Water Cycle Management Strategy and Flood Modelling Report

North Appin Planning Proposal

345 Appin Road, Appin, NSW 2560

For Ingham Property Group, 29th June 2023

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DOCUMENT CONTROL

Issue	Date	Purpose	Author	Approved
A	16/6/2023	Draft for review	K. Smith	Carrozza
B	27/6/2023	Updated with Client Comments	K. Smith	F.Carrozza
C	29/6/2023	Final	K. Smith	F. Carrozza

This report has been prepared by Craig & Rhodes Pty Ltd and has undergone a quality assurance review. The signatures below confirm review completion.

Acknowledgement of Country

Craig & Rhodes acknowledges the traditional custodians of the land in Wollondilly, the Tharawal people. We acknowledge the living culture and spiritual connections to the land for the Tharawal people, and pay our respects to elders' past, present and emerging and we acknowledge the cultural significance of the Appin region to the Aboriginal people.

Abbreviations

AEP	Annual Exceedance Probability
ARI	Annual Recurrence Interval
DCP	Development Control Plan
DSP	Draft Structure Plan
IWM	Integrated Water Management
LiDAR	Light Detection and Ranging
NorBE	Neutral or Beneficial Effect
PET	Potential Evapotranspiration
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
QGIS	Quantum Geographic Information System
TIN	Triangulated Irregular Network
WSC	Wollondilly Shire Council
WSUD	Water Sensitive Urban Design

1. Introduction

Craig & Rhodes have been engaged by Ingham Property Group to prepare a Water Cycle Management Strategy report to support the North Appin (part) Precinct Planning Proposal. The Water Cycle Management Plan (WCMP) is required to support the application at 345 Appin Road, Appin.

The Planning Proposal seeks to rezone the site comprising approximately 301 hectares of land, which is in the North Appin Precinct that forms part of the Greater Macarthur Growth Area (GMGA). Ingham Property Group is the majority landowner within the North Appin Precinct referred to as North Appin (part) Precinct, and is answering the NSW Government's call for efficient land supply, working to unlock an immediate opportunity to deliver housing supply in Southwest Sydney. This land is "shovel-ready", capable of delivering around 3,000 lots within the precinct that has total capacity for 5,000-plus lots. The site is not heavily encumbered by Cumberland Plain Conservation areas, existing koala habitat or flood risk and has capacity for connection to potable water, high voltage power, wastewater and the regional road network as needed.

As there is currently no site-specific Development Control Plan (DCP) pertaining to the North Appin (part) Precinct, this Water Cycle Management Strategy and Flood Modelling Report has been developed in accordance with the Wollondilly Shire Council ('Council') DCP, Council's Integrated Water Management Strategy and Council's Water Sensitive Urban Design Guidelines.

The Planning Proposal is based on development areas indicated in the Draft Structure Plan and has not adopted the Indicative Layout Plan. As such, from a design perspective, this report has focused on storm water elements in critical locations rather than across the whole site.

The approach, methodology and assumptions are outlined within each relevant section of the report.

This report will demonstrate that the flooding, stormwater quality and quantity management analysis supports the North Appin (part) Precinct Planning Proposal.

1.1 Background

In response to the recent NSW Government announcement, Ingham Property Group is seeking to lead an initial rezoning of approximately 301 hectares at 345 Appin Road, Appin.

This Water Cycle Management Report will address the key risks associated with the rezoning pertaining to hydrology, flooding, stormwater, and water quality.

1.2 Proposed Development

North Appin precinct is located adjacent to the existing Appin township. The site encompasses approximately 301 hectares of largely cleared and well drained land. The site is bounded by Appin Road to the east, Mallaty Creek and rural land to the north, Ousedale Creek to the south and Water NSW's heritage listed Upper Canal to the west. The southwestern boundary of the site is heavily vegetated and largely aligns with streams and creeks that feed into the Nepean River (Ingham Property Group, 2022).

The proposed development will consist of approximately 3,000 lots, a school site, a retail shopping centre, significant ecological benefits, and community infrastructure as well as forward funded civil infrastructure.

Figure 1-1 below illustrates the location of the proposed North Appin (part) Precinct with other known proposals and the Greater Macarthur structure plan land release area. Figure 1-2 shows the Ingham Property Group Draft Structure Plan.

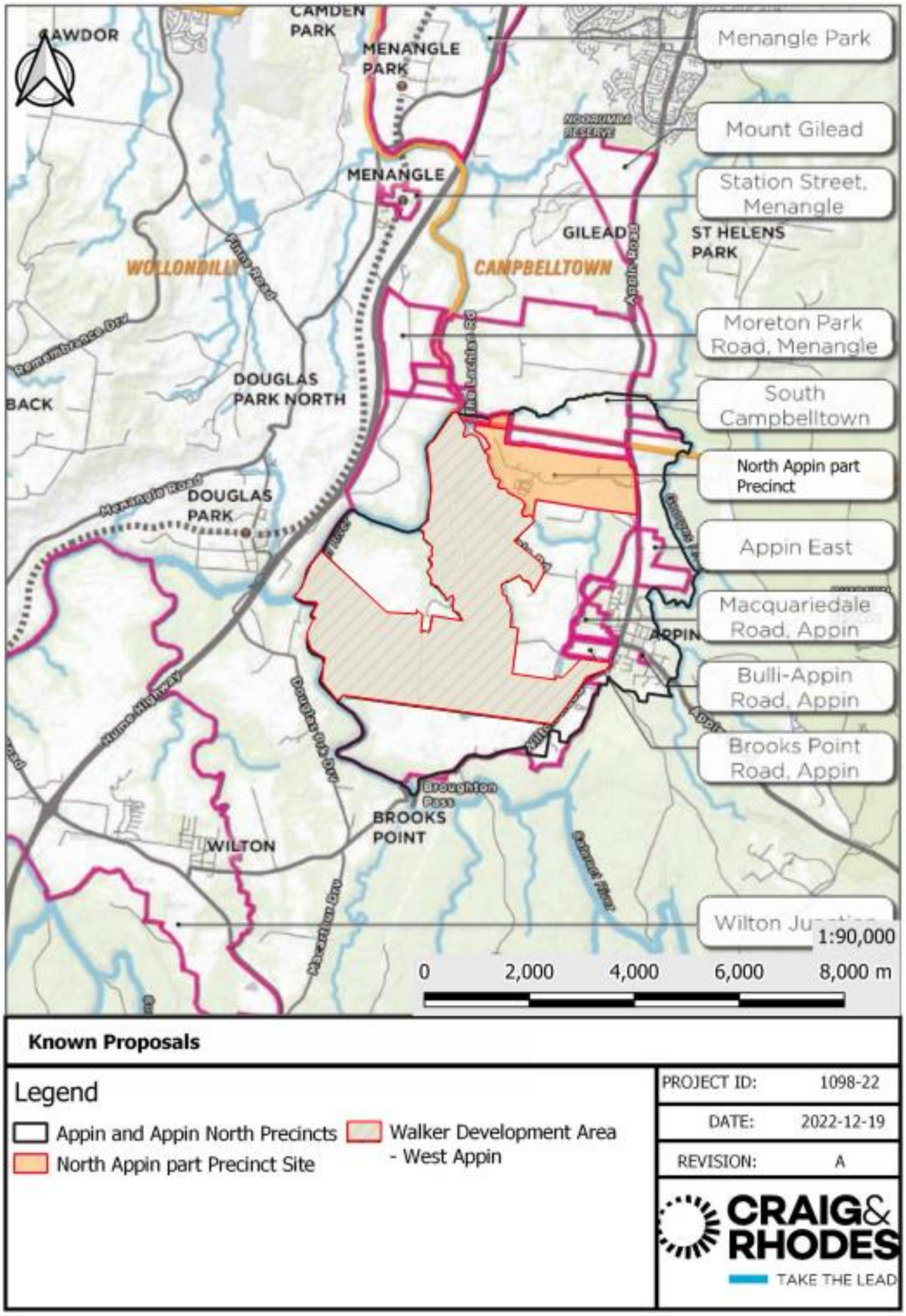

Figure 1-1 North Appin (part) Precinct and Greater Macarthur known proposals.

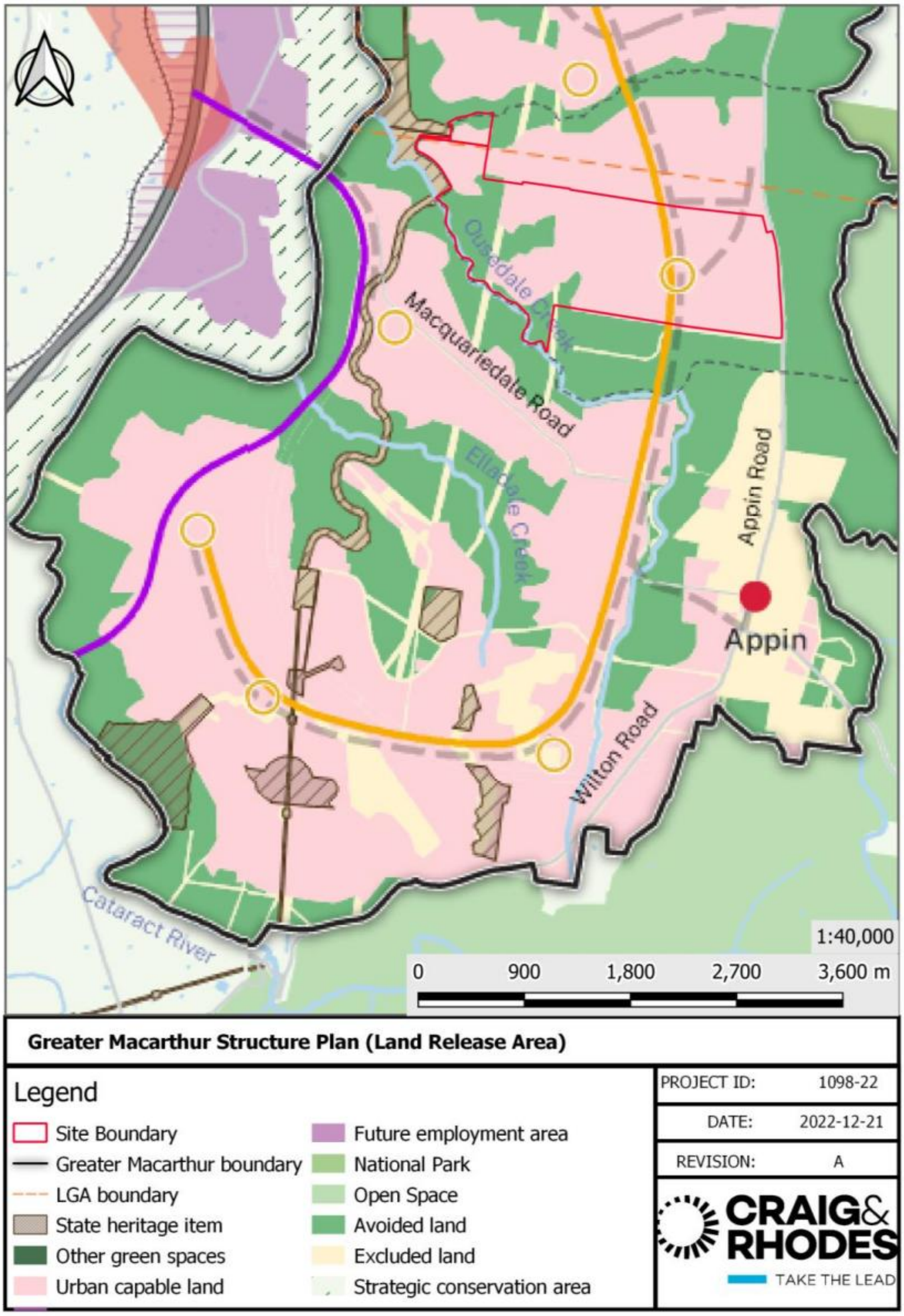

Figure 1-2: Appin Precinct Layout Indicative Plan (Source: Appin and North Appin Precinct Indicative Plan – Appin (part) Precinct Planning Proposal)

DRAFT STRUCTURE PLAN

Figure 1-3 North Appin (part) Precinct Draft Structure Plan

1.3 Scope of work

This report addresses the surface water management strategy for North Appin (part) Precinct, NSW. The following works have been undertaken:

1. Preparation of a draft Integrated Water Management Plan that is inclusive of catchment analysis, flood assessment, stormwater quantity & quality management strategies;
2. Ensure modelling and assessments are in line with Wollondilly Shire Council's DCP requirements and Guidelines;
3. Provide indicative 1% AEP flood flow hydrographs and validate existing runoff to available data where available;
4. Provide indicative 1% AEP existing conditions flood levels to inform future flood planning levels;
5. Build the proposed development Structure Plan into the TUFLOW model and run the TUFLOW model for existing and developed conditions for the 1% AEP storm event;
6. Assess the impacts of the proposed development on the existing flood regime and adjust the masterplan accordingly;
7. Produce flood mapping for the 1% AEP storm event;
8. Provision of high-level recommendations for detention basin locations; and
9. Provision of high-level discussion regarding possible water quality treatment strategies.

It is noted that this is a high-level report for the purposes of site rezoning and answering the NSW Government call for efficient land supply. It is acknowledged that further detailing of hydrology, hydraulics, basin sizing and optimisation, water quality and underground stormwater drainage will be required as the project progresses.

1.4 Objectives

The objective of this report is to:

- Undertake a Water Cycle Management Strategy for the purposes of the proposed Draft Structure Plan;
- Undertake a flooding assessment – hydrologic and hydraulic analysis to determine existing flood behaviour and the potential impacts of the development on flood behaviour;
- Prepare a preliminary water quality assessment of the site in accordance with the Wollondilly Shire Council Integrated Water Management Strategy and Policy; and
- Identify and undertake high-level concept design of detention basin layout and bioretention basins that may be required for water quantity and quality management purposes.

2. Data Collation and Review

2.1 Guidelines and Previous Studies

Available guidelines reviewed and adopted for this study include the following:

- WSC Water Sensitive Urban Design (WSUD) Guidelines (WSC 2020)
- NSW MUSIC Modelling Guidelines (BMT WBM, 2015)
- WSC Development Control Plan (DCP) (WSC 2016)
- WSC Integrated Water Management Policy and Strategy (WSC, 2020)
- Australian Rainfall and Runoff: A Guide to Flood Estimation (Commonwealth of Australia, Geoscience Australia, 2019)
- NRAR Guidelines (NSW National Resources Access Regulation, Guidelines for Controlled Activities on Waterfront Land, 2022)
- Greater Macarthur 2040 – An interim plan for the Greater Macarthur Growth Area (NSW DPE, 2018)
- Greater Macarthur Structure Plan (Land Release Area (NSW DPE, 2022)
- Gilead Stormwater Management Strategy (Enspire, 2022)
- Water Cycle Management Strategy Report, Walker Corporation Appin (Part) Precinct, (J. Wyndham Prince, 2022)
- WSC Flood Study (Advisian 2021)

The North Appin (part) Precinct lies mostly within Wollondilly Shire Council and Greater Macarthur Growth Area and is therefore subject to the WSC DCP. As such, Water Quality and Environmental Flow Targets have been adopted in line with the WSC Stormwater Objectives. In addition, Water Quality results have been compared to the NorBE (Neutral or Beneficial Effect) targets for reference purposes.

The Wollondilly Shire Council LGA wide Flood Study was used to determine the basis of the flood extents at the site, however, as discussed later in this report, the LGA wide Flood Study is not appropriate for this assessment and therefore a new site-specific model has been created.

2.2 Data

- Wollongong 2019, 1m resolution LiDAR, 2kmx2km sets, produced using Triangular Irregular Network method with 0.3m vertical and 0.8m horizontal accuracy, NSW Foundation Spatial Data Framework (Geoscience Australia, 2021)
- Wollongong 2011 1m resolution LiDAR, 2kmx2km sets, produced using Triangular Irregular Network methods, with 0.3m vertical and 0.8m horizontal accuracy, for DFSI Spatial Services, a unit of Department Finance, Services and Innovation, via Australian Government (Geoscience Australia, 2021)
- Wollondilly Shire Council Cadastral Data, NSW Department of Customer Service, Spatial Services;
- Wollondilly Shire Council Topography, NSW Department of Customer Service, Spatial Services;
- Campbelltown Council Cadastral Data, NSW Department of Customer Service, Spatial Services;
- Campbelltown Council Topography, NSW Department of Customer Service, Spatial Services;
- A 1m resolution Triangulate Irregular Network (TIN) prepared by Craig & Rhodes of the development site earthworks.

2.3 Development Documentation

This report is to be read in conjunction with the following documentation supporting the proposed development:

- North Appin (part) Precinct Planning Proposal by Urbis Pty Ltd dated 30th June 2023
- CPCP Compliance Report by Travers Bushfire & Ecology dated 19th December 2022.
- Watercourses and riparian buffers map by Travers Bushfire & Ecology dated 28th November 2022
- Riparian Assessment by J. Wyndham Prince, June 2023

3. Water Quality Management Strategy

3.1 Wollondilly Shire Council WSUD Design Guidelines

The WSC Water Sensitive Urban Design Guidelines (Wave Consulting, 2021), 'The WSUD Guidelines', were released in conjunction with the WSC Integrated Water Management (IWM) Strategy in January 2021. The vision outlined in the IWM strategy is to maintain pristine creeks and rivers to be swimmable and ecologically rich and diverse. The IWM Strategy is supported by the WSUD Guidelines, which integrate urban water cycle management with urban planning with the aim of mimicking natural systems to minimise negative impacts on the natural water cycle and receiving waterways (Wave Consulting, 2021).

The WSUD Guidelines (2021) outline the key principles as follows:

a) Protect and enhance natural water systems within urban environments.
b) Integrate stormwater treatment into the landscape, maximising the visual and recreational amenity of developments.
c) Improve the quality of water draining from urban developments into receiving environments.
d) Reduce runoff and peak flows from urban developments by increasing local detention times and minimising impervious areas.
e) Minimise drainage infrastructure costs of development due to reduced runoff and peak flows.

These principles speak to the aspirations held by the Wollondilly Community Strategic Plan (CSP), which provides a clear mandate to protect and maintain the environment.

The flow and volume of stormwater and the pollutants contained therein, can be one of the largest contributors to water degradation if not managed. As such, the WSUD Guidelines have outlined a suite of seven recommended actions to retain stormwater on-lot or within the catchment as much as possible. The remaining runoff that is not retained within the catchment is to be treated to best practice.

3.2 Objectives and Targets

The objectives of the WSC WSUD Guidelines and IWM Strategy are threefold:

1. Achieve a zero impact of stormwater on local waterways;
2. Achieve a zero impact of wastewater on local waterways; and
3. Use water to support sustainable development.

To achieve a zero impact, the policies require runoff from impervious surfaces to be reduced to a near natural condition and it is through the suite of seven recommended actions outlined within the Guidelines that this can be achieved.

In particular,

- Maximising use of rainwater tanks on a lot-scale basis reduces run-off and pollutants and reduces potable water use; and
- Runoff from impervious roads and pavements can be reduced by using central swales for retention and treatment.

The WSUD Guidelines also state that it is expected that a 79% reduction in impervious flows would be as close as possible to a zero-impact scenario, and it is not practical or appropriate to reduce runoff to zero (Wave Consulting, 2021).

Zero impact also refers to the impact of wastewater discharge, however, this report will address only the impacts of stormwater runoff.

Sections 4.2.1, 4.2.2 and 4.3 of the WSUD Guidelines (2021) provides tables of requirements to meet the WSUD zero impact targets. Since North Appin (part) Precinct is a subdivision of greater than 10+ lots, all targets outlined within the tables will apply, however, items of relevance to the North Appin (part) Precinct and this Water Cycle Management Plan only, are outlined in Table 3-1 below. The items to be addressed at rezoning stage are discussed in Sections 3.3 through 3.15, with the results of modelling outlined in Section 3.17.

Table 3-1 Summary of Sections 4.2 and 4.3 of WSC WSUD Guidelines, as they pertain to this Water Cycle Management Plan

Requirements	**10+ lots or 2500+ m^2**	**Addressed at Rezoning Stage**
Reduce stormwater runoff to an equivalent of between 2.5 and 3 ML / year / 1 hectare of urban area	Yes	Yes Refer Section 5
Reduce potable water use by > 70% compared to business as usual	Yes	No Potable water analysis to be undertaken as part of the Water management Design as part of future Development Applications[1]
Ensure smart tank technology could in the future be integrated into residential, commercial, and industrial developments.	Yes	No Analysis to be undertaken at DA Stage[2]
Prepare an Integrated Water Plan, including who owns and maintains all associated assets, and where all impervious surfaces drain to. See section 8.2 Early Planning for requirements.	Yes	Yes
Use Council MUSIC template model to demonstrate how the outcomes of this policy will be achieved.	Yes	Yes - Adopted
Design and build streetscapes in new subdivisions to achieve zero impact.	Yes	Yes Although further details and analysis to be undertaken at DA stage
For developments where demand is greater than 5 ML/year demonstrate how this water will be sourced through rainwater, stormwater, or recycled water.	Yes	No Potable water demand to be addressed within the Water management Design as part of future Development Applications[1]
Routine monitoring of WSUD effectiveness should be undertaken on an ongoing basis.	Yes	No

		Maintenance schedules to be provided as required by Council Policy at Detailed Design phase
Monitoring of waterways to demonstrate downstream waterway of urban development is of a similar condition / quality to designated reference stream.	Yes	No Part of ongoing monitoring and maintenance
Subdivision Specific		
Road reserve to be designed to filter and convey more stormwater runoff	Yes	Yes Although further details and analysis to be undertaken at DA stage
Median reserve to be designed and constructed to maintain stormwater runoff and may need to be increased from 5m to 7m, with a swale that has a 2m base.	Yes	Yes Although further details and analysis to be undertaken at DA stage.

[1] Note that Water and Sewer Design to be undertaken at DA Stage and will involve analysis of the water supply and consumption associated with the rainwater tanks and the proposed recycled water network.

[2] Analysis of the smart tank technology will require individual residential, commercial, and industrial lot owners to submit separate DA applications for rainwater tanks including smart tanks.

[3] Note that Environmental and Cultural Heritage Considerations, preliminary construction, operations and maintenance requirements and funding opportunities are not addressed within this report.

