1. Introduction

1.1 Background

GHD has been commissioned by Warringah Council to update the Dee Why Town Centre Traffic Model. This report comprises the initial testing of the revised 'Base Case' and 'Option 2A2' Paramics models previously prepared by GTA Consultants in 2007 to identify potential changes in road network performance as a result development that could be realised under the Dee Why Masterplan. This includes testing of the assumed mix of commercial, residential and retail land uses within Dee Why that are currently permissible under the Warringah LEP.

1.2 Purpose of this report

The purpose of this study is to determine the level of development in Dee Why Town Centre that can be accommodated under the Option 2A2 scenario road network under a revised set of land use assumptions reflecting likely market take-up. This report documents the changes in traffic conditions throughout the Dee Why Town Centre a under range of development densities and using a new mix of land uses with substantially less commercial development.

The model has been developed using the Paramics micro simulation traffic modelling software suite and has been calibrated and validated according to the methodology set out in the *RMS Traffic Modelling Guidelines, 2013.* This calibrated model has been used to test the impacts of likely development under the Warringah LEP 2011 on the basis of performance measures including travel times and intersection Levels of Service under existing, and forecast traffic flows.

DRAFT

1.3 Limitations and Assumptions

As is normal in traffic modelling studies, the scope of this work entails a number of limitations and assumptions on the latitude of this study. The main limitations and assumptions include:

- Traffic count data collected by SkyHigh for Thursday morning and evening peak periods (including turning movement counts, travel time surveys and origin-destination surveys) are a true and accurate representation of existing traffic conditions along Pittwater Road;
- Traffic demand for the Saturday peak period has been determined by applying the growth factor between the surveys conducted by GTA in 2007 and the surveys conducted in 2013 to GTA's surveyed traffic flows for the Saturday peak.
- Information relating to changes in land use provided by Warringah Council for the Cobalt, Woolworths and PCYC sites is correct;
- Traffic generation rates for approved and pending development applications are based on the rates used by GTA Consultants and outlined in their original traffic report.
- Signal timing data provided by RMS is correct (confirmed by site visits);
- Revised intersection arrangements for the proposed option including traffic signal phasing have been taken from the original traffic models produced by GTA Consultants in 2007;
- The right-turn into the Dee Why Hotel development from Pacific Parade West that was originally banned in GTA's traffic model has been permitted to reflect existing traffic conditions (confirmed by site visits);
- The Option 2A2 AM peak modelling scenario has been developed based on GTA's Option 2A2 PM model incorporating updated traffic demand and optimized signal timing; and

- Does not include modelling of cycleways or mid-block pedestrian crossings.

1.4 Report Structure

This report is structured as follows:

- Model Revision and Update – Outlines the scope and methodology used to revise and update the traffic model (Section 2).
- Scenario Testing – Outlines the scenarios tested as a part of this assessment (Section 3).
- Model Results – Outlines the results of scenario testing (Section 4).
- Summary and Conclusions – Outlines the conclusions of the scenario testing and assessment process (Section 5).

2. Model Revision and Update

2.1 Overview

The Dee Why Town Centre micro simulation model was originally developed by GTA consultants in 2007. This model has been revised and updated by GHD to determine changes in traffic conditions throughout the Dee Why Town Centre as a result of increasing the proposed density of development that is currently allowed under the Warringah LEP 2011. The model has been revised and updated using the Paramics micro simulation modelling package (version 6.7.1) with additional functionality provided by the CeeJazz suite of Plugins. Version 6.7.1 G05 of Ceejazz was used, with the following Plugins active:

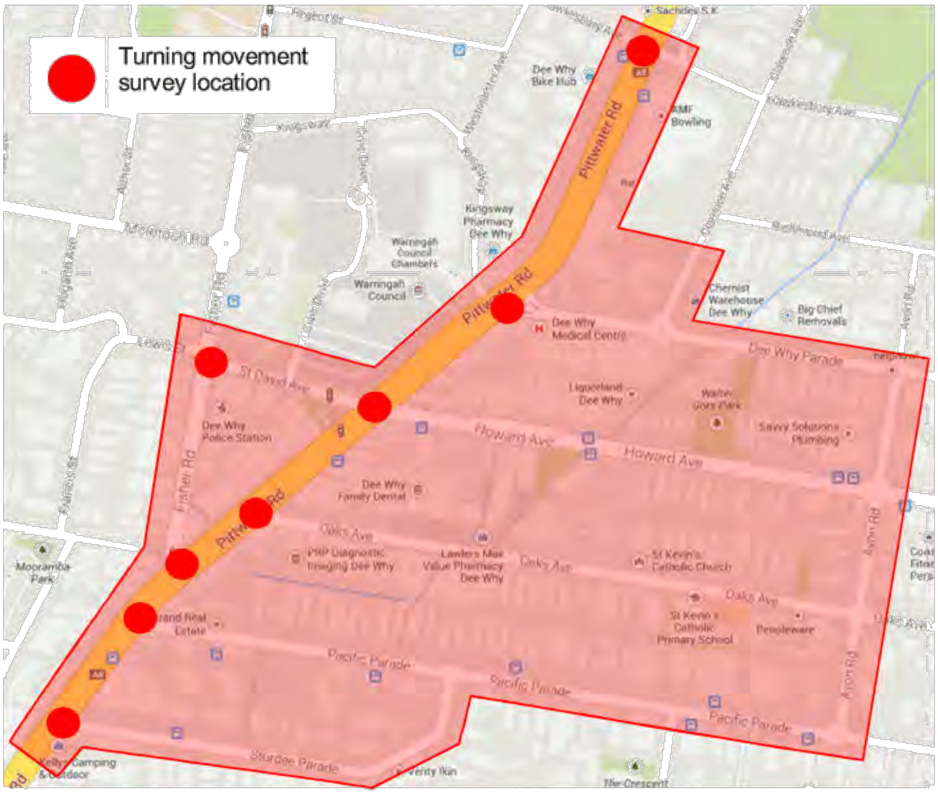
- Lane Choice;
- Validator;
- Level of Service; and
- Trailmaker.

Of these Plugins, only the Lane Choice Plugin has an effect on the model operation, while the other Plugins are used only for reporting purposes.

2.2 Model Extents

The Dee Why Town Centre micro simulation traffic model covers the Dee Why Town Centre bounded by Francis Street in the West, Avon Road in the East, Hawkesbury Avenue in the North and Sturdee Parade in the South. A map of the study area is shown in Figure 1.

Figure 1 Dee Why Town Centre Micro Simulation Model Extents



Source: Warringah Council

The Dee Why Town Centre models have been revised and updated using a synthesis of traffic data from 2013 including surveyed traffic counts and travel time surveys.

2.3 Traffic Data

Traffic data collected by SkyHigh for Thursday AM and PM peak periods was used to update the models to reflect existing traffic conditions and included:

- Classified intersection turning movement counts at the following intersections:
  - Pittwater Road – Sturdee Parade;
  - Pittwater Road – Pacific Parade;
  - Pittwater Road – Fisher Road;
  - Pittwater Road – Oaks Avenue;
  - Pittwater Road – Howard Avenue – St David Avenue;
  - Pittwater Road – Dee Why Parade – Kingsway;
  - Pittwater Road – Hawkesbury Avenue; and
  - Fisher Road – St David Avenue – Lewis Street.
- Travel time surveys undertaken along Pittwater Road between Sturdee Parade and Hawkesbury Avenue.

Since Saturday peak period surveys were not undertaken, the traffic demand for this period was determined by applying a growth factor between the surveys conducted by GTA in 2007 and the surveys conducted in 2013 to GTA's surveyed traffic flows for the Saturday peak.

In addition to the traffic survey data, signal timing data provided by RMS was used in the model calibration and validation process.

2.4 Temporal Coverage

The Dee Why Town Centre micro simulation traffic model covers the following time periods:

- Weekday morning peak (07:00 to 09:00);
- Weekday evening peak (16:00 to 18:00); and
- Saturday midday peak (10:00 to 12:00).

These time periods have been updated to represent the intersection survey periods and consist of a "warm-up" hour, which is used to allow the model to reach typical congested traffic conditions during the analysis period (second hour).

2.5 Model Calibration and Validation

Calibration and validation of the Dee Why Town Centre micro simulation model has been undertaken according to the methodology set out in the RMS Traffic Modelling Guidelines, 2013. The results of this process indicate that the model is well-calibrated and validated and meets the standards outlined in the guidelines. A detailed outline of the calibration and validation process used in the development of the Dee Why Town Centre Model is included in Appendix A.

3. Scenario Testing

3.1 Overview

The Base Case and Option 2A2 models originally produced by GTA Consultants in 2007 have been modified and updated to reflect 2013 traffic conditions, optimised signal arrangements and changes in land use proposed by Warringah Council.

The traffic modelling for the scenarios detailed below was undertaken for the morning, evening and Saturday peak periods. This is in contrast to the traffic modelling undertaken by GTA, which only considered the weekday evening and Saturday peak periods.

3.2 Road Network Options

The following road network configurations were tested as part of the modelling process.

3.2.1 Base Case (Existing Road Network)

The base case modelling scenario assumes that no changes will be made to the road network. The models have been revised and tested based on changes in traffic demand identified by traffic count surveys conducted by SkyHigh in October 2013, for the morning, evening and Saturday peak periods.

3.2.2 Option 2A2

Option 2A2 incorporates a one-way road system eastbound on Oaks Avenue and westbound on Howard Avenue. All traffic management measures included in the Option 2A2 road network remains consistent with that originally modelled by GTA, with the exception of the removal of a right-turn ban from Pacific Parade West into the Dee Why Hotel development.

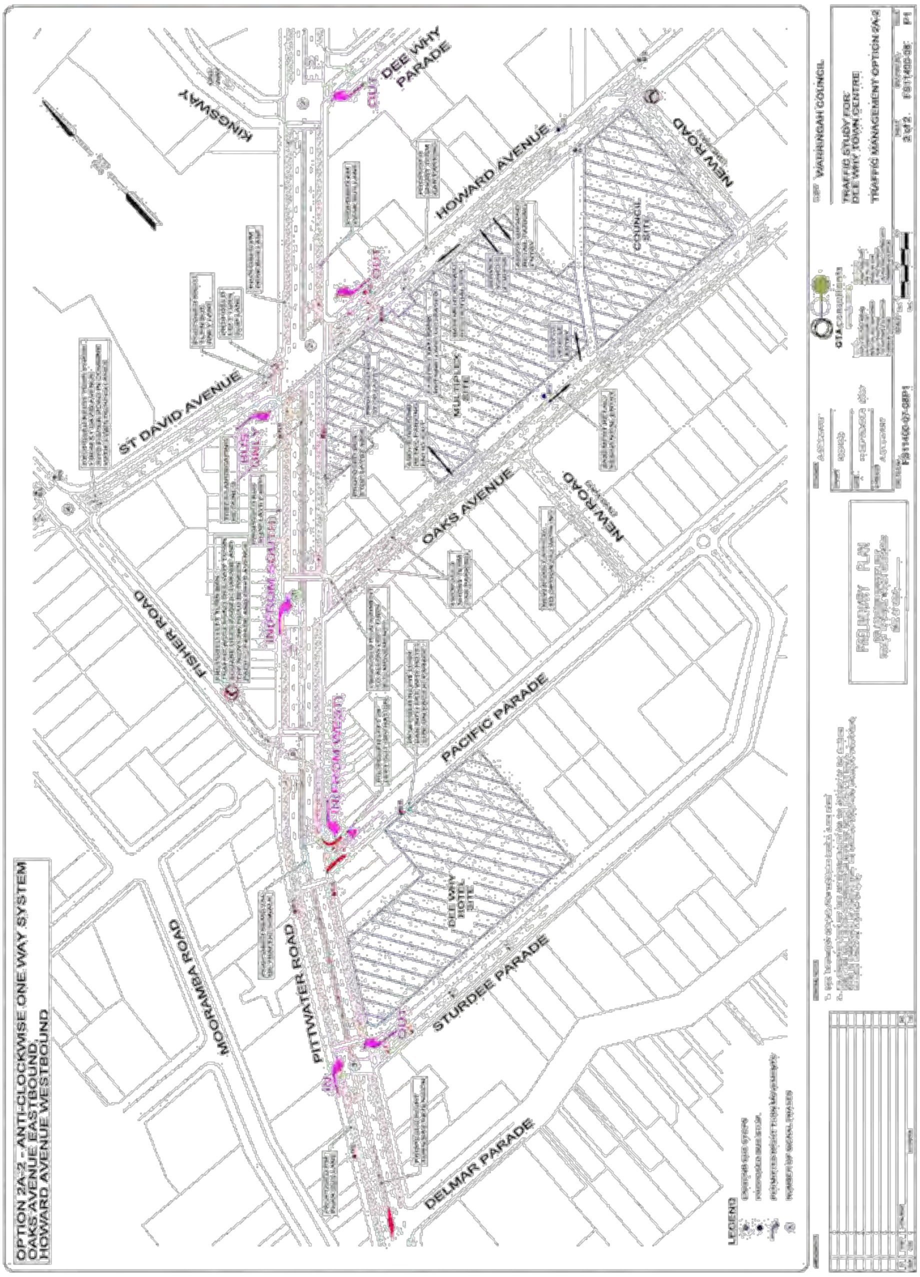
In summary, Option 2A2 applies the following traffic management measures to the existing road network:

- The removal of traffic signals at the intersection of Pacific Parade and Pittwater Road and conversion to a left-in left-out priority controlled intersection arrangement;
- The establishment of a one-way anti-clockwise road system that runs eastbound along Oaks Avenue and westbound on Howard Avenue. This system includes a one-way northbound road link that runs between Oaks Avenue and Howard Avenue.
- The addition of a right-turn signal phase from Sturdee Parade into Pittwater Road.
- The extension of the right-turn bay on the southern approach of Pittwater Road and Sturdee Parade;
- The removal of the right turn from Delmar Parade onto Pittwater Road;
- The establishment of four-phase signal arrangement at the intersection of Pittwater Road and Fisher Road;
- The establishment of a bus-only right-turn bay from St David Avenue onto Pittwater Road;
- The establishment of a left-slip lane from St David Avenue onto Pittwater Road;
- Removal of parking on the southern kerb of Sturdee Parade;
- Restriction of parking during the Saturday peak along the eastern kerb of Fisher Road between Pittwater Road and St David Avenue;

- The right-turn into the Dee Why Hotel development from Pacific Parade West that was originally banned in GTA's traffic model has been permitted to reflect existing traffic conditions (confirmed by site visits); and
- Altering the geometry of the north-eastern corner of the intersection of Oaks Avenue and Pittwater Road to permit left turn bus movements from the northern approach of Pittwater Road into Oaks Avenue.

A preliminary plan showing road network arrangements under Option 2A2 is provided in Figure 2.

Figure 2 Option 2A2 Preliminary Plan



During the revision of the Option 2A2 model, the removal of the road link between Pacific Parade and Oaks Avenue (originally proposed by GTA Consultants as a part of the Option 2A2 scheme) was tested to determine if the one-way road system would perform adequately without this link. Further testing showed that the road link is essential to the operation of the one-way road system, and its removal results in network-wide congestion under all modelling scenarios. This is consistent with the original assumptions made by GTA Consultants.

3.2.3 Inclusion of Signalised Pedestrian Crossing under Option 2A2

Option 2A2 would require the replacement of the existing marked pedestrian crossings on Oaks Avenue and Howard Avenue with mid-block signalised pedestrian crossings. This was not documented within the original GTA report, and these pedestrian crossings were not part of the original model developed by GTA. Paramics does not model unsignalised pedestrian crossings and no data was available regarding the demand at these crossings.

It is expected that the provision of signalised pedestrian crossings on Howard Avenue and Oaks Avenue will formalise pedestrians crossing opportunities and improve safety pedestrian safety, particularly on these proposed one-way streets. These signalised crossings can be coordinated with traffic signals on Pittwater Road to streamline traffic flow and reduce interruption of traffic flow through the one way system.

The introduction of signalised pedestrian crossing on Howard Avenue and Oaks Avenue needs to be further investigated to ascertain the likely traffic implications.

3.2.4 Inclusion of Cycling Lane on Howard Avenue under Option 2A2

The modelling results indicate Howard Avenue is approaching capacity during the morning peak period. In order for the intersection of Howard Avenue and Pittwater Road to operate satisfactorily under Option 2A2, the proposed lane configuration on the Howard Avenue East will require three westbound lanes.

The inclusion of a cycle lane in Howard Avenue will either require the removal of parking or a traffic lane. The latter will have a detrimental effect on the road carrying capacity of Howard Avenue. The other option will be to reduce the footpath width on Howard Avenue to accommodate a cycle lane.

3.2.5 Pacific Parade Swept Path Analysis

A swept path analysis was undertaken for rigid and articulated heavy vehicles turning left from Pittwater Road north into Pacific Parade, plots of which are provided in Appendix E. This analysis determined that due to the physical constraints of the intersection, rigid and articulated heavy vehicles would not be able to complete the left turn manoeuvre unless significant modifications are made to the north-east corner of the intersection to widen the road. If road widening is not undertaken, then any developments along Pacific Parade that are serviced by heavy vehicles need to consider that heavy vehicles will not be able to complete the left-turn manoeuvre from Pittwater Road north. In order to maintain heavy vehicle access along Pacific Parade, these developments would need to arrange alternative access routes for the heavy vehicles; or road widening at the intersection of Pittwater Road and Pacific Parade will need to be undertaken.

3.3 Land Use Options

The land use options tested within the model are described below.

3.3.1 Approved and Pending Development Applications S

Of the identified development applications within the study area, 12 have received Council approval with 5 still pending. The trip generation for the majority of these sites remains consistent with what was originally assumed by GTA Consultants in 2007 and is provided in Appendix C. These trips were assigned to the model based on the spatial distribution assumptions outlined in Section 3.2.

The trip generation for the Woolworths site (27-33 Oaks Avenue) and associated pass-by traffic has been determined based on the land use information provided in the 'Preliminary Redevelopments Concepts' by Marchese Partners (10/09/2012) and the traffic generation rates originally used by GTA consultants in 2007 (presented in Table 1) and is consistent with assumptions provided by Council.

Recent development applications for Woolworths and Cobalt sites have indicated that there is reduced market demand for commercial space within Dee Why Town Centre, with both these development applications proposing no commercial space and a single floor of retail. As residential land uses generally generate fewer trips for the same developable area than commercial trips, the change in land use assumptions from commercial to residential development present the opportunity to develop these sites with greater floor area for the same traffic impact.

3.3.2 Potential LEP Development

A total of 48 sites (listed in Appendix D) have been earmarked by Council for potential development under the Warringah LEP 2011. Some of these sites fall outside what is considered the 'town centre' under the Dee Why Masterplan, but been included as part of trip generation associated with potential LEP developments (refer to Figure 3) as agreed with Warringah Council. The trip generation for these sites is provided in Appendix D and the trip generation rates are provided in Table 1.

The traffic generation for potential LEP developments has been determined based on the assumption that all sites are to comprise the following land-use mix:

- Zero (0) floors of commercial GFA,
- One (1) floor of retail GFA (ground floor)
- Remaining floors assumed to be residential.

The above assumptions reflect the changing trend in market demand away from commercial development and towards residential development (also identified in Section 3.3.1). The aforementioned land-use assumptions were applied to all of the potential LEP developments in the study area, resulting in the following split of GFA by land use type:

- 0% Commercial
- 18% Retail
- 82% Residential

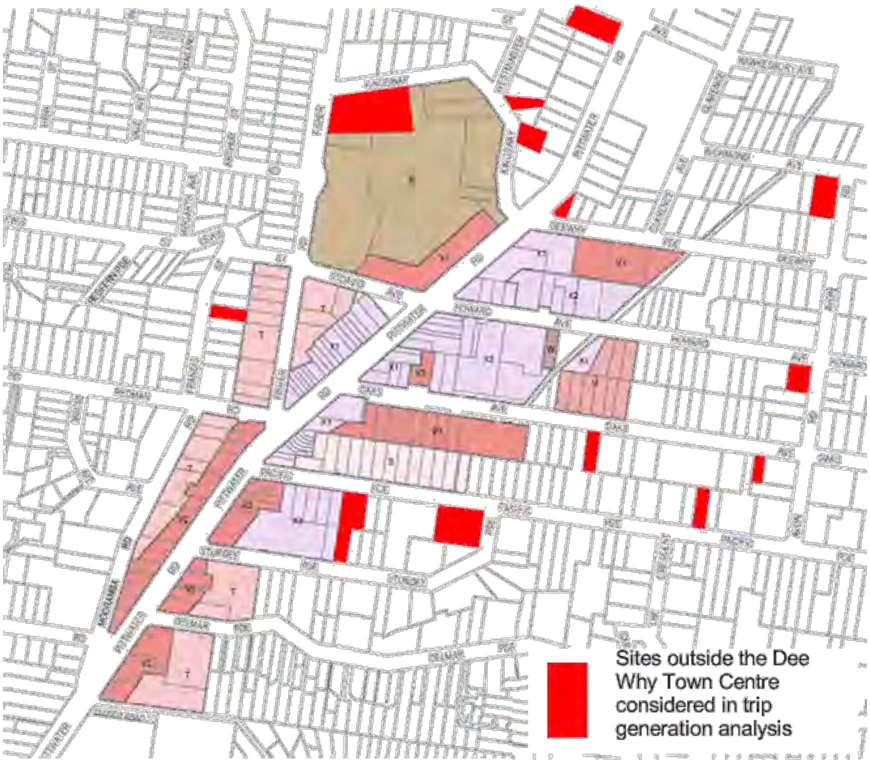
The traffic generation estimated as a part of this exercise differs significantly from that originally estimated by GTA. This difference in traffic generation can be attributed to the following changes:

- Adoption of the updated trip generation rates as prescribed by Roads and Maritime Services NSW in 2013.
- Changes in land-use mix assumptions, as detailed above.

