# Flood Impact and Risk Assessment Report

**Patyegarang Project,** Morgan Road, Belrose

For Metropolitan Local Aboriginal Land Council, July 2023

## Contents



| Issue | Date | Author | Approved |
|---|---|---|---|
| **A** | 02/06/22 | Leo Zhou | Minh Vu |
| **B** | 20/9/22 | Leo Zhou | Minh Vu |
| **C** | 17/07/23 | Rebecca Famularo | Andrew Halmarick |

*On 9th June 2023, the Department of Planning and Environment issued a Gateway determination for the planning proposal. Following the issue of the Gateway determination, the Metropolitan Aboriginal Land Council resolved to adopt an alternative name for the project to reflect the Aboriginal cultural heritage of the site. This report has accordingly been updated to reference the Patyegarang Project. No other changes have been made to the content of this report.*

# 1 Introduction

## 1.1 Background

Craig & Rhodes was engaged to prepare a Flood Impact and Risk Assessment (FIRA) for the Morgan Road, Belrose site on behalf of the Metropolitan Local Aboriginal Land Council.

The purpose of this report is to assist in establishing the feasibility of the rezoning in the proposed layout plan prepared by COX Architecture. The Plan has been developed to correspond to the broad level design outcomes required by Council and the Department of Planning and Environment (DoPE).

The overall strategy comprises key waterway measures for flooding, water quality and ecological management within the study area. A concept design has also been performed for the key flood management and water quality measures proposed for the site to support the planning proposal and to ensure that there are no adverse impacts on the downstream environment.

This report should be read in conjunction with the *Stormwater Management Plan* (2022) prepared for the site by Craig & Rhodes.

## 1.2 Site Location

The site is located in the suburb of Belrose in Sydney's northern beaches area, bounded by Forest Way and Morgan Road, shown in Figure 1. The downstream receiving waters are Middle Creek and Narrabeen Lagoon.


*Figure 1 General Site location*

A detailed site location is provided in Figure 2, showing the location of Snake Creek and Middle Creek.

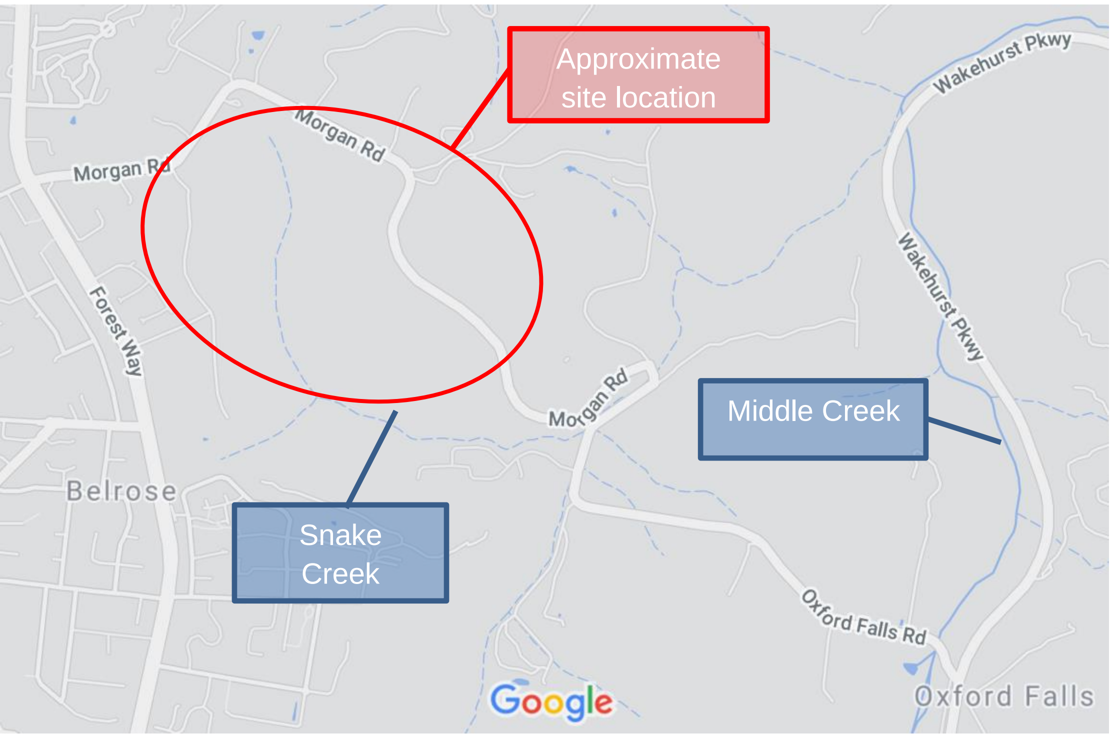


*Figure 2 Site location*

## *1.3 Proposed Development*

The proposed development extents are shown in Figure 3 below in the context of Morgan Rd and Forest Way.

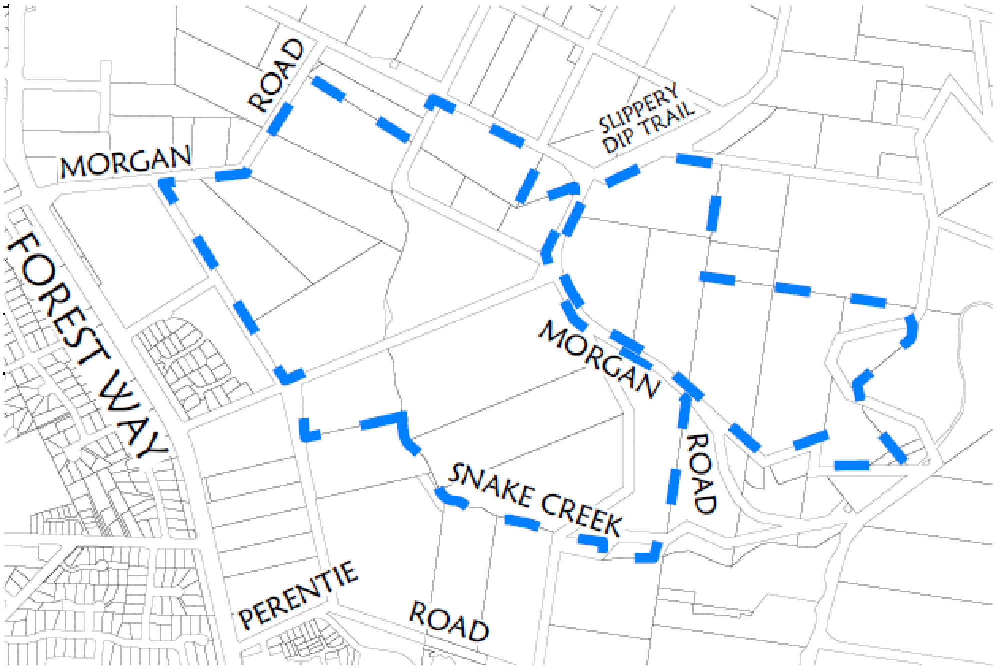


*Figure 3 Proposed Subdivision Extent*

The draft structure plan of this area is shown in Figure 4. The pink shaded areas denote potential residential areas, and the green shaded areas represent various reserved areas for conservation, bushfire management, parklands, riparian corridor, and stormwater treatment.

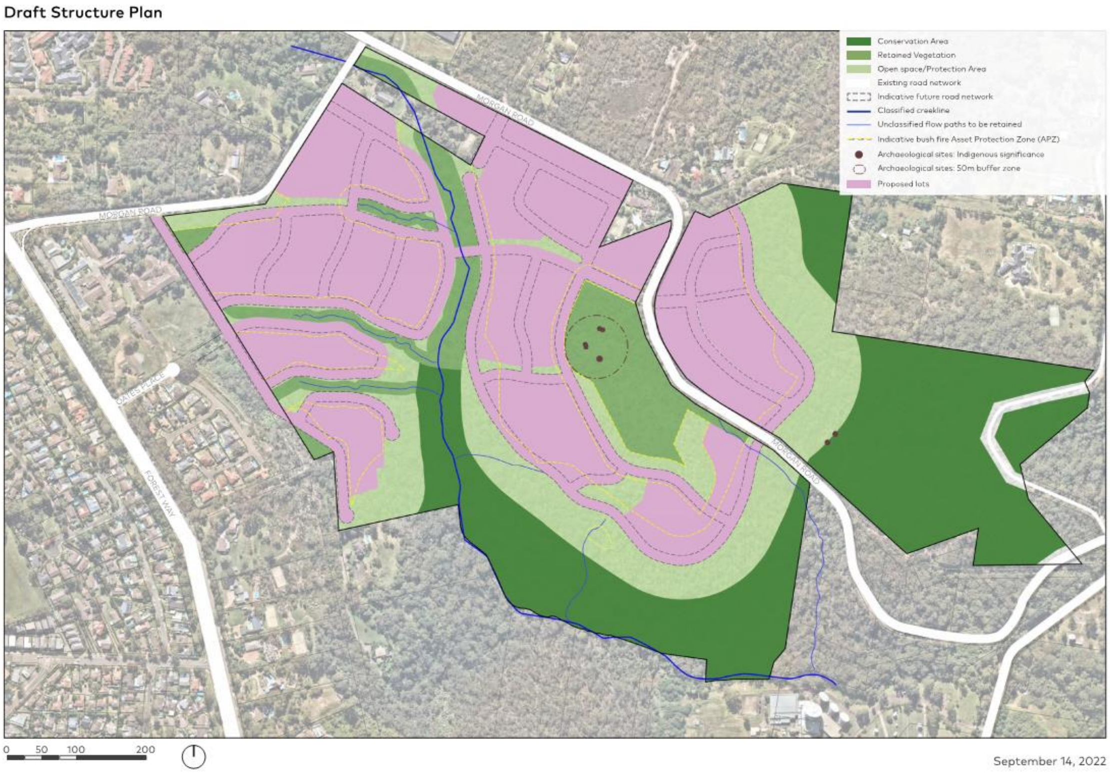


*Figure 4 Draft Structure Plan by Cox*

## 1.4 Objective

The purpose of this report is to:

- Review existing Northern Beaches Council (Council) flood modelling data and planning requirements;
- Identify flood behaviour for the proposed development for the specified 5%, 1%, 0.5%, 0.2% Annual Exceedance Probability (AEP) and Probable Maximum Flood (PMF) events;
- Undertake a Flood Impact and Risk Assessment for the proposed draft layout plan in accordance with the Department of Planning and Environment (DoPE) Local Environment Plan Making Guidelines;

## 1.5 Scope of Work

This report addresses the flood impact and risk assessment requirements for the Morgan Road, Belrose site. It serves to facilitate the enhancement and conservation of biodiversity and ecological health within the existing riparian corridors and provide an integrated natural resource for the community.

The scope as understood by Craig & Rhodes is;

- Adopt the hydrologic XP-RAFTS model from the previous *Stormwater Management Plan* prepared by Craig & Rhodes, with amendments to the catchment setup and parameters where appropriate
- Undertake hydrologic and hydraulic assessment of the site as an integrated approach to flood risk and water cycle management;
- Undertake preliminary concept earthworks design grading to inform the post-developed flood assessment;
- Develop a two-dimensional TUFLOW hydraulic flood model for the site and assess the above-mentioned storm events under both pre- and post-development conditions;
- Assess different development scenarios within the hydraulic model to determine the potential impact of the development on the flood regime and the impacts of flooding on the development, through an iterative process;
- Prepare preliminary flood maps for the pre- and post-development conditions;
- Prepare a Flood Impact and Risk Assessment report to support the rezoning for the Precinct, detailing the investigations, findings, calculations, and design details.

It is noted that this is a high-level report undertaken primarily to assess the feasibility of the proposed masterplan layout and Planning Proposal. It is acknowledged that further detailing and refinement of the various flood, water quantity and quality management elements proposed for the area would be necessary at the Development Application stage, and as part of the design process.

## 2 Background

### 2.1 Topography

The site is located in a relatively steep and elevated area, with slope gradients reaching upwards of 35%, with rock cliffs and ledges scattered throughout. There are a number of ridge lines separating the site into sub-catchments, however overall the entire site falls to Snake Creek which runs in a north to southeast direction through the site. The upper boundary of the site is lined by Morgan Road, which also functions as a ridge line that runs through the site. As the site is high in elevation, there is expected to be no oceanic influences on flood behaviour.

### 2.2 Land Use

The existing area of Belrose which encompasses the site is largely undeveloped and is not currently zoned for any purposes. The site is largely vacant, with a number of rural residential properties adjacent. The land west of the site adjacent to Forest Road contains the urban areas of Belrose and retirement villages.

### 2.3 Waterways

The site encompasses the headwaters of Snake Creek that drains into Middle Creek and Narrabeen Lagoon.  There are stormwater culverts under Morgan Rd that direct upstream urban runoff into Snake Creek at the headwaters. The higher reaches of Snake Creek within the proposed development area are deeply incised in a sandstone terrain as shown in Plates 1 and 2.

*Plate 1: General view of Snake Creek*

*Plate 2: Example of escarpment profile*

The creek is characterised as a seasonal stream, with intermittent creek flows throughout the year. The site geology and soil profile is conducive to a stable creek. Baseflow for an extended period of time after a rain event.

The creek bed is very stable, being predominantly bedrock.  An example is shown in Plate 3 below.

*Plate 3:  Exposed bedrock*

The *Warringah Creek Management Study* (2004) classifies Snake Creek and Oxford Creek as Class B acknowledging some degradation in the upper reaches.

Council uses the Strahler System of Stream Order (1957) in their *Policy for Protection of Waterways and Riparian Land (PL 740)* to classify waterways and riparian corridor widths.

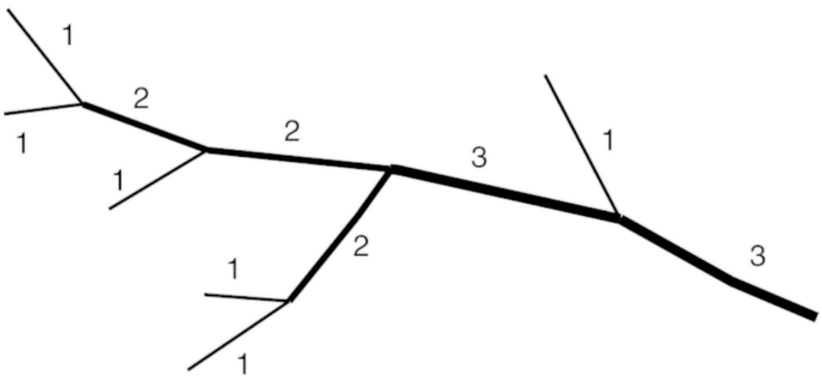


*Figure 5 Strahler Stream Order System (extracted from Protection of Waterways and Riparian Land)*

Figure 6 shows the extent of 1st order and 2nd order streams within the site extent. Most of the development is adjacent to 1st order with the south-east extremity being 2nd order.


