Our Ref 59917042\Lt02:DW

Contact Daniel Wood

27 February 2017

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Dear Sir,

2 MACHPERSON STREET, WARRIEWOOD - ADDENDUM FLOOD IMPACT ASSESSMENT

1.0 Introduction

Council has recently reviewed the documentation provided as part of the rezoning submission and, concerning flooding, found the following deficiencies in the information provided:

- *The Flood Report (lodged with the Planning Proposal), is unclear as to if the site will be filled to 3.8m AHD (1% AEP plus climate change) or 4.3m AHD (Flood Planning Level plus climate change).*
- *The Flood Report merely states that the proposed filling for the subject site will have less impact than the filling proposed as part of the Macpherson Street upgrade. First, this is not considered to be adequate justification, and second, the Flood Report does not provide sufficient information to demonstrate the impact of filling (i.e. the resultant flood behaviour), particularly on surrounding, upstream and downstream properties.*
- *It is stated that 'Cardno has modelled the impact of the proposed filling for the development, and concluded that the filling does not cause an actionable impact to flood levels' (whereby 20mm is noted as the maximum afflux), however the Flood Report does not incorporate any 'difference' mapping (or similar) to demonstrate whether or not there may be any adverse impacts upstream or downstream of the subject site as a result of the proposed fill. This is considered to be vital to making an informed decision regarding whether it is appropriate to permit dwellings on the subject site.*
- *The Flood Report (lodged with the Planning Proposal) states that habitable floor levels will be at the Flood Planning Level (plus climate change) (though it should be noted that there is an inconsistency in the documentation provided as to the proposed floor levels), however this would still result in any future dwellings being subject to 1m of water in a PMF event. This means that should dwellings be permitted on the subject site, they would need to be two-storey dwellings to facilitate vertical refuge or shelter-in-place during a Probable Maximum Flood event (the detail of any potential future dwellings is not clear in the information submitted with the Planning Proposal).*
- *The Flood Report does not provide any further information to support the potential need for vertical refuge or shelter-in-place, including the potential length of time for the floodwater to recede around this site – the report simply states that '…the site is unlikely to be isolated for unacceptable periods of time'. This is, however, contrary to the Warriewood Valley Strategic Review Report (2013), which identifies 2 Macpherson Street, Warriewood as Category F whereby '…flood isolation/entrapment (beyond short durations)…' is a criterion. Subsequently, it is considered that the Flood Report does not contain enough detail to adequately and satisfactorily address risk to life and property.*

- *It is noted that the submission from the SES incorporates the fact that the risks associated with sheltering in place should be 'adequately assessed to determine the tolerability of isolation', and that the subject Planning Proposal does not incorporate such information*

This addendum flood impact assessment provides further advice to support the rezoning of 2 Macpherson Street, Warriewood. The aim of this document is to provide further advice with regards to the above deficiencies and provide council with sufficient information to confidently assess the applications intent with regards to flooding.

2.0 Summary of Issues

The following addendum provides clarity with regards to the following key issues, derived from the above comments:

- Final fill levels of the site
- The impact of the proposed fill level on the floodplain and surrounding properties
- The proposed flood emergency response for the site in events that exceed the floor levels of dwellings on site.

3.0 Final Fill Levels

The final proposed floor levels and fill levels are provided on drawing number SK02 P3 provided as an attachment to this document. The following criteria are addressed within this earthworks plan:

- The development level should be above the planning level (above the 1% AEP with 30% climate change plus 0.9m sea level rise). The flood planning level for this site is considered to be 4.29 mAHD based on current flood mapping of the site;
- No adverse impacts upstream and downstream of the subject site; and
- No loss of flood storage up to the probable maximum flood (PMF) design flood

The finished floor level of the development is set to 4.29 mAHD. The internal roadway within the development ranges from 3.50 mAHD to 4.10 mAHD. The internal roadway does not have 1% AEP with 30% climate change and 0.9 m sea level rise immunity however is deemed trafficable in this event. Further discussion on trafficability is provided in section 5.

4.0 Impact of Fill on Floodplain and Surrounding Properties

As discussed within the provided flood report, Cardno has undertaken flood modelling to determine the impact of flooding due to the proposed development. In order to assess this, Cardno have used the Council approved Narrabeen Lagoon Flood Model.

As the approved flood model does not have the proposed Macpherson Street Road upgrade incorporated, the first task was to update this and redefine the base case flooding for the site. In addition to this, detailed ground survey of the development site was incorporated into the model.

The Narrabeen Lagoon (and tributaries) TUFLOW model, was used as a basis for the flood impact assessment. Given the size and the long run time of the model, it was truncated for the purposes of this assessment.

The truncated model was run and compared to full model prior to modification to ensure consistent output. The model extends downstream past the site by approximately 800 m (Downstream of Jackson Road) where a time varying water level boundary, derived from the catchment wide model, was established.

Upon verification the truncated model was modified to reflect the site survey and the proposed Macpherson Street design. The additional works included in the truncated base case model are as follows:

- A site survey tin provided by Bonacci Group Pty Ltd was included in the model; and
- The design surface level of Macpherson Street were digitized based on the Issued for Construction Drawings of Macpherson Street which were obtained from the Northern Beaches Council. In addition, the proposed culvert and bridge details were obtained from these drawings and incorporated into the model.

Modelling of Macpherson Street Upgrade

In order to represent the Macpherson Street upgrade the proposed alignment was incorporated into the hydraulic model. The alignment and levels utilised are on the information provided by Northern Beaches Council (Macpherson Street Warriewood Road Upgrade April 2016 reduced.pdf).

The details of the proposed culverts and bridge under Macpherson Street are provided in the Table 3-1. Initial modelling showed that due to the large size of the culverts, model instabilities occurred around the culverts causing unrealistic flood levels. To overcome this issue, the culverts were modelled in the 2D domains using the layered flow constriction approach. Appropriate flow constriction parameters were determined to represent the head loss that would occur through the culvert structure. These losses were calibrated against a HEC-RAS model of the culverts to confirm their suitability. The adopted flow constriction parameters are provided in Table 3-2.

Table 3-1 Macpherson Street Culvert and Bridge Details

Parameters	Parameters	
	Culvert	Bridge
Size	9x 3.6x1.2 RCBCs	Open Bridge with no piers in the waterway
		Base width of 3.6m
		Top width to waterway 6.9m
		Underside of Bridge 3.42 mAHD
Length	15	15
Upstream Invert Level	1.90	0.79
Downstream Invert Level	1.84	0.73

Table 3-2 Macpherson Street Culvert and Bridge Details

Bridge Layer	Levels	Form Loss Coefficient (K)	Blockage (%)
Layer 1 (below deck)	Invert level of 1.9 mAHD Obvert level 3.1 mAHD	0.5	11
Layer 2 (deck level)	Underside of deck 3.1 mAHD Road Level 4.2 mAHD	1.2	100
Layer 3 (above road level)	Level to top of handrail 5.11 mAHD	0.5	10

Developed Case Model

Subsequent to base case modelling and calibration, a post-development model was created to reflect the proposed development of the site. The proposed design tin of the development site was provided by Bonacci Group Pty Ltd which was included in the flood model to assess the flood impacts. The design surface information utilised is provided on drawing SK02 P3 provided as an attachment to this document.

Results of Flood Modelling

Impacts of the Roadway Upgrade

A comparison of the base model vs the model with the proposed Macpherson Street upgrade was undertaken to confirm the impact of the alignment. In general no actionable impacts were noted however a minor increase in flood levels (20 mm) are noted to the west of the fill pad.

Table 4-1 Base Case Model Validation Results

Reporting Location	1% AEP with 30% climate change Flood Levels (mAHD)	
	Model without Road Upgrade	Model with Road Upgrade
Upstream of Macpherson Street, West of Development	3.78	3.80
Upstream of Macpherson Street, East of Development	3.78	3.78
Immediately Downstream of Macpherson Street	3.77	3.77

Development Flood Impacts

Figure 1 shows the depth plot of the 1% AEP with 30% climate change plus 0.9m sea level rise when the development is considered onsite. Figure 2 shows the water level impact map of the same event when comparing the developed condition to the base condition model with the Macpherson Street Road upgrade incorporated.

Figure 3 shows the hazard profile for the site in the 1% AEP with 30% climate change plus 0.9 m sea level rise. The roadway, while inundated in some areas is considered to be low hazard and trafficable. In events that exceed the roadway level however, it is recommended that residents onsite do not evacuate. Further discussion on emergency management procedures is provided in section 5.0.

Figure 4 shows the maximum depth experienced onsite during the PMF event. In this event the finished floor level of the proposed development is exceeded. Depths of approximately 0.7 m are present in the area where dwellings are proposed. The PMF Event is largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. The PMF event is generally considered to have a probability of occurrence between 1:10,000 and 1:100,000.

The results of the modelling confirm that no adverse impacts external to the site are present in the 1% AEP with 30% climate change plus 0.9m sea level rise. A maximum afflux of 20 mm has been obtained for the 1% AEP with 30% climate change plus 0.9m sea level rise at the north western boundary of the site. Minor reductions are present to the east of the site of up to 20 mm.

The PMF event exceeds the proposed finished floor level of the site. As a result the site must be considered at risk of flooding and flood emergency management considered to ensure the safety of persons onsite.