Further sensitivity testing was undertaken to test the capacity of the road network under the current Warringah LEP 2011. This was achieved by increasing the floor-to-space (FSR) ratio for each of the identified sites listed in Appendix D by a nominated percentage. Accordingly, the increase in traffic generation for each of the subsequent scenarios (i.e FSR 105, FSR 110) correlates to the percentage increase in FSR. The increase in the FSR was then applied uniformly across all of the potential development sites within the study area, and the resulting traffic was assigned to the model based on the directional and distribution splits outlined in Section 3.2.

Traffic generation for the proposed PCYC development (36-48 Kingsway) has been determined based on the land use information provided in the 'PCYC Project and Car Park Redevelopment, Dee Why Traffic Impact Assessment' by Bitzios Consulting (page 7) updated traffic generation rates (presented in Table 1), and is consistent with assumptions defined by Council.

Figure 3 Location of LEP Developments outside of Dee Why Town Centre



3.3.3 Trip Generation Rates

The following table provides a summary of the trip generation rates used in the development of the models. It compares the old rates originally used by GTA Consultants in 2007 with the updated trip generation rates as prescribed by Roads and Maritime Services NSW in 2013.

Table 1 Trip Generation Rates

Peak	Residential (Trips per Unit Dwelling)			Commercial (Trips/GFA)	Retail (Trips/GLFA)	School (veh/stu)
	House	High Density Sub-metro	Aged/Disabled Housing			
GTA Trip Generation Rates						
Morning	0.85	0.29	0.2	0.02	0.01	0.8
Evening	0.85	0.29	0.2	0.02	0.04	0.7
Saturday	0.425	0.145	0.1	0	0.052	0
Updated Trip Generation Rates						
Morning	0.95	0.19	0.4	0.016	0.046	0.8
Evening	0.99	0.15	0.4	0.012	0.046	0.7
Saturday	0.495	0.075	0.2	0	0.061	0

The update of trip generation rates has resulted in a reduction in the number of trips generated by high-density residential dwellings, and an increase in the number of retail trips. With respect to revisions to the Dee Why Masterplan, the replacement of commercial units with high-density residential dwellings has resulted in a reduction in the overall trip generation associated with potential LEP developments.

Directional Distribution

The directional distributions used by GHD in updating the traffic generation are consistent with the original assumptions used by GTA Consultants in 2007. The directional distribution for AM, PM and Saturday peaks is shown in Table 2.

Table 2 Directional Distribution Rates

Period	Residential	Commercial	Retail
Morning, Evening and Saturday			
North	15%	40%	40%
East	15%	20%	20%
South	40%	20%	20%
West	30%	20%	20%

Directional Split

The directional split used by GHD to determine inbound and outbound trips remains consistent with those originally used by GTA Consultants in 2007. The directional splits for incoming and outgoing vehicle trips are shown in Table 3.

Table 3 Directional Split for Incoming and Outgoing Vehicles

Period	Residential	Commercial	Retail
Incoming			
Morning	20%	90%	90%
Evening	60%	10%	50%
Saturday	50%	-	50%
Outgoing			
Morning	80%	10%	10%
Evening	40%	90%	50%
Saturday	50%	-	50%

3.4 Scenario Tests

Traffic model 'Option 2A2' was used by GHD as the basis for further scenario testing, with each scenario being assessed for AM, PM and Saturday peak period traffic conditions. The scenarios that were tested using the 'Base Case' and 'Option 2A2' models include the following:

- Scenario 1: Existing traffic network with 2013 surveyed traffic flows;
- Scenario 2: 'Option 2A2' with 2013 surveyed traffic flows + traffic demand derived from approved and pending development applications;
- Scenario 3: 'Option 2A2' with 2013 surveyed traffic flows + traffic demand derived from approved and pending development applications + traffic demand derived from full (100%) LEP development;
- Scenario 4: 'Option 2A2' with 2013 surveyed traffic flows + traffic demand derived from approved and pending development applications + traffic demand derived from 105% of the full LEP development; and
- Scenario 5: 'Option 2A2' with 2013 surveyed traffic flows + traffic demand derived from approved and pending development applications + traffic demand derived from 110% of the full LEP development.

3.5 Trip Generation

The total trip generation associated with each of the land use options is shown in Table 4.

Table 4 Land Use Option Total Trip Generation

Peak	Total Trip Generation
Approved and Pending Development Applications	
Morning	857
Evening	1401
Saturday	1121
LEP FSR 100%	
Morning	749
Evening	668
Saturday	1003
LEP FSR 105%	
Morning	773
Evening	689
Saturday	1011
LEP FSR 110%	
Morning	799
Evening	711
Saturday	1023

A more detailed breakdown of the trip generation is provided in Appendix C and Appendix D. The table shows that approved and pending development applications and the LEP developments generate a similar quantum of trips.

4. Model Results

4.1 Overview

The Dee Why Town Centre traffic models have been evaluated as agreed with Warringah Council on the basis of the following performance measures:

- Network statistics including unreleased vehicles;
- Intersection Level of Service; and
- General traffic travel times.

Analysis of all of the scenarios tested showed that the critical peak period for the operation of the Option 2A2 network was the morning peak period, when the performance of the intersection of Pittwater Road and Howard Avenue is closest to capacity. This is in contrast to modelling work undertaken by GTA, which concentrated on the evening and Saturday peak periods only, and which has overlooked this critical period in the assessment of the capacity of the surrounding road network.

4.2 Network Statistics

Network statistics were collected for each of the models, including the following:

- Vehicle Hours of Travel (VHT);
- Vehicle Kilometres of Travel (VKT);
- Average Network Speed (km/hr); and
- Total Unreleased Vehicles.

These statistics are summarised in Table 5 below.

Table 5 Morning Peak Network Statistics Summary

Option	VHT (hr)	VKT (km)	Average Travel Speed (km/hr)	Total Unreleased Vehicles
Morning Peak				
Scenario 1: Base Case (Existing)	387	10,018	26	1
Scenario 2: Option 2A2 + DA	566	13,041	23	22
Scenario 3: Option 2A2 + DA + LEP FSR 100	695	14,040	20	150
Scenario 4: Option 2A2 + DA + LEP FSR 105	700	14,009	20	170
Scenario 5: Option 2A2 + DA + LEP FSR 110	705	14,082	20	174
Evening Peak				
Scenario 1: Base Case (Existing)	472	10,722	23	58
Scenario 2: Option 2A2 + DA	564	14,962	27	9
Scenario 3: Option 2A2 + DA + LEP FSR 100	649	15,862	24	54
Scenario 4: Option 2A2 + DA + LEP FSR 105	655	15,927	24	14
Scenario 5: Option 2A2 + DA + LEP FSR 110	690	16,021	23	76

Option	VHT (hr)	VKT (km)	Average Travel Speed (km/hr)	Total Unreleased Vehicles
Saturday Midday Peak				
Scenario 1: Base Case (Existing)	433	10,663	25	1
Scenario 2: Option 2A2 + DA	505	14,526	29	0
Scenario 3: Option 2A2 + DA + LEP FSR 100	652	15,939	24	16
Scenario 4: Option 2A2 + DA + LEP FSR 105	649	15,999	25	9
Scenario 5: Option 2A2 + DA + LEP FSR 110	659	15,937	24	25

Analysis of the network statistics shows a general tendency towards increased vehicle hours and kilometres travelled across the network as a result of the introduction of traffic generated by approved and pending development applications as well as potential LEP scenarios.

The number of total unreleased vehicles represents queuing at various locations throughout the Dee Why Town Centre network. It is evident that the number of total unreleased vehicles increases drastically under both LEP scenarios during the morning peak, which can be attributed to changes in signal timing at the intersection of Pittwater Road and Howard Avenue. The eastern approach of Howard Avenue requires a greater proportion of green-time allocation in order to account for increased traffic as a result of the one-way road system.

The requirement to provide more phase time for east-west traffic at the intersection of Pittwater Road and Howard Avenue results in greater congestion for northbound and southbound traffic on Pittwater Road. Consequently, southbound queues on Pittwater Road tend to increase as development density through Dee Why Town Centre increases. This issue is presented in Figure 4.

Figure 4 Queuing on Pittwater Road during Morning Peak – LEP FSR 105%

Analysis of the morning peak LEP scenarios showed that the critical movement in the Option 2A2 network is the westbound movement from Howard Avenue at Pittwater Road. Increasing development results in larger demand and longer queues on this approach. Due to the constrained nature of the one-way pair, excess queuing on this approach will result in extensive congestion through Dee Way Town Centre. Consequently, increase in development density and traffic in the Dee Why must come at the cost of decreased through capacity on Pittwater Road.

The theoretical maximum level of LEP development that can be accommodated by the 'Option 2A2' road network before queuing becomes excessive and impacts on the operation of the network is in the order of 105% of full LEP development (refer to Section 3.3.2). This corresponds to approximately 170 vehicles queued on Pittwater Road north of Howard Avenue during the morning peak. Queues of longer than this are likely to impact on other intersections on Pittwater Road to the north of Dee Why.

4.3 Intersection Performance

The assessment of intersection operation is based on criteria outlined in Table 6 as defined in the Guide to Traffic Generating Developments published by the NSW Roads and Traffic Authority (RTA) in 2002.

Table 6 Intersection Levels of Service

Level of Service	Average Delay per Vehicle	Traffic Signals and Roundabouts	Give Way and Stop Signs
A	<14	Good operation	Good operation
B	15 to 28	Good with acceptable delays and spare capacity	Acceptable delays and spare capacity
C	29 to 42	Satisfactory	Satisfactory, but accident study required
D	43 to 56	Operating near capacity	Near capacity and accident study required
E	57 to 70	At capacity; at signals, incidents will cause excessive delays Roundabouts will require other control mode	At capacity, requires other control mode
F	>70	Over capacity, unstable operation	Over capacity, unstable operation

Source: Guide to Traffic Generating Developments, NSW RTA (2002)

Intersection Levels of Service have been reported for Weekday (0800 to 0900 and 1700 to 1800) and Saturday (1100 to 1200) peak hours for the following intersections:

- Pittwater Road/Sturdee Parade
- Pittwater Road/Pacific Parade
- Pittwater Road/Fisher Road
- Pittwater Road/Oaks Avenue
- Pittwater Road/Howard Avenue/St David Avenue
- Pittwater Road/Dee Why Parade
- Pittwater Road/Hawkesbury Street
- Pittwater Road/Fisher Road

A summary of the modelled average delays and intersection levels of service in the 'Base Case' and 'Option 2A2' networks is shown in Table 7.

Table 7 Intersection Levels of Service

Intersection	Morning Peak		Evening Peak		Saturday Peak	
	Av Delay (s)	LoS	Av Delay (s)	LoS	Av Delay (s)	LoS
Scenario 1: Base Case (Existing)						
Pittwater Road and Sturdee Parade	17	B	32	C	16	B
Pittwater Road and Pacific Parade	12	A	17	B	16	B
Pittwater Road and Fisher Road	24	B	16	B	20	B
Pittwater Road and Oaks Avenue	13	A	8	A	16	B
Pittwater Road and Howard Avenue/St David Avenue	20	B	19	B	32	C
Pittwater Road and Dee Why Parade	21	B	18	B	19	B
Pittwater Road and Hawkesbury Street	21	B	25	B	20	B
Fisher Road and St David Avenue/Lewis Street	27	B	27	B	20	B
Scenario 2: Option 2A2 + Pending and Approved DA's						
Pittwater Road and Sturdee Parade	29	C	42	C	25	B
Pittwater Road and Pacific Parade	27	B	14	A	7	A
Pittwater Road and Fisher Road	30	C	21	B	15	B
Pittwater Road and Oaks Avenue	32	C	13	A	17	B
Pittwater Road and Howard Avenue/St David Avenue	40	C	19	B	22	B
Pittwater Road and Dee Why Parade	39	C	19	B	20	B
Pittwater Road and Hawkesbury Street	21	B	20	B	18	B
Fisher Road and St David Avenue/Lewis Street	39	C	22	B	29	C
Scenario 3: Option 2A2 + Pending and Approved DA's + LEP FSR 100%						
Pittwater Road and Sturdee Parade	32	C	48	D	26	B
Pittwater Road and Pacific Parade	26	B	15	B	10	A
Pittwater Road and Fisher Road	30	C	26	B	19	B
Pittwater Road and Oaks Avenue	32	C	15	B	25	B
Pittwater Road and Howard Avenue/St David Avenue	46	D	22	B	41	C
Pittwater Road and Dee Why Parade	49	D	20	B	34	C
Pittwater Road and Hawkesbury Street	24	B	19	B	19	B
Fisher Road and St David Avenue/Lewis Street	46	D	35	C	45	D
Scenario 4: Option 2A2 + Pending and Approved DA's + LEP FSR 105%						
Pittwater Road and Sturdee Parade	30	C	46	D	29	B
Pittwater Road and Pacific Parade	26	B	14	B	10	A
Pittwater Road and Fisher Road	31	C	26	B	19	B
Pittwater Road and Oaks Avenue	33	C	16	B	24	B
Pittwater Road and Howard Avenue/St David Avenue	45	D	24	B	39	C
Pittwater Road and Dee Why Parade	48	D	21	B	30	C
Pittwater Road and Hawkesbury Street	24	B	19	B	18	B
Fisher Road and St David Avenue/Lewis Street	45	D	38	C	44	D
Scenario 5: Option 2A2 + Pending and Approved DA's + LEP FSR 110%						
Pittwater Road and Sturdee Parade	32	C	47	D	26	B
Pittwater Road and Pacific Parade	29	C	15	B	8	A
Pittwater Road and Fisher Road	31	C	28	B	19	B
Pittwater Road and Oaks Avenue	33	C	16	B	25	B
Pittwater Road and Howard Avenue/St David Avenue	41	C	18	B	33	C
Pittwater Road and Dee Why Parade	49	D	15	B	31	C
Pittwater Road and Hawkesbury Street	30	C	28	B	31	C
Fisher Road and St David Avenue/Lewis Street	43	D	46	D	39	C

LEGEND

LoS A	Delay < 14 sec	LoS B	Delay < 15 to 28 sec	LoS C	Delay < 29 to 42 sec	LoS D	Delay < 43 to 56 sec	LoS E	Delay < 57 to 70 sec	LoS F	Delay > 70

Analysis of the modelled intersection Levels of Service show that the all of intersections in the study area are forecast to operate satisfactorily, with a Level of Service D or better under both the Base Case and Option 2A2 models.

It should be noted that the intersection delays shown above are for interrelated intersections, hence high delays at one intersection can result in reduced flow to downstream intersections, which in turn reduces delay for those downstream intersections. It is this "gating" effect that can result in some intersection performing better under higher demands.

Under Option 2A2, average delay at some intersections may increase during the weekday morning peak when compared to the Base Case scenario. These average delays are likely to increase further with the introduction of traffic generated by potential LEP developments.

Average delay at most intersections is largely comparable during the weekday evening and Saturday midday peaks under all modelling scenarios, with the exception of Fisher Road/St David Avenue and Pittwater Road/Sturdee Parade, which are forecast to increase with the introduction of traffic generated by potential LEP developments.

4.4 Travel Time Comparison

Travel time observations were conducted by SkyHigh along Pittwater Road between Sturdee Parade and Hawkesbury Avenue on Wednesday October 9th 2013 during morning (08:00-09:00) and evening (17:00-18:00) peak periods. A comparison of the observed and modelled travel times along this section are presented in the following section.

Table 8 Comparison of Observed and Modelled Travel Times

Section	Travel Time (min:sec)					
	Observed	Scenario 1: Base Case	Scenario 2: Option 2A2 + DA	Scenario 3: Option 2A2 + DA + LEP FSR 100%	Scenario 4: Option 2A2 + DA + LEP FSR 105%	Scenario 5: Option 2A2 + DA + LEP FSR 110%
Northbound						
Thursday: 08:00-09:00	02:01	01:19	01:33	01:34	01:34	01:34
Thursday: 17:00-18:00	01:50	01:15	01:20	01:23	01:23	01:23
Saturday: 11:00–12:00	-	01:38	01:21	01:22	01:22	01:25
Southbound						
Thursday: 08:00-09:00	01:39	01:25	03:11	03:29	03:35	03:41
Thursday: 17:00-18:00	01:35	01:26	01:58	02:13	02:12	02:14
Saturday: 11:00–12:00	-	01:33	01:38	02:49	02:39	02:55

Analysis of the modelled travel times along Pittwater Road shows that forecast travel times are comparable during the both weekday peak periods under the Base Case and Option 2A2 modelling scenarios. The only exception is the southbound route which increases as a result of traffic generation of approved and pending development applications as well as potential LEP changes. This can be attributed to changes in signal timing at the intersection of Pittwater Road and Howard Avenue. The eastern approach of Howard Avenue requires a greater proportion of green-time allocation in order to account for increased traffic as a result of the one-way road system.

In comparison to the surveyed travel times, the results of the Base Case and Option 2A2 scenarios are generally favourable for northbound vehicles, with forecast reductions in travel times under all modelling scenarios.

5. Summary and Conclusion

5.1 Key Findings

The key findings from the review and update of the Dee Why Town Centre traffic models are as follows:

- The implementation of a road link between Pacific Parade and Oaks Avenue is essential to the operation of the one-way road system, proposed under Figure 2. Removing this link results in network-wide congestion under all modelling scenarios.
- The intersection of Howard Avenue and Pittwater Road is the critical intersection within the one way system as this intersection controls the overall capacity of the surrounding road network.
- Testing of the various land use scenarios showed that the morning peak period is the critical period, where the intersection of Howard Avenue and Pittwater Road experiences the highest delays. This was not identified as part of the assessment undertaken by GTA, as that previous assessment was focussed only on the evening and Saturday peak periods.
- There is likely to be a significant change in the operation for the majority of intersections in Dee Why during the morning peak with the addition of traffic generated by pending and approved developments as well as potential LEP developments. However, the majority of intersections are not likely to change substantially during weekday evening and Saturday midday peak periods under the same circumstances.
- Northbound travel times along Pittwater Road under all development scenarios are likely to remain comparable with observed times. Changes to signal timing at the intersection of Pittwater Road and Howard Avenue under the one-way road system means that southbound travel times are likely to increase under the proposed development scenarios.

5.2 Key Conclusions

The key conclusions from the modelling of the Dee Why Town Centre are:

- The addition of traffic generated by approved and pending development applications can be accommodated by the 'Option 2A2' network.
- The theoretical maximum level of LEP development that can be accommodated by the 'Option 2A2' road network is in the order of 105% of full LEP development. Increasing the level of LEP development beyond this may result in excessive queuing southbound on Pittwater Road during the morning peak, potentially affecting other intersections to the north of Dee Why.
- Original modelling undertaken by GTA indicated that the road network surrounding Dee Why could accommodate approximately 85% of the proposed LEP development. The difference between the two outcomes is largely a result of the change from commercial land use to residential land use, which generates less traffic.
- The intersection of Pittwater Road and Howard Avenue operates close to capacity with the application of traffic generated by approved and pending development applications, and full (100%) LEP development.

Appendices

Appendix A Model Calibration and Validation

Data Collection and Validation

Traffic count data for each hour in the morning, evening and Saturday midday peak periods was plotted on a network diagram to identify any mismatches or discrepancies in vehicle flow. No significant discrepancies in vehicle flows were identified during this process.

Model Calibration

Overview

Calibration of the Dee Why Town Centre micro simulation model has been undertaken according to the methodology set out in the RMS Traffic Modelling Guidelines, 2013. Calibration has been undertaken for the weekday morning and evening peak periods based on a comparison against average hourly turning movements for the peak two-hour period.