*Figure 6 Stream Order definition according to Strahler System*

## 2.4 Soils

The precinct is mapped by various soil landscapes, including Gymea, Oxford Falls, Hawkesbury and Lambert. The site is underlain by the Hawkesbury Sandstone formation of the Wianamatta group.  The Hawkesbury sandstone formation typically comprises of course-grained quartz sandstone with minor shale and laminate lenses. These are overlain by podzolic soils with shallow to moderately deep siliceous sands along drainage lines.

The precinct is considered to have a high susceptibility to erosion due to the characteristics of the colluvial and erosional soil-landscape combine with the high rainfall intensity resulting in soil loss conditions.  Soil depths will vary depending on the bedrock, with typical depths of 0.5m. It is expected that gullies will have a greater depth of soil cover up to 2m. It is expected that the hydraulic conductivity of the soil would vary from 60-120 mm/hr due to the variety of soil textures.

# 3 Review of Available Data

## *3.1 Structure Plan/Masterplan*

The plan prepared by COX Architecture as shown in **Appendix A** shows the proposed layout of the development, including roads, superlots and parks/reserves conservation areas. This plan encompasses the recommendations for:

- Bushfire management
- Flora and fauna
- Infrastructure requirements to service the development
- Conservation areas, including the riparian zone

This plan has been relied upon for the development of the stormwater management Plan as detailed in the previous *Stormwater Management Plan* (2022) report by Craig & Rhodes.

## *3.2 Topographic Data*

1-metre LiDAR data (2020) has been sourced from ELVIS for the purposes of this assessment. Although a full detailed survey of the site has been commissioned, the data was not yet available for this study.

## *3.3 Previous Flood Studies and Flooding History*

A number of previous studies have been undertaken in the vicinity of the site, including the following:

- Frenchs Creek Flood Study (DHI Water & Environment, 2010)
- Narrabeen Lagoon Flood Study (BMT WBM, 2013)
- Pittwater Overland Flow Flood Study (Cardno, 2013)

Although Snake Creek and Oxford Creek which pass through the site are tributaries of Middle Creek which discharges to Narrabeen Lagoon, the extents of the flood studies do not cover the site.

Additionally, in consideration of the catchment properties, specifically the high elevation conditions as well as the bushland environment, there is limited available information on the history of overland flooding in the study area. There is also no flow gauging or monitoring for the catchment that we are aware of.

## *3.4 Emergency Management*

The regional emergency response procedures are generally outlined in Emergency Management Plans (EMPLANs) and associated sub-plans. The NSW State EMPLAN outlines the general approach to emergency management and the roles and responsibilities of the respective agencies, with the NSW State Emergency Services (SES) being in charge of flood emergencies.

The Northern Beaches Local Emergency Management Plan (EMPLAN) was authorised in March 2021, followed by the Northern Beaches Flood Emergency Sub Plan which was authorised in April 2021 as a sub plan to the Northern Beaches Local EMPLAN. These plans detail general strategies for flood emergency management, as well as identify types of flooding risks and areas that are highly susceptible to flooding which would require emergency response procedures. Overall, the Morgan Road, Belrose site is not deemed as an area which is at risk of either flash flooding or lagoon flooding.

There are no evacuation plans prepared for the area, however it is expected that in the event that evacuation is required (likely for a medical emergency), evacuation should be determined by access to the nearest medical emergency centre which would be Northern Beaches Hospital located approximately 3 km south of the site. The major road through this area, Forest Way, is assumed to be the regional evacuation route for the suburb of Belrose.

## *3.5 Relevant Development Controls*

Available guidelines reviewed and adopted for the study include the following.

### *3.5.1 Flood Impact and Risk Assessment Flood Risk Management Guide [LU01] (DoPE, 2022);*

This guideline prepared by the DoPE  provides advice on the scope and scale of a Flood Impact and Risk Assessment (FIRA). It outlines the report structure and output requirements of a typical FIRA, which has been used as the basis for this assessment.

### *3.5.2 Warringah Development Control Plan (2011)*

The overriding objective of the DCP is to create and maintain a high level of safety and environmental quality throughout Warringah. Development should result in an increased level of local amenity and environmental sustainability.

The DCP currently applies planning controls to land uses mapped in the Warringah LEP 2011. Section E11 outlines the controls for flood prone land. Although the site is not identified as being affected by flooding on Council's Flood Risk Precinct Map (refer to Figure 7), and hence the development matrix does not have any controls that apply to the site, the flood precinct map is based on Council's information from publicly available flood studies and floodplain risk management plans of which there may be none available for the site. As the DCP controls are the best prescriptive controls available to

Craig & Rhodes, the planning controls in Section E11 of the DCP have been considered for the purposes of this assessment.

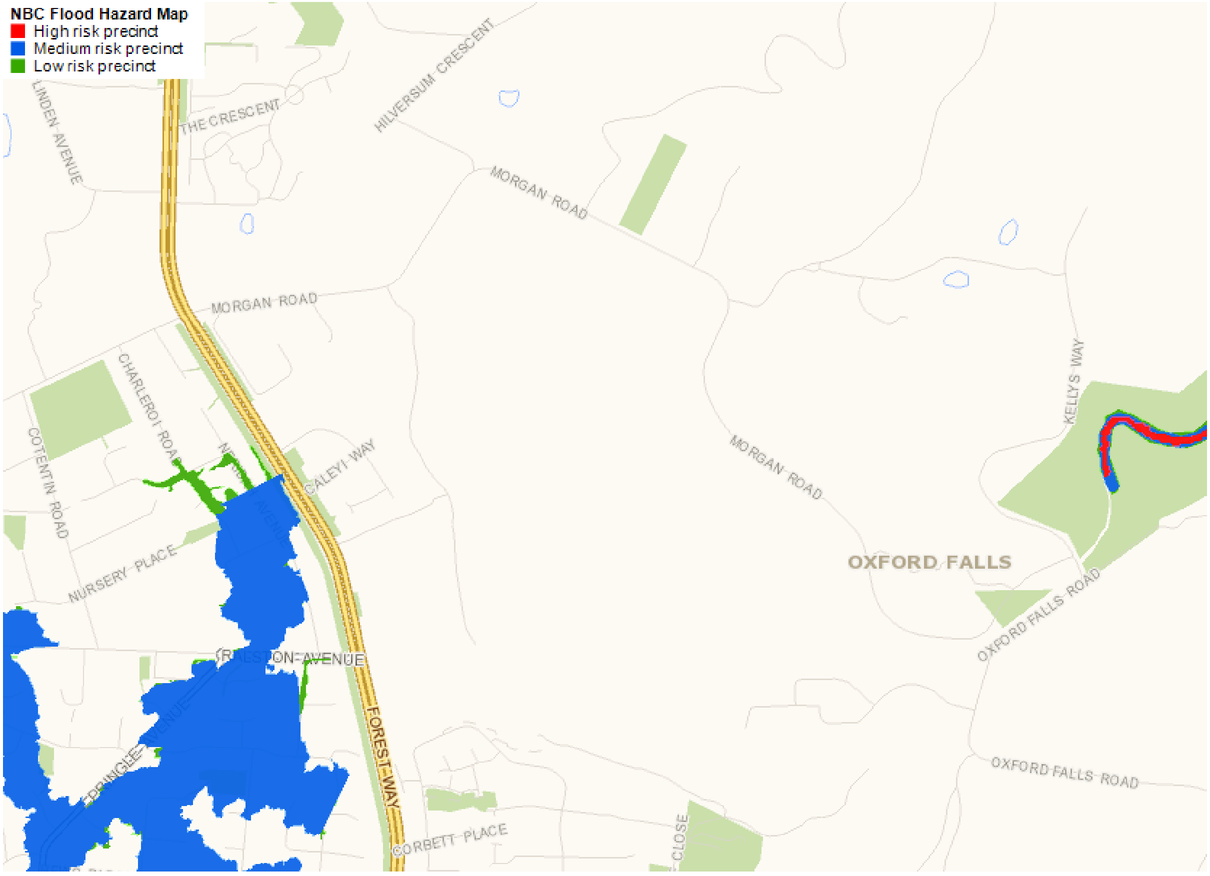


*Figure 7 Extract from Northern Beaches Council flood risk precinct online map*

### *3.5.3 Warringah Local Environmental Plan (2011)*

The objective of the LEP is to make planning provisions for land in the Warringah area to create and maintain a high level of safety and environmental quality throughout Warringah. Section 5.21 of the LEP specifically relates to flood planning, and its general objectives aim to:

1. Minimise the flood risk to life and property associated with the use of land,
2. Allow development on land that is compatible with the flood function and behaviour on the land, taking into account projected changes as a result of climate change
3. Avoid adverse or cumulative impacts on flood behaviour and the environment,
4. Enable the safe occupation and efficient evacuation of people in the event of a flood.

# 4 Hydrology Assessment

This assessment undertook hydrologic modelling of the study area using XP-RAFTS (Version 2018.1.1) for the study area. XP-RAFTS is a widely used hydrological modelling tool for predicting the stormwater runoff for large catchments in pre- and post-development conditions. Modelling was undertaken using the Australian Rainfall & Runoff (2019) ensemble storm methodology for the 5% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF storm events under existing and developed conditions.

The adopted XP-RAFTS parameters and details have been refined and updated based on those provided in the *Stormwater Management Plan* (2021) by Craig & Rhodes.

1. Sub-catchment delineations were adopted from the XP-RAFTS hydrologic model based on topographical features in the LiDAR (2020) data.
2. Intensity Frequency Duration (IFD) data and rainfall temporal patterns were based on the Bureau of Meteorology (BoM, 2022) data and the ARR Data Hub (2022).
3. Probable Maximum Precipitation (PMP) intensities and temporal patterns were determined using the BoM (2003) Generalised Short-Duration Method (GSDM).

## *4.1 Pre-Development Conditions*

The XP-RAFTS model was developed for the pre-development conditions to generate catchment hydrographs. The 'pre-development' scenario is defined as the proposed development in an undeveloped state. The subject site has been divided into six existing catchments based on topographical features and representative overland flow paths with existing catchment parameters applied. (Refer to **Appendix B**).

The site catchments were further divided into five additional sub-catchments representing the private roof, driveway, pervious and public open space, road areas to match post development catchment delineation, while adopting pre-development catchment parameters.

The upstream external catchments have been divided into six sub-catchments. The fraction imperviousness of the external catchments has been estimated by measuring existing developed areas from recent Nearmaps aerial imagery (April 2021).

A review of the existing high-level catchment XP-RAFTS models was considered in the selection of catchment parameters. An initial loss of 7mm/hr and a continuing loss of 0.5mm/hr was adopted for the pervious surfaces. The XP-RAFTS sub-catchment layout for the existing scenario is shown below in Figure 8.

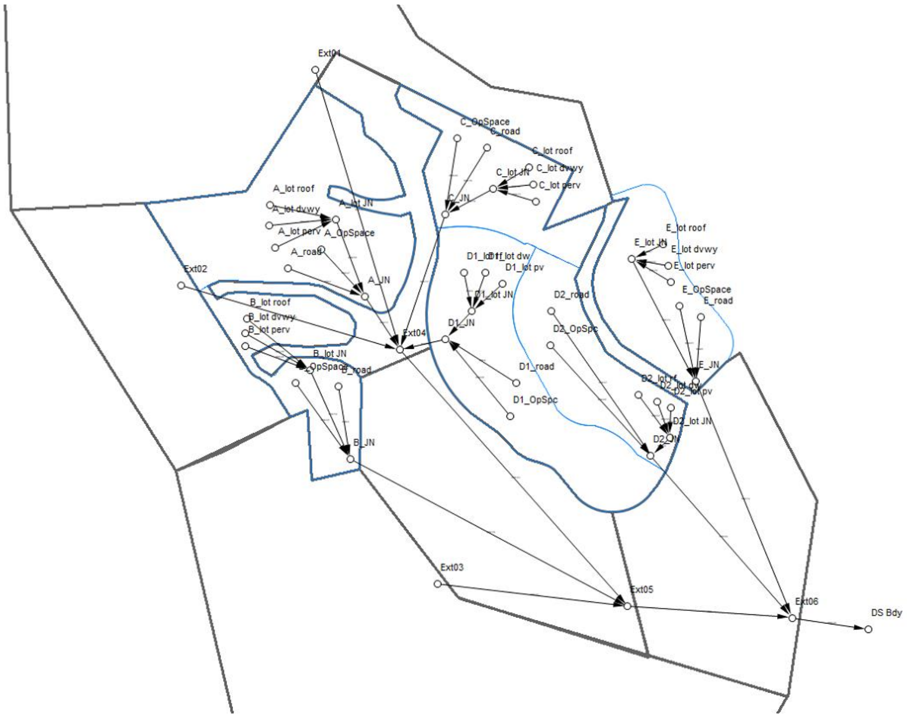


*Figure 8 XP-RAFTS Model Layout*

## *4.2 Post-Development Conditions*

The 'post-development' scenario is defined as the subject site in a developed state as per the Draft Structure Plan by COX Architecture (see **Appendix A**), with stormwater quantity and quality infrastructure operational.

The XP-RAFTS model was produced for the proposed scenario to generate catchment hydrographs. The total catchment was divided into six existing sub-catchments and five proposed sub-catchments, based on topographical features, the proposed design layout, representative overland flow paths and the input requirement. The catchment delineation between the pre-development and post-development case remains consistent, and the overall model layout remains the same as per Figure 8.

The stormwater volume retention from the proposed water quality and quantity features was modelled by increasing the initial loss of the developed areas, and the site development area was represented by increasing the impervious area of these catchments. The proposed stormwater features are described in detail in Craig & Rhodes' *Stormwater Management Plan* (2021) report. Further information on the developed catchment parameters is located in **Appendix B.**

## *4.3 Catchment Hydrology Results*

The critical durations and median temporal patterns were determined at the site sub-catchment boundary for the 5% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF design storm events.