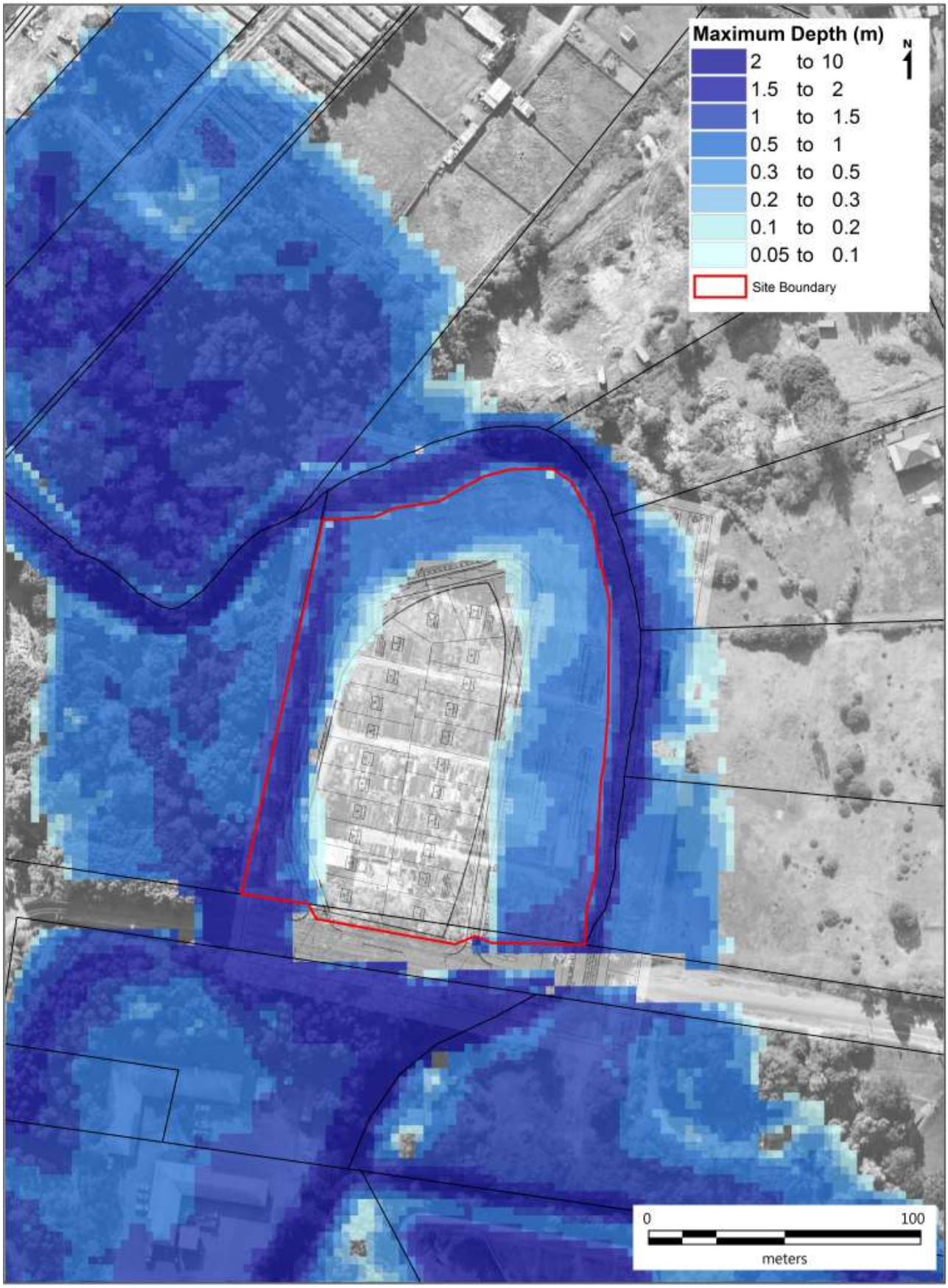

Figure 1 – 1% AEP with 30% climate change plus 0.9m sea level rise Maximum Depth

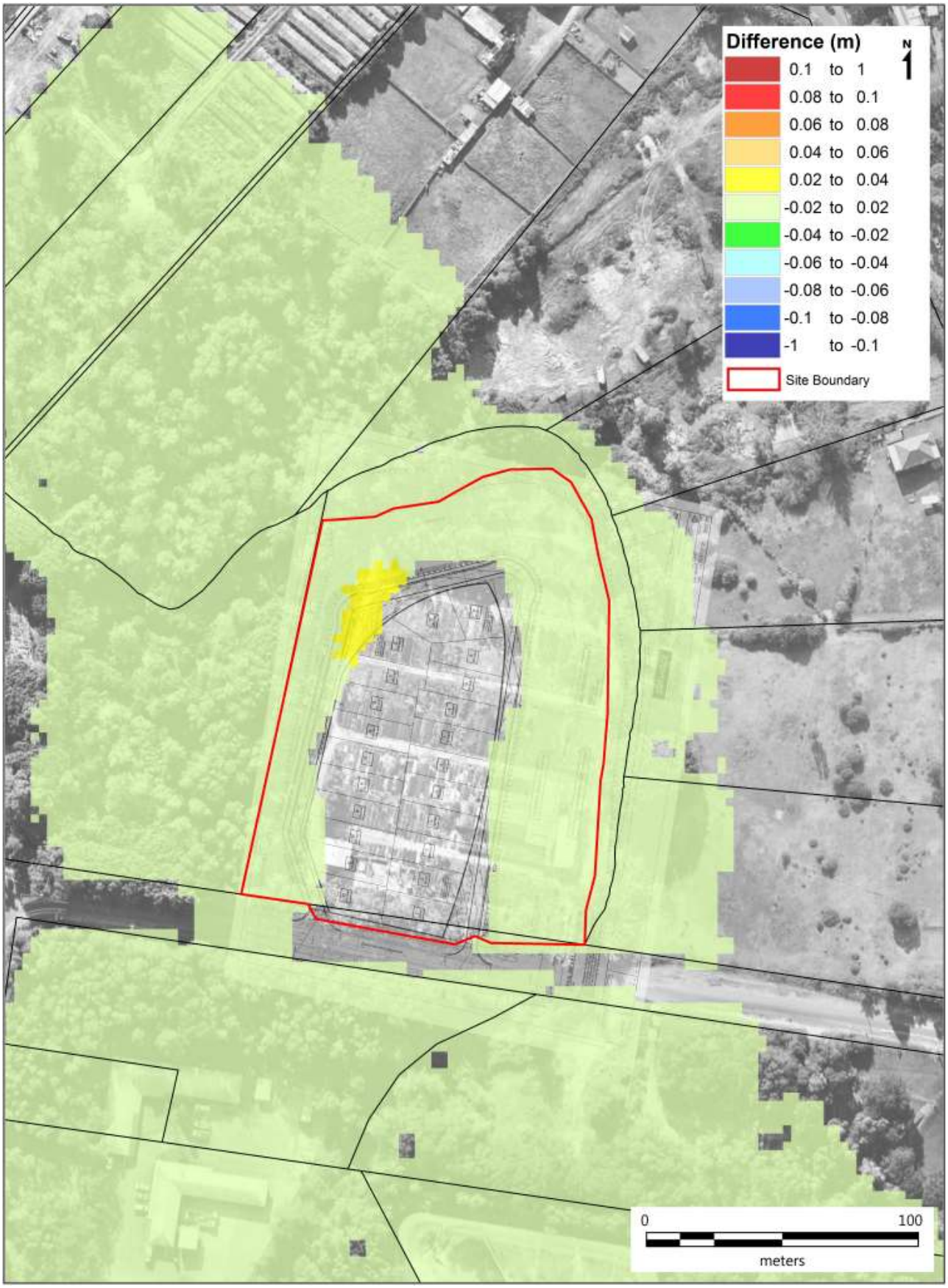

Figure 2 – Impacts 1% AEP with 30% climate change plus 0.9m sea level rise Maximum Depth – Developed v Existing Condtions

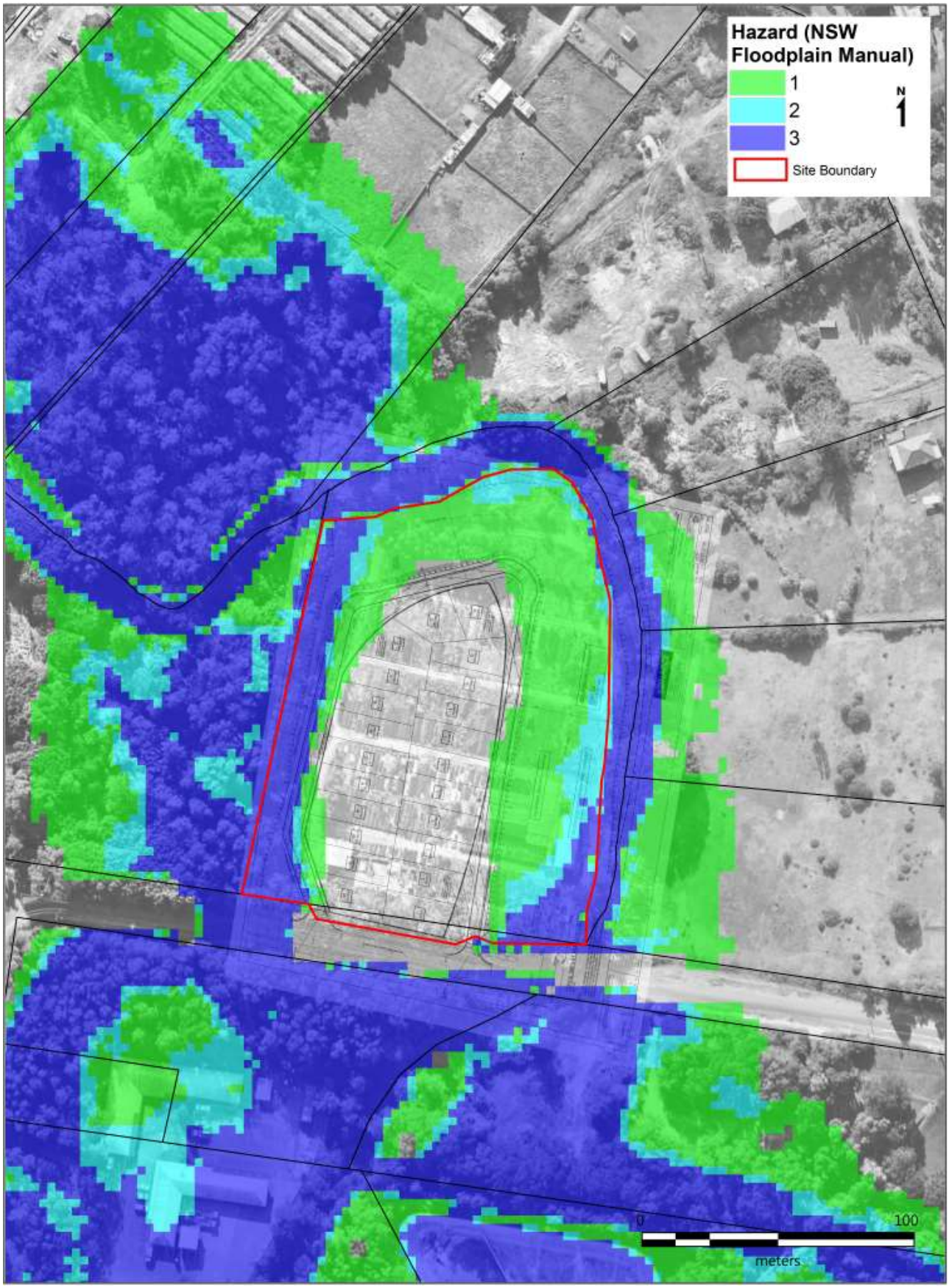

Figure 3 – Hazard 1% AEP with 30% climate change plus 0.9m sea level rise Maximum Depth