Model Stability

The flow of traffic and the associated traffic conditions are randomly variable phenomena, and micro simulation models attempt to capture this variability by releasing traffic into the network at randomly varying intervals. Whether or not a vehicle is released from a zone in any given second is dependent on the outcome of a random number generator, and this generator is controlled by the seed value. The same model run under different seed values will results in a different simulation result. For this reason, micro simulation models are generally run using a range of seed values, with results being reported over a range of runs. The Dee Why Town Centre micro simulation model has been run under the prescribed RMS seed values of 560, 28, 7771, 86524, and 2849.

Calibration Statistics

Model calibration was undertaken on the basis of comparison of modelled and observed traffic volumes. The GEH statistic is used in the calibration of traffic models to compare the difference between observed and modelled traffic flows. The GEH statistic is defined as follows:

$$GEH = \sqrt{\frac{(V_{Observed} - V_{Modelled})^2}{(0.5 \times (V_{Observed} + V_{Modelled}))}}$$

Based on the calibration and validation guidelines presented in RMS *Traffic Modelling Guidelines, 2013*, a calibrated model must conform to the following requirements:

- No flow comparisons with GEH greater than 10; and
- At least 85% of flow comparisons with GEH less than 5.

Based on the adjusted traffic flows, a total of 62 individual turning counts were used in the calibration of the model. Barred turns were omitted from the turning count comparison. The table below shows the turning count comparisons for the morning and evening peak periods.

GEH Turning Count Comparisons

	Number of Movements with GEH			
Period	<3	<5	<10	>10
Morning Peak				
07:00-09:00	45 (75%)	53 (88%)	62 (100%)	0 (0%)

Period	Number of Movements with GEH			
	<3	<5	<10	>10
Evening Peak				
16:00-18:00	47 (78%)	58 (97%)	62 (100%)	0 (0%)

Analysis of the turning flow comparisons for the morning and evening peak periods shows that the model is well calibrated and conforms to the requirements set out in the RMS *Traffic Modelling Guidelines, 2013*. A detailed list of turning movement comparisons is provided in Appendix B.

Model Validation

In order to determine the suitability of the Dee Why Town Centre micro simulation traffic model in forecasting future traffic conditions, it is necessary to validate the model against a set of data that is independent to that used in the calibration process.

Travel times northbound and southbound along Pittwater Road, between Sturdee Parade and Hawkesbury Avenue were used to validate the operation of the model. Validation to travel times demonstrates that the model accurately reflects the volume to delay response that occurs in the field.

For the Dee Why Town Centre micro simulation traffic model, the travel time validation criteria from RMS *Traffic Modelling Guidelines, 2013, Section 11.5* has been adopted. This standard requires that 85% of modelled travel times be within 15% or one minute (whichever is greater) of observed travel times to be considered valid. A summary of the modelled and observed travel times for the morning and evening peak period is presented in the following tables.

Base Model Travel Time Comparison – Morning Peak

Route		8AM – 9AM		
		Observed	Modelled	%Diff
Pittwater Road	NB	02:01	01:19	-35%
Pittwater Road	SB	01:39	01:25	-14%

Base Model Travel Time Comparison – Evening Peak

Route		5PM – 6PM		
		Observed	Modelled	%Diff
Pittwater Road	NB	01:50	01:15	-32%
Pittwater Road	SB	01:35	01:26	-9%

Analysis of the observed and modelled travel times shows that all of the 'base model' travel times are within 15% or one minute (whichever is greater) of the observed travel times. In general, the modelled travel times are lower than the observed travel times. Comparisons of travel time for very short sections are difficult to calibrate to within one minute or less and these differences are generally not significant. Overall, comparisons of travel time for the Dee Why Town Centre model show that the model is well-validated with respect to travel times through the study area.

Appendix B GEH Statistics

AM Peak Turning Movement Comparison

GHD Mvmt	Turn ID	Observed	Modelled	Diff	%	GEH
i1302m1	7:1302:8	87	103	16	18.39%	1.64
i1302m10	8:1302:68	36	86	50	138.89%	6.40
i1302m11	8:1302:63	87	55	-32	-36.78%	3.80
i1302m12	8:1302:7	57	57	0	0.00%	0.00
i1302m2	7:1302:68	422	442	20	4.74%	0.96
i1302m3	7:1302:63	238	193	-45	-18.91%	3.07
i1302m4	63:1302:7	147	157	10	6.80%	0.81
i1302m5	63:1302:8	50	44	-6	-12.00%	0.88
i1302m6	63:1302:68	14	1	-13	-92.86%	4.75
i1302m7	68:1302:63	13	8	-5	-38.46%	1.54
i1302m8	68:1302:7	347	398	51	14.70%	2.64
i1302m9	68:1302:8	36	56	20	55.56%	2.95
i940m10	52:940:62	36	41	5	13.89%	0.81
i940m11	52:940:53	134	144	10	7.46%	0.85
i940m12	52:940:121	23	22	-1	-4.35%	0.21
i940m2	121:940:62	1663	1664	1	0.06%	0.02
i940m3	121:940:53	458	510	52	11.35%	2.36
i940m4	53:940:121	176	195	19	10.80%	1.40
i940m5	53:940:52	70	77	7	10.00%	0.82
i940m6	53:940:62	24	28	4	16.67%	0.78
i940m7	62:940:53	49	43	-6	-12.24%	0.88
i940m8	62:940:121	1057	1044	-13	-1.23%	0.40
i940m9	62:940:52	22	16	-6	-27.27%	1.38
i941m2	61:941:73	1618	1580	-38	-2.35%	0.95
i941m3	61:941a:40	105	142	37	35.24%	3.33
i941m4	941a:941:61	302	286	-16	-5.30%	0.93
i941m5	941a:941:58	85	74	-11	-12.94%	1.23
i941m6	941a:941:73	80	60	-20	-25.00%	2.39
i941m8	73:941:61	826	827	1	0.12%	0.03
i941m9	73:941:58	47	30	-17	-36.17%	2.74
i942m11	85:942:64	251	176	-75	-29.88%	5.13
i942m12	85:942:74	48	58	10	20.83%	1.37
i942m2	74:942:75	1623	1595	-28	-1.73%	0.70
i942m3	74:942:64	75	36	-39	-52.00%	5.24
i942m4	64:942:74	71	50	-21	-29.58%	2.70
i942m5	64:942:85	181	200	19	10.50%	1.38
i942m6	64:942:75	66	56	-10	-15.15%	1.28
i942m8	75:942:74	754	756	2	0.27%	0.07
i942m9	75:942:85	46	29	-17	-36.96%	2.78
i943m2	76:943:80	1604	1634	30	1.87%	0.75
i943m3	76:943:29	85	29	-56	-65.88%	7.42
i943m6	29:943:80	124	80	-44	-35.48%	4.36
i943m7	77:943:29	201	248	47	23.38%	3.14

i943m8	77:943:76	800	786	-14	-1.75%	0.50
i944m10	67:944:945	440	453	13	2.95%	0.62
i944m12	67:944:77	32	87	55	171.88%	7.13
i944m2	80:944:945	1728	1728	0	0.00%	0.00
i944m8	945:944:77	969	943	-26	-2.68%	0.84
i944m9	945:944:67	396	460	64	16.16%	3.09
i945m2	944:945:81	2013	2061	48	2.38%	1.06
i945m3	944:945:21	155	131	-24	-15.48%	2.01
i945m4	21:945:944	170	109	-61	-35.88%	5.16
i945m6	21:945:81	96	80	-16	-16.67%	1.71
i945m8	81:945:944	1195	1296	101	8.45%	2.86
i946m2	82:946:120	2071	2079	8	0.39%	0.18
i946m3	82:946:14	38	39	1	2.63%	0.16
i946m4	14:946:82	38	11	-27	-71.05%	5.45
i946m6	14:946:120	278	241	-37	-13.31%	2.30
i946m7	120:946:14	160	179	19	11.88%	1.46
i946m8	120:946:82	1157	1277	120	10.37%	3.44

Count	60	100%
>10	0	0%
<5	53	88%
<3	45	75%

Evening Peak Turning Movement Comparison

GHD Mvmt	Turn ID	Observed	Modelled	Diff	%	GEH
i1302m1	7:1302:8	94	129	35	37.23%	3.31
i1302m10	8:1302:68	37	46	9	24.32%	1.40
i1302m11	8:1302:63	121	89	-32	-26.45%	3.12
i1302m12	8:1302:7	132	118	-14	-10.61%	1.25
i1302m2	7:1302:68	412	394	-18	-4.37%	0.90
i1302m3	7:1302:63	216	184	-32	-14.81%	2.26
i1302m4	63:1302:7	150	149	-1	-0.67%	0.08
i1302m5	63:1302:8	65	62	-3	-4.62%	0.38
i1302m6	63:1302:68	24	14	-10	-41.67%	2.29
i1302m7	68:1302:63	22	5	-17	-77.27%	4.63
i1302m8	68:1302:7	487	464	-23	-4.72%	1.05
i1302m9	68:1302:8	60	99	39	65.00%	4.37
i940m10	52:940:62	41	37	-4	-9.76%	0.64
i940m11	52:940:53	147	162	15	10.20%	1.21
i940m12	52:940:121	28	26	-2	-7.14%	0.38
i940m2	121:940:62	1133	1196	63	5.56%	1.85
i940m3	121:940:53	294	360	66	22.45%	3.65
i940m4	53:940:121	186	190	4	2.15%	0.29
i940m5	53:940:52	127	139	12	9.45%	1.04
i940m6	53:940:62	22	21	-1	-4.55%	0.22
i940m7	62:940:53	110	106	-4	-3.64%	0.38
i940m8	62:940:121	1620	1566	-54	-3.33%	1.35
i940m9	62:940:52	28	35	7	25.00%	1.25
i941m2	61:941:73	1063	1058	-5	-0.47%	0.15
i941m3	61:941a:40	133	185	52	39.10%	4.12
i941m4	941a:941:61	300	296	-4	-1.33%	0.23
i941m5	941a:941:58	113	97	-16	-14.16%	1.56
i941m6	941a:941:73	85	52	-33	-38.82%	3.99
i941m8	73:941:61	1458	1389	-69	-4.73%	1.83
i941m9	73:941:58	59	23	-36	-61.02%	5.62
i942m11	85:942:64	285	224	-61	-21.40%	3.82
i942m12	85:942:74	47	50	3	6.38%	0.43
i942m2	74:942:75	1080	1032	-48	-4.44%	1.48
i942m3	74:942:64	68	69	1	1.47%	0.12
i942m4	64:942:74	112	107	-5	-4.46%	0.48
i942m5	64:942:85	205	200	-5	-2.44%	0.35
i942m6	64:942:75	82	70	-12	-14.63%	1.38
i942m8	75:942:74	1358	1262	-96	-7.07%	2.65
i942m9	75:942:85	29	16	-13	-44.83%	2.74
i943m2	76:943:80	1059	1042	-17	-1.61%	0.52
i943m3	76:943:29	103	55	-48	-46.60%	5.40
i943m6	29:943:80	159	116	-43	-27.04%	3.67
i943m7	77:943:29	324	324	0	0.00%	0.00
i943m8	77:943:76	1387	1282	-105	-7.57%	2.87
i944m10	67:944:945	412	422	10	2.43%	0.49
i944m12	67:944:77	61	33	-28	-45.90%	4.08

i944m2	80:944:945	1218	1157	-61	-5.01%	1.77
i944m8	945:944:77	1650	1573	-77	-4.67%	1.92
i944m9	945:944:67	569	565	-4	-0.70%	0.17
i945m2	944:945:81	1459	1440	-19	-1.30%	0.50
i945m3	944:945:21	171	135	-36	-21.05%	2.91
i945m4	21:945:944	296	246	-50	-16.89%	3.04
i945m6	21:945:81	107	93	-14	-13.08%	1.40
i945m8	81:945:944	1923	1890	-33	-1.72%	0.76
i946m2	82:946:120	1490	1468	-22	-1.48%	0.57
i946m3	82:946:14	76	61	-15	-19.74%	1.81
i946m4	14:946:82	55	42	-13	-23.64%	1.87
i946m6	14:946:120	198	175	-23	-11.62%	1.68
i946m7	120:946:14	334	310	-24	-7.19%	1.34
i946m8	120:946:82	1868	1864	-4	-0.21%	0.09
	Count	60	100%			
	>10	0	0%			
	<5	58	97%			
	<3	47	78%			

Appendix C Approved and Pending Development Applications

AM Peak	Zone	Residential	Commercial	Retail	School	TOTAL
Approved DA's						
25 Fisher Road	12	3	--	--	--	3
4-16 Kingsway	14	25	--	--	--	25
9 Kingsway	14	--	--	--	--	0
2 Clarence Ave	15	1	--	--	--	1
7 Oaks Ave	19	--	35	3	--	39
61-67 Oaks Ave	21	--	--	--	110	110
69-71 Oaks Ave	21	3	--	--	--	3
30 Pacific Pde	19	2	--	--	--	2
629-631 Pittwater Rd	10	10	-14	3	--	-2
697 Pittwater Rd	13	12	-3	2	--	11
701 Pittwater Rd	13	4	14	1	--	19
834 Pittwater Rd (Dee Why Hotel)	20	43	101	68	--	213
Pending DA's						
914-922 Pittwater Rd	15	14	-24	--	--	-10
Multiplex	18	90	38	96	--	224
Council	17	37	99	6	--	141
27-33 Oaks Ave (Woolworths)	19	--	--	88	--	88
Pass-by	13	--	--	-15	--	-10

PM Peak	Zone	Residential	Commercial	Retail	School	TOTAL
Approved DA's						
25 Fisher Road	12	3	--	--	--	3
4-16 Kingsway	14	25	--	--	--	25
9 Kingsway	14	--	--	--	--	--
2 Clarence Ave	15	1	--	--	--	1
7 Oaks Ave	19	--	35	14		49
61-67 Oaks Ave	21	--	--	--	96	96
69-71 Oaks Ave	21	3			--	3
30 Pacific Pde	19	2			--	2
629-631 Pittwater Rd	10	10	-14	11	--	7
697 Pittwater Rd	13	12	-3	6	--	15
701 Pittwater Rd	13	4	14	4	--	22
834 Pittwater Rd (Dee Why Hotel)	20	43	101	273	--	417
Pending DA's						
914-922 Pittwater Rd	15	14	-24	0	--	-10
Multiplex	18	90	38	385	--	513
Council	17	37	99	23	--	159
27-33 Oaks Ave (Woolworths)	19	--	--	130	--	130
Pass-by	13	--	--	-31	--	-31

Saturday Peak	Zone	Residential	Commercial	Retail	School	TOTAL
Approved DA's						
25 Fisher Road	12	1	--	--	--	1
4-16 Kingsway	14	13	--	--	--	13
9 Kingsway	14	--	--	--	--	--
2 Clarence Ave	15	--	--	--	--	--
7 Oaks Ave	19	--	--	18	--	18
61-67 Oaks Ave	21	--	--	--	--	0
69-71 Oaks Ave	21	2	--	--	--	2
30 Pacific Pde	19	1	--	--	--	1
629-631 Pittwater Rd	10	5	--	14	--	18
697 Pittwater Rd	13	6	--	8	--	14
701 Pittwater Rd	13	2	--	6	--	7
834 Pittwater Rd (Dee Why Hotel)	20	22	--	355	--	376
Pending DA's						
914-922 Pittwater Rd	15	7	--	--	--	7
Multiplex	18	45	--	501	--	546
Council	17	18	--	29	--	48
27-33 Oaks Ave (Woolworths)	19	--	--	110	--	110
Pass-by	13	--	--	-40	--	-40

Appendix D Potential LEP Developments

LEP FSR 100% - AM Peak

AM Peak	FSR	Zone	Residential	Commercial	Retail	School	TOTAL
6 Dee Why Pde	100%	15	2	0	14	0	16
18-22 Howard Ave	100%	22	18	-48	18	0	-12
31-35 Howard Ave & 36-44 Oaks Ave	100%	17	31	0	204	0	235
9 Oaks Ave	100%	19	5	0	5	0	9
19-21 Oaks Ave	100%	19	10	0	12	0	22
33 Oaks Ave	100%	19	38	0	-47	0	-8
L8 & 12 Pacific Pde	100%	19	5	0	39	0	44
16 Pacific Pde	100%	19	2	0	-41	0	-39
33 Oaks Ave	100%	19	38	0	-47	0	-8
900 Pittwater Rd & 10 Howard Ave	100%	22	17	0	-5	0	11
854-860 Pittwater Rd	100%	19	15	0	63	0	78
836-844 Pittwater Rd & 1 Pacific Pde	100%	20	11	-7	37	0	41
627 Pittwater Rd	100%	11	1	-3	-2	0	-4
635 Pittwater Rd	100%	11	8	-36	41	0	14
643 Pittwater Rd	100%	11	1	0	10	0	11
651-661 Pittwater	100%	11	14	-35	33	0	12
673-683A Pittwater Rd	100%	23	16	-30	-8	0	-22
687-693A Pittwater Rd	100%	23	10	-24	7	0	-7
699 Pittwater Rd	100%	23	6	0	-21	0	-15
23 Fisher Rd	100%	13	21	0	0	0	21
Civic Centre	100%	13	103	0	2	0	105
727 Pittwater Rd	100%	13	3	-4	17	0	16
10 Fisher Rd	100%	11	2	0	-7	0	-5
16-20 Fisher Rd	100%	11	9	-18	62	0	53
28-30 Fisher Rd	100%	11	9	-17	62	0	54
36 Fisher Rd	100%	11	5	0	30	0	35
1-3 St. David; L1 & L2 Fisher	100%	23	10	-11	72	0	71
21 Mooramba & 665 Pittwater Rd	100%	11	7	-17	23	0	13
14 Dee Why Pde	100%	15	0	0	0	0	0
50 Pacific Pde	100%	21	0	0	0	0	0
23-27+29 Pacific Pde+ 16-22 Sturdee Pde	100%	20	6	0	0	0	6
39-45 Pacific Pde	100%	20	3	0	0	0	3
703 Pittwater Rd	100%	23	0	0	0	0	0
36-48 Kingsway (PCYC)	100%	13	0	0	0	0	0
7 Kingsway	100%	2	0	0	0	0	0
11 Kingsway	100%	2	1	0	0	0	1
20-26 Avon Rd	100%	4	2	0	0	0	2
30-40 Howard; Park	100%	16	0	0	0	0	0
46-50 Oaks Ave	100%	17	0	0	0	0	0
65-69 Howard Ave	100%	17	0	0	-10	0	-10
45 Oaks Ave	100%	21	0	0	0	0	0
57-59 Oaks Ave	100%	21	0	0	0	0	0
74 Pacific Pde	100%	21	0	0	0	0	0
73 Oaks Ave	100%	21	0	0	0	0	0
755 Pittwater Rd	100%	2	2	0	0	0	2
2 Dee Why Pde	100%	15	2	0	0	0	2
13 & L36 Redman	100%	11	0	0	0	0	0
9 Francis St	100%	11	2	0	0	0	2

LEP FSR 100% - PM Peak

PM Peak	FSR	Zone	Residential	Commercial	Retail	School	TOTAL
6 Dee Why Pde	100%	15	2	0	14	0	16
18-22 Howard Ave	100%	22	14	-48	18	0	-16
31-35 Howard Ave & 36-44 Oaks Ave	100%	17	24	0	204	0	228
9 Oaks Ave	100%	19	4	0	5	0	8
19-21 Oaks Ave	100%	19	8	0	12	0	20
33 Oaks Ave	100%	19	30	0	-47	0	-17
L8 & 12 Pacific Pde	100%	19	4	0	39	0	43
16 Pacific Pde	100%	19	2	0	-41	0	-39
33 Oaks Ave	100%	19	30	0	-47	0	-17
900 Pittwater Rd & 10 Howard Ave	100%	22	13	0	-5	0	8
854-860 Pittwater Rd	100%	19	12	0	63	0	75
836-844 Pittwater Rd & 1 Pacific Pde	100%	20	9	-7	37	0	38
627 Pittwater Rd	100%	11	1	-3	-2	0	-5
635 Pittwater Rd	100%	11	7	-36	41	0	12
643 Pittwater Rd	100%	11	1	0	10	0	11
651-661 Pittwater	100%	11	11	-35	33	0	9
673-683A Pittwater Rd	100%	23	12	-30	-8	0	-25
687-693A Pittwater Rd	100%	23	8	-24	7	0	-9
699 Pittwater Rd	100%	23	5	0	-21	0	-16
23 Fisher Rd	100%	13	16	0	0	0	16
Civic Centre	100%	13	81	0	2	0	83
727 Pittwater Rd	100%	13	2	-4	19	0	17
10 Fisher Rd	100%	11	2	0	-7	0	-6
16-20 Fisher Rd	100%	11	7	-18	62	0	51
28-30 Fisher Rd	100%	11	7	-17	62	0	52
36 Fisher Rd	100%	11	4	0	30	0	34
1-3 St. David; L1 & L2 Fisher	100%	23	8	-11	72	0	69
21 Mooramba & 665 Pittwater Rd	100%	11	6	-17	23	0	11
14 Dee Why Pde	100%	15	0	0	0	0	0
50 Pacific Pde	100%	21	0	0	0	0	0
23-27+29 Pacific Pde+ 16-22 Sturdee Pde	100%	20	3	0	0	0	3
39-45 Pacific Pde	100%	20	1	0	0	0	1
703 Pittwater Rd	100%	23	0	0	0	0	0
36-48 Kingsway (PCYC)	100%	13	0	22	0	0	22
7 Kingsway	100%	2	0	0	0	0	0
11 Kingsway	100%	2	0	0	0	0	0
20-26 Avon Rd	100%	4	1	0	0	0	1
30-40 Howard; Park	100%	16	0	0	0	0	0
46-50 Oaks Ave	100%	17	0	0	0	0	0
65-69 Howard Ave	100%	17	-1	0	-10	0	-11
45 Oaks Ave	100%	21	-1	0	0	0	-1
57-59 Oaks Ave	100%	21	0	0	0	0	0
74 Pacific Pde	100%	21	0	0	0	0	0
73 Oaks Ave	100%	21	-1	0	0	0	-1
755 Pittwater Rd	100%	2	1	0	0	0	1
2 Dee Why Pde	100%	15	1	0	0	0	1
13 & L38 Redman	100%	11	0	0	0	0	0
9 Francis St	100%	11	1	0	0	0	1