3.3 Water Quality Management Objectives

This Water Cycle Management Strategy and Flood Modelling Report will demonstrate that at Planning Proposal stage a Regional Scale focus will sufficiently manage the stormwater quality requirements, with the street- and lot-scale to be addressed at Development Application stage when more detail becomes available. At DA stage, additional treatment train elements such as tree pits may be considered for incorporation into the modelling.

For the purposes of Rezoning Approval, it is proposed to present a strategy that incorporates Regional Scale WSUD elements such as:

- Rainwater Tanks;
- Vegetated Swales;
- Constructed Wetlands; and
- Detention Basins.

The MUSIC model prepared for the Planning Proposal incorporates this treatment train at a high-level and the detailing of these items will occur later in the project.

3.4 Pollutant Reduction Targets

Currently there is no relevant site specific DCP. As such, the WSC Integrated Water Management Strategy and the WSUD Guidelines were used to determine the pollutant reduction targets shown in Table 3-2. The NorBE targets are more stringent than those adopted within the Wollondilly WSUD Guidelines and therefore, both target requirements have been considered within this document.

Table 3-2 Stormwater Quality PerformanceTargets

Pollutant	Stormwater Management Objective	NorBE
Gross Pollutants > 5mm	90%	90%
Total Suspended Solids (TSS)	85%	Neutral or beneficial effect on Water Quality, i.e. loads of pollutants from future development- must be equivalent to or less than that from existing rural land use.
Total Phosphorus (TP)	60%	
Total Nitrogen (TN)	45%	
Stream Erosion Index (SEI)	1.0 – 3.5	1:1

3.5 Water Quality Management Strategy

The adopted stormwater quality management strategy includes provision of a treatment train to treat surface runoff to the drainage network for the fully developed conditions. Treatment systems can be integrated within the landscape and open space areas and distributed throughout the catchment, such as rainwater tanks, vegetated swales, infiltration trenches or tree-pits, or they can be concentrated in centralised locations as end-of-line treatments, such as bio-retention basins and detention basins.

The following water quality control assets are proposed for implementation within North Appin (part) Precinct:

a. Distributed rainwater tanks – for collection of runoff from roofs and re-use of water for irrigation and household use;
b. Distributed vegetated roadside swales within road median strips – for conveyance and filtration of coarse and medium sediment from stormwater runoff;
c. End-of-line Gross Pollutant Traps (GPTs) - for removal of coarse sediment and large debris, reducing maintenance obligations and pollutant loads on the tertiary treatment controls. These will typically be sized for the 3–6-month flow; and
d. End-of-line bioretention systems for capture of finer sediment and treatment of nutrients.

3.6 Methodology

The stormwater quality management modelling was prepared using the industry standard MUSIC Model (Model for Urban Stormwater Improvement Conceptualisation) Version 6.3. WSC has a MUSIC template available for use and this template was adopted for modelling of the site.

A portion of the development, catchments P3_a and P3_b, was modelled as an indicative sample of the overall North Appin (part) Precinct to demonstrate that the requirements can be achieved, and this approach also facilitated determination of bioretention sizing per hectare of the site. A representative split of roads, residential lots, and open space areas was determined for these catchments, as the full Indicative Layout Plan (ILP) is not currently available.

Modelling of the full precinct will be completed at DA Stage to optimise the water quality treatment train and sizing.

The developed site catchments with a possible indicative bioretention basin and vegetated swale layout is illustrated in Figure 3-1 below.

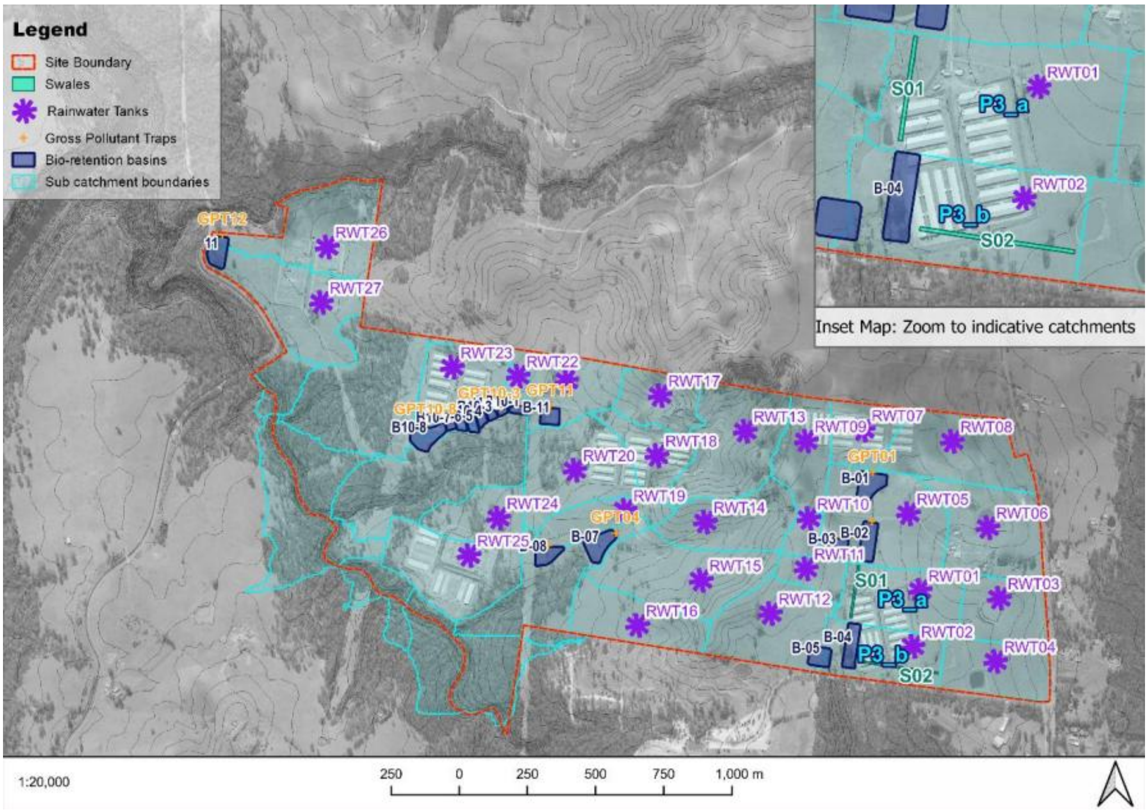

Figure 3-1 Possible Indicative layout of bioretention basins and vegetated swales

3.7 Assumptions

The Water Quality Management Strategy for the Planning Proposal submission has adopted the following assumptions:

- The WSC MUSIC template can be adopted as-is, with minimal adjustment to source nodes and treatment train parameters;
- That a regional strategy is sufficient for preliminary investigation to demonstrate that the targets can be achieved;
- That the two catchments adopted for analysis are representative of the whole North Appin (part) Precinct; and
- That separate water quality and water quantity analysis is sufficient to demonstrate that both runoff as well as pollutant targets can be achieved (c.f. using the MUSIC model to undertake detention basin design)

3.8 Hydrologic Data Inputs

Wollondilly Shire Council's MUSIC template uses 6-minute rainfall and monthly PET (potential evapotranspiration) data from Rainfall Station No. 066164 – Rookwood Station. The data was based on the timeseries 01/01/1975 to 31/12/1984. Rainfall and PET for the period are presented in Figure 3-2 below.

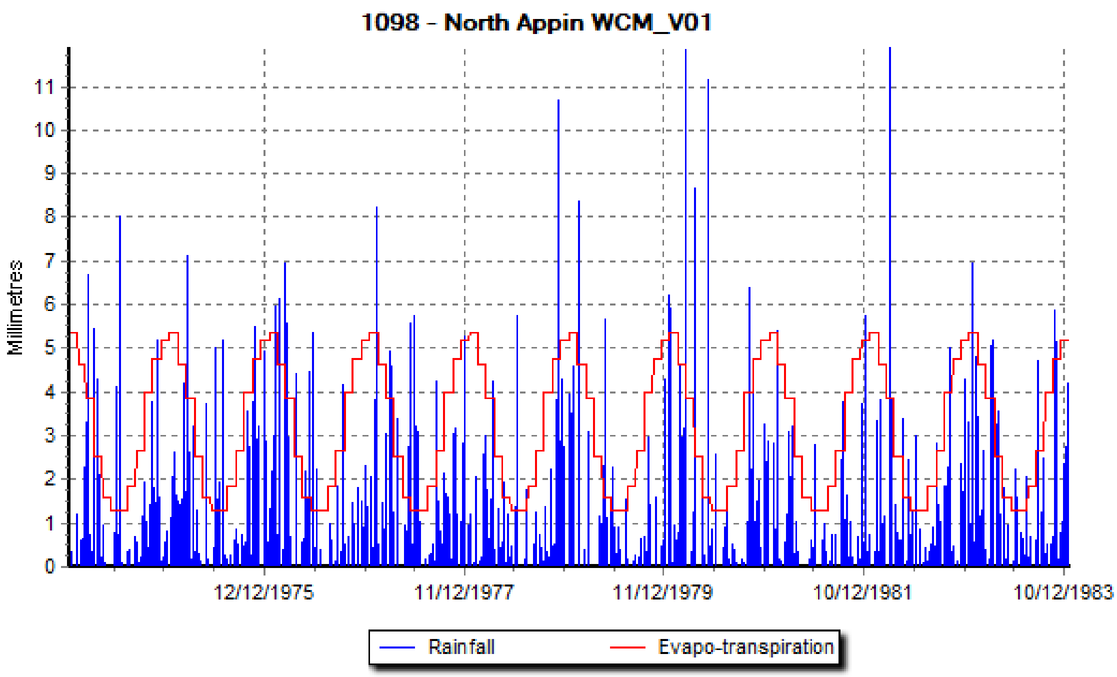

Figure 3-2 Rainfall and PET graph (MUSIC)

3.9 Source Node Data Inputs

The MUSIC Source Node parameters were adopted from Wollondilly Shire Council's provided MUSIC template (Wave Consulting, 2020). The following table summarises these source node inputs.

Table 3-3 Stormwater Quality parameters – Source Nodes

Land use Category		Total Suspended Solids (mg/L Log_{10})		Total Phosphorus (mg/L Log_{10})		Total Nitrogen (mg/L Log_{10})	
		Storm Flow	Base Flow	Storm Flow	Base Flow	Storm Flow	Base Flow
Residential Areas	Mean Std Dev	2.15 0.32	1.20 0.17	-0.60 0.25	-0.85 0.19	0.30 0.19	0.11 0.12
Roof Areas	Mean Std Dev	1.30 0.32	1.10 0.17	-0.89 0.25	-0.82 0.19	0.30 0.19	0.32 0.12
Sealed Road Areas	Mean Std Dev	2.43 0.32	1.20 0.17	-0.30 0.25	-0.85 0.19	0.34 0.19	0.11 0.12
Mixed Use/ Residential Areas	Mean Std Dev	2.20 0.32	1.10 0.17	-0.45 0.25	-0.82 0.19	0.42 0.19	0.32 0.12

3.10 Soil Parameters

MUSIC rainfall-runoff parameters were adopted from WSC's MUSIC Template Data for all urban source nodes.

The parameters outlined in Table 3-4 were provided by Ocean Protect in correspondence dated 5th December 2012, and these were sourced from (Macleod, 2008). The parameters were adopted for the Agricultural Source Node and pervious areas in the developed conditions.

Table 3-4 Soil parameter table

Dominant Soil Description	Soil Storage Capacity (mm)	Field Capacity (mm)
Sand	175	74
Loamy Sand	139	69
Clayey Sand	107	75
Sandy Loam	98	70
Loam	97	79
Silty Loam	100	87
Sandy Clay Loam	108	73
Sandy Clay	142	94
Silty Clay	54	51

Light Clay	98	73
Light-Medium Clay	90	67
Medium Clay	94	70
Medium-Heavy Clay	94	70
Heavy Clay	90	58

3.11 Catchment Details

The proposed development site has been divided into several sub-catchments based on a combination of the 1m LIDAR data, the design tin, the proposed masterplan, and land use. The site was divided into the three main categories for modelling. Areas of bushland, riparian corridor, and conservation land that remains undisturbed compared to existing conditions was excluded from the modelling. The three categories are as follows:

- Residential;
- Road Reserve; and
- Parkland / open space areas.

The draft structure plan was used to determine the average catchment land use breakdown, to allow for estimates of sizing of water quality treatment features. A split of 65% residential, 30% road reserve and 5% open space was determined. The residential component was further divided into lots with rainwater tanks and lots that runoff directly to vegetated swales. This high-level analysis is considered to be sufficient at Planning Proposal Phase, a more detailed analysis will be undertaken for DA stage.

The total area of roof source nodes was calculated to be approximately 55% of the residential lot area and was modelled as 100% impervious. The remainder of the residential lots was treated as 10% driveway, 20% “other” impervious and 15% pervious.

The impervious percentage of each of the land uses is detailed below in Table 3-5. These values match the assumptions adopted for neighbouring planning proposals including Gilead Stage 2 (Enspire, 2022) and Appin part Precinct (J. Wyndham Prince, 2022).

Table 3-5 Catchment Landuse Characteristics

Land Use	Impervious Area (%)
Residential Lots[1]	60
Road Reserve	70
Parkland[2]	10

1. The adopted impervious area accounts for the separation of the 100% impervious roof areas from the residential areas. The sum of the impervious roof area and the impervious area for the residential areas is equal to the total impervious area of the urban catchment.
2. 10% is adopted to assume potential future amenity buildings, footpaths, and hard surfaces.

3.12 Treatment Train

The stormwater design for the development will use a combination of at-source conveyance controls and end-of-line features to treat the stormwater runoff from the site. The treatment trains proposed for this development are detailed in Sections 3.12.1 through 3.12.4.

3.12.1 Rainwater Tanks

Rainwater tanks are proposed for each dwelling as part of the treatment train and BASIX requirements. The WSC rainwater tank recommendations are detailed in Table 3-6 below. For the purposes of preliminary indicative modelling, an average roof size of 350m^2 was adopted from the planning documents preliminary yield estimates, this corresponds to a 12,000 L tank size. The size and number of rainwater tanks can be further refined at DA stage, when the details of lot and roof sizing within the precinct become available.

Table 3-6 Rainwater tanks recommended in the Council WSUD Guidelines

Size of roof (sqm)	Minimum size of rainwater tank (litres)
100	400
200	8,000
300	12,000
500	20,000
1,000	40,000
5,000	200,000

The WSC WSUD Guidelines (2021) *Section 4.4 Water demand baseline and targets,* as outlined in Table 3-7 below, have provided water consumption and supply figures as sourced from the Sydney Water Wave Conservation Report (2018), Sydney Water Daily Water Use Report, Smart Water Melbourne Residential Water Use Study (2013), and Green Building Council of Australia Potable Water Calculator (2015). Accordingly, the internal daily re-use rate for the modelling of the North Appin (part) Precinct has been adopted as 252L/day, which is the average rainwater tank supply rate/household (litres/day) in Table 3-7. To be conservative, the tanks have been modelled as half full at the start of the storm event, with a 25% reduction in the number of tanks to account for owner non-compliance.

Table 3-7 Water demand baseline and targets in Council WSUD Guidelines

Development Type	Average potable water use – baseline (litres/day)	Average water efficiency saving (litres/day)	Average rainwater tank supply (litres/day)	Average WSC potable target (litres/day)
1 household	620	180	252	185
Commercial (1 ha area) *	6,800	80% less potable water use 1,200		
Industrial (1 ha area) *	7,700	80% less potable water use 1,800		

3.12.2 Gross Pollutant Traps

Gross Pollutant Traps (GPTs) are proposed upstream of all bioretention systems. An example proprietary GPT, the Rocla CDS Unit has been adopted for this study and is illustrated in Figure 3-3. The performance criteria for the Rocla GPT are presented in Table 3-8 below.

Figure 3-3 Rocla CDS Unit (source: Rocla Technical Manual)

Table 3-8 Gross Pollutant Trap capture efficiency table

Pollutant	Capture Efficiency
Gross Pollutant (> 1mm)	98%
Total Suspended Solids (TSS) (> 200 µm)	70%
Total Phosphorous (TP)	30%
Total Nitrogen (TN)	0 %

3.12.3 Vegetated Swales

It is proposed to incorporate vegetated swales within the median strips or verges of appropriate roads throughout North Appin (part) Precinct as part of the distributed stormwater treatment. Vegetated swales will provide both water quality treatment as well as an aesthetically pleasing landscape feature for the development, and they are relatively inexpensive to construct and maintain (Wave Consulting, 2021).

Vegetated swales form an important flow conveyance and filtration function, whereby the interaction between the vegetation facilitates an even distribution and slowing of flows. This encourages sediment and particulates to drop out and allows low flows to infiltrate, which serves to remove coarse and medium sediment from the water (Wave Consulting, 2021 and Blacktown City Council, 2020).

As per the WSC WSUD Guidelines (Wave Consulting, 2021), the vegetated swales are to be designed with an infiltration trench to increase the capacity for conveyance and pollution reduction. The swale base is to include up to 600mm filter to allow infiltration and absorption and the swale longitudinal grade should typically be between 0% - 5%.

It is proposed that the vegetated swales will receive flows either laterally across vegetated batters, or directly from piped outlets.

An indicative illustration of vegetated swales is provided in Figure 3-4, and the parameters adopted for modelling of the vegetated swales within MUSIC are outlined in Table 3-9.

Figure 3-4 Example roadside vegetated swale (Image Source: Biofiltration in the Hills Shire Factsheet)

Table 3-9 Swale parameters adopted in MUSIC.

Parameters	MCC Requirement	Value
Infiltration Trench	Up to 0.6m of 5-7mm screenings	0.3m
Longitudinal Slope	0% = 5%	Varies
Low Flow Bypass	0.00	0.00
Length		Varies
Swale Characteristics	2m Base 7m Top Width	2m Base width 7m Top width 0.3m depth[1]
Vegetation Height	0.05m	0.05m
Exfiltration / Seepage Loss	0 mm/hour	0.00 (mm/hr)[1]
TSS	Not provided	160 (m/yr)
TP	Not provided	100 (m/yr)
TN	Not provided	10 (m/yr)

1. Adopted from the NSW MUSIC Guidelines (2015)

3.12.4 Bioretention Systems

It is proposed to incorporate bioretention systems as end-of-line treatment.

End-of-line bioretention systems are incorporated for all impervious catchments. The basins will have a high flow bypass to convey the 1% AEP flows and low flows will be treated before they are discharged downstream. Figure 3-5 shows a typical section of the bioretention basin adopted for this study.

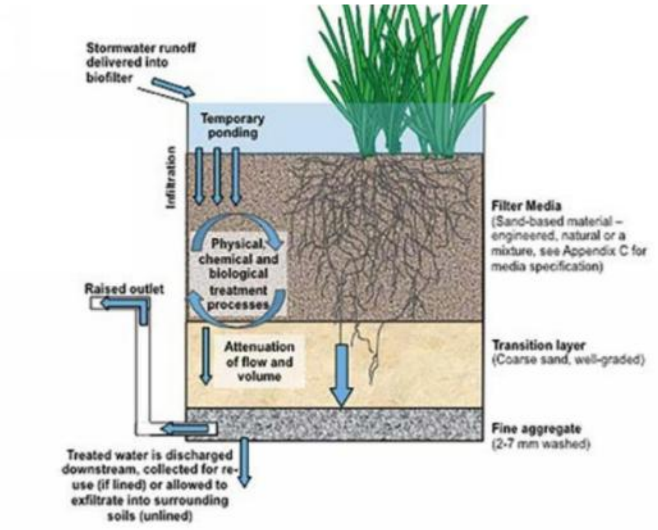

Figure 3-5 Bioretention system schematic

The design parameters adopted for the bioretention systems are shown below in Table 3-10.

Within the MUSIC model, the basin surface area (the surface area at the extended detention depth) was set equal to the filter media area (basin invert area). This is a conservative approach as in reality, all basins are likely to have side slopes of at least 1V:4H meaning the surface area will be greater than the filter media area. However, this simplified approach is considered to be appropriate at this stage as it allows for optimisation of bioretention design in later detailed design stages.

Table 3-10 Bioretention Basin Parameters adopted in MUSIC

Parameters	WCC Requirement	Value
Pre-treatment / Inlet Protection	Required	GPT upstream of all bioretention (See above)
Extended Detention Depth	0.2m Minimum	0.3m
Filter Media Depths	Typically, 0.6m 0.3m-0.6m acceptable	0.6m
Filter Media	Loamy Sand	Loamy Sand
Filter Media Permeability (Saturated Hydraulic Conductivity) (mm/hr)	180-300 mm/hr	200
TN Content (mg/kg)		400
Orthophosphate Content (mg/kg)		40[2]
Exfiltration Rate (mm/hr)		0.0 Set to 0, when base is lined[2]
Impervious Base Liner		YES
Overflow Pit	Overflow pit or other controlled overflow required	High-flow bypass included
Edge treatment	Raised kerb or bollards	Included as required
Submerged Zone		Included as temporary ponding Typically, 0.2-0.4m[2]

1. Blacktown City Council (2013), MUSIC Modelling Guidelines Handbook Part 4

2. BMT WBM (2015) NSW MUSIC Modelling Guidelines

3.13 MUSIC Model

The MUSIC model layout adopted for the North Appin (part) Planning Proposal is provided in Figure 3-6 below.

Figure 3-6 Post Development MUSIC MODEL (1098 – North Appin WCM_V02.sqz)

3.14 Water Quality Modelling Results – Target Reduction

The modelling results analysis from MUSIC are presented in Table 3-11 below. The results indicate that the proposed treatment train provides adequate treatment compared to the WSC Stormwater requirements for all pollutants and significantly exceeds the required Stormwater Management Targets.

Whilst the results indicate that the flow targets have not been achieved, detention basins have not been included within the MUSIC model and detention has been modelled separately. Refer to the discussion on water quantity management in Section 5.

Table 3-11 Target Reduction Targets (Reference 1098 – North Appin WCM_V02.sqz)

Pollutant	Post-Development without Treatment	Post-Development with Treatment	Overall Reduction	Stormwater Management Target	Meets Performance Objectives
Flow (ML/yr)	93.5	77.7	16.9%	79%	No Refer Section 5
Gross Pollutants (kg/yr)	2,320	0	98.6%	100%	Yes
Total Suspended Solids (kg/yr)	14700	208	98.6%	85%	Yes
Total Phosphorus (kg/yr)	29.2	4.92	83.2%	60%	Yes
Total Nitrogen (kg/yr)	209	47.9	77.1%	45%	Yes

3.15 Water Quality Modelling Results – NorBE

Further to the Target Reduction performance objectives, a Neutral or Beneficial Effect (NorBE) analysis was also targeted.