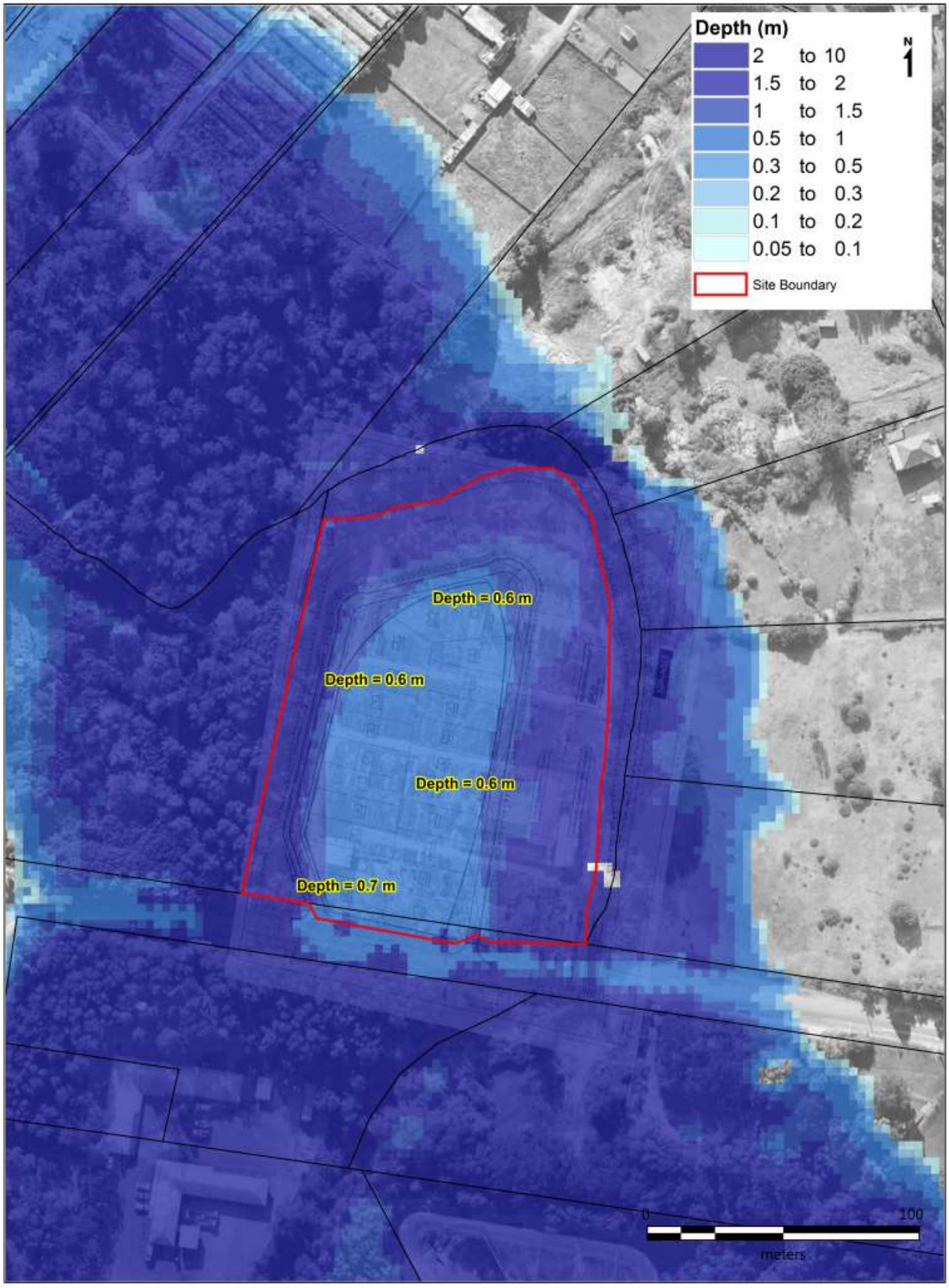

Figure 4 – PMF Maximum Depth

Flood Storage

Opportunities to compensate for the loss of flood storage due to the proposed fill within the subject site have been analysed. The maximum potential excavation is constrained by the following:

- No encroachment in the vegetation protection area along the creek;
- Minimal encroachment into the 25 m bushfire offset line; and
- Maximum batter slope of 1:4.

Based on the above constraints, an excavation volume of approximately 5,400 m^3 is achievable. A comparison of the flood storage for the 1% AEP climate change and sea level rise (0.9m) is presented in Table 4-2. The results show the proposed excavation would result in a net gain of flood storage of 740 m^3 for 1% AEP climate change design event.

The flood modelling or flood impact maps included in this report did not include this excavation volume and hence represent a conservative scenario.

In the case of the PMF design event, with the above excavation in place a net loss flood storage of 3,100 m^3 would occur. A further investigation showed that no loss of flood storage for the PMF could be achieved by encroaching into the vegetation protection and bushfire offset line.

As the flood storage capacity of the floodplain in the PMF event is so great, this additional flood storage would provide no net benefit to the flood condition. This is discussed within Narrabeen Lagoon Flood Study (BMT WBM, 2013) which states that filling in areas such as this development (Flood Fringe) has minimal impact on the overall flood behaviour. The additional cut required will however will result in both environmental and visual amenity issues in the region.

Table 4-2 Flood Storage Calculations

Scenario	1% AEP with climate change Volume (m^3)	Net Loss (-) or Gain (+) Volume (m^3)
Pre-development	18,000	n/a
Post-development without excavation	13,263	-4,737
Post-development excavation	18,704	+740

Based on this assessment it is considered that the majority of compensatory cut can be provided for flood storage for events up to the 1% AEP climate change and sea level rise (0.9 m) however as proven within the hydraulic modelling this would result in little to no change in the flood behaviour onsite or on surrounding properties.

5.0 Flood Emergency Management Planning

As highlighted in council responses, while the proposed residential properties onsite are flood immune up to the 1% AEP climate change and sea level rise (0.9m) plus 0.5 m in the PMF event properties onsite are subject to inundation with depths of approximately 0.7 m potentially present onsite in this event. Figure 4 shows the PMF depth extent for the site.

Similarly, Macquarie Street in this event is significantly overtopped and cannot be relied upon to enable evacuation of the site.

The proposed development has a prescribed finished floor level that will ensure that the development encounters flooding in only very unlikely events. A flood emergency management plan to identify the residual risk onsite and provide solutions which minimise the risk to life to residents has been developed. This document is provided as an attachment to this addendum.

The following outcomes have been identified:

- The defined FPL is in excess of the predicted flood levels of the 0.1% AEP event under existing catchment conditions
- There is insufficient warning time to enable safe evacuation thus Shelter-In-Place is required;
- Two storey dwellings are required to enable vertical Shelter-In-Place;
- Dwellings will not be required to be specially engineered to enable Shelter-In-Place; and
- The time of inundation of the site is relatively short with the maximum expected time of inundation of the site in the order of 6.0 hours

Based upon the assessment undertaken it is considered that Shelter-In-Place is an appropriate emergency management solution for the proposed development and is consistent with other measures in place for similar developments in the area.

6.0 Conclusion

The aim of this addendum was to provide council with greater clarity concerning the following:

- Final fill levels of the site
- The impact of the proposed fill level on the floodplain and surrounding properties
- The proposed flood emergency response for the site in events that exceed the floor levels of dwellings on site.

These issues were raised as being deficient in the previously submitted assessment. The addendum has confirmed:

- The final fill level of dwellings onsite is 4.29 mAHD, which is the defined flood planning level for the site (1% AEP climate change and sea level rise (0.9m))
- No adverse flood impacts would occur upstream and downstream of the site; and
- A potential excavation volume of 5,400 m^3 would result in a net gain of flood storage of 704 m^3 for the 1% AEP with climate change and 0.9m sea level scenario. However is not necessary for the site to have no adverse impacts on surrounding properties.
- Shelter in Place is a viable emergency response option and does not result in an increase in risk to life if appropriately incorporated into the development.