LEP FSR 100% - Saturday Peak

Saturday Peak	FSR	Zone	Residential	Commercial	Retail	School	TOTAL
6 Dee Why Pde	100%	15	1	0	18	0	19
18-22 Howard Ave	100%	22	7	0	23	0	30
31-35 Howard Ave & 36-44 Oaks Ave	100%	17	12	0	270	0	283
9 Oaks Ave	100%	19	2	0	6	0	8
19-21 Oaks Ave	100%	19	4	0	16	0	20
33 Oaks Ave	100%	19	15	0	-62	0	-47
L8 & 12 Pacific Pde	100%	19	2	0	51	0	53
16 Pacific Pde	100%	19	1	0	-54	0	-53
33 Oaks Ave	100%	19	15	0	-62	0	-47
900 Pittwater Rd & 10 Howard Ave	100%	22	7	0	-7	0	0
854-860 Pittwater Rd	100%	19	6	0	84	0	90
836-844 Pittwater Rd & 1 Pacific Pde	100%	20	4	0	49	0	53
627 Pittwater Rd	100%	11	1	0	-3	0	-3
635 Pittwater Rd	100%	11	3	0	55	0	58
643 Pittwater Rd	100%	11	0	0	13	0	14
651-661 Pittwater	100%	11	6	0	43	0	49
673-683A Pittwater Rd	100%	23	6	0	-10	0	-4
687-693A Pittwater Rd	100%	23	4	0	10	0	14
699 Pittwater Rd	100%	23	2	0	-28	0	-26
23 Fisher Rd	100%	13	8	0	0	0	8
Civic Centre	100%	13	41	0	2	0	43
727 Pittwater Rd	100%	13	1	0	23	0	24
10 Fisher Rd	100%	11	1	0	-9	0	-9
16-20 Fisher Rd	100%	11	3	0	82	0	86
28-30 Fisher Rd	100%	11	3	0	82	0	85
36 Fisher Rd	100%	11	2	0	40	0	42
1-3 St. David; L1 & L2 Fisher	100%	23	4	0	95	0	100
21 Mooramba & 665 Pittwater Rd	100%	11	3	0	30	0	33
14 Dee Why Pde	100%	15	0	0	0	0	0
50 Pacific Pde	100%	21	0	0	0	0	0
23-27+29 Pacific Pde+ 16-22 Sturdee Pde	100%	20	1	0	0	0	1
39-45 Pacific Pde	100%	20	1	0	0	0	1
703 Pittwater Rd	100%	23	0	0	0	0	0
36-48 Kingsway (PCYC)	100%	13	0	90	0	0	90
7 Kingsway	100%	2	0	0	0	0	0
11 Kingsway	100%	2	0	0	0	0	0
20-26 Avon Rd	100%	4	0	0	0	0	0
30-40 Howard; Park	100%	16	0	0	0	0	0
46-50 Oaks Ave	100%	17	0	0	0	0	0
65-69 Howard Ave	100%	17	0	0	-14	0	-14
45 Oaks Ave	100%	21	0	0	0	0	0
57-59 Oaks Ave	100%	21	0	0	0	0	0
74 Pacific Pde	100%	21	0	0	0	0	0
73 Oaks Ave	100%	21	0	0	0	0	0
755 Pittwater Rd	100%	2	1	0	0	0	1
2 Dee Why Pde	100%	15	0	0	0	0	0
13 & L36 Redman	100%	11	0	0	0	0	0
9 Francis St	100%	11	1	0	0	0	1

LEP FSR 105% - AM Peak

AM Peak	FSR	Zone	Residential	Commercial	Retail	School	TOTAL
6 Dee Why Pde	105%	15	3	0	14	0	17
18-22 Howard Ave	105%	22	19	-48	18	0	-11
31-35 Howard Ave & 36-44 Oaks Ave	105%	17	33	0	204	0	237
9 Oaks Ave	105%	19	5	0	5	0	10
19-21 Oaks Ave	105%	19	11	0	12	0	23
33 Oaks Ave	105%	19	41	0	-47	0	-6
L8 & 12 Pacific Pde	105%	19	6	0	39	0	44
16 Pacific Pde	105%	19	2	0	-41	0	-39
33 Oaks Ave	105%	19	41	0	-47	0	-6
900 Pittwater Rd & 10 Howard Ave	105%	22	18	0	-6	0	12
854-860 Pittwater Rd	105%	19	16	0	63	0	79
836-844 Pittwater Rd & 1 Pacific Pde	105%	20	12	-7	37	0	41
627 Pittwater Rd	105%	11	1	-3	-2	0	-4
635 Pittwater Rd	105%	11	9	-36	41	0	15
643 Pittwater Rd	105%	11	1	0	10	0	11
651-661 Pittwater	105%	11	15	-35	33	0	13
673-683A Pittwater Rd	105%	23	17	-30	-8	0	-21
687-693A Pittwater Rd	105%	23	11	-24	7	0	-6
699 Pittwater Rd	105%	23	7	0	-21	0	-15
23 Fisher Rd	105%	13	22	0	0	0	22
Civic Centre	105%	13	108	0	2	0	110
727 Pittwater Rd	105%	13	3	-4	17	0	17
10 Fisher Rd	105%	11	2	0	-7	0	-5
16-20 Fisher Rd	105%	11	9	-18	62	0	53
28-30 Fisher Rd	105%	11	9	-17	62	0	54
36 Fisher Rd	105%	11	5	0	30	0	35
1-3 St. David; L1 & L2 Fisher	105%	23	11	-11	72	0	72
21 Mooramba & 665 Pittwater Rd	105%	11	8	-17	23	0	13
14 Dee Why Pde	105%	15	0	0	0	0	0
50 Pacific Pde	105%	21	0	0	0	0	0
23-27+29 Pacific Pde+ 16-22 Sturdee Pde	105%	20	6	0	0	0	6
39-45 Pacific Pde	105%	20	3	0	0	0	3
703 Pittwater Rd	105%	23	0	0	0	0	0
36-48 Kingsway (PCYC)	105%	13	0	0	0	0	0
7 Kingsway	105%	2	0	0	0	0	0
11 Kingsway	105%	2	1	0	0	0	1
20-26 Avon Rd	105%	4	2	0	0	0	2
30-40 Howard; Park	105%	16	0	0	0	0	0
46-50 Oaks Ave	105%	17	0	0	0	0	0
65-69 Howard Ave	105%	17	0	0	-10	0	-10
45 Oaks Ave	105%	21	0	0	0	0	0
57-59 Oaks Ave	105%	21	0	0	0	0	0
74 Pacific Pde	105%	21	0	0	0	0	0
73 Oaks Ave	105%	21	0	0	0	0	0
755 Pittwater Rd	105%	2	2	0	0	0	2
2 Dee Why Pde	105%	15	2	0	0	0	2
13 & L36 Redman	105%	11	0	0	0	0	0
9 Francis St	105%	11	2	0	0	0	2

LEP FSR 105% - PM Peak

PM Peak	FSR	Zone	Residential	Commercial	Retail	School	TOTAL
6 Dee Why Pde	105%	15	2	0	14	0	16
18-22 Howard Ave	105%	22	15	-48	18	0	-15
31-35 Howard Ave & 36-44 Oaks Ave	105%	17	26	0	204	0	230
9 Oaks Ave	105%	19	4	0	5	0	8
19-21 Oaks Ave	105%	19	8	0	12	0	21
33 Oaks Ave	105%	19	32	0	-47	0	-15
L8 & 12 Pacific Pde	105%	19	5	0	39	0	43
16 Pacific Pde	105%	19	2	0	-41	0	-39
33 Oaks Ave	105%	19	32	0	-47	0	-15
900 Pittwater Rd & 10 Howard Ave	105%	22	14	0	-5	0	9
854-860 Pittwater Rd	105%	19	12	0	63	0	76
836-844 Pittwater Rd & 1 Pacific Pde	105%	20	9	-7	37	0	39
627 Pittwater Rd	105%	11	1	-3	-2	0	-4
635 Pittwater Rd	105%	11	7	-36	41	0	13
643 Pittwater Rd	105%	11	1	0	10	0	11
651-661 Pittwater	105%	11	12	-35	33	0	9
673-683A Pittwater Rd	105%	23	13	-30	-8	0	-25
687-693A Pittwater Rd	105%	23	9	-24	7	0	-8
699 Pittwater Rd	105%	23	5	0	-21	0	-16
23 Fisher Rd	105%	13	18	0	0	0	18
Civic Centre	105%	13	85	0	2	0	87
727 Pittwater Rd	105%	13	3	-4	19	0	17
10 Fisher Rd	105%	11	2	0	-7	0	-5
16-20 Fisher Rd	105%	11	7	-18	62	0	51
28-30 Fisher Rd	105%	11	7	-17	62	0	52
36 Fisher Rd	105%	11	4	0	30	0	34
1-3 St. David; L1 & L2 Fisher	105%	23	9	-11	72	0	69
21 Mooramba & 665 Pittwater Rd	105%	11	6	-17	23	0	11
14 Dee Why Pde	105%	15	0	0	0	0	0
50 Pacific Pde	105%	21	0	0	0	0	0
23-27+29 Pacific Pde+ 16-22 Sturdee Pde	105%	20	3	0	0	0	3
39-45 Pacific Pde	105%	20	1	0	0	0	1
703 Pittwater Rd	105%	23	0	0	0	0	0
36-48 Kingsway (PCYC)	105%	13	0	22	0	0	22
7 Kingsway	105%	2	0	0	0	0	0
11 Kingsway	105%	2	0	0	0	0	0
20-26 Avon Rd	105%	4	1	0	0	0	1
30-40 Howard; Park	105%	16	0	0	0	0	0
46-50 Oaks Ave	105%	17	0	0	0	0	0
65-69 Howard Ave	105%	17	-1	0	-10	0	-11
45 Oaks Ave	105%	21	-1	0	0	0	-1
57-59 Oaks Ave	105%	21	0	0	0	0	0
74 Pacific Pde	105%	21	0	0	0	0	0
73 Oaks Ave	105%	21	-1	0	0	0	-1
755 Pittwater Rd	105%	2	1	0	0	0	1
2 Dee Why Pde	105%	15	1	0	0	0	1
13 & L36 Redman	105%	11	0	0	0	0	0
9 Francis St	105%	11	1	0	0	0	1

LEP FSR 105% - Saturday Peak

Saturday Peak	FSR	Zone	Residential	Commercial	Retail	School	TOTAL
6 Dee Why Pde	105%	15	1	0	18	0	19
18-22 Howard Ave	105%	22	7	0	23	0	31
31-35 Howard Ave & 36-44 Oaks Ave	105%	17	13	0	270	0	283
9 Oaks Ave	105%	19	2	0	6	0	8
19-21 Oaks Ave	105%	19	4	0	16	0	21
33 Oaks Ave	105%	19	16	0	-62	0	-46
L8 & 12 Pacific Pde	105%	19	2	0	51	0	53
16 Pacific Pde	105%	19	1	0	-54	0	-53
33 Oaks Ave	105%	19	16	0	-62	0	-46
900 Pittwater Rd & 10 Howard Ave	105%	22	7	0	-7	0	0
854-860 Pittwater Rd	105%	19	6	0	84	0	90
836-844 Pittwater Rd & 1 Pacific Pde	105%	20	5	0	49	0	53
627 Pittwater Rd	105%	11	1	0	-3	0	-3
635 Pittwater Rd	105%	11	4	0	55	0	58
643 Pittwater Rd	105%	11	0	0	13	0	14
651-661 Pittwater	105%	11	6	0	43	0	49
673-683A Pittwater Rd	105%	23	7	0	-10	0	-4
687-693A Pittwater Rd	105%	23	4	0	10	0	14
699 Pittwater Rd	105%	23	3	0	-28	0	-26
23 Fisher Rd	105%	13	9	0	0	0	9
Civic Centre	105%	13	43	0	2	0	45
727 Pittwater Rd	105%	13	1	0	23	0	24
10 Fisher Rd	105%	11	1	0	-9	0	-9
16-20 Fisher Rd	105%	11	4	0	82	0	86
28-30 Fisher Rd	105%	11	4	0	82	0	86
36 Fisher Rd	105%	11	2	0	40	0	42
1-3 St. David; L1 & L2 Fisher	105%	23	4	0	95	0	100
21 Mooramba & 665 Pittwater Rd	105%	11	3	0	30	0	33
14 Dee Why Pde	105%	15	0	0	0	0	0
50 Pacific Pde	105%	21	0	0	0	0	0
23-27+29 Pacific Pde+ 16-22 Sturdee Pde	105%	20	1	0	0	0	1
39-45 Pacific Pde	105%	20	1	0	0	0	1
703 Pittwater Rd	105%	23	0	0	0	0	0
36-48 Kingsway (PCYC)	105%	13	0	90	0	0	90
7 Kingsway	105%	2	0	0	0	0	0
11 Kingsway	105%	2	0	0	0	0	0
20-26 Avon Rd	105%	4	0	0	0	0	0
30-40 Howard; Park	105%	16	0	0	0	0	0
46-50 Oaks Ave	105%	17	0	0	0	0	0
65-69 Howard Ave	105%	17	0	0	-14	0	-14
45 Oaks Ave	105%	21	0	0	0	0	0
57-59 Oaks Ave	105%	21	0	0	0	0	0
74 Pacific Pde	105%	21	0	0	0	0	0
73 Oaks Ave	105%	21	0	0	0	0	0
755 Pittwater Rd	105%	2	1	0	0	0	1
2 Dee Why Pde	105%	15	0	0	0	0	0
13 & L36 Redman	105%	11	0	0	0	0	0
9 Francis St	105%	11	1	0	0	0	1

LEP FSR 110% - AM Peak

AM Peak	FSR	Zone	Residential	Commercial	Retail	School	TOTAL
6 Dee Why Pde	110%	15	3	0	14	0	17
18-22 Howard Ave	110%	22	20	-48	18	0	-10
31-35 Howard Ave & 36-44 Oaks Ave	110%	17	35	0	204	0	239
9 Oaks Ave	110%	19	5	0	5	0	10
19-21 Oaks Ave	110%	19	11	0	12	0	24
33 Oaks Ave	110%	19	43	0	-47	0	-4
L8 & 12 Pacific Pde	110%	19	6	0	39	0	45
16 Pacific Pde	110%	19	2	0	-41	0	-38
33 Oaks Ave	110%	19	43	0	-47	0	-4
900 Pittwater Rd & 10 Howard Ave	110%	22	19	0	-5	0	13
854-860 Pittwater Rd	110%	19	17	0	63	0	80
836-844 Pittwater Rd & 1 Pacific Pde	110%	20	13	-7	37	0	42
627 Pittwater Rd	110%	11	2	-3	-2	0	-4
635 Pittwater Rd	110%	11	10	-36	41	0	15
643 Pittwater Rd	110%	11	1	0	10	0	11
651-661 Pittwater	110%	11	16	-35	33	0	13
673-683A Pittwater Rd	110%	23	18	-30	-8	0	-20
687-693A Pittwater Rd	110%	23	11	-24	7	0	-6
699 Pittwater Rd	110%	23	7	0	-21	0	-14
23 Fisher Rd	110%	13	24	0	0	0	24
Civic Centre	110%	13	113	0	2	0	115
727 Pittwater Rd	110%	13	4	-4	17	0	17
10 Fisher Rd	110%	11	2	0	-7	0	-5
16-20 Fisher Rd	110%	11	10	-18	62	0	54
28-30 Fisher Rd	110%	11	10	-17	62	0	55
36 Fisher Rd	110%	11	6	0	30	0	36
1-3 St. David; L1 & L2 Fisher	110%	23	12	-11	72	0	72
21 Mooramba & 665 Pittwater Rd	110%	11	8	-17	23	0	14
14 Dee Why Pde	110%	15	0	0	0	0	0
50 Pacific Pde	110%	21	0	0	0	0	0
23-27+29 Pacific Pde+ 16-22 Sturdee Pde	110%	20	6	0	0	0	6
39-45 Pacific Pde	110%	20	3	0	0	0	3
703 Pittwater Rd	110%	23	0	0	0	0	0
36-48 Kingsway (PCYC)	110%	13	0	0	0	0	0
7 Kingsway	110%	2	0	0	0	0	0
11 Kingsway	110%	2	1	0	0	0	1
20-26 Avon Rd	110%	4	2	0	0	0	2
30-40 Howard; Park	110%	16	0	0	0	0	0
46-50 Oaks Ave	110%	17	0	0	0	0	0
65-69 Howard Ave	110%	17	0	0	-10	0	-10
45 Oaks Ave	110%	21	0	0	0	0	0
57-59 Oaks Ave	110%	21	0	0	0	0	0
74 Pacific Pde	110%	21	0	0	0	0	0
73 Oaks Ave	110%	21	0	0	0	0	0
755 Pittwater Rd	110%	2	2	0	0	0	2
2 Dee Why Pde	110%	15	2	0	0	0	2
13 & L36 Redman	110%	11	0	0	0	0	0
9 Francis St	110%	11	2	0	0	0	2

