Table 4 – Hazard Curves - Vulnerability Thresholds (D. McLuckie et. al., 2014)

Hazard Classification	Description (and defined limits)
H1	Relatively benign flow conditions. No vulnerability constraints. (D < 0.3 m, V < 2.0 m/s, or V x D < 0.3)
H2	Unsafe for small vehicles. (D < 0.5 m, V < 2.0 m/s, or V x D < 0.6)
H3	Unsafe for all vehicles, children and the elderly. (D < 1.2 m, V < 2.0 m/s, or V x D < 0.6)
H4	Unsafe for all pedestrians and vehicles. (D < 2.0 m, V < 2.0 m/s, or V x D < 1.0)
H5	Unsafe for all pedestrians and vehicles. Buildings require special engineering design and construction. (D < 4.0 m, V < 4.0 m/s, or V x D < 4.0)
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure. (D > 4.0 m, V > 4.0 m/s, or V x D > 4.0)

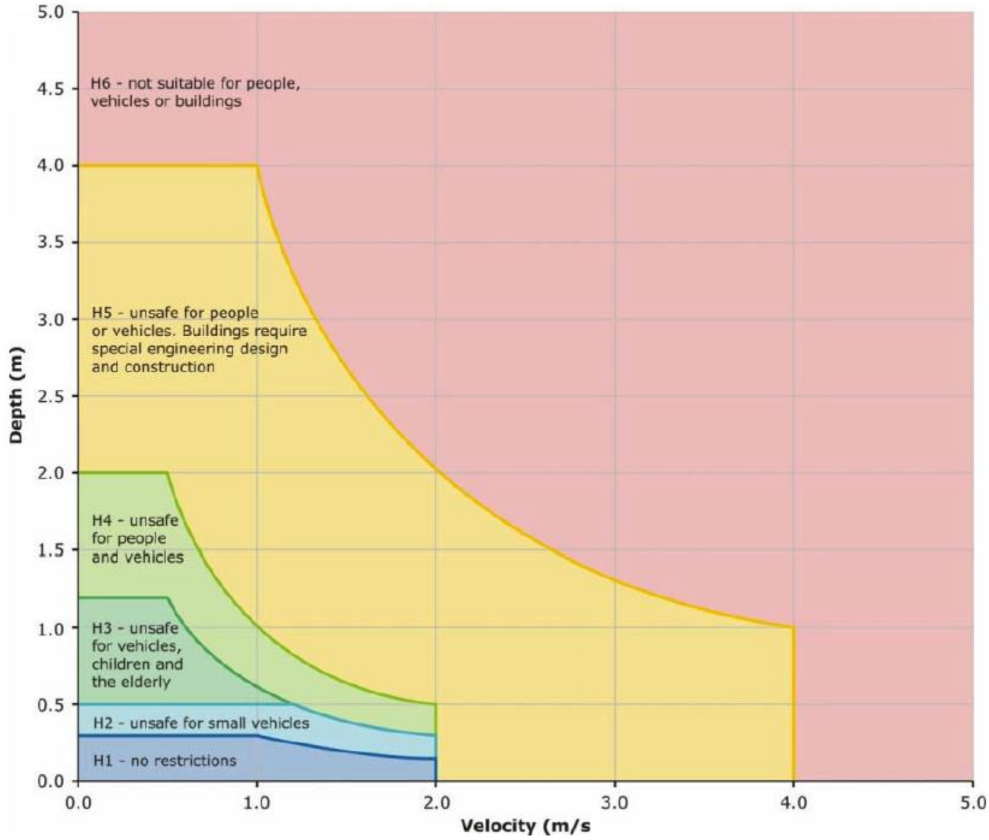


Figure 48 – Combined Flood Hazard Curve Classifications (McLuckie et al, 2014)

Table 5 – Flow Hazard Regimes for People
(Included in ARR 2016, originally Cox et al, 2010)

<table>
<tr><th>DV (m^2s^{-1})</th><th>Children (H.M = 25 to 50)[1]</th><th>Adults (H.M > 50)</th></tr>
<tr><td>0</td><td>Safe</td><td>Safe</td></tr>
<tr><td>0 - 0.4</td><td>Low Hazard if depth < 0.5m and velocity < 3m/s otherwise Extreme Hazard</td><td rowspan="2">Low Hazard if depth < 1.2m and velocity < 3m/s otherwise Extreme Hazard</td></tr>
<tr><td>0.4 - 0.6</td><td>Significant Hazard; Dangerous to most if depth < 0.5m and velocity < 3m/s otherwise Extreme Hazard</td></tr>
<tr><td>0.6 - 0.8</td><td rowspan="3">Extreme Hazard; Dangerous to all</td><td>Moderate Hazard; Dangerous to some[2] if depth < 1.2m and velocity < 3m/s otherwise Extreme Hazard</td></tr>
<tr><td>0.8 - 1.2</td><td>Significant Hazard; Dangerous to most[3] if depth < 1.2m and velocity < 3m/s otherwise Extreme Hazard</td></tr>
<tr><td>> 1.2</td><td>Extreme Hazard; Dangerous to all</td></tr>
</table>

Maximum depth stability limit of 0.5 m for children and 1.2 m for adults under good condition. Maximum velocity stability limit of 3.0 ms^{-1} for both adults and children.
[1]More vulnerable community members such as infants and the elderly should avoid exposure to floodwater. Flood flows are considered extremely hazardous to these community members under all conditions
[2]Working limit for trained safety workers or experienced and well equipped persons (D.V < 0.8 m^2s^{-1})
[3]Upper limit of stability observed during most investigations (D.V > 1.2 m^2s^{-1})

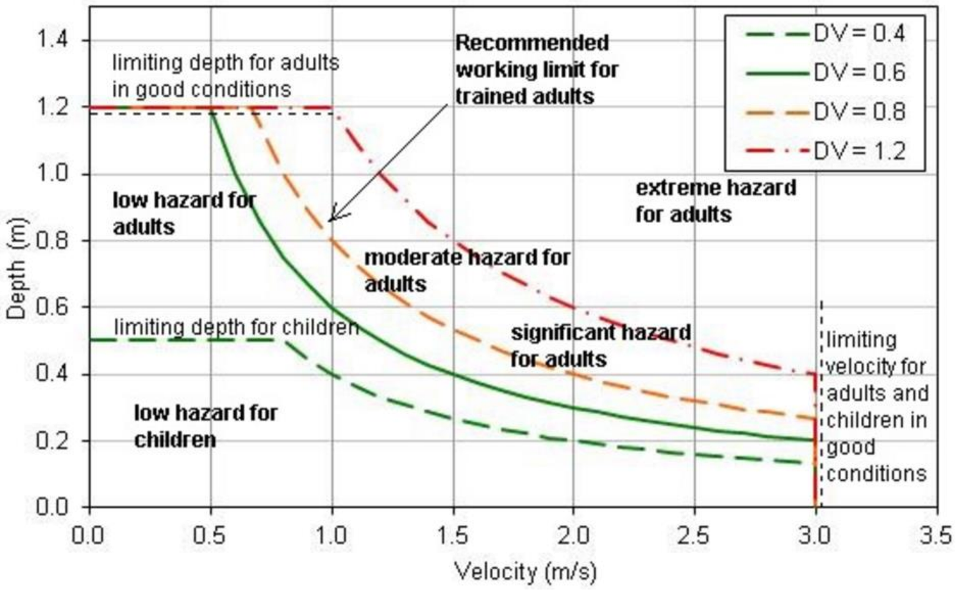


Figure 49 – Safety Criteria for People in Variable Flow Conditions
(Included in ARR 2016, originally Cox et al, 2010)