A comparison was undertaken using the same representative catchment areas as above. Compared to an undeveloped agricultural node of the same size. The results show the mean annual loads have been reduced from the predevelopment conditions by more than 60% for all pollutants, satisfying the NorBE requirements.

Pollutant (kg/yr)	Pre-Development	Post-Development With reduction	Meets Performance Objectives
Total Suspended Solids	8,500	208 (97.6%)	Yes
Total Phosphorus	22.5	4.92 (78.1%)	Yes
Total Nitrogen	156	47.9 (69.3%)	Yes
Gross Pollutants	5.65	0 (100%)	Yes

Furthermore, pollutant concentrations for TP and TN were compared in accordance with the assessment requirements. As can be seen for both TP and TN, the pollutant concentration (mg/L) for post-development is reduced in comparison to the pre-development concentration. Therefore, the results below show that the reductions have been achieved for this proposal. The cumulative frequency graphs for both TP and TN are provided in Figure 3-7 and Figure 3-8 respectively.

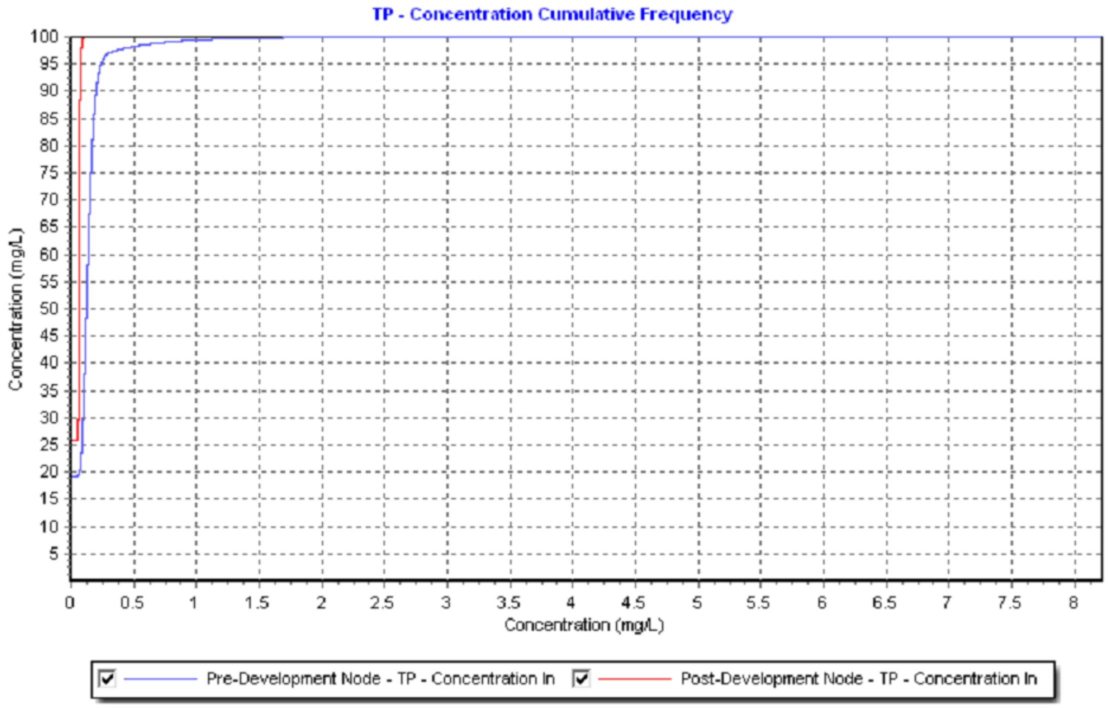

Figure 3-7 Cumulative frequency analysis of TP concentrations (1098 – North Appin WCM_V02.sqz)

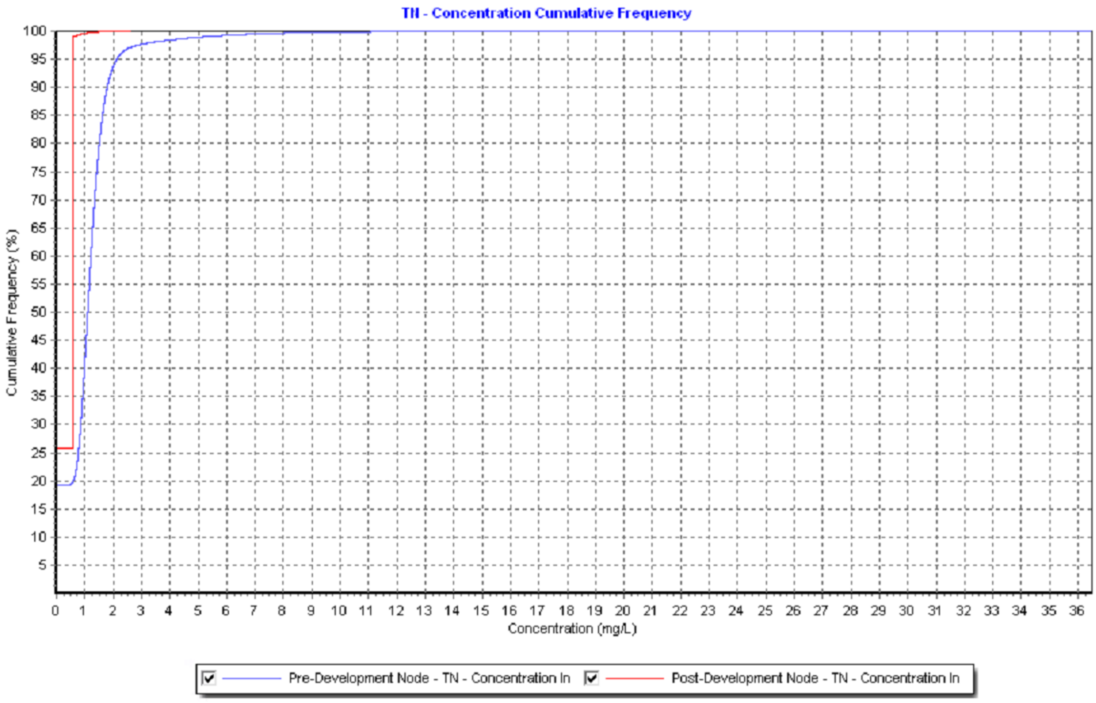

Figure 3-8 Cumulative frequency analysis of TN concentrations (1098 – North Appin WCM_V01.sqz)

3.16 Stream Erosion Index

The Stream Erosion Index (SEI) was determined for the proposed development (Interim Scenario) using the method outlined in the NSW MUSIC Modelling Guidelines (2015).

The bioretention system detains and slows the outflow of waters from the site, resulting in a Stream erosion index of less than 1, which exceeds the stormwater requirements of the NoRBE targets.

Key parameters and values used in the assessment of the SEI are presented in Table 3-12.

Table 3-12 Stream Erosion Index (Reference 1098 – North Appin WCM_V01_SEI.sqz)

Parameter	Value
Catchment Area (m^2)	200,000 m^2 (20Ha sample catchment)
Time of Concentration (hrs)	0.41
2yr ARI Intensity (mm/hr)	44.3
Critical Flow (m^3/s)	0.387
Stream Forming Q_{pre} (ML/yr)	8.01
Stream Forming Q_{post} (ML/yr)	3.30
Stream Erosion Index	0.41

3.17 Discussion

The preliminary assessment of Water Quality measures undertaken for the site shows that the treatment train of distributed rainwater tanks and vegetated swales in combination with end-of-line gross pollutant traps and bioretention basins, which were sized to be approximately 450m^2 of bioretention per hectare, exceeds the requirements for Target Reduction, NorBE, and SEI. This indicates that the preliminary treatment train adopted for this study will be sufficient to satisfy the water quality targets for North Appin (part) Precinct.

Furthermore, it is noted that the commercial centres within the precinct will provide their own water quality treatment onsite, which will further reduce the requirements of the precinct-wide water quality treatment train.

Additionally, developments in filter media research have shown that optimized filter media materials can further reduce the footprint required for treatment while maintaining the same level of efficacy. While this has not been used in the current modelling, targeted use of the validated filter media may assist in the treatment of areas in the precinct which would benefit from a reduced bioretention area, with benefits including increased recreational area and reduced land take.

The details of the water quality treatment train is subject to further detailed design and modelling at DA stage. It is expected that further design iterations will result in the size of the water treatment being smaller than the nominated areas, owing to the result exceeding that of the Stormwater Management Objectives, as well as the aforementioned characteristics of the catchment and potential for improvements in the filter media.

4. Flood Assessment

4.1 Study Area

North Appin (part) Precinct consists of approximately 301 ha rural land. The site is bounded by Ousedale Creek to the southwest and lies between the Nepean River to the west and Appin Road to the east. Mallaty Creek flows along parts of the north boundary of the site, whilst the remaining northern boundary is typically rural land. The site generally slopes in a south-westerly direction, with the entire site draining to Ousedale Creek.

The Nepean River flows past the site along the western boundary, which includes the upstream catchments of Douglas Park, Wilton, Tahmoor, Picton, and Thirlmere, as well as flows from Bargo River, Cataract River and Cordeaux River. These catchments result in high flows, noted by the defined channels within the riverbanks from flood velocities and flood depths.

The site is marked by steep valleys and ridgelines with local watercourses that run through the site. Due to these steep slopes, the site generally lies metres above the main watercourses, which appear to be incised, however, the site may be subject to shallow sheet flooding as it lies at the top of the catchment.

Advisian, part of the Worley Group, undertook the Wollondilly Shire Flood Study Broad Scale Assessment in 2021, which mapped flood levels and depths for flood events including the 10% AEP, 1% AEP, 0.2% AEP, and PMF events. These levels were used to determine the preliminary effects of mainstream flooding at the site and reported in the Water Cycle Management Strategy Report, North Appin part Planning Proposal (Craig & Rhodes, 2022).

Review of the WBNM catchments and delineation of the local topography shows the presence of several watercourses traversing the site, however, the proposed indicative layout generally lies outside the mainstream flood extents of the Nepean River. The watercourses are typically unnamed and for the purpose of this study have been marked as Watercourse 1 – Watercourse 5 as illustrated in Figure 4-1.

The site predominantly drains southwest to Ousedale Creek, which is a 12.8 km^2 catchment that confluences with Mallaty Creek near the outlet to the Nepean River. The east of the site is bounded by Appin Road, which acts as a ridgeline separating the Ousedale Creek and Georges River catchments.

The study area is illustrated in Figure 4-1 and the surrounding watershed catchment boundaries are illustrated in Figure 4-2.

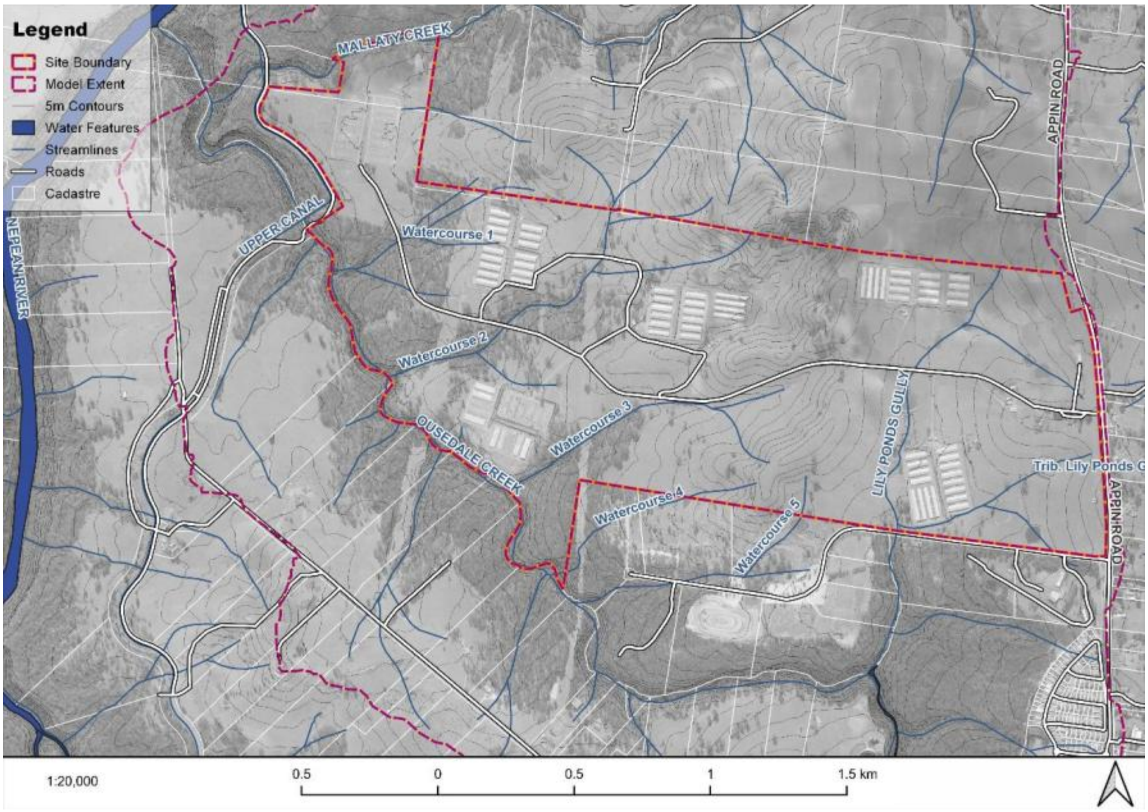

Figure 4-1 Study Area

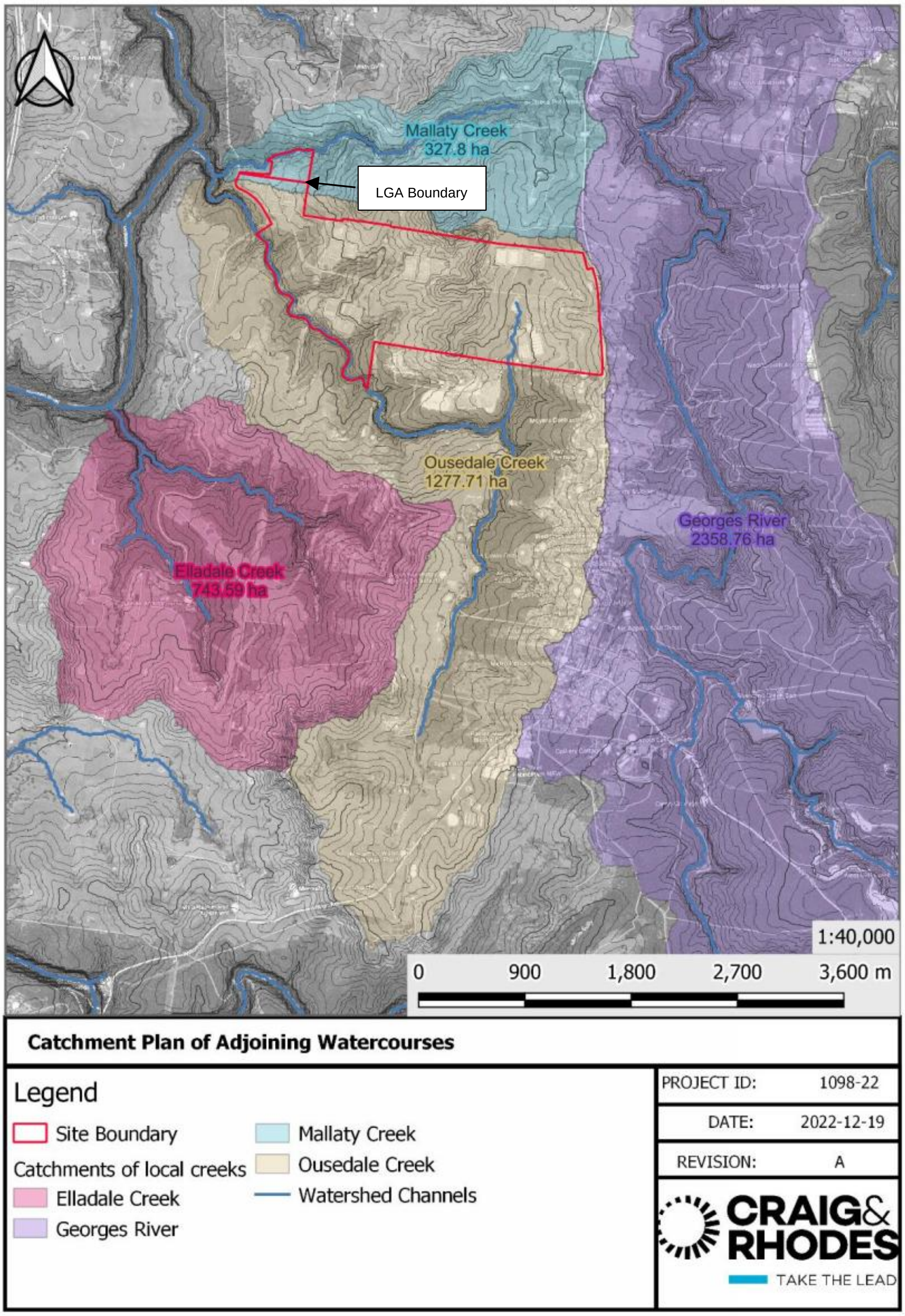

Figure 4-2 Watershed catchments overlaid on Study Area

4.2 Data Collation and Review

Data relevant to the flood assessment has been collated and reviewed as a data gap analysis. A data quality analysis is not relevant at this stage, as the acquired data (i.e. from SixMaps, Council etc.) is assumed to have been reviewed by relevant authorities. Data prepared by Craig & Rhodes, such as design TINs, basins, and hydraulic structures have been quality checked, both by the Civil Design Team and by the Flooding Team.

The primary data collated for this study was outlined in Section 2.2. This data includes cadastral data, topography data, and LiDAR data and the Civil Design TIN.

4.2.1 Specific Flood Study Data

Additional data collated specifically for the flood study component is as follows:

- Rainfall data was downloaded from the ARR2019 Data Hub and utilised with due consideration for the NSW jurisdiction guidelines for the rainfall boundary discussed in Section 4.3.
- Streamflow data was not utilised for calibration of this model. A search was undertaken for nearby streamflow gauges utilising the NSW Government data available via the Bureau of Meteorology website and no streamflow data was available for Ousedale Creek, Mallaty Creek or the Nepean River within the vicinity of the site boundary.

4.2.2 Digital Elevation Model

A digital elevation model was prepared from the 1m LiDAR obtained from *Elvis* (Geoscience Australia, 2021), outlined in Section 2.2.

When adopting a rain-on-grid modelling approach (described later in Section 4.3 the DEM needs to be “sink-filled” to avoid attenuating flows within artificial LiDAR artefacts. This process has been undertaken using the GRASS GIS tools available within QGIS.

The resultant Digital Elevation Model is illustrated in Figure 4-3.

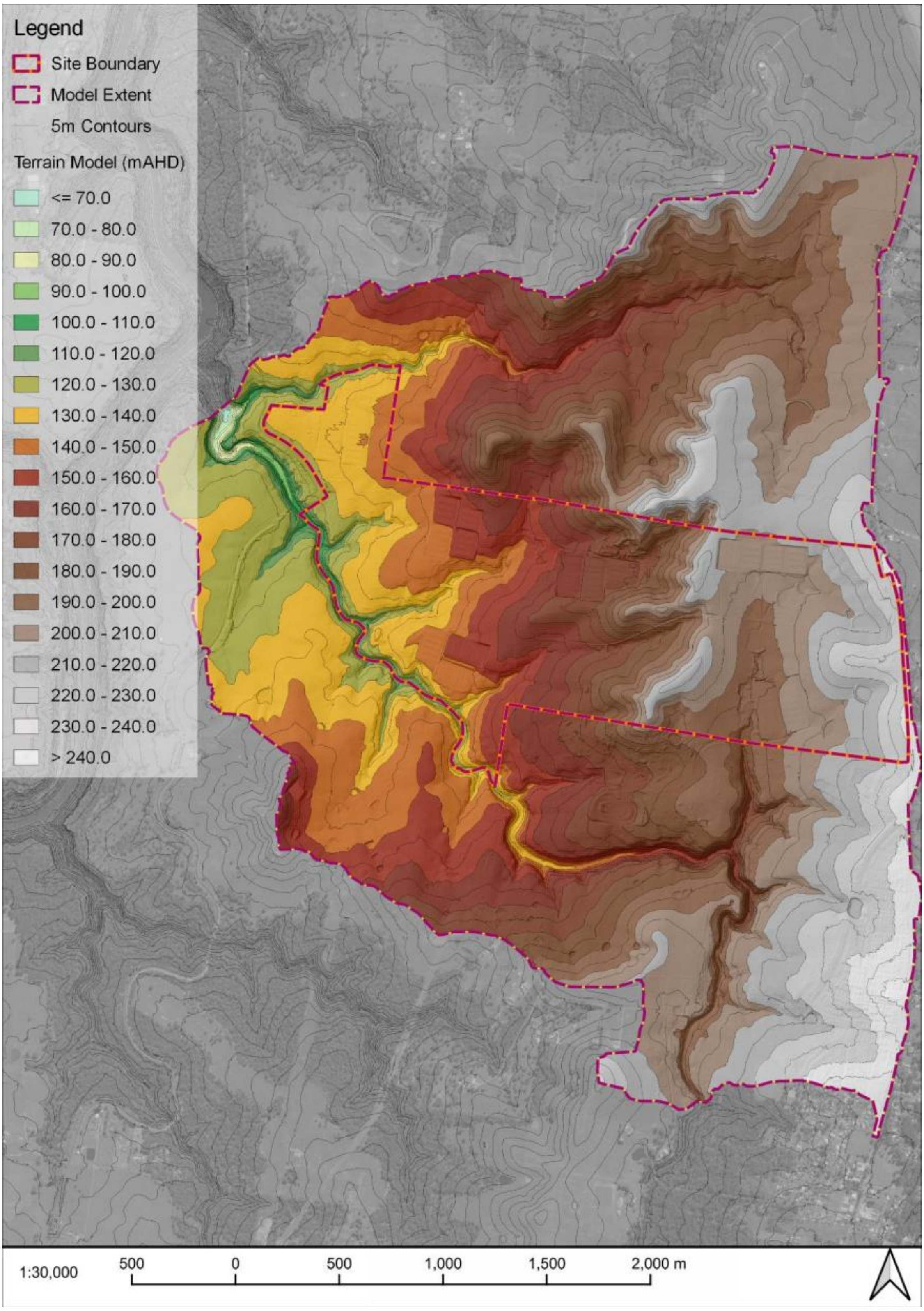

Figure 4-3 Digital Elevation Model – Existing Conditions

4.2.3 Data Gaps

At this stage of the analysis there remain several outstanding data gaps. It is expected that these will be obtained and incorporated into the model for subsequent work required at Development Application stage. The data gaps are as follows:

- Site feature and level survey;
- Details for hydraulic structures such as bridges and culverts;
- A separate hydrological model was not prepared, although the direct rainfall approach is considered a valid alternative to traditional hydrological modelling approaches according to validation undertaken by Ryan et.al. (2022) and the direct rainfall model is considered sufficient at this stage of the project;
- Detailed detention basin design has not yet been undertaken, although an indicative analysis was prepared, and these basins are included in the mitigation options analysis detailed in Section 5.