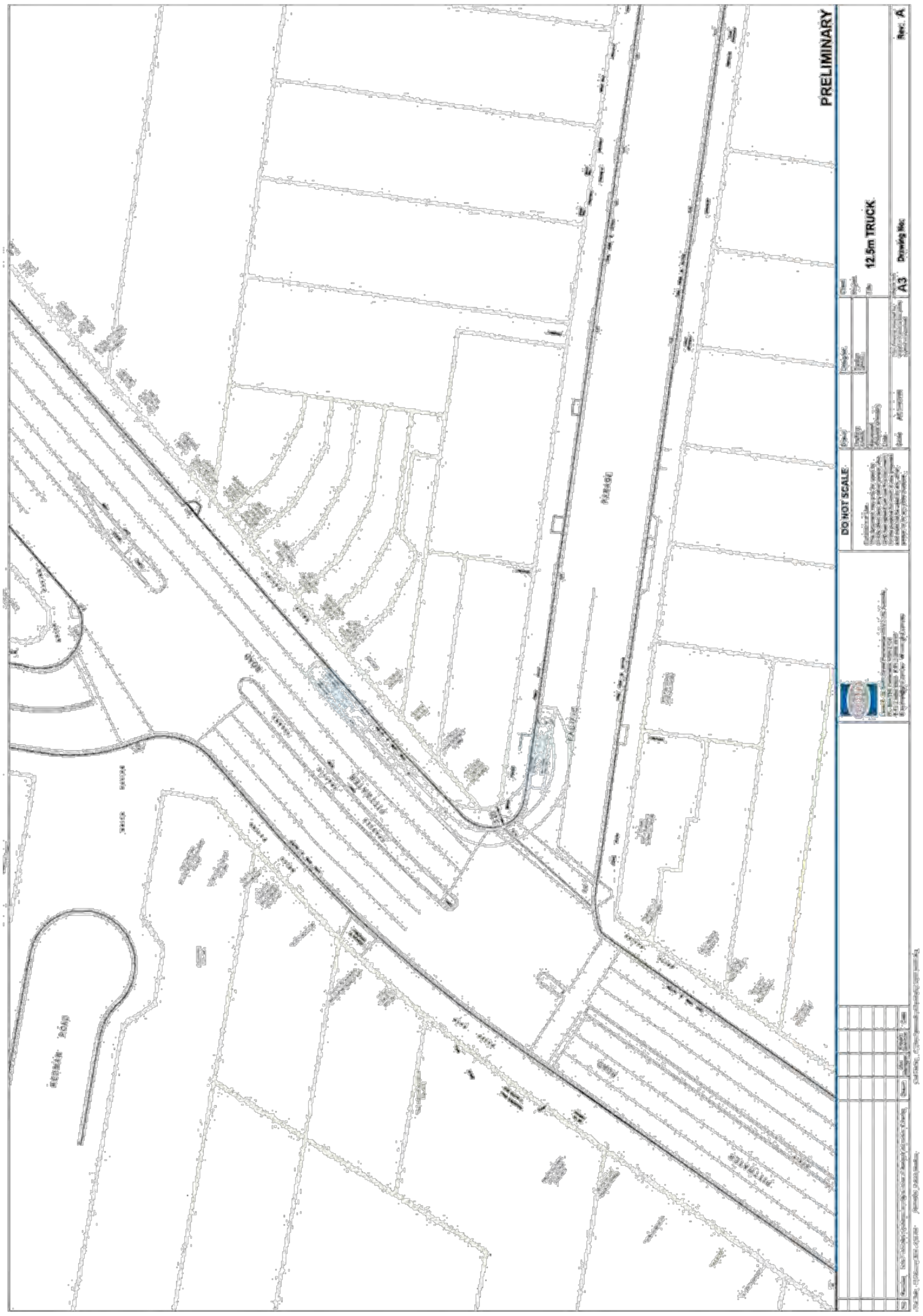
LEP FSR 110% - PM Peak

PM Peak	FSR	Zone	Residential	Commercial	Retail	School	TOTAL
6 Dee Why Pde	110%	15	2	0	14	0	16
18-22 Howard Ave	110%	22	16	-48	18	0	-14
31-35 Howard Ave & 36-44 Oaks Ave	110%	17	27	0	204	0	231
9 Oaks Ave	110%	19	4	0	5	0	9
19-21 Oaks Ave	110%	19	9	0	12	0	21
33 Oaks Ave	110%	19	34	0	-47	0	-13
L8 & 12 Pacific Pde	110%	19	5	0	39	0	43
16 Pacific Pde	110%	19	2	0	-41	0	-39
33 Oaks Ave	110%	19	34	0	-47	0	-13
900 Pittwater Rd & 10 Howard Ave	110%	22	15	0	-5	0	9
854-860 Pittwater Rd	110%	19	13	0	63	0	77
836-844 Pittwater Rd & 1 Pacific Pde	110%	20	10	-7	37	0	39
627 Pittwater Rd	110%	11	1	-3	-2	0	-4
635 Pittwater Rd	110%	11	8	-36	41	0	13
643 Pittwater Rd	110%	11	1	0	10	0	11
651-661 Pittwater	110%	11	13	-35	33	0	10
673-683A Pittwater Rd	110%	23	14	-30	-8	0	-24
687-693A Pittwater Rd	110%	23	9	-24	7	0	-8
699 Pittwater Rd	110%	23	6	0	-21	0	-16
23 Fisher Rd	110%	13	19	0	0	0	19
Civic Centre	110%	13	90	0	2	0	92
727 Pittwater Rd	110%	13	3	-4	19	0	18
10 Fisher Rd	110%	11	2	0	-7	0	-5
16-20 Fisher Rd	110%	11	8	-18	62	0	52
28-30 Fisher Rd	110%	11	8	-17	62	0	53
36 Fisher Rd	110%	11	4	0	30	0	35
1-3 St. David; L1 & L2 Fisher	110%	23	9	-11	72	0	70
21 Mooramba & 665 Pittwater Rd	110%	11	6	-17	23	0	12
14 Dee Why Pde	110%	15	0	0	0	0	0
50 Pacific Pde	110%	21	0	0	0	0	0
23-27+29 Pacific Pde+ 16-22 Sturdee Pde	110%	20	3	0	0	0	3
39-45 Pacific Pde	110%	20	1	0	0	0	1
703 Pittwater Rd	110%	23	0	0	0	0	0
36-48 Kingsway (PCYC)	110%	13	0	22	0	0	22
7 Kingsway	110%	2	0	0	0	0	0
11 Kingsway	110%	2	0	0	0	0	0
20-26 Avon Rd	110%	4	1	0	0	0	1
30-40 Howard; Park	110%	16	0	0	0	0	0
46-50 Oaks Ave	110%	17	0	0	0	0	0
65-69 Howard Ave	110%	17	-1	0	-10	0	-11
45 Oaks Ave	110%	21	-1	0	0	0	-1
57-59 Oaks Ave	110%	21	0	0	0	0	0
74 Pacific Pde	110%	21	0	0	0	0	0
73 Oaks Ave	110%	21	-1	0	0	0	-1
755 Pittwater Rd	110%	2	1	0	0	0	1
2 Dee Why Pde	110%	15	1	0	0	0	1
13 & L36 Redman	110%	11	0	0	0	0	0
9 Francis St	110%	11	1	0	0	0	1

LEP FSR 110% - Saturday Peak

Saturday Peak	FSR	Zone	Residential	Commercial	Retail	School	TOTAL
6 Dee Why Pde	110%	15	1	0	18	0	20
18-22 Howard Ave	110%	22	8	0	23	0	31
31-35 Howard Ave & 36-44 Oaks Ave	110%	17	14	0	270	0	284
9 Oaks Ave	110%	19	2	0	6	0	8
19-21 Oaks Ave	110%	19	4	0	16	0	21
33 Oaks Ave	110%	19	17	0	-62	0	-45
L8 & 12 Pacific Pde	110%	19	2	0	51	0	54
16 Pacific Pde	110%	19	1	0	-54	0	-53
33 Oaks Ave	110%	19	17	0	-62	0	-45
900 Pittwater Rd & 10 Howard Ave	110%	22	7	0	-7	0	0
854-860 Pittwater Rd	110%	19	7	0	84	0	91
836-844 Pittwater Rd & 1 Pacific Pde	110%	20	5	0	49	0	54
627 Pittwater Rd	110%	11	1	0	-3	0	-3
635 Pittwater Rd	110%	11	4	0	55	0	58
643 Pittwater Rd	110%	11	0	0	13	0	14
651-661 Pittwater	110%	11	6	0	43	0	50
673-683A Pittwater Rd	110%	23	7	0	-10	0	-3
687-693A Pittwater Rd	110%	23	5	0	10	0	14
699 Pittwater Rd	110%	23	3	0	-28	0	-26
23 Fisher Rd	110%	13	10	0	0	0	10
Civic Centre	110%	13	45	0	2	0	47
727 Pittwater Rd	110%	13	1	0	23	0	24
10 Fisher Rd	110%	11	1	0	-9	0	-9
16-20 Fisher Rd	110%	11	4	0	82	0	86
28-30 Fisher Rd	110%	11	4	0	82	0	86
36 Fisher Rd	110%	11	2	0	40	0	42
1-3 St. David; L1 & L2 Fisher	110%	23	5	0	95	0	100
21 Mooramba & 665 Pittwater Rd	110%	11	3	0	30	0	33
14 Dee Why Pde	110%	15	0	0	0	0	0
50 Pacific Pde	110%	21	0	0	0	0	0
23-27+29 Pacific Pde+ 16-22 Sturdee Pde	110%	20	1	0	0	0	1
39-45 Pacific Pde	110%	20	1	0	0	0	1
703 Pittwater Rd	110%	23	0	0	0	0	0
36-48 Kingsway (PCYC)	110%	13	0	90	0	0	90
7 Kingsway	110%	2	0	0	0	0	0
11 Kingsway	110%	2	0	0	0	0	0
20-26 Avon Rd	110%	4	0	0	0	0	0
30-40 Howard; Park	110%	16	0	0	0	0	0
46-50 Oaks Ave	110%	17	0	0	0	0	0
65-69 Howard Ave	110%	17	0	0	-14	0	-14
45 Oaks Ave	110%	21	0	0	0	0	0
57-59 Oaks Ave	110%	21	0	0	0	0	0
74 Pacific Pde	110%	21	0	0	0	0	0
73 Oaks Ave	110%	21	0	0	0	0	0
755 Pittwater Rd	110%	2	1	0	0	0	1
2 Dee Why Pde	110%	15	0	0	0	0	0
13 & L36 Redman	110%	11	0	0	0	0	0
9 Francis St	110%	11	1	0	0	0	1

Appendix E Pacific Parade Turning Path Analysis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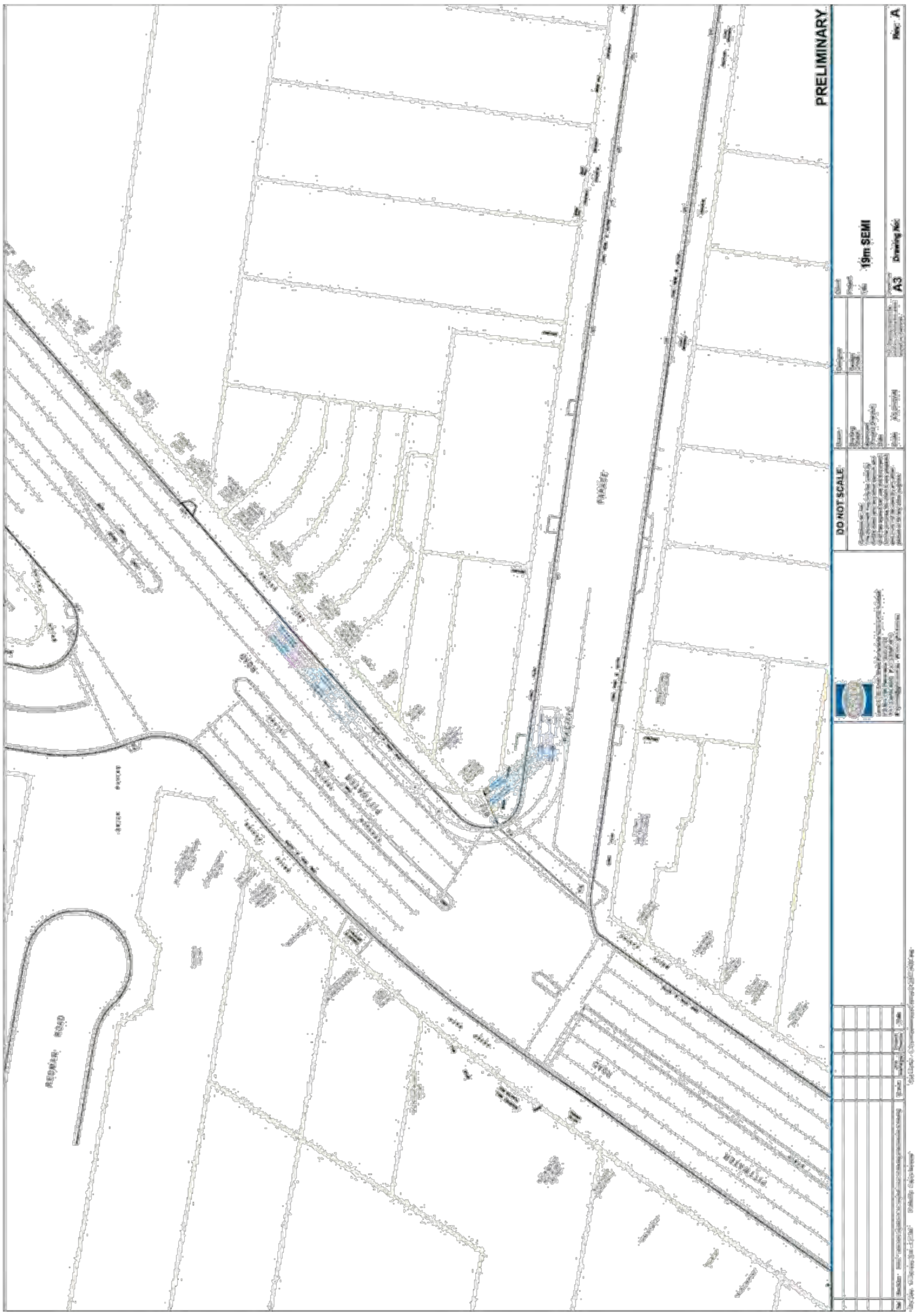
DO NOT SCALE
A3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Dee Why South Catchment Floodplain Risk Management Study

59914084

Prepared for
Warringah Council

31 July 2014

Cardno
Shaping the Future

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Foreword

The NSW Government *Flood Prone Land Policy* is directed towards providing solutions to existing flood problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the policy, the management of flood prone land is the responsibility of Local Government. The State Government subsidises flood management measures to alleviate existing flooding problems, and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain management measures.

The Policy identifies the following floodplain management 'process' for the identification and management of flood risks:

1. Formation of a Committee	Established by a Local Government Body (Local Council) and includes community group representatives and State agency specialists.
2. Data Collection	The collection of data such as historical flood levels, rainfall records, land use, soil types etc.
3. Flood Study	Determines the nature and extent of the flooding problem.
4. Floodplain Risk Management Study	Evaluates floodplain management measures for the floodplain in respect of both existing and proposed development. This is the stage Council is currently undertaking for the Dee Why South Catchment.
5. Floodplain Risk Management Plan	Involves formal adoption by Council of a management plan for the floodplain.
6. Implementation of the Plan	Implementation of actions to manage flood risks for existing and new development.

This report forms the fourth stage of the floodplain management process for the Dee Why South Catchment Floodplain. The Dee Why South Catchment Flood Study was prepared by Cardno (2013).

This report has been prepared for Warringah Council by Cardno (NSW/ACT) Pty Ltd to examine floodplain risk management options to aid the preparation of a Floodplain Risk Management Plan.

Executive Summary

Flooding in the Dee Why South Catchment can pose a high flood risk to residents, businesses and members of the public living and working within the catchment. The Dee Why South Catchment Floodplain Risk Management Study identifies floodplain management options and evaluates these options based upon a range of economic, social and environmental criteria. This study builds upon previous work, including the Dee Why South Catchment Flood Study (Cardno, 2013) which defined the nature and extent of flooding in the catchment.

The objectives of this Floodplain Risk Management Study include:

- To identify feasible options that reduce the flood risk to people and property within the community
- To ensure actions recommended are sustainable in social, environmental and economic terms

The Study covers the Dee Why South Catchment which is bordered by McIntosh Road to the north, Waratah Parade to the west, May Road to the south. The catchment area is approximately 268 hectares and is characterised by a steep escarpment grading down to a low floodplain area, discharging to Dee Why Lagoon. This catchment includes parts of the suburbs of Dee Why and Narraweena. While the majority of the catchment contains residential development, there is a major commercial sector, the Dee Why Town Centre, located in its lower reaches.

Flooding has previously caused property damage and inundated areas of the Dee Why Town Centre. Council's records indicate that the catchment has experienced major flood events in 1947, 1953 and 1954.

In selecting management options a wide range of potential management actions were considered, including those consistent with all Floodplain Risk Management Studies such as flood education and flood warning. These non-structural options are considered a high priority. Management options specific to the catchment are listed in order of the benefit they provide compared to their cost and include:

1. **Increase drainage capacity along Oaks Avenue** – this option aims to capture overland flows that currently travel down Oaks Avenue. It results in a reduction in flood depth of up to 0.22m in the 100 year ARI event in Oaks Avenue and further reductions between Oaks Avenue and Howard Avenue.
2. **Storage basins at Mooramba Road car park and under Redman Road** – the tanks intercept flooding upstream of Pittwater Road and store it whilst the main peak of the flood occurs. This results in very large reductions in both flood depth and velocity throughout the Town Centre.
3. **Increased Drainage Capacity at Oaks Avenue and Underground Storage at Redman Road and Mooramba Road** – this is a combination of the above two options, both capturing flooding upstream of Pittwater Road and excess flooding that is present along Oaks Avenue. Results include significant reductions in flood depths of more than 0.3m in the 100 year ARI event throughout much of the town centre.
4. **Increased drainage along Oaks Avenue, divert main drain to the east, reconnect to existing drain at Howard Avenue** – this option intends to capture overland flows along Oaks Avenue as well as reducing the potential for the existing main drain from being overloaded following the addition of a new pipe in Oaks Avenue. This option acts in a very similar way to the pipe in Oaks Avenue alone, and does not provide significant benefit over the Oaks Avenue pipe.
5. **Addition of detention basin in Walter Gors Park in combination with increased drainage capacity along Oaks Avenue** – this option aims to improve the visual amenity, capture overland flows and reduce flood depths in Oaks Avenue, Howard Avenue and Dee Why Parade. This option has little to no benefit over the increased drainage capacity along Oaks Avenue alone.
6. **Pipes upgrade between Pacific Parade and Oaks Avenue** – Significant ponding occurs along Pacific Parade and Oaks Avenue, this option aims minimise this ponding. This option reduces ponding in Pacific Parade while also reducing the level of flooding downstream by up to 0.1m.

7. **Raise level of Oaks Avenue and Howard Avenue to redirect flow down Pittwater Road to Dee Why Parade in combination with increased drainage capacity along Oaks Avenue** – this aims to divert flooding to Dee Why Parade that would currently travel down Oaks Avenue and Howard Avenue. This option results in lower depths of up to 0.3m along Oaks Avenue but associated increases of up to 0.3m on Pittwater Road in the 100 year ARI event. This option may require extensive intersection works for it to be feasible.

8. **Decommissioning the open channel between Oaks Avenue and Pacific Parade with new pipe under Pittwater Road between Pacific Parade and Oaks Avenue with combination of increased drainage capacity on Pacific Parade and Oaks Avenue** – This aims to reduce flood depths in Oaks Avenue and Pacific Parade and minimise the flood risk to properties adjacent to the open channel. The results of the option are significant reductions in flood depth, with reductions of up to 0.22m in Oaks Avenue in the 100 year ARI event. The removal of the open channel does however create increased local flooding.

9. **Daylighting of box culvert between Howard Avenue and Dee Why Parade** – this option aims to improve visual amenity, capture overland flows and provide an opportunity for future water reuse. This option does have minimal benefits on Dee Why Parade but commensurate negative impacts in Richmond Avenue. The option does highlight the potential to gain social benefits without creating unmanageable flooding impacts.

The *Dee Why South Catchment Floodplain Risk Management Study* will now be placed on public exhibition to provide the community and stakeholders an opportunity to comment on these recommendations, prior to final selection of the flood management options, which will be developed further in the *Dee Why South Catchment Floodplain Risk Management Plan* in the next stage of the project.

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Glossary and Abbreviations

Australian Height Datum (AHD)	A standard national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random. That is, an event of a certain magnitude may occur several times within its estimated return period.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 1 in 1 year ARI flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels (FPLs)	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the "Standard flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined

	channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
NPER	National Professional Engineers Register. Maintained by Engineers Australia.
NSW	New South Wales
Overland Flow	The term overland flow is used interchangeably in this report with "flooding".
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a more detailed explanation see Average Recurrence Interval.

1 Introduction

Cardno (NSW/ACT) Pty Ltd (Cardno) was commissioned by Warringah Council (Council) to undertake a Floodplain Risk Management Study (FRMS) for the Dee Why South Catchment. This FRMS has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible management options to reduce flood damage and risk.

This Floodplain Risk Management Study follows on from the Dee Why South Catchment Flood Study (Cardno, 2013) which was prepared in 2013 and subsequently adopted by Council.

A number of floodplain management options have been examined as part of this FRMS to manage flooding within the Dee Why South Catchment. The identification and examination of these options was done in accordance with the *NSW Floodplain Development Manual: The Management of Flood Liable Land* (NSW Government, 2005).

1.1 Study Context

The NSW Government *Flood Prone Land Policy* is directed towards providing solutions to existing flood problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the policy, the management of flood prone land is the responsibility of Local Government. The State Government subsidises flood management measures to alleviate existing flooding problems, and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain management measures.

The Policy identifies the following floodplain management 'process' for the identification and management of flood risks:

1) Formation of a Floodplain Management Committee;
2) Data collection;
3) Flood Study;
4) **Floodplain Risk Management Study;**
5) Floodplain Risk Management Plan; and
6) Implementation of the Floodplain Risk Management Plan.

Council have completed stages 1-3, and this study represents stage 4 of the floodplain management process.

1.2 Study Purpose

The purpose of this study is to:

> review Council's existing environmental planning policies and instruments including Councils long-term planning strategies for the study area;

> identify works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events;

> assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future;

> consider whether the proposed works and measures might produce adverse effects (environmental, social, economic or worsened flooding) in the floodplain and whether they can be minimised;

> examine the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's development and disaster planning requirements; and

> identify modifications that are required to current policies in light of the investigations.