Table 6 – Interim Flow Hazard Regimes for Vehicles (Included in ARR 2016, originally Shand et al, 2011)

Class of vehicle	Length (m)	Kerb Weight (kg)	Ground clearance (m)	Limiting still water depth[1]	Limiting high velocity flow depth[2]	Limiting velocity[3]	Equation of stability
Small passenger	< 4.3	< 1250	< 0.12	0.3	0.1	3.0	$DV \leq 0.3$
Large passenger	> 4.3	> 1250	> 0.12	0.4	0.15	3.0	$DV \leq 0.45$
Large 4WD	> 4.5	> 2000	> 0.22	0.5	0.2	3.0	$DV \leq 0.6$

[1]At velocity = 0 ms^{-1}; [2]At velocity = 3.0 ms^{-1}; [3]At low depth

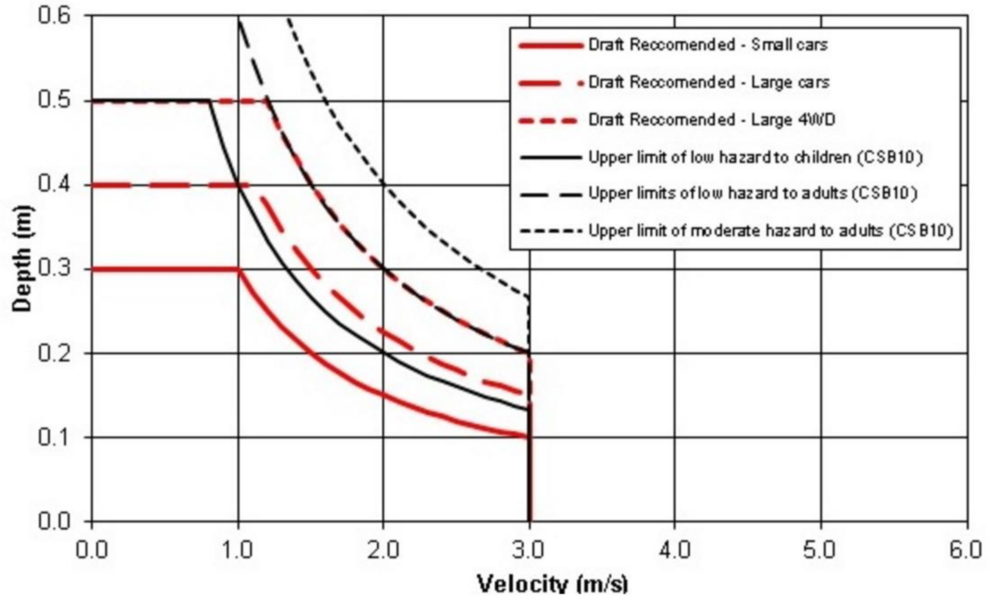


Figure 50 – Interim Safety Criteria for Vehicles in Variable Flow Conditions (Included in ARR 2016, originally Shand et al, 2011)

7.1.2 Pre-Developed Peak Flood Hazard Classification 1% AEP and PMF

Figure_A 7 and Figure_A 8 provide the hazard classifications for the pre-developed 1% AEP and PMF event based on Figure 48. The existing car parking zone along the southern boundary is currently classified as category H5 & H6 due to velocities exceeding 2 m/s, which is nominated as unsafe for pedestrians and vehicles. The depths of flow along this parking area however are expected to reach up to 280 mm and 470 mm in depth during the 1% AEP and PMF storm events.

7.1.3 Post-Developed Peak Flood Hazard Classification 1% AEP

Figure_A 18 provides the hazard classification for the post-developed 1% AEP event based on Figure 48. The car parking zone along the southern boundary is classified as category H5 due to velocities exceeding 2 m/s, which is still nominated as unsafe for pedestrians and vehicles when compared to Figure 48. When reviewing the velocities however, based on Table 5 and Figure 49 for pedestrians and Table 6 and Figure 50 for vehicle, the ARR 2016 guidelines suggest that a safe velocity can be considered up to 3 m/s for both pedestrians and vehicles, provided that the DxV product does not exceed 0.4 m^2/s for pedestrians and 0.3 m^2/s for vehicles.

Figure_A 12 and Figure_A 15 show that the velocities along the southern car parking area typically meet the 3 m/s limit, with only a couple spots reaching 3.1 m/s, and that VxD product does not exceed 0.3 m^2/s. In accordance with the ARR 2016 guidelines, the proposed southern car parking area generally meets acceptable flood hazard limits.

To mitigate the potential risk of vehicles being washed from the driveway bollards are required immediately downstream of the driveway between the basement car park entrance and the southern boundary.

Downstream of the driveway, within the overland flow paths, hazard classification understandably reaches very high levels, especially at the outlet to the proposed pipe culvert. The overland flow paths should not be promoted as publicly accessible areas and should never be used to store items or equipment as this would greatly affect the flow path operation during flood events.

7.1.4 Post-Developed Peak Flood Hazard Classification PMF

Figure_A 20 provides the hazard classification for the post-developed PMF event based on Figure 48. The car parking zone along the southern boundary is classified as category H6 due to velocities exceeding 2 m/s, which is nominated as unsafe for pedestrians and vehicles when compared to Figure 48.

It is expected that vehicles along the southern driveway area would lose traction and become buoyant during the PMF event. The bollards nominated above would help mitigate the risk of vehicle being washed downstream of the driveway, however, would likely cause some blockage to the flow path and lead to flood water entering the basement car park.

8 FLOOD EVACUATION REQUIREMENTS

8.1 INTRODUCTION

Figure_A 9 shows calculated flood depths and levels at the Site, with the proposed redevelopment constructed. These are results for the 1% AEP (1 in 100 year) event. The various shades of blue indicate maximum depths of floodwater. The Site will be inundated, particularly from the entrance of Beach Street continuing along the southern boundary.

Figure_A 18 shows hazard categories in a 1% AEP flood. The categories are explained in Figure 48. Most of the Site around the buildings is either not flood affected or Category H1, which is generally safe for vehicles and adult pedestrians. However, Beach Street at the Site entrance, and the driveway along the southern boundary of the Site will be Category H5 and H6, which will be unsafe for vehicles, children and the elderly.

8.2 HAZARDS

8.2.1 General

The main hazards that would be present under flooding conditions are:

- Possible entry of water into buildings;
- Possible entry of water into and filling of the basement car park;
- Possible danger to persons and vehicles on the Site outside of buildings;
- Danger to pedestrians and vehicles on public roads (Beach Street);
- Danger of cars being swept into the Site from Beach Street; and
- Danger of persons or cars being swept from the driveway into the overland flow paths.

In the event of severe blockage, such as vehicles being washed up against structures, local water levels could be expected to increase.

8.2.2 Water Entry into the Buildings

The entrance levels to buildings are shown in Table 2 along with the associated flood levels for the 1% AEP and PMP storms. It is unlikely that flood water will enter the buildings or basement car park entrance during a 1% AEP storm, unless vehicles or large objects are placed in flow path creating a blockage.