Overall, on the basis of this information the proposed development would demonstrate compliance against Council's flooding conditions

Yours sincerely

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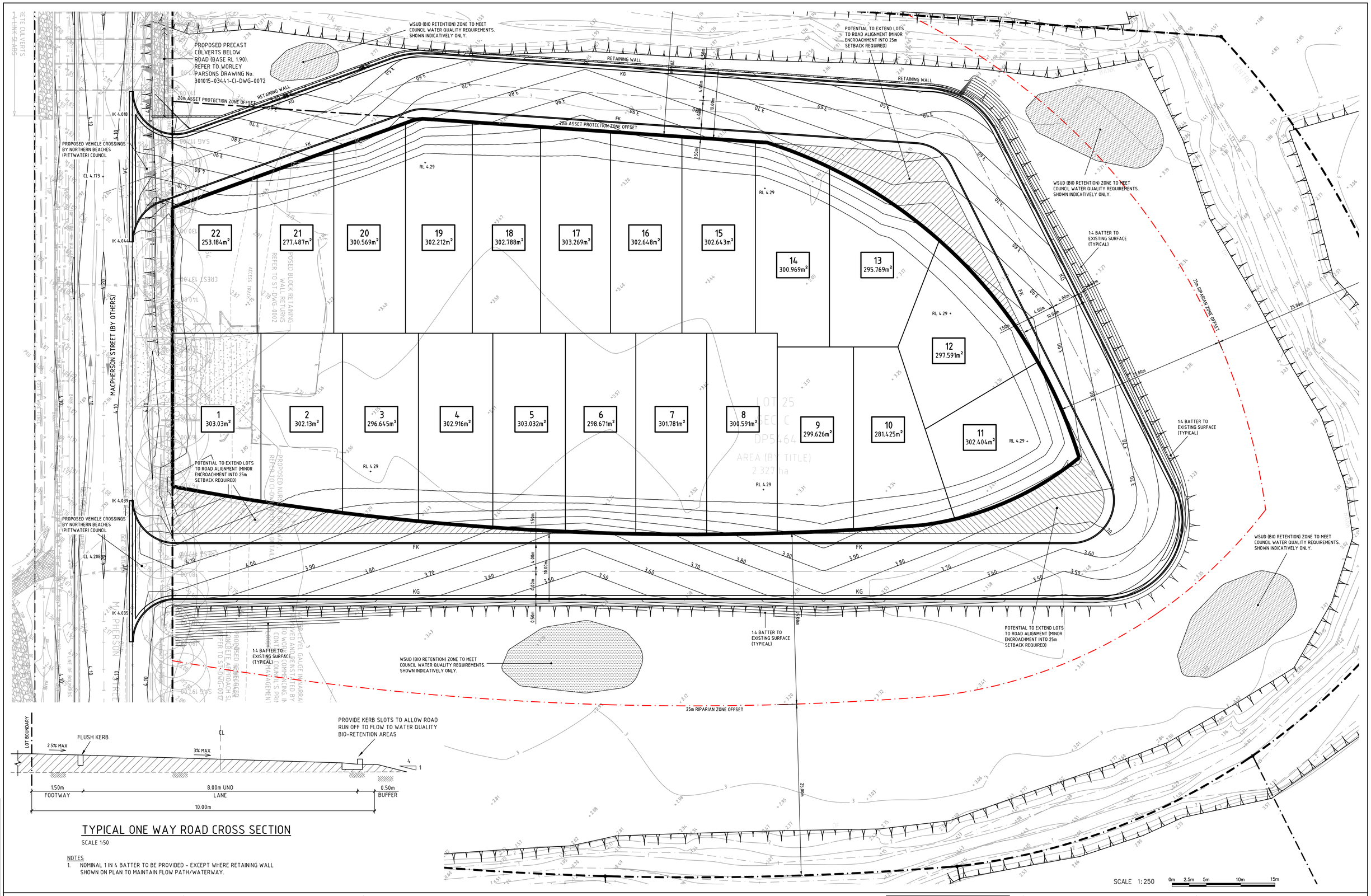

TYPICAL ONE WAY ROAD CROSS SECTION

SCALE 1:50

NOTES

1. NOMINAL 1 IN 4 BATTER TO BE PROVIDED – EXCEPT WHERE RETAINING WALL SHOWN ON PLAN TO MAINTAIN FLOW PATH/WATERWAY.

Rev	Description	Date	By	App
P3	COUNCIL SUBMISSION	24.10.16	JF	-
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Project Name: 2 MACPHERSON STREET, WARRIEWOOD, NSW 2102

Drawing Title: SITE REDEVELOPMENT CONCEPT PLAN ONE-WAY ROAD

PRELIMINARY

Designed	JF	Project Director Approved	Date
Drawn	JF		
Scale	1:250		
Date	AUG 2016		
Sheet	A1		

Project Ref: 20 21791 01 Drawing No: SK02 Rev: P3

File: G:\Job\2021791\01_Civil\Issued\Dwg\2021791101C-SK02-CAD[P3].dwg Plotted: 24.10.16 at 2:22 PM By: Jonathan Franco

Flood and Emergency Management Plan

2 Macpherson Street, Warriewood

59917042

Prepared for
Meriton Group

27 February 2017

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Shaping the Future

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Rev1	21/02/2017	For Review	Daniel Wood	
Rev2	22/02/2017	For Submission	Daniel Wood	Andrew Reid
Rev3	27/02/2017	For Submission	Daniel Wood	Andrew Reid

Executive Summary

A flood emergency management plan of 2 Macpherson Street, Warriewood has been developed to identify and mitigate the risk of flooding onsite. The site is currently considered to have a high flood risk due to its location within the Narrabeen Creek and Narrabeen Lagoon Floodplain.

As part of the proposed development it is proposed to provide a minimum finished floor level of the 1% AEP flood with 30% climate change and 0.9 m sea level rise plus 0.5 m freeboard in accordance with the Pittwater Local Environment Plan. This proposed floor level significantly improves the flood immunity of the site as the buildings are protected against the majority of flooding, but not every possible flood. The finished floor level proposed results in a flood immunity of in excess of the 0.1% AEP under existing flood conditions.

For events which result in water levels greater than the finished floor level it has been established that Shelter-in-Place is both necessary for the development of the site and, with appropriate implementation, ensure the residual risk of flooding is managed for the site.

The analysis of the residual risk undertaken has shown:

- There is insufficient time to rely upon evacuation for the site;
- The dwellings onsite being two storey can accommodate for refuge on the second storey;
- The isolation time for the site is sub daily for the site and Macpherson Street, thus the flood risk to life associated with shelter-in-place isolation is expected to be negligible.
- The development of the site will not require the dwellings to be specially engineered to ensure structural stability.

The assessment undertaken confirms that the development, if undertaken in accordance with the measures proposed within this document will not result in a significant increase to risk of property or life.

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Figures

Glossary

Average Recurrence Interval (ARI)	The long-term average period between occurrences equalling or exceeding a given value. For example a 20 year ARI flood would occur on average once every 20 years.
Annual Exceedance Probability (AEP)	The probability of an event occurring or being exceeded within a year. For example a 5% AEP flood would have a 5% chance of occurring in any year. An approximate conversion between ARI and AEP is provided.

AEP	ARI
63.2 %	1 year
39.3 %	2 year
18.1 %	5 year
10 %	10 year
5 %	20 year
2 %	50 year
1 %	100 year
0.5 %	200 year
0.2 %	500 year

Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Flood	The covering of normally dry land with water from a stream, river, estuary, lake, dam, major drainage and/or due to super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Freeboard	A height added to flood levels to provides reasonable certainty that the risk exposure accepted by deciding on a particular flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, driveway crest levels, etc.
Probable maximum flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.

1 Introduction

In order to determine and manage the flood risk associated with the proposed development of 2 Macpherson Street, Warriewood a flood emergency management plan for the site has been prepared. The site is currently considered to have a high flood risk due to its location within the Narrabeen Creek and Narrabeen Lagoon Floodplain. As part of the proposed development it is proposed to provide a minimum finished floor level of the 1% AEP flood with 30% climate change and 0.9 m sea level rise plus 0.5 m freeboard.

This proposed floor level significantly improves the flood immunity of the site as the buildings are protected against the majority of flooding, but not every possible flood.

The purpose of this document is to provide confidence to Council that the residual flood risk for events in excess of the 1% AEP flood with 30% climate change and 0.9 m sea level rise has been appropriately considered. The document also highlights appropriate management solutions to ensure that the risk to property and life in these extreme events is understood and appropriately mitigated, if development is to occur.

1.1 Site Characteristics

The proposed development site is located at 2 Macpherson Street, Warriewood .The site comprises approximately 2.1 Hectares of land at 2 Macpherson Street (the site) in Warriewood Valley. Legally, the site is described as Lot 25 Section C in DP5464 and is shown in Figure 1.

The parcel of land is of an irregular shape has a 120 metre frontage to Macpherson Street to the south. A central portion of the site has been raised and levelled and is currently surrounded by undeveloped land. Levels across the site range from 1.4m AHD in the northern section of the site (within the creek) to a high point of 3.7 mAHD within the central portion of the site.

Figure 1-1 Site Locality Plan (Source – Urbis)

1.2 Relevant Documents

The report has regard to the following documents:

- Floodplain Development Manual by NSW Government (April 2005);
- Pittwater Local Environment Plan (LEP) 2014;

1.3 Statutory Requirements

A recent review of the previous application submission has identified that insufficient information was provided to determine the development could meet the objectives of Clause 7.3 (Flood planning) in the Pittwater LEP 2014, specifically:

- *to minimise the flood risk to life and property associated with the use of land; and*
- *to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change*

In order to address the above concerns this document has been developed.

In addition to council requirements, NSW government Section 117 Local Planning Direction 4.3 has also been considered and achieved where relevant.

1.4 Previous Investigations

Previous relevant investigations for this site include:

- Narrabeen Lagoon Flood Study (BMT WBM 2013);
- Narrabeen Lagoon Floodplain Risk Management Study and Plan Stage 3 & Stage 4 Interim Report (Cardno, 2016);
- Flood Assessment Report for 2 Macpherson Street, Warriewood (Bonacci, 2016); and
- Flood Impact Assessment Addendum for 2 Macpherson Street, Warriewood (Cardno, 2017).

1.5 Format of this Document

The format of this document is as follows:

- **Section 2** describes the flood behaviour on the site discusses the risks present to the site under the proposed development; and
- **Section 3** discusses the proposed flood protection measures to be incorporated into the development; and
- **Section 4** discusses the proposed flood evacuation measures to be employed on the site to account for flood events that exceed the flood protection level; and
- **Section 5** provides a summary of the findings of the assessment

2 Flood Behaviour

Floods are discussed in terms of how likely the flood is to occur or be exceeded in any given year. This is called the Annual Exceedance Probability or “AEP”. A flood that occurs on average every 100 years has a 1 % chance of occurring in any given year. Larger floods do occur, although they have less chance of occurring in any given year.

The site is subject to both flooding from Narrabeen Creek and the Narrabeen Lagoon Floodplain. Results from the Narrabeen Lagoon Flood Study (WBM BMT, 2013) indicate that Macpherson Street in its current arrangement is overtopped in the 1% AEP due to the flow present in Narrabeen Creek and the influence of backwater from Narrabeen Lagoon. In the PMF event the area is significantly inundated due to the levels present in the Narrabeen Lagoon Floodplain.

Currently Macpherson Street is in the process of being upgraded. This will result in the roadway having a level of immunity greater than 1% AEP with 30% climate change and 0.9 m sea level rise. The road not be trafficable in the PMF event however.

