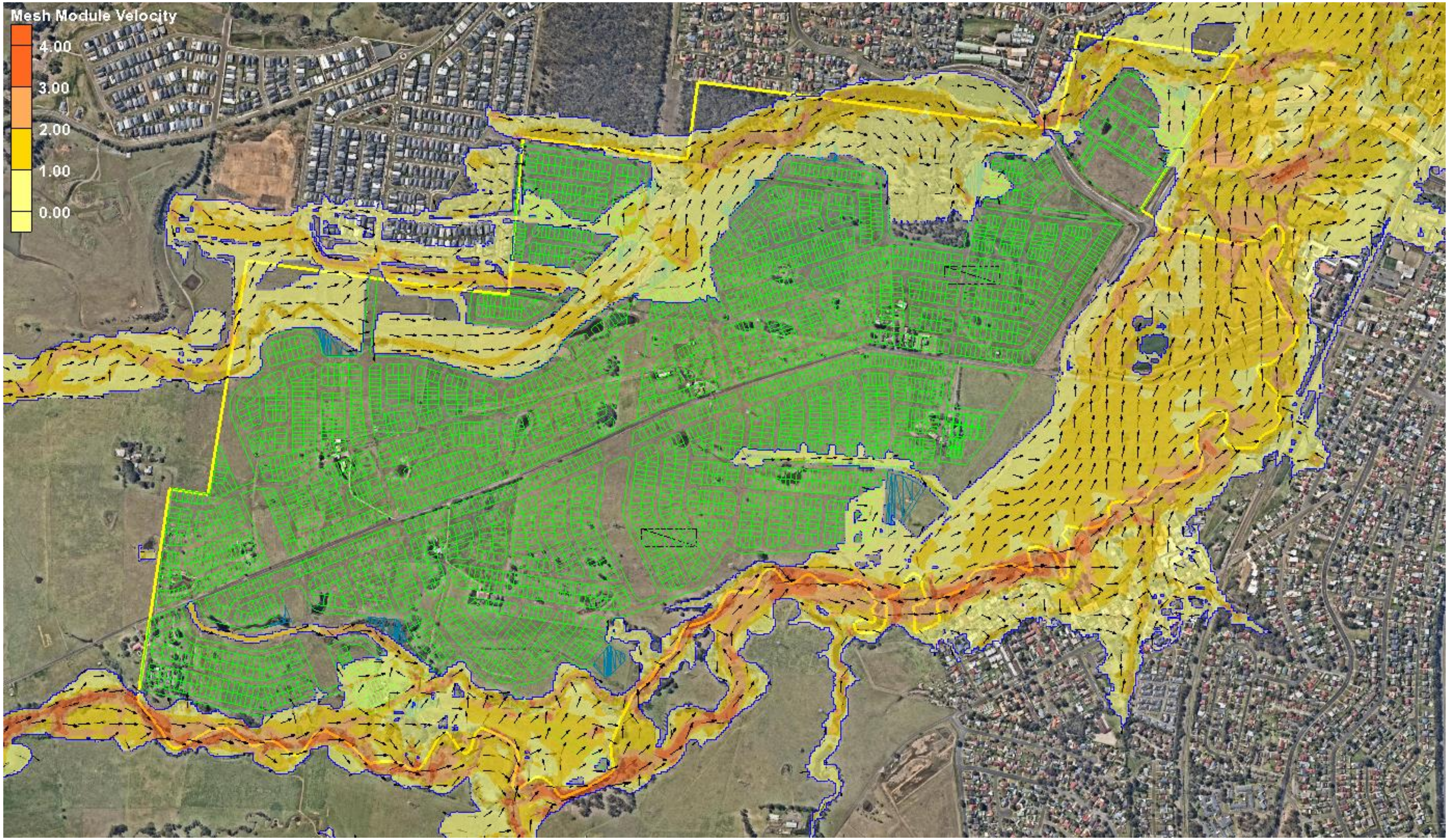


Figure C4.3: PMF Flood Velocity - Post-Development

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 C7 – IMPACT MAPS AND OTHER MODEL DATA