During the peak of a PMF event the modelled overland flood water is expected to enter the basement carpark over the vehicular entrance, especially if vehicles have washed against the proposed bollards, and flood water is also expected to exceed the lower ground floor entry levels.

The level of inundation over the lower ground floor is expected to be minimal, and not pose a significant risk to life. During a significant storm event, it is recommended that occupants of the proposed building seek higher refuge on the ground floor or higher levels.

Water entering the basement car park entrance during a PMF event will cause inundation of the basement carpark, and likely the adjoining lower ground floor level if the water is unable to be adequately drained away.

It is also possible that water may enter the existing Cliffbrook House and The Stables building during a PMF event.

8.2.3 Hazards Outside the Building

The entrance driveway, southern car parking spaces and areas south of all buildings will be generally inundated in a 1% AEP flood to a depth of about 0.2 m, and in a PMF flood to a depth of up to 0.4 m (Figure_A 9 and Figure_A 11). Velocities will be low around buildings, however quite high along the driveway and southern car parking area (Figure_A 12 and Figure_A 14). While hazards directly around buildings will be fairly low in the 1% AEP and PMF event, it would be dangerous for persons or vehicles to attempt to leave the Site out to Beach Street.

8.2.4 Conditions on Public Roads

As Figure_A 18 indicates, conditions on the public roads will be hazardous in the 1% AEP storm, especially at the Site's vehicular entrance in Beach St where stormwater is expected to pond and enter at very high velocities (Figure_A 12). It is possible that vehicles parked close to the Site entrance on Beach Street might become buoyant and wash into the Site.

At times during storm events, visibility will be poor, and it will be difficult for pedestrians and drivers to assess water depths. It would be dangerous for drivers to attempt to leave the Site, or to enter it from Beach Street.

8.2.5 Hazards within the Primary & Secondary Overland Flow Paths

Without some form of barrier, vehicles, whether washed into the Site, parked along the southern car parking spaces or attempting to leave the basement car park, might be washed off the driveway into the downstream overland flow paths which lead towards downstream residential properties and Gordons Bay. Risk to loss of life in this situation would be high.

Additionally, it would be hazardous for persons to attempt to enter the flood waters during storm events or to ever store items or equipment in the overland flow paths.

8.3 EVACUATION STRATEGY

8.3.1 NSW Government Floodplain Development Manual

In accordance with the Floodplain Development Manual (FDM), in flood prone land the responsibility lies with Government to ensure new developments minimise flood risk through the implementation of effective flood emergency response measures.

To help minimise the flood risk to occupants, it is important that developments have provisions to facilitate flood emergency response. The two main forms of accepted flood emergency response that may be adopted within the floodplain are:

- Evacuation, which is the movement of occupants out of the floodplain before the property becomes flood affected; and,
- Shelter-in-place, which is the movement of occupants to a building that provides vertical refuge on the Site or near the Site before their property becomes flood affected.

8.3.2 Evacuation Strategy for The Site

As the catchment draining to the Site is relatively small (18.2 ha / 0.182 km^2), the onset of flooding will be rapid, and most occupants will only be aware of this by observing heavy rain, which is also likely to stop traffic on Beach Street near the Site.

A 'Shelter-In-Place' evacuation strategy is proposed for the Site. It is advisable that pedestrians and drivers remain within the buildings during a storm, due to the potentially dangerous conditions outside, and the duration of flooding being short. During the storm, persons should not enter or leave the buildings until water levels and velocities have subsided.

As it is expected that floodwater could enter all buildings during a rare PMF event, especially the lower ground floor and basement car park, evacuation of these areas needs to occur via stairs to higher levels. At present, there is no internal entrance to a staircase from the lower ground floor or basement car park without exiting the building. It looks possible to add an internal entrance to the stairs nominated as 'Stair 3' on the architectural plans, which would address this requirement.

Persons with cars in the basement car park, or along the southern car parking zone would need to be dissuaded from trying to recover their cars, as it would be impossible to exit the Site during large storm events.

If persons are located within their vehicles along the southern boundary parking zone, it would be advisable for them to wait in their vehicle until the peak of the short duration storm has passed rather than attempting to cross potentially hazardous conditions along the driveway by foot. If a buoyant vehicle happened to float into the Site via the main entrance, and collide with the parked vehicle, it might be possible that parked vehicle could be pushed towards proposed bollards at the base of the driveway.

During a rare PMF event, it is recommended that persons evacuate the small 'The Stables' building and make their way into the larger proposed building.

In the event that the Site needed to be completely evacuated, or emergency services needed to access the Site during a significant storm event, the northern pedestrian entry from Battery Street would provide the best access.

8.4 RECOMMENDED ACTIONS

8.4.1 Structural Measures

The floor and entrance levels set out in Table 2 have been established to ensure that the building and its occupants will be safe in the 1% AEP flood. Other hazard reduction features that should be incorporated into the final development are:

(a) a wall (which is shown on the plans) between the staircase and primary overland flow path near where the outlet and dissipation structure is proposed to reduce the chance of pedestrians being washed into the overland flow path, and to also provide flood protection to the lower levels of the new eastern building;

(b) bollards should be placed adjacent to the driveway between the basement car park entrance and the southern boundary of the Site, to prevent vehicles from being washed into the overland flow paths;

(c) the basement car park floor should slope upwards to doors with emergency EXIT signs, so that any person caught in water entering the basement will not go into deeper water as they walk to the nearest exit. This should only be at an entry into the lower ground floor area of the proposed building, not the south eastern exit into the out door potentially flooded area;

(d) there appears to be no stormwater drainage, pump out system, or proposed grading in the basement car park to facilitate the removal of possible flood water entering. Some form of system should be included in the final design to ensure that water can be removed from the basement car park in significant and rare storm events. This could help reduce risk of damage to vehicles, and also from water entering the lower ground floor, which is currently nominated with a flush floor level. Any proposed system needs to consider the downstream hydraulic conditions at the discharge location;

(e) at present, there is no internal access to a staircase from the lower ground floor or basement car park without exiting the building into potential flood water. It appears possible to add an internal entrance to the stairs nominated as 'Stair 3' on the architectural plans, which would address this requirement.

(f) it would be advantageous if the lower ground floor level could be raised further to achieve greater freeboard, or alternatively the south eastern entrances to the lower ground floor could be sealed off and designed to include flood proof doors for a minimum height of 500 mm; and

(g) all ventilation openings should be set well above flood levels.

8.4.2 Signage

Signs should be provided:

(a) At the lower ground level foyers and entrances to stairs, indicating that there is a risk of flooding;

(b) at the basement car park vehicular entrance indicating that the Site is flood prone, and warning drivers attempting to exit to be careful of flooding during storm events;

(c) at doors leading to the basement car park, advising people not to try to retrieve cars if water is entering the building or car park; and

(d) along the overland flow paths persuading people not to enter flood waters during storm events, or to store items or equipment at any time.

It may be possible to provide variable electronic signs as part of the everyday operation of the campus that during certain situations can display messages targeted to particular emergencies, such as floods and fires. In the event of a flood, these could advise people not to try to recover cars or to leave the building during a flood event. They could also direct people do higher refuge or to an emergency assembly area.

8.4.3 Emergency Response

Table 7 sets out details of preparations and responses needed to deal with flood emergencies at the Site. These are based on processes outlined by the NSW State Emergency Service on its Flood Safe website:

www.ses.nsw.gov.au/communitysafety/floodsafe/

A Site manager (campus manager or security officer) is required to be present on the Site, with an office on the ground floor of the proposed building.