4.3 Hydrological Model Development

A rain-on-grid approach was undertaken for the hydrological analysis of the North Appin part Planning Proposal. The latest ARR2019 Guidelines and most recent industry standard TUFLOW software was adopted to model flow behaviour within the catchment for both existing and developed conditions.

4.3.1 Direct Rainfall Approach

The rain-on-grid approach applies a rainfall depth to every active cell within a specified active modelling area, based on an input rainfall hyetograph. The rainfall losses are controlled within the model via the Materials Definition File and rainfall losses applied remove the loss depth from the rainfall prior to application to the model (BMT, 2018). Rainfall data was obtained from the ARR Data Hub (Australian Rainfall & Runoff, 2022).

4.3.2 Existing Conditions Hydrology

The existing conditions catchment delineation was undertaken using the QGIS Plugin, PCRaster, following the methodology outlined by Hans van der Kwast (2021). The PCRaster tool automates the delineation of catchments, sub catchments and streams using the underlying 1m LiDAR data. PCRaster generates a set of maps indicating local drainage direction, Strahler Order of streams, and subsequently the catchments and sub-catchments were derived.

The rainfall catchment was extended sufficiently south of the site such that analysis of potential impacts on the adjacent township could be ascertained. The resultant rainfall inflow boundary is therefore 11.4 km^2.

4.3.3 Tailwater Boundaries

Two tailwater conditions were supplied by WSC for use within the model as follows:

- An inflow hydrograph for Ousedale Creek was provided at a specified location upstream of the development. These Ousedale Creek flows acted as tailwater conditions to the flow within the channels traversing the site.
- Downstream tailwater levels for Nepean River were provided by WSC. The Nepean River level is quite close to the western boundary of the site and consideration of joint probability at this location may be important. For the preliminary rezoning application however, the 1% AEP Nepean River level was adopted to determine the impacts on the western boundary of the site, however, a detailed joint probability analysis may be undertaken at a later stage of the project.

The existing case rainfall catchment and inflow and outflow boundaries are illustrated in Figure 4-4, whilst the specific parameters adopted for the modelling are included in A.1 for reference.

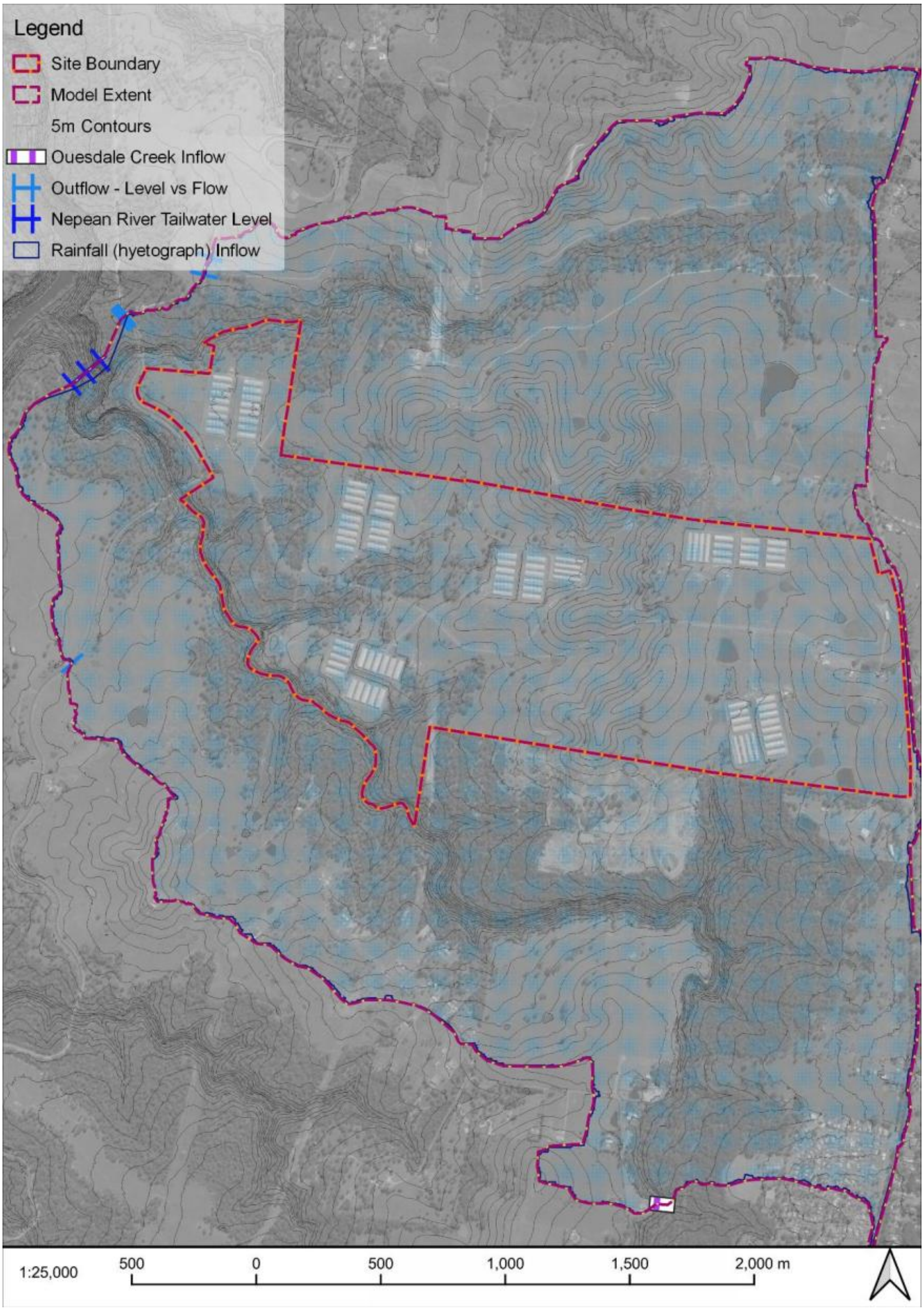

Figure 4-4 Inflow and outflow boundaries – existing conditions

4.3.4 Losses

The Australian Rainfall & Runoff ARR Data Hub recommends a five-step hierarchy for determination of catchment losses. Steps 1 through 3 rely on available calibration data from either the actual study area or similar adjacent catchments. Step four of the hierarchy uses the NSW Flood Frequency Analysis reconciled losses available through the Data Hub. For the North Appin (part) Precinct proposed site, the nearest catchment is the Nepean River, which is almost 40 times in size and contains significantly more catchment complexity comparatively. Southeast of the North Appin (part) Precinct site is the Wedderburn catchment, with a catchment area of 86 km^2. Although significantly larger than the catchment of interest, it was noted that the flows from this catchment utilising the Standard ARR method losses are very similar to the flows utilising the FFA-Reconciled losses. As such, it is assumed that the standard ARR losses can be adopted for the North Appin (part) Precinct study.

For pervious areas, event-based probability-neutral burst initial loss values available through the ARR Data Hub (2022) were adopted and the default ARR Data Hub (2022) continuing loss value with a multiplication factor of 0.4 was adopted as per the NSW jurisdiction specific Guidelines (WMA Water, 2019).

The loss values adopted for this study are outlined in Table 4-1.

Table 4-1 Rainfall losses

Parameter	Value Adopted
Initial Loss (Pervious)	45.0mm (Probability neutral for storm durations)
Continuing Loss (Pervious)	2.4 * 0.4 = 1.0 mm/hour
Initial Loss (Impervious)	1.0 mm
Continuing Loss (Impervious)	0 mm/hour

The full set of parameters adopted for the hydrology analysis are outlined in A.1.

4.3.5 Rainfall Spatial Analysis

Catchments with areas up to and including 20 km^2 are considered sufficiently small that there is little available data to derive a spatial pattern. For these catchments, it is usually acceptable to adopt a uniform spatial pattern (Jordan, et.al. eds., 2019). As discussed in Section 4.3.2, the 2D rainfall boundary adopted for modelling of the North Appin Project is 11.4 km^2 and as such a uniform spatial analysis was considered appropriate.

4.3.6 Critical Storm Duration

Advisian (2021) ran the Wollondilly Shire Flood Study for several durations and events. Their analysis suggests that watercourses draining roughly 10km^2 result in critical durations of approximately 3 hours. This varies significantly owing to catchment features such as shape, elongation, slope, topography etc. but shows insight into critical storm durations within the catchment. Given the site itself would have sub catchments less than 1km^2 it is expected that the time of concentration would be <1 hour. Review of the

Advisian (2021) map of the 1% AEP critical storm durations shows that Ousedale Creek transitions from a 1hr critical storm to a 3hr critical storm over the length of the site.

Owing to the size and complexity of the Nepean River catchment, an analysis of critical duration of the Nepean River is not within the scope of this study.

The Advisian study 1% AEP critical storm durations are illustrated in Figure 4-5 below.

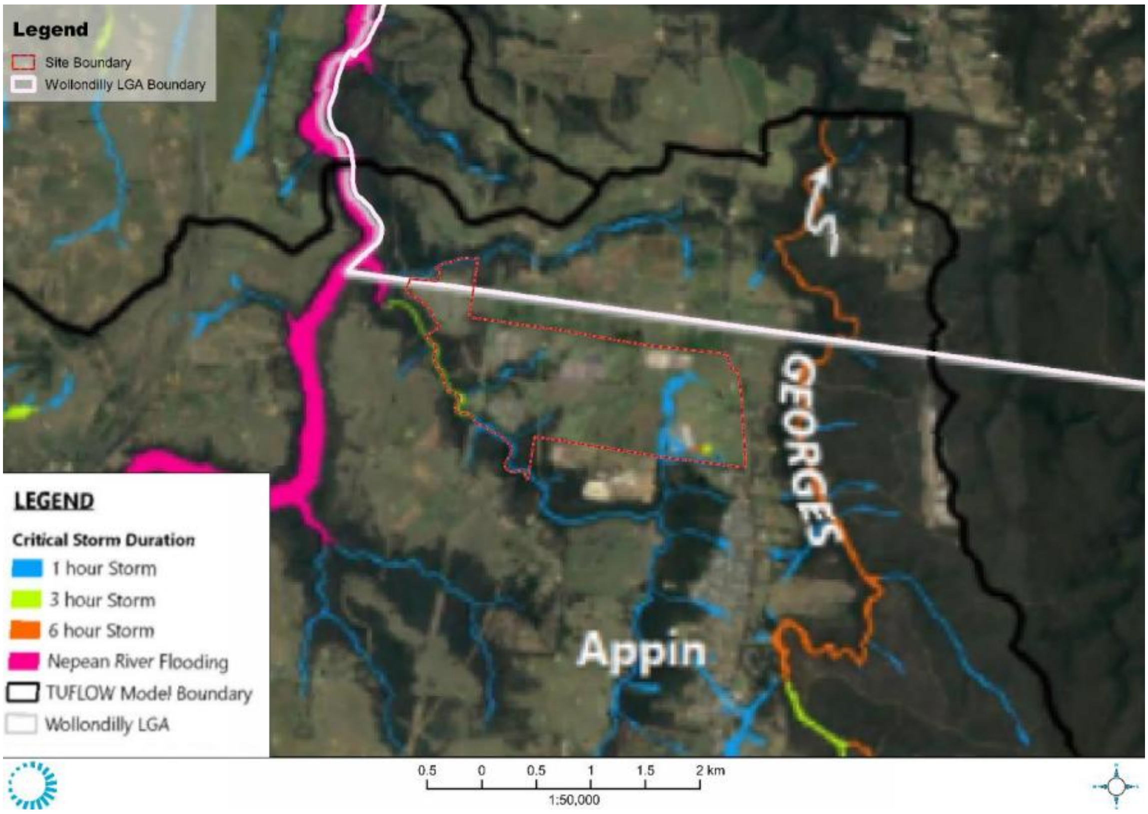

Figure 4-5 1% AEP Critical Storm Duration as outlined within the Wollondilly Flood Study

4.3.7 Simulated Storm Events

Following the Advisian (2021) critical storm duration analysis, an analysis of a range of ten storm durations, ranging from 15-minutes to 270-minutes, for all ten temporal patterns were initially simulated for existing conditions within this study for the purpose of determining the critical storm durations across the subject site. The simulation results were then analysed following the process outlined in Figure 4-6.

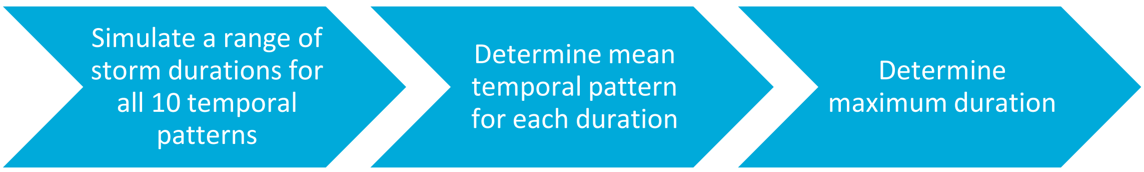

Figure 4-6 Process for determination of critical storm

This analysis illustrated that critical storm durations across the site are typically very short – ranging from 15-minutes to 45-minutes – owing to steep terrain in conjunction with the site being situated at the top of the catchment.

As can be seen in Figure 4-7 below, the key critical storm durations across the site are the 15-minute, 25-minute and 30-minute events.

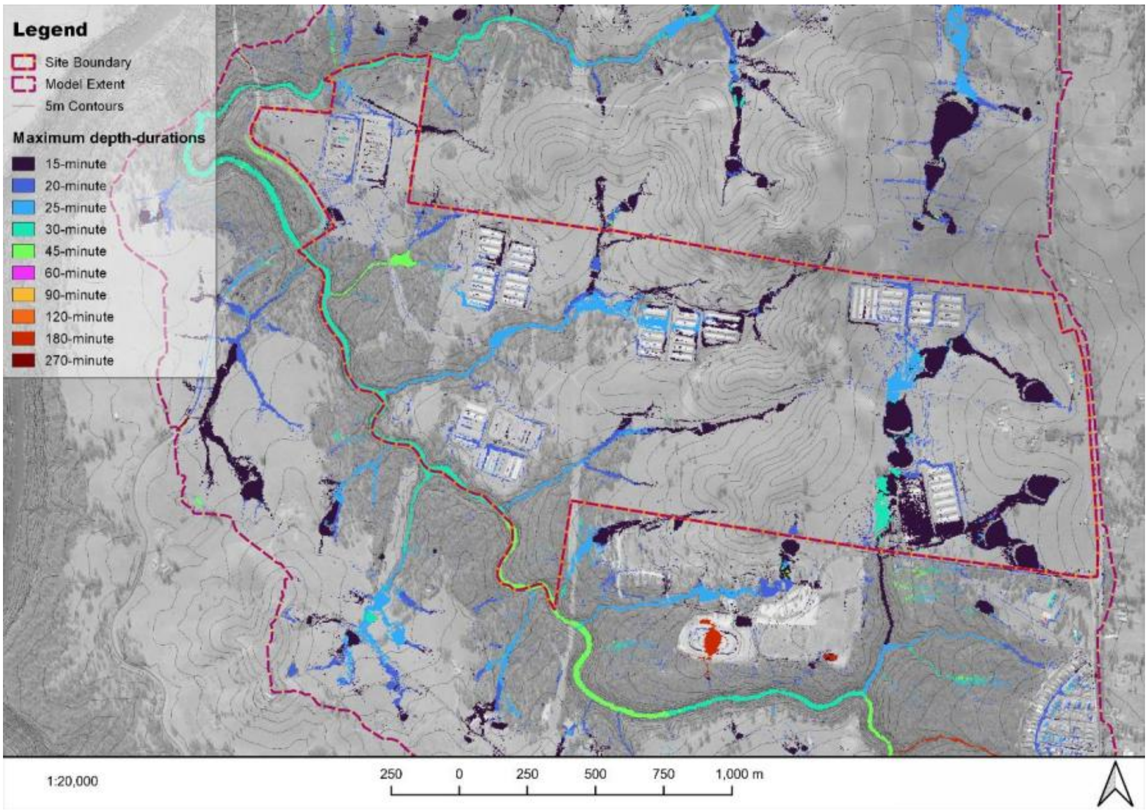

Figure 4-7 Site critical storm durations

For subsequent simulations four key storm durations were adopted from the initial analysis undertaken for this study (short-duration storms), and two storm durations adopted from the Advisian (2021) Wollondilly Flood Study Report to represent the critical storms for Ousedale Creek (60-minute and 180-minute). The mean temporal pattern was determined for each of these six storm durations.

The storms that were adopted for subsequent simulations are outlined in Table 4-2. The mean temporal patterns that were adopted for the short duration events were the patterns that were typically found to be mean across the site, whilst the temporal patterns adopted for the 60-minute and 180-minute durations were those that were found to be mean for Ousedale Creek.

A single hydrograph for each of the 10%, 1% and 0.2% AEP events was provided for the Ousedale Creek Inflow location by WSC, extracted from the Advisian (2021) Flood Study. The storm duration and temporal pattern for these hydrographs is unknown.

Table 4-2 Critical storm durations and mean temporal patterns adopted for simulation

Storm Duration	Mean Temporal Pattern
15-minute	TP08
20-minute	TP06
25-minute	TP09
30-minute	TP09
60-minute	TP08
180-minute	TP02

Upon simulation of the above six key storm events, with the inclusion of the Ousedale Creek inflow hydrograph provided by WSC, it can be seen from Figure 4-8 that the critical durations within Ousedale Creek now match those determined by the Wollondilly Flood Study – namely 1-hour and 3-hour storm events.

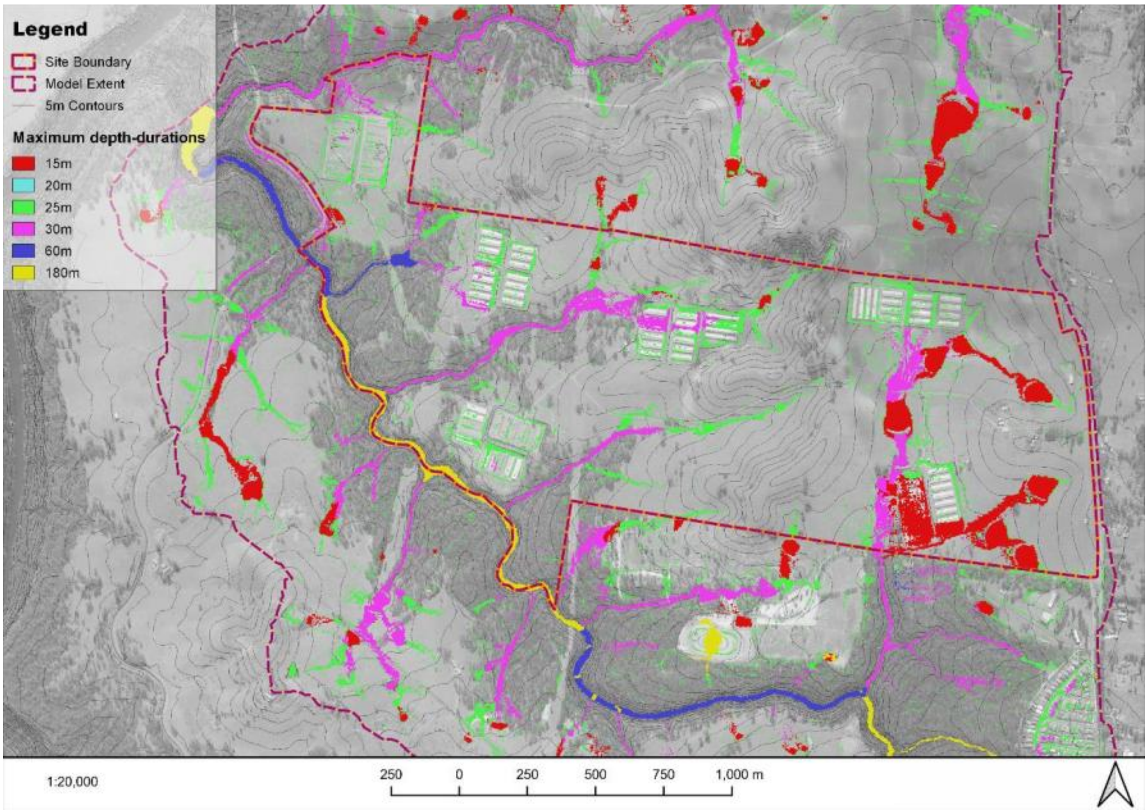

Figure 4-8 Critical storm with inclusion of Ousedale Creek inflow hydrograph

4.3.8 Developed Conditions Hydrology

For the developed conditions, it is assumed that all developed urban lots will be filled above the 1% AEP flood level. Therefore, the only change to the developed conditions hydrology was the removal of the lot boundaries from the rainfall catchment. At this preliminary stage of analysis, although the underground drainage network has not been designed and is not included in the TUFLOW model, it is assumed that direct rainfall from the lots will be managed by on-site drainage and directed into the adjacent road corridors. This was achieved via a modelling technique (2d_sa_rf boundaries) that allowed for the total rainfall depths to be maintained between existing and developed conditions. As the project proceeds, lot scale drainage will be modelled in more detail and the rainfall inflow boundary and 2d_sa_rf boundaries will be further refined.

All other parameters and storm events were retained between existing and developed conditions.

4.3.9 9Calibration/Validation

The flood modelling results are discussed in Section 4.6. Presented here is a comparison of the flows at key locations within the catchment to assess the validity of the hydrologic modelling approach adopted.