It is important to note also that this project is being undertaken in a larger strategic context, namely the re-development of the Dee Why Town Centre, and that this provides opportunities with respect to flood mitigation.

The Dee Why Town Centre is in need of urban renewal, with limited pedestrian connectivity, poor stormwater drainage, inconsistent building designs and a lack of streetscape definition and access to open space. To address these issues and provide a framework for change, Council prepared the Dee Why Town Centre Masterplan. This framework is driving increased private investment within the Town Centre, providing unique opportunities for private infrastructure contributions to potentially assist in funding of floodplain management measures (i.e. structural works to alleviate flood risk). The Masterplan is now being implemented through a staged infrastructure upgrade process, and by running this FRMS concurrently Council is seeking to identify opportunities for floodplain management options (such as drainage upgrades) to be incorporated into the wider road and streetscape upgrades, thereby achieving efficiencies in project delivery and minimising disruption to the community and businesses.

1.3 Study Objectives

The specific objectives of the study are to:

> reduce the flood hazard and risk to people and property in the community in the present day, and to ensure future development is controlled in a manner consistent with the flood hazard and risk;

> reduce private and public losses due to flooding;

> where possible, protect and enhance waterways and the floodplain environment;

> be consistent with the objectives of relevant state policies, in particular, the Government's *Flood Prone Land* and *State Rivers and Estuaries Policies* and satisfy the objectives and requirements of the *Environmental Planning and Assessment Act 1979*;

> recommend actions for incorporation in the floodplain risk management plan (the next stage) to reduce flood risk; and

> ensure actions recommended for incorporation in the floodplain risk management plan (the next stage) are sustainable in social, environmental, ecological and economic terms.

The development of a list of actions to be undertaken from the options considered in this study is part of the next stage; the Floodplain Risk Management Plan (FRMP).

1.4 Study Methodology

The report structure follows the study methodology outlined below:

> an overview of the features of the catchment and floodplain (**Section 2**);

> details of available data to inform the study (**Section 3**);

> a summary of the stakeholder consultation undertaken for the study (**Section 4**);

> an overview of the existing flood behaviour and issues (**Section 5**);

> an assessment of the economic impact of flooding under existing conditions (flood damages) (**Section 6**);

> an overview of the existing flood emergency response arrangements (**Section 7**):

> discussion of policies and planning controls around flooding (**Section 8**);

> an assessment of the appropriate flood planning levels for development (**Section 9**);

> an overview of the potential flood management options, including discussion of the flood modelling results for structural options (**Section 10**);

> an economic assessment of potential options and an assessment (**Section 11**);

> a multi-criteria matrix assessment of the relevant merits of these options for the Dee Why South Catchment floodplain (**Section 12**); and

> conclusions and recommendations for the next stage in the floodplain management process; the floodplain risk management plan (**Section 13**).

2 Catchment Description

The physical, environmental and social characteristics of the study area may influence the type and extent/location of flood management options able to be implemented under the FRMP.

Environmental characteristics, such as topography, sensitive environments, the presence of threatened species, and soils are constraints for any structural flood modification works proposed under the FRMS.

Social characteristics such as housing and demographics may impact the community's response to flooding and therefore affect the type of flood management options proposed.

The following physical, environmental and social characteristics have been considered in the assessment:

> Catchment topography;

> Land use;

> Demographic characteristics;

> Geology and soils;

> Flora and fauna; and

> Aboriginal and non-Aboriginal cultural heritage.

2.1 Catchment Topography

The Dee Why South Catchment is bordered by McIntosh Road to the north, Waratah Parade to the west, and May Road to the south, and Dee Why Lagoon in the east (**Figure 2-1**). The catchment area is approximately 268 ha and is characterised by a steep escarpment which grades down to a low floodplain area, before discharging to the ocean via Dee Why Lagoon. The majority of the catchment, which incorporates parts of Dee Why and Narraweena, is developed for residential purposes, with the central business district (CBD) located in its lower reaches. Additionally, as previously discussed in **Section 1.2**, the Dee Why Town Centre is the subject of a Masterplan to incorporate additional high rise mixed use development in the future, which will have implications for both existing and future flood risk. **Figure 2-2** provides a more detailed map of the Town Centre.

Dee Why Town Centre is situated at the confluence of three drainage lines, with a relatively large upstream catchment draining to Dee Why Lagoon. Dee Why has evolved from a low density residential development in the 1940s, to include commercial and retail areas in the present day. Over time the various stormwater drainage lines in the catchment have been upgraded to accommodate additional urban development based on the flows generated from the upstream catchment at the time the development took place. A number of these upgrades incorporate piped or covered channels to convey flood flows underground, without consideration of designated overland flow paths.

Flooding in the catchment is a combination of overland flow and mainstream flooding. Generally the main overland flow path starts from several branches at Alfred Street to Beverley Job Park. Stormwater flowing down the open channel at Victor Road and Redman Road combines with overland flows from Mooramba Road, Fisher Road, and Pittwater Road at the intersection of Redman Road and Pittwater Road. These overland flows are then conveyed along several roads and properties to Dee Why Lagoon, and also via the open channels between Pacific Parade and Oaks Avenue and downstream of Dee Why Parade.

A feature of the catchment is the prevalence of 'trapped' low points formed by depressions where stormwater drainage is restricted, leading to significant ponding and flooding of adjacent properties and roads. High traffic pedestrian and vehicular areas in the Dee Why Town Centre also experience inundation from overland flows, particularly along Redman Road, Pittwater Road, Oaks Avenue and Howard Avenue.

The Dee Why South Catchment is a sub-catchment of the greater Dee Why Lagoon Catchment, which includes parts of Cromer, Dee Why and Narraweena that form the Dee Why North Catchment.

Figure 2-1 Study Area

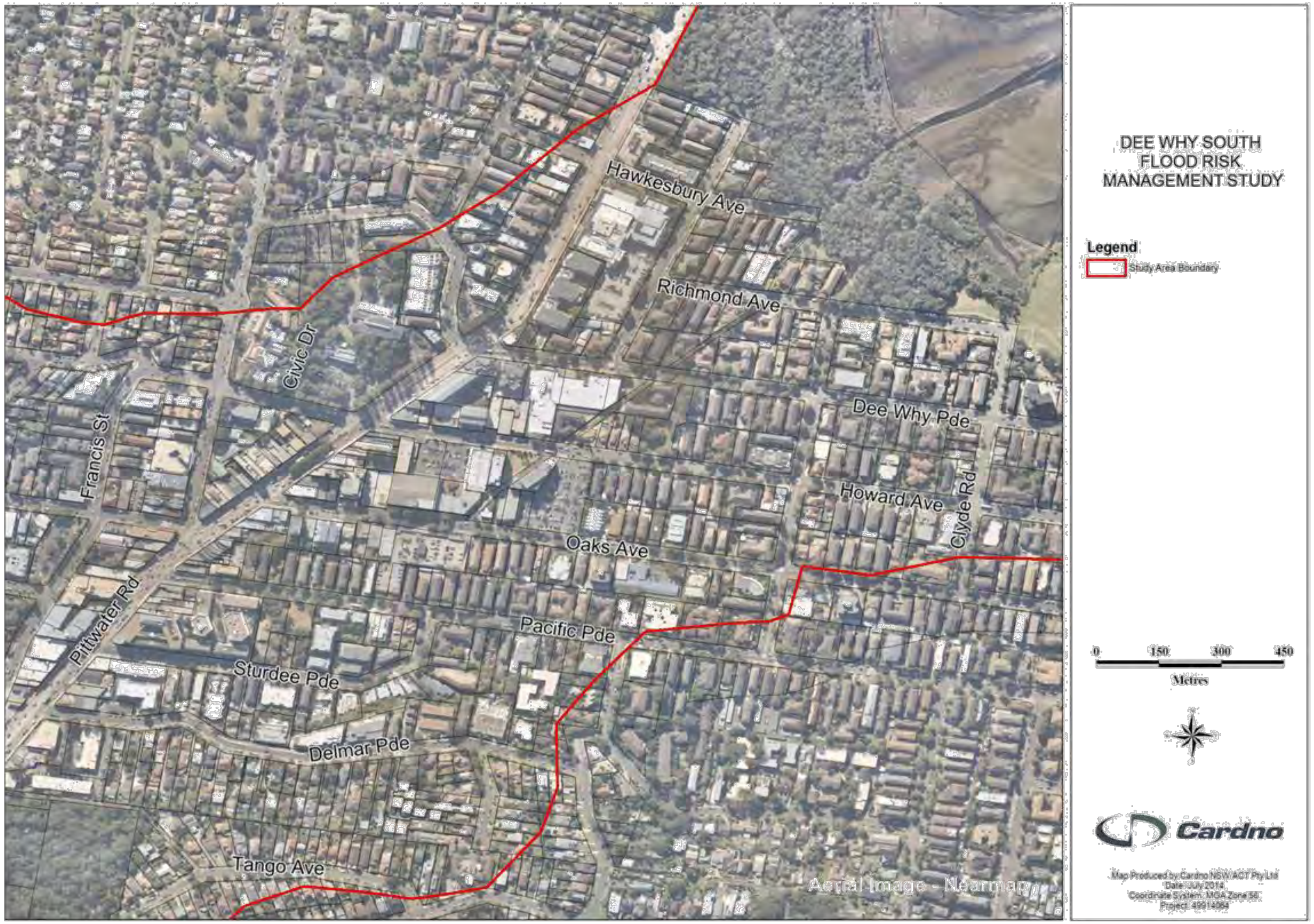


Figure 2-2 Locality Plan

2.2 Land Use

Land use within the catchment is controlled by the *Warringah Local Environmental Plan 2011* (LEP), which indicates locations where certain activities and types of development are permissible (**Figure 2-3**). The upstream/western portion of the catchment is predominantly zoned R2 (low density residential) and RE1 (public recreation zone), which is evident as public open space areas. The Dee Why Town Centre and adjacent residential areas are zoned B4 (mixed use) and R3 (medium density residential) respectively.

Table 2-1 provides a breakdown of the different land use zones and the flood affected areas within each zone.

The Dee Why Town Centre is located roughly in the centre of the catchment, and is an established commercial centre, with more recent introduction of mixed use developments combining commercial and residential uses. Further east there is a residential area comprised largely of apartments, and then Dee Why Beach and Dee Why Lagoon. Due to the limited availability of Council or Crown land within the floodplain, the opportunity to provide a diverse range of mitigation options is severely hindered.

The majority of the Dee Why South Catchment is developed with some consolidation/redevelopment of existing properties occurring over the last decade. As part of the state governments *Metropolitan Plan for Sydney to 2036* (NSW Government, 2010), Brookvale-Dee Why will remain the 'Major Centre' for the north east region. In order to accommodate this, a Masterplan for the Dee Why Town Centre has been developed.

2.3 Demographic Characteristics

An appreciation of the demographics of the community within the Dee Why South Catchment will assist in the preparation and evaluation of flood management options which are appropriate for the local community. For example, this is relevant to consideration of emergency response or evacuation procedures; for example, information may need to be presented in a range of languages and special arrangements may need to be made for less mobile members of the community.

The demographic characteristics of the Dee Why South Catchment presented in this report include the suburbs of Dee Why and Narraweena. Population data for was sourced primarily from the Australian Bureau of Statistics 2011 Census and aggregated to produce an overall synopsis for the catchment/region. A summary of the demographic data is (ABS, 2011):

> The median age of people living within the Dee Why South Catchment was 38.5 years. In fact, 70% of the population were aged below 55 years. This indicates a community which may primarily comprise able-bodied people who are able to evacuate effectively and/or assist with evacuation procedures.

> 62.1% of people were born in Australia. The most common countries of birth outside of Australia were England, New Zealand, Italy, China, India, Korea and Brazil.

> English was the only language spoken in approximately 71% of homes in the Dee Why South Catchment. The most common languages spoken at home other than English were Portuguese, Serbian, Mandarin, Italian, Tongan and Tagalog. This indicates that there may be a requirement for flooding information to be prepared in languages other than English.

> The average median weekly income for individuals in the region was $654, compared to the NSW average of $561. This trend of above average income for the region compared to the NSW average was also evident for family ($1,699 compared to $1,477 for NSW) and household incomes ($1,330 compared to $1,237 for NSW). This may have implications for the economic damages incurred on property contents during a flood event.

> In the catchment, the median house price is $924,000, and the unit price is $538,000 (APM, 2014). In NSW, the median house price is $500,000 and unit price is $511,000 (APM, 2014). This information has implications for the economic damages incurred during a flood event.

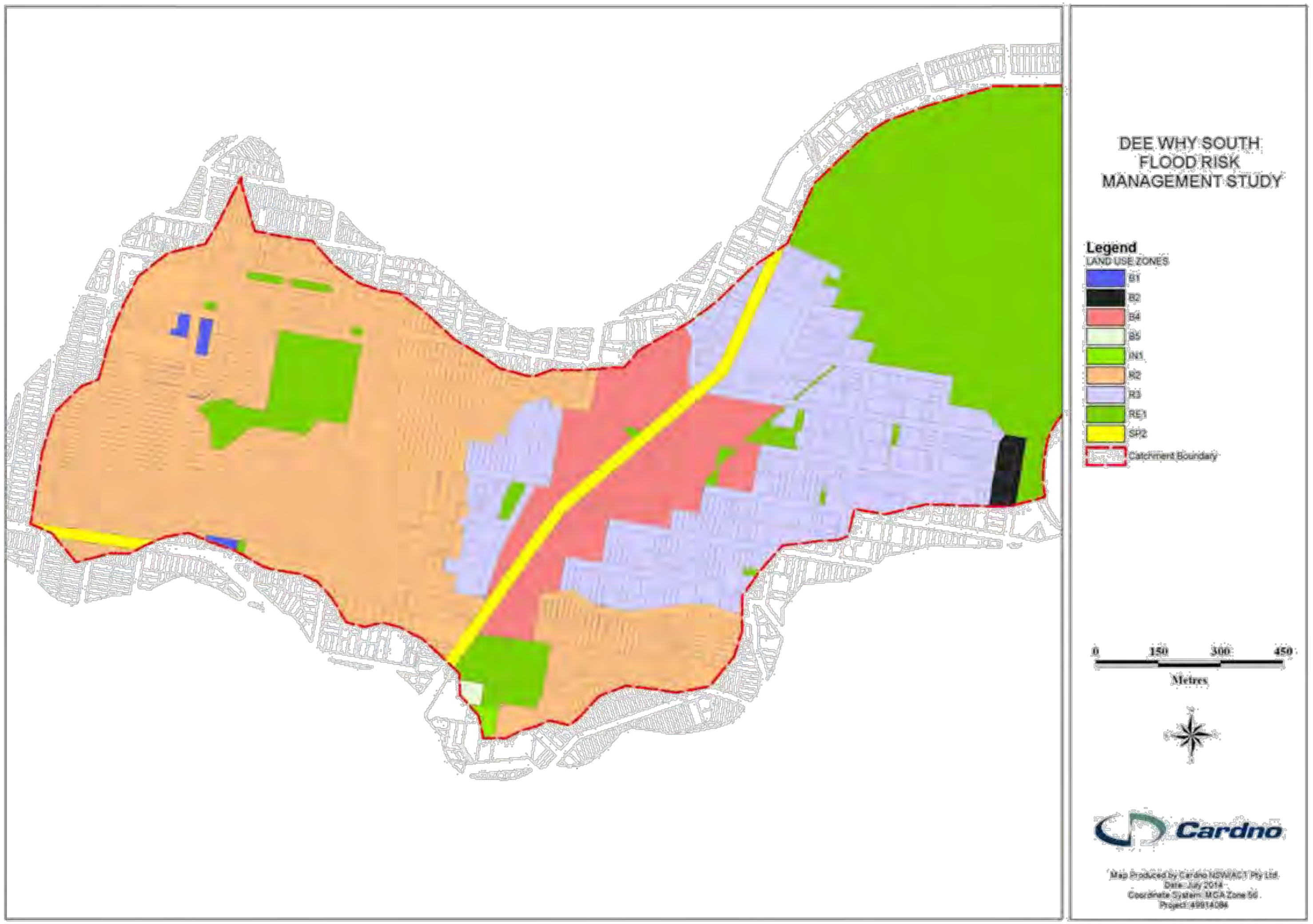


Figure 2-3 Land Use Zoning

Table 2-1 Dee Why South Catchment Land Use Zoning

Land Use Type	Land Use Zoning (LUZ)	Description	Total Area in Catchment (ha)	Area Affected by PMF (ha)	Area Affected by 100 Years ARI (ha)
Business	B1 Neighbourhood Centre	To provide a range of small-scale retail, business and community uses that serve the needs of people who live or work in the surrounding neighbourhood. To ensure that neighbourhood centres provide a village-like atmosphere and safety and comfort for pedestrians. To minimise conflict between land uses in the zone and adjoining zones and ensure the amenity of any adjoining or nearby residential land uses.	0.62	0.04	0.15
	B2 Local Centre	To provide a range of retail, business, entertainment and community uses that serve the needs of people who live in, work in and visit the local area. To encourage employment opportunities in accessible locations. To maximise public transport patronage and encourage walking and cycling. To provide an environment for pedestrians that is safe, comfortable and interesting. To create urban form that relates favourably in scale and in architectural and landscape treatment to neighbouring land uses and to the natural environment. To minimise conflict between land uses in the zone and adjoining zones and ensure the amenity of any adjoining or nearby residential land uses.	1.14	0.13	0.63
	B4 Mixed Use	To provide a mixture of compatible land uses. To integrate suitable business, office, residential, retail and other development in accessible locations so as to maximise public transport patronage and encourage walking and cycling. T To reinforce the role of Dee Why as the major centre in the sub-region by the treatment of public spaces, the scale and intensity of development, the focus of civic activity and the arrangement of land uses. To promote building design that creates active building fronts, contributes to the life of streets and public spaces and creates environments that are appropriate to human scale as well as being comfortable, interesting and safe To promote a land use pattern that is characterised by shops, restaurants and business premises on the ground floor and housing and offices on the upper floors of buildings. To encourage site amalgamations to facilitate new development and to facilitate the provision of car parking below ground	19.83	2.01	5.91
	B5 Business Development	To enable a mix of business and warehouse uses, and bulky goods premises that require a large floor area, in locations that are close to, and that support the viability of, centres. To provide for the location of vehicle sales or hire premises. To create a pedestrian environment that is safe, active and interesting by incorporating street level retailing and business uses.	0.30	0	0

Land Use Type	Land Use Zoning (LUZ)	Description	Total Area in Catchment (ha)	Area Affected by PMF (ha)	Area Affected by 100 Years ARI (ha)
Industrial	IN1 General Industrial	To provide a wide range of industrial and warehouse land uses. To encourage employment opportunities. To minimise any adverse effect of industry on other land uses. To support and protect industrial land for industrial uses. To enable other land uses that provide facilities or services to meet the day to day needs of workers in the area. To enable a range of compatible community and leisure uses. To maintain the industrial character of the land in landscaped settings.	0.34	0	0
Residential	R2 Low Density Residential	To provide for the housing needs of the community within a low density residential environment. To enable other land uses that provide facilities or services to meet the day to day needs of residents. To ensure that low density residential environments are characterised by landscaped settings that are in harmony with the natural environment of Warringah.	83.51	1.09	10.64
	R3 Medium Density Residential	To provide for the housing needs of the community within a medium density residential environment. To provide a variety of housing types within a medium density residential environment. To enable other land uses that provide facilities or services to meet the day to day needs of residents. To ensure that medium density residential environments are characterised by landscaped settings that are in harmony with the natural environment of Warringah. To ensure that medium density residential environments are of a high visual quality in their presentation to public streets and spaces.	46.30	2.92	16.33
Recreation	RE1 Public Recreation	To enable land to be used for public open space or recreational purposes. To provide a range of recreational settings and activities and compatible land uses. To protect and enhance the natural environment for recreational purposes. To protect, manage and restore public land that is of ecological, scientific, cultural or aesthetic value. To prevent development that could destroy, damage or otherwise have an adverse effect on those values.	87.82	1.81	17.26
Special Purpose Zones	SP2 Infrastructure	To provide for infrastructure and related uses. To prevent development that is not compatible with or that may detract from the provision of infrastructure.	4.71	0.58	2.52

2.4 Geology and Soils

2.4.1 Geology

When developing floodplain management options it is important to understand the geology of the catchment to ensure appropriate locations for management options are selected and to assist with the planning of suitable foundations.

The Dee Why South Catchment is situated on Hawkesbury Sandstone and alluvium. Hawkesbury Sandstone is a sedimentary rock that was laid down in the Middle Triassic period between 180 and 220 million years ago (Herbert and Helby, 1980). The Hawkesbury Sandstone consists of massive and cross-bedded sheet bedforms with minor siltstone and mudstone beds.