For the purposes of the analysis undertaken it is considered that Macpherson Street upgrade has been completed, as the development will not occur prior to this scenario.

2.1 Flood levels

Each LGA generally defines a flood planning level based upon an AEP with an allowance for freeboard to cater for uncertainties. In the Pittwater LGA, where the proposed development results in an *intensification of development* the flood event that is utilised as the flood planning level is the 1% AEP with 30% climate change and 0.9 m sea level rise. A freeboard of 0.5 m above this level is expected for all proposed dwellings.

While dwellings onsite will not be inundated by floodwaters in a 1% AEP with 30% climate change and 0.9 m sea level rise or smaller floods, the site is subject to inundation in extreme flood events greater than a 1% AEP with 30% climate change and 0.9 m sea level rise. The defined flood level for this site in this event is 3.79 mAHD.

The floor levels for all residential lots within the proposed development is 4.29 mAHD. This is equal to the required Flood Planning Level for the site. All proposed residential dwellings will be two storeys.

Based on information provided within Narrabeen Lagoon Flood Study (WBM BMT, 2013) this FPL is noted to be in excess of the predicted flood levels of the 0.1% AEP event under existing catchment conditions, with a freeboard of 700 mm present on this AEP scenario.

Once the water reaches the level of 4.29 m AHD floodwaters will enter the dwellings onsite resulting in flooding of the ground floor.

2.2 PMF Flood Event

The PMF Event is largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. The PMF event is generally considered to have an equivalent AEP of between 0.0001% and 0.00001% AEP.

Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.

The purpose of utilising the PMF flood event within an assessment is to ensure the residual risk (that is the risk that exists once the flood immunity of a development is exceeded) that is present onsite is considered and planned for.

Figure 2-1 provides an overview of the flooding experienced within the Narrabeen Lagoon area at a catchment level in the existing flood conditions. In the PMF flood event over 3000 properties are flood affected, with almost 1400 dwellings experiencing over floor flooding (Cardno, 2016).

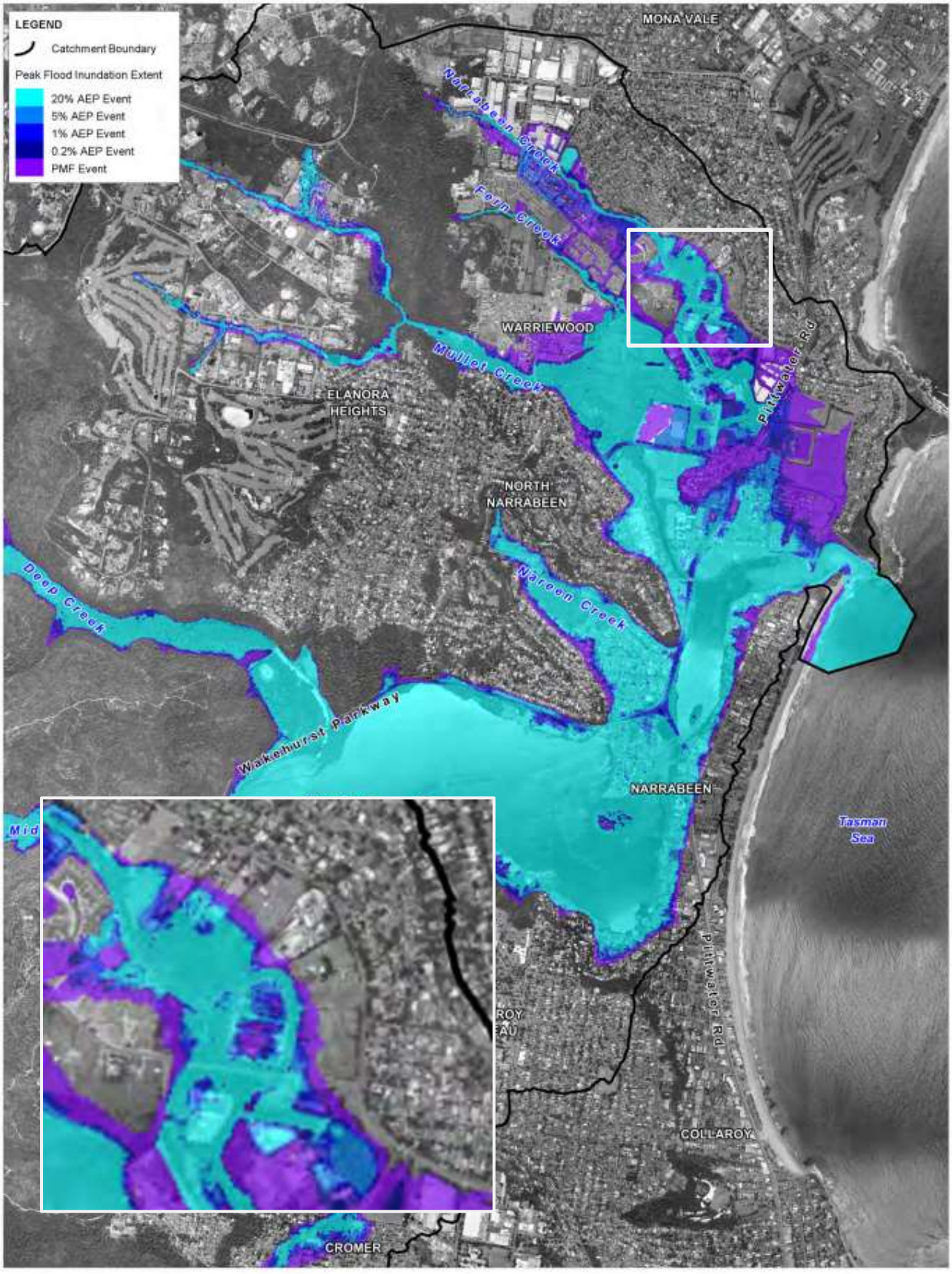

Figure 2-1 Peak Flood Extent – Catchment Derived Events (source Narrabeen Lagoon Flood Study, BMT, 2013)

FAST FACTS

In the 1% AEP with 30% climate change and 0.9 m sea level rise,

- **Around the dwellings, water will be up to 0.25 m deep on the road.**
- **The dwellings will not be flooded.**

In the probable maximum flood,

- **Around the building on the roadway, water will be up to 1.5 m deep.**
- **The finished floor levels of the dwellings will be inundated up to 0.6 m.**

2.3 Flood Warning Times

Narrabeen Lagoon Floodplain Risk Management Study and Plan Stage 3 & Stage 4 Interim Report (Cardno, 2016) indicates the PMF event likely to impact the development site is the 6 hour PMF duration. This event dominates all areas influenced by the Narrabeen Lagoon flood level.

The internal roadway within the development is expected to be overtopped in this event approximately 2.5 hours after the onset of the PMP rainfall event. After 3 hours Macpherson Street is expected to be overtopped. After 3.5 hours it is expected the first floor of the dwellings will be inundated.

The short warning times mean that in the case of extreme floods that there would be insufficient time to evacuate any residents and/or visitors from the site and that instead residents and/or visitors would need to Shelter-in-Place.

In events less extreme than the PMF but of sufficient severity to overtop the internal roadway a Shelter-in-Place emergency response should still be followed.

The expected time that visitors and/or residents would need to Shelter-in-Place would be around 6 hours in a PMF.

2.4 Flood Hazard

2.4.1 1% AEP Flood

For events up to and including the 1% AEP flood, the subject site, including the internal roadway are not flood affected. Once the Macpherson Street upgrade is complete this roadway will also be flood free in this event and as such evacuation both east and west along Macpherson Street will be possible.

2.4.2 1% AEP with 30% climate change and 0.9 m sea level rise

In the 1% AEP flood with 30% climate change and 0.9 m sea level rise, the residential dwellings onsite are not flooded however the internal roadway servicing the dwellings will be inundated. **Figure 2-2** shows the predicted impact of this event. The level of inundation will generally be less than 0.25 m and low hazard. Whilst this flow is considered low hazard and trafficable, Shelter-in-Place is still recommended to ensure the safety of residents and visitors.

2.4.3 Extreme Floods

In the PMF, the site and surrounding roads will be flooded by creek flows and the Narrabeen Lagoon backwater. Water depths will increase by up to 1 m over the 1% AEP with 30% climate change and 0.9 m sea level rise flood level. The site will be encircled by deep, high hazard floodwaters, as illustrated in **Figure 2-3**. All surrounding local roads will also be inundated to high depths likely to be hazardous to both vehicular and pedestrian safety. Residents and visitors will be required to either prior to the event occurring evacuate or Shelter-in-Place. Due to the short flood warning times available for the site Shelter-in-Place is considered the safest approach to flood management in this event.