Validation of the TUFLOW results was undertaken utilising two separate methodologies. The ARR2019 recommended approach – The Regional Flood Frequency Estimation Model (RFFE) (Rahman & Haddad, 2016) is the most current means of validation for an ungauged catchment. The RFFE model has stated limitations that are applicable to this project as outlined below and therefore consideration of the now superseded Rational Method may be considered a viable flow comparison methodology. In addition, the Rational Method is applicable to small rural catchments like the three main catchments compared for this project.

The limitations of the RFFE model applicable to this project are as follows:

- Catchments which have been significantly affected by agricultural activities, construction of drainage or irrigation infrastructure, soil conservation works or mining activities;
- Catchments that are significantly steep; and
- Catchments with an area less than 0.5 sq km or greater than 1,000 sq km (Rahman & Haddad, 2016).

Results of the validation analysis are provided in Table 4-3, whilst the flow validation locations are illustrated in Figure 4-10.

Table 4-3 Flow validation

Validation Catchment	RFFE (m³/s)				TUFLOW (m³/s)	
	RFFE Result	Lower 5% Confidence Interval (m³/s)	Upper 95% Confidence Interval (m³/s)	NSW Rural Rational Method (m³/s)	TUFLOW Result	Difference From RFFE (%)
Watercourse 1	6.9	2.5	19	5.9	5.3	23.2
Watercourse 3	7.6	2.8	21	7.1	14.7	51.7
Watercourse 5	8.4	3.1	23.2	5.9	10.1	20.2
Full rainfall inflow boundary**	148	54	409	84.2	148.6	0.5

**Note: These values are prior to inclusion of the Ousedale Creek hydrograph and captures only the runoff from the rainfall inflow boundary in all cases.

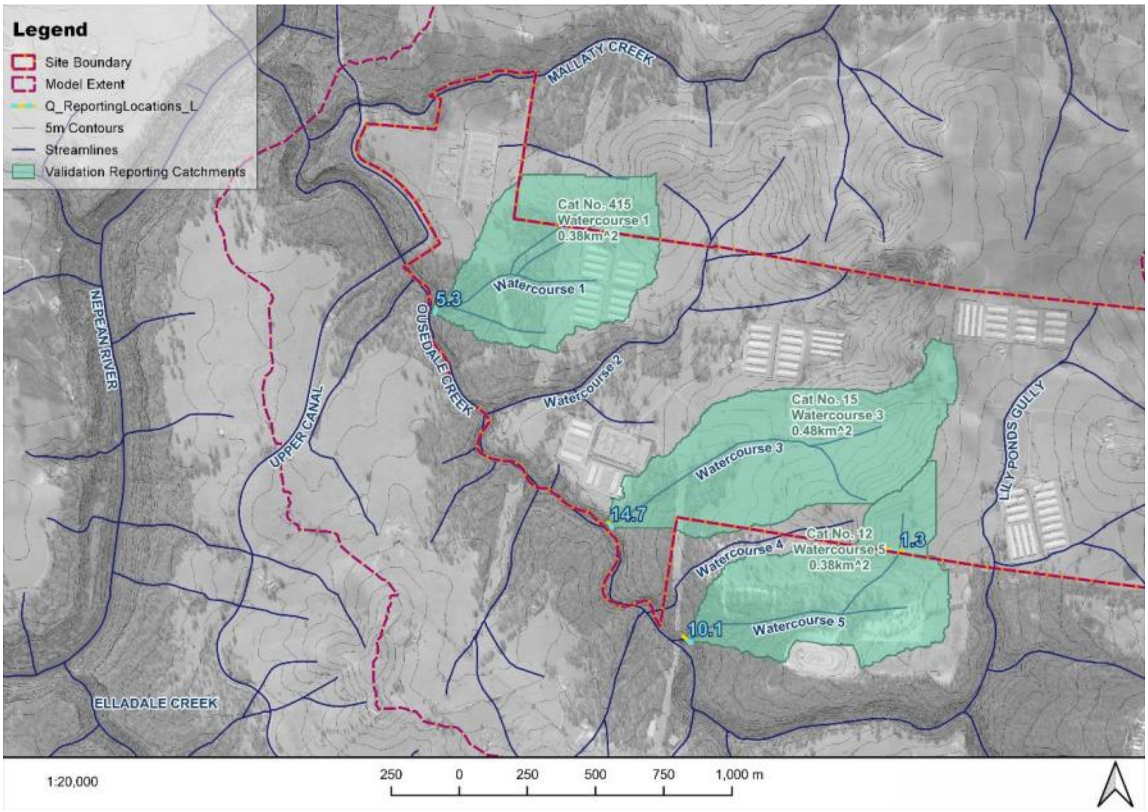

Figure 4-10 Flow validation locations

As can be seen from Table 4-3 above, the TUFLOW results typically fall well within the confidence intervals of the RFFE model and excepting Watercourse 3, are generally within 20% of the RFFE flow values. However, as described earlier, it should be noted that the limitations as specified by the RFFE model stipulate that the model has lower accuracy where the catchments are less than 0.5 square kilometres, have experienced large scale land clearing and affected by agricultural activities and for catchments with atypical characteristics (c.f. the gauged catchments used to create the model) such as steep catchments and streams with little vegetation along banks. It is likely that the RFFE model will underestimate the flows in these types of catchments.

Nevertheless, the final flow at the outlet of the model (utilising only the rainfall inflow polygon without the Ousedale Creek Inflow) is very similar to that predicted by RFFE. As such, it is considered that the flows determined by the TUFLOW model for this project are sufficiently appropriate for this high-level analysis.

4.4 Existing Conditions Hydraulic Model Development

The 2D model built for the hydrologic analysis for this study was also adopted for the hydraulic analysis to model flow behaviour and determine flood levels, depths, velocities, and hazard for both existing and developed conditions across the subject site.

The hydraulic model, the parameters adopted, and any assumptions made to undertake this flooding assessment are outlined in Sections 4.4.2 to 4.5.5 inclusive. An analysis of the model results and any impacts due to the proposed development are presented in Section 4.6.

4.4.1 Previous Studies

A full broad scale catchment analysis of flood depths and extents was undertaken by Advisian (2021) and preliminary analysis in the context of the North Appin (part) Precinct site shows that the proposed development generally lies outside of the mainstream flood extents of the Nepean River and Ousedale Creek. This site-specific study provides a more in-depth analysis of the flows within the creeks that traverse the site and the overland flooding across the site. The preliminary analysis was undertaken by Craig & Rhodes (2022) in their Water Cycle Management Strategy Report (attached).

4.4.2 Boundary Conditions

As discussed in Section 4.3, the hydrologic modelling adopted a direct rainfall approach.

The main model outflow at the Nepean River utilised an HT (water-level vs time) boundary. WSC provided result grids for the 10%, 1% and 0.2% AEP events and the PMF from the Wollondilly Shire Flood Study (Advisian, 2021). For this preliminary analysis, the 1% AEP flood level was adopted to achieve the most conservative result, however, joint probability analysis may be undertaken at a later stage in the project if required.

In other locations, the model utilised HQ boundaries, where HQ boundaries are water-level-flow boundaries that are automatically generated by TUFLOW based on a provided hydraulic grade line. In this case the slope used was the water surface elevation slope generated following preliminary model runs, as recommended by TUFLOW.

4.4.3 Farm Dams

It is assumed that existing farm dams do not act as detention within the study area and therefore they were assumed to be filled to the dam spillway level. This approach is conservative and ensures that dams do not unnecessarily act to attenuate overland flows. This is particularly important in a rain-on-grid (direct rainfall) model, as there can be significant resultant shallow sheet flows with depths less than 30-50mm across the catchment.

4.4.4 Mannings ‘n’ Roughness (Materials Definition File)

A materials definition file was used to define the Mannings roughness of the terrain surface. Aerial imagery and SixMaps cadastral data was used to delineate the specific roughness regions. Depth varying Mannings ‘n’ values were adopted due to the direct rainfall approach and the adopted values are consistent with the WSC Flood Study wherever possible. The roughness map is illustrated in Figure 4-11, whilst the values adopted for each respective ‘n’ value are outlined in Table 4-4.

Table 4-4 Mannings 'n' roughness values

Id	Material	'n' Value (y_1, n_1, y_2, n_2)
1	Impervious Area Rainfall Losses	IL = 1.0 mm CL = 0.0 mm/hr
2	Design ARR2016 Pervious Losses	Probability Neutral Burst Losses varying by storm duration
3	Concrete Lined / Irrigation Channels	0.05, 0.04, 0.1, 0.02
4	Watercourses	0.5, 0.1, 1.0, 0.04
5	Waterbodies, no emergent vegetation [assume zero infiltration]	0.03, 0.08, 0.1, 0.03
6	Roads	0.05, 0.06, 0.1, 0.03
7	Gravel Roads	0.03, 0.08, 0.1, 0.025
8	Rail Corridor	0.1, 0.16, 0.2, 0.08
9	Open Space (e.g., Minimal vegetation (grassed))	0.1, 0.06, 0.2, 0.04
10	Moderate vegetation (shrubs)	0.15, 0.16, 0.3, 0.08
11	Heavy vegetation (trees)	0.2, 0.24, 0.4, 0.12
12	Building Footprints	0.1, 0.02, 0.3, 0.3
13	Low density residential lots	0.1,0.12,0.2,0.06
14	Medium Density Residential	0.15,0.2,0.3,0.1
15	Large Residential Lots	0.1, 0.1, 0.2, 0.05
16	Industrial/Commercial (Large significant buildings)	0.15, 0.2, 0.3, 0.1
17	Limestone Quarry	0.05, 0.1, 0.1, 0.025
18	Default Model 'n' value – Rural, generally unmaintained grass, lightly vegetated	0.03, 0.1, 0.1, 0.045
19	Developed Conditions – Parks, Open Space, Minimal Vegetation, neatly maintained grass [assumed pervious]	0.1, 0.06, 0.2, 0.03
20	High Density Residential, slightly increased c.f. Wollondilly Flood Study	0.15, 0.25, 0.3, 0.15

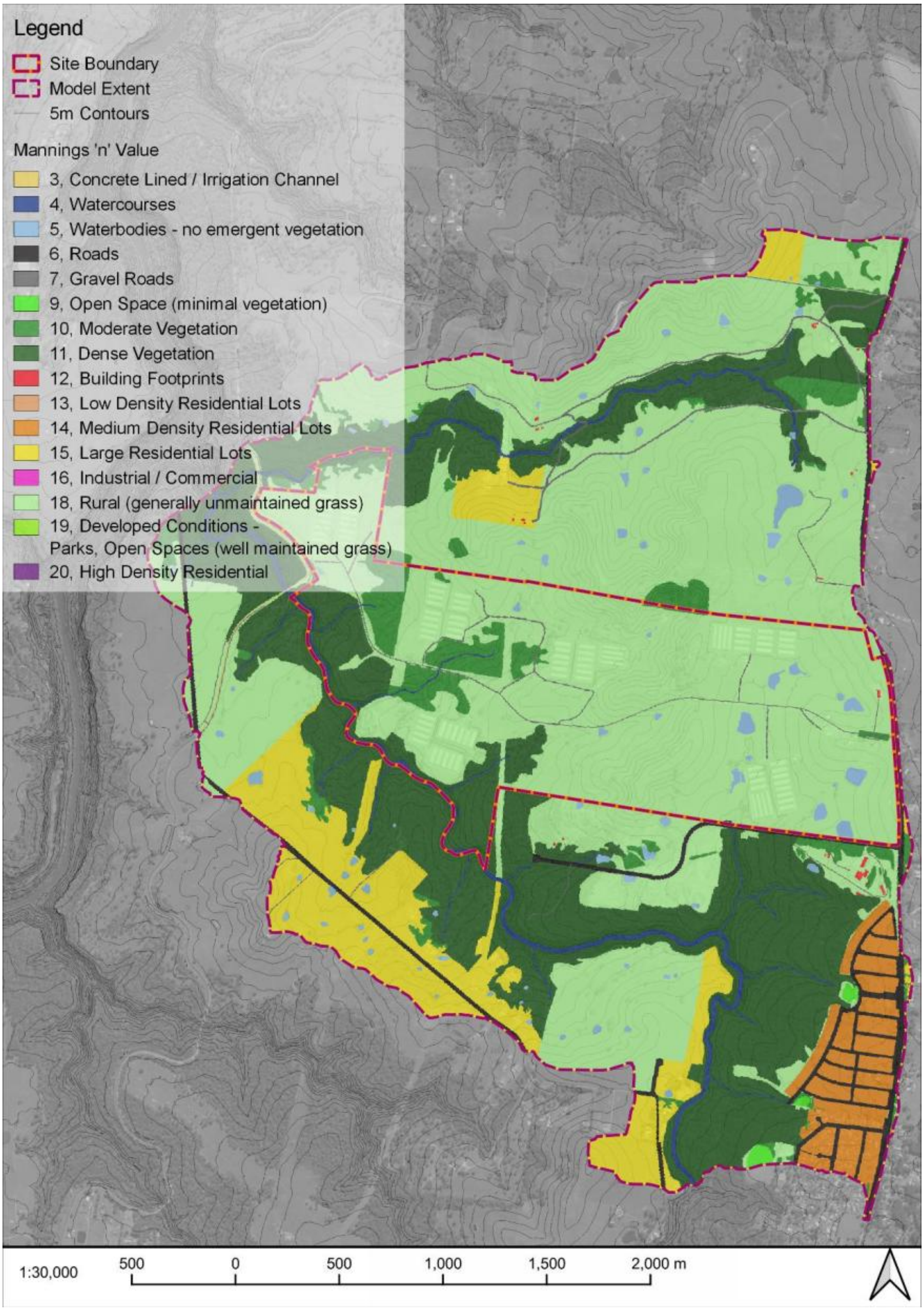

Figure 4-11 Mannings 'n' roughness layer – Existing Conditions

4.4.5 Structures

Due to insufficient information, a minimal number of existing structures were included within the model build. It is noted that there are likely to be bridge and culvert crossings along major and minor roads, as currently water is showing as ponded behind the roads, but there is no allowance in the model for detention at these locations. However, for the purpose of a preliminary assessment this is a conservative approach for flooding behaviour on-site but will need to be updated as the project progresses.

At this stage of the project, one bridge structure has been included over Ousedale Creek as illustrated in Figure 4-12. It is part of the Upper Canal maintenance track outside the site. It was felt important to include this bridge structure as it is close to the boundary of the site and may have backwater effects. Full details of this bridge are unknown; however, an approximate determination was able to be made using Aerial Imagery and Google Earth and these can be refined upon further investigation. The parameters adopted for the bridge are outlined in Table 4-5.

Table 4-5 Bridge structures

Existing Bridge	Parameter	Value adopted
Ousedale Creek @ southwest site boundary	Obvert	109.0 mAHD
	Deck thickness (Measured from Google Earth)	0.5m
	Bridge width (Measured from Aerial Imagery)	4.2m
	No handrails	

Figure 4-12 Location of existing bridge on Ousedale Creek

4.5 Developed Conditions Hydraulic Model Development

The following details were changed within the model to represent the Draft Structure Plan of the subdivision.

4.5.1 Terrain

A design tin that broadly represents the grading of the Draft Structure Plan was included into the developed case TUFLOW model. The resultant updated terrain is illustrated in Figure 4-13.

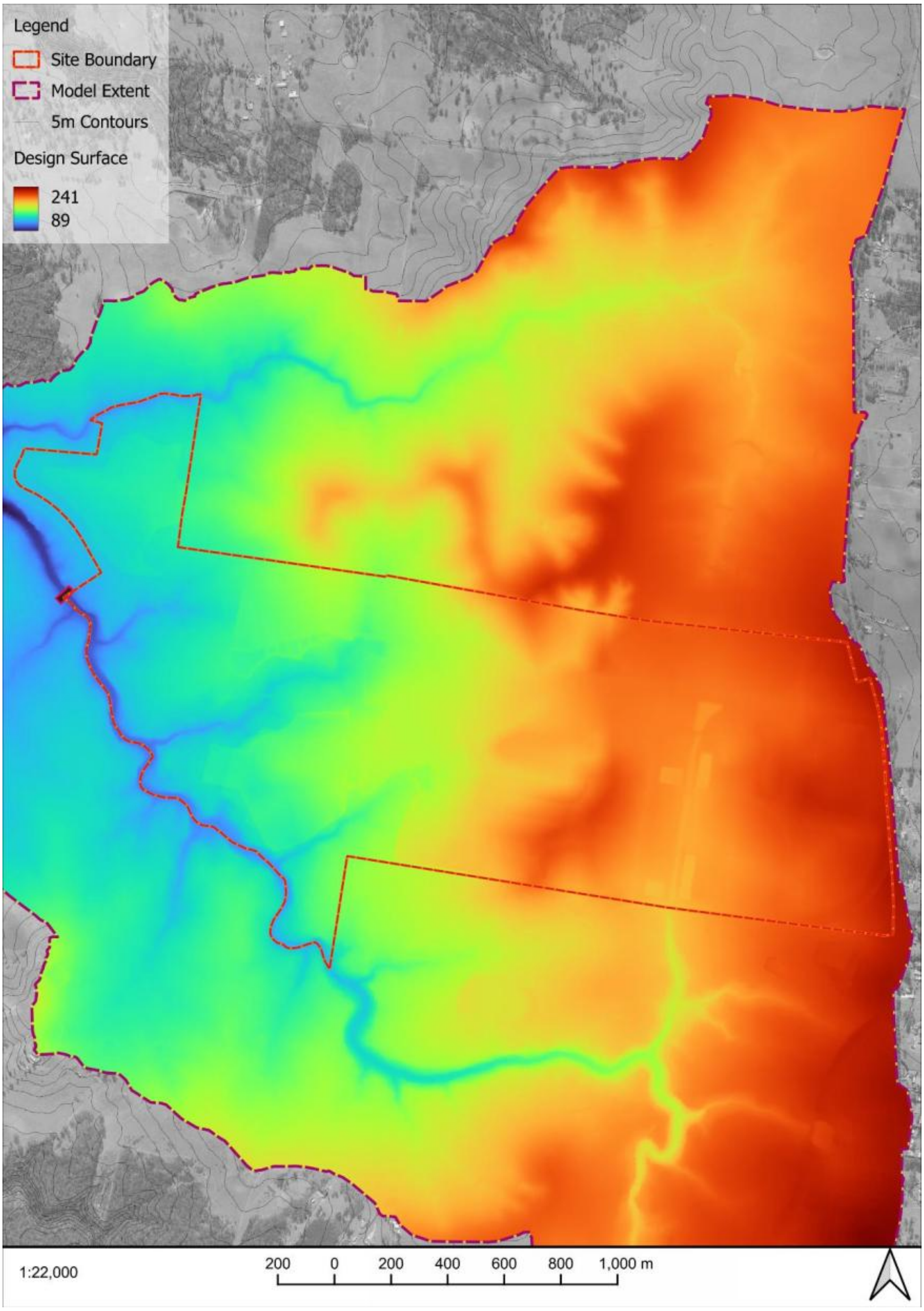

Figure 4-13 Digital Elevation Model – Developed Conditions

4.5.2 Boundary Conditions

The developed case inflow boundary changes to the hydraulic model were previously discussed in Section 4.3.

The outflow boundaries throughout the catchment remained the same as those adopted for the existing conditions.

4.5.3 Farm Dams

For the developed case model, several dams that are located within the site boundary were removed, all other dams were retained.

4.5.4 Mannings ‘n’ Roughness

The Mannings ‘n’ Roughness layer within the boundary of the site was updated to reflect the Draft Structure Plan, the same values as those outlined in Table 4-4 were adopted.

4.5.5 Structures

Several culverts were included within the model at the location of new roads. Indicative sizes have been adopted at this early stage of modelling and the culvert sizes will be optimised and reported as the project develops.

4.6 Flood Modelling Results

The results of the existing case and developed case flood modelling are detailed in Sections 4.6.1 and 4.6.2 respectively, whilst the impacts of the development on flooding are discussed in Section 4.6.3.

4.6.1 Existing Conditions Flooding

The terrain of the proposed development site is quite undulating and steep in parts and therefore it is located well above the Ousedale Creek and Nepean River floodplains, although the northwestern boundary does sit within the centreline of Mallaty Creek. In addition, the site is heavily modified by agricultural usage and therefore overland flooding is patchy and often follows agricultural tracks rather than the original natural valley lines.

The main watercourses that traverse the site tend to be quite incised and therefore flooding is typically contained within the banks of the channels, except where there are numerous farm dams that overtop and cause flooding across the floodplains.

Lily Ponds Gully carries water that is typically 0.3 – 0.75m deep through the site and further channelises downstream, where depths increase to 1.5 – 1.75m. There is shallow sheet overland flooding across the original chicken farm pads in the east of the site to a depth of 0.15m.

Watercourse 5 ponds behind a set of existing raised tracks in the Macarthur Motorcycle Club to a depth of 0.95m and then follows a series of motorcycle tracks downstream, rather than the original formed watercourse.

Watercourse 4 is very shallow and traverses the northern boundary of the motorcycle track, with depths ranging from 0.1m to 0.25m.

The depth of Watercourse number 3 ranges from 0.3m upstream to 1.2m at the confluence with Ousedale Creek and the downstream site boundary.

Watercourse 2 presents the most typical watercourse behaviour within the site. There is some ponding at the northern boundary to a depth of 1.5m, shallow sheet overland flows downstream to the dam and then the floodwaters are contained within the channel until the confluence with Ousedale Creek. However, ponding behind an internal farm road occurs, where water ponds to a depth of 5.5m. This is presented conservatively, however, as there is likely to be culverts or a bridge at this location, which would allow water to pass freely downstream.

Watercourse 1 has only shallow sheet flows around the location of the northern site boundary, however once the three tributaries confluence at a farm dam, the water ponds behind a road to a depth of 4m and then flow downstream of the road is contained within the channel. Like Watercourse 2, it is likely that a culvert or bridge would be present at the road and therefore the ponding illustrated is probably conservative.

Across the northwest corner of the site, a tributary of Mallaty Creek is flowing with depths between 0.3m and 1.5m.

Shallow sheet flow behaviour is observed across the site, with depths between 0.15 and 0.35m, particularly around the chicken farm fill pads. There are several farm dams located across the site that typically fill to depths of 1.0 – 1.5m and in some cases these dams spill and flow downstream.

