

365 MARSHALL MOUNT ROAD

WATER CYCLE MANAGEMENT STRATEGY

MKR00156

OCTOBER 2024

Prepared For:

CAVI
DEVELOPMENTS

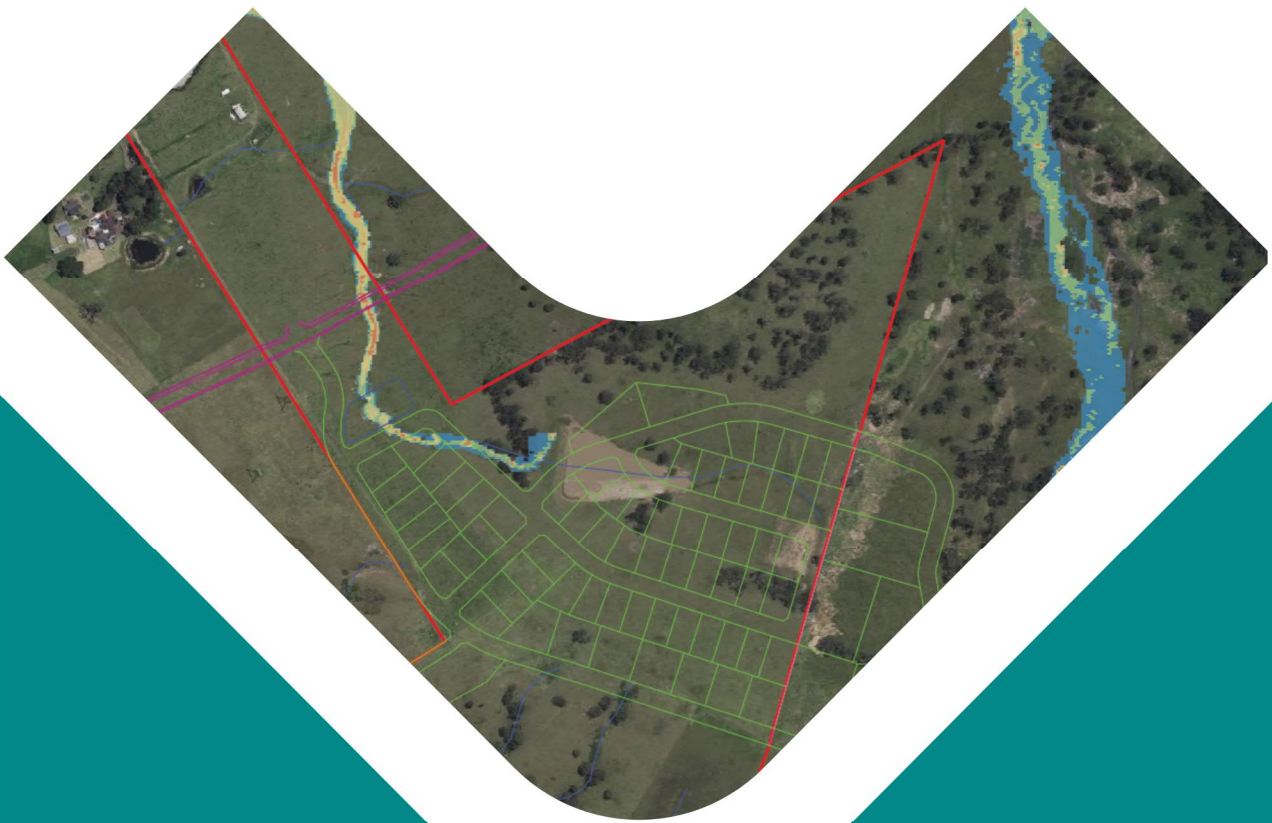




TABLE OF CONTENTS

1	AGENCY CONSULTATION	4
2	INTRODUCTION	5
2.1	Site Background	5
2.2	Timber Glades Neighbourhood Plan	6
2.3	Proposed Development.....	7
3	FLOOD IMPACT ASSESSMENT	8
3.1	Assessment Framework, Relevant Studies And Guides.....	8
3.1.1	Duck Creek Flood Study	8
3.2	Model Development.....	9
3.2.1	Hydrology	9
3.2.2	Initial Water Levels	10
3.2.3	Proposed Development Modelling	11
3.3	Results	12
3.3.1	Flood Depths.....	12
3.3.2	Flood Hazard	12
3.3.3	Hydraulic Classification – Flood Function	12
3.3.4	Flood Risk Precinct.....	13
3.3.5	Change in Flood Levels	13
3.4	Future Flood Management	14
3.4.1	Flood Planning Area.....	14
3.4.2	Evacuation	14
4	ONSITE STORMWATER DETENTION	15
4.1	Assessment Methodology	15
4.1.1	Hydrological Parameters.....	15
4.1.2	Rainfall Data.....	16
4.1.3	Catchment and Structure Details.....	16
4.2	Results	18
5	WATER QUALITY STRATEGY	19
5.1	WSUD Strategy.....	19
5.1.1	MUSIC Modelling	19
5.1.2	Climate Data.....	20
5.1.3	Source Nodes.....	20
5.1.4	Treatment Nodes.....	20



5.1.5	Bioretention Basin.....	20
5.1.6	Results	21
5.1.7	Operation and Maintenance Plan.....	21
6	CONCLUSION.....	22
APPENDIX A: FLOOD MAPS		
APPENDIX B: OSD CATCHMENTS		



Prepared By: Chetak Dalvi Date: 28/10/2024

Approved: Tim Howe Date: 28/10/2024

External Issue Register

Version No.	Description	Issued By	Date
1	Issue to inform Planning Proposal	Chetak Dalvi	02 May 2024
2	Reissue to inform Planning Proposal	Chetak Dalvi	28 Oct 2024



1 AGENCY CONSULTATION

	Comments	Maker Response
SES Comments	a) Proposal would increase lot yield significantly at a site which becomes isolated by flood waters from a tributary of Duck Creek crossing the only access road.	a) Access from the site to the flood reliable road network, as identified in WCC DCP chapter D16, is provided for all flood events up to the PMF event.
	b) Clarify flood behaviour and constraints (incl frequency and max duration of isolation for the site	b) The site remains flood free in all event up the the PMF, with flood free connection to the flood reliable road network to be provided. Critical storm and flood events within the wider catchment are short in duration, with large floods generally lasting between 45min to 3hrs. This flash flooding type behaviour typical of the region generally causes potential isolation to last less than an hour before flood affected roads are trafficable again.
	c) Understand any impact the bulk earthworks will have on the site and communities downstream of the proposed changes.	c) Flood maps have been provided in Appendix A, including impact maps. No negative impacts were noted downstream as a result of the proposed works.
WCC Comments	a) One access point is a concern for access in an emergency – fire, flood	a) The site provides flood free access to the Flood reliable road network, as identified in WCC DCP Chapter D16.
	b) It is noted that the proposal would significantly increase lot yields in an area which is isolated and proposed to have only one access point (which also could be isolated by flooding or fire). This access point cannot be finalised until the proposed bypass road is completed.	b) Refer to response to SES comment (a) above in relation to flood free access. As noted in the Traffic Impact Assessment by Amber and the conceptual layout plans, the proposed site access has been designed with consideration to the 80% Bypass Road design in the ultimate scenario. Should the subject development be delivered prior to the Bypass Road, an interim access arrangement will be provided through the northern Iwona NP road network, which is also owned by the proponent



2 INTRODUCTION

Maker ENG Pty Ltd (Maker) has been engaged by CAVI Developments to prepare a Water Cycle Management Strategy (WCMS) to support the proposed development of 365 Marshall Mount Road, Marshall Mount, herein referred to as the broader site.

This report has been prepared to accompany a Planning Proposal and associated Neighbourhood Plan for the land holding, which will deliver a broader range of housing responsive to the site and its servicing capabilities. Maker's scope includes the assessment of water quality, on-site detention, and flooding requirements to ensure that this planning proposal can be managed to have an acceptable impact on receiving waterways.

2.1 SITE BACKGROUND

The broader site is legally described as Lot 8 DP 626078 and has a total area of 36 hectares. The site is located within Stage 5 of the West Dapto Urban Release Area (WDURA), known as Yallah Marshall Mount, which forms the southern extent of both the WDURA and the Wollongong City Council municipality. The portion of the broader site that is subject to the intended Planning Proposal comprises approximately 12 hectares and is identified in Figure 1 below, herein referred to as the subject site.



Figure 1 - Site context map, the broader site (blue), and subject site (red)

(Source: Nearmap & Ethos Urban)

The broader site has a split zoning, comprising part R2 Low Density Residential, C3 Environmental Management, C2 Environmental Conservation and C4 Environmental Living land use zonings. The subject site consists of the C4 land only.

The broader site comprises a mixture of low to medium density vegetation, farm dams, a dwelling house, farms sheds and a sealed driveway. The subject site is free of any structures and is sparsely vegetated as a result of historic clearing and grazing activities.



A ridgeline dissects the broader site, such that the northern portion of the site falls to the north-west and is part of the Duck Creek Catchment; and the southern portion of the site falls in the Macquarie Rivulet Catchment. The subject site predominantly falls to a tributary of Duck Creek.

The subject site is within the catchment of Lake Illawarra, with Duck Creek entering Lake Illawarra 5km downstream, and Marshall Mount Creek entering the lake 6km downstream.

The site locality and characteristics are illustrated in Figure 2 below.



Figure 2 - Site Locality (Source: SixMaps)

2.2 TIMBER GLADES NEIGHBOURHOOD PLAN

The broader site is located across two WDURA neighbourhoods, Iowna and Timber Glades (as shown in Figure 3 below). A draft Neighbourhood Plan for the Iowna Precinct has been formally exhibited in 2021 and is currently being considered by Council. The preparation of a Neighbourhood Plan for the Timber Glades Precinct will be required prior to the granting of consent for any development of the site.

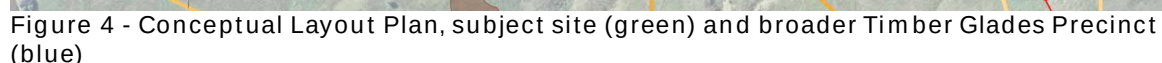
The subject site forms the primary holding of the Timber Glades precinct, with the other developable allotments in the precinct being the southern portion of 377 Marshall Mount Road (Lot 2 DP105826) and 297 Marshall Mount Road (Lot 5 DP24143) and identified in Figure 2.

Due to the pivotal size and location of the subject site in reference to the Timber Glades precinct, this water cycle management strategy gives consideration to the broader precinct rather than just the subject site in isolation.



The Planning Proposal seeks to adopt an implied lot size of 1,000m² (mapped as 999m²) over the C4 'Environmental Living' land within the subject site. The broader Timber Glades precinct will retain the current 4,999m² minimum lot size for strategic reasons described in the planning submission. This will deliver a transition in the lot size and housing arrangements.

The conceptual lot layout is illustrated in Figure 4 below, with 72 lots ranging from 1,000m² to 3,300m² (green) proposed within the subject site and approximately 11 large residential lots (5,000m² or more) shown within 297 and 377 Marshall Mount Road (blue).





3 FLOOD IMPACT ASSESSMENT

The proposed development site is primarily located within the Duck Creek catchment, with multiple tributaries of Duck Creek travelling north through the site. These continue flowing north from the site under Marshall Mount Road before joining Duck Creek 950m downstream of the site.

A small portion of the site straddles the ridgeline and will inevitably drain south into Marshall Mount Creek, part of the Macquarie Rivulet Catchment. However, this portion remains far removed from the floodplain and is located at the very top of its respective catchment. As such flooding within the Macquarie Rivulet is not considered further within this assessment.

3.1 ASSESSMENT FRAMEWORK, RELEVANT STUDIES AND GUIDES

This flood strategy has been developed to be consistent with the Wollongong City Council Development Control Plan and other relevant guidelines and studies relevant to the area, particularly:

- NSW Floodplain Development Manual
- DCP Chapter E13: Floodplain Management
- DCP Chapter E14: Stormwater Management
- DCP Chapter E15: Water Sensitive Urban Design
- DCP Chapter D16, West Dapto Release Area
- Duck Creek Flood Study, Rhelm 2019
- Macquarie Rivulet Flood Study, WMA Water 2017

This report will provide information on the extent of flooding, identifying areas of different flood function, the variation of flood hazard across the site, the impacts of the proposed development on flood behaviour and identification of the flood planning area.

3.1.1 Duck Creek Flood Study

Wollongong City Council have adopted the Duck Creek Flood Study, prepared by Rhelm in 2019 (DCFS). This study was prepared to define the existing flood behaviour in the Duck Creek Catchment and establish the basis for subsequent floodplain management activities. The study encompasses an area of 19 sq.km located in the Yallah region and the creek flows east and discharges into Lake Illawarra. The study was made available to Maker through the SES Flood Data portal. The study includes the site within its analysis and forms a suitable basis for further assessment for flooding within the site.

The study used a WBNM hydrological model and TUFLOW hydraulic model. The study analysed the models for PMF, 0.2% AEP, 0.5% AEP, 1% AEP, 2% AEP, 10% AEP and 20% AEP, with multiple storm durations. The study included flood extents, depths, velocities, and hazard for an existing and a proposed scenario. More details of the hydrological modelling can be found in the Duck Creek Flood Study Final Report Volume 1 (Rhelm-2019)



3.2 MODEL DEVELOPMENT

Maker have adopted the DCFS as the basis for all flood modelling within the site, using the 2-dimensional TUFLOW model developed for this assessment. The method and assumptions made in developing the site model are generally as per the DCFS. Any changes from the modelling presented within the DCFS are discussed in the following sections.

3.2.1 Hydrology

A WBNM hydrological model, as used in the WCC adopted DCFS, was used to model the proposed site. The existing catchments were generally adopted as identified within the DCFS, with the exception of the catchments directly interacting with the site. The catchments areas within the site were further altered from those presented within the DCFS to better identify and represent flows leaving the site.

The existing catchments from the Duck Creek model are shown below in Figure 5. Where catchments have been altered are further presented in below in Figure 6.



Figure 5 - Duck Creek Flood Study WBNM Catchments



Figure 6 - Duck Creek Flood Study catchments (yellow) and adjusted catchments used to assess changes to study area (orange)

Beyond further division of the existing catchments to better represent the site outflows, no further changes to the hydrology are proposed within this assessment.

Any changes to catchment extents and impervious fractions within the site are to be compensated for with the provision of On-Site Detention which is discussed in section 3 of this report.

3.2.2 Initial Water Levels

Discharges from a farm dam located centrally within the site form the upstream inflow boundary of the TUFLOW model within the DCFS. This is depicted in the following figure from the DCFS.



Figure 7 - DCFS 1% AEP Flood Depths (Rhelm 2019)

Upon further analysis of the provided TUFLOW model and existing results from the site, it was identified that an Initial Water Level (IWL) was present within the dam. IWL's are useful within flood models to ensure water bodies are full or at capacity prior to the flood event, preventing over representation of flood storages within flood models, as well as controlling the interface between larger waterbodies and stream flows.

In this instance, the IWL modelled within the farm dam had an elevation higher than the existing dam embankment. As IWL's are an infinite water source, this has resulted in a constant inflow of floodwaters from the dam into the wider TUFLOW model.

On a catchment wide scale, such an inconsistency within a small area such as this is unlikely to have a meaningful impact upon the wider floodplain, however in the context of this site assessment it has a drastic effect on local flooding outflows from the site.

To remedy this, the IWL was removed from the model, and the catchment inflows from catchment surrounding the dam were moved to the downstream embankment of the dam to prevent the dam providing any attenuation to floodwaters.

3.2.3 Proposed Development Modelling

The proposed development will result in the removal of the existing farm dam and the upper extents of the associated watercourse within the site. These areas will be replaced with the future stormwater network that will collect runoff and direct them to the OSD basin as required. This is reflected within the flood model with removal of flows from these areas, and a revised site outflow at the outlet of the future OSD basin.