These are summarised along with the peak flows of each sub-catchment for the pre-development and post-development conditions in Table 1 below.

*Table 1 Pre & Post Development Peak Flow Comparison at Site Sub-Catchment Boundary*

| 50% AEP | PRE DEVELOPMENT | | POST DEVELOPMENT | |
|---|---|---|---|---|
| | Peak Flow ($m^3/s$) | Critical Duration (Temporal ID) | Peak Flow ($m^3/s$) | Critical Duration (Temporal ID) |
| **Area A** | 1.69 | 15m#5 | 1.61 | 25m#2 |
| **Area B** | 0.86 | 15m#5 | 0.80 | 25m#2 |
| **Area C** | 0.93 | 15m#5 | 0.81 | 25m#2 |
| **Area D1** | 1.45 | 15m#5 | 1.33 | 25m#2 |
| **Area D2** | 0.87 | 15m#5 | 0.82 | 15m#5 |
| **Area E** | 0.97 | 15m#5 | 0.84 | 25m#2 |

| 5% AEP | PRE DEVELOPMENT | | POST DEVELOPMENT | |
|---|---|---|---|---|
| | Peak Flow ($m^3/s$) | Critical Duration (Temporal ID) | Peak Flow ($m^3/s$) | Critical Duration (Temporal ID) |
| **Area A** | 3.96 | 15m#4 | 4.69 | 15m#5 |
| **Area B** | 2.00 | 15m#4 | 2.32 | 15m#5 |
| **Area C** | 2.16 | 15m#4 | 2.42 | 15m#5 |
| **Area D1** | 3.35 | 15m#4 | 3.90 | 15m#5 |
| **Area D2** | 2.02 | 15m#4 | 1.98 | 15m#4 |
| **Area E** | 2.23 | 15m#4 | 2.50 | 15m#5 |

| 1% AEP | PRE DEVELOPMENT | | POST DEVELOPMENT | |
|---|---|---|---|---|
| | Peak Flow ($m^3/s$) | Critical Duration (Temporal ID) | Peak Flow ($m^3/s$) | Critical Duration (Temporal ID) |
| **Area A** | 5.42 | 15m#8 | 5.85 | 15m#7 |
| **Area B** | 2.63 | 15m#7 | 2.85 | 15m#7 |
| **Area C** | 2.86 | 15m#7 | 2.97 | 15m#7 |
| **Area D1** | 4.56 | 15m#7 | 4.84 | 15m#7 |
| **Area D2** | 2.23 | 15m#8 | 2.78 | 15m#8 |
| **Area E** | 2.97 | 15m#4 | 3.07 | 15m#7 |

| 0.5% AEP | PRE DEVELOPMENT | | POST DEVELOPMENT | |
|---|---|---|---|---|
| | Peak Flow ($m^3/s$) | Critical Duration (Temporal ID) | Peak Flow ($m^3/s$) | Critical Duration (Temporal ID) |
| **Area A** | 5.91 | 15m#7 | 6.34 | 15m#8 |
| **Area B** | 2.85 | 15m#7 | 3.10 | 15m#8 |
| **Area C** | 3.10 | 15m#7 | 3.21 | 15m#8 |
| **Area D1** | 4.94 | 15m#7 | 5.24 | 15m#8 |
| **Area D2** | 3.04 | 15m#8 | 3.04 | 15m#8 |
| **Area E** | 3.23 | 15m#7 | 3.32 | 15m#8 |

| 0.2% AEP | PRE DEVELOPMENT | | POST DEVELOPMENT | |
|---|---|---|---|---|
| | Peak Flow ($m^3/s$) | Critical Duration (Temporal ID) | Peak Flow ($m^3/s$) | Critical Duration (Temporal ID) |
| **Area A** | 6.76 | 15m#7 | 7.27 | 15m#8 |
| **Area B** | 3.24 | 15m#1 | 3.55 | 15m#8 |
| **Area C** | 3.53 | 15m#1 | 3.68 | 15m#8 |
| **Area D1** | 5.68 | 15m#7 | 6.02 | 15m#8 |
| **Area D2** | 3.50 | 15m#8 | 3.49 | 15m#7 |
| **Area E** | 3.68 | 15m#1 | 3.81 | 15m#8 |

The results show that the stormwater footprint methodology can manage the peak flows to within a reasonable level of the pre-development condition. Mild variations in the shorter critical durations were found, but critically the stormwater volumes of each hydrograph were comparable.

## *4.4 Downstream Boundary Flow Comparison*

The 5% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF storm durations were modelled for the downstream boundary for the existing and developed conditions. The peak flows and hydrographs downstream of the site for each storm event are provided in Table 2 below.

*Table 2 Downstream Boundary Flow Comparison*

| AEP | PRE DEVELOPMENT | | POST DEVELOPMENT | |
|---|---|---|---|---|
| | Peak Flow ($m^3/s$) | Critical Duration - Temporal Pattern | Peak Flow ($m^3/s$) | Critical Duration (Temporal Pattern) |
| **5%** | 40.1 | 25min - #1 | 40.44 | 25min - #1 |
| **1%** | 60.2 | 25min - #3 | 60.73 | 25min - #7 |
| **0.5%** | 65.7 | 25min - #3 | 66.24 | 25min - #7 |
| **0.2%** | 75.6 | 25min - #7 | 76.17 | 25min - #7 |
| **PMF** | 267.4 | 15min | 266.7 | 15min |

Overall, the results indicate that that the stormwater management system proposed is effective in attenuating flow peaks and volumes to pre-development levels. Mild variations in the shorter critical durations were found, but critically the stormwater volumes of each hydrograph were comparable. This is also reflected in the hydrographs at the downstream boundary as per the TUFLOW modelling (refer to Figure 11 to Figure 15).

# 5 Hydraulic Assessment

## 5.1 Model Setup

The flood behaviour of the 5% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF design storm events under existing (pre-development) and post-development conditions at the site have been modelled using a two-dimensional TUFLOW hydraulic model. The TUFLOW model extends from Forest Way to just upstream of Oxford Falls Road at the downstream boundary.

The hydraulic modelling was undertaken with user defined inflows from the XP-RAFTS model to assess the existing flows and the potential flood impacts resulting from the proposed development.

Due to the limited availability of existing flow or water level data to calibrate to in the catchment, there was no validation to existing data performed.

## 5.2 Pre-Development Scenarios

The TUFLOW modelling of the pre-development study area was undertaken using the following model parameters:

1. TUFLOW version 2020-10-AB was adopted, using the HPC GPU solution scheme.
2. A 2m topographic grid was used in the model construction based on the available LiDAR (2020) data sourced from ELVIS.
3. The model domain was defined from Morgan Road west of the site to a location approximately 350 m downstream of the proposed development, just upstream of Oxford Falls Road.
4. Source area (SA) inflow boundary conditions based on the critical duration hydrographs from the XP-RAFTS model for pre-development conditions were used to discharge runoff from the sub-catchments into the model.
5. Manning’s n roughness values were specific for land use zones in the study area based on aerial photography (Nearmaps, 2022). The adopted values are specified in Table 3 below.
6. Existing buildings in the study area were modelled as flow obstructions.
7. A PO line was placed at the site downstream boundary to assess the flows leaving the site.

*Table 3 Manning's roughness coefficients*

| Material | Manning's n Values |
|---|---|
| **Creeks and waterways** | 0.06 |
| **Open grassed space** | 0.04 |
| **Roads** | 0.02 |
| **Residential** | 0.05 |
| **Vegetation - dense** | 0.10 |
| **Vegetation - medium** | 0.08 |

## 5.3 Pre-Development Hydraulic Modelling Results

The pre-development TUFLOW modelling was undertaken to simulate the 5% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF events. Peak flood depth, level, hazard and extent mapping for these results are presented in **Appendix C**.

The results of the pre-development conditions flood modelling are discussed below:

1. The primary flood mechanism on the site is mainstream flooding from Snake Creek and other overland flow paths. Runoff from the upstream catchment to the northwest flows past Morgan Road and into Snake Creek.
2. The peak flood depths and levels at the locations indicated in Figure 9 are summarised in Table 4 below.
3. Flood velocities in the creek are generally high, reaching above 4 m/s in all modelled storm events. This is largely due to the steep topography on site.
4. Subsequently flood hazards in the creek are also high, reaching up to H6 hazard in all modelled storm events.
5. As the site and its surroundings are currently bushland, there is negligible flood affectation of existing properties. There is an existing Telstra communications facility downstream of the site adjacent to Snake Creek which appears to be partially flood affected only in the PMF event.

*Table 4 Peak existing flood depths and levels at observation locations*

| | Observation Location | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **AEP** | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** |
| | **5%** | 128.8 | 118.1 | 105.9 | 101.9 | 140.3 | 140.0 | 87.4 | 102.8 | 55.4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Peak Level (mAHD)** | **1%** | 128.9 | 118.2 | 106.1 | 102.0 | 140.4 | 140.0 | 87.6 | 102.8 | 55.7 |
| | **0.5%** | 128.9 | 118.3 | 106.1 | 102.1 | 140.4 | 140.0 | 87.7 | 102.9 | 55.8 |
| | **0.2%** | 129.0 | 118.4 | 106.2 | 102.1 | 140.4 | 140.0 | 87.8 | 102.9 | 56.0 |
| | **PMF** | 129.6 | 119.0 | 107.0 | 102.9 | 141.0 | 140.1 | 89.0 | 103.5 | 57.7 |
| **Peak Depth (m)** | **5%** | 1.3 | 1.2 | 1.1 | 0.7 | 0.5 | 0.1 | 1.1 | 0.6 | 1.5 |
| | **1%** | 1.4 | 1.3 | 1.3 | 0.9 | 0.6 | 0.1 | 1.3 | 0.6 | 1.9 |
| | **0.5%** | 1.4 | 1.3 | 1.3 | 0.9 | 0.6 | 0.1 | 1.4 | 0.7 | 2.0 |
| | **0.2%** | 1.5 | 1.4 | 1.4 | 1.0 | 0.6 | 0.1 | 1.5 | 0.7 | 2.2 |
| | **PMF** | 2.1 | 1.8 | 2.2 | 1.8 | 1.2 | 0.2 | 2.6 | 1.3 | 3.9 |

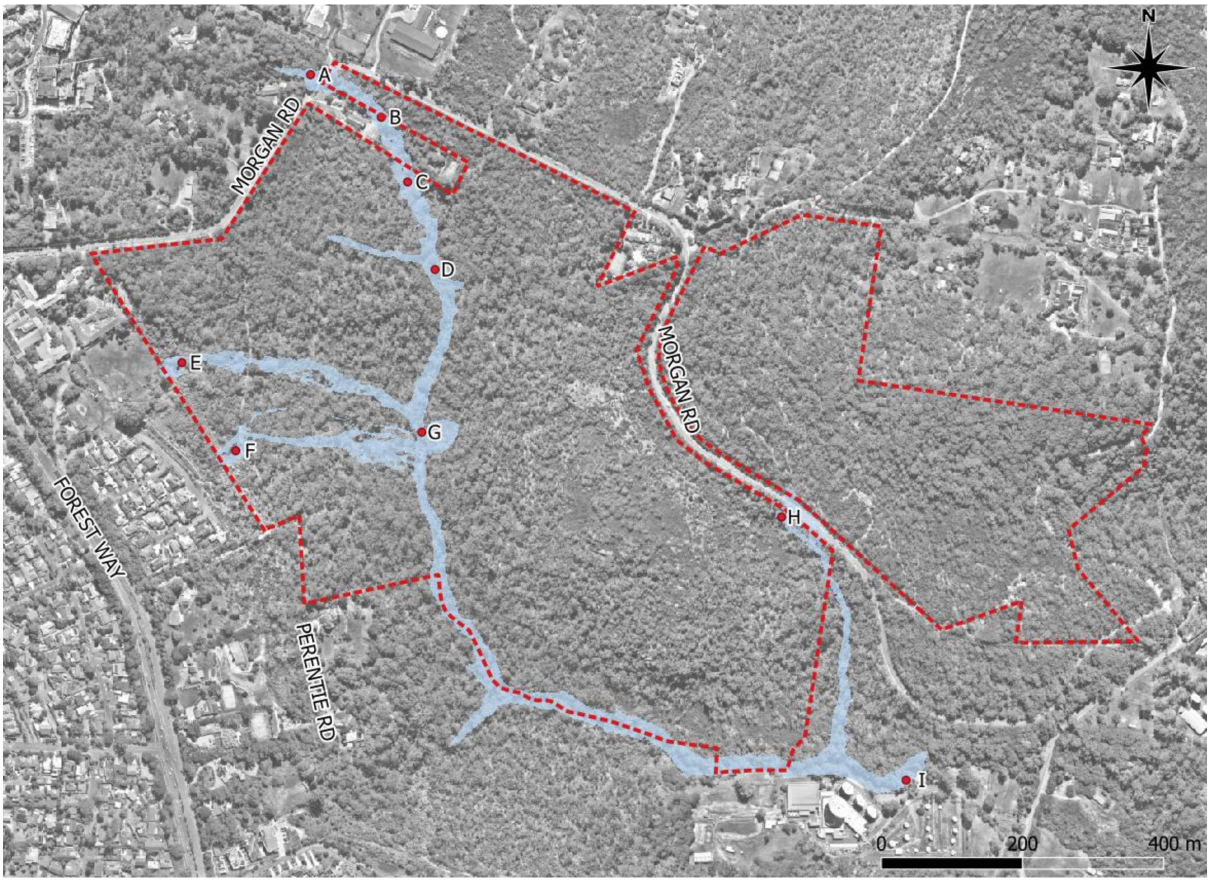


*Figure 9 Key Observation Locations from TUFLOW Model*

## *5.4 Post-Development Scenarios*

The post-development hydraulic model was prepared to account for the proposed changes in land use under post-development conditions as per the draft layout plan. The following model elements were modified for proposed conditions:

- The site's Manning's roughness zones were updated to represent the proposed design surfaces as per the draft layout plan.
- The inflows for the SA boundary conditions for the proposed development sub-catchments were updated based on the XP-RAFTS model for post-development conditions, with implemented stormwater features.
- Preliminary concept earthworks grading pads for the proposed road and lot layout were modelled to raise them above the proposed development above the floodplain.
- Preliminary grading of the overland flow paths throughout the development were modelled. This mostly involved slightly lowering the flow paths to channelise the overland flow through these areas.