There are several locations where flood waters pond behind existing roads, this is due to the lack of structure information and therefore culverts or bridges are not included within the model. This prevents water from flowing freely downstream and realistically the ponding may not be as significant as illustrated. Nevertheless, ponding behind the roads will need to be considered in the proposed lot layout.

Finally, provision for riparian corridors will be needed in the proposed lot layout to account for the presence of the channels illustrated and to allow water to pass through the site without impacting urban lot development.

The existing case flood depth results are illustrated in Figure 4-14 below.

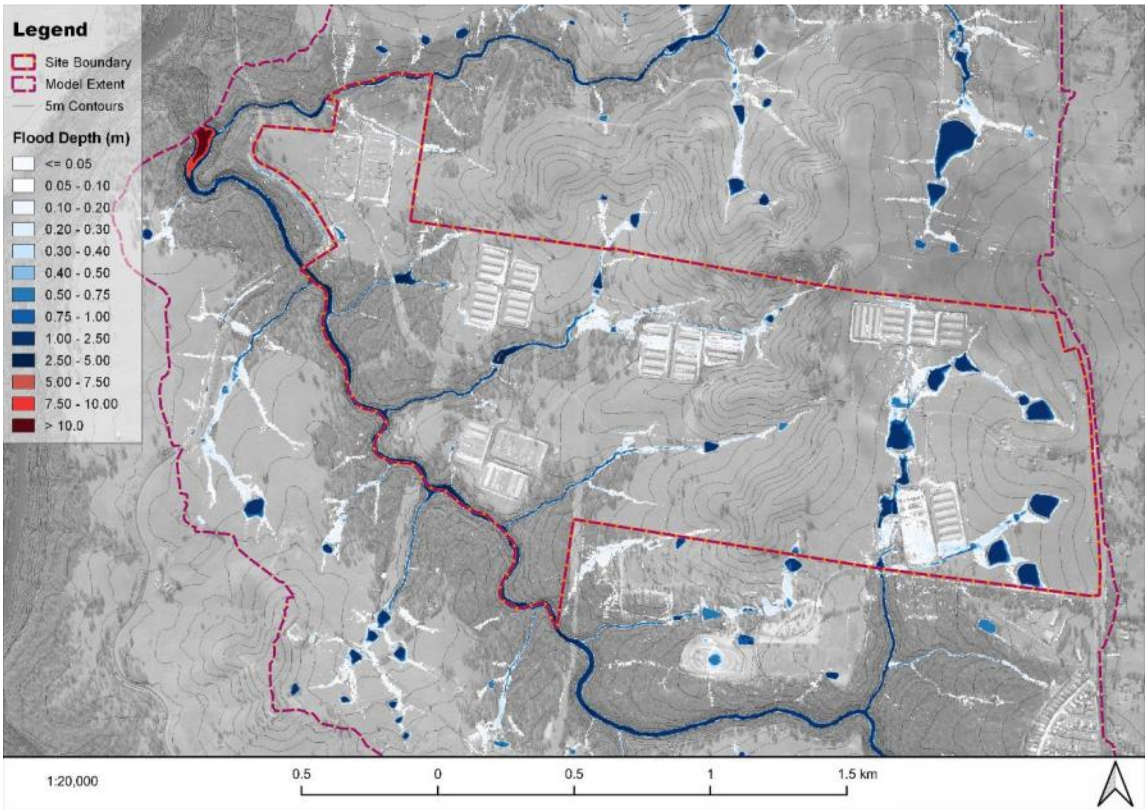

Figure 4-14 Existing conditions flood depth map

4.6.2 Developed Conditions Flooding

The 1% AEP developed conditions flood depth map for North Appin (part) Precinct is illustrated in Figure 4-15 below. As illustrated, the following flood behaviour is evident:

- Most of the flooding across the development site is shallow sheet flooding of depths up to 150-200mm, which can easily be contained within an underground drainage system once designed.
- The shallow sheet flooding is mostly contained within road corridors.
- There is some ponding upstream of the precinct due to the earthworks grading, however, this can be refined within the next iteration of modelling at DA stage
- Waterway flooding is typically contained within the proposed riparian corridors and not overtopping onto residential areas.
- The detention basins are currently acting to contain flows, with only one detention basin in the east noticeably spilling, however, the basin and culvert design within the model has not been optimized and this can also be refined within the next iteration of modelling at DA stage.
- The Ousedale Creek floodplain is not impacting residential areas of the development in the 1% AEP.
- The downstream tailwater of the Nepean River also does not impact residential areas of the development utilising a worst-case modelling scenario of combining the 1% AEP flood events of both Ousedale Creek and the Nepean River.

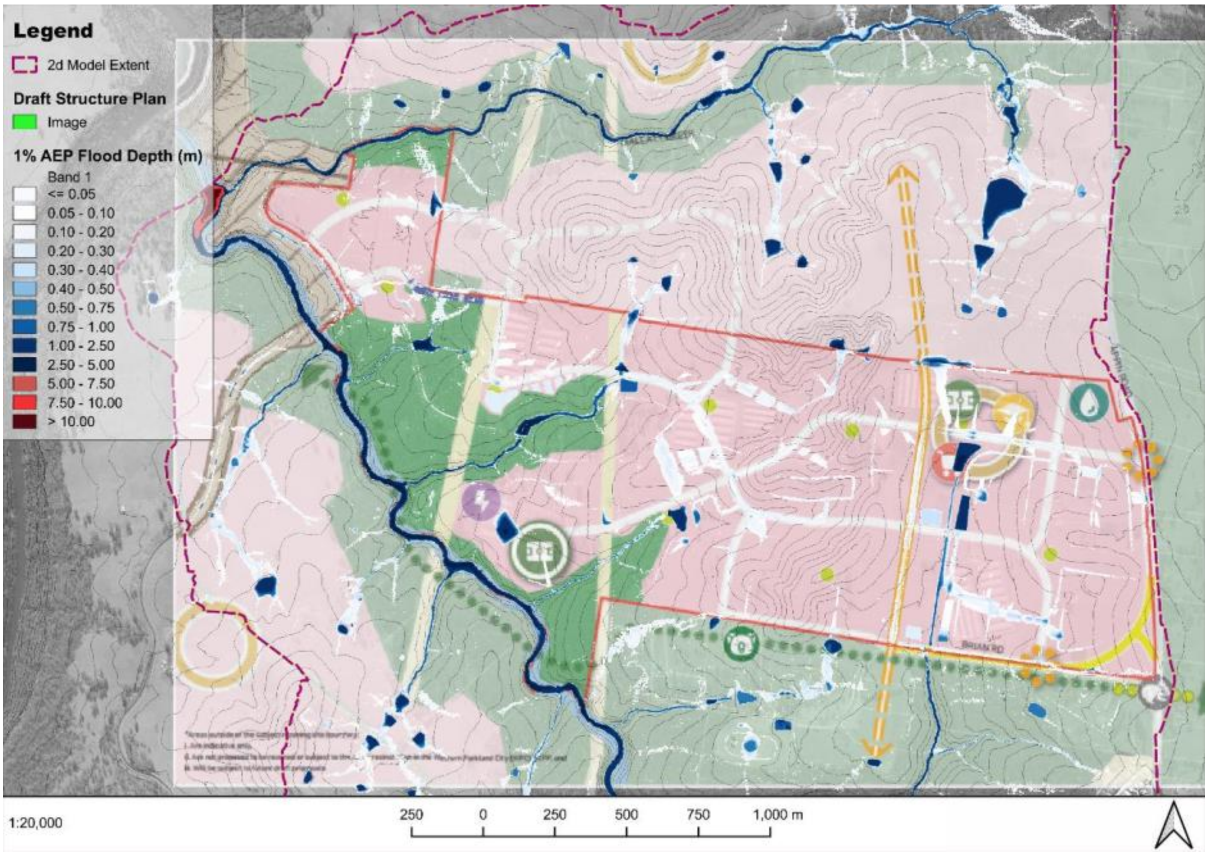

Figure 4-15 1% AEP developed conditions flood depth (m)

4.6.3 Impacts

Afflux is the difference between water surface elevation levels in the developed case and water surface levels in the existing case. The afflux map is illustrated in Figure 4-16 below. The following changes in flood behaviour are evident due to the North Appin (part) Precinct draft structure plan:

- Off-site impacts are contained to two areas of localised ponding along the northern boundary, with increased depths of up to 1.5 and 4m in each location respectively. Both areas are contained within the rural landscape and do not affect existing dwellings.
- The downstream waterways show a reduction in flood levels of approximately 0.4-0.5m. This is likely due to minimal culvert design within the model at Planning Proposal stage, this will be undertaken in further detail at DA stage.
- There are negligible impacts to Ousedale Creek, with a reduction in flood levels of typically less than 0.1m.
- Increased flood levels are contained within the site boundary and are most commonly due to addition of detention basins and the changed alignment of Lily Ponds Gully.
- Other changes in flood levels within the site boundary are due to the changed earthworks terrain.

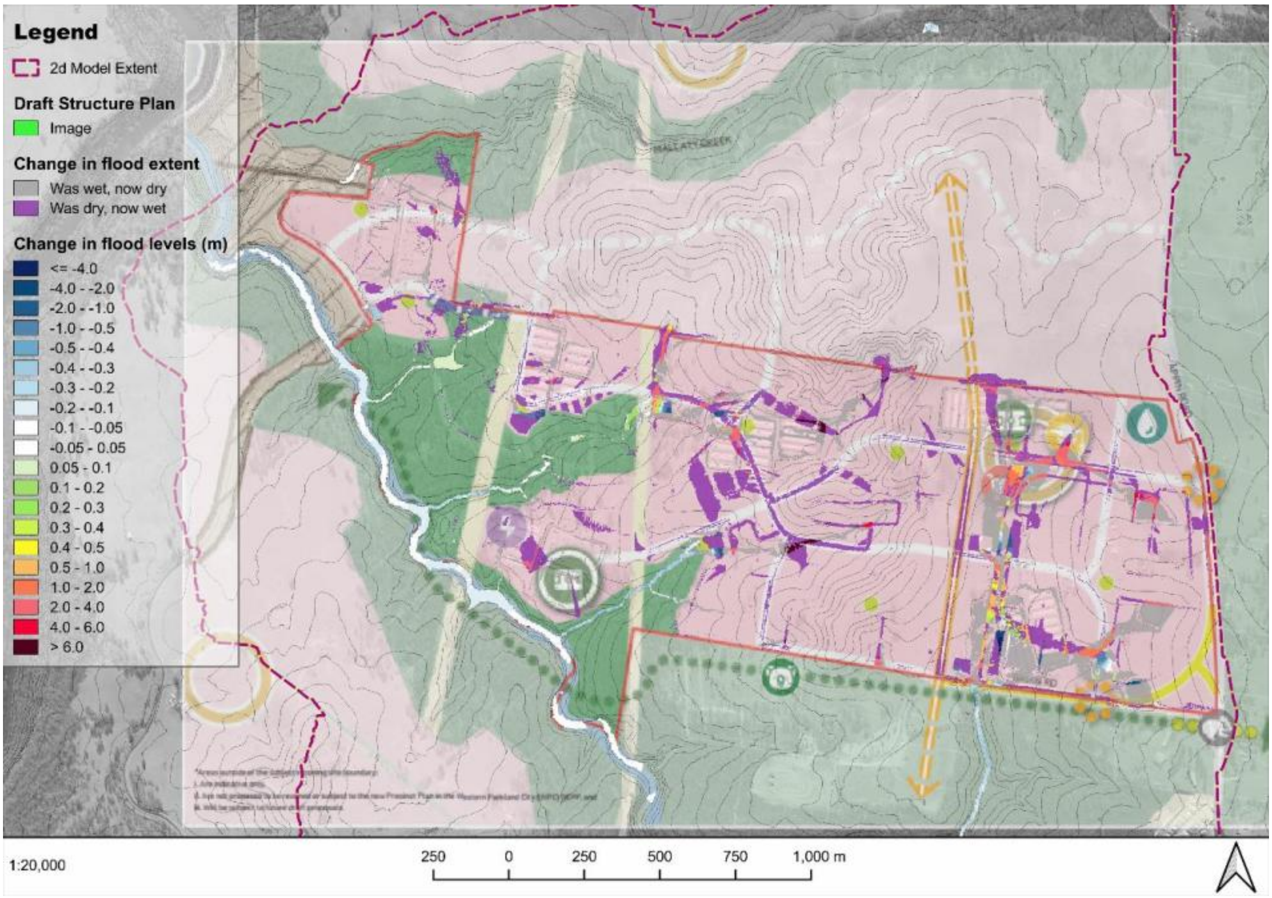

Figure 4-16 1% AEP afflux map

4.7 Discussion

Preliminary 1% AEP flood modelling for North Appin (part) Precinct demonstrates that there are negligible offsite impacts due to the Draft Structure Plan. Changes in flood levels within the site are due to changed earthworks terrain and flooding is typically contained within riparian corridors and the preliminary road alignment. Nevertheless, with further refinement of the basin sizing, outlet culverts and the addition of an underground stormwater drainage system at DA stage, we are confident that these minor impacts can easily be mitigated. Thus, the proposed development is considered acceptable from a flooding perspective.

5. Water Quantity Management Strategy

An analysis of the flow behaviour and preliminary detention basin sizing was undertaken using the industry standard hydrologic software RORB. The site generally drains in a south-westerly direction towards Ousedale Creek. As the site is located at the top of the catchment, the majority of flows originate within the site boundary and have short times of concentration.

It is generally unlikely that peak flows from the developed site will coincide with the peak flows within Ousedale Creek, as the critical durations for the site runoff is very short – 10-20 minutes, whilst Ousedale Creek has a critical duration of typically 3 hours. However, from the Riparian Corridor Assessment undertaken by J. Wyndham Prince (2023), there are several waterways within North Appin (part) Precinct that are required to be retained, and inclusion of detention basins at these locations will ensure that peak runoff from the developed site does not co-occur with peak flow within these waterways. In addition, stormwater runoff requirements within the Water Quality analysis were not met, and therefore inclusion of detention basins will offset the peak daily stormwater runoff.

Detention is primarily proposed for the northern portions of the development where external catchments from north of the site cause slightly larger runoff within the site and it can be demonstrated that this is sufficient to ensure that flows reaching the downstream outlet to the receiving waterways can be retarded to existing, therefore ensuring there are no adverse impacts on the waterways, particularly Ousedale Creek.

5.1 Preliminary Onsite Detention Basin

A preliminary analysis was undertaken using a Site Storage Requirement (SSR) of approximately 450m3/ha. This figure is more conservative than the Upper Parramatta River Catchment Trust's (UPRCT) range of values for key catchments.

Following this preliminary analysis, the basin sizes and locations were tested within the RORB model, and it was found that an optimised basin arrangement was warranted. The proposed indicative detention basin layout is provided in Figure 5-1. Within the RORB model, refinement, and sizing of basins D01, D02 and D03 was undertaken, and the remainder of the basins were analysed at a high-level within the same model. This approach provided an indicative understanding of the basin requirements for the site and demonstrated that flows can be attenuated to pre-development level.

The results of the RORB analysis for D01, D02, and D03 are provided in Table 5-1 and a comparison of the resultant flows downstream of North Appin (part) Precinct are provided in Table 5-2.

The basins are situated in locations within the catchment to minimize bypassing flows and are designed to ensure attenuation of flows up to and including the 1% AEP.

Table 5-1 Detention basin results - eastern catchments

Basin	Design Inflow (m^3/s)	Outflow (m^3/s)
D01	9.2	3.2
D02	7.8	6.1
D03	2.5	1.4

Table 5-2 Comparison of flow results downstream of site

Location	Existing Flow ((m^3/s))	Mitigated Flow (m^3/s)
Eastern outlet at Brian Road (d/s site boundary)	23.3	22.0
Ousedale Creek	67.7	66.9

Table 5-2 demonstrates that for the eastern portion of the site, flows are attenuated to slightly lower than pre-development for both the immediate outlet to Lily Ponds Gully and further downstream to Ousedale Creek.

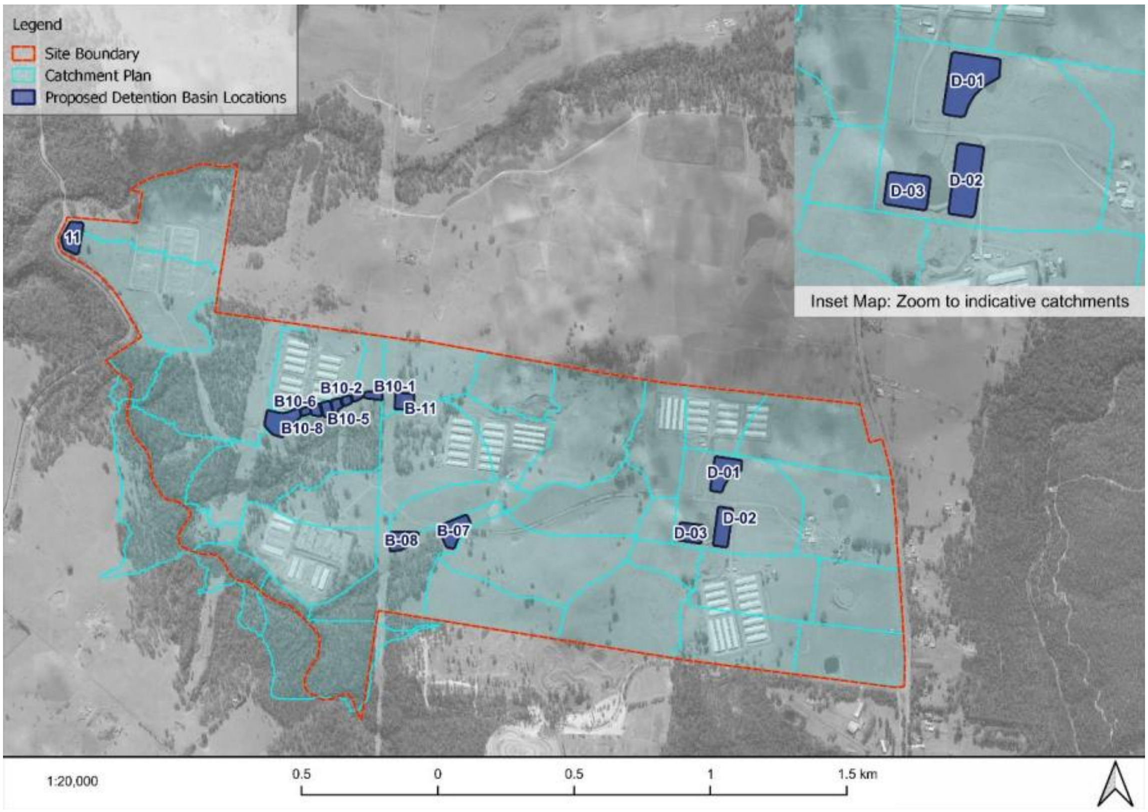

Figure 5-1 Proposed indicative detention basin layout

The basin design will be further optimised at DA stage, and it is expected that refinement of the basin outlets will result in the basin volumes and footprints being altered in future design iterations.

Further detail of water quantity control structures is to be designed at DA stage. These controls include sediment and erosion control, outlet structures, rip-rap design, and other measures to ensure the proper disposal of flows from the site in a manner compatible with Council's controls and the receiving environment.

6. Ecology and Habitat Management

The proposed Water Cycle Management Strategy manages the effect of waters leaving the development, and their effect on the downstream ecology. The infrequent flows are managed through onsite detention with peak flow attenuation to pre-developed conditions of all flows up to and including the 1% AEP.

Travers Bushfire and Ecology prepared a CPCP Compliance assessment which covers aspects of the ecology and habitat management. The proposal is to comply with any future Ecological and Habitat Management assessments.

7. Riparian Corridor Assessment

Watercourse mapping was undertaken by J. Wyndham Prince (2023) and shows that the development site is intersected by a series of existing watercourses, many of which are located within environment conservation areas. Ousedale Creek traverses the southern site boundary, and the Nepean River traverses the western site boundary.

The assessment was undertaken in accordance with the NRAR (2018) *Guidelines for controlled activities on waterfront land* (The Guidelines) are shows that the watercourses range between first and fourth order using the Strahler classification system.

The Guidelines state that where a watercourse does not exhibit the features of a defined channel with bed and banks, the regulator may determine that the watercourse is not waterfront land for the purposes of the Water Management Act (2000) (J. Wyndham Prince, 2023).

J. Wyndham Prince (2023) completed an assessment to determine whether the watercourses that traverse the site could be reclassified to not be considered waterfront land and therefore remove the need for riparian corridor considerations. The results of the assessment are illustrated in below. The results of this assessment were taken into consideration when preparing this Water Cycle Management and Flooding Report.

Figure 7-1 Riparian Corridor Assessment undertaken by J. Wyndham Prince (2023)

8. Conclusion and Recommendations

This Water Cycle Management Strategy Report details the high-level assessments that were undertaken for Water Quality, Water Quantity and Flooding for North Appin (part) Precinct.

The analysis provided high level sizing and locations of proposed water quality treatment train features. The water quality management strategy was developed and modelled in MUSIC, with the assessment confirming that a combination of rainwater tanks, vegetated swales, gross pollutant traps and bioretention basins achieve the water quality targets for both the Wollondilly Shire Council and NorBE for all pollutants.

Flood modelling was undertaken utilising the industry standard software TUFLOW, flood behaviour is described, and flood maps are provided within the appendices. The results of the flooding analysis demonstrates that there are negligible offsite impacts due to the proposed draft structure plan and all development lots will be located above the 1% AEP flood levels. PMF flood modelling was not undertaken for the Planning Proposal and will be undertaken at DA stage to assess evacuation constraints and address Emergency Management Planning.

On-site detention basins were sized based on high level assessments consistent with the UPRCT and then modelled within the industry standard software, RORB. The analysis demonstrates that stormwater runoff can be attenuated to existing conditions flows leaving the site. The basin volumes and footprints will be further refined at a future stage upon completion of the masterplan.

The findings of this report support the proposed North Appin (part) Precinct rezoning application with further analysis and detail proposed at DA stage to confirm and refine these findings. The future analysis will include catchment specific modelling of water quality and water quantity requirements for the site and refined flood modelling that incorporates stormwater drainage, culvert and bridge structures feature and level survey if required.

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Appendix A
Flood Modelling Parameters

A.1 Hydrology Parameters

The following parameters were obtained from the ARR2019 Data Hub and are detailed in Table A.1 - 1 and Table A.1 - 2.