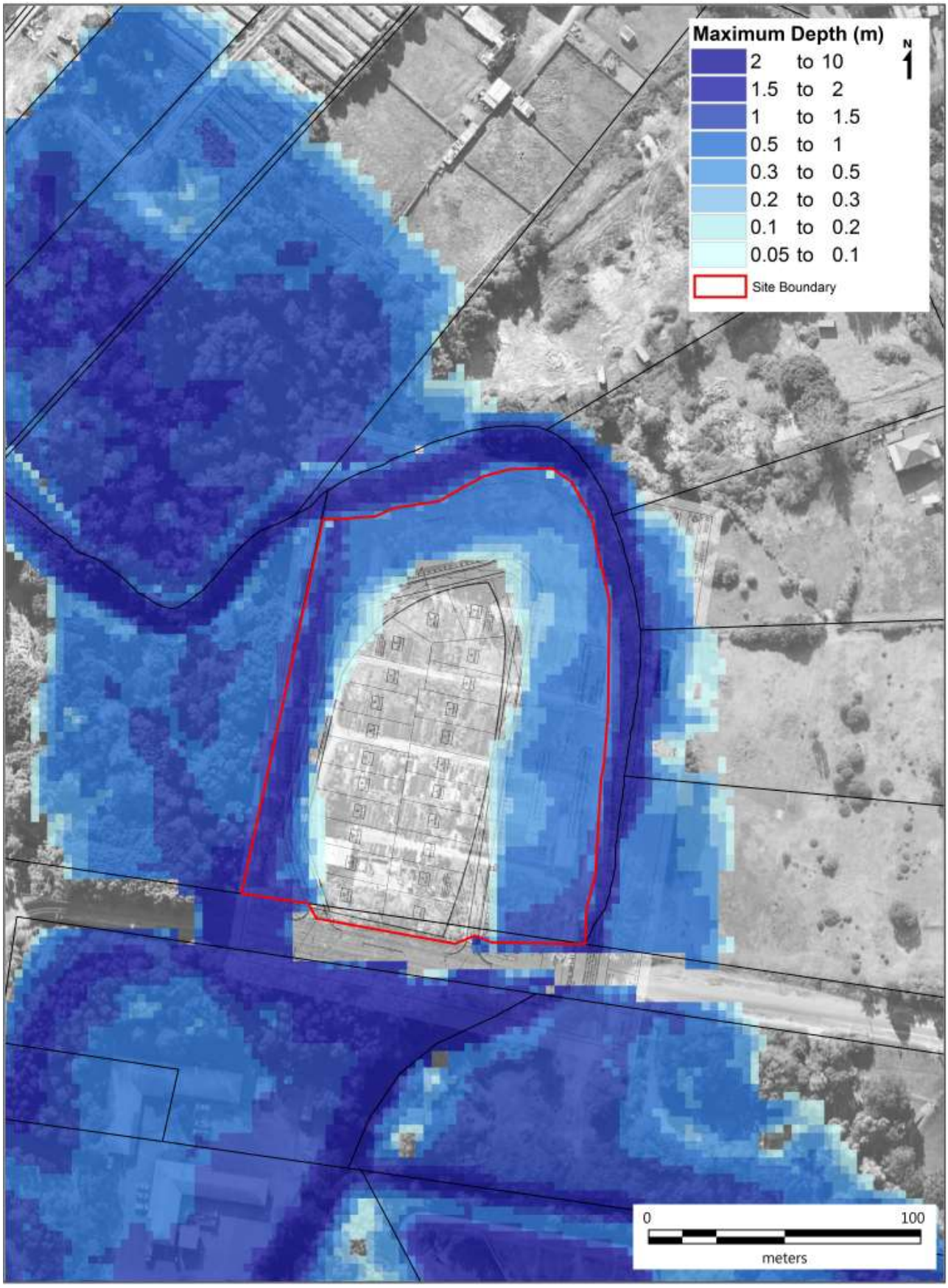

Figure 2-2 1% AEP with 30% climate change plus 0.9m sea level rise Peak Water Levels

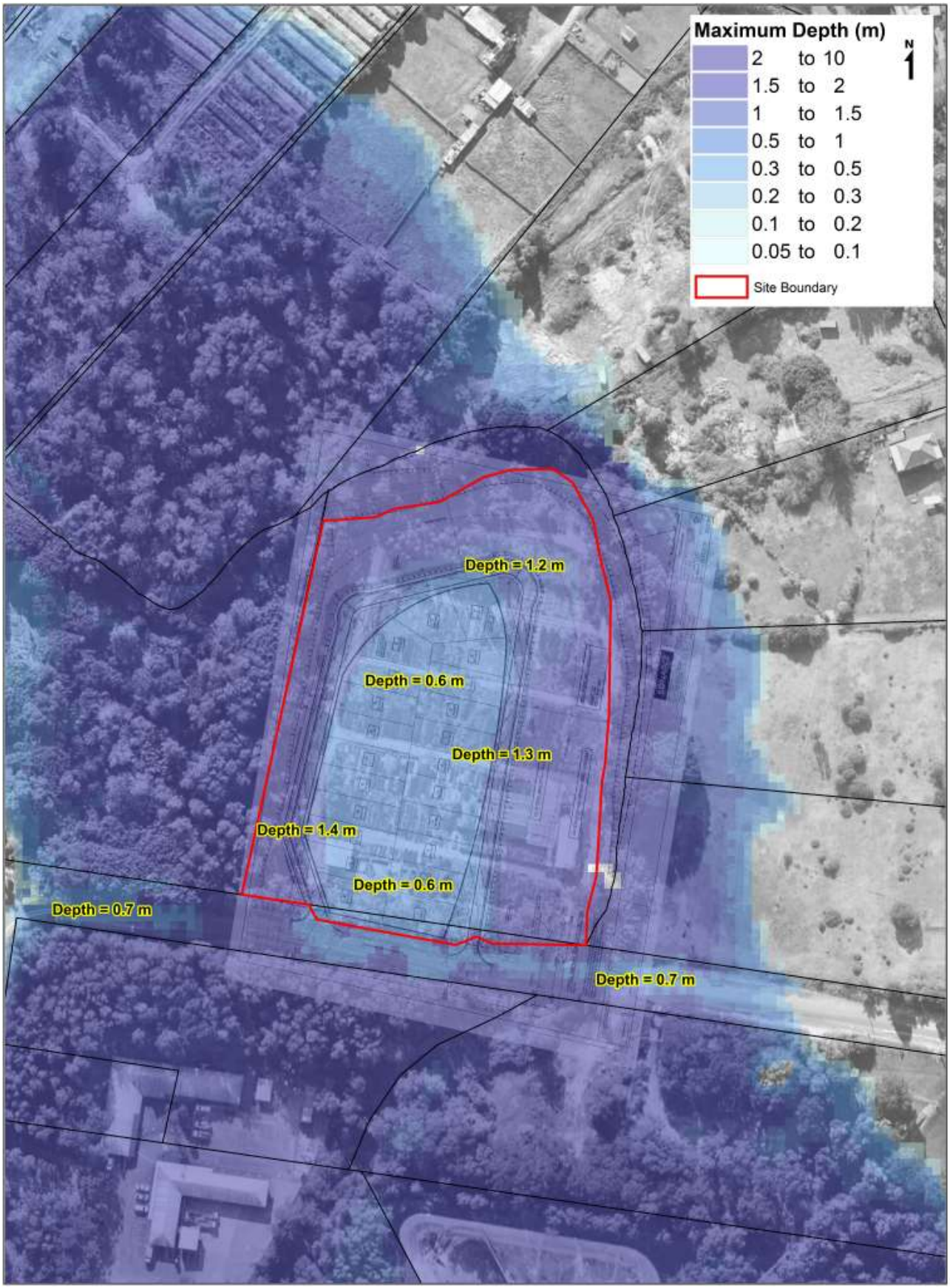

Figure 2-3 PMF Peak Water Levels

3 Flood Protection Measures

This section discusses the proposed flood protection measures that are proposed to be incorporated into the development. Protection for events up to and including the 1% AEP flood with 30% climate change and 0.9 m sea level rise is provided by permanent measures, namely the raised habitable floor levels.

3.1 Floor levels

The Pittwater LEP 2014 defines the Flood Planning Level in Section 7.3 Flood Planning, under Item (5):

Flood planning level *means the level of a 1:100 ARI (Average Recurrent Interval) flood event plus 0.5 m freeboard, or other freeboard determined by an adopted floodplain risk management plan.*

Additionally, Section B3.23 – Climate Change (Sea Level Rise and Increased Rainfall Volume) of the Pittwater 21 DCP, states that for any "intensification of development" climate change must be considered. The consideration for climate change at present includes a 30% rainfall increase (as adopted by Council on 15/02/2010) with 0.9m sea level rise (as adopted by Council on 7/12/2009). "Intensification of development" includes but is not limited to:

- An increase in the number of dwellings (but excluding dual occupancies and secondary dwellings); and
- An increase in commercial or retail floor space.

As this site will result in an intensification of development the minimum floor level required has been assumed to be the 1% AEP flood with 30% climate change and 0.9 m sea level rise plus 0.5 m freeboard. Based on flood mapping undertaken as part of Narrabeen Lagoon Flood Study (BMT WBM, 2014) and advice provided by Councils the flood level of this event is 3.79 mAHD. Thus, with a 0.5 m freeboard incorporated the flood planning level is 4.29 mAHD.

The proposed finished floor levels are consistent with current Council policy and surrounding developments.

In events greater than the 1% AEP flood with 30% climate change and 0.9 m sea level rise, flood evacuation by vertical evacuation is proposed. Section 4 justifies and details this approach.

3.2 Flood Awareness

In addition to the above, residents and visitors to the site should be made aware of the flood hazard and evacuation procedures through a combination of measures:

- Signage should be installed at key locations such as along internal roadways. Signage of this nature draws awareness to flooding on site. Flood warning signs while raising awareness of flooding during dry times also serve to alert pedestrians and drivers to the depth of floodwaters during flood events;
- Information regarding the flood risk and evacuation procedures for the site should be provided on each dwelling to ensure all occupants are aware of the procedure. This may be provided as a sign located within each dwellings power box for instance; and
- Occupants should be encouraged to prepare a FloodSafe Plan. Information regarding this process should be provided to all owners either through signage onsite (in the power box for example) or through information provided to residents upon moving in.

3.3 Flood Warning

While the warning systems discussed below are not specific to the site they are important to highlight the information that is available to the public to inform them of a developing event. Similar to the development of a FloodSafe Plan, residents should be encouraged to familiarise themselves with the flood warning systems in the area.

3.3.1 Observation of local rainfall or flood water

An important indication of likely imminent flood activity would be intense local rainfall. Northern Beaches Flood Information Network http://www.mhl.nsw.gov.au/users/NBFloodWarning/ provides information regarding water levels and rainfall as well as information regarding flood preparedness.

3.3.2 The Bureau of Meteorology

The Bureau of Meteorology does not prepare flood predictions for the Narrabeen Lagoon, but does issue Severe Thunderstorm Warnings and Severe Weather Warnings for Sydney.

Severe Thunderstorm Warnings are issued together with maps indicating the current location and predicted path of thunderstorms. Severe Weather Warnings are for severe weather not related to thunderstorms, cyclones or fire, but for other causes of intense rainfall or storm surge, such as “east coast lows”.

These warnings are available at http://www.bom.gov.au/nsw/warnings/.

BoM also provides real time rain radar coverage for Sydney at http://www.bom.gov.au/products/IDR713.loop.shtml.