3.3 RESULTS

The site is located at the top of the catchment and proposes the removal of the upper most extents of some small 1st order watercourses, with minimal interaction with any flood prone areas. Flood modelling results at the site further re-affirm this, with no impact to the wider floodplain as a result of the proposed works.

Flood maps including a range of outputs requested in DCP Chapter E13 for the proposed scenario are provided in Appendix A. Further discussion of these maps is provided in the following sections.

3.3.1 Flood Depths

As identified above, the pre-developed case was developed using the WCC supplied DCFM, however excludes the existing dam within the site. Beyond this change, flow depths remain generally consistent with those presented within DCFS. Pre-developed 1% AEP results show depths between 0.2m to 0.4m at the discharge of the existing dam, gradually increasing downstream towards the site boundary, where flows range from between 0.6m to 0.9m deep.

In the proposed case, stream flows are isolated to the downstream extents of the site at the discharge of the future OSD basin. Flow depths are generally reduced in all scenarios with the removal of the upstream portion of the watercourse for subsequent piping of catchment flows.

3.3.2 Flood Hazard

The flood hazard categorisation has been prepared in accordance with the hazard curves defined in Chapter E13 of the WCC DCP.

In the 1% AEP pre-developed case, the existing watercourse proposed for removal has a hazard ranging between H1 to H3, with small pockets of H5 in isolated depressions. Beyond the proposed OSD basin, more consistent stretches of H5 develop as the stream gains more flow volume and velocity.

Removal of the upstream portion of the watercourse in the proposed scenario impedes the ability of the stream immediately downstream of the site from gaining flow velocity and depth, reducing overall hazards within the watercourse.

3.3.3 Hydraulic Classification – Flood Function

The flood function of different parts of the floodplain have been considered by categorising it into Floodway, Flood Storage and Flood Fringe areas, using the criteria from the Duck Creek Flood Study shown in Table 1. This definition is an indicator technique which has limitations as described in Flood Risk Management Guide FB02 'Flood Function' (DPE, 2022).



Table 1 - Hydraulic Categorisation Definition

Hydraulic Category	Definition
Floodway	Velocity depth product greater than 0.4 m ² /s
Flood storage	Velocity depth product is greater than 0.4 m ² /s. Areas that are not floodway and where depth is greater than 0.5m.
Flood fringe	The remainder of the flood extent

As can be seen in the provided flood maps, the portion of the watercourse proposed for removal is primarily defined as flood fringe, with isolated pockets of floodway associated with localised deep sections of the watercourse. The floodway develops in truth shortly downstream of the proposed OSD basin. This further indicates that removal of this portion of the watercourse would have negligible effect on the wider floodplain, which is further reaffirmed in the proposed scenario results.

3.3.4 Flood Risk Precinct

Flood Risk Precincts have been defined at the site as per the guidelines set out in WCC DCP Chapter E13 and as listed in Table 2 below.

Table 2 - Flood hazard & Flood Risk Precincts

Hydraulic Category	Definition
High Flood Risk Precinct	Areas greater than H3 hazard Land within 10m of top of bank Floodways
Medium Flood Risk Precinct	Land not within the High flood risk precinct that is less than 0.5m above the 100 year ARI flood level
Low Flood Risk Precinct	The remainder of the floodplain defined by the PMF extent

As can be seen within the provided flood maps, and consistent with the hydraulic category discussed above, the portion of watercourse proposed for removal is defined primarily as within the Low Flood Risk Precinct.

Furthermore, removal of this portion of the watercourse, as presented within the proposed scenario, results in a slight reduction of high flood risk areas immediately downstream of the proposed works.

3.3.5 Change in Flood Levels

The difference in flood levels between the existing and proposed case were calculated and are shown within the provided maps for all flood events.

The proposed removal of the uppermost portion of the watercourse and piping of the catchment to the outlet results in overall decreases in flood levels downstream in all events.



3.4 FUTURE FLOOD MANAGEMENT

3.4.1 Flood Planning Area

The flood planning area is a key consideration in the approach to strategic land use planning outlined in the prescriptive controls relevant to the site. The flood planning level (FPL) is adopted from Chapter E13 of the WCC DCP, defined as 1% AEP with a freeboard of 0.5m.

The proposed works result in all proposed lots being located outside of the PMF extents. As such, further flood controls or flood management within the development site are not recommended, and future lot owners will be able to construct homes without further consideration of flood requirements.

3.4.2 Evacuation

The entire site is proposed to be accessed via the future road connection at the northwest extent of the subject site, where it will tie into the future road network of the West Dapto Urban Release Area.

The future roadways within the site remain entirely flood free in the proposed modelling for the site. The connecting road is also identified as a 1% AEP Flood immune road within WCC DCP Chapter D16. These factors should ensure reasonable evacuation and access to the proposed site in a flood event.

All lots have reliable refuge above the PMF level.



4 ONSITE STORMWATER DETENTION

Development within the Wollongong Local Government area generally must provide On Site Detention (OSD) for any proposed increases to catchment runoff due to development. Furthermore, it is generally preferred that OSD structures be constructed at a subdivision level to provide one consolidated asset at each outlet where required.

Under WCC DCP Chapter E14, OSD is not required for buildings in non-urban zoning areas including C2, C3 and C4. As such, OSD assessment for the proposed lots within the precinct is not required. Despite this, the proposed reduction in lot size at the site will result in an increase in runoff for a considerable area, which has the potential to impact the downstream watercourse and environment. In order to limit this potential impact and to ensure the planning proposal can be supported with confidence, it is recommended that OSD be provided for runoff from the entire planning proposal area. In light of this, OSD assessment has been undertaken for all proposed lots and roads within the proposed residential rezoning area only (the subject site).

Concept OSD Design has also been undertaken for the future roadways that would service the C4 lots outside of the subject site. This is for information purposes only to ensure a holistic approach to OSD is achieved within the wider Timber Glades neighbourhood.

For the purposes of this OSD assessment and the Water Sensitive Urban Design Assessment in the following section, the subject site is referred to as Stage 1, and the future development east of the site within the C4 zoned area not proposed for rezoning, is referred to as Stage 2.

4.1 ASSESSMENT METHODOLOGY

A DRAINS model has been established for the site to understand the proposed catchment flows and to effectively model OSD structures within the site for a variety of storm events.

4.1.1 Hydrological Parameters

As a detailed storm water network is not designed or practical for this level of assessment, the Drains model utilises WBNM runoff and routing procedures to model the catchment flows.

The hydrological parameters adopted within the model have been chosen in line with the WCC adopted Duck Creek Flood Study and further listed in Table 3 below.

Table 3 - Adopted WBNM hydrological parameters.

Parameter	Adopted Value
Lag parameter (C)	1.6
Initial Loss (pervious)	20 (critical duration)
Continuing loss (pervious)	2.5
Initial Loss (impervious)	2.5
Continuing loss (impervious)	0
Stream Routing Factor	1



4.1.2 Rainfall Data

Rainfall data was sourced from the Bureau of Meteorology using the ARR 87 procedures for the site location, in accordance with the Duck Creek Flood Study.

4.1.3 Catchment and Structure Details

Existing catchments at the site have been determined from Aerial Lidar Survey from NSW Government Spatial Services. The Timber Glades precinct is proposed to discharge at three locations, with an OSD structure proposed at each respectively. The existing and proposed catchments reflect this outcome for assessment purposes.

The proposed site has been sympathetically designed to utilise the existing topography as much as possible. Despite this, and in order to also achieve an efficient urban design outcome at the site, the proposed catchments discharging to each location are slightly altered from the existing catchments. Any minor changes in catchment area draining to each OSD structure is to be attenuated accordingly within each structure.

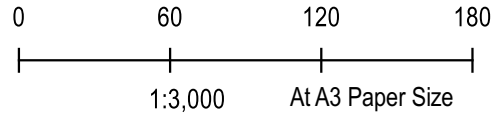
Impervious fractions for each existing catchment have been assumed as 0% as a conservative measure. Proposed impervious fractions have been manually calculated for each proposed catchment in consideration of the proposed road network and respective lot sizes and types within each catchment. This has resulted in an overall impervious fraction of 51% for Stage 1, and 20% for Stage 2.

The existing and proposed catchments utilised for the OSD assessment can be seen within Appendix B.

Figure 8 below shows the location of the proposed basins.

FIGURE 8. PROPOSED BASIN
PLAN

- Legend
- Site Boundary
 - Watercourse
 - GPT
 - Swale
 - Proposed Basins



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Apr 2024





4.2 RESULTS

Proposed site discharges, when attenuation via OSD structures, are provided in Table 5, Table 6 & Table 7 below. As can be seen, site discharges can be maintained at pre-development levels when attenuation via OSD is provided.

The OSD structures used to achieve this outcome are further detailed in Table 4 below.

Table 4 – Recommended OSD Structures

Structure Location	Stage 1 North	Stage 1 South	Stage 2
100yr ARI Peak flow rate in	8.44 m ³ /s	0.878 m ³ /s	3.33 m ³ /s
100yr ARI Peak flow rate out	3.34 m ³ /s	0.689 m ³ /s	2.09 m ³ /s
Outlet Control	750mm circular culvert and 4m weir overflow	600mm circular culvert and 2m weir overflow	675mm circular culvert and 2m weir overflow
Required Volume	6,250 m ³	210 m ³	1,650 m ³

Table 5 - Proposed Stage 1 North Site Discharge

Scenario	5 year ARI	20 year ARI	100 year ARI
Pre-developed	2.08	3.58	5.26
Post-developed	2.08	2.91	4.57

Table 6 - Proposed Stage 1 South Site Discharge

Scenario	5 year ARI	20 year ARI	100 year ARI
Pre-developed	0.881	1.45	2.07
Post-developed	0.809	1.33	1.89

Table 7 - Proposed Stage 2 Site Discharge

Scenario	5 year ARI	20 year ARI	100 year ARI
Pre-developed	2.09	3.6	5.29
Post-developed	2.07	3.21	4.84

As can be seen in the above tables, the proposed development discharges can effectively be managed with the provision of OSD. Further refinement of the proposed OSD structures is recommended at the detailed design stage once more detailed stormwater network modelling is available to ensure the OSD provided at the site functions efficiently.



5 WATER QUALITY STRATEGY

5.1 WSUD STRATEGY

A WSUD strategy has been developed for Stage 1 & 2 of the proposed subdivision. This has been prepared in accordance with the Wollongong City Council DCP Chapter E15 - Water Sensitive Urban Design, in conjunction with Chapter E13 and Chapter E14 of the DCP.

Section 9.1 of DCP Chapter E15 requires that the storm water quality performance targets, as listed in Table 8 below, are achieved for the development.

Table 8 - Stormwater quality performance targets

Pollutant	Target % reduction
Gross Pollutants	90
Total Suspended Solids (TSS)	85
Total Phosphorus (TP)	60
Total Nitrogen (TN)	45

Stormwater treatment is proposed to be managed communally for all residential areas including the roads.

5.1.1 MUSIC Modelling

Conceptual modelling was undertaken using MUSICX 1.10.0 with configuration of 6-minute time interval, based on the Rainfall and evapotranspiration data Bureau of Meteorology. A diagram of the MUSIC model is shown in Figure 4.

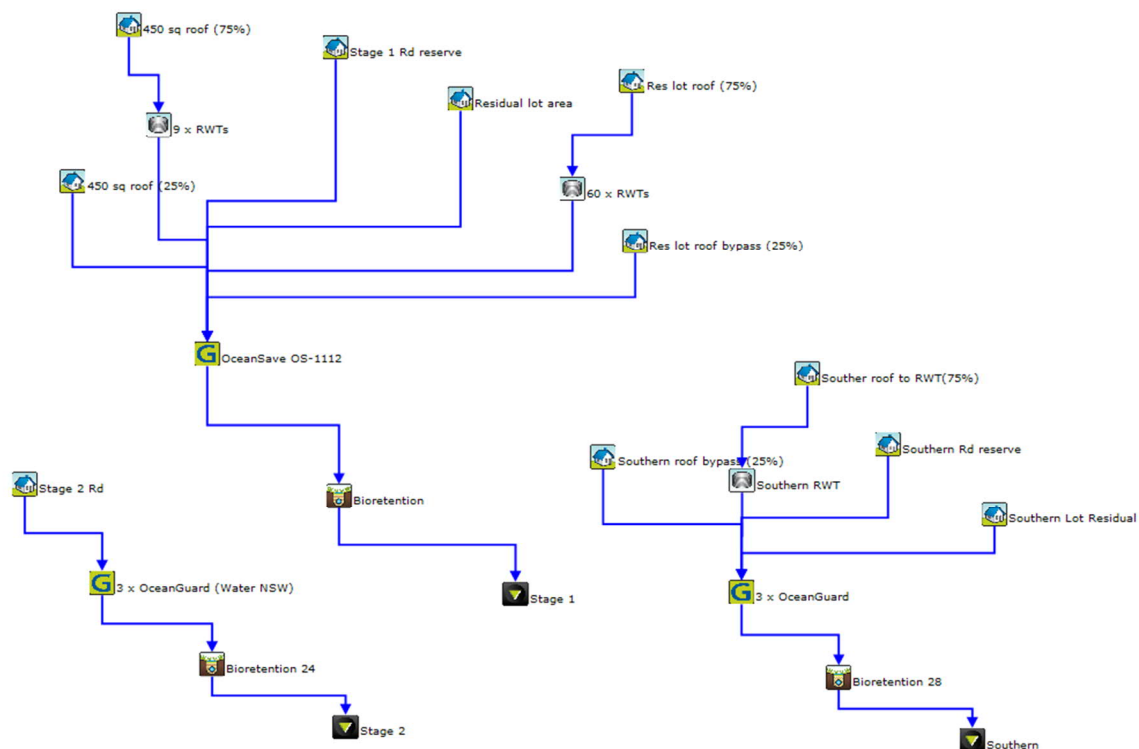


Figure - 4: Site WSUD MUSIC model schematic



5.1.2 Climate Data

Rainfall and evapotranspiration data from Station 68131 Port Kembla (BSL Central Lab) over a 10-year period between 1965 to 1975 was used. Monthly average areal potential evapotranspiration data was obtained from the same configuration.

5.1.3 Source Nodes

The source nodes were split based on the varying lot and the subsequent assumed roof sizes. Lots sizes between 1500 m² and 1800 m² were assumed to have a roof area of 450 m², whereas lots below this size were assumed to have a roof area of 350 m². It was assumed that 75% of each properties roof area would be captured within a rainwater tank.

5.1.4 Treatment Nodes

The treatment train for the proposed subdivision consists of rainwater tanks, a gross pollutant trap, and a bioretention basin. All lots are proposed to have a 5kl rainwater tank. 75% of the roof area is modelled to drain into the rainwater tanks, while 25% bypasses the tank. The rainwater tanks are modelled to provide internal reuse for toilet flushing and external reuse for irrigation/gardening. The residual lot area for the lots is represented as a single node for both medium and large lots.

The residual area, along with the overflow from the rainwater tanks and the roof bypass area is treated further by a Atlan Vortceptor before discharge into a bioretention basin. The proposed bioretention media is assumed to be located within the proposed OSD basins discussed in the sections above.

5.1.5 Bioretention Basin

The bioretention basin is proposed to be located within the OSD basin with the following parameters, shown in Table 9.