Table A.1 - 1 ARR2019 Data Hub Parameters

Parameter	Value
Storm Continuing Loss	2.4 * 0.4 = 0.96 (has been rounded to 1.0 by the Data Hub)
Storm Initial Loss	Outlined in Table A.1 - 2
Temporal Patterns	East Coast South
Areal Reduction Factors	Southeast Coast a = 0.06, b = 0.361, c = 0.0, d = 0.317, e = 8.11e-05, f = 0.651, g →I = 0.0
Climate Change Factor (when required)	2090, RCP 8.5
Pre-burst	Not required

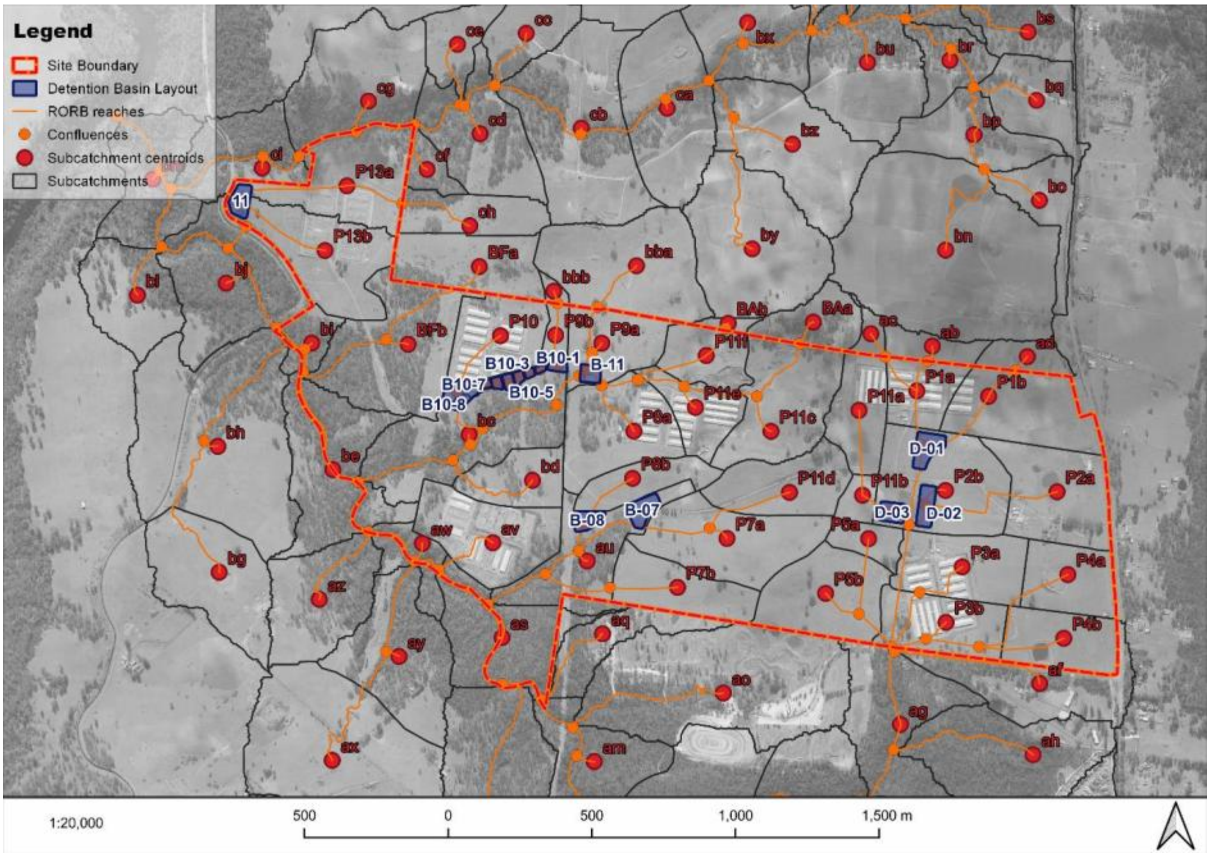
Table A.1 - 2 Probability Neutral Burst Initial Losses

Duration (mins)	63.20%	50%	20%	10%	5%	2%	1%
10	-	3.4	1.9	1.9	2.2	2.2	2.1
15	-	5	2.8	2.9	3.2	3.4	3.1
20	-	6.7	3.7	3.9	4.3	4.5	4.2
25	-	8.4	4.7	4.9	5.4	5.6	5.2
30	-	10.1	5.6	5.8	6.5	6.8	6.2
45	-	15.1	8.4	8.8	9.7	10.1	9.4
60	-	20.1	11.2	11.7	12.9	13.5	12.5
90	-	23.9	13.7	13.8	14.7	15	10.9
120	-	24	14.3	13.9	13.7	13.1	11.4
180	-	24	16.2	15.4	14.7	13.2	9.3
270	-	23.5	16.2	15.7	14.1	13.2	8.4
360	-	23	16.3	15.9	13.6	13.2	7.6
540	-	26.9	19.5	17.9	15.1	13.2	5.5
720	-	30.7	22.6	19.9	16.7	13.3	3.4

Appendix B
RORB Model

B.1 RORB Model

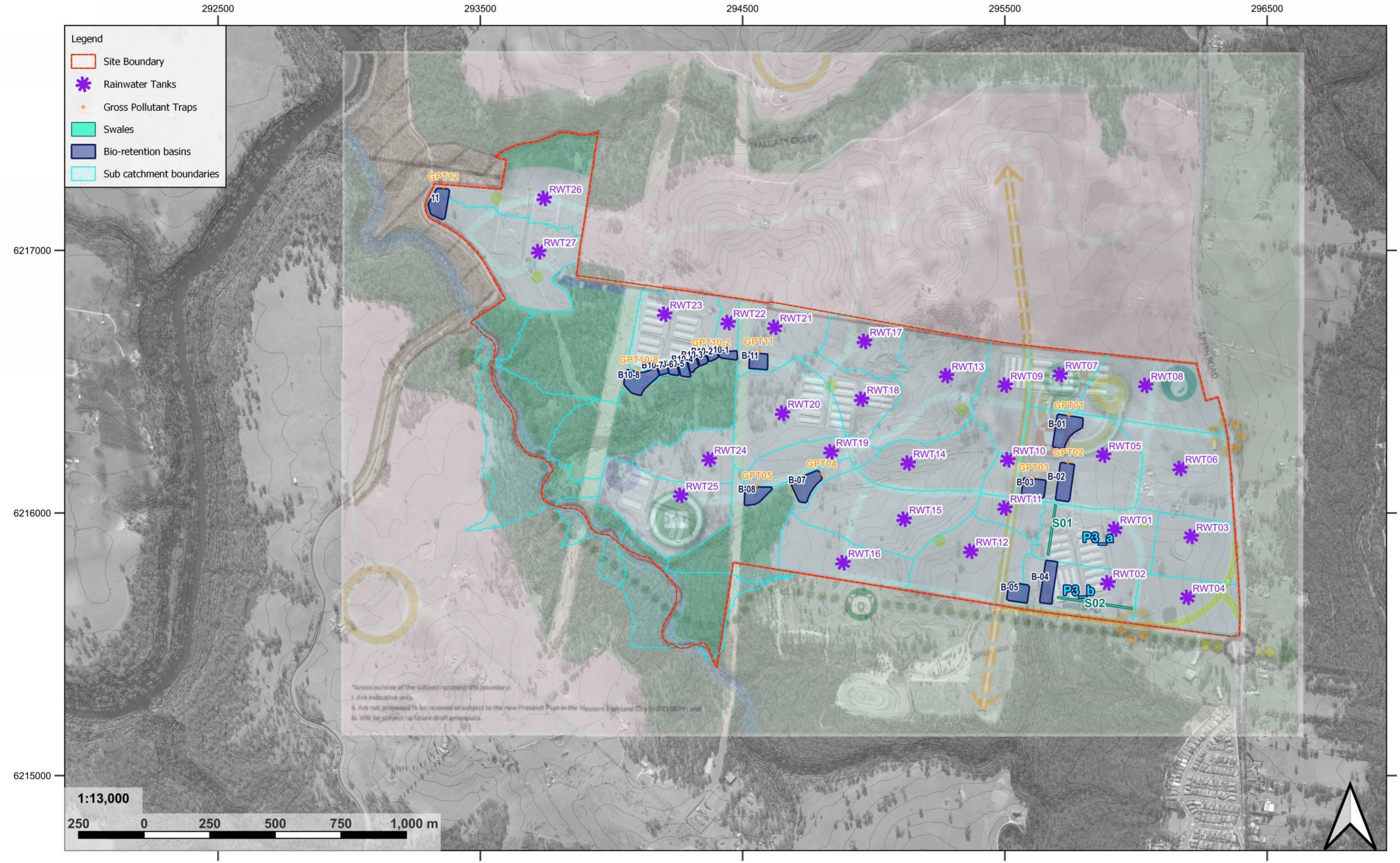
RORB model schematic built for the Detention Basin Assessment – Developed Conditions Model



Appendix C

Water Quality Management Strategy

C.1 Water Quality Management Strategy



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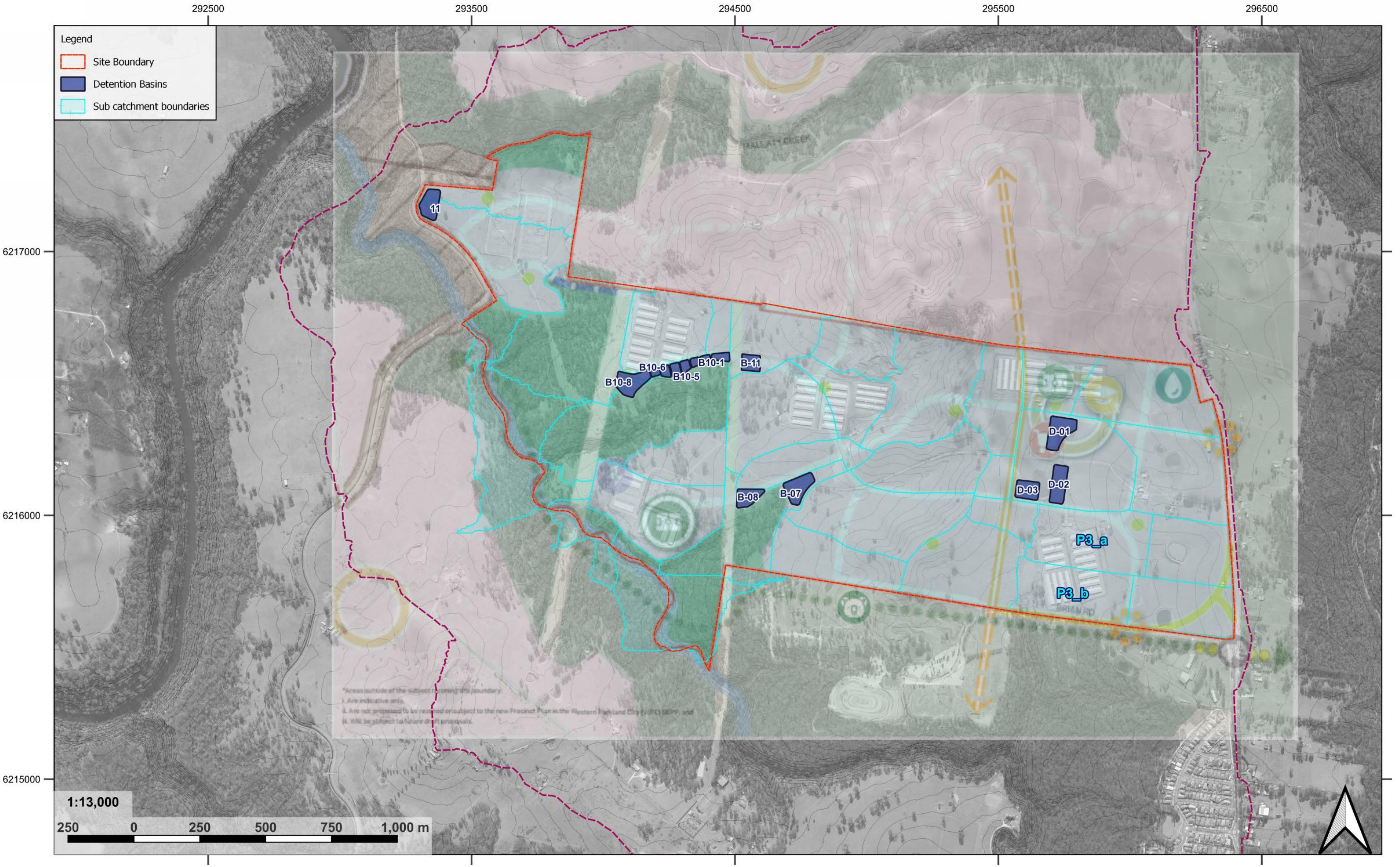
Map 01: Water Quality Strategy
Project: North Appin part Precinct Planning Proposal
Project Number: 1098-22
Client: Ingham Property Group



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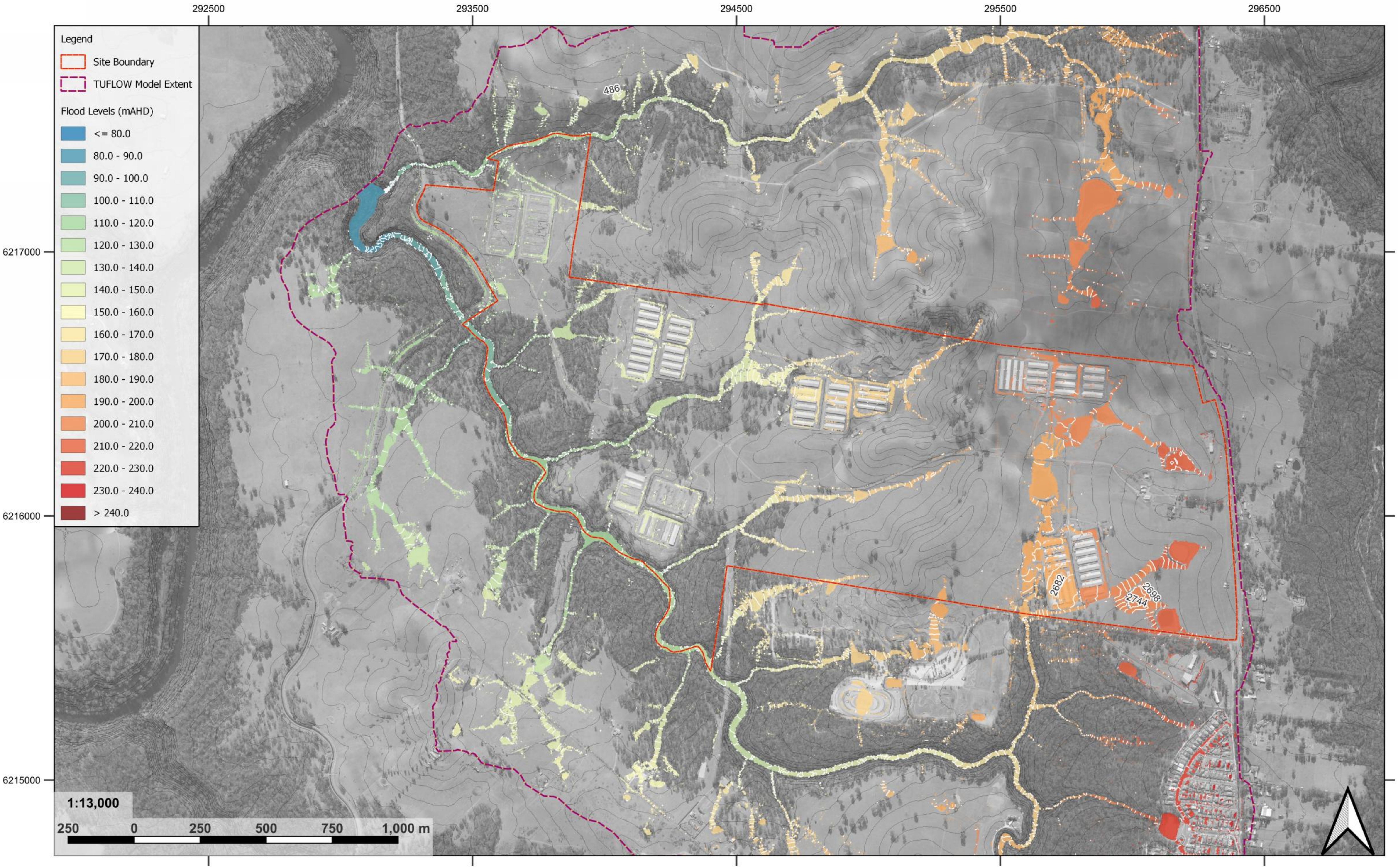
Map 02: Detention Strategy
Project: North Appin part Precinct Planning Proposal
Project Number: 1098-22
Client: Ingham Property Group

Appendix D
Flood Mapping

D.1 Flood Mapping



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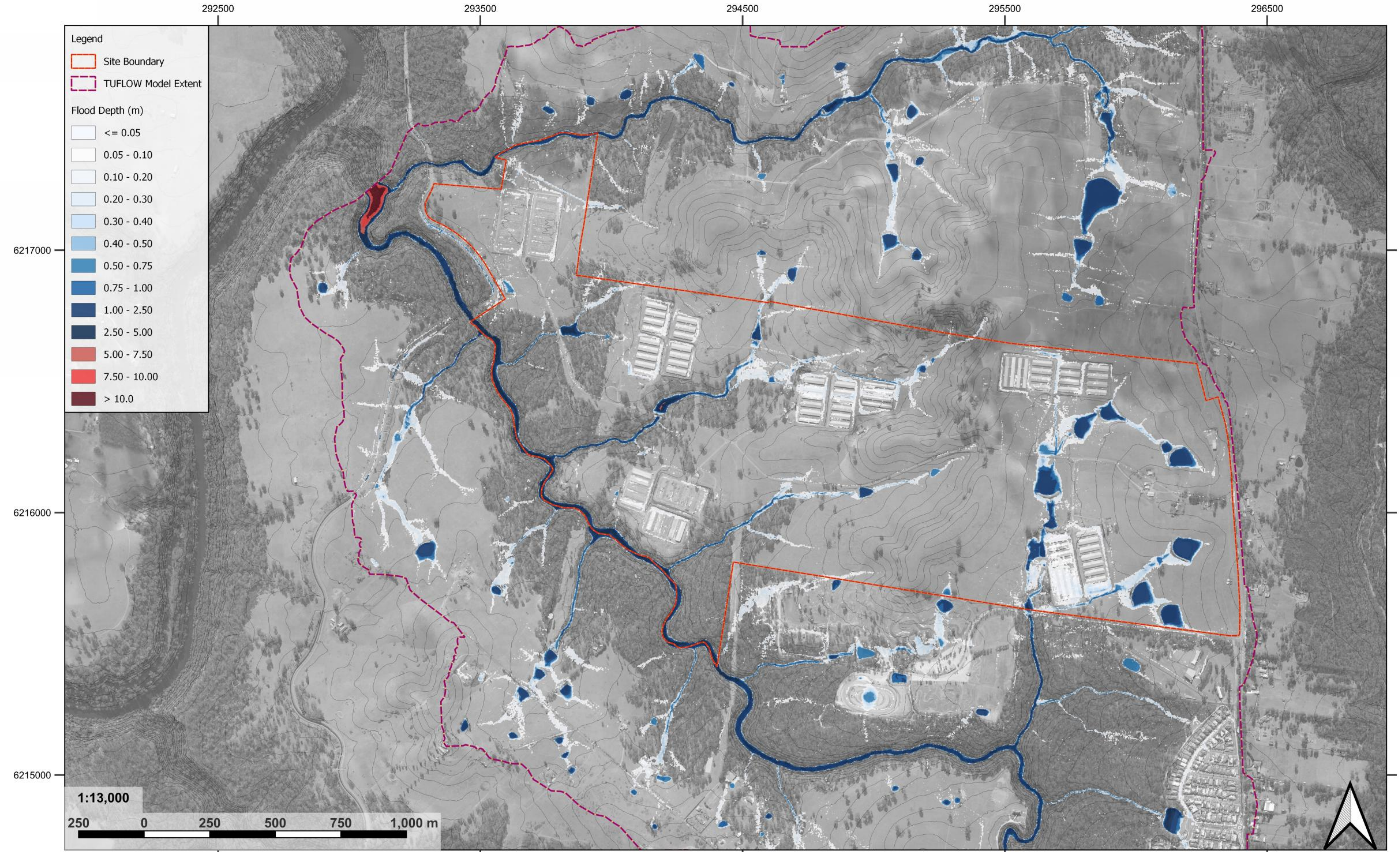
Map 01: 1% AEP Flood Levels - Existing
Project: North Appin part Precinct Planning Proposal
Project Number: 1098-22
Client: Ingham Property Group