A Flood Evacuation Plan needs to be prepared by a suitably qualified and experienced practitioner and made available to the Site manager as part of the development's Emergency Management Plan.

Table 7 – Preparations and Emergency Responses

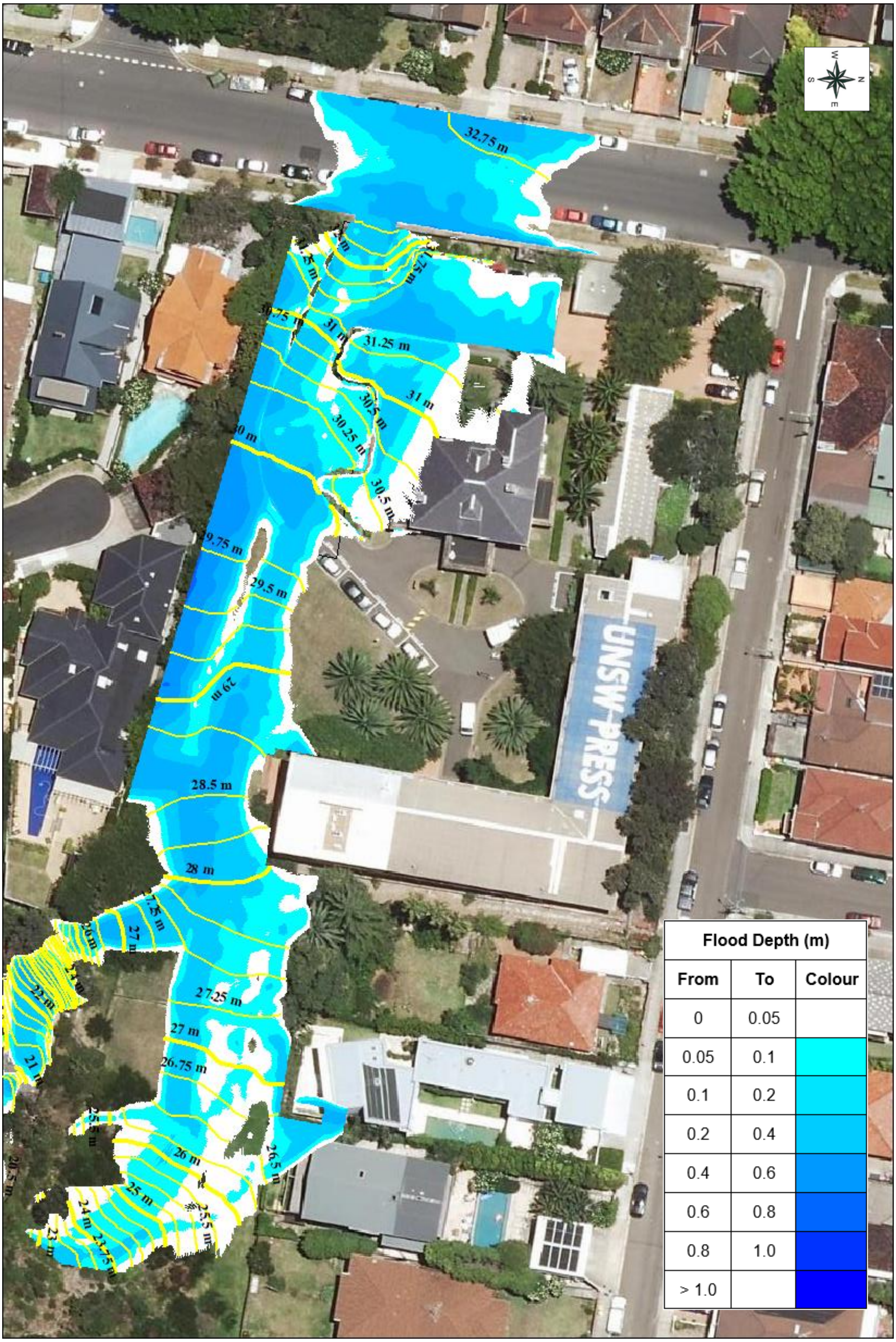
Type of Flooding	Rapid, Flash flooding
Passive Devices	Ensure evacuation pathways are signposted, accessible and clear.
Responsibilities of Site manager	Needs to be aware of flood hazard and the flood emergency plan. Must know the organisations to liaise with (SES, council, police, utility service providers, etc.), and the actions to be taken in an emergency. Stairs and other emergency pathways should be kept clear, and signs maintained. Will need to operate a communication network and advise residents in emergencies.
Warnings	Bureau of Meteorology warnings on radio, TV , smartphones and internet. Calls from friends and neighbours. Contact with local Canterbury-Bankstown Council. Possible warnings by building management.
Actions of Site manager	Site manager should consult flood emergency plan, liaise with emergency bodies), monitor flood levels, then advise and marshal people, dissuading them from leaving the building during a flood, or attempting to recover cars when this is dangerous. (Doorknocking of offices and classes will probably be unnecessary.) The manager should inform people when it is safe to go to underground areas, or to leave the building. They could issue 'All Clear' messages in conjunction with authorities once the flood is over and potentially hazardous conditions are investigated.
Actions of persons on Site	Persons on Site can 'shelter in place' until the flood subsides; no need to move from the main buildings, however, if in the smaller 'The Stables' building, then it is recommended to relocate into the larger building. Resist temptation to move vehicles out of building. Prevent children from leaving building during flood.
Other possible actions	Signs activated by Site manager at lifts and entrances to and exits to stairwells, warning in particular against entering a level if water is ponding there. Lifts might be stopped at the ground floor or first floor in the event of an emergency. Access to lower levels should only be by stairs.