All other modelling elements remain unchanged from the pre-development model.

## *5.5 Post-Development Hydraulic Modelling Results*

The post-development TUFLOW modelling was undertaken to simulate the 5% AEP, 1% AEP, 0.2%, 0.5% and PMF events. Peak flood depth, level, hazard and extents mapping for these results are presented in **Appendix C**.

The results of the post-development conditions flood modelling are discussed below:

1. The post-development flood behaviour and conditions are largely unchanged from the pre-development conditions as the proposed development is largely outside of the flood extents in all modelled events.
2. Runoff from the upstream external catchments is concentrated slightly towards the overland flow paths indicated in the draft layout plan, however Snake Creek is largely untouched.
3. Although a climate change scenario with increased rainfall intensity was not specifically run, the design 0.5% and 0.2% AEP events represent an increased rainfall intensity of approximately 8% and 22% from the design 1% AEP event respectively. The rise in water level in the creeks due to the increased rainfall intensity in these events do not cause additional flood inundation of the proposed development and therefore climate change is not considered to be a risk to the development.
4. The peak flood depths and levels at the locations indicated in Figure 9 are summarised in Table 5 below.

*Table 5 Peak proposed flood depths and levels at observation locations*

| Observation Location |
|---|

| | AEP | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|---|
| Peak Level (mAHD) | **5%** | 128.8 | 118.1 | 105.9 | 101.9 | 140.0 | 139.7 | 87.4 | 102.6 | 55.4 |
| | **1%** | 128.9 | 118.2 | 106.1 | 102.1 | 140.1 | 139.8 | 87.6 | 102.8 | 55.7 |
| | **0.5%** | 128.9 | 118.3 | 106.1 | 102.1 | 140.1 | 139.8 | 87.7 | 102.8 | 55.8 |
| | **0.2%** | 129.0 | 118.4 | 106.2 | 102.2 | 140.1 | 139.8 | 87.8 | 102.8 | 56.0 |
| | **PMF** | 129.6 | 118.8 | 107.0 | 103.0 | 140.7 | 139.9 | 88.9 | 103.5 | 57.7 |
| Peak Depth (m) | **5%** | 1.3 | 1.2 | 1.1 | 0.7 | 0.5 | 0.1 | 1.0 | 0.6 | 1.5 |
| | **1%** | 1.4 | 1.3 | 1.3 | 0.9 | 0.6 | 0.1 | 1.2 | 0.7 | 1.8 |
| | **0.5%** | 1.4 | 1.3 | 1.4 | 0.9 | 0.6 | 0.1 | 1.3 | 0.8 | 1.9 |
| | **0.2%** | 1.5 | 1.4 | 1.5 | 1.0 | 0.6 | 0.1 | 1.4 | 0.8 | 2.1 |
| | **PMF** | 2.1 | 1.8 | 2.3 | 1.8 | 1.2 | 0.2 | 2.6 | 1.4 | 3.8 |

### *5.6 Flood Impacts of Proposed Development*

Afflux results for the 1% AEP event have been provided in **Appendix C**. The afflux results show some minor, localised water level increases directly adjacent to the proposed concept earthworks pad at locations where the pad is within the flood extents. However, these impacts are located within the waterways and do not extend upstream or downstream of the impacted area. These impacts also do not represent an increased risk to people or property; hence they are considered to be acceptable. It is noted that it is possible for these impacts to be managed or removed entirely once detailed site grading is implemented.

Although the peak flow from the post-development sub-catchments modelled by XP-RAFTS are slightly above pre-development peak flows in some cases (as outlined in Table 1), there is an overall reduction in the peak water level within Snake Creek as runoff from the developed catchments tend to discharge to the creek earlier than they would in the existing catchments. Therefore, the runoff from the development is conveyed through the site slightly before the peak of the runoff from the external catchments arrives.

Additionally, design flows downstream of the site were compared under pre-development and post-development conditions to assess the potential impact of the proposed development and the effectiveness of the flood management strategy (see Table 6). The location where the result comparisons were made are shown below in Figure 10, with flow hydrographs at the location presented in Figure 11 to Figure 15**.**

In Table 6**,** the results indicate that the network of proposed stormwater detention and treatment features in the post-development scenario are still adequate in attenuating the peak flow to pre-development levels in all modelled events even though the calculated peak flows from post-development XP-RAFTS model are slightly above pre-development flows in some cases. This shows that there is no overall impact to flood behaviour as a result of the proposed development. The flow hydrographs also further confirm that the timing of the catchment flows in the post-development scenario are shifted to be slightly earlier than those in the pre-development scenario.

*Table 6 Peak Flow Comparison Downstream of Site*

| AEP | **Pre-development** Flow ($m^3/s$) | **Post-Development** Flow ($m^3/s$) |
|---|---|---|
| **5%** | 36.55 | 35.89 |
| **1%** | 57.44 | 57.14 |
| **0.5%** | 63.31 | 63.32 |
| **0.2%** | 77.86 | 77.86 |
| PMF | 298.17 | 297.63 |