Table 9 - Bioretention Basin Parameters

Parameter	Stage 1 North Bioretention Basin	Stage 1 South Bioretention Basin	Stage 2 Bioretention Basin
Filter media area (m ²)	600	100	120
Filter media depth (m)	0.5	0.5	0.5
Extended detention depth (m)	0.3	0.3	0.3
Extended detention area (m ²)	180	180	180
Saturated hydraulic conductivity (m m/hour)	100	100	100
Filter media TN (mg/kg)	400	400	400
Filter media Orthophosphate (mg/kg)	40	40	40



5.1.6 Results

Pollutant load reduction results of the MUSIC model are shown in Table 10, Table 11 & Table 12 below. The proposed treatment train achieves the target reduction percentages for all pollutants.

Table 10 - Stage 1 North MUSIC model treatment train effectiveness.

Pollutant	Source Load (kg/year)	Residual Load (kg/year)	Reduction (%)
Total suspended solids	15630	2040	86.95
Total phosphorus	28.82	9.561	66.83
Total nitrogen	187.9	102.7	45.32
Gross Pollutants	1778	0	100

Table 11 - Stage 1 South MUSIC model treatment train effectiveness.

Pollutant	Source Load (kg/year)	Residual Load (kg/year)	Reduction (%)
Total suspended solids	1474	194.7	86.8
Total phosphorus	2.604	0.8227	68.41
Total nitrogen	16.33	7.866	51.54
Gross Pollutants	118.5	0	100

Table 12 - Stage 2 MUSIC model treatment train effectiveness.

Pollutant	Source Load (kg/year)	Residual Load (kg/year)	Reduction (%)
Total suspended solids	4476	601	86.57
Total phosphorus	7.64	2.228	70.84
Total nitrogen	30.88	16.48	46.64
Gross Pollutants	309	0	100

5.1.7 Operation and Maintenance Plan

All elements of the proposed treatment train require regular maintenance to operate effectively. Responsibility for ongoing management rests with the asset owners, that is Council and the Lot owners respectively.



6 CONCLUSION

A water cycle management strategy has been prepared for the proposed residential subdivision of the C4 zoned land at 365 Marshall Mount Road, Marshall Mount, consisting of Lot 8 DP626078, and Lot 5 DP24143. The proposed strategy has been developed to meet the stormwater controls as specified in Wollongong City Council DCP.

Flooding behaviour of the site has been assessed to determine the level of risk to the proposed development and any likely impacts downstream that may result from the development. This assessment has determined that the site is generally removed from the floodplain with very little interaction proposed. A small portion of the flood fringe area associated with the top of a first order watercourse would be removed as a result of the proposed development. This generally results in a reduction in hazard and depth in the areas immediately downstream of the site. A flood planning area has been defined and the planning proposal has been shown to be consistent with the prescriptive controls in the DCP.

On-site detention has been proposed at the respective discharges of the site. A Drains model utilising WBNM hydrological procedures has been developed to identify concept outlet controls and structures to attenuate post-developed flows to pre-developed levels.

A WSUD treatment train has been proposed consisting of rainwater tanks, GPT and bioretention basin, to manage runoff water quality from the site. This has been assessed against the requirements in DCP Chapter E15. MUSIC modelling undertaken identifies that water quality within the site can effectively be managed within the proposed treatment in accordance with the required pollutant reduction targets.

APPENDIX **A**
FLOOD MAPS

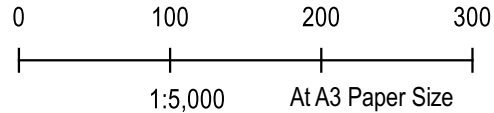
EXISTING 5 YEAR ARI FLOOD
EXTENT

Legend

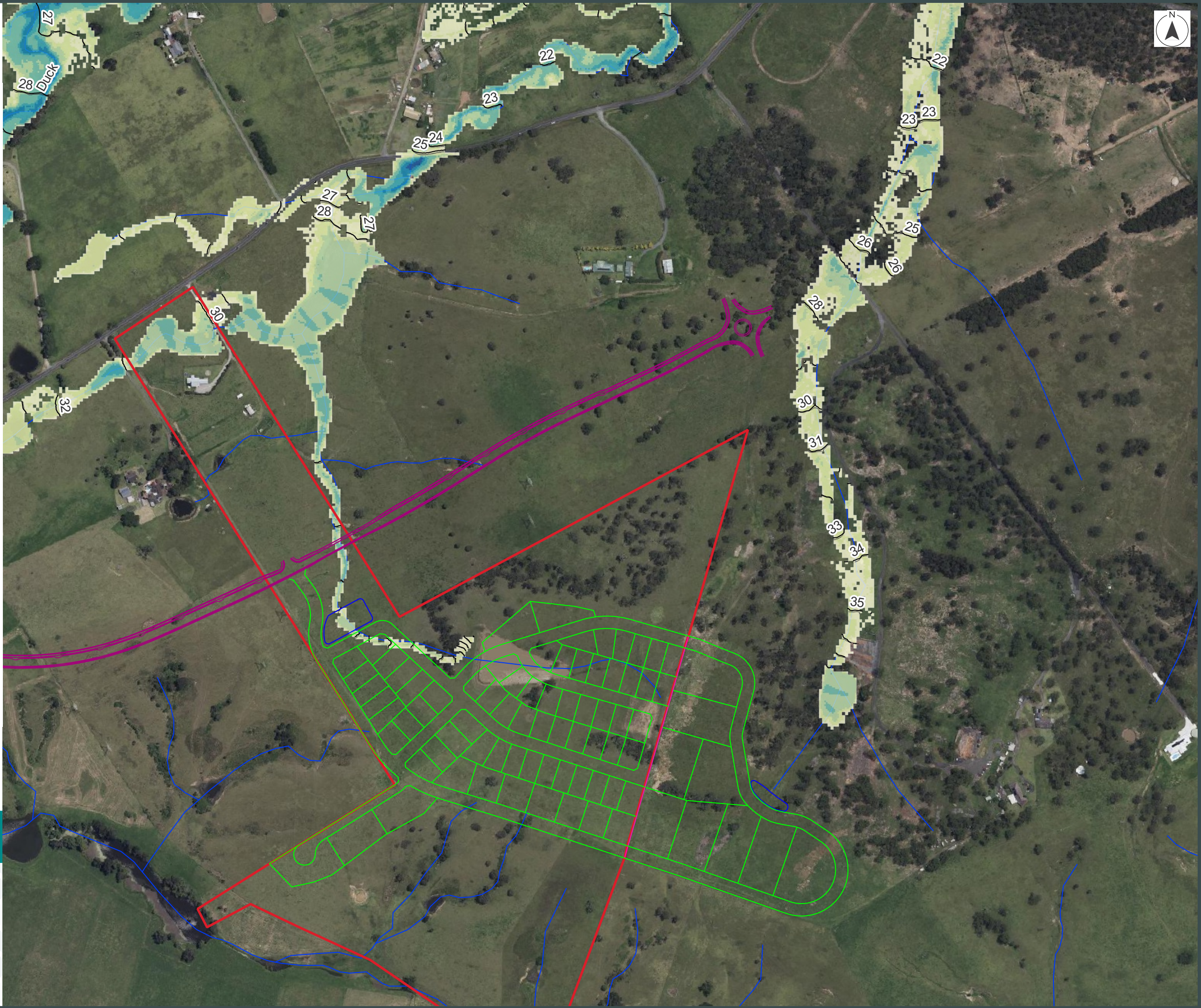
— Site Boundary
— Watercourse

Depth (m)

<= 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 4
> 4



MKR00156
REVISION 1
Apr 2024



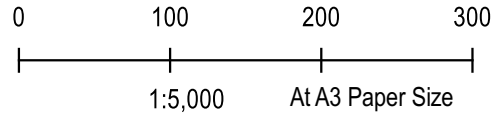
EXISTING 100 YEAR ARI FLOOD
EXTENT

Legend

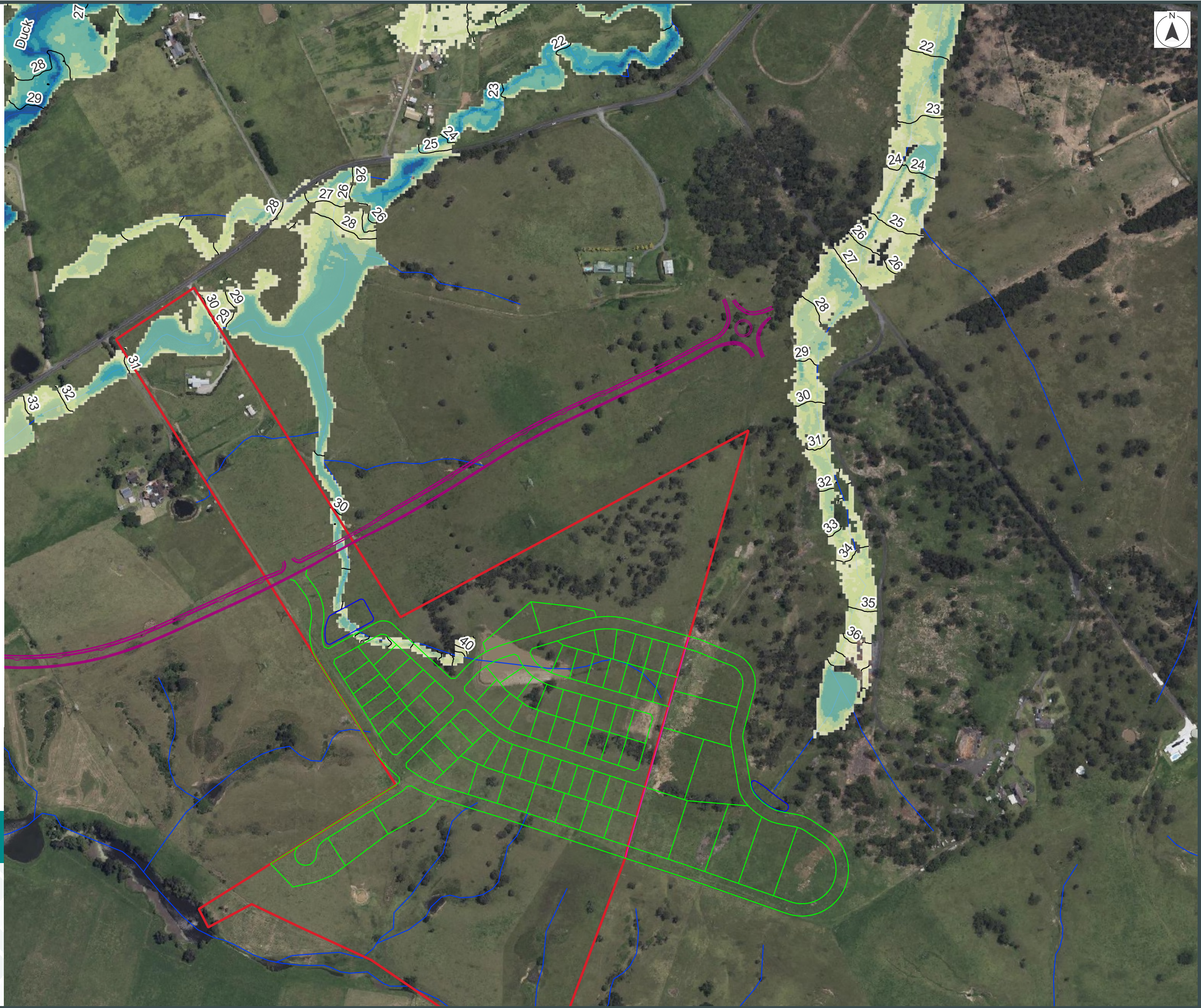
— Site Boundary
— Watercourse

Depth (m)

<= 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 4
> 4



MKR00156
REVISION 1
Apr 2024



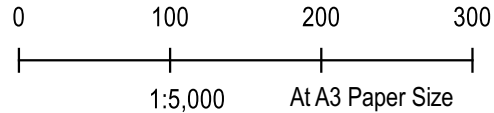
EXISTING PMF EXTENT

Legend

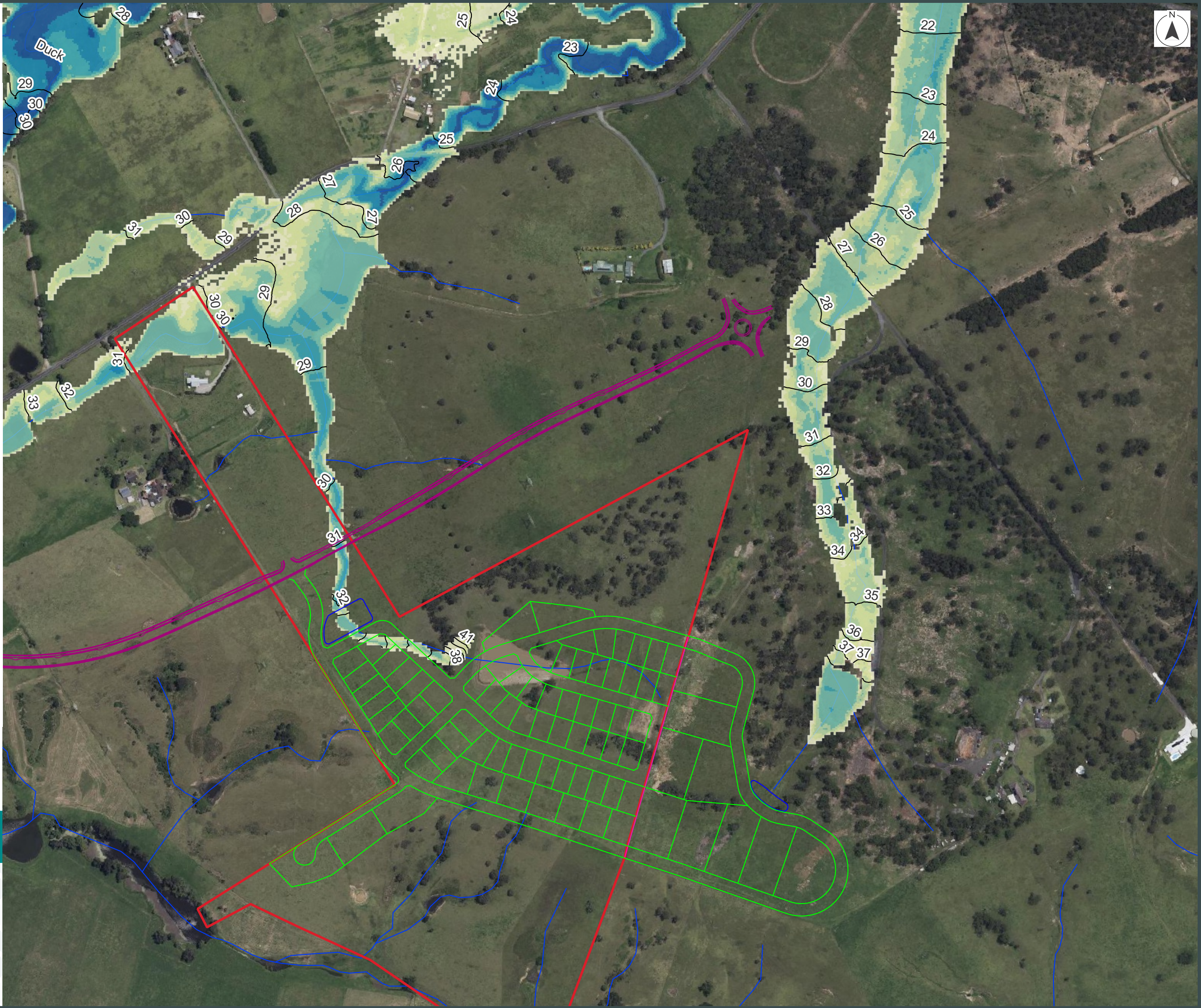
— Site Boundary
— Watercourse

Depth (m)