9 REFERENCES

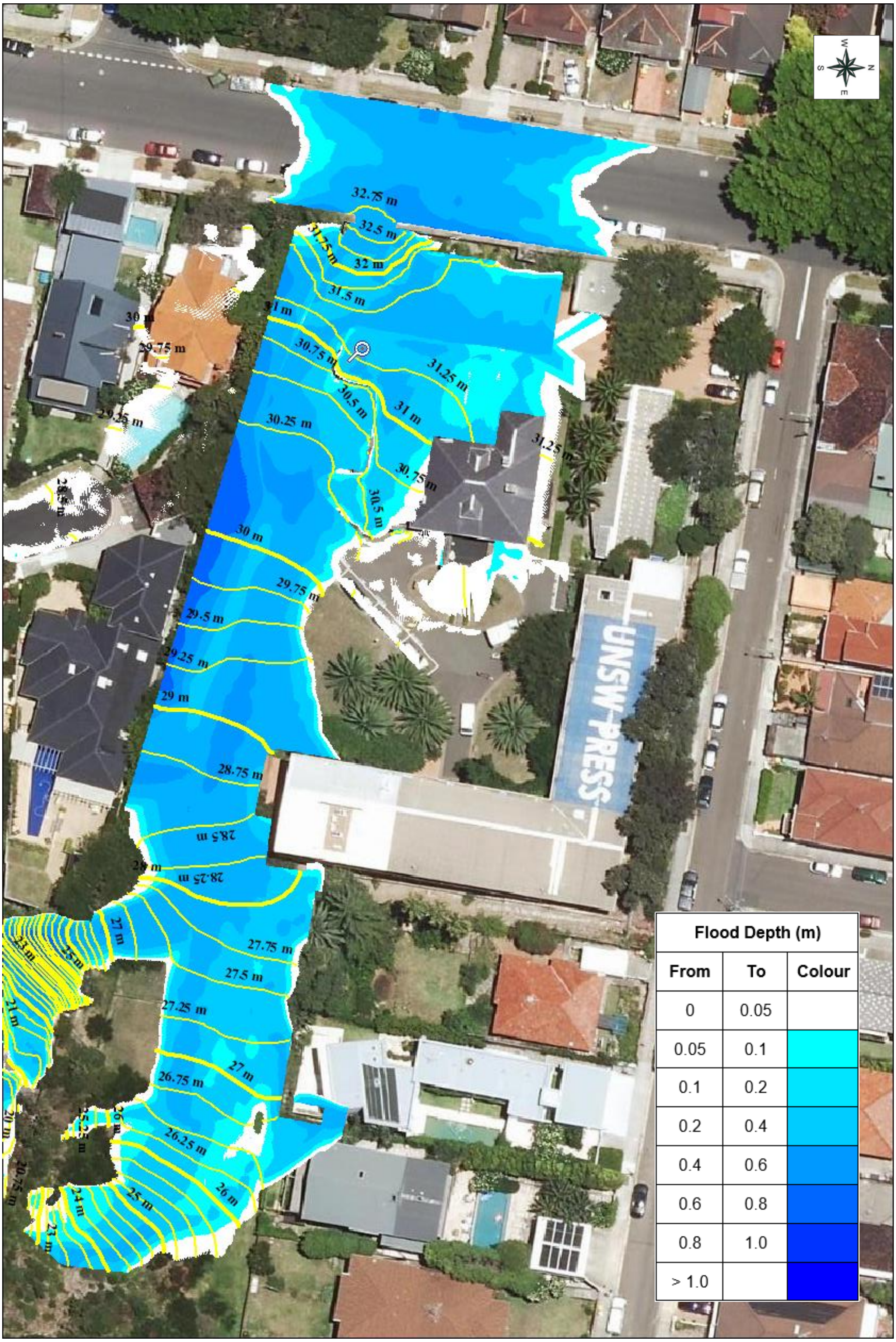
The following documents and resources have been utilised by Kustom Engineering during preparation of this report:

- O'Loughlin, G. and Stack, B. (2016) DRAINS User Manual, Sydney;
- AEMI, Australian Emergency Management Institute. (2013). Managing the floodplain: a guide to best practice in flood risk management in Australia - Handbook 7. Australian Emergency Management Institute Barton, ACT.
- AEMI, Australian Emergency Management Institute. (2014). Technical flood risk management guideline: Flood hazard. Australian Emergency Management Institute Barton, ACT.
- AEMI, Australian Emergency Management Institute. (2014). Technical flood risk management guideline: Flood emergency response classification of communities. Australian Emergency Management Institute Barton, ACT.
- Aerial photography and Street View imagery from Google Maps;
- Aerial photography from NSW Land and Property Information;
- Architectural Plans by ArtMade Architects, Dated 5 July 2016;
- Australia, Bureau of Meteorology (1994), The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method, Bulletin 53, Department of the Environment, Sport and Territories, AGPS, Canberra;
- Australia, Bureau of Meteorology, Intensity Frequency Duration - Online design rainfall tool;
- Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia
- Contours and topography data generated from licensed NSW LPI LiDAR Data, flown 2013;
- Cox, R. J., Shand, T. D. and Blacka, M. J. (2010). Australian Rainfall and Runoff Revision Project 10: Appropriate Safety Criteria for People. Australian Rainfall and Runoff Revision Project 10. Stage 1 Report. Prepared by the Water Research Laboratory. P10/S1/006. April 2010.
- *Floodplain Development Manual* published by the NSW Government, April 2005;
- Institution of Engineers, Australia (1987), Australian Rainfall and Runoff, A Guide to Flood Estimation, 2 volumes, (edited by D.H. Pilgrim and R.P. Canterford), Canberra (revised into eight loose-leaf books, 1998);
- McLuckie D et al, 2014 'Updating National Guidance on Best Practice Flood Risk Management'
- Randwick Comprehensive Development Control Plan 2013
- Survey Plan by Watson Buchan Pty Ltd, Dated 01 August 2008, reference 08/0409;
- Shand, T. D., Cox, R. J., Blacka, M. J. and Smith, G. P. (2011). Australian Rainfall and Runoff Revision Project 10: Appropriate Safety Criteria for Vehicles - Literature Review. Australian Rainfall and Runoff Revision Project 10. Stage 2 Report. Prepared by the Water Research Laboratory. P10/S2/020. February 2011.
- Smith, G. P., Davey, E. K., and Cox, R. J. (2014). Flood Hazard Water Research Laboratory Technical Report 2014/07. Prepared by the Water Research Laboratory. April 2014
- UNSW Australia, Plan of Cliffbrook Campus Consolidated Services & Updated Survey, Dated 03 June 2014
- US Army Corps of Engineers, Hydrologic Engineering Center
    - HEC-RAS Hydraulic Reference Manual Version 5.0 February 2016
    - HEC-RAS 5.0 User's Manual Version 5.0 February 2016
    - HEC-RAS 5.0 2D Modeling User's Manual Version 5.0 February 2016

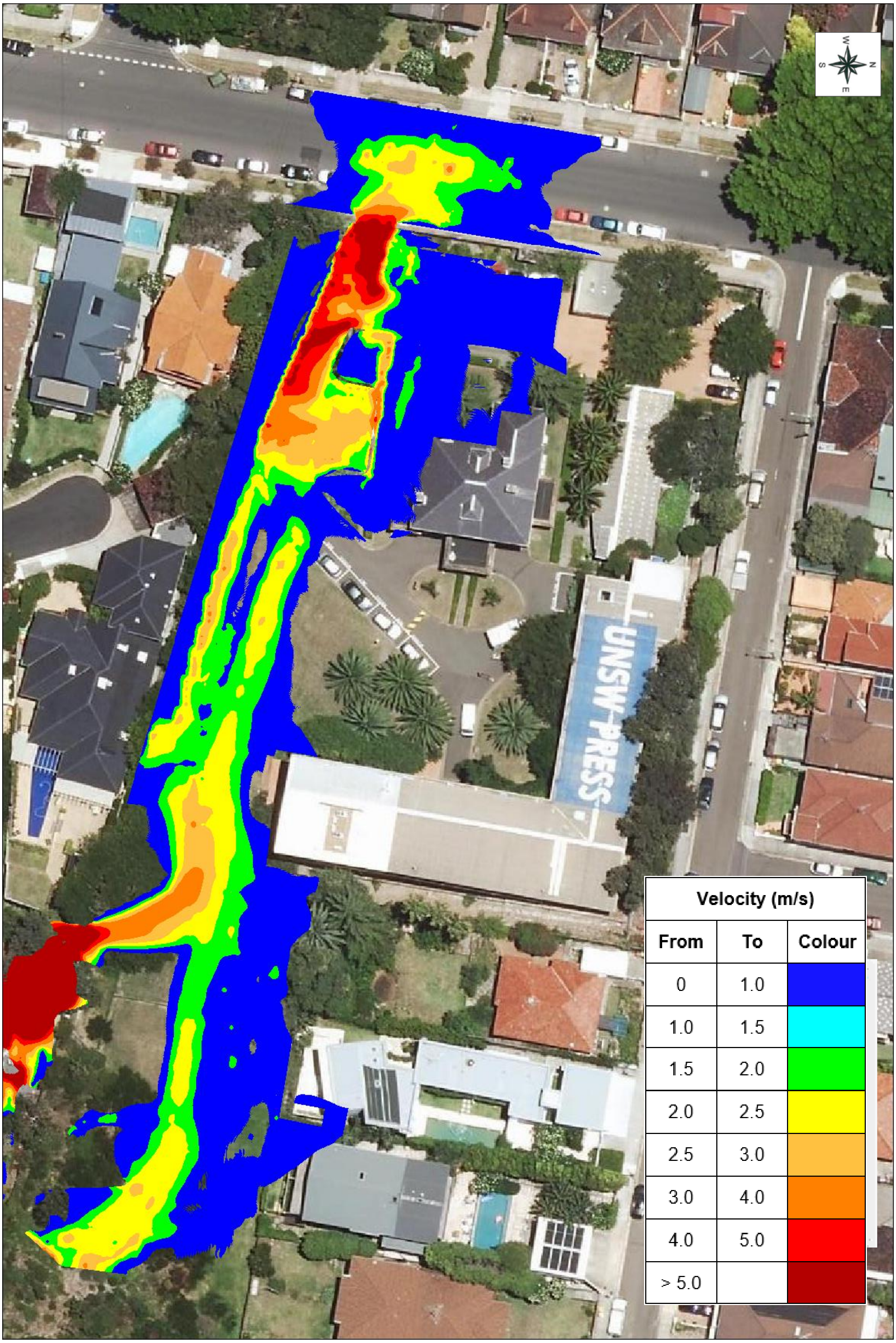
10 APPENDIX – PRE AND POST DEVELOPED FLOOD MAPS