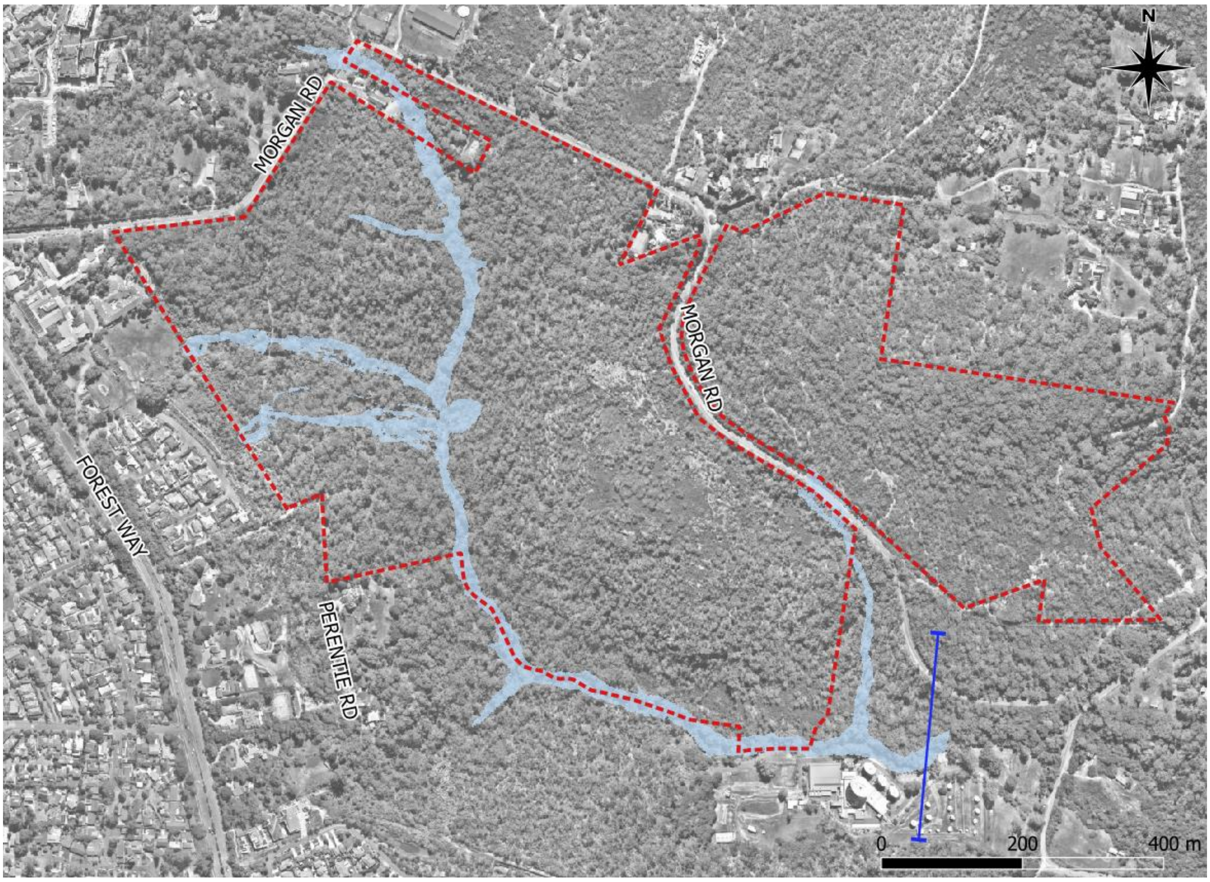


*Figure 10 Downstream of Site Observation Location from TUFLOW Model*

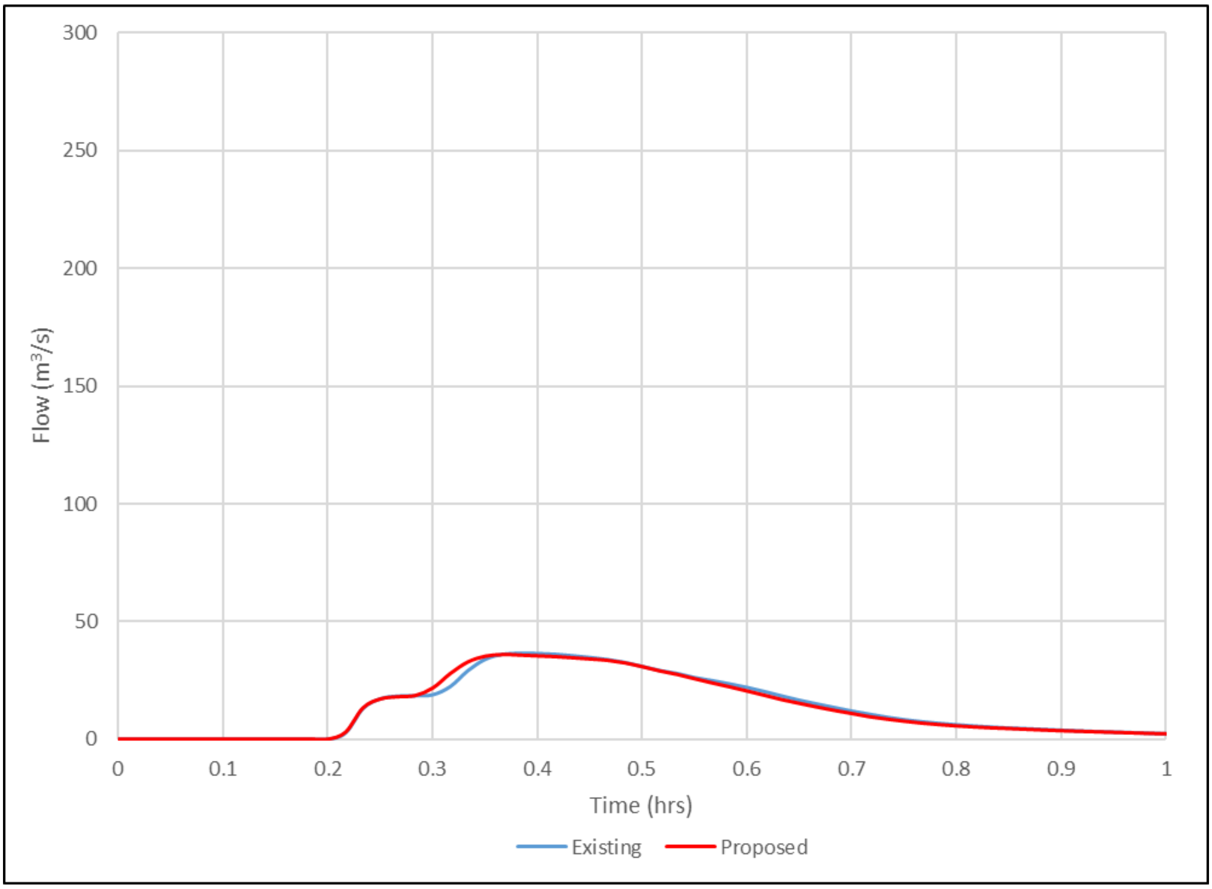


*Figure 11 Flow Hydrograph Comparison Downstream of Site (5% AEP)*

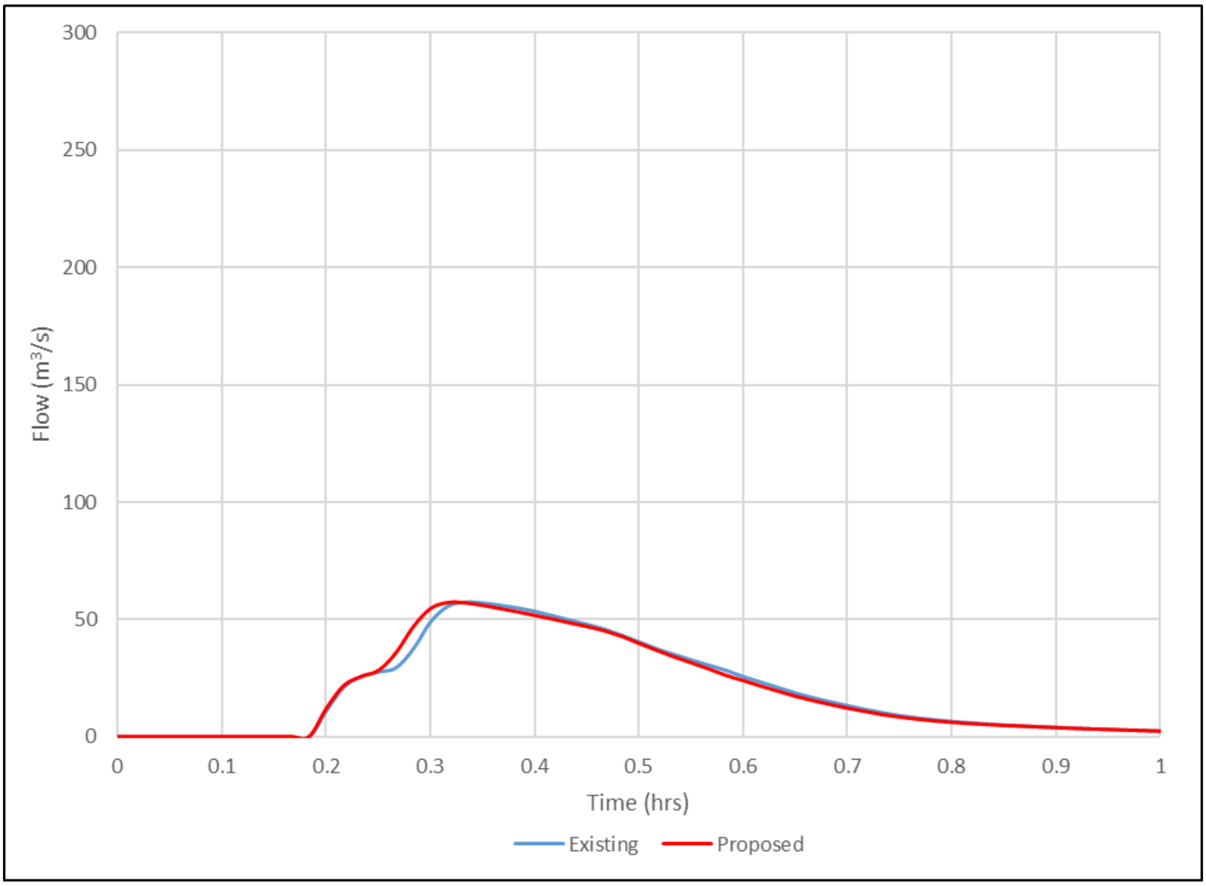


*Figure 12 Flow Hydrograph Comparison Downstream of Site (1% AEP)*

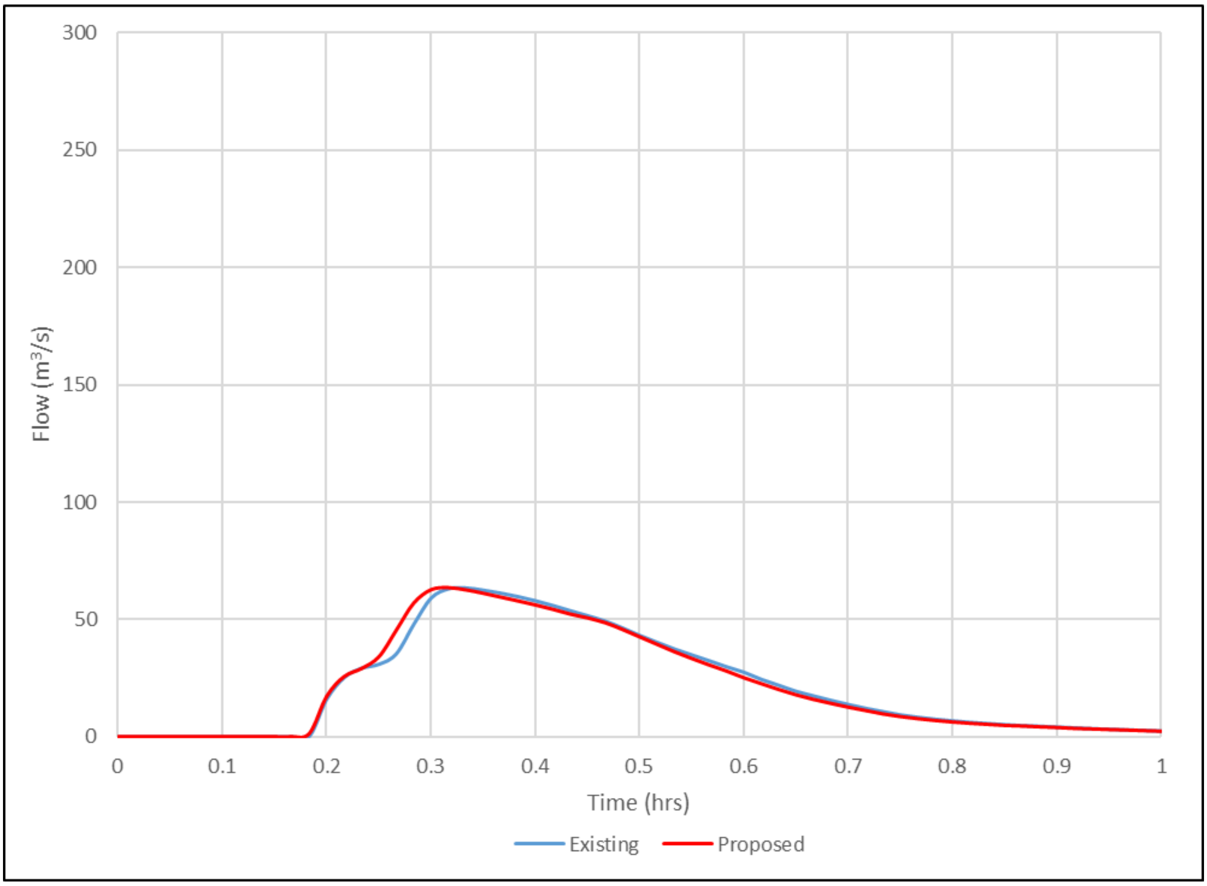


*Figure 13 Flow Hydrograph Comparison Downstream of Site (0.5% AEP)*

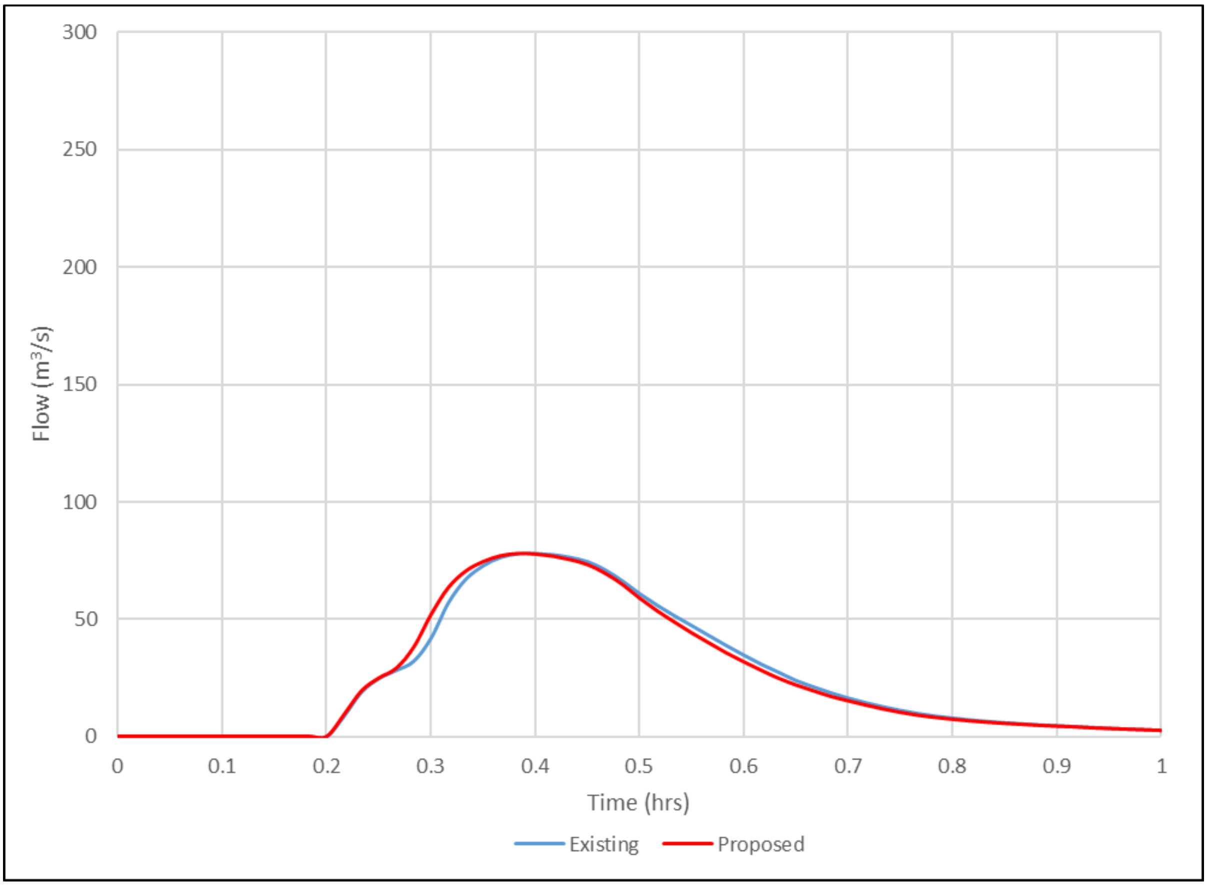


*Figure 14 Flow Hydrograph Comparison Downstream of Site (0.2% AEP)*

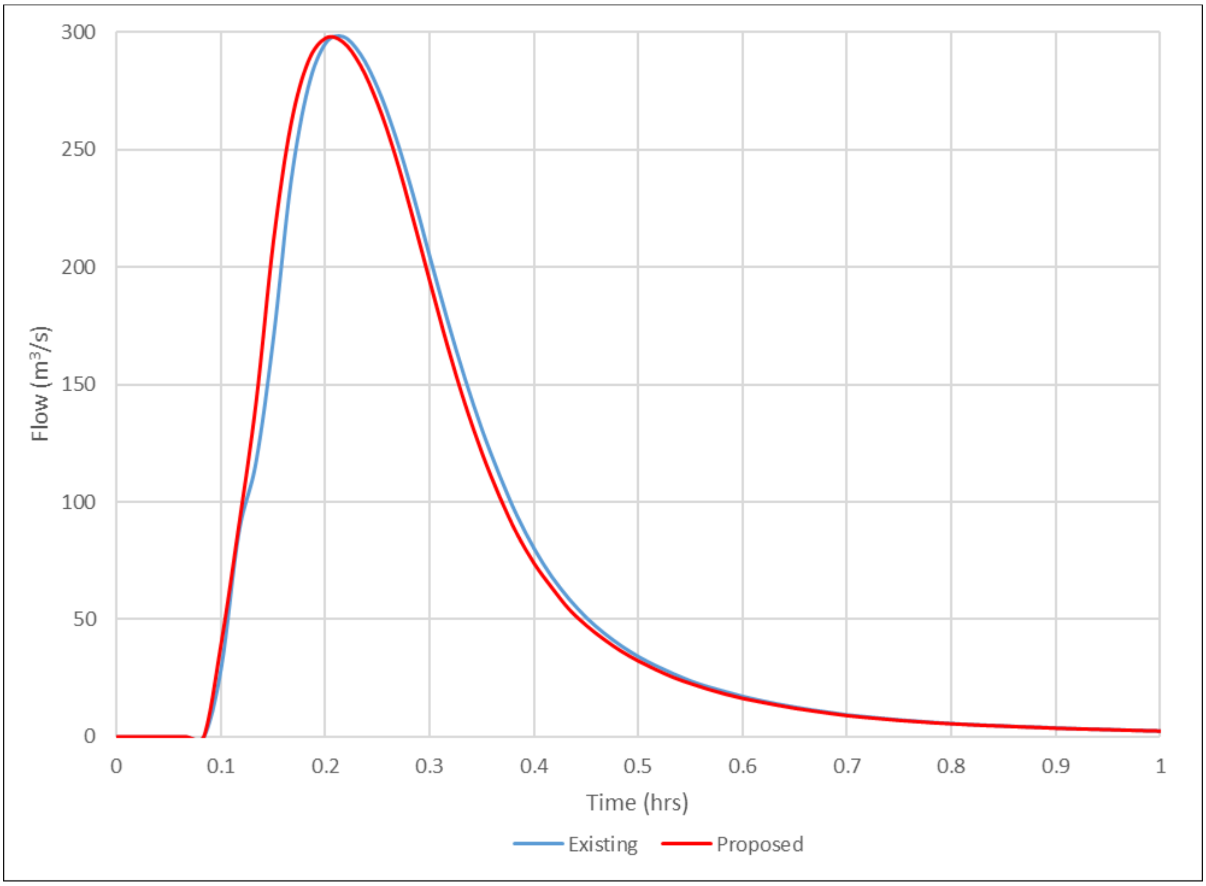


*Figure 15 Flow Hydrograph Comparison Downstream of Site (PMF)*

# 6 Key Findings and Recommendations

The key findings of the flood assessment and the proposed recommendations are discussed below:

1. The proposed layout plan is found to be compatible with the existing floodplain environment and is adequate to support the planning proposal from a flooding perspective. The flood assessment demonstrates the site can be developed in accordance with Council and DoPE's flood planning requirements without causing adverse offsite impacts to water levels and peak discharge.
2. The proposed stormwater detention and bioretention features located within the lots and roads are able to manage the increase in catchment runoff due to the proposed development by reducing the post-development peak discharge from each sub-catchment to within a reasonable amount as pre-development.
3. Flood planning levels for the proposed developments are to be considered in the detailed design stage. As previously mentioned, the Council DCP planning controls do not cover the site as it is not deemed to be in a flood affected precinct, however they have still been considered in this assessment. In Council planning controls it is required for residential developments in any flood risk precinct to have building floor levels at the flood planning level (FPL) which is defined as the 1% AEP flood level plus freeboard, typically 500mm. In the current concept earthworks grading, the development has been raised to be above this level, although this will need to be revisited for detailed design at a later stage.
4. Any road crossings over floodways and overland flow paths will need to be designed as bridges or contain culverts to allow flood waters to be conveyed underneath. The culverts should ideally be adequately sized such that there are no upstream impacts due to a backwater effect, and so that any flood waters overtopping the crossing will not be hazardous for people or vehicles in the event that evacuation or emergency access is required. These hydraulic structures are subject to detailed design and modelling at a later stage along with proposed site grading.
5. The flood emergency response will need to be considered for the site. Currently the proposed concept earthworks grading for the site has been designed such that all proposed development areas and roads would be filled to an elevation that is above the PMF event. Although this isn't strictly required by the DCP, this design is easily accommodated by the natural topography of the site, and also reduces the need for evacuation in the event of a flood. Hence the majority of the proposed development including access roadways are not expected to be inundated for all storm events up to even the PMF event. This is evident in the post-development flood result maps presented in **Appendix C**, however it is

subject to detailed site grading and stormwater design for the road crossings as mentioned above. Accordingly, shelter-in-place is the recommended emergency response for all future residents of the Morgan Road, Belrose development as there is no risk of flood affectation for the project. The only time that evacuation is recommended is in the case of a medical emergency occurring.