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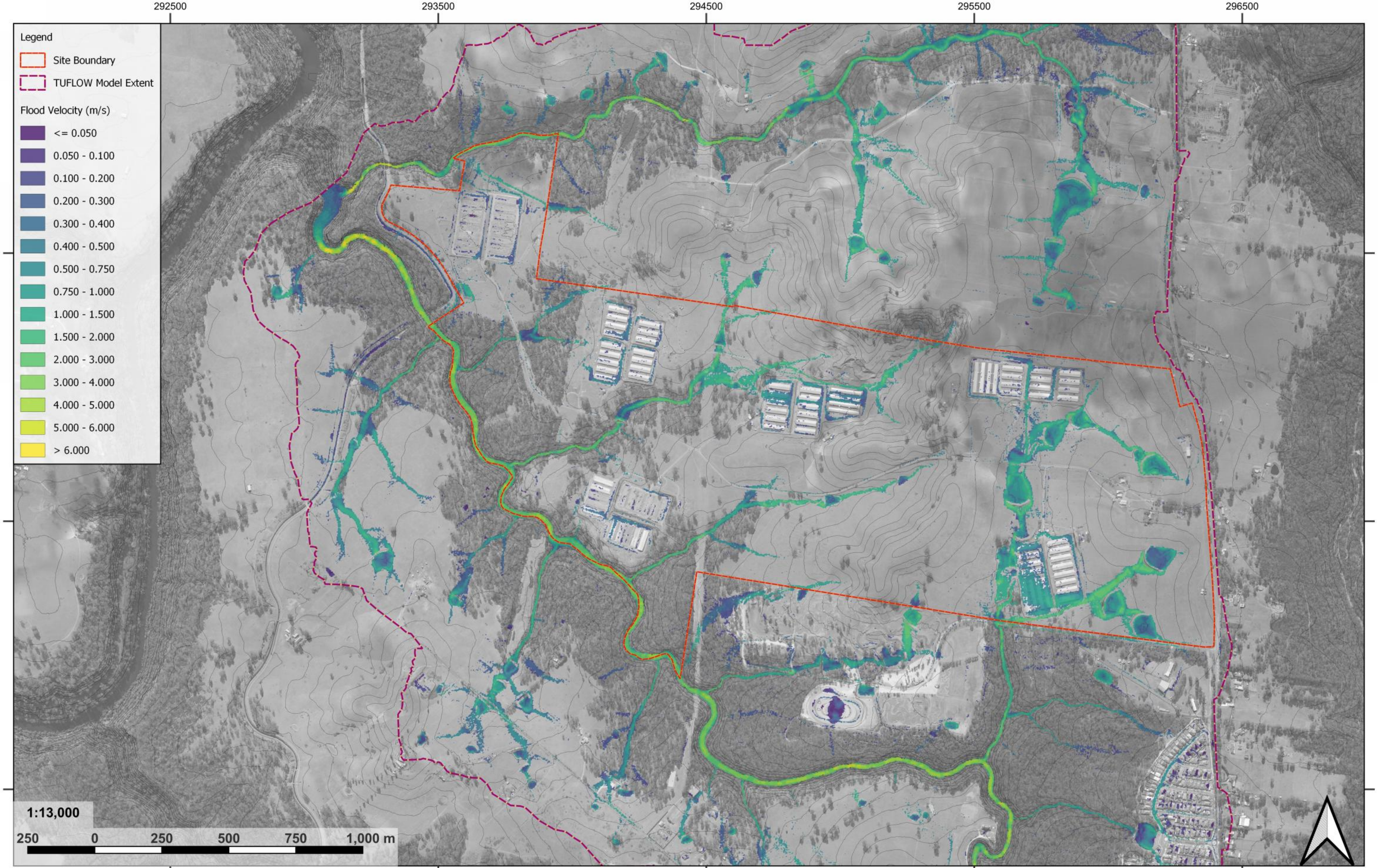
Map 02: 1% AEP Flood Depth - Existing
Project: North Appin part Precinct Planning Proposal
Project Number: 1098-22
Client: Ingham Property Group



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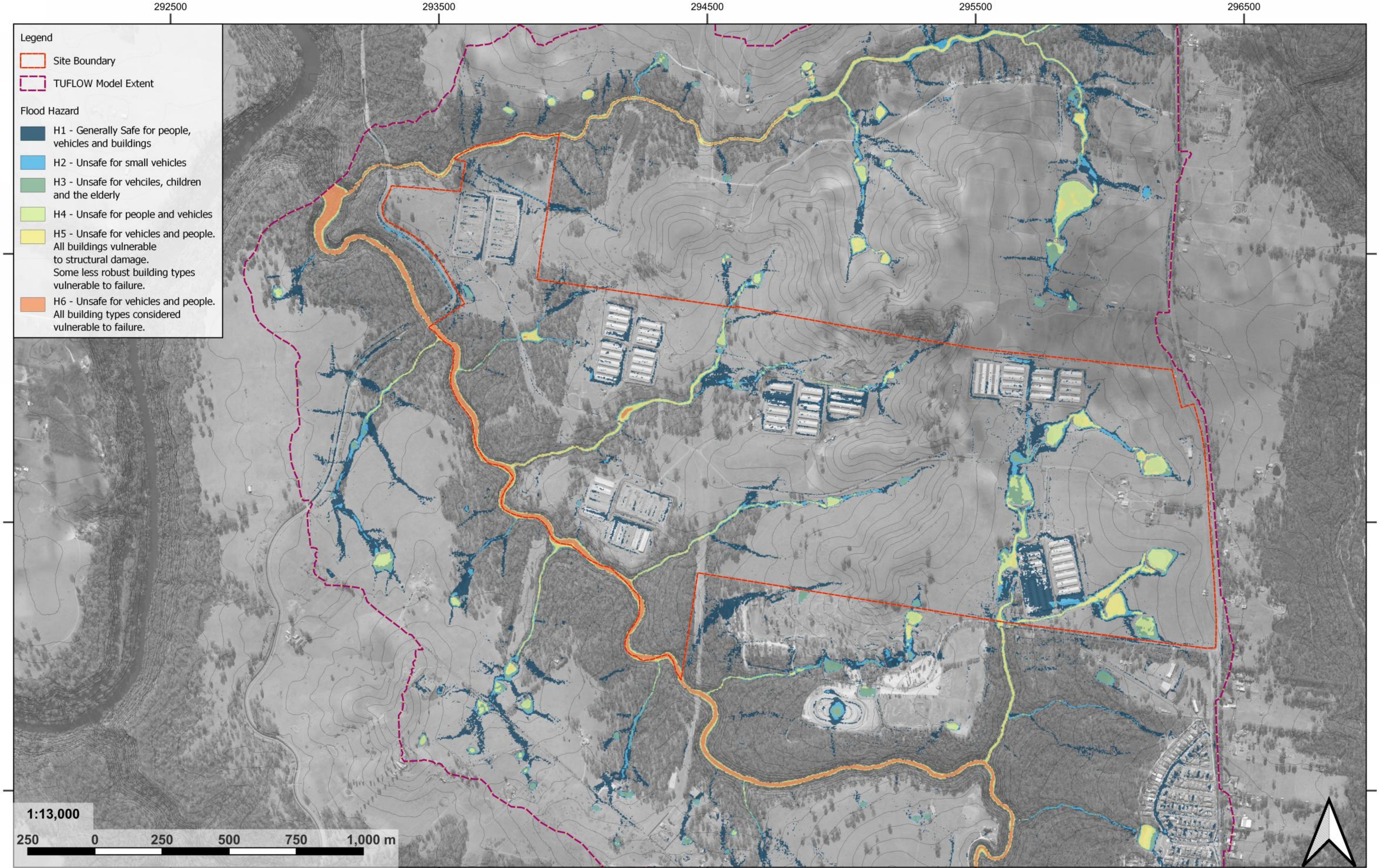
Map 03: 1% AEP Flood Velocity - Existing
Project: North Appin part Precinct Planning Proposal
Project Number: 1098-22
Client: Ingham Property Group



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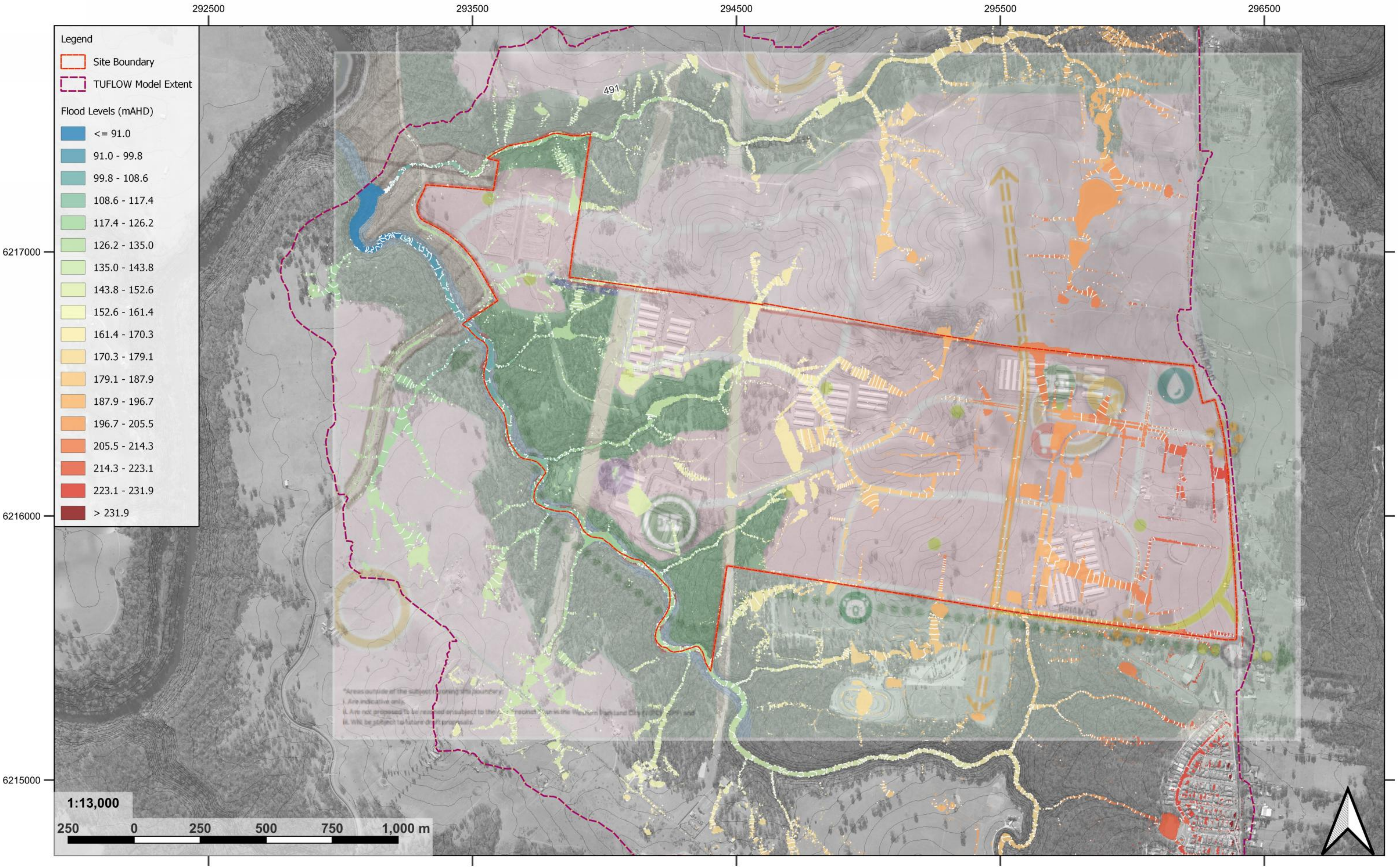
Map 04: 1% AEP Flood Hazard - Existing
Project: North Appin part Precinct Planning Proposal
Project Number: 1098-22
Client: Ingham Property Group



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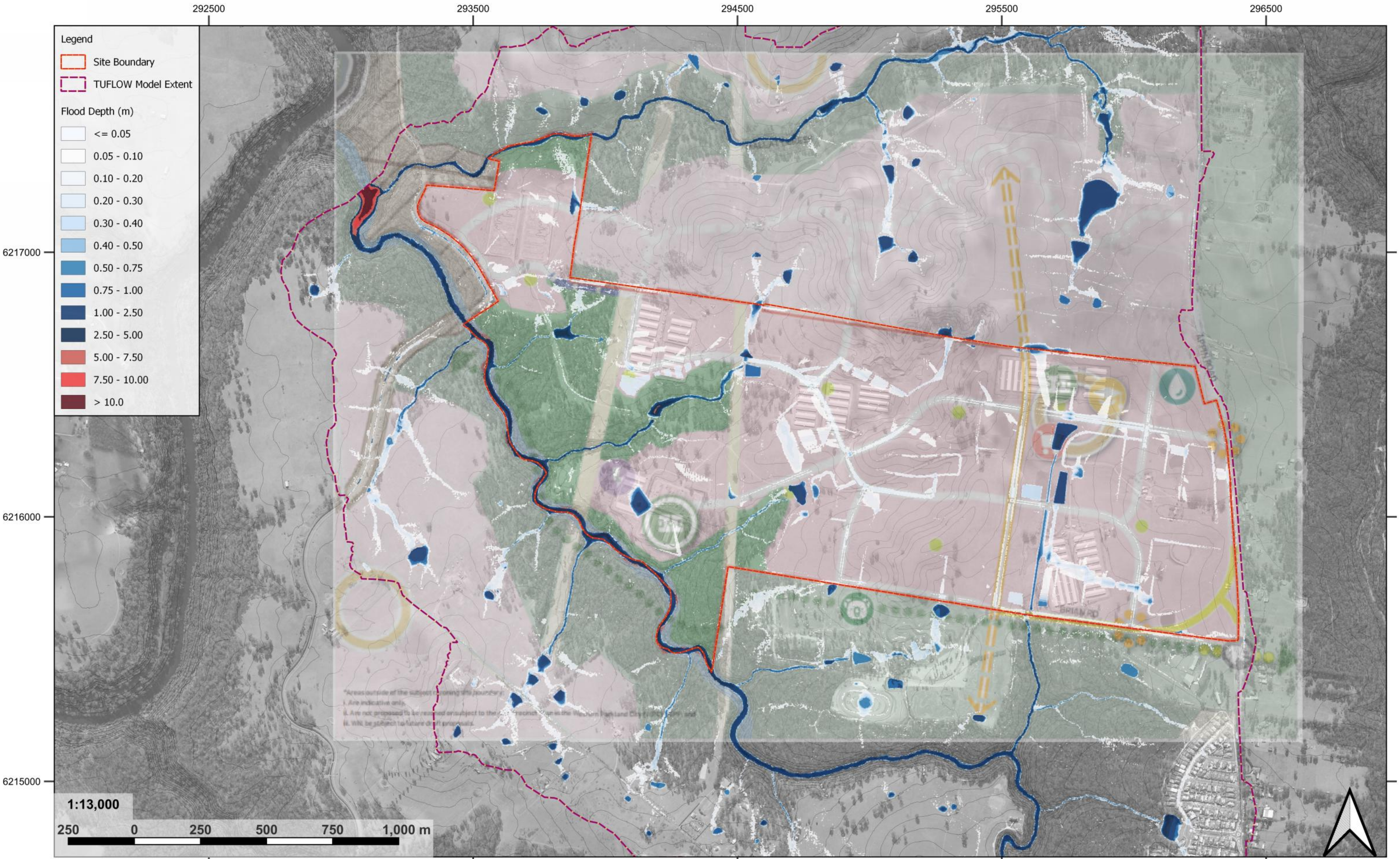
provided in this map is correct at the time of publication. Craig & Rhodes does not warrant, guarantee or make representations regarding the currency and accuracy of information contained within this map.

Map 01: 1% AEP Flood Levels - Developed
Project: North Appin part Precinct Planning Proposal
Project Number: 1098-22
Client: Ingham Property Group



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Map 02: 1% AEP Flood Depth - Developed
Project: North Appin part Precinct Planning Proposal
Project Number: 1098-22
Client: Ingham Property Group

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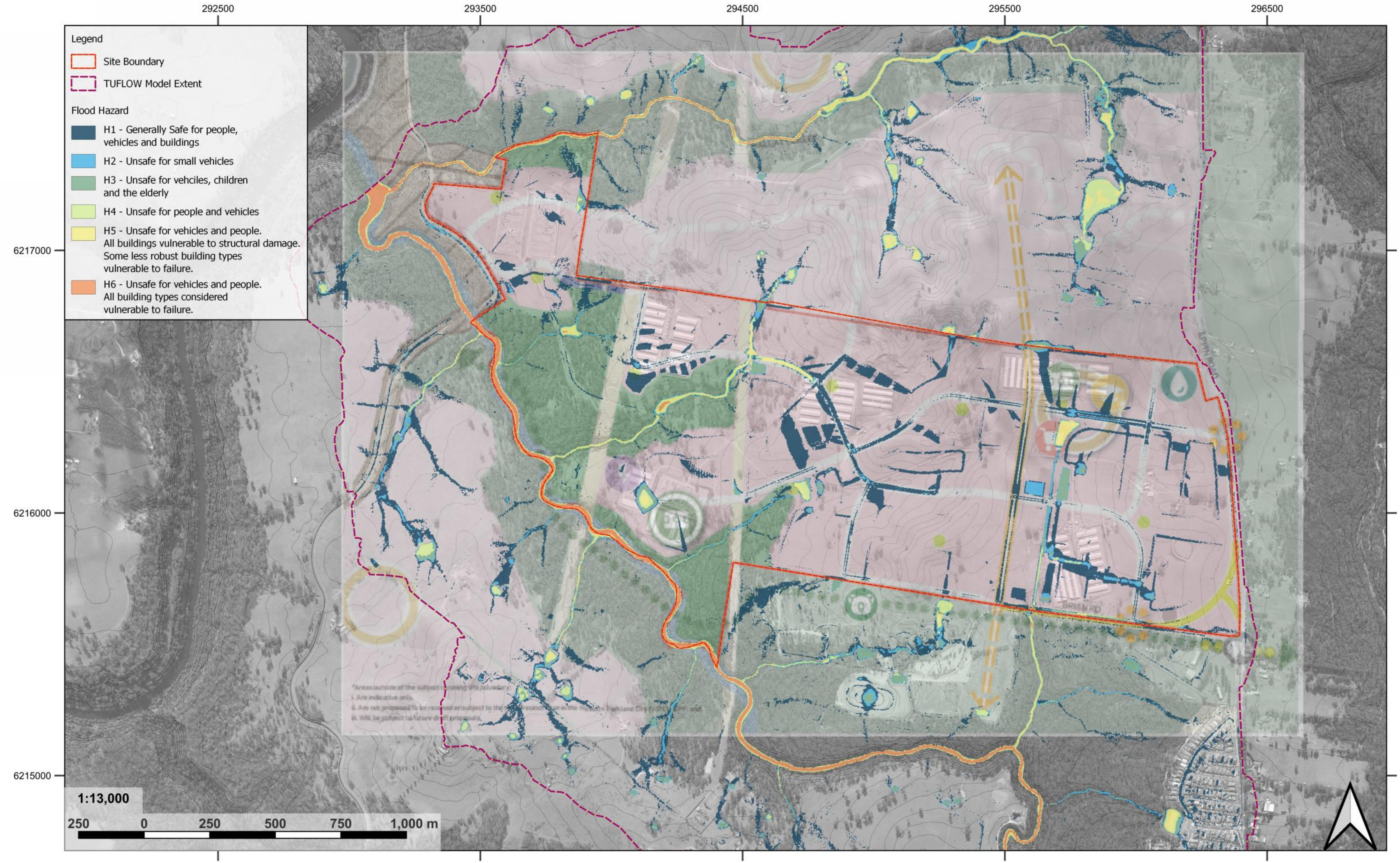
Map 03: 1% AEP Flood Velocity - Developed
Project: North Appin part Precinct Planning Proposal
Project Number: 1098-22
Client: Ingham Property Group



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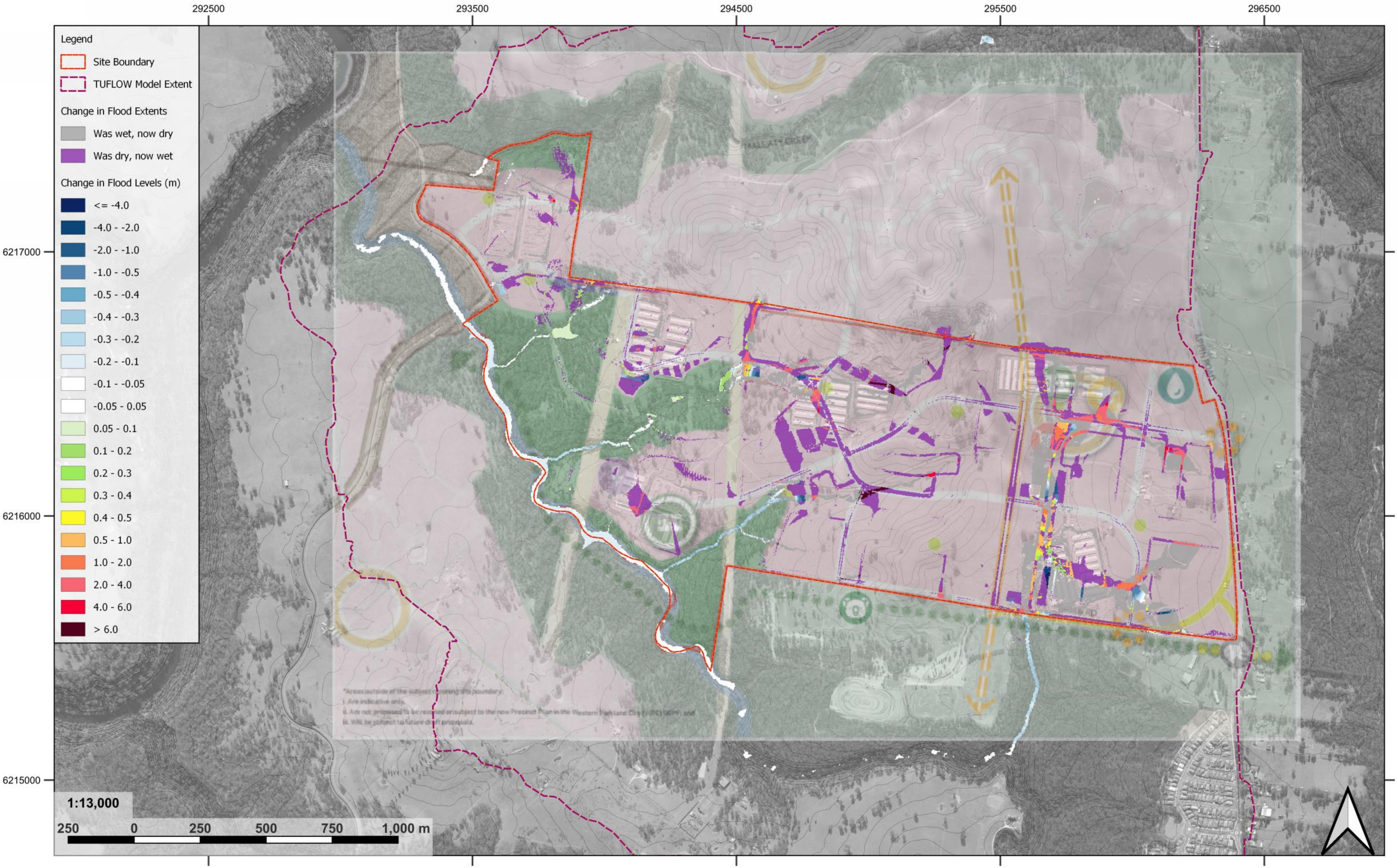
Map 04: 1% AEP Flood Hazard - Developed
Project: North Appin part Precinct Planning Proposal
Project Number: 1098-22
Client: Ingham Property Group



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Map 01: 1% AEP Flood Afflux
Project: North Appin part Precinct Planning Proposal
Project Number: 1098-22
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