3.3.3 The NSW SES (Emergency Phone Number 132 500)

The local SES unit is Warringah- Pittwater which operates a facebook page for informing members of the public (https://www.facebook.com/WPWSES/). The applicable region is the Sydney Northern Region, which operates also operates a facebook page (https://www.facebook.com/NSWSESSNR/).

The SES issues Local Flood Advices. These are issued on the basis of localised valley watch information for locations for which the BoM does not issue Flood Warnings. They normally predict which class of flooding (minor, moderate or major) will occur, and must not contradict any Flood Warnings provided by the BoM for other gauges on the same river. Local Flood Advices are to be clearly identified as being issued by the SES.

At the time of writing, a Draft Flood Warning Plan had been prepared the NSW SES. However, this draft was prepared a number of years ago and the timing for finalisation is uncertain.

3.3.4 Local Emergency Management

Local emergency management plans are prepared to avoid burdening local emergency management with additional responsibilities.

Based on a review of available information it does not appear that a local emergency management plan is available in the public domain for this region. In the absence of this information the Manly-Warringah-Pittwater Disaster Plan (DISPLAN) (MWPLEMC, 2005) or the North West Metropolitan Emergency Management District DISPLAN (Interim) (NWMDEMC, 2011) should be utilised.

3.3.5 Local television and radio stations

Local television and radio stations would disseminate warnings from the Bureau of Meteorology, SES and other relevant sources. The local radio station for emergency information is 702 ABC.

4 Flood Evacuation

The proposed floor level of the dwellings cater for the majority of events that are likely to impact the site, but not all events. In events that result in flood levels greater than the 1% AEP flood with 30% climate change and 0.9 m sea level rise plus 0.5 m freeboard, the ground floor levels of dwellings onsite will be flooded and evacuation necessary.

Due to the likely short timeframe available between the beginning of rainfall and the onset of flooding in extreme rainfall events, Shelter-in-Place via vertical evacuation has been proposed as the flood emergency measure utilised on this site. The following section details the analysis undertaken as to why this is the most appropriate emergency management option available for the site and the mechanisms to be put in place to ensure the risk to life under this approach is minimal.

4.1 Flood Evacuation Timeline

4.1.1 Background

A key consideration as to the appropriate flood evacuation policy in place on a development is the available flood evacuation time. The NSW SES Timeline Evacuation Model has been the de facto standard for evacuation calculations in NSW since it was first developed for evacuation planning in the Hawkesbury Nepean Valley. Though the guideline has not yet been released, the paper *Technical Guideline for SES Timeline Evacuation Model* was prepared by Molino et al. (2013) to brief the industry on the use of the guideline.

The timeline assessment of evacuation potential relates to the time required for regional evacuation of floodplains from doorknocking by SES volunteers through to the evacuation of all occupants from the region.

At the centre of the timeline methodology is the following concept:

Surplus Time = Time Available – Time Required

If surplus time is positive then evacuation of all occupants is feasible, while a negative value implies evacuation of all occupants is not likely to be achieved.

An analysis of the proposed development within the regional Narrabeen Lagoon floodplain has been undertaken utilising the above methodology.

4.1.2 Time Available

This variable is dependent on rate of rise of waters, meaning it varies for each evacuation scenario. The proposed development lies within the lower Narrabeen Lagoon floodplain. As the lower Narrabeen Lagoon floodplain, from lower South Creek to Warriewood Valley, is an inter-connected storage area the water level time series for the majority of the floodplain is nearly identical regardless of the location of development within the floodplain.

The proposed development is required to have finished floor levels equal the flood planning level prescribed. For this site this is the1% AEP flood with 30% climate change and 0.9 m sea level rise plus 0.5 m freeboard, or 4.29 mAHD. As such events lower than this will not impact the dwellings onsite. The 6 hour PMF event however will exceed the floor levels and has been considered for the following assessment. The PMF 30 minute event is not likely to impact the dwellings onsite.

The times to reach inundation after the onset of rainfall for the PMF flood event is 2.5 hours to inundation of the internal roadway and 3.5 hours to inundation of the dwellings. After 3 hours Macpherson Street is expected to be overtopped. As the internal roadway is part of the only safe evacuation route this is considered the critical timeline for this assessment.

It should be noted that theoretical flood events do not always match actual events and the time to reach inundation after the onset of rainfall may be shorter or longer than listed here.

4.1.3 Time Required

The SES evacuation timeline model uses the following equation to calculate Time Required:

Time Required = Warning Acceptance Factor (WAF) + Warning Lag Time (WLT) + Travel Time (TT) + Travel Safety Factor (TSF)

Where the following values are recommended in the guideline:

WAF = 1 hour – accounts for the delay between occupants receiving the evacuation warning and acting upon it.

WLT = 1 hour – an allowance for the time taken by occupants to prepare for evacuation.

TT = Variable – the number of hours taken for the evacuation of all vehicles based on road capacity. NSW SES recommend a road lane capacity of 600 vehicles per hour. Since there are many evacuation routes to flood-free land across the Narrabeen Lagoon floodplain the Travel Time is assumed to be negligible (in the order of minutes, not hours).

TSF = Variable – added to travel time to account for any delays along the evacuation route, resulting from accidents for example, this value is a variable of TT between 1 hour and 3.5 hours.

Note that Time Required is calculated from the time that SES have mobilised and are ready to begin doorknocking. Before this time there are two additional considerations.

- Forecast and actual rainfall monitoring – in the case of Narrabeen Lagoon tools for flood forecasting to inform flood evacuation are inadequate. Actual rainfall monitoring is the only feasible warning system. The flood warning system that is in place is the Northern Beaches Flood warning system (MHL, 2014), which recommends response only after 3 hours of sustained heavy rainfall.
- Mobilisation – the time taken for SES to mobilise and travel to residences to commence doorknocking. There is no data available on mobilisation time for local SES services, so this has not been included in the evacuation timeline for Narrabeen Lagoon.

Based on the above contributors, the overall time required for evacuation of the Narrabeen Lagoon floodplain is a minimum of 5 hours (2 hours for WAF and WLT, 3 hours for actual rainfall monitoring). It should be noted that this is a low bound estimate, as various factors such as Travel Time, Travel Safety Factor and SES mobilisation have been disregarded.

4.1.4 Surplus Time

For this development the surplus time is negative, because the time available (150 minutes for the PMF 360 minute storm) is less than the time required to evacuate (minimum of 5 hours).

Under the current flood warning system and the existing provisions available, there is insufficient time to safely assume evacuation of the site based on SES doorknocking and assisted evacuation. Based on this outcome Vertical Evacuation, or Shelter-in-Place is considered the most appropriate evacuation solution for this site.

4.2 Shelter-in-Place

While not the preferred form of emergency response, Shelter-in-Place is a feasible form of emergency response for some parts of the Narrabeen Lagoon floodplain. In accordance with the Australasian Fire and Emergency Service Authorities Council (AFAC) guideline, where localised evacuation is not possible, Shelter-in-Place is seen as an acceptable alternative if designed appropriately.

Shelter-in-Place in this instance has been selected as the best solution for the site as the evacuation timeline (refer Section 4.1) indicates that the time available prior to the PMF flood event inundating the site is less than the required time to evacuate.

The Shelter-in-Place approach is utilised throughout Warriewood as the primary flood management technique due to the large extent of flooding experienced within the PMF event. The proposed development has a prescribed finished floor level that will ensure that the development encounters flooding in only very unlikely events.

As Shelter-in-Place results in isolation of residents from emergency services for a period of time as well as relies on the structural capability of the dwelling additional assessments are necessary to ensure the safety of residents. The following sections detail the assessment undertaken to ensure Shelter-in-Place is a suitable emergency management measure.

4.2.1 Refuge Area

The proposed development is to consist of 22 dwellings, all of which will be two storey.

In events up to the 1% AEP flood with 30% climate change and 0.9 m sea level rise plus 0.5 m freeboard the finished flood level will not be exceeded. In events greater than this the ground floor of the dwellings will be exceeded. In events of this magnitude residents will be required to seek refuge on higher ground. For this development all proposed dwellings will be two storeys and as such the proposed refuge areas will be the second storey.

4.2.2 Duration of Inundation

Duration of inundation relates to the length of isolation of any shelter-in-place refuges within the floodplain. Isolation results in the following sources of risk to life.

- Isolation from medical services – in the event of a medical emergency, a pre-existing condition, injury, or sudden onset event such as heart attack, medical services may not be accessible. This is a particularly high risk for vulnerable developments occupied by residents who are more likely to experience a medical emergency at any given time than other demographics. It is not considered that this development would be more vulnerable to events of this nature than any other development in the area.
- Isolation from supplies – including drinking water, food, amenities, and communication lines. This becomes a particular concern when the period of isolation exceeds 24 hours.

In the 6 hour PMF event the duration of inundation is expected to be approximately 6 hours. Since the duration of inundation is expected to be sub-daily for the site and Macpherson Street, the flood risk to life associated with shelter-in-place isolation is expected to be manageable through provision of supplies and services to the refuge.

It is considered that if the above approach is appropriately implemented then the increased risk to life due to the presence of the development will be negligible.

4.2.3 Egress from Site

The area surrounding the site will be inundated at hazardous depths in events greater than the 1% AEP, and therefore egress from the site is not recommended during flood events.

4.2.4 Evacuation Routes

For events up to and including the 1% AEP flood, the subject site, including the internal roadway are not flooded. Once the Macpherson Street upgrade is complete this roadway will also be flood free and as such evacuation both east and west along Macpherson Street will be possible.

In the 1% AEP flood with 30% climate change and 0.9 m sea level rise, the residential dwellings onsite are not flooded however the internal roadway servicing the dwellings will be inundated. The level of inundation will generally be less than 250 mm and considered low hazard.

As the intensity and final level of flooding that may be experienced onsite is difficult to predict the general policy for the site in all events of elevated flood waters would be to remain onsite until flood waters recede.

4.2.5 Evacuation Centres

Evacuation centres are not proposed as the initial place of refuge, as vertical evacuation to higher floors is safer and egress from the site will be hazardous and limited.