# 7 Conclusion

This FIRA study for the proposed masterplan layout & Planning Proposal for the Morgan Road, Belrose site has been undertaken in accordance with the requirements outlined in Council's LEP and DCP and the Department of Planning and Environment's policies.

Based on the results of the study, it is concluded that the management measures proposed for the site, including its network of stormwater quantity and quality features, are effective in ensuring that there would be no adverse impacts in the overall Snake Creek catchment as a result of the proposed development. Although there may be some minor localized impacts in areas of fill, these are negligible and do not have any widespread effects on people, property or the environment, hence they are considered to be immaterial. It is considered that opportunities exist after the rezoning stage to further refine and optimize the design grading to potentially alleviate these minor impacts.

Overall, the proposed layout plan is deemed sufficient to support the planning proposal from a flooding perspective.

# 8 References


Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) *Australian Rainfall and Runoff: A Guide to Flood Estimation*, © Commonwealth of Australia (Geoscience Australia), 2019.

Bureau of Meteorology (2021), *Rainfall IFD Data System*

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Montgomery Watson Harza (MWH) (2004), *Warringah Creek Management Study.*

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Northern Beaches Council (2011), *Warringah Local Environmental Plan (LEP)*.

# Appendix A – Preliminary Concept Plans

# Appendix B – XP-RAFTS Model Information

## Hydrology

### Adopted Loss Values

| Land Type | %Impervious | Pervious IL | Pervious CL (mm/hr) | Pervious 'n' | Impervious IL | Impervious CL (mm/hr) | Impervious 'n' |
|---|---|---|---|---|---|---|---|
| Existing | 10 | 7 | 0.5 | 0.03 | 1 | 0 | 0.013 |
| Lot – Roof | 100 | - | - | - | **17.7** | 0 | 0.013 |
| Lot – Driveway | 100 | - | - | - | 1 | 0 | 0.013 |
| Lot – Pervious | 0 | 7 | 0.5 | 0.03 | - | - | - |
| Public road | 70 | 7 | 0.5 | 0.03 | **7** | 0 | 0.013 |
| Open Space | 10 | 7 | 0.5 | 0.03 | 1 | 0 | 0.013 |
| External Catchment | Varies | 7 | 0.5 | 0.03 | 1 | 0 | 0.013 |

### Design storms

Design rainfalls have been obtained from 2016 BOM IFD at the site location. Temporal patterns have been obtained from ARR Datahub. The design rainfall and temporal hydrologic data have been used in the RAFTS modelling for both the pre and post development scenarios.

## Catchment

### Catchment delineation

Internal catchments have been delineated based on the site Draft Structure Plan, 29th April 2021 by Cox Architecture. External catchments have been delineated based on site topography using lidar data.

### Vector Average slope

The catchment average slope has been calculated using lidar levels and representative flowpath for each catchment.

### Hydraulic routing

Existing and developed catchments has been routed based on existing site topography. Catchment lag times have been calculated based on the uniform flow velocity of 2m/s and measured flowpath lengths between nodes.

## EXISTING MODEL CATCHMENT PROPERTIES

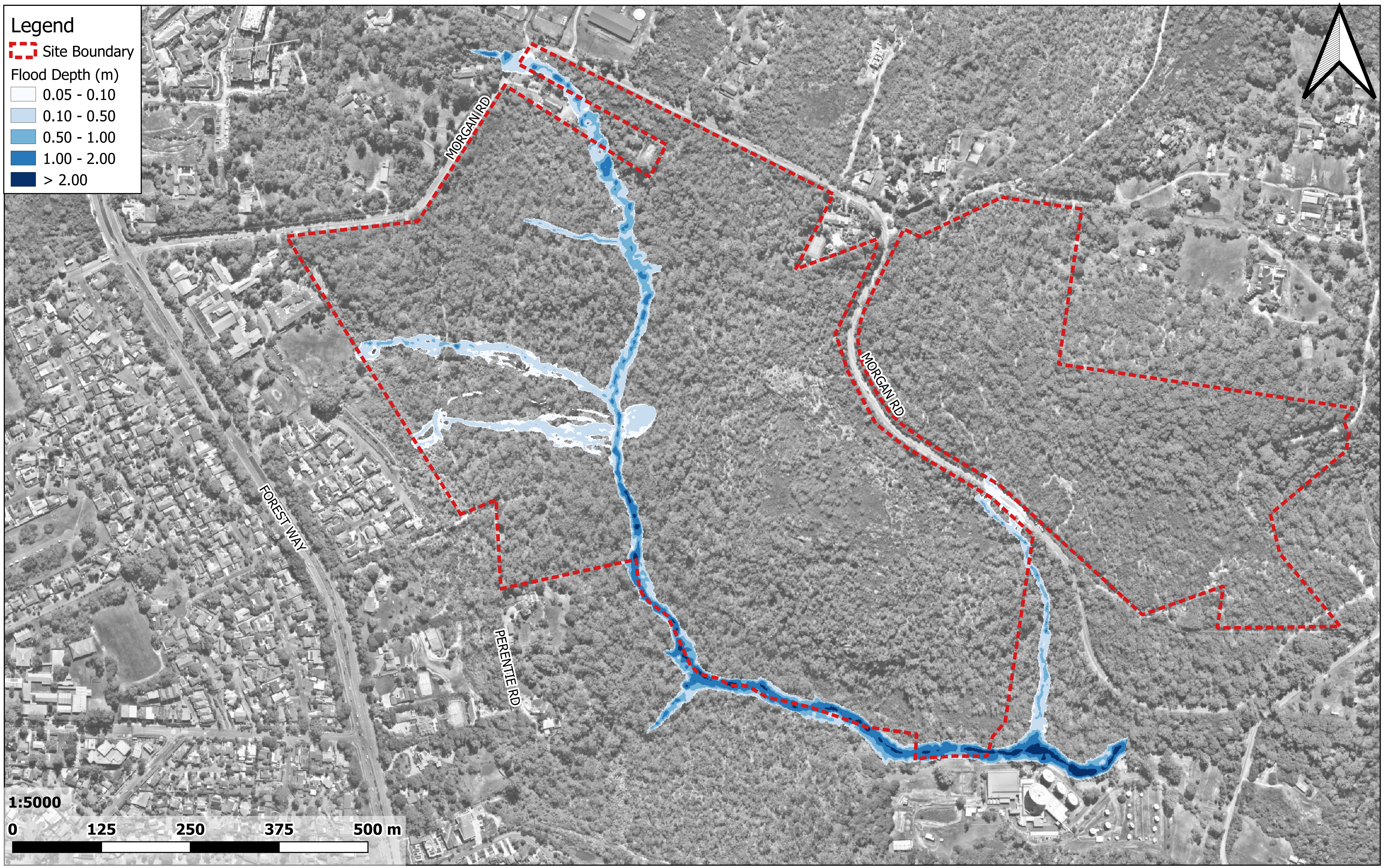
| Node ID | Total Area [ha] | %Imp | Vectored Slope [%] |
|---|---|---|---|
| A_lot dvwy | 0.520 | 10% | 15 |
| A_lot perv | 2.080 | 10% | 15 |
| A_lot roof | 2.601 | 10% | 15 |
| A_OpSpace | 0.612 | 10% | 15 |
| A_road | 4.380 | 10% | 15 |
| B_lot dvwy | 0.228 | 10% | 15 |
| B_lot perv | 0.912 | 10% | 15 |
| B_lot roof | 1.140 | 10% | 15 |
| B_OpSpace | 0.407 | 10% | 15 |
| B_road | 2.025 | 10% | 15 |
| C_lot dvwy | 0.368 | 10% | 15 |
| C_lot perv | 1.474 | 10% | 15 |
| C_lot roof | 1.842 | 10% | 15 |
| C_OpSpace | 0.192 | 10% | 15 |
| C_road | 1.242 | 10% | 15 |
| D1_lot dvwy | 0.477 | 10% | 15 |
| D1_lot perv | 1.908 | 10% | 15 |
| D1_lot roof | 2.385 | 10% | 15 |
| D1_OpSpace | 0.506 | 10% | 15 |
| D1_road | 3.138 | 10% | 15 |
| D2_lot dvwy | 0.066 | 10% | 15 |
| D2_lot perv | 0.264 | 10% | 15 |
| D2_lot roof | 0.330 | 10% | 15 |
| D2_OpSpace | 4.279 | 10% | 15 |
| D2_road | 0.401 | 10% | 15 |
| E_lot dvwy | 0.376 | 10% | 15 |
| E_lot perv | 1.504 | 10% | 15 |
| E_lot roof | 1.880 | 10% | 15 |
| E_OpSpace | 0.048 | 10% | 15 |
| E_road | 1.488 | 10% | 15 |
| Ext01 | 32.521 | 10% | 12.5 |
| Ext02 | 10.741 | 10% | 12 |
| Ext03 | 37.826 | 10% | 21 |
| Ext04 | 5.906 | 10% | 7 |
| Ext05 | 13.983 | 10% | 3 |
| Ext06 | 15.245 | 10% | 15 |

## DEVELOPED MODEL CATCHMENT PROPERTIES

| Node ID | Total area [ha] | %Imp | Vectored Slope [%] |
|---|---|---|---|
| A_lot dvwy | 0.520 | 100 | 15 |
| A_lot perv | 2.080 | 0 | 15 |
| A_lot roof | 2.601 | 100 | 15 |
| A_OpSpace | 0.612 | 10 | 15 |
| A_road | 4.380 | 70 | 15 |
| B_lot dvwy | 0.228 | 100 | 15 |
| B_lot perv | 0.912 | 0 | 15 |
| B_lot roof | 1.140 | 100 | 15 |
| B_OpSpace | 0.407 | 10 | 15 |
| B_road | 2.025 | 70 | 15 |
| C_lot dvwy | 0.368 | 100 | 15 |
| C_lot perv | 1.474 | 0 | 15 |
| C_lot roof | 1.842 | 100 | 15 |
| C_OpSpace | 0.192 | 10 | 15 |
| C_road | 1.242 | 70 | 15 |
| D1_lot dvwy | 0.477 | 100 | 15 |
| D1_lot perv | 1.908 | 0 | 15 |
| D1_lot roof | 2.385 | 100 | 15 |
| D1_OpSpace | 0.506 | 10 | 15 |
| D1_road | 3.138 | 70 | 15 |
| D2_lot dvwy | 0.066 | 100 | 15 |
| D2_lot perv | 0.264 | 0 | 15 |
| D2_lot roof | 0.330 | 100 | 15 |
| D2_OpSpace | 4.279 | 10 | 15 |
| D2_road | 0.401 | 70 | 15 |
| E_lot dvwy | 0.376 | 100 | 15 |
| E_lot perv | 1.504 | 0 | 15 |
| E_lot roof | 1.880 | 100 | 15 |
| E_OpSpace | 0.048 | 10 | 15 |
| E_road | 1.488 | 70 | 15 |
| Ext01 | 32.521 | 26 | 12.5 |
| Ext02 | 10.741 | 57 | 12 |
| Ext03 | 37.826 | 35 | 21 |
| Ext04 | 5.906 | 10 | 7 |

| | | | |
|---|---|---|---|
| Ext05 | 13.983 | 10 | 3 |
| Ext06 | 15.245 | 15 | 15 |

# Appendix C – Flood Maps

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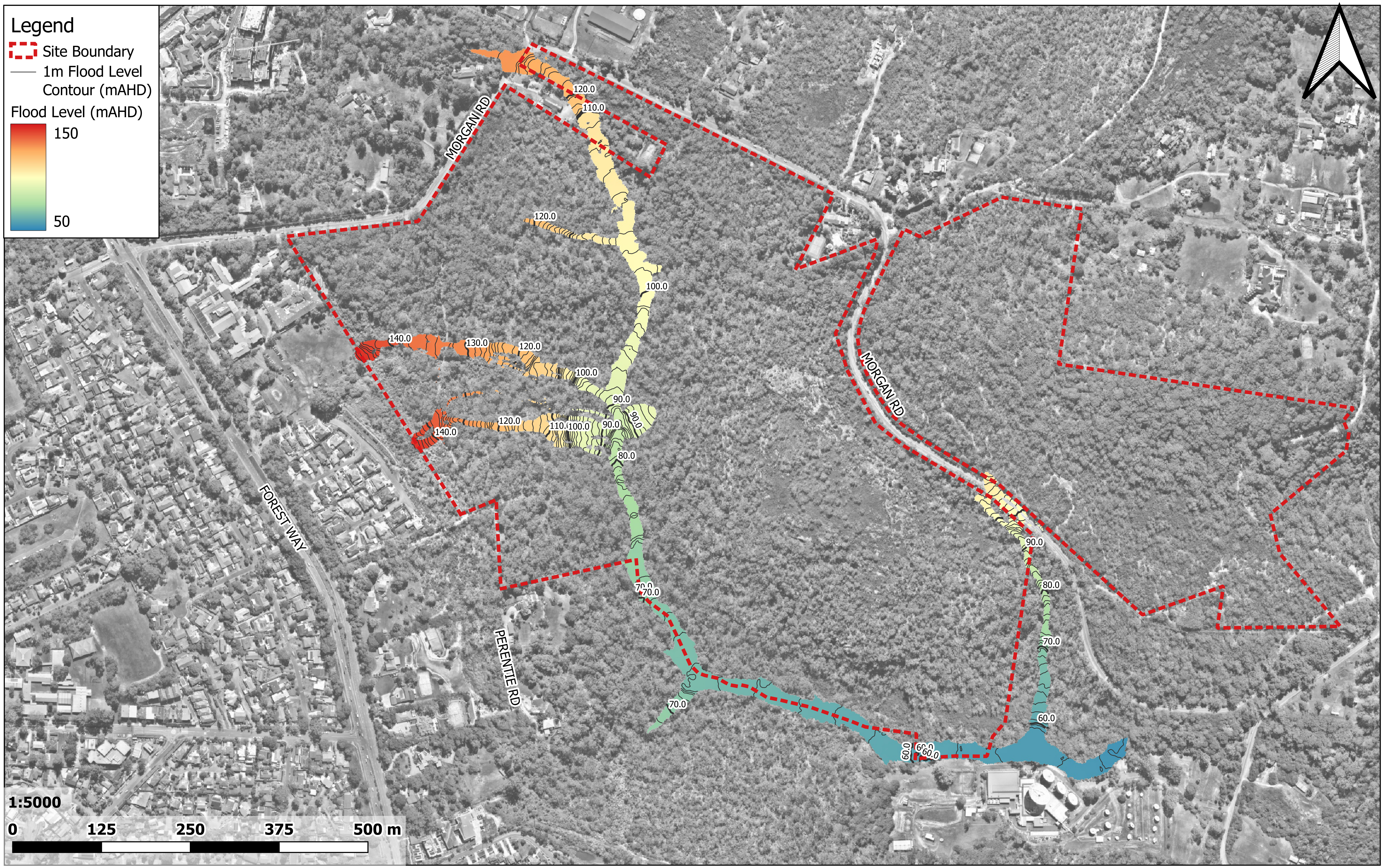
**Map 01 - Existing Flood Depth**
**1% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**