<= 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 4
> 4



MKR00156
REVISION 1
Apr 2024



EXISTING 5 YEAR ARI FLOOD
VELOCITY

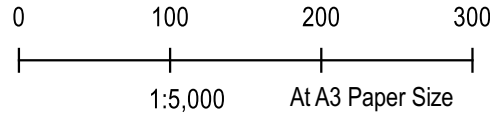
Legend

— Site Boundary
— Watercourse

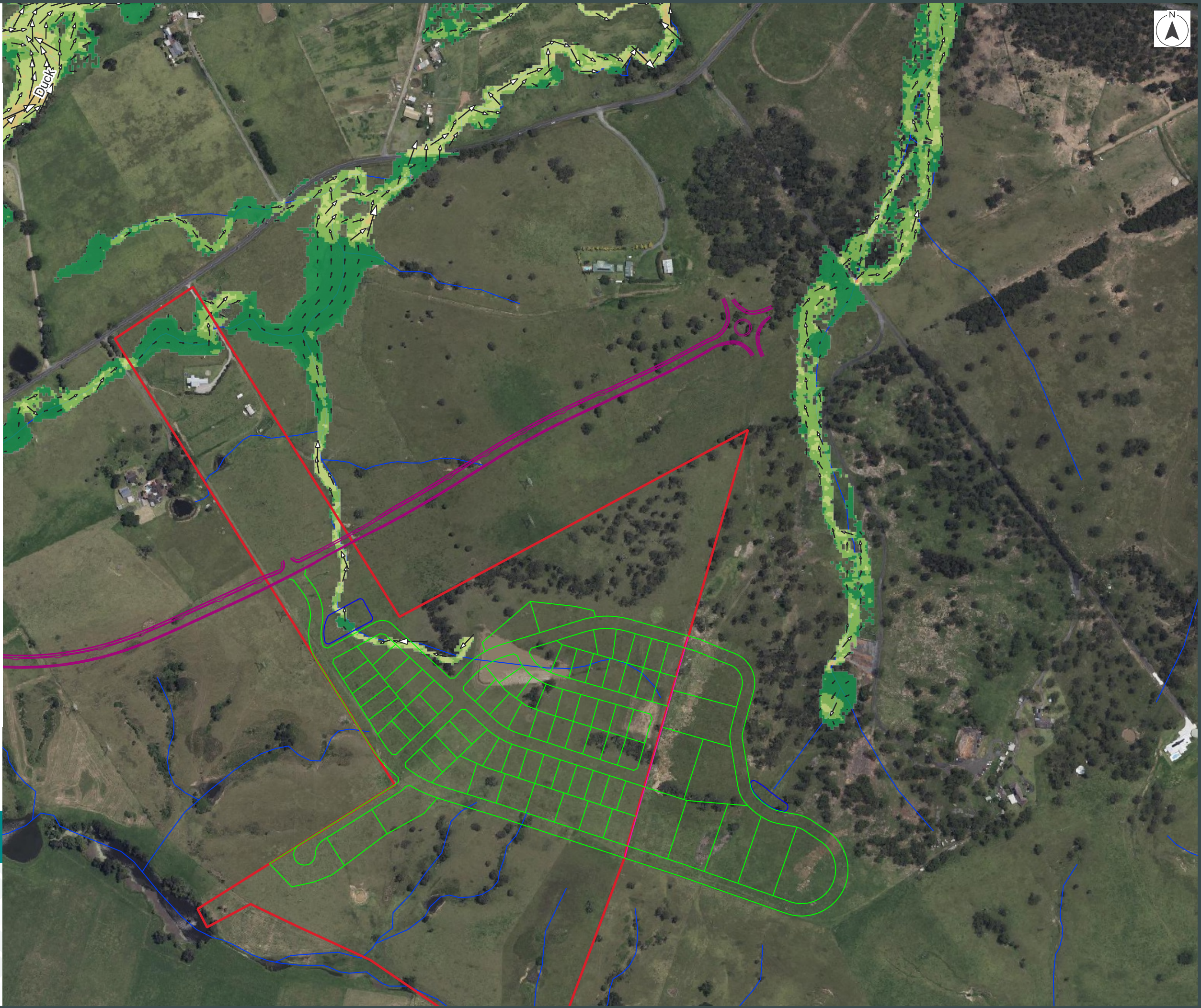
Velocity (m/s)

Band 1

<= 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
> 4



MKR00156
REVISION 1
Apr 2024



EXISTING 100 YEAR ARI FLOOD
VELOCITY

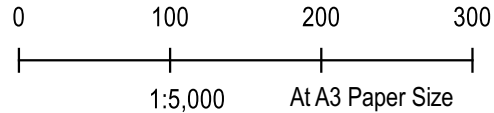
Legend

— Site Boundary
— Watercourse

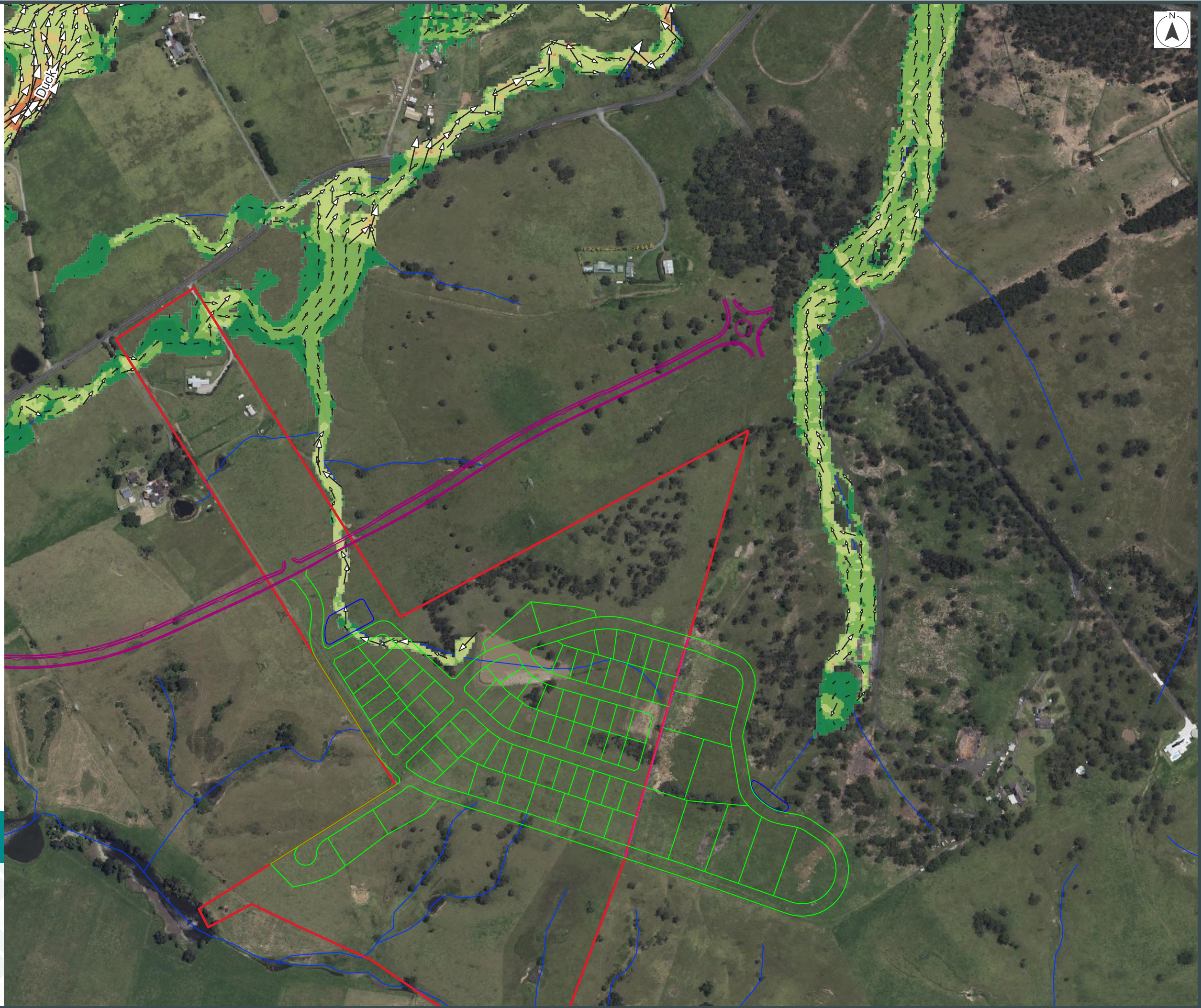
Velocity (m/s)

Band 1

<= 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
> 4



MKR00156
REVISION 1
Apr 2024



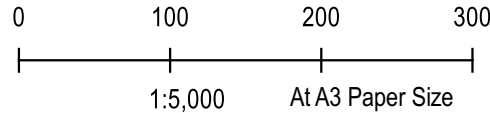
EXISTING PMF VELOCITY

Legend

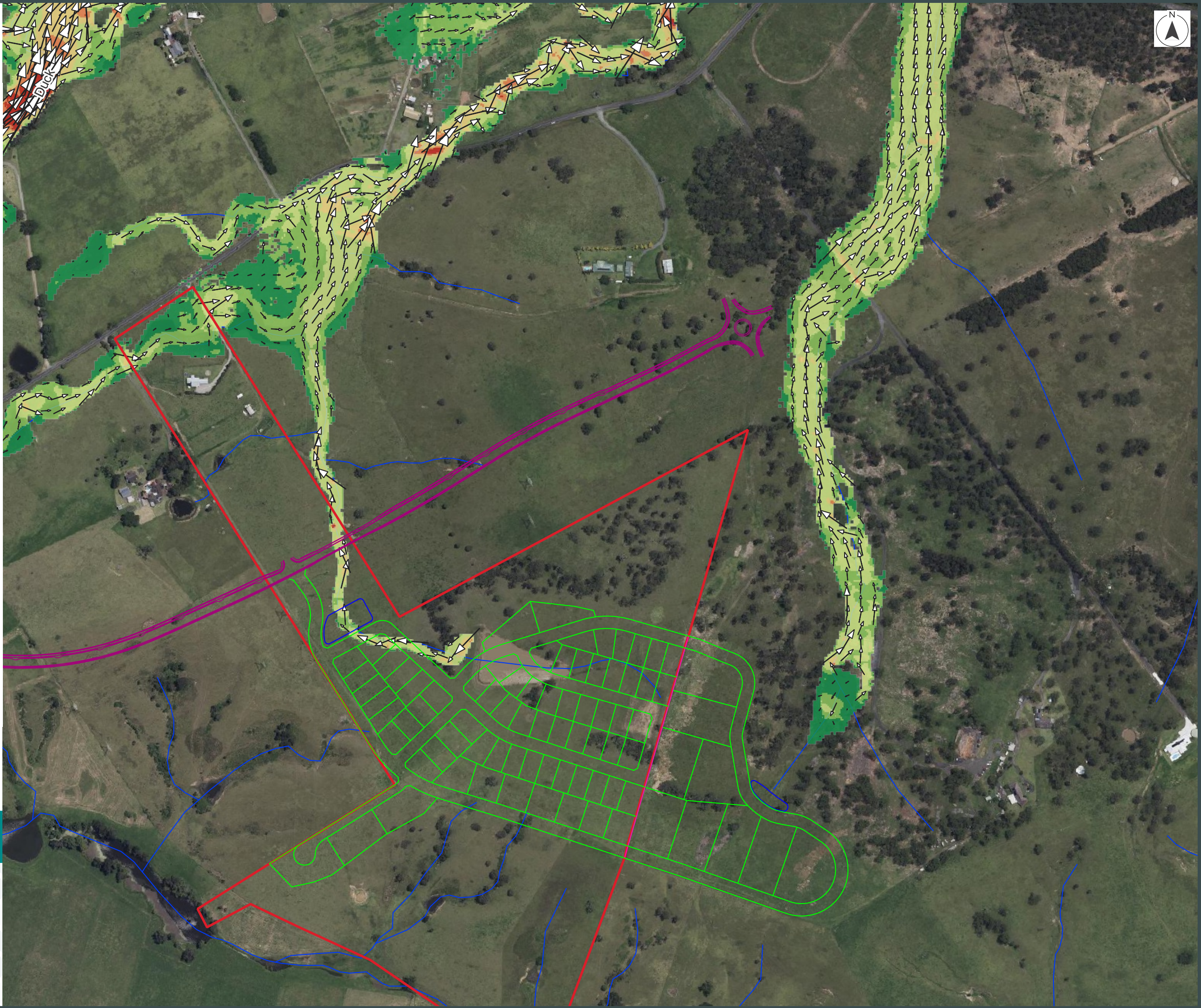
— Site Boundary
— Watercourse

Velocity (m/s)
Band 1

<= 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
> 4

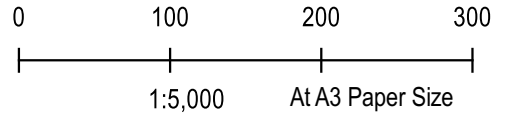


MKR00156
REVISION 1
Apr 2024

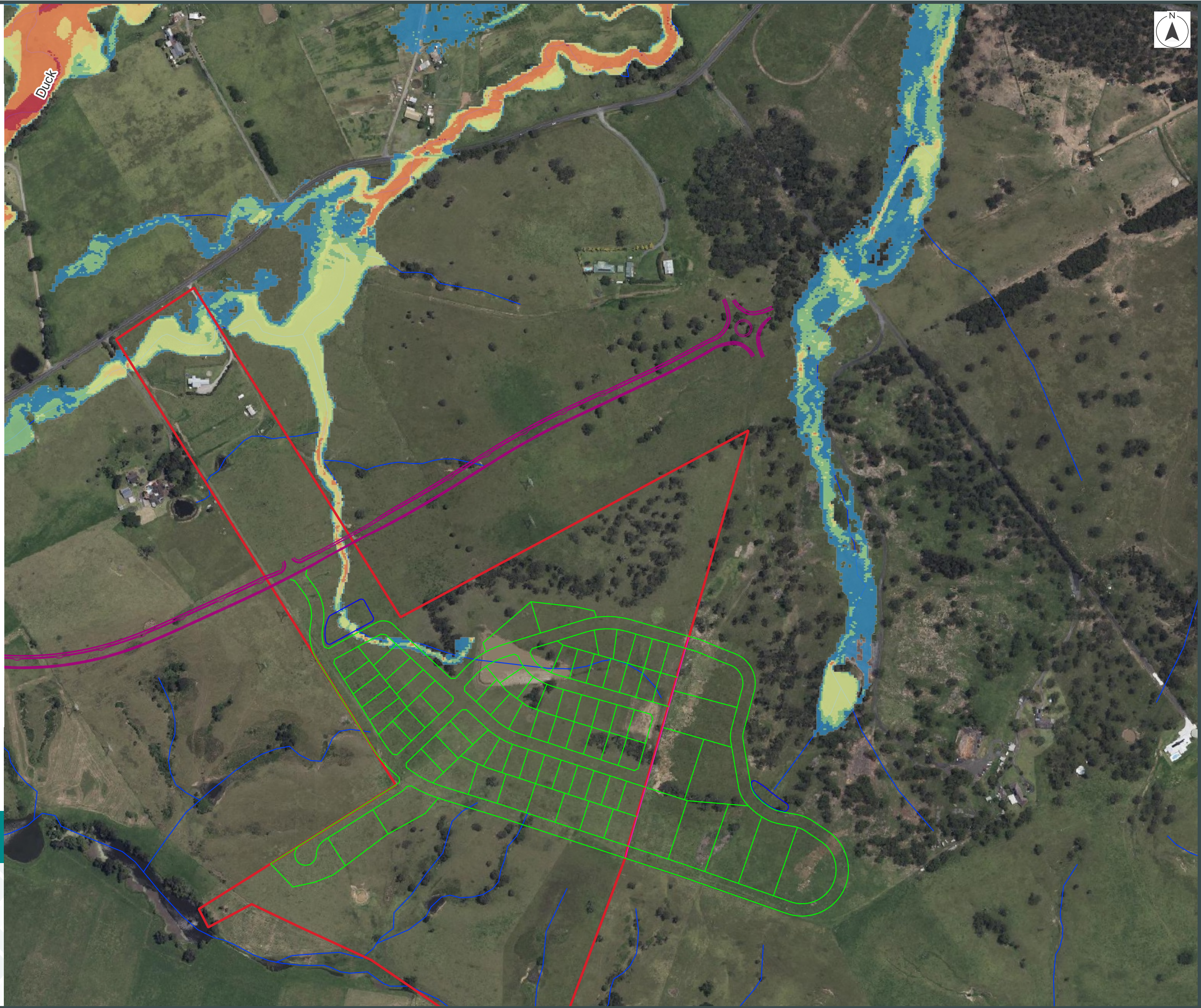


EXISTING 100 YEAR ARI FLOOD HAZARD

- Legend**
- Site Boundary
 - Watercourse
 - Flood Hazard
 - H1 - Generally safe for vehicles, people and buildings
 - H2 - Unsafe for small vehicles
 - H3 - Unsafe for vehicles, children and the elderly
 - H4 - Unsafe for vehicles and people
 - H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure
 - H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure

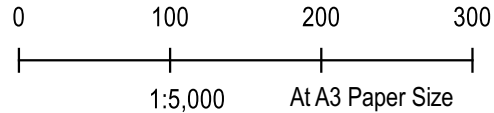


MKR00156
REVISION 1
Apr 2024

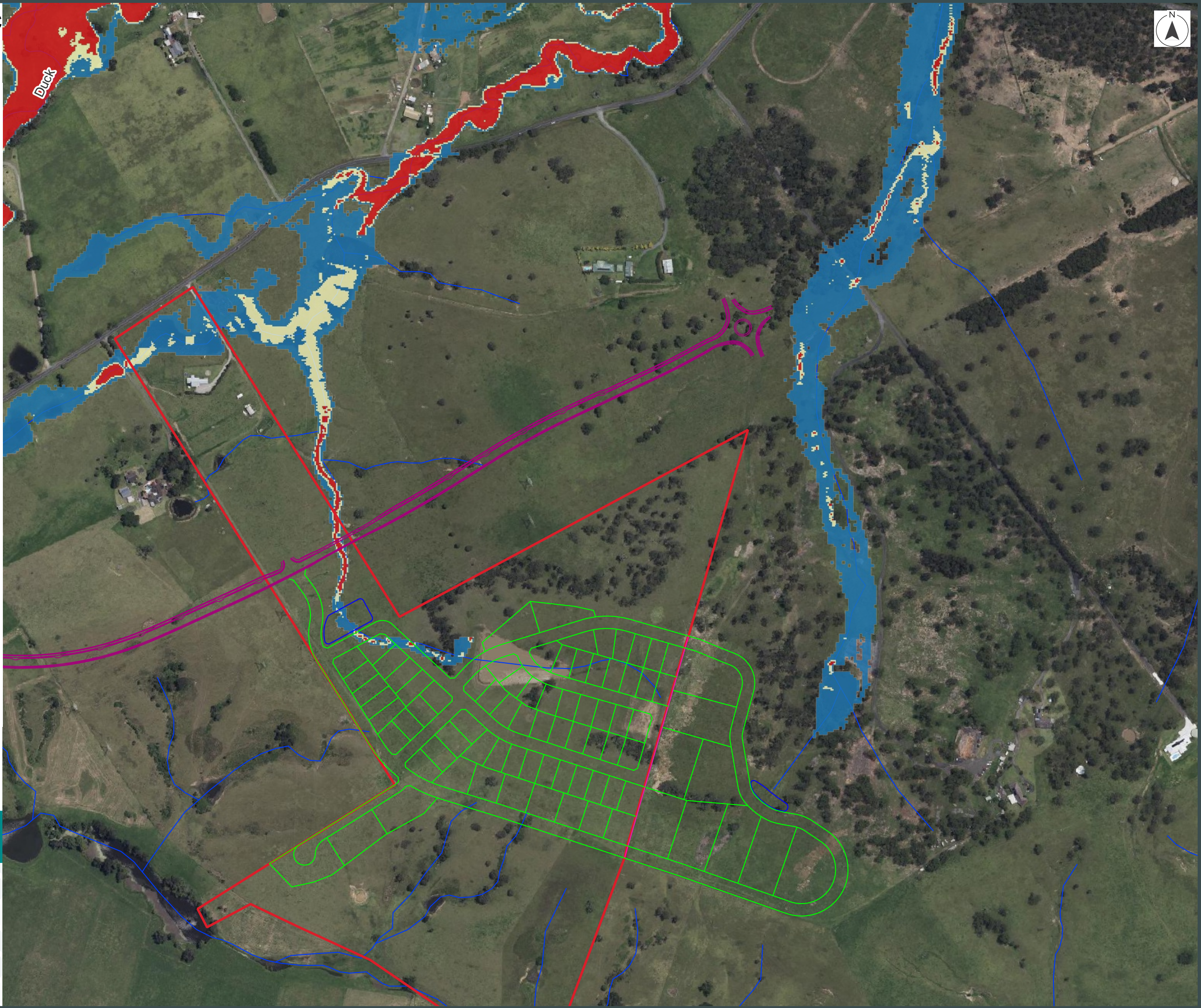


EXISTING 100 YEAR HYDRAULIC
CATEGORISATION

- Legend
- Site Boundary
 - Watercourse
 - Hydraulic Categorisation
 - Flood Fringe
 - Flood Storage
 - Floodway

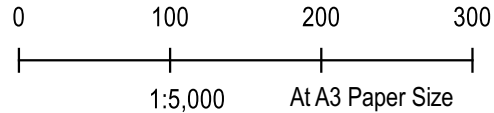


MKR00156
REVISION 1
Apr 2024

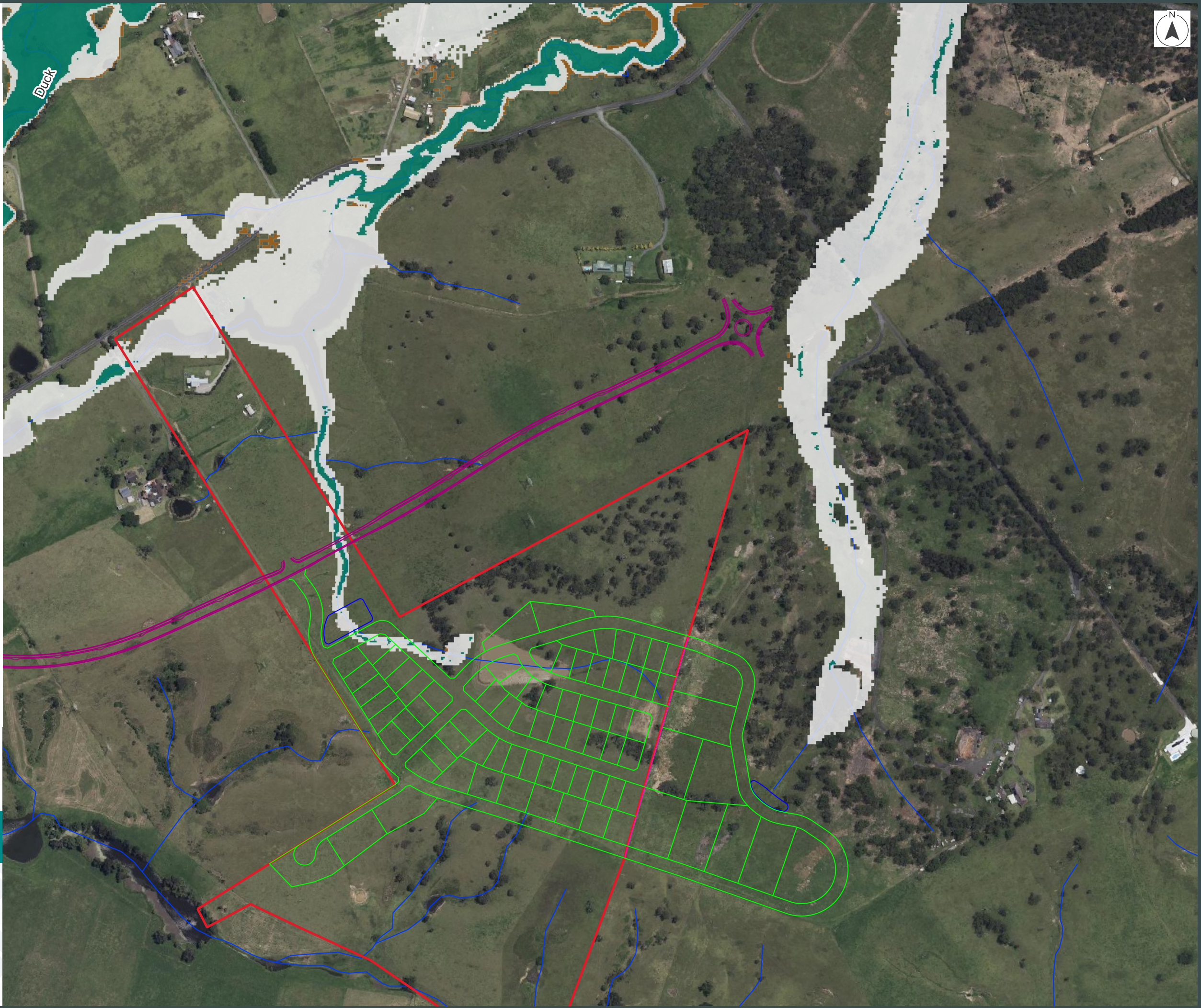


EXISTING FLOOD RISK
PRECINCT

- Legend
- Site Boundary
 - Watercourse
 - Flood Risk Precinct
 - Low
 - Medium
 - High



MKR00156
REVISION 1
Apr 2024



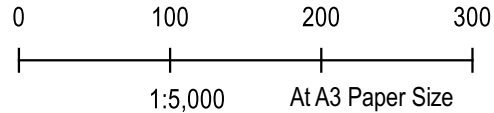
PROPOSED 5 YEAR ARI FLOOD
EXTENT

Legend

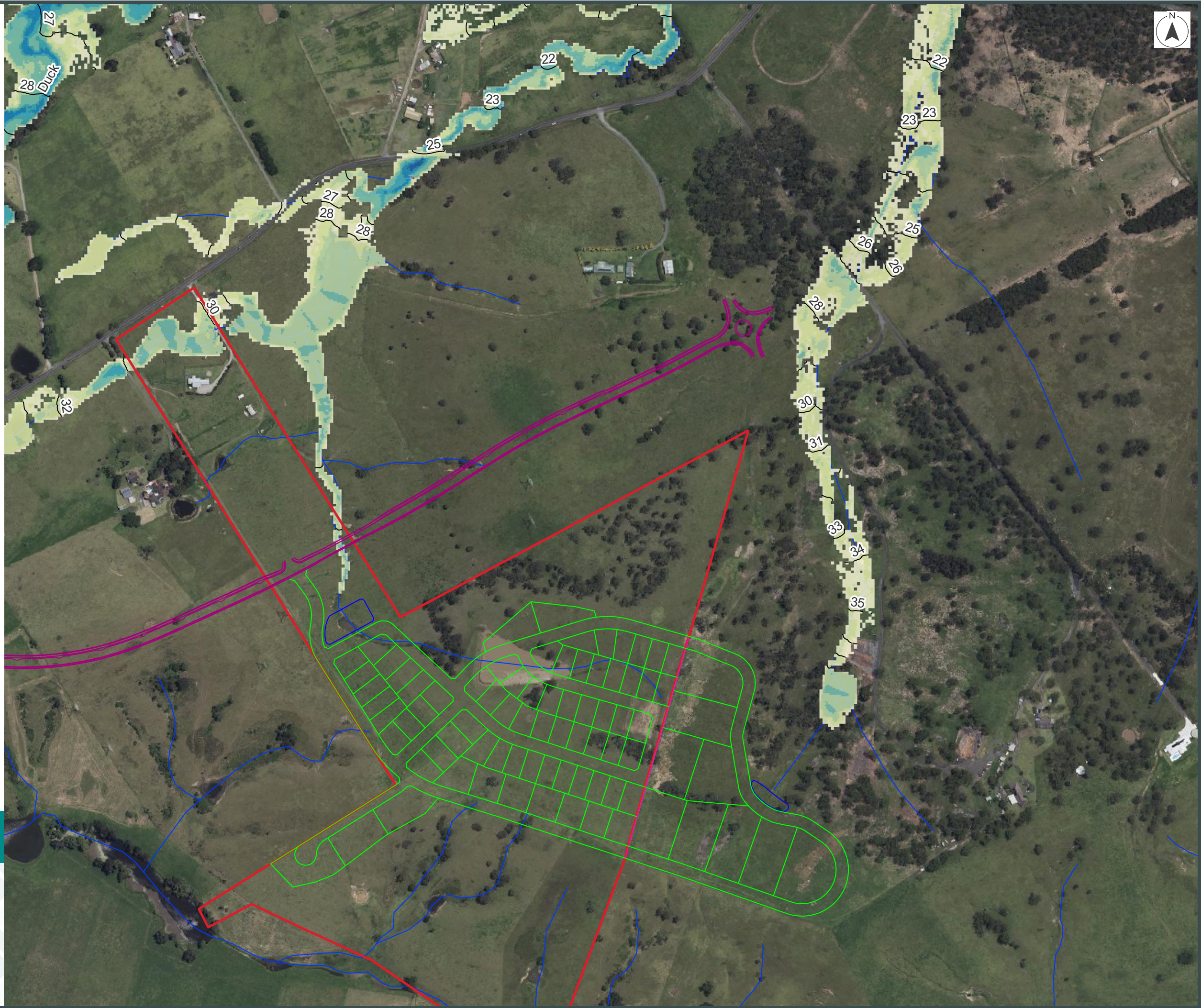
— Site Boundary
— Watercourse

Depth (m)