4.2.6 Structural Stability

The collapse of a shelter-in-place refuge could result in loss of life and therefore is not acceptable under any flood event. By utilising the Combined Flood Hazard Curves (Source: Commonwealth Government, 2014) shown in Figure 4-1, it is possible to identify approximate levels of structural stability for the following structures:

- All normal structures are assumed to have structural stability up to and including Hazard Category H4; and
- All specially engineered structures are assumed to have structural stability up to and including Hazard Category H5.

Based on the information provided within Narrabeen Lagoon Floodplain Risk Management Study and Plan Stage 3 & Stage 4 Interim Report (Cardno, 2016), the undeveloped site is based in an area of H4-H5 Hazard. In the proposed development conditions the increased ground levels onsite will reduce this to a H3 flood condition. Figure 4-2 shows the flood hazard categorisation for the developed conditions.

As all normal structures are assumed to have structural stability up to and including Hazard Category H4 no specialised engineering structures would be required to enable Shelter-in-Place on this site.

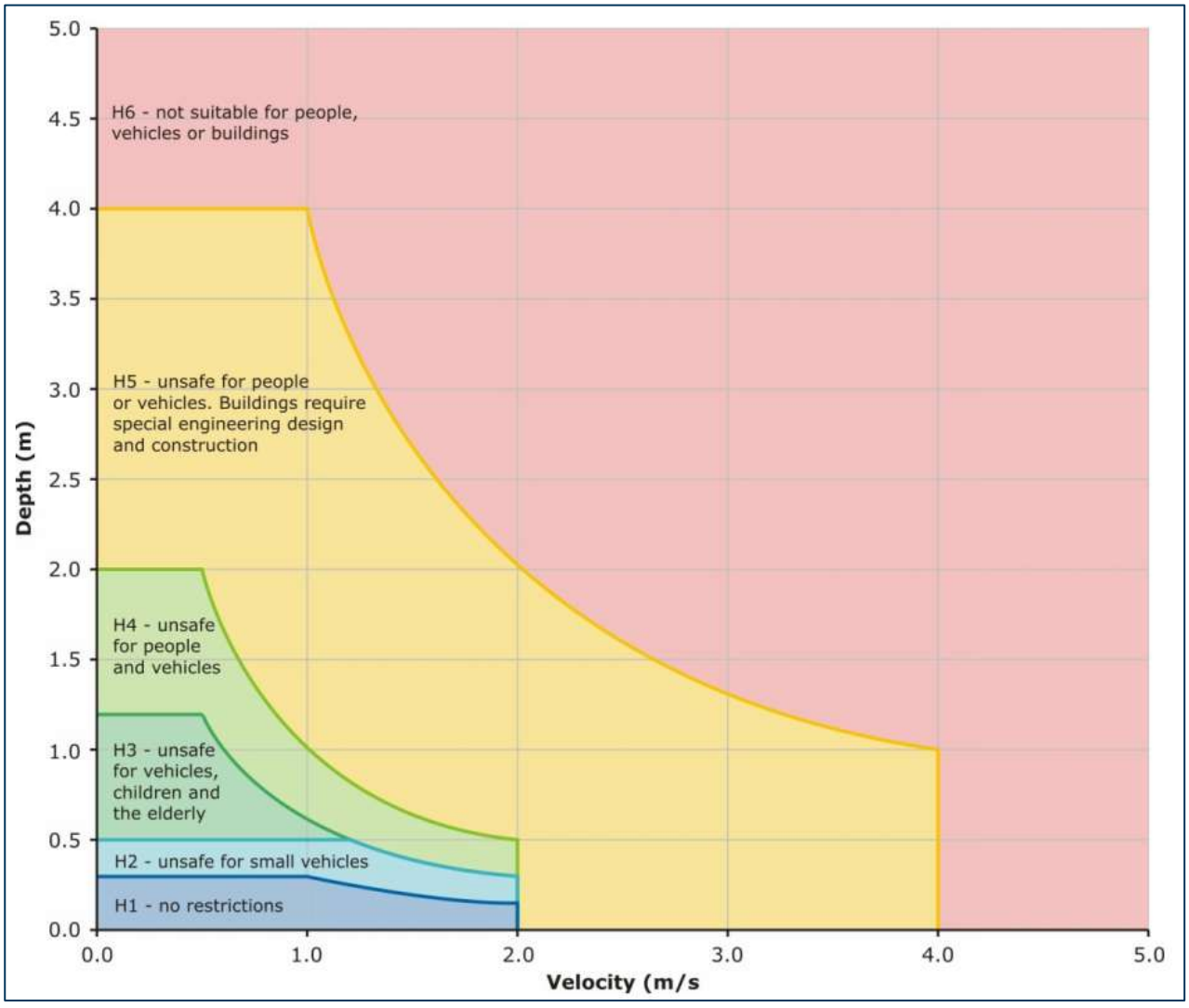

Figure 4-1 Combined Flood Hazard Categories (Source: Commonwealth Government, 2014)

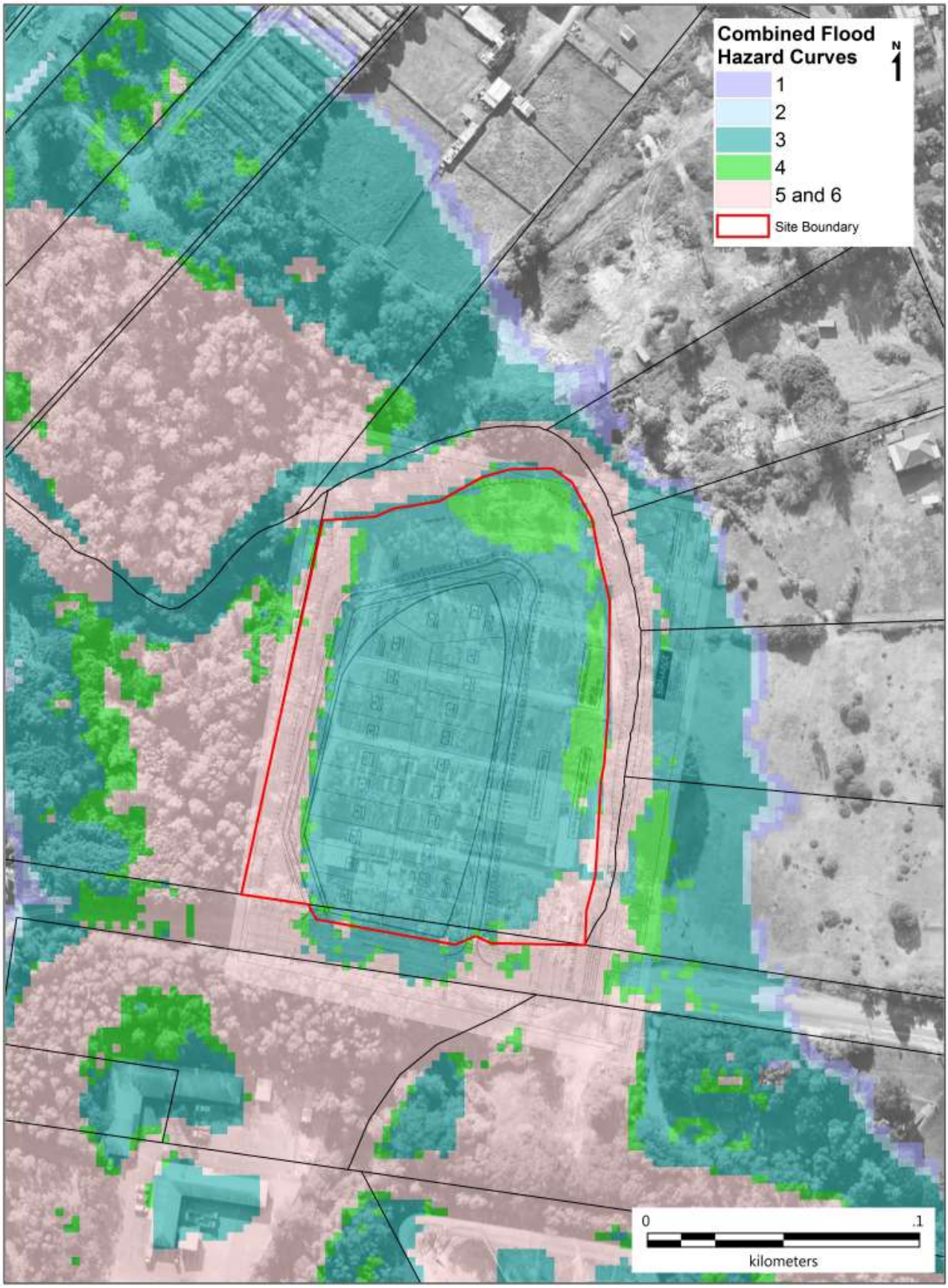

Figure 4-2 PMF Event – Combined Flood Hazard Category Results for the Developed Site

5 Conclusions

In order to determine and manage the flood risk associated with the proposed development of 2 Macpherson Street, Warriewood a flood emergency management plan for the site has been developed. The site is in its existing development condition is considered to have a high flood risk due to its location within the Narrabeen Creek and Narrabeen Lagoon Floodplain. As part of the proposed development it is proposed to provide a minimum finished floor level of the 1% AEP flood with 30% climate change and 0.9 m sea level rise plus 0.5 m freeboard.

This proposed floor level significantly improves the flood immunity of the site as the buildings are protected against the majority of flooding, but not every possible flood.

For events greater than the 1% AEP flood with 30% climate change and 0.9 m sea level rise plus 0.5 m freeboard it has been established that Shelter-in-Place is both necessary for the development of the site and, with appropriate implementation, ensure the residual risk of flooding is managed for the site.

The analysis of the residual risk undertaken has shown:

- There is insufficient time to rely upon evacuation for the site;
- The dwellings onsite being two storey can accommodate for refuge on the second storey;
- The isolation time for the site is sub daily for the site and Macpherson Street, thus the flood risk to life associated with shelter-in-place isolation is expected to be negligible.
- The development of the site will not require the dwellings to be specially engineered to ensure structural stability.

Based on the outcomes of this assessment it is considered that the implementation of dwellings with a finished floor level of the 1% AEP flood with 30% climate change and 0.9 m sea level rise plus 0.5 m freeboard coupled with a refuge in place emergency evacuation policy for events that exceed this level will not result in a significant increase to risk of property or loss of life.