Channel and floodplain alluvium consists of gravel, sand, silt and clay.

The geological constraints on floodplain management depend on the management options selected. However, no significant geological constraints have been identified which would impact the assessment of options undertaken in this FRMS.

2.4.2 Soils

According to the Soil Landscape Map of Sydney (Scale 1:100,000) the Dee Why South Catchment is situated on the Erina, Ettalong, Gymea, Hawkesbury, Lambert, Narrabeen, Newport, North Head and Warriewood soil landscape groups (**Figure 2-4**).

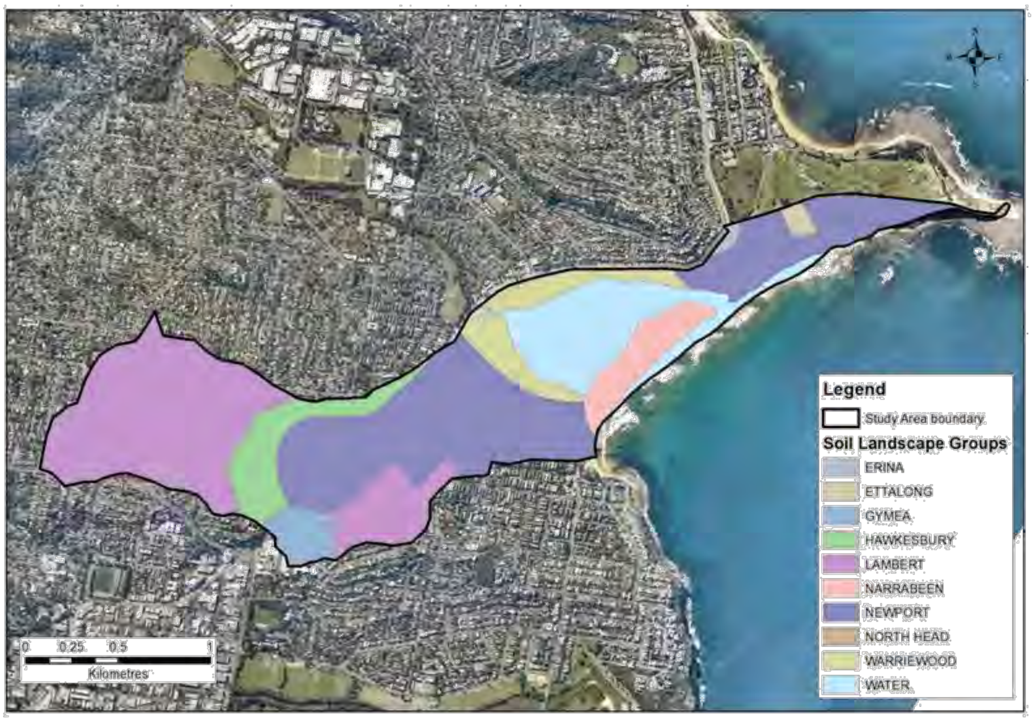


Figure 2-4 Soil Landscape Groups

A description of each landscape group is provided in **Table 2-1**. The majority of soils found within the study area have a high soil erosion hazard which can exacerbate flooding. Any flood modification works should consider the impacts on the numerous soil landscapes.

Table 2-2 Soil Landscapes in the Dee Why South Catchment

Soil Landscape Group	Description
Erina	Undulating to rolling rises and low hills. Rounded narrow crests with moderately inclined slopes. The limitations of the soil landscape group are the very high soil erosion hazard, localised run-on and seasonal waterlogging.
Ettalong	Ettalong soils are characterised by level to very gently undulating coastal swamps. The limitations of this landscape group are flooding, permanently high water table, and extremely acid organic soil of low fertility.
Gymea	Soils of the Gymea Group are derived from Hawkesbury Sandstone and consist of medium-to coarse-grained quartz sandstone with minor shale and laminate lenses. The limitations of the soil landscape group are the high soil erosion hazard and very low soil fertility.
Hawkesbury and Lambert	The Lambert and Hawkesbury soil landscapes are characterised by medium to coarse grained Hawkesbury Sandstone with minor shale and laminate lenses, and are undulating to rolling low hills. These soils are typically found on rocky outcrops and at shallow depths. The soils are prone to an extreme and high level of soil erosion hazard, as well as high permeability and low soil fertility.
Narrabeen	Narrabeen soils occur on exposed mainland and barrier beaches, with relief and elevation of less than 6m, and slopes of less than 3%. The topography is subject to continuous change as a result of varying wave energy and tidal dynamics. Soils are typically deep (>200mm), non-cohesive and subject to extreme wind and wave erosion (Chapman and Murphy, 1989).
Newport	The Newport landscape group is characterised by gently undulating plains to rolling rises of Holocene sands mantling other soil materials or bedrock. The limitations of the Newport soil landscape group include a very high soil erosion hazard, localised steep slopes, very low soil fertility and non-cohesive topsoil.
North Head	North Head soils are characterised by elevated undulating sand sheet plains to rolling dune fields and sand sheets of windblown sands on coastal headlands. The soils have an extreme wind erosion hazard, high water erosion hazard and very low soil fertility.
Warriewood	The Warriewood soil landscape is typically found in swales and infilled coastal lagoons on Quaternary sands. These soils are deep and are prone to localised flooding and run-off, have high water tables and are highly permeable (Chapman and Murphy 1989).

2.4.3 Acid Sulfate Soils

Acid Sulfate Soils (ASS) occur when soils containing iron sulfides are exposed to air and the sulfides oxidise producing sulphuric acid (DECC, 2008). This usually occurs when soils are disturbed through excavation. The production of sulfuric acid results in numerous environmental problems and leads to the degradation of infrastructure. It is therefore important to be aware of the distribution of ASS within the catchment (**Figure 2-5**), so that potential management options are developed and assessed in a manner that is sensitive to the problems of ASS (potential and actual ASS).

Dee Why Lagoon has a high probability of ASS, within 1 m of the ground surface (severe environmental risk if ASS materials are disturbed by activities such as shallow drainage, excavation or clearing). There are severe threats to the surrounding environment (e.g. the release of acid and/or the mobilisation of heavy metals) if high risk materials are disturbed. Soil investigations would be necessary to assess these areas for acid sulfate potential should any flood management works be proposed.

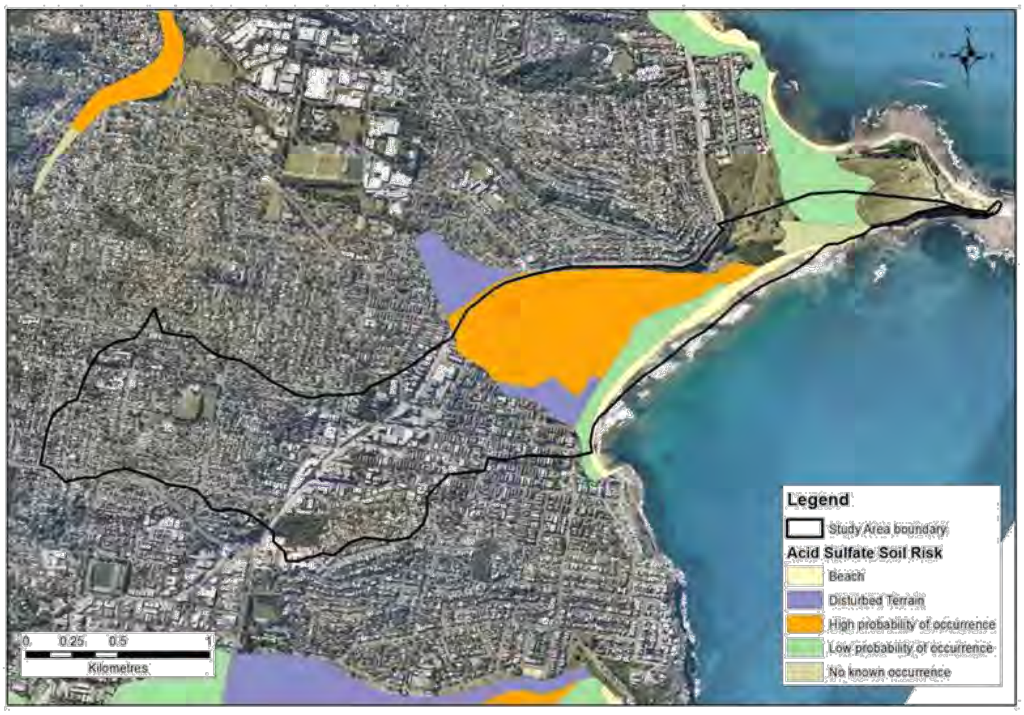


Figure 2-5 Acid Sulfate Soil Risk (OEH, 2013)

2.5 Contaminated Land and Licensed Discharges

Contaminated land refers to any land which contains a substance at such concentrations as to present a risk of harm to human or environmental health, as defined in the *Contaminated Land Management Act 1997*. The Office of Environment and Heritage (OEH) is authorised to regulate contaminated land sites and maintains a record of written notices issued by the Environment Protection Authority (EPA) in relation to the investigation or remediation of site contamination. A search of the OEH Contaminated Land Record on 30 April 2014 identified the Dee Why Town Centre as a contaminated site. Flood modification works within the catchment should consider the impacts that may be caused due to this contaminated site and further investigation may be necessary.

A search of the public register under *section 308 of the Protection of the Environment Operations Act 1997* on 30 April 2014 did not identify any licenced premises within the catchment.

2.6 Flora and Fauna

A search of the NSW Bionet Wildlife Atlas (OEH, 2014a) on 30 April 2014 for threatened species recorded since 1980 showed 14 known threatened flora species (**Appendix B**) within a 10 km by 10 km search area surrounding the catchment, and 50 known threatened fauna species (**Appendix B**).These species are listed under the *Threatened Species Conservation Act 1995*. **Figure 2-6** shows the distribution of threatened species records within the Dee Why South Catchment.

Figure 2-6 Threatened Species (NSW Wildlife Atlas (OEH, 2014a)

A search was also undertaken using the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* Protected Matters Search Tool with a 2 km by 2 km search area surrounding the catchment, which included:

> One Threatened Ecological Community (Subtropical and Temperate Coastal Saltmarsh);

> 62 threatened species; and

> 45 migratory species.

The results of this search are provided in **Appendix B.**

As shown in **Figure 2-6**, a number of threatened species have been recorded within the immediate catchment area including the threatened microbat species:

> Eastern Bent-wing Bat (Miniopterus schreibersii oceanensis);

> Little Bent-wing Bat (Miniopterus australis); and

> Southern Myotis (Myotis macropus).

As part of the *Options Report for Dee Why Town Centre Drainage Design* undertaken by SMEC (2011), the Eastern Bent-wing Bat (*M. s. oceanensis*) was detected inhabiting the main culvert that leads to Dee Why Lagoon. An investigation was undertaken to determine the conservation significance of the microbat species inhabiting the culvert as well as the likelihood of occurrence of other threatened and common microbats in the catchment.

All threatened microbat species assessed were considered likely to utilise the culverts as roosting habitat. The Eastern Bent-wing Bat was confirmed, and the Little Bent-wing Bat and Southern Myotis were considered highly likely (SMEC, 2011). The vegetation fringing Dee Why Lagoon and the lagoon itself were also identified as potential foraging habitat for these species.

Any proposed flood modification measures or flood protection works should consider the potential impacts on roosting microbat species, or any other of the identified threatened species could be affected.

2.6.2 Native Vegetation

Based on vegetation mapping of the Sydney Metropolitan Region (source: The Native Vegetation of the Sydney Metropolitan Area. Volume 1: Technical Report), 12 plant communities have been mapped as occurring within the Dee Why South Catchment (**Table 2-2**). Of these, 7 are identified as Endangered or Threatened Ecological Communities as listed under the NSW **Threatened Species Conservation Act 1995**.

Table 2-3 Plant Communities of the Dee Why South Catchment

Plant Community	Corresponding Endangered Ecological Community
Beach Spinifex Grassland	
Coastal Headland Grassland	Themeda Grassland on seacliffs and coastal headlands
Coastal Foredune Wattle Scrub	
Estuarine Swamp Oak Forest	Swamp Oak Floodplain Forest
Estuarine Saltmarsh	Coastal Saltmarsh
Estuarine Reedland	Swamp Oak Floodplain Forest
Coastal Tea-tree-Banksia Scrub	
Hinterland Riverflat Paperbark Swamp Forest	Swamp Sclerophyll Forest on Coastal Floodplains
Coastal Sand Swamp Mahogany Forest	Swamp Sclerophyll Forest on Coastal Floodplains
Hornsby Enriched Sandstone Exposed Woodland	

The majority of native vegetation in the Dee Why South Catchment is located within the bounds of the Dee Why Lagoon Wildlife Refuge which is located downstream and to the north of Dee Why Town Centre. Where any proposed flood modification measures or flood protection works have the potential to alter downstream hydrology, further consideration and assessment of threatened species and communities located downstream may be required.

2.7 Aboriginal and Non-Aboriginal Cultural Heritage

2.7.1 Aboriginal Cultural Heritage

A preliminary investigation of indigenous heritage was undertaken by searching the Aboriginal Heritage Information Management System (AHIMS) (OEH, 2014b) in May 2014 for known or potential indigenous archaeological or cultural heritage sites within or surrounding the Dee Why South Catchment. Four sites were identified within the catchment, including:

> One midden, open camp site;

> One shelter with midden; and

> Two Potential Archaeological Deposits (PADs).

A more detailed heritage assessment should be undertaken prior to implementation of any management actions to ensure that any proposed flood modification works will not impact upon these sites.

All Aboriginal sites are protected under the *National Parks and Wildlife Act 1974* and therefore any management considerations that impact upon Aboriginal sites must include this in their design. Known Aboriginal sites should be left undisturbed if possible, however if a management measure requires their destruction, an Aboriginal Heritage Impact Permit must be sought from OEH. Under the

National Parks and Wildlife Act 1974 it is a requirement that any developments show "due diligence" with regard to Aboriginal heritage in the area.

2.7.2 Non-Aboriginal Heritage

There are three different types of statutory heritage listings of non-Aboriginal origin; local, state or national heritage items. A property is a heritage item if it falls into a listings category. The category of an item depends on whether it is considered to be significant to the nation, state or a local area. The significance of an item is a status determined by assessing its historical, scientific, cultural, social, archaeological, architectural, natural or aesthetic value.

A desktop review of non-Aboriginal heritage was undertaken for the catchment. Searches were undertaken on a number of databases to determine the cultural heritage within this area, including:

> Australian Heritage Database (incorporates World Heritage List, Register of the National Estate, Commonwealth Heritage List);
> NSW Heritage Office – State Heritage Register; and
> *Warringah Local Environmental Plan 2011*.

Four items found within the catchment area have been listed on the Register of the National Estate, which include:

> Dee Why Lagoon Reserve;
> Dee Why Rock Pools;
> Factory Building and Shelters (800 Pittwater Road, Dee Why); and
> Stony Range Flora Reserve.

A further 13 local heritage items of significance were found within the catchment which are listed under Schedule 5 of the Warringah LEP. Dee Why Lagoon and Stony Range Flora Reserve are also listed as Heritage Conservation Areas under the Warringah LEP. No items were found to be included on the State Heritage Register.

There are a number of flood management options proposed in the vicinity of the Dee Why Lagoon Reserve. Under Part 5, Clause 5.10 of the Warringah LEP, an outline of the provisions that must be followed in relation to heritage items is provided. It is recommended that a heritage assessment is undertaken prior to the implementation of any management options, as there are development restrictions and procedures that may need to be followed.

2.8 Summary of Environmental and Social Issues

Environmental and social characteristics of the study area may influence the type and extent of flood modification measures able to be implemented. The key issues identified through this review include:

> The soil types that are present may potentially pose issues related to earth movement and construction due to erosion risk, low soil fertility, poor soil drainage and high permeability;
> Dee Why Lagoon has a high probability of ASS, within 1 m of the ground surface (severe environmental risk if ASS materials are disturbed by activities such as shallow drainage, excavation or clearing);
> English was the only language spoken in approximately 71% of homes in the Dee Why South Catchment. The most common languages spoken at home other than English are Portuguese, Serbian, Mandarin, Italian, Tongan and Tagalog;
> The majority of native vegetation in the Dee Why South Catchment is located within the bounds of the Dee Why Lagoon Wildlife Refuge which is located downstream and north of Dee Why Town Centre. Where any proposed flood modification measures or flood protection works have the potential to alter downstream hydrology, further consideration and assessment of threatened species and communities located downstream may be required;
> Four Aboriginal heritage items were identified within the catchment; and

- Four non-Aboriginal heritage items are found within the catchment area and have been listed on the Register of the National Estate. A further 13 items are listed by Warringah Council.

3 Available Data

3.1 Previous Studies and Reports

3.1.1 Dee Why South Catchment Flood Study

The Dee Why South Catchment Flood Study (Cardno, 2013) is the key input to the FRMS. The primary objective of the Flood Study was to define the flood behaviour in the study area, including both mainstream and overland flooding. Extensive data compilation and review was undertaken, and included review of a number of previous studies, together with collection of available rainfall records and survey data (floor levels, stormwater pits and pipes).

A detailed 1D/2D computer-based flood model was established to describe the flooding behaviour throughout the study area, incorporating all data on stormwater pits and pipes provided by and adopting a 2 m grid resolution. Computer-based hydrological and hydraulic modelling was undertaken through the application of the Direct Rainfall methodology, alternatively known as rainfall-on-grid.

The Direct Rainfall approach allows for the spatial distribution of rainfall on the catchment, with excess rainfall applied directly to the hydraulic model grids that represent the catchment. The water then flows according to the hydraulic properties of the land surface as defined by the topography and roughness characteristics (i.e. is the catchment vegetated or hard surfaces like roads). Due to the density and spatial distribution of stormwater pipes in the catchment, it was concluded that the hydraulic routing approach would provide a more accurate representation of catchment flows than the more traditional hydrological routing approach.

In the absence of available gauged rainfall and flow data for calibration, model verification was undertaken by comparison of the hydrological results against a separate hydrological model (XP-RAFTS), and the hydraulic results were compared against the previous SMEC (2011) model for the area. The comparison of results indicated a reasonable agreement, providing confidence in the overall modelling results presented in the Flood Study (Cardno, 2013).

The Flood Study characterised flood behaviour for the 1,000 years, 200 years, 100 years, 20 years, 10 years, 5 years, and 1 year Average Recurrence Interval (ARI) events as well as the Probable Maximum Flood (PMF). The primary flood characteristics reported for the design events considered include depths and velocities. The study has also defined the flood planning level, hydraulic categories and provisional flood hazard for flood-affected areas.

A series of climate change scenarios were also modelled to evaluate potential impacts from elevated sea levels and increased rainfall intensity. Results showed that the modelled increases in water levels in Dee Why Lagoon have a localised impact on flood inundation of low-lying land near the Lagoon. Most properties within the Dee Why South Catchment do not show a significant change in inundation extent for the modelled climate change scenarios. Increases in rainfall intensity resulted in a rise in peak water levels across the catchment, particularly in trapped low points such as on Sturdee Parade and Alfred Street.

3.1.2 Additional Studies

A number of additional flood assessments have been undertaken in Dee Why since 1975, and these were also considered for both the Flood Study (Cardno, 2013) and for the purposes of this FRMS. These studies include:

> Physical Model Sydney University, 1975, Test No T244;

> Warringah Council ILSAX model;

> *Dee Why Town Square Flood Study Investigation* (Lyall and Associates, 2001a);

> *Dee Why Central Business District Flood Study* (Lyall and Associates, 2001b);

> *Feasibility Study: Proposed Oaks Avenue Stormwater Drainage Upgrade* (Lyall and Associates, 2002);

> *Dee Why Lagoon Wildlife Refuge Plan of Management* (Warringah Council, 2002);

> *Dee Why Lagoon and Curl Curl Lagoon Flood Studies* (Lyall and Associates, 2004);
> *Dee Why Lagoon and Estuary Management Study* (Lawson and Treloar, 2004);
> *Dee Why Triangle Park* (Lyall and Associates, 2004);
> *Dee Why and Curl Curl Floodplain Risk Management Studies and Plan* (Lyall & Associates, 2006a);
> *Dee Why Central Business District Flood Study* (Lyall and Associates, 2006b);
> *Dee Why CBD Flood Study Update* (Cardno Lawson Treloar, 2007a);
> *Dee Why CBD Flood Study - Augmentation Options: Interim Results* (Cardno Lawson Treloar, 2007b);
> *Dee Why CBD Flood Study Update* (Cardno Lawson Treloar, 2007c);
> *Dee Why CBD Flood Feasibility Assessment: Proposed Augmentation Options* (Cardno Lawson Treloar, 2008a);
> *Dee Why CBD Feasibility Assessment – Results for Option 4* (Cardno Lawson Treloar, 2008b);
> *Dee Why CBD Feasibility Assessment: Results for Option 4 + 10% Rainfall increase* (Cardno Lawson Treloar, 2008c);
> Warringah Council XP-SWMM 2D Model Development, December 2009;
> *Options Report for Dee Why Town Centre Drainage Design* (SMEC, 2011);
> *North West Metropolitan Emergency Management District Disaster Plan* (DISPLAN) (NSW SES, 2011);
> Manly-Warringah-Pittwater *Flood Emergency Sub-plan* (NSW SES, 2013);
> Millener, D, Howley, D, Galloway, M, and Leszczynski, P. (2013) *Flash Flood Warning System for Sydney's Northern Beaches.* FMA National Conference 2013;
> *Northern Beaches Flood & Coastal Storm* (Micromex, 2012); and
> *Beverly Job Park Detention Basin Feasibility Study* (SMEC, 2012).