<= 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 4
> 4



MKR00156
REVISION 1
Apr 2024



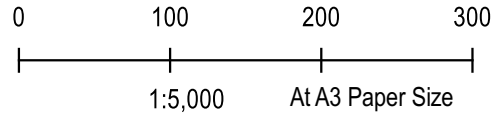
PROPOSED 100 YEAR ARI
FLOOD EXTENT

Legend

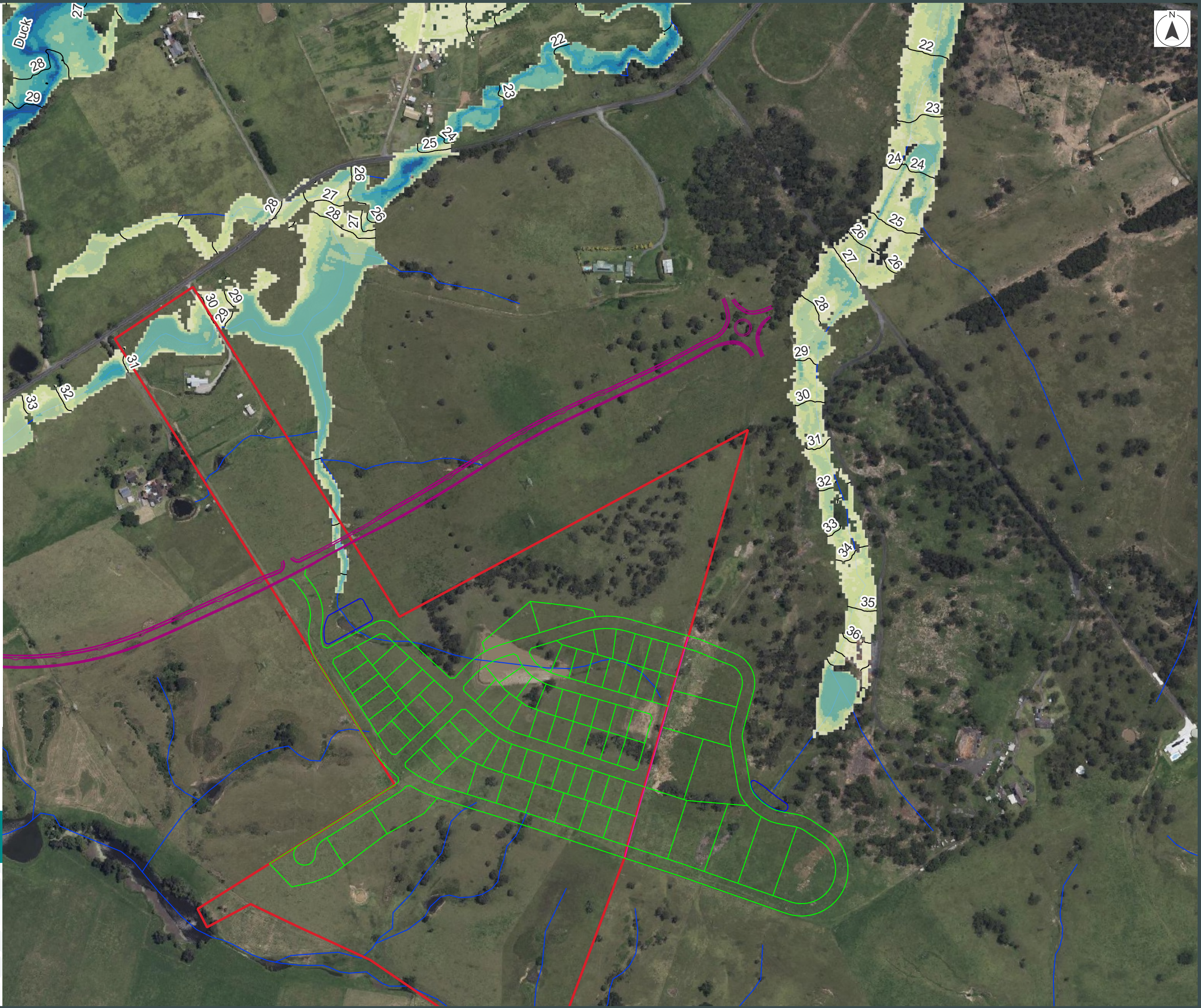
— Site Boundary
— Watercourse

Depth (m)

<= 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 4
> 4



MKR00156
REVISION 1
Apr 2024



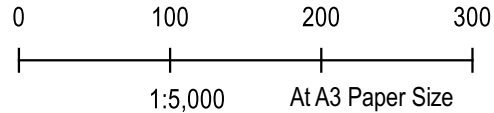
PROPOSED PMF EXTENT

Legend

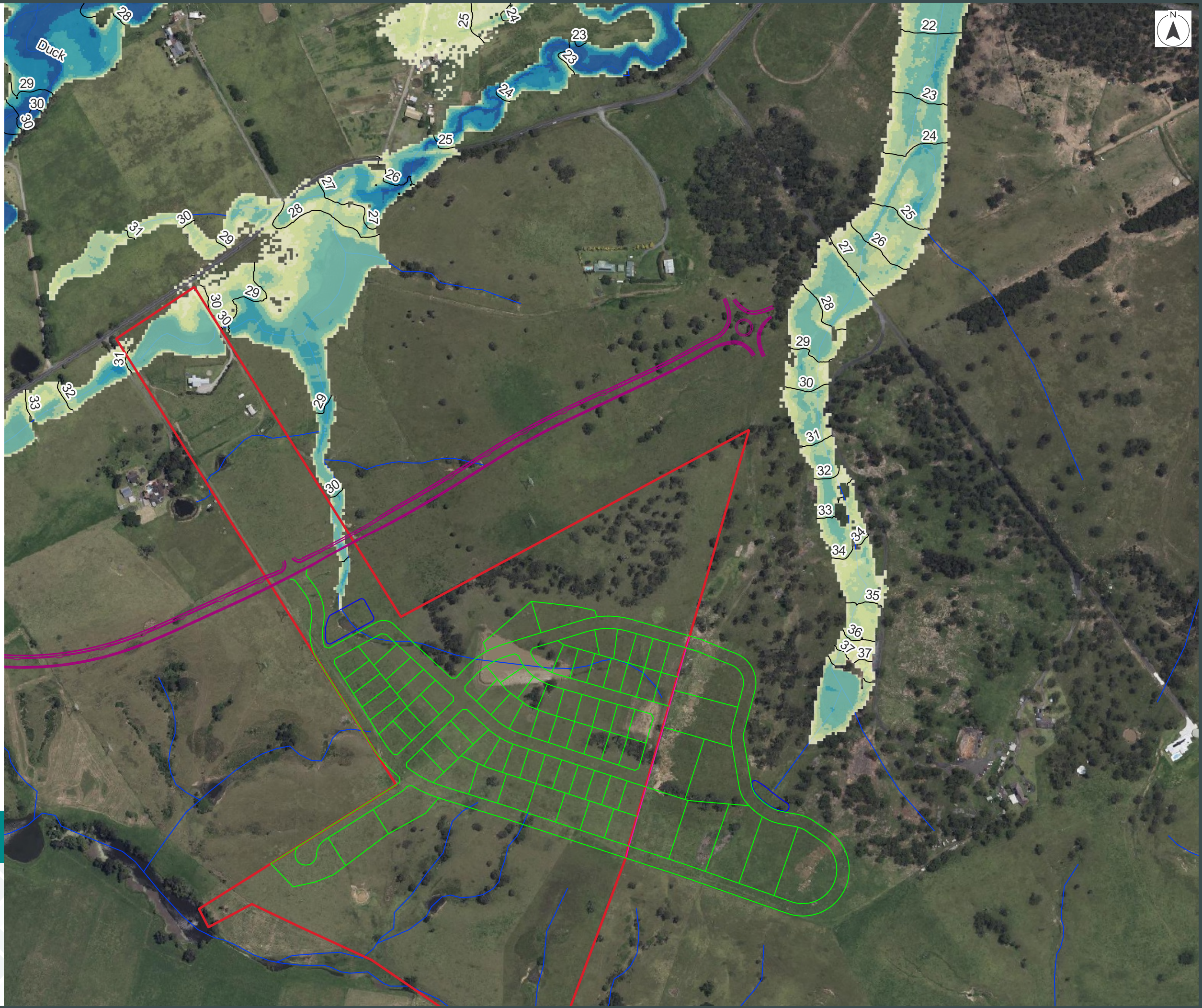
— Site Boundary
— Watercourse

Depth (m)

<= 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 4
> 4



MKR00156
REVISION 1
Apr 2024



PROPOSED 5 YEAR ARI FLOOD
VELOCITY

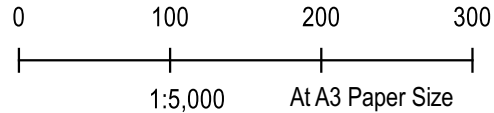
Legend

— Site Boundary
— Watercourse

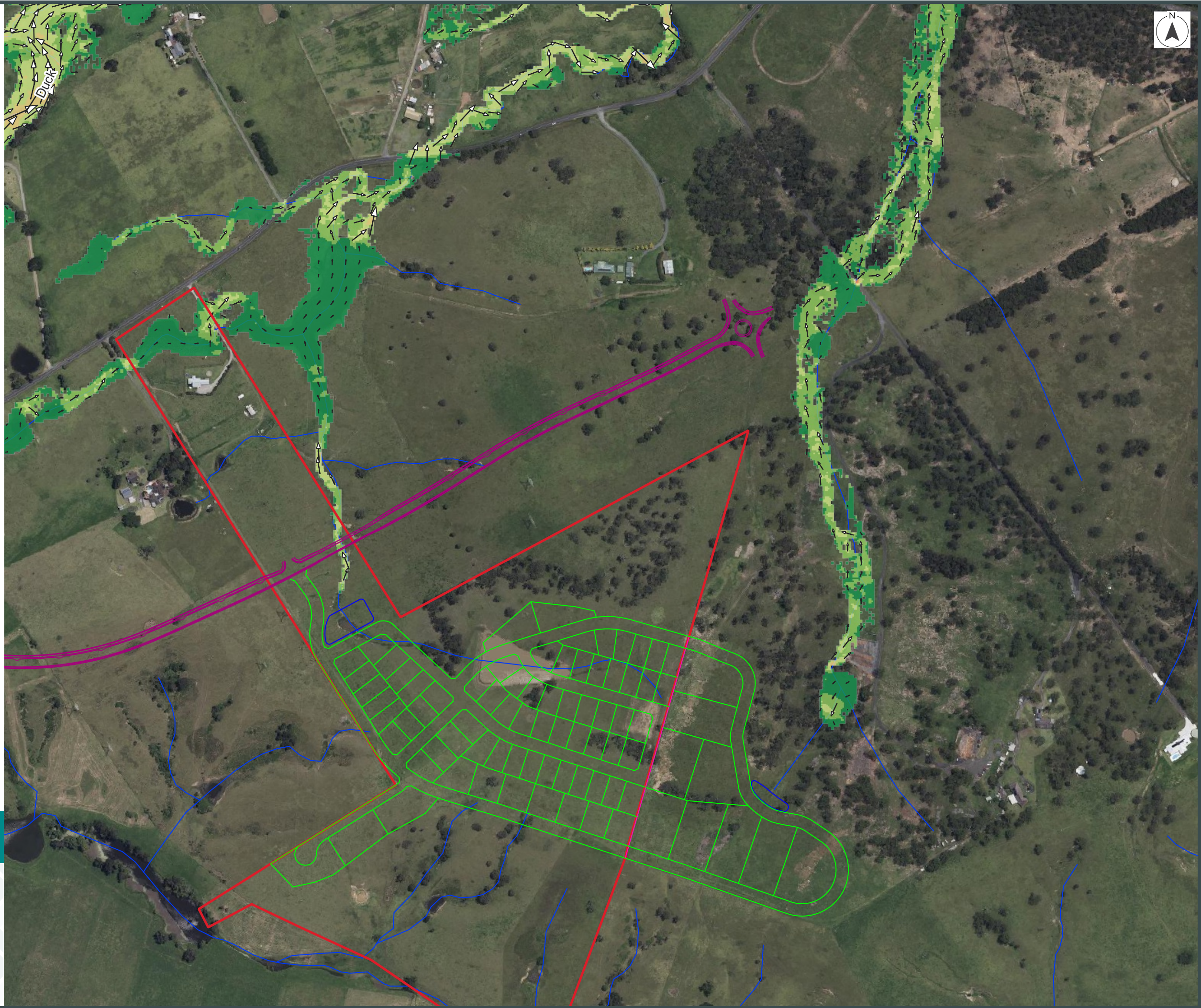
Velocity (m/s)

Band 1

<= 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
> 4



MKR00156
REVISION 1
Apr 2024



PROPOSED 100 YEAR ARI
FLOOD VELOCITY

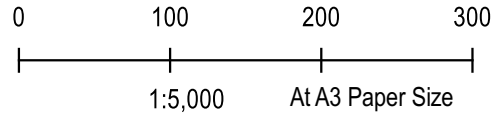
Legend

— Site Boundary
— Watercourse

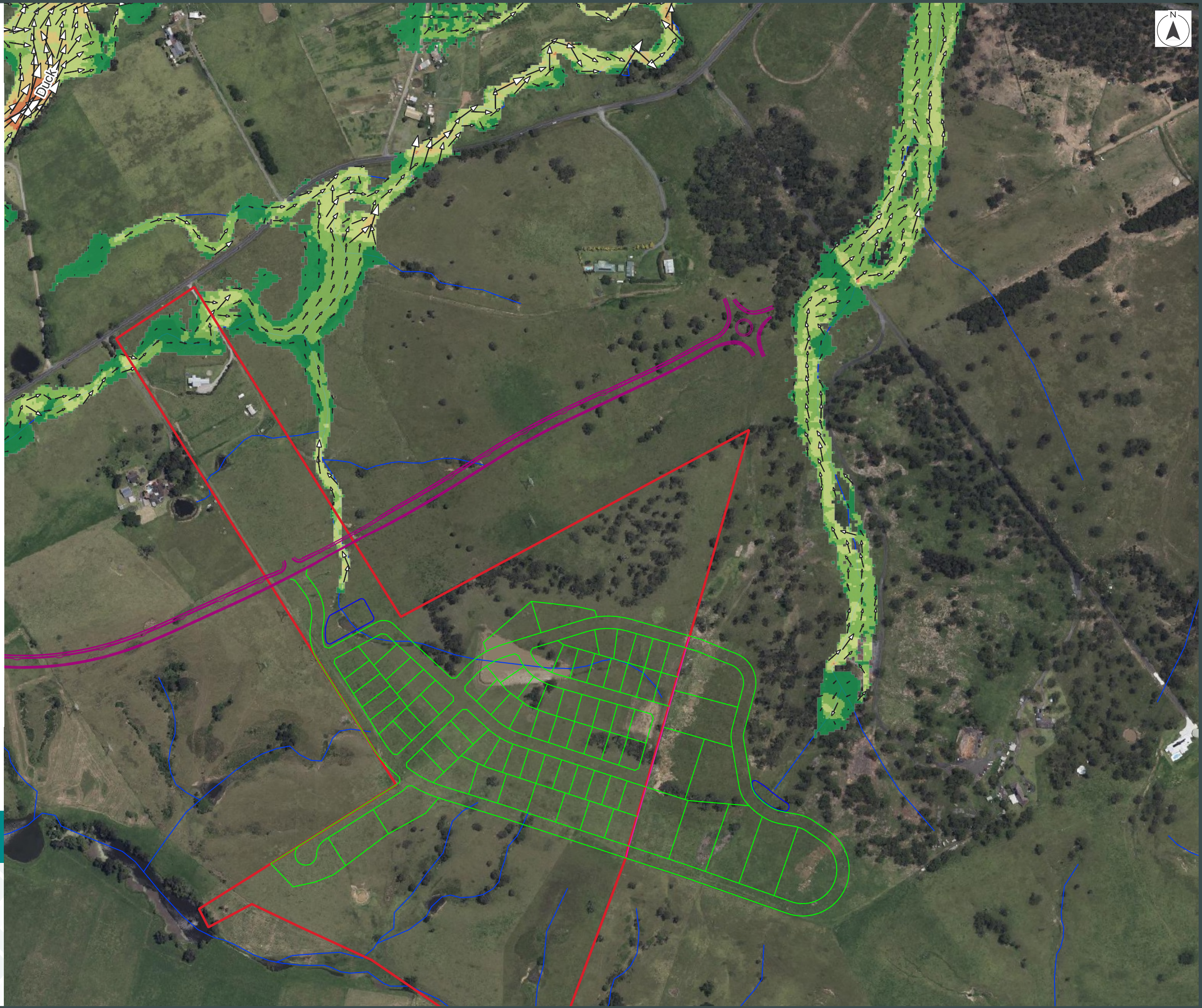
Velocity (m/s)