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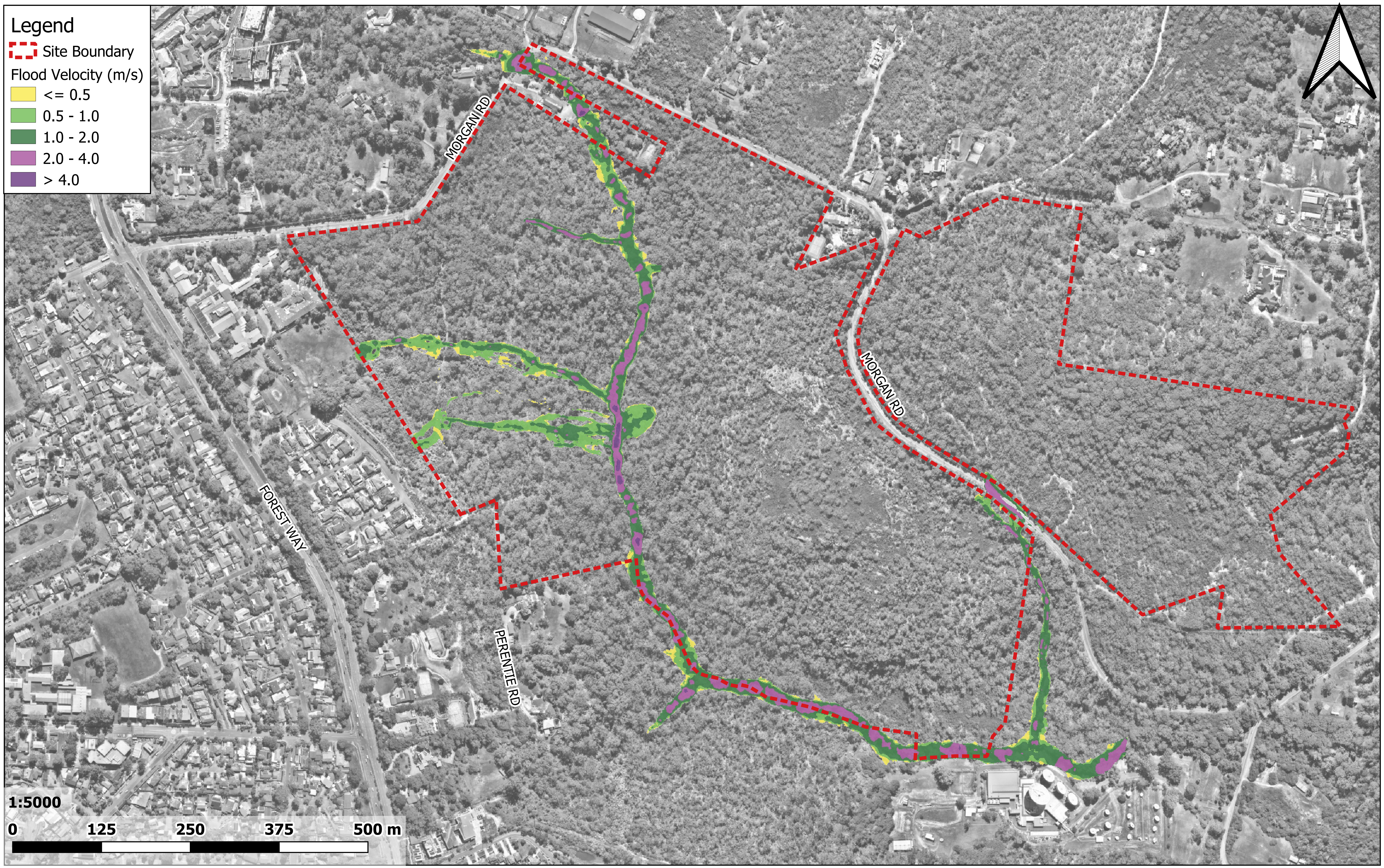
**Map 02 - Existing Flood Level**
**1% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**

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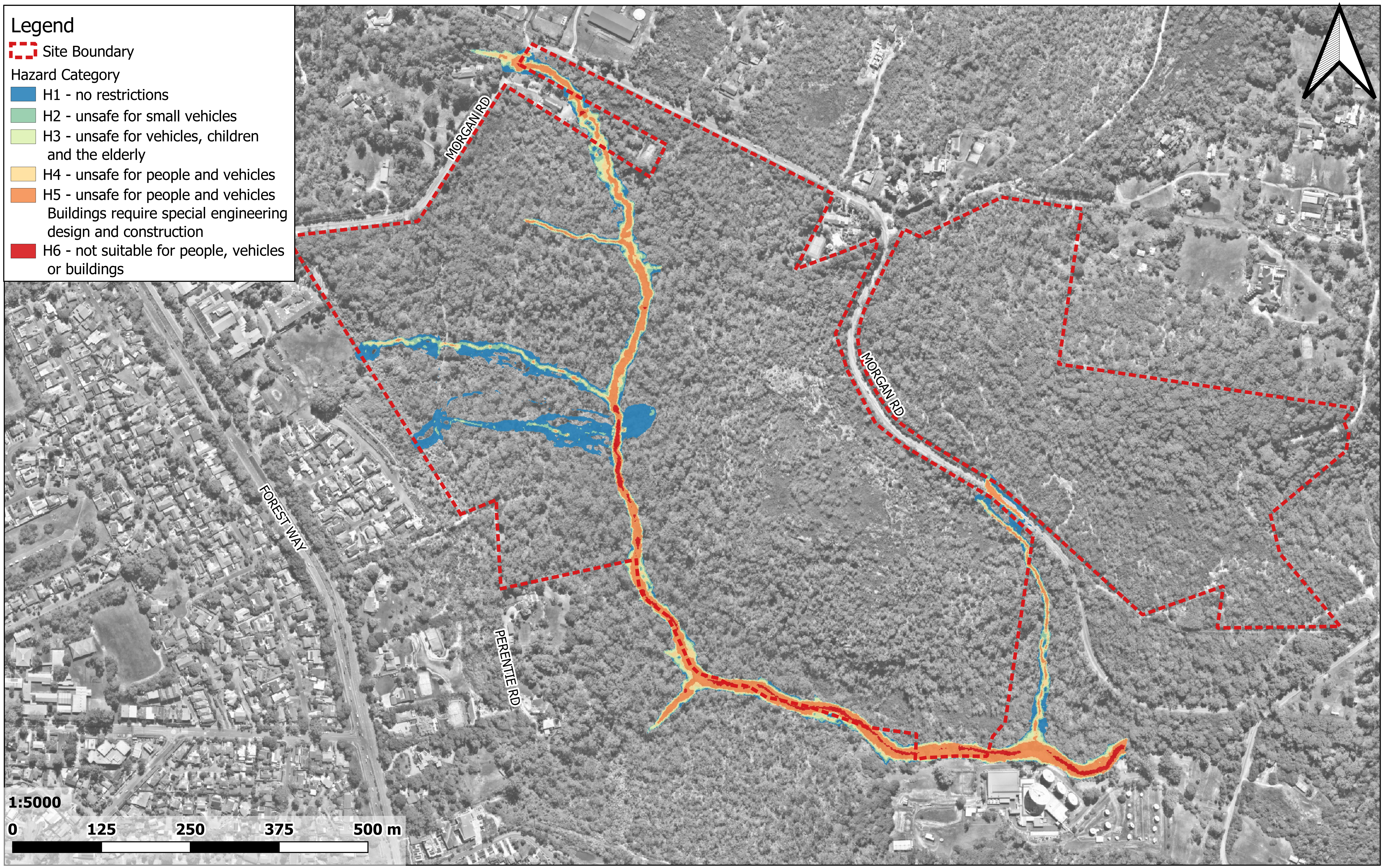
**Map 03 - Existing Flood Velocity**
**1% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**

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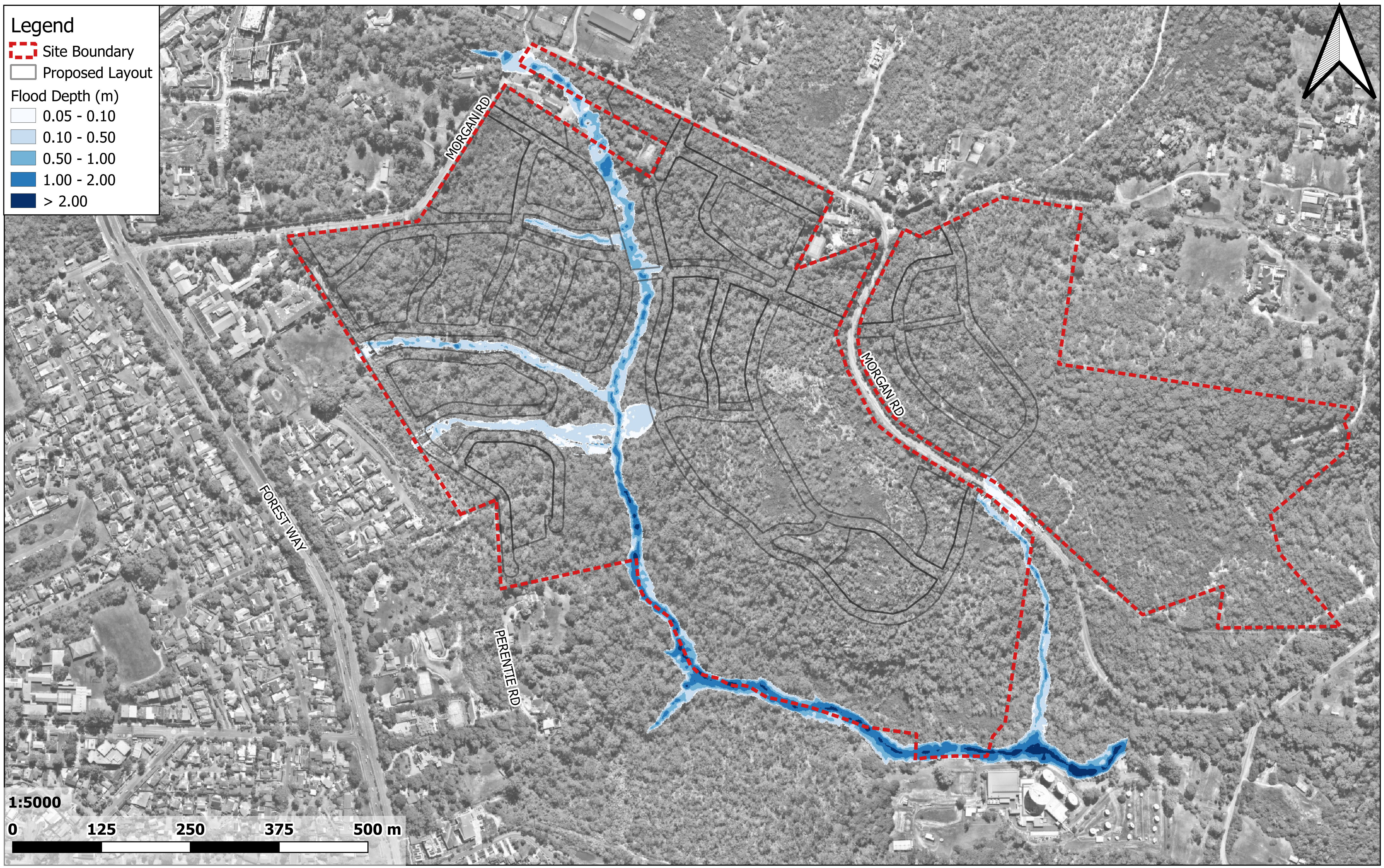
**Map 04 - Existing Flood Hazard**
**1% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**