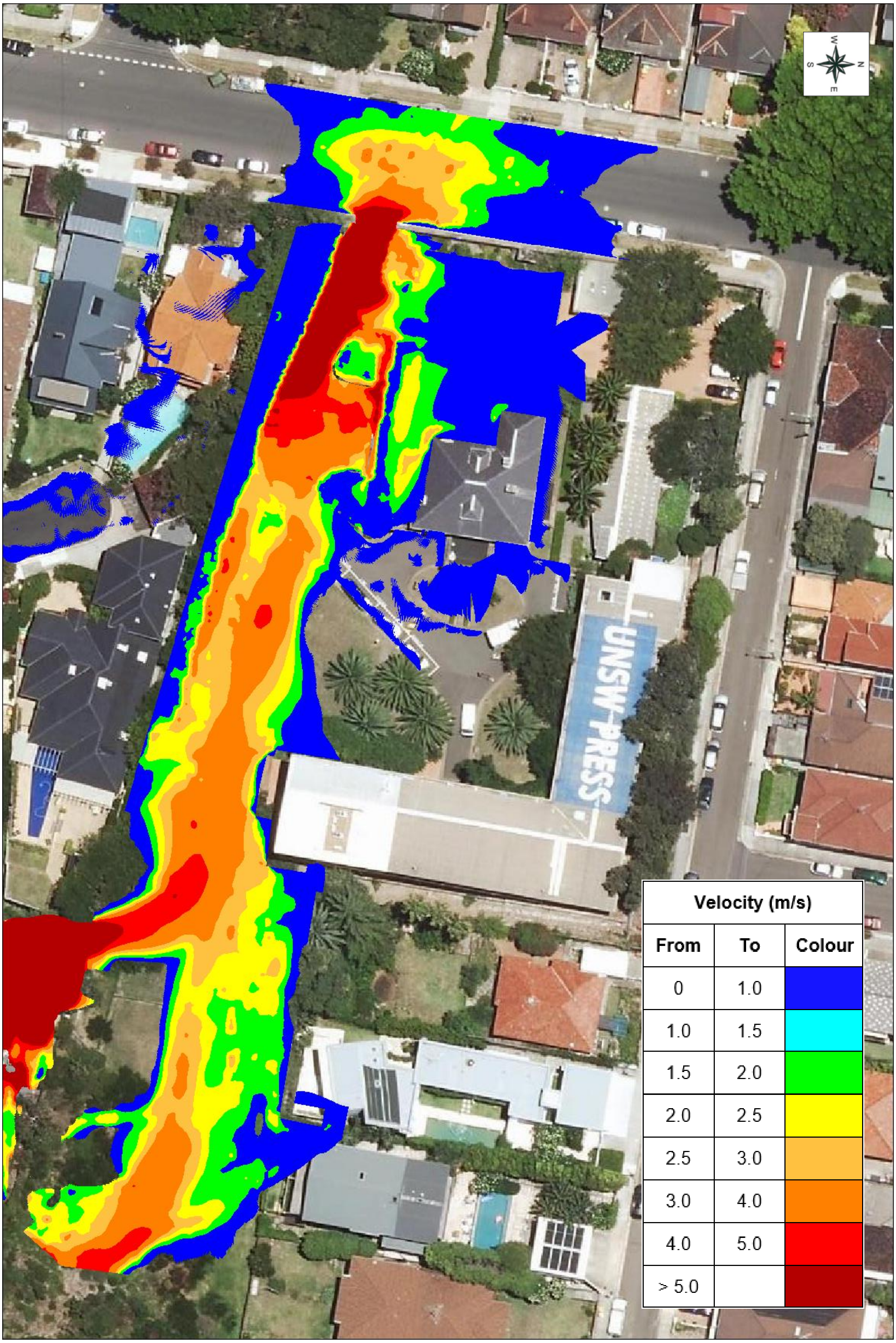
Figure_A 1 – Pre Developed – Peak Flood Depths & Contours – 1% AEP