Band 1

<= 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
> 4



MKR00156
REVISION 1
Apr 2024



PROPOSED PMF VELOCITY

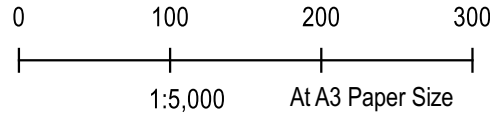
Legend

— Site Boundary
— Watercourse

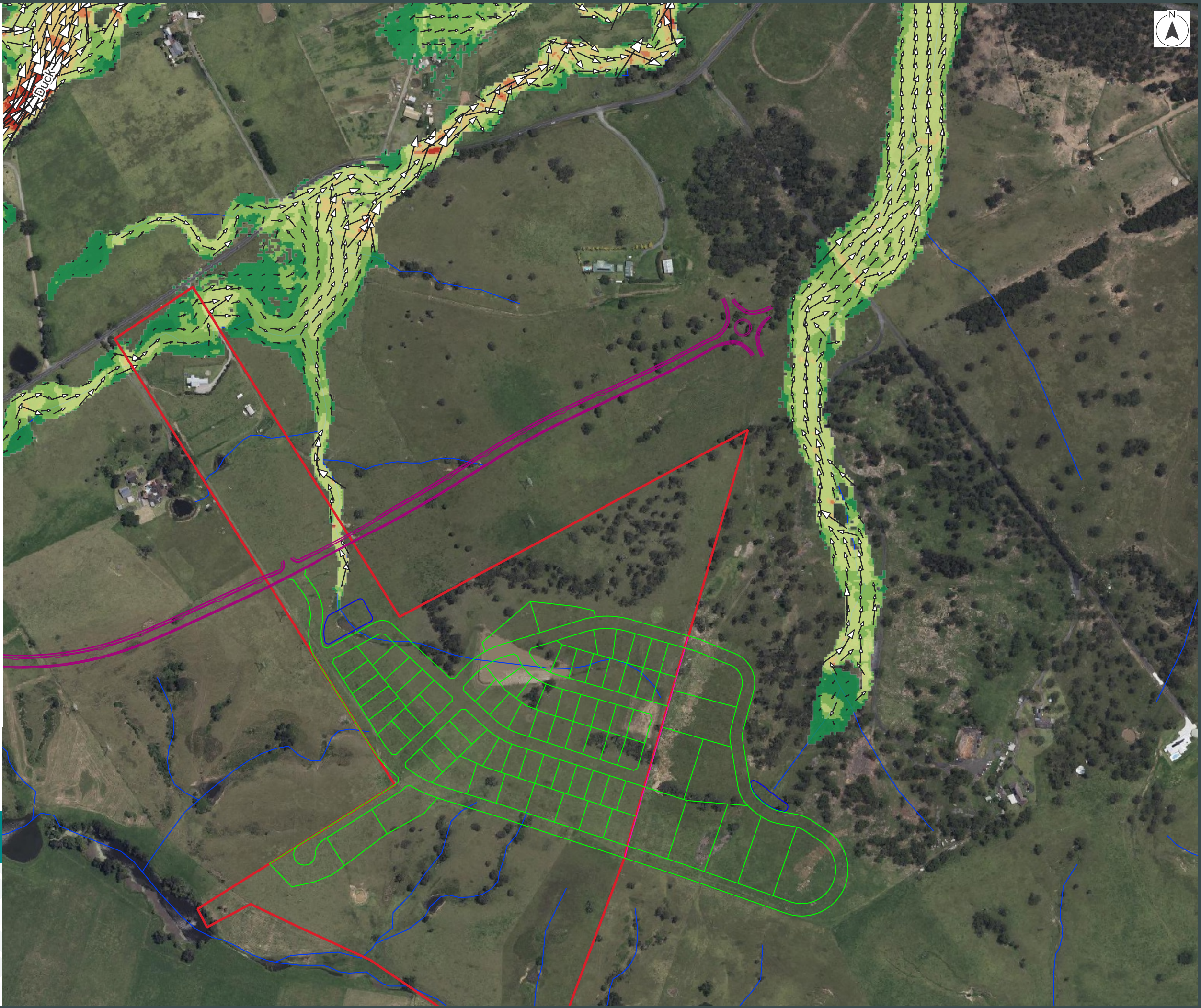
Velocity (m/s)

Band 1

<= 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
> 4



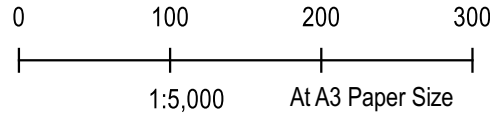
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REVISION 1
Apr 2024



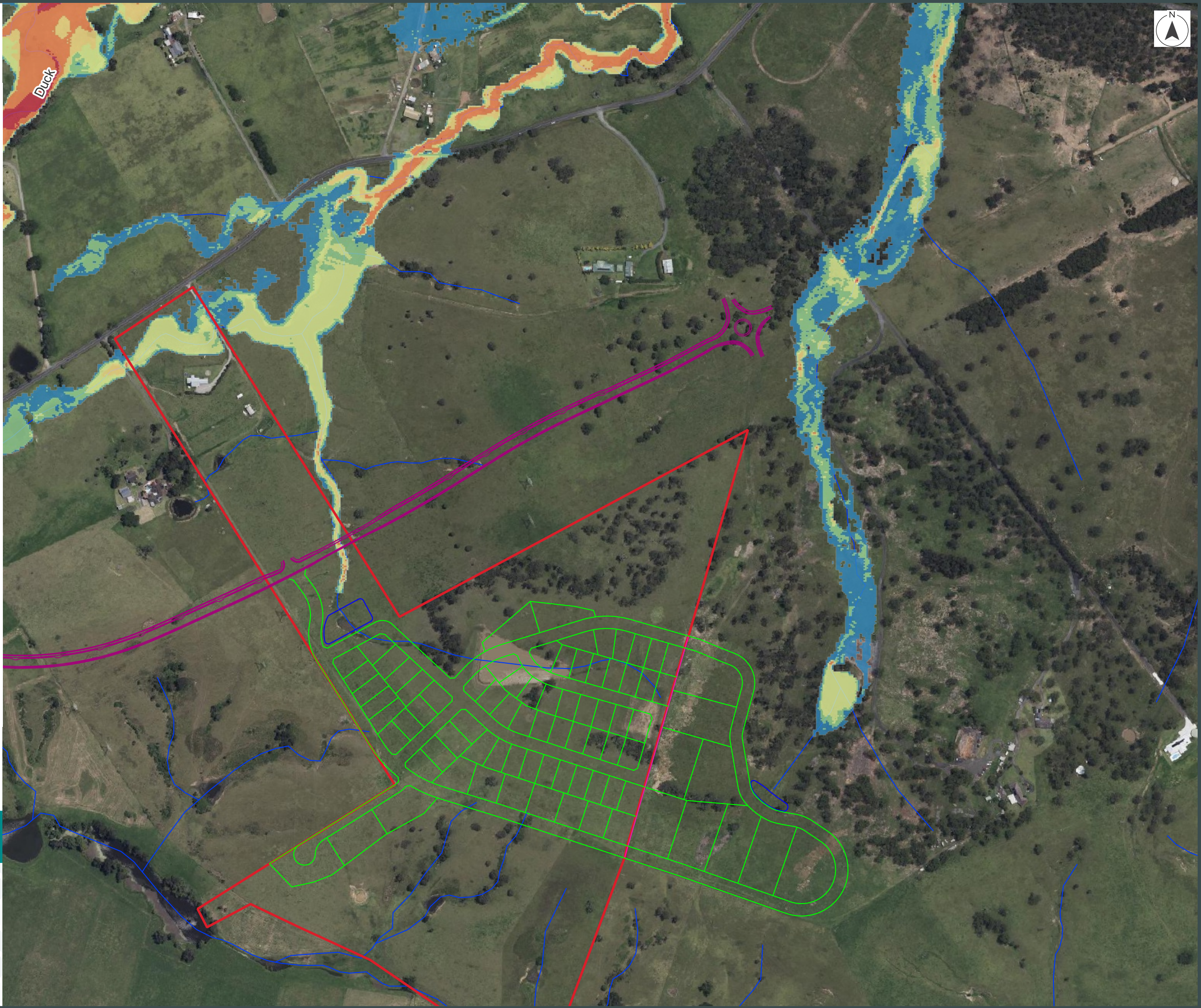
PROPOSED 100 YEAR ARI
FLOOD HAZARD.

Legend

- Site Boundary
- Watercourse
- Flood Hazard
 - H1 - Generally safe for vehicles, people and buildings
 - H2 - Unsafe for small vehicles
 - H3 - Unsafe for vehicles, children and the elderly
 - H4 - Unsafe for vehicles and people
 - H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure
 - H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure

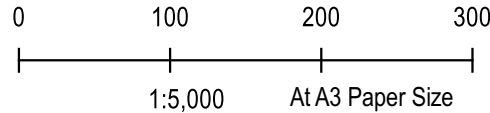


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REVISION 1
Apr 2024

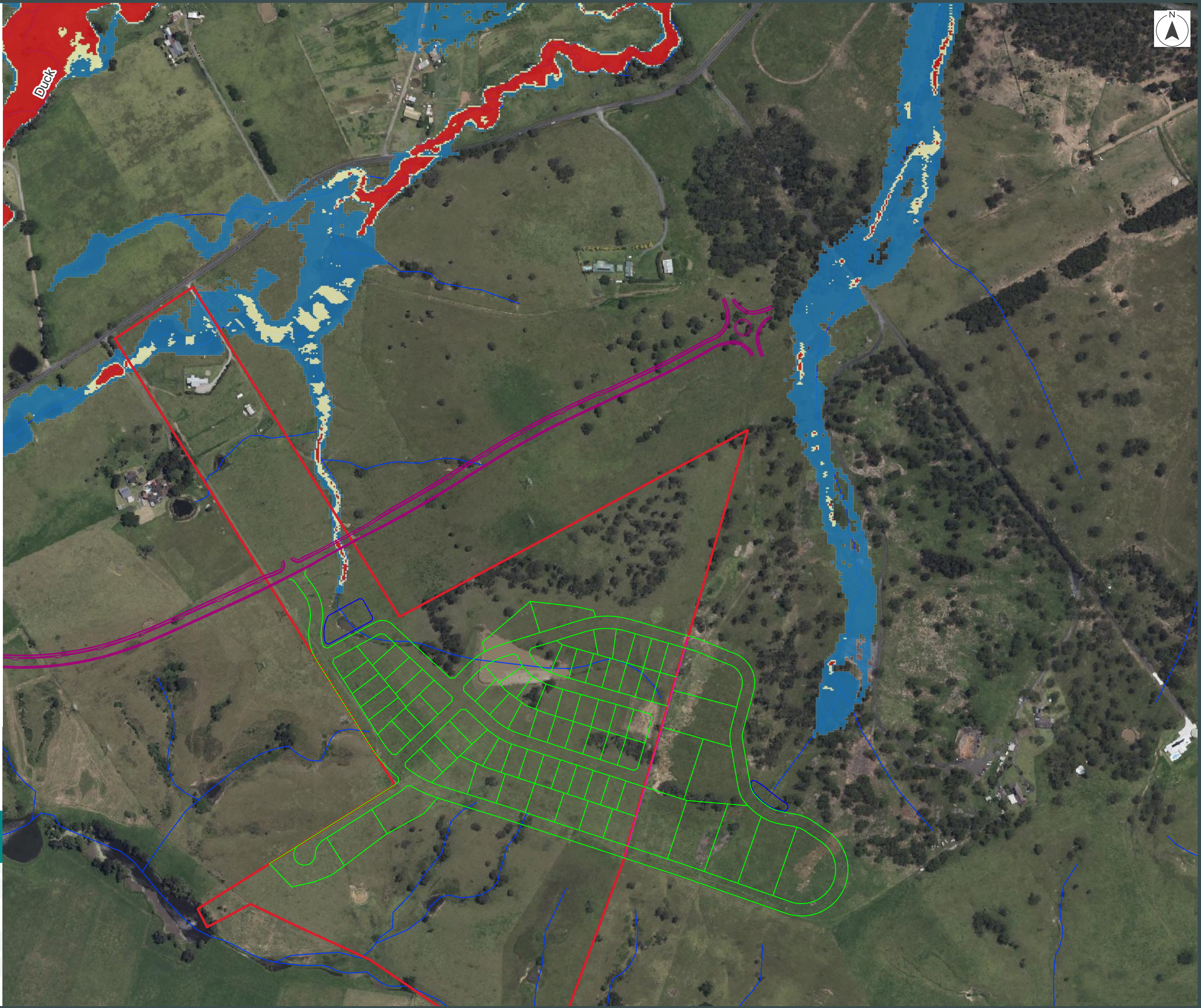


PROPOSED 100 YEAR ARI
HYDRAULIC CATEGORISATION

- Legend
- Site Boundary
 - Watercourse
 - Hydraulic Categorisation
 - Flood Fringe
 - Flood Storage
 - Floodway

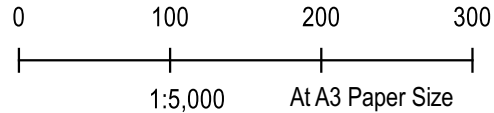


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Apr 2024

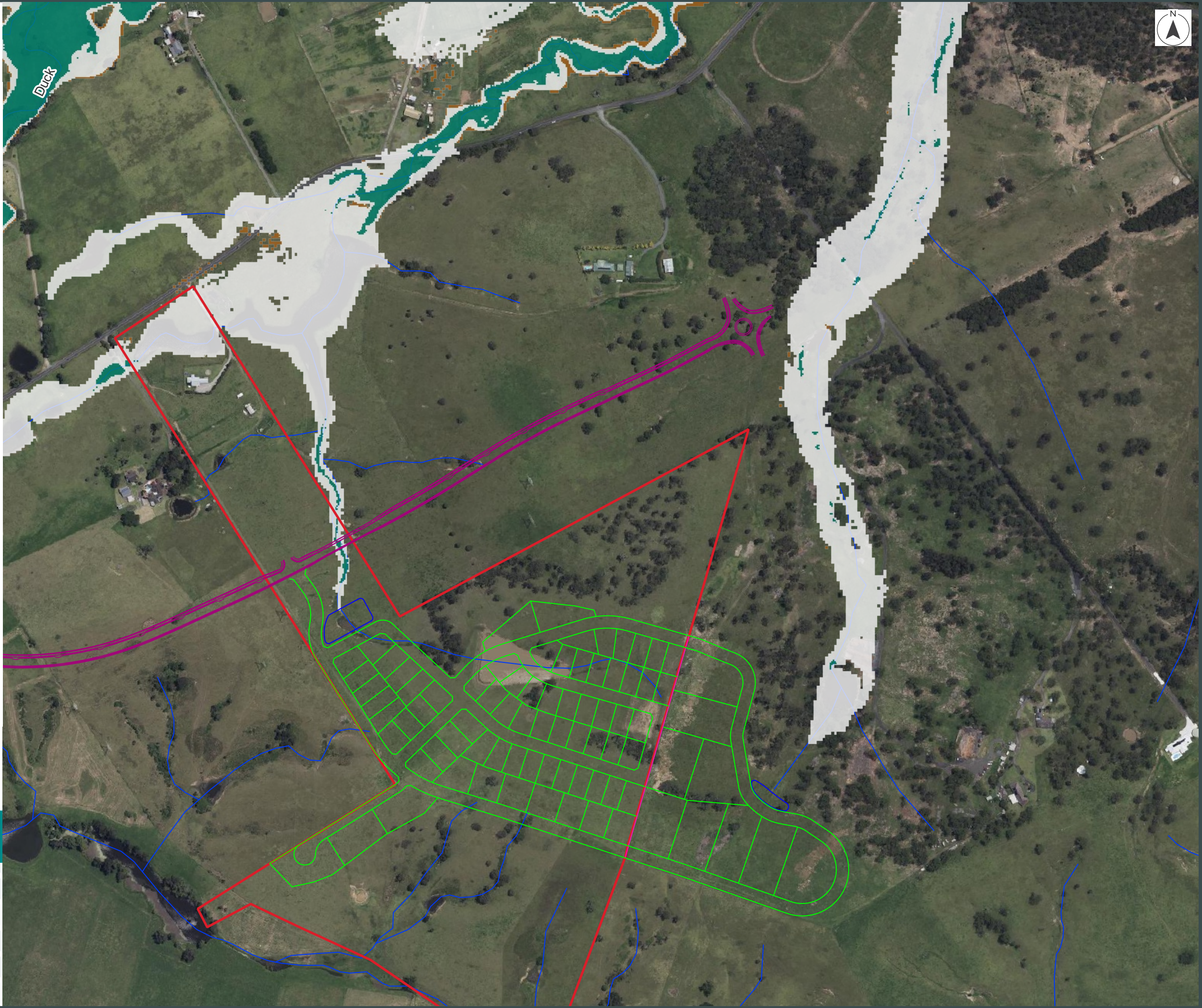


PROPOSED FLOOD RISK
PRECINCT

- Legend
- Site Boundary
 - Watercourse
 - Flood Risk Precinct
 - Low
 - Medium
 - High