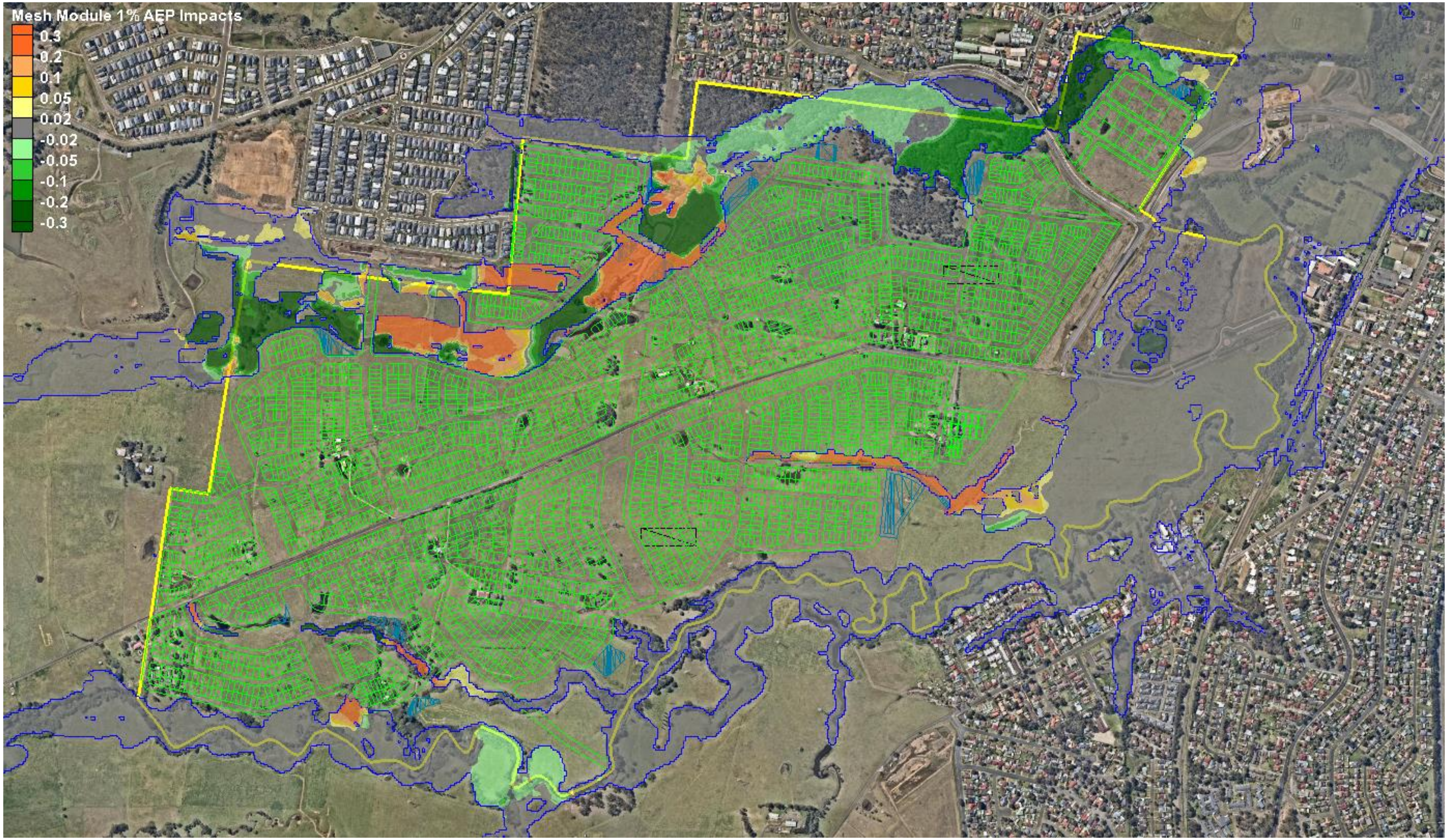


Figure C7.1: 1% AEP Development Related Changes to Peak Flood Surface Levels under Post-Development Conditions