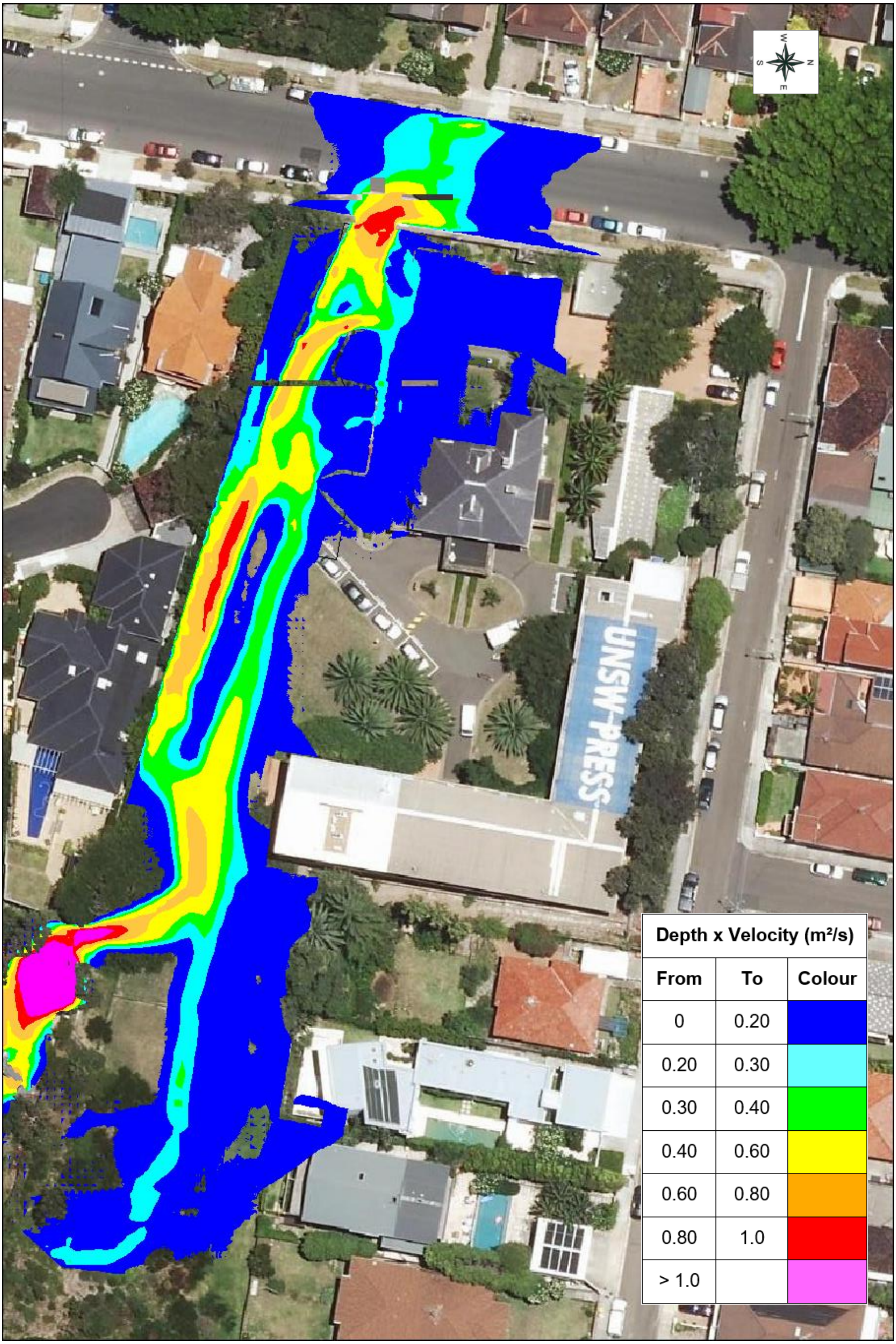
Figure_A 2 – Pre Developed – Peak Flood Depths & Contours – PMF



Figure_A 3 – Pre Developed – Peak Velocities – 1% AEP

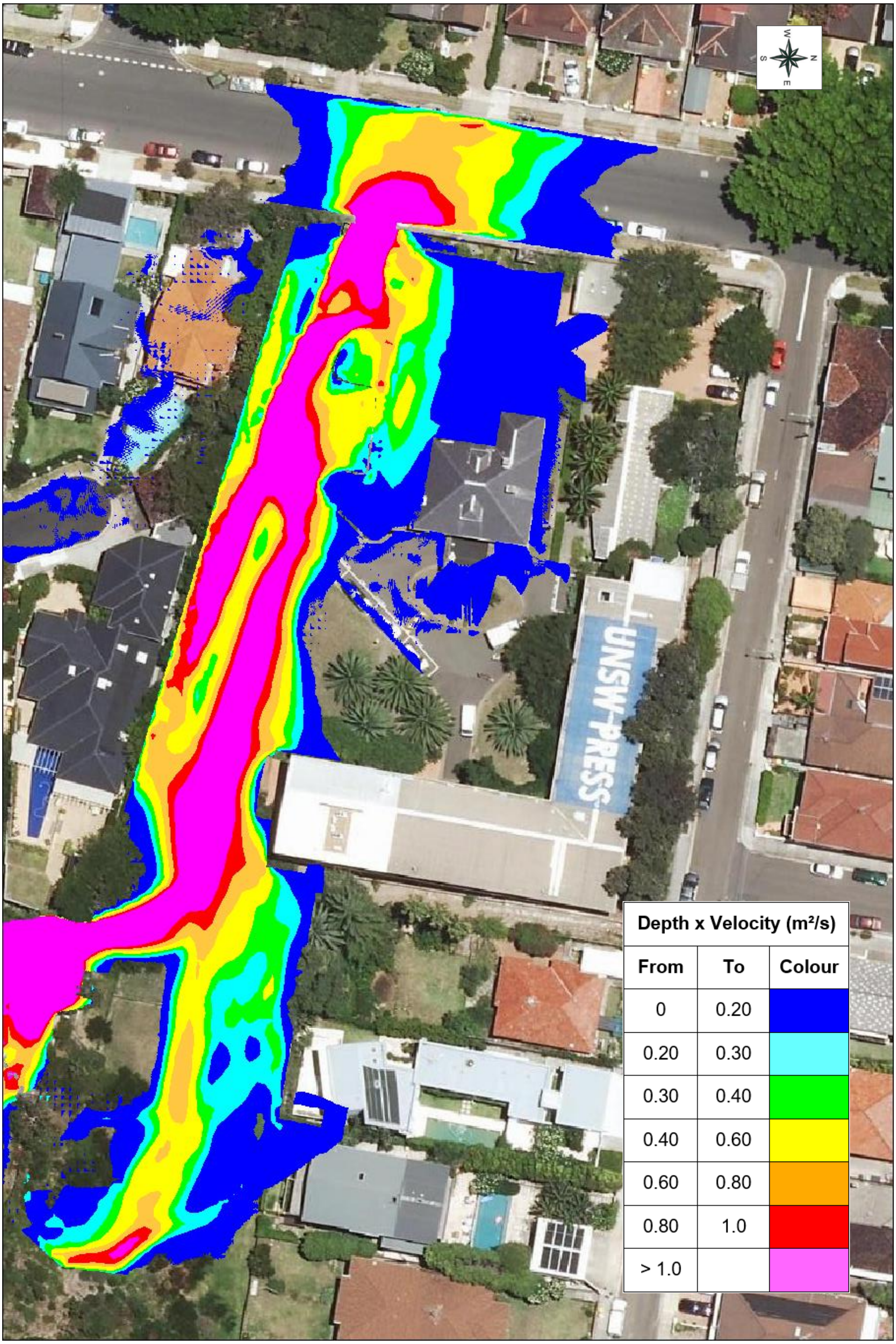


Figure_A 4 – Pre Developed – Peak Velocities – PMF



Depth x Velocity (m²/s)		
From	To	Colour
0	0.20	
0.20	0.30	
0.30	0.40	
0.40	0.60	
0.60	0.80	
0.80	1.0	
> 1.0		