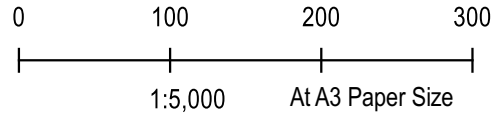


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REVISION 1
Apr 2024

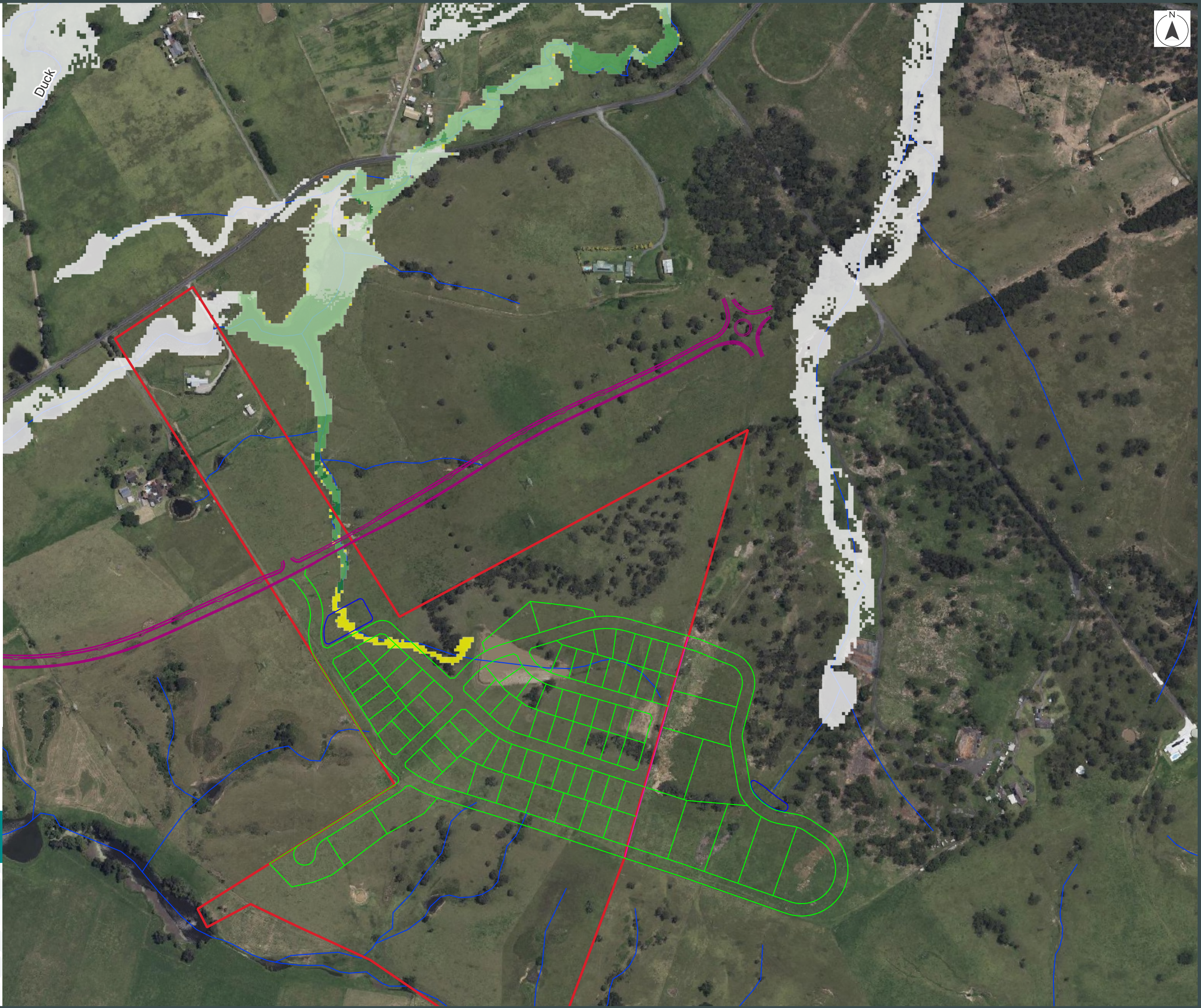


CHANGE IN 5 YEAR ARI WATER LEVEL

- Legend**
- Site Boundary
 - Watercourse
 - Change in Water Level (m)
 - No Longer Flooded
 - <=-0.1
 - 0.1 - -0.05
 - 0.05 - -0.02
 - 0.02 - -0.01
 - 0.01 - 0.01
 - 0.01 - 0.02
 - 0.02 - 0.05
 - 0.05 - 0.1
 - >0.1
 - Newly Flooded

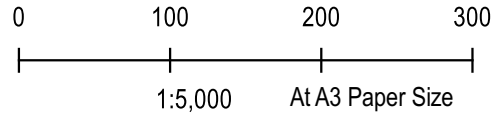


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Apr 2024

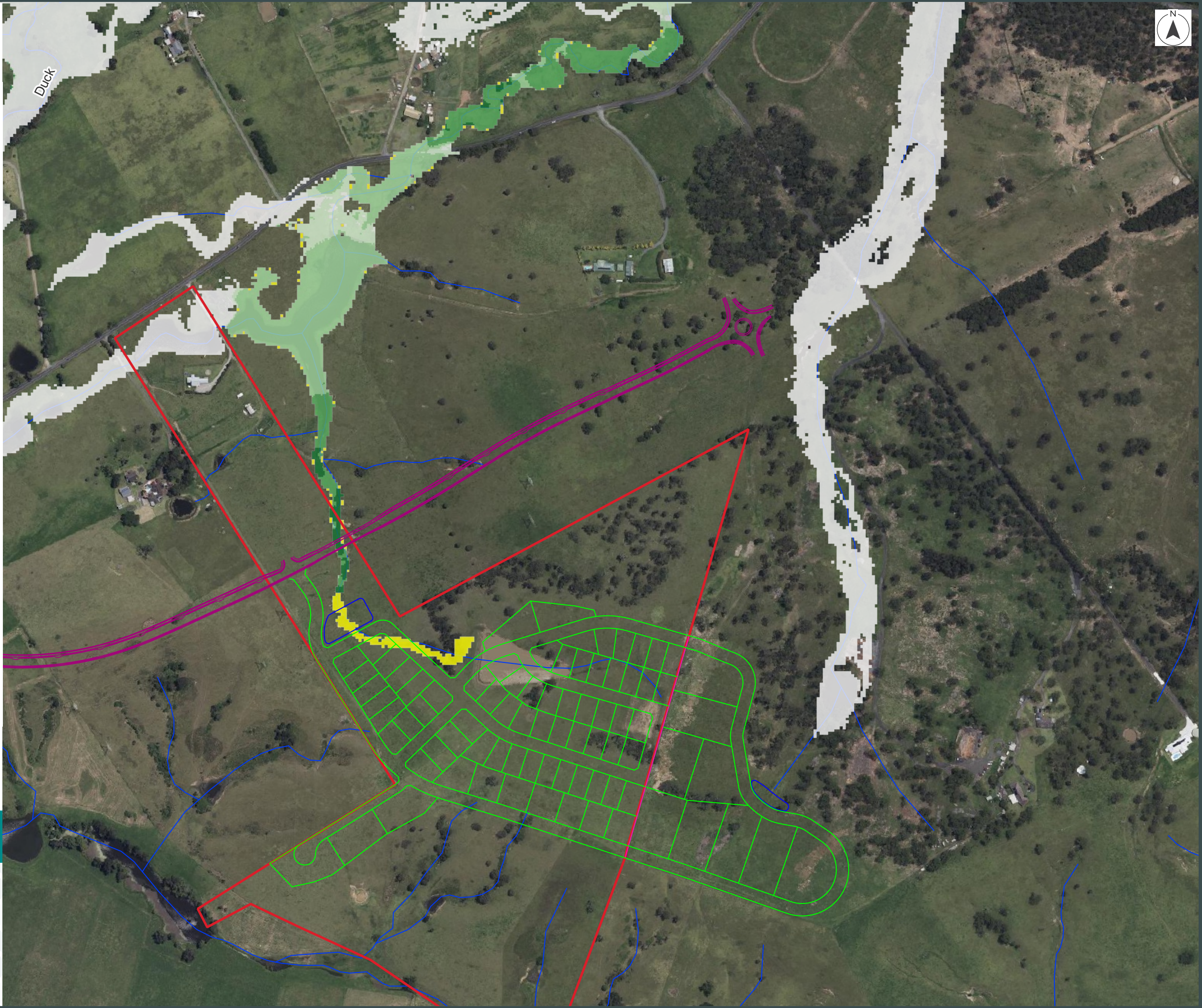


CHANGE IN 100 YEAR ARI
WATER LEVEL

- Legend**
- Site Boundary
 - Watercourse
 - Change in Water Level (m)
 - No Longer Flooded
 - <=-0.1
 - 0.1 - -0.05
 - 0.05 - -0.02
 - 0.02 - -0.01
 - 0.01 - 0.01
 - 0.01 - 0.02
 - 0.02 - 0.05
 - 0.05 - 0.1
 - >0.1
 - Newly Flooded

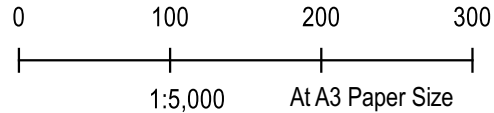


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Apr 2024

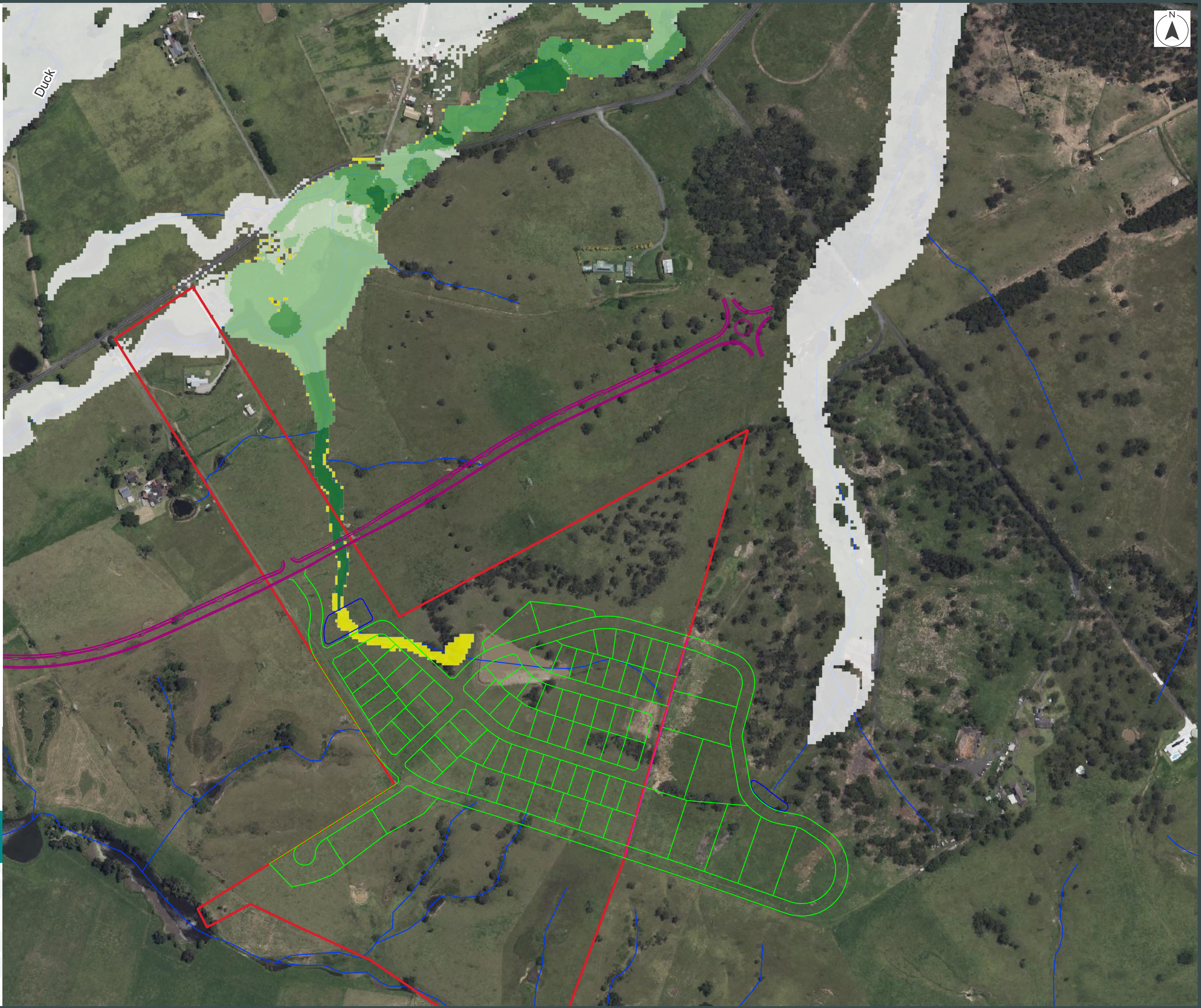


CHANGE IN PMF LEVEL

- Legend**
- Site Boundary
 - Watercourse
 - Change in Water Level (m)
 - No Longer Flooded
 - ≤ -0.1
 - 0.1 - -0.05
 - 0.05 - -0.02
 - 0.02 - -0.01
 - 0.01 - 0.01
 - 0.01 - 0.02
 - 0.02 - 0.05
 - 0.05 - 0.1
 - >0.1
 - Newly Flooded



MKR00156
REVISION 1
Apr 2024

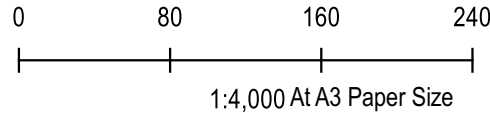


APPENDIX **B**
OSD CATCHMENTS

Pre-Development OSD
Catchments

Legend

- Existing Catchments
- Site Boundary
- Discharge Location
- Future Road Connection

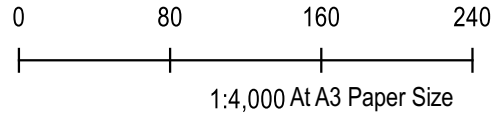


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REVISION 1
Apr 2024



Post-Development OSD
Catchments

- Legend**
- Existing Catchments
 - Site Boundary
 - Discharge Location
 - Future Road Connection
 - Proposed Layout



MKR00156
REVISION 1
Apr 2024



Office Locations

Maker ENG
Wollongong Office
Level 3, 280 Keira Street
Wollongong NSW 2500
P: 02 4228 4401

Maker ENG VIC
Torquay Office
4/110 Geelong Road
Torquay VIC 3228

www.makereng.com.au

Management Systems

Quality and safety are extremely important to Maker ENG and as such we are certified to the following Australian Standards:

- ISO 9001:2015 Quality Management Systems
- ISO 45001:2018 Occupational Health and Safety Management Systems
- ISO 14001:2015 Environmental Management Systems