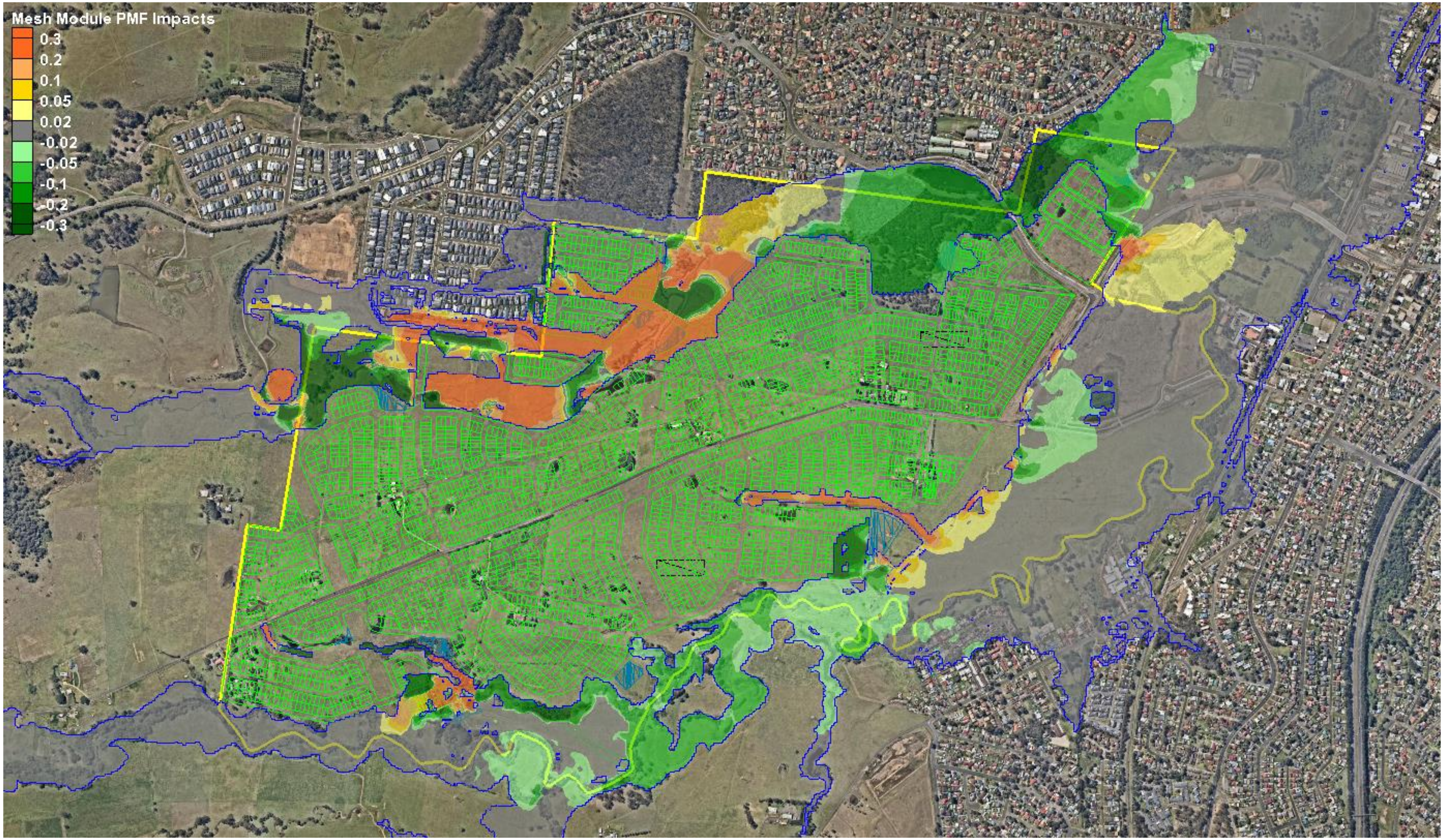


Figure C7.2: PMF Development Related Changes to Peak Flood Surface Levels under Post-Development Conditions