3.2 Survey Information

3.2.1 Stormwater Infrastructure Survey

Stormwater pit and pipe details compiled in the SMEC (2011) XP-SWMM model were adopted for the Cardno (2013) Flood Study model.

Council has also conducted closed-circuit television (CCTV) inspections of some stormwater pipe sections in the catchment and has also surveyed stormwater infrastructure. CCTV footage of the drainage network can be utilised for maintenance assessments (to identify blockages and structural damage), and assessments of the conduit configuration (external connections and pipe alignments). Debris was noticed in some sections, potentially resulting in reduced capacity of the pipe. Effects of blockage by debris on the flood model results were assessed by consideration of blockage scenarios included in the sensitivity runs (see Cardno, 2013).

The stormwater network configuration in the flood model was reviewed based on the CCTV footage. Sections of the network reviewed include:

> Dee Why Grand (Pacific Parade) – an additional pipe connection to the trunkline was evident that had not been included in the model. This branch line is thought to be for internal site drainage (which is not explicitly modelled) rather than Council's street drainage network.
> Pacific Parade – a section of culvert is larger than the upstream and downstream links. In the model, this section is adopted as the size of the downstream culvert which will be the factor limiting flow conveyance.
> Pittwater Road (near Pacific Parade) – the pipelines crossing Pittwater Road may not be constructed in a straight line between the west and east side of the road as set-up in the flood model. Instead it may comprise additional bends to allow a more perpendicular crossing of the road. CCTV footage of the west side of the road did not clarify the layout. The straight line layout has been retained in the model as the

alternate layout would likely only result in a relatively minor increase in energy losses (due to bends and pipe friction).

An upgrade to a stormwater pipe (from the existing 600 mm diameter to 1,200 mm diameter) from Painters Parade to Mooramba Road is also proposed, but is not included in the model as it is not in place at time of preparation of this report.

3.2.2 Channel Survey

The study area includes three reaches of open channel that are defined in the Flood Study (Cardno, 2013) model:

> Victor Road to Redman Road (Reach 1);

> Downstream of Pittwater Road between Pacific Parade and Oaks Avenue (Reach 2); and

> Downstream of Dee Why Parade (Reach 3).

Council supplied detailed survey for Channel Reach 1 by Craig & Rhodes, and for Reach 2 by Land Partners. Survey of Channel Reach 3 and cross-sections of inundated road profiles along Lewis Street, Dela Close, Redman Road, Delmar Parade, Sturdee Parade and Pacific Parade were not undertaken as part of this study.

3.2.3 Floor Level Survey

A survey of building floor levels within the Dee Why Town Centre was conducted in 2010 for the purposes of the SMEC (2011) study. A total of 367 floor levels were surveyed from the western side of Pittwater Road to Richmond Avenue, including multiple levels at a single property which had varying floor levels for different units within the same complex (**Figure 3-1**).

This data was provided to Cardno for use in the current study, noting that the 367 floor levels that have been provided do not cover the entire catchment or the entire area affected by flooding. The data is, however, considered adequate to provide an indication of the flood impact.

3.3 GIS Data

In addition to the GIS data supplied as part of the Flood Study (Cardno, 2013), Council also provided for the FRMS updated GIS layers for the cadastre, catchment boundary and local flood investigations. Ground level data in the form of raw LiDAR (Light Detection and Ranging or Aerial Laser Survey) data was provided for the entire Dee Why South Catchment by Council. The LiDAR data was collected over 15-16 March 2007 by AAM Hatch. The supplier advised that it has a vertical accuracy +/- 0.15 m at 68% confidence and horizontal accuracy +/- 0.55 m at 68% confidence. The raw LiDAR data was used to derive a high resolution (2 m grid) digital elevation model (DEM) for the Dee Why South Catchment.

3.4 Site Inspections

A site inspection was carried out on 14 February 2014. During this visit, key hydraulic systems were investigated, such as the open channel between properties between Oaks Avenue and Pacific Parade. In addition, particular attention was taken with regards to existing basement car park entrances with respect to the likelihood of inundation in low frequency events. Key features recorded in photographs can be found in **Appendix A**.

Figure 3-1 Floor Level Survey

4 Consultation

4.1 Community Consultation

Community consultation undertaken as part of the Flood Study (Cardno, 2013) was to inform the community about the study and gain an understanding of the community's experience with historical flooding in the catchment. The additional consultation undertaken as part of this FRMS will build on the earlier consultation, building flood awareness in the community and providing people with an opportunity to give feedback on the proposed flood management options.

This Draft FRMS will be placed on public exhibition to enable community members and stakeholders to provide input to the study. The draft report details existing flooding behaviour, catchment characteristics, a range of options that have been examined, and an assessment of potential outcomes enabling informed responses. Submissions received from the public exhibition will be reviewed and compiled for the subsequent revision of the report to ensure specific community concerns are addressed.

4.2 Floodplain Committee and Stakeholder Consultation

The floodplain committee, comprising various agency and community representatives, fulfils an important role in assisting local Council in the development and implementation of the Floodplain Risk Management Study and Plan. The Cardno project team have reported to the committee, known as the Dee Why South Catchment Flood Study Working Group, and undertaken workshops with both the Working Group and additional stakeholders at key stages of the study as detailed below:

> **Inception Meeting (14 January 2014):** The project team provided an overview of the project purpose, scope and methodology to the Working Group. Key issues and ideas regarding the direction of the study were raised by the Working Group for consideration by Cardno and Council. A key outcome of the inception meeting was the critical timeframe and the need to have a greater understanding of plausible mitigation options for within the Dee Why Town Centre. The project timeline was driven by the requirement to have structural flood management options available for tender by the beginning of April to coincide with the next stage of the Dee Why Town Centre Masterplan.

> **Council Meeting (30 January 2014):** An internal meeting of Council's project team and department representatives was undertaken to review potential flood mitigation options. A shortlist of options for further analysis was prepared from an initial list of options presented by Cardno. The options analysis included feasibility, overall outcomes for the catchment, land tenure and access constraints, cost of implementation and related issues (such as landscaping). Current Council strategies were also considered where relevant to the FRMS.

> **Working Group Meeting (24 February 2014):** Cardno presented an overview of work completed to date on the FRMS, including the shortlisted floodplain mitigation options. Working Group members were encouraged to provide comment on the options to enable consideration of key stakeholder requirements by the project team.

> **Meeting of the Project Team (9 April 2014):** This meeting with the project team members from both Council and Cardno was held to discuss the progress and direction of the FRMS. A draft report outlining the results of modelling of the structural flood mitigation options was provided at the end of March to Council along with a proposed framework for assessing and ranking the various options under consideration.

> **Presentation of Preliminary Options Ranking (8 May 2014):** A second meeting of the Working Group was held to review the preliminary outcomes of the options assessment and seek feedback on any modifications that might be required to ensure a triple-bottom line approach (i.e. considering economic, social and environmental aspects) and address matters raised by the Working Group.

As part of the implementation of the FRMP and detailed design of the floodplain management measures, liaison should be undertaken with key stakeholders, including, but not limited to:

> Private residents (particularly those in proximity to the works);

> Community groups;
> Roads and Maritime Services;
> NSW State Emergency Service (SES); and
> OEH.

5 Existing Flood Behaviour

This section provides an overview of flooding in the Dee Why South Catchment, summarised from Cardno (2013). Reference is made to **Figures 5-1** and **5-2**, which show the 100 years ARI and PMF flood extents.

5.1 Flooding Behaviour

Flooding in the Dee Why South Catchment is caused by a combination of geographic features of the catchment, which comprises a steep escarpment and coastal hinterland, and increasing urban development, which has caused a complex system of flow regimes and flooding mechanisms.

The critical duration rainfall events within the catchment are 60 minutes for the PMF event and 90 minutes for all other flood events. The Flood Study (Cardno, 2013) showed that the main overland flow path originates at the location smaller flow paths from Alfred Street and Beverley Job Park converge. Flows are then conveyed by the open channel that runs from Victor Road parallel with Redman Road, subsequently combining with overland flows from Mooramba Road, Fisher Road, and Pittwater Road at the intersection of Redman Road and Pittwater Road. Overland flows are then conveyed along several roads and properties, and via open drainage channels located between Pacific Parade and Oaks Avenue and downstream of Dee Why Parade, eventually draining to Dee Why Lagoon.

In the 100 years ARI event (see **Figure 5-1**), the results show that ponding of runoff occurs at several locations with restricted stormwater outlet capacity. This is potentially the result of insufficient piped stormwater drainage capacity or localised depressions that result in trapped low points. Examples of such locations include Sturdee Parade (near Pittwater Road) and Alfred Street (near McIntosh Road) as well as Beverley Job Park. Ponding also occurs at several locations in the catchment due to localised depressions in ground levels or building structures restricting overland flow paths.

High pedestrian areas in Dee Why Town Centre also experience overland flow inundation, particularly along Redman Road, Pittwater Road, Oaks Avenue and Howard Avenue. Ponding of up to 0.5 to 1.0 m depth has been modelled at low points in these roads (Cardno, 2013). Some roads show scattered inundation up to 0.3 m, such as Alfred Street (near McIntosh Road), Redman Road, and Howard Avenue as well as on the Victor Road side of Beverley Job Park.

Significant inundation occurs in a PMF event (**Figure 5-2**) with some roads having a flood depths greater than 1 m and velocities greater than 2 m/s. Overall, the PMF results show that the catchment comprises a series of trapped low points due to lack of sufficient piped drainage capacity or dedicated overland flow paths.

Figure 5-1 100 Years ARI Flood Extent – Existing Conditions

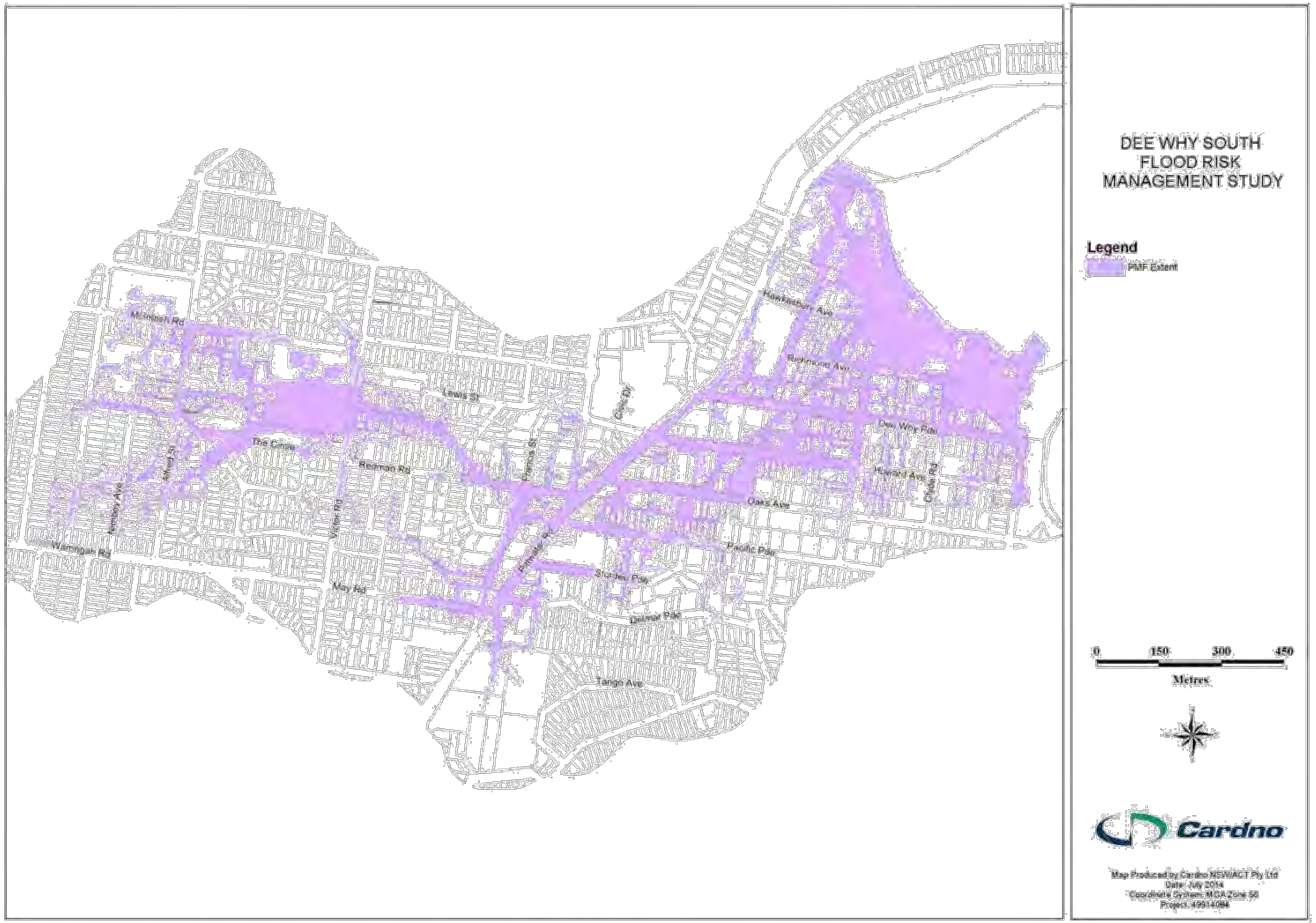


Figure 5-2 Probable Maximum Flood Extent – Existing Conditions

5.2 Historical Flooding

Council's records indicate that the catchment has experienced flooding in the past. Photographs available for the major flood events that occurred in 1947, 1953 and 1954 show both the Dee Why Town Centre and outer catchment area affected by significant overland flow during a flood event (**Figures 5-3** and **5-4**).

The rainfall data for these flood events was not available to assist in estimating the recurrence interval of these events or for use in calibrating the hydraulic model. However, photographs provided by Council indicate that major storm events have potential to create hazardous flooding conditions along the major flow paths within the catchment.

Information provided by Council showing the location/extent of local flood investigations indicates that recent reports of flooding are likely due to localised issues with the drainage network. No recent reports of extreme flooding have been received, and reports from the community on flooding issues are infrequent. Hence it is considered that flood mitigation options are better targeted at assessing the capacity of local stormwater drainage where issues occur, as opposed to a whole of catchment analysis.

Figure 5-3 Flooding of Pittwater Road, Dee Why, 1953 (Source: Warringah Council)

Figure 5-4 Flooding of Redman Road, Dee Why, 1953 (Source: Warringah Council)

5.3 Conduit Blockage

Blockages of the stormwater drainage system, such as inlet pits, pipes, and culverts, can cause significant reduction of the system capacity and consequently exacerbate flooding as additional stormwater runoff is conveyed overland. Blockages of major culverts and road crossings have historically occurred during large storm events, as observed in Wollongong in 1998 and Newcastle in 2007. In some cases, stormwater culverts were completely blocked by debris.

Several modes of blockage to the stormwater drainage system may occur, affecting the surface inlet pits in gutters, underground stormwater pipes, and/or open channels / culverts. Blockage may result from a build-up of debris comprising leaves, litter, and/or sediment over a period of time. During storm events debris from building sites, unsecured items from properties, tree branches and even vehicles can cause blockages.

Responses to the resident questionnaire conducted for the Dee Why South Catchment Flood Study (Cardno, 2013) identified that blockages to the stormwater drainage network have historically occurred in this catchment. As such, the Flood Study (Cardno, 2013) included an assessment of the impact of inlet blockage. The computer-based model of flood behaviour included a blockage factor of 50% for sag pits and 20% for on-grade pits. Two sensitivity scenarios were modelled:

> Unlimited inlet capacity - to evaluate sensitivity for a case where pipes are operating to maximum capacity; and

> Complete blockage to the inlets - for a case where the piped drainage conveys no flow.

The unlimited inlet capacity case does not show significant changes in peak water levels as the pipe system is already at capacity in a number of sections in the 100 years ARI event.

Complete blockage of the inlets, which effectively renders the pipe system ineffective, results in significant increases to peak water levels across the catchment as the stormwater runoff is conveyed overland. Increases in peak water levels of over 0.5 m are evident in the Dee Why Town Centre and further downstream, partially due to the constriction of overland flowpaths by buildings. Under these circumstances, water levels in the open channel near Hawkesbury Avenue are reduced as overland flows are concentrated to the east due to the lack of capacity in the piped stormwater drainage system. Maintenance of the stormwater drainage system and removal of reported blockages is important for the effective operation of the stormwater network.

Analysis of the impacts of blockages to individual pipes was not undertaken as part of this FRMS due to the unknowns associated with culvert blockage scenarios (i.e. location and degree of blockage).

5.4 Flood Hazard

Flood hazard can be defined as the risk to life caused by a flood, and is categorised in accordance with Appendix L of the NSW Government (2005) *Floodplain Development Manual* as follows:

> **Provisional hazard** is based on the hydraulic characteristics of the floodwaters, namely the relationship between the depth and velocity of floodwaters (provisional hazard = depth x velocity) and is discussed in **Section 5.4.1**; and

> **True hazard** is an extension of provisional hazard, considering a range of additional factors that contribute to flood risk, as discussed in **Section 5.4.2**.

5.4.1 Provisional Flood Hazard

Provisional flood hazard was assessed as part of the Flood Study (Cardno, 2013) in accordance with Appendix L of the *Floodplain Development Manual* (NSW, Government 2005), which defines two hazard categories:

> **High hazard** – Otherwise known as floodway; represents possible danger to personal safety, evacuation by trucks difficult, able-bodied adults would have difficulty in wading to safety, potential for significant structural damage to buildings; and

> **Low hazard** – Otherwise known as flood fringe; should it be necessary, a truck could be used to evacuate people and their possessions, able-bodied adults would have little difficulty in wading to safety.

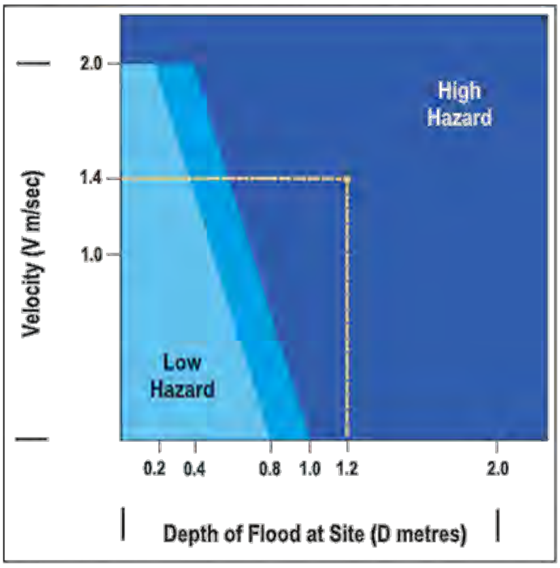


Figure 5-5 Provisional Flood Hazard Categories

Provisional flood hazard for the 100 year ARI and PMF events are shown in **Figures 5-6** and **5-7** respectively.

A large portion of the catchment is categorised as high provisional hazard. These areas are primarily along roads, and also include properties upstream of Beverley Job Park, located adjacent to the open channel from Victor Road to Redman Road and downstream of Pittwater Road.

For the 100 years ARI flood event the following locations are subject to high provisional hazard:

> The intersection of Victor Road and Lewis Street;

> Redman Road, Pittwater Road, Oaks Avenue, and Howard Avenue in the Dee Why Town Centre;

> Downstream of the Dee Why Town Centre along Dee Why Parade and Clyde Road;

> Along the open channels of Victor Road to Redman Road, between Pacific Parade and Oaks Avenue and downstream of Dee Why Parade to the Lagoon; and

> Some properties near these areas.

Cardno (2013) mapped high provisional hazard in a 20 years ARI event occurring in the open channels and along Redman Road and Pittwater Road.