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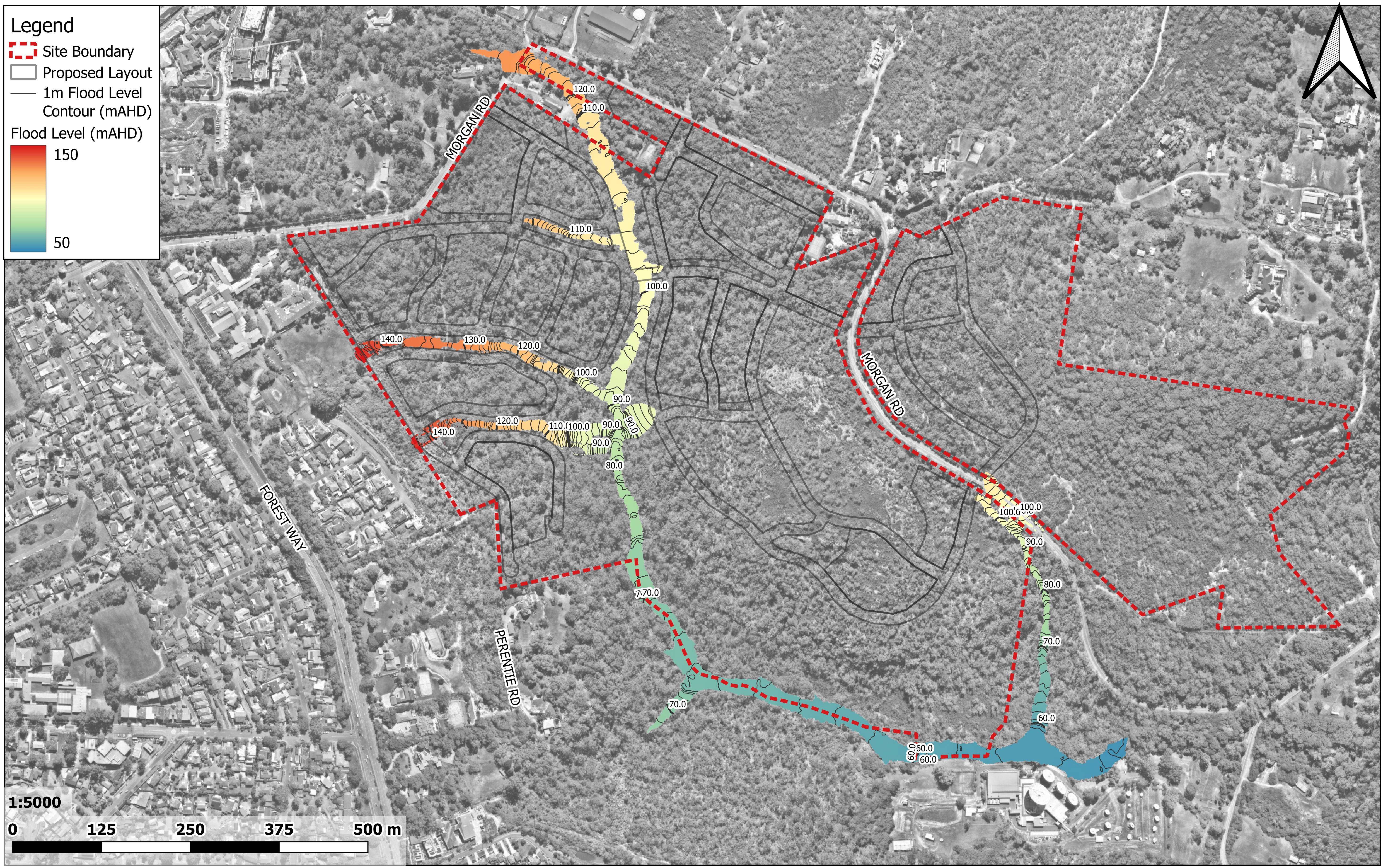
**Map 05 - Proposed Flood Depth**
**1% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**

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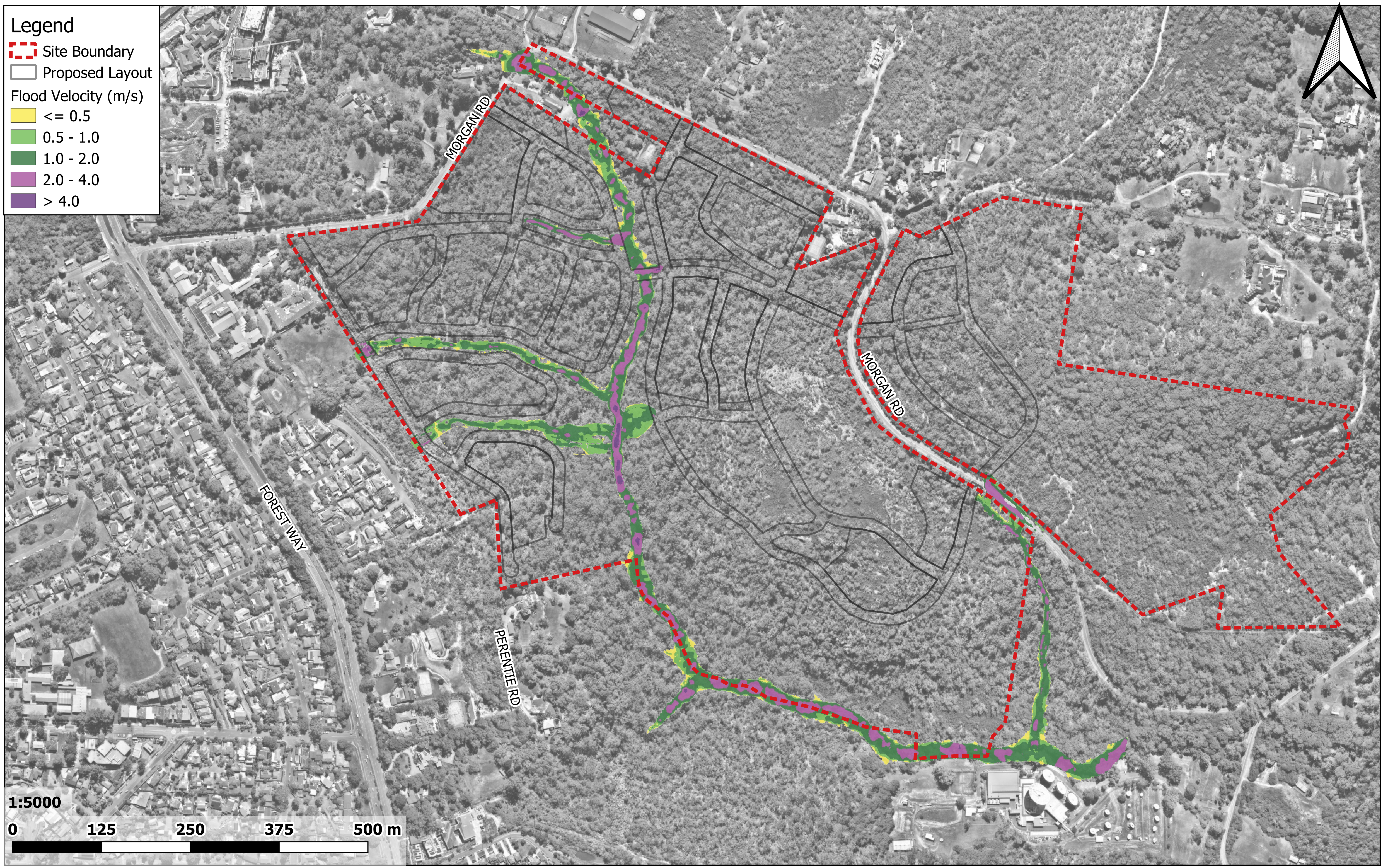
**Map 06 - Proposed Flood Level**
**1% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**

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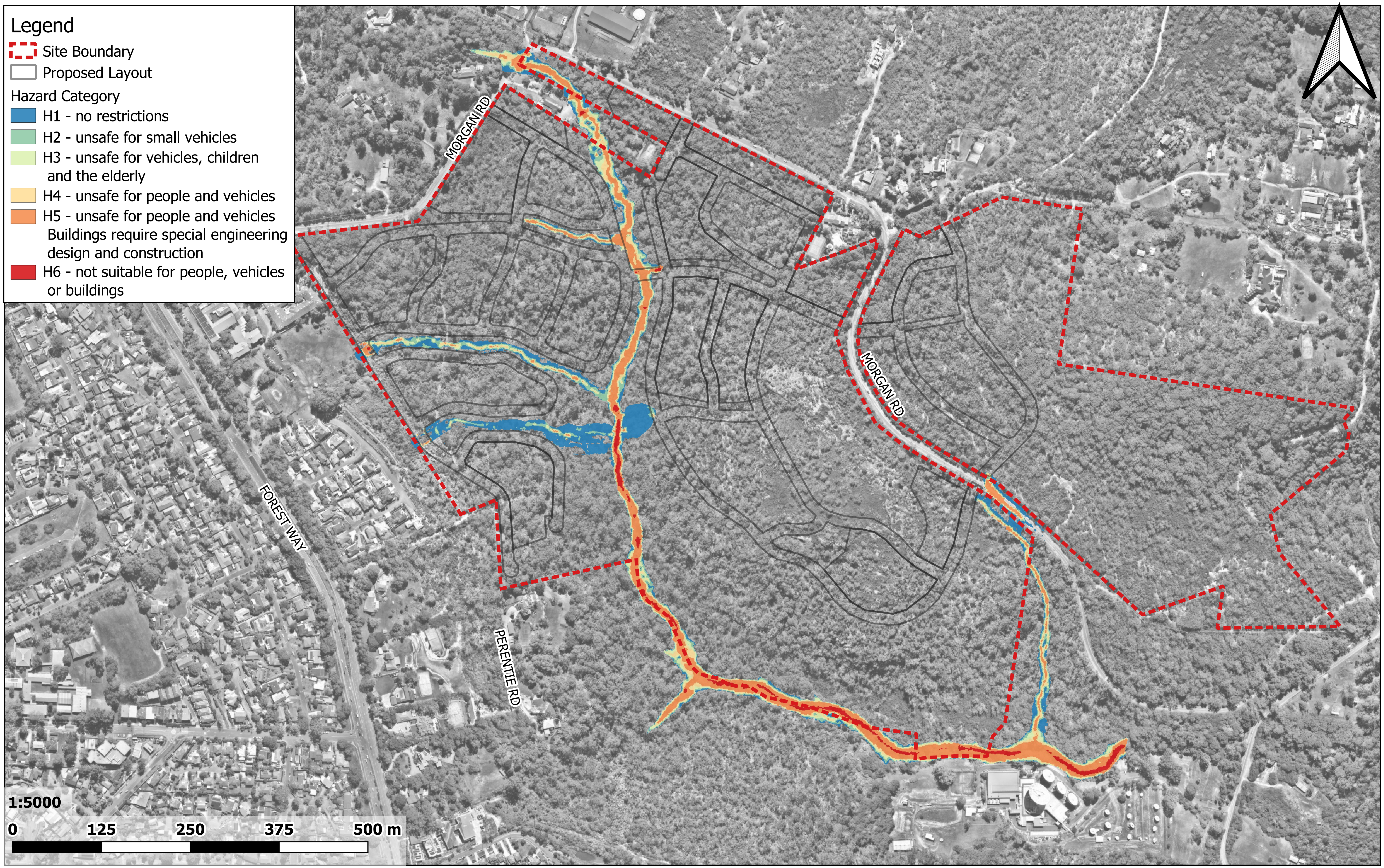
**Map 07 - Proposed Flood Velocity**
**1% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**

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**Map 08 - Proposed Flood Hazard**
**1% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**


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**Map 09 - Water Level Afflux**
**1% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**


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**Map 10 - Existing & Proposed Flood Extents**
**5% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**


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**Map 11 - Existing & Proposed Flood Extents**
**1% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**


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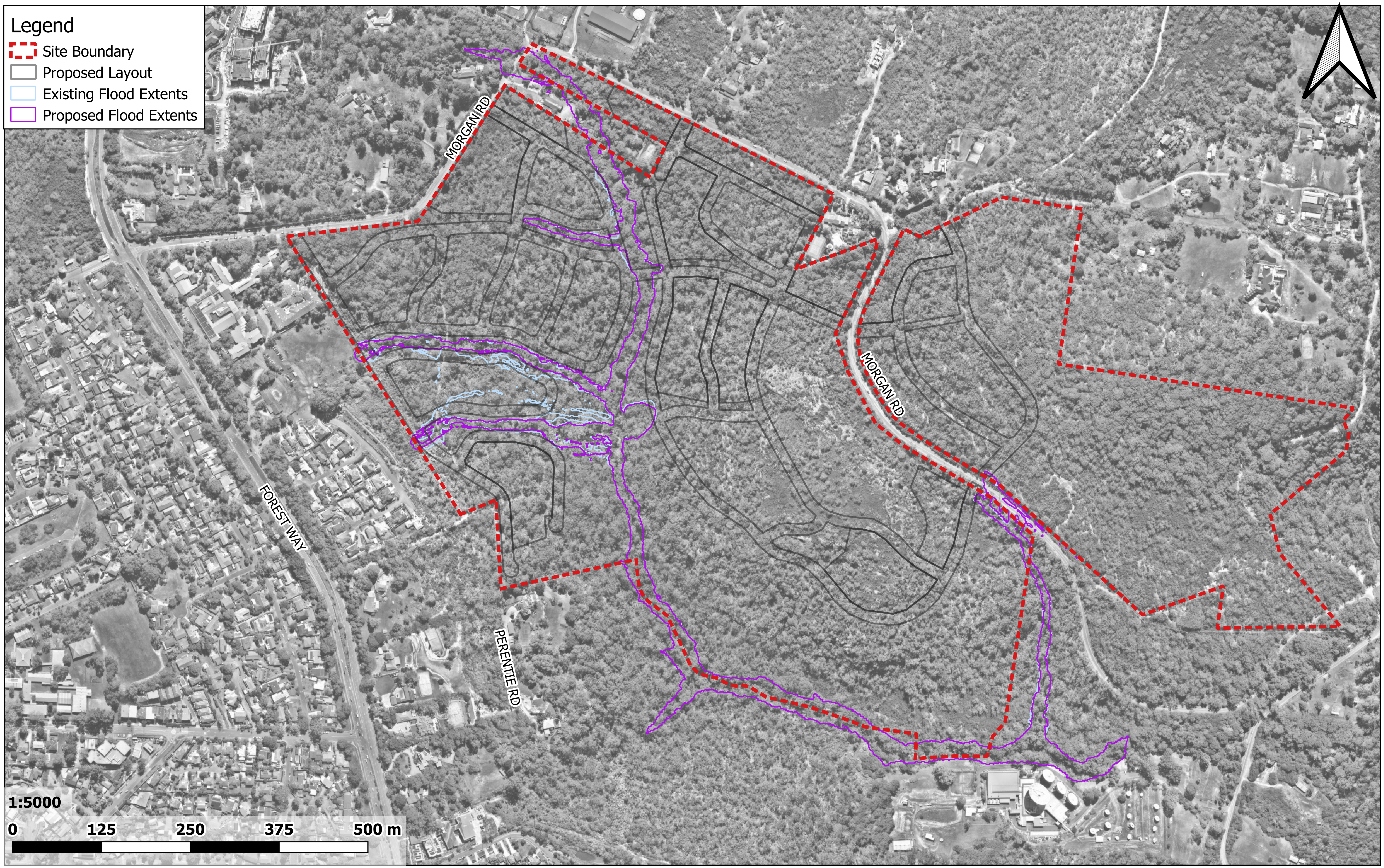
**Map 12 - Existing & Proposed Flood Extents**
**0.5% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**

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**Map 13 - Existing & Proposed Flood Extents**
**0.2% AEP Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**


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**Map 14 - Existing & Proposed Flood Extents**
**PMF Critical Storm Duration**
**Morgan Road, Belrose (Northern Beaches Council)**
**Project Number: 096-16**