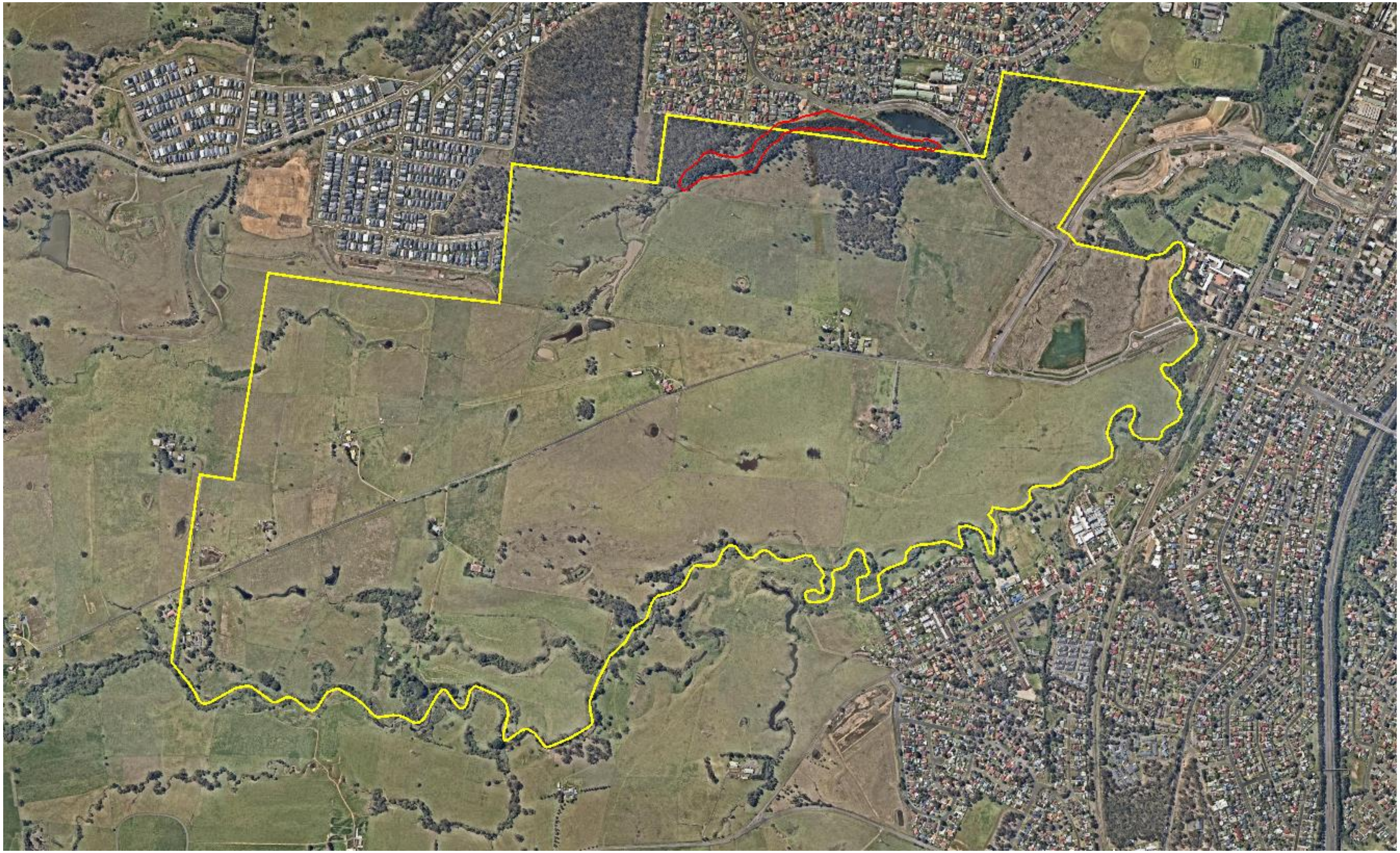


Figure C7.3: Location of Northern Precinct Survey Patch

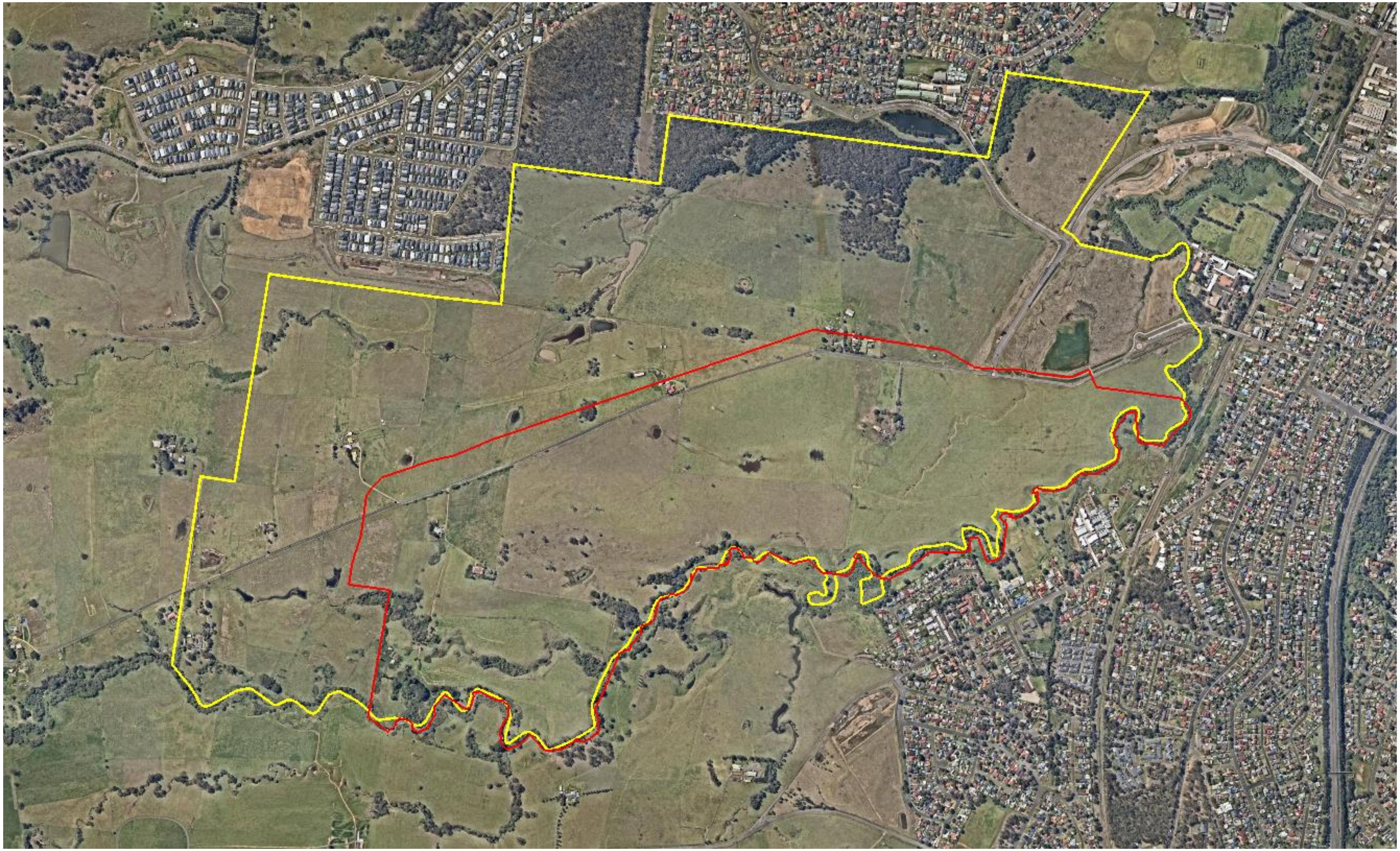


Figure C7.4: Location of Southern Precinct Survey Patch

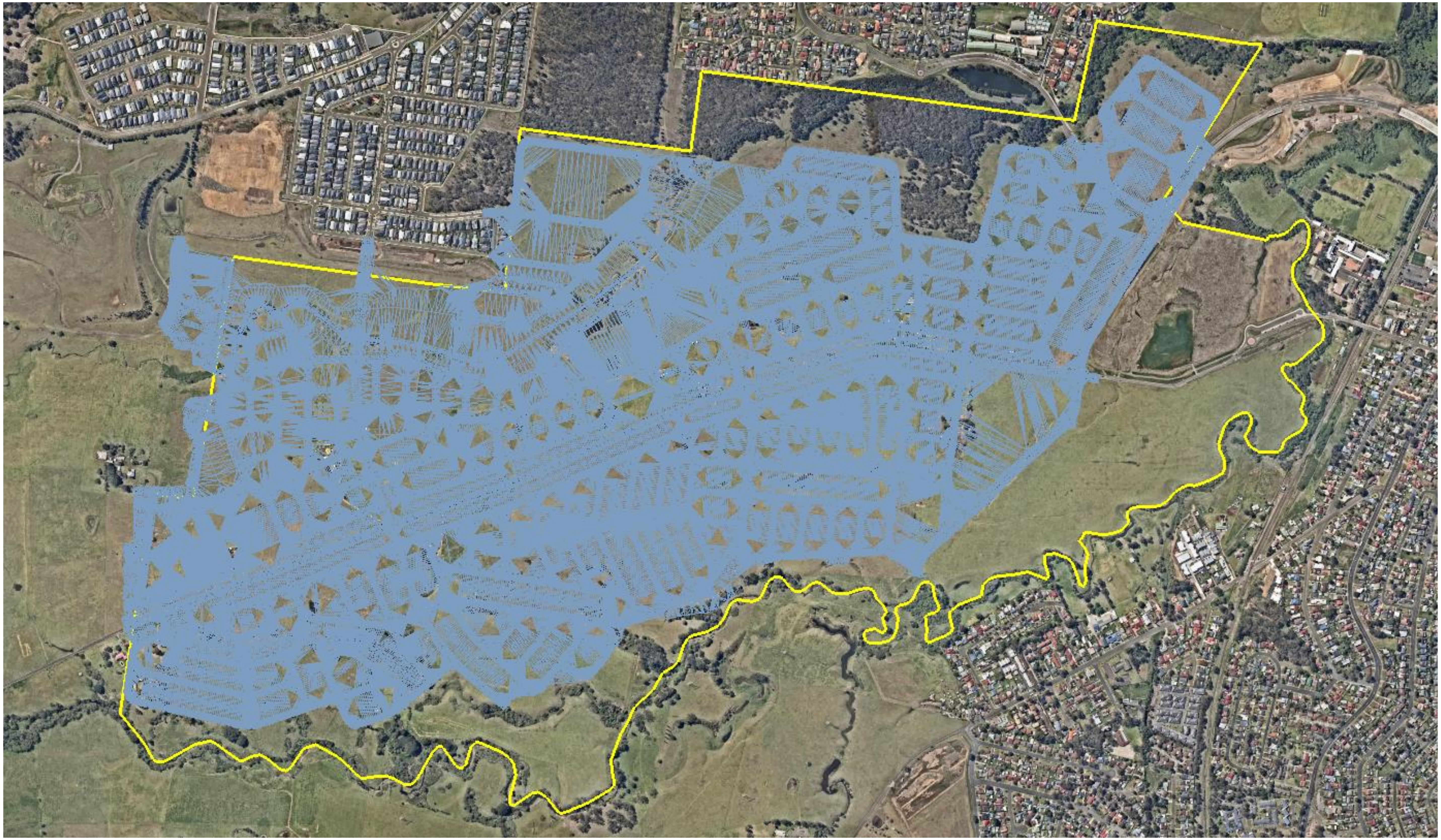


Figure C7.5: Extent of Post-Development TIN Patch

APPENDIX D – WSUD CATCHMENT PLAN

POST-DEVELOPMENT CATCHMENT PLAN FOR WSUD MEASURES

ISSUE:	DESCRIPTION:	DATE:	BY:
A	ISSUED FOR COORDINATION	DEC '19	AB
B	ISSUED FOR COORDINATION	SEP '20	AB
C	ISSUED FOR COORDINATION	OCT '20	AB
D	ISSUED FOR COORDINATION	OCT '20	AB

RIENCO CONSULTING
Providing Specialist Services in Hydrology and Hydraulics
PO BOX 3094, AUSTINMER NSW 2515
www.rienco.com.au

TITLE:			
WSUD PLAN			
CLIENT: NewQuest Property		LOCATION: Cleveland Road, Cleveland	
DRG No: 1002	SCALE: 1 : 5,000	DRAWN BY: AB	REVISION: D