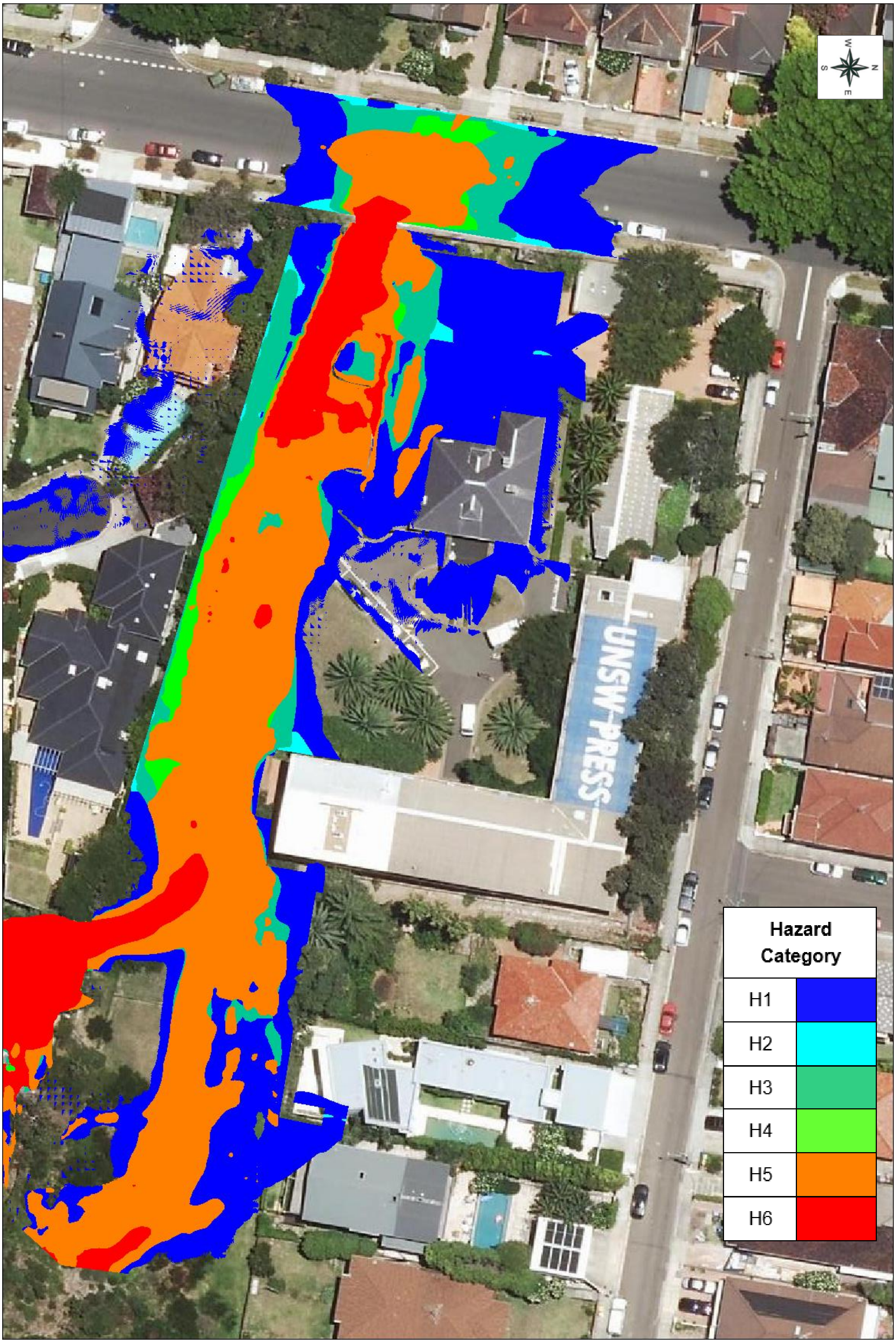
Figure_A 5 – Pre Developed – Peak Velocity Depth Product – 1% AEP



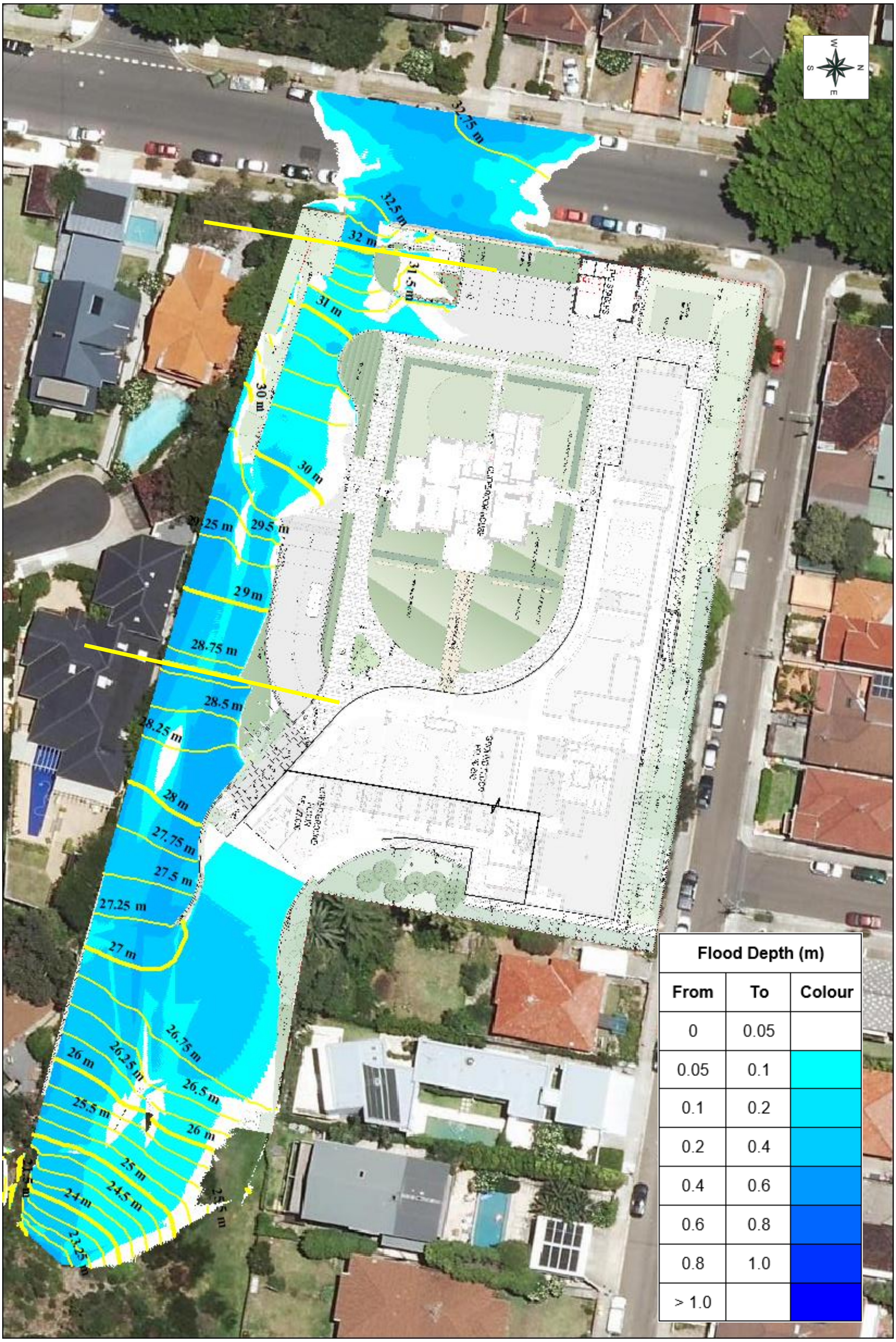
Depth x Velocity (m²/s)		
From	To	Colour
0	0.20	
0.20	0.30	
0.30	0.40	
0.40	0.60	
0.60	0.80	
0.80	1.0	
> 1.0		

Figure_A 6 – Pre Developed – Peak Velocity Depth Product – PMF

Figure_A 7 – Pre Developed – Peak Hazard Classification – 1% AEP



Figure_A 8 – Pre Developed – Peak Hazard Classification – PMF



Figure_A 9 – Post Developed – Composite Peak Flood Depths and Contours – 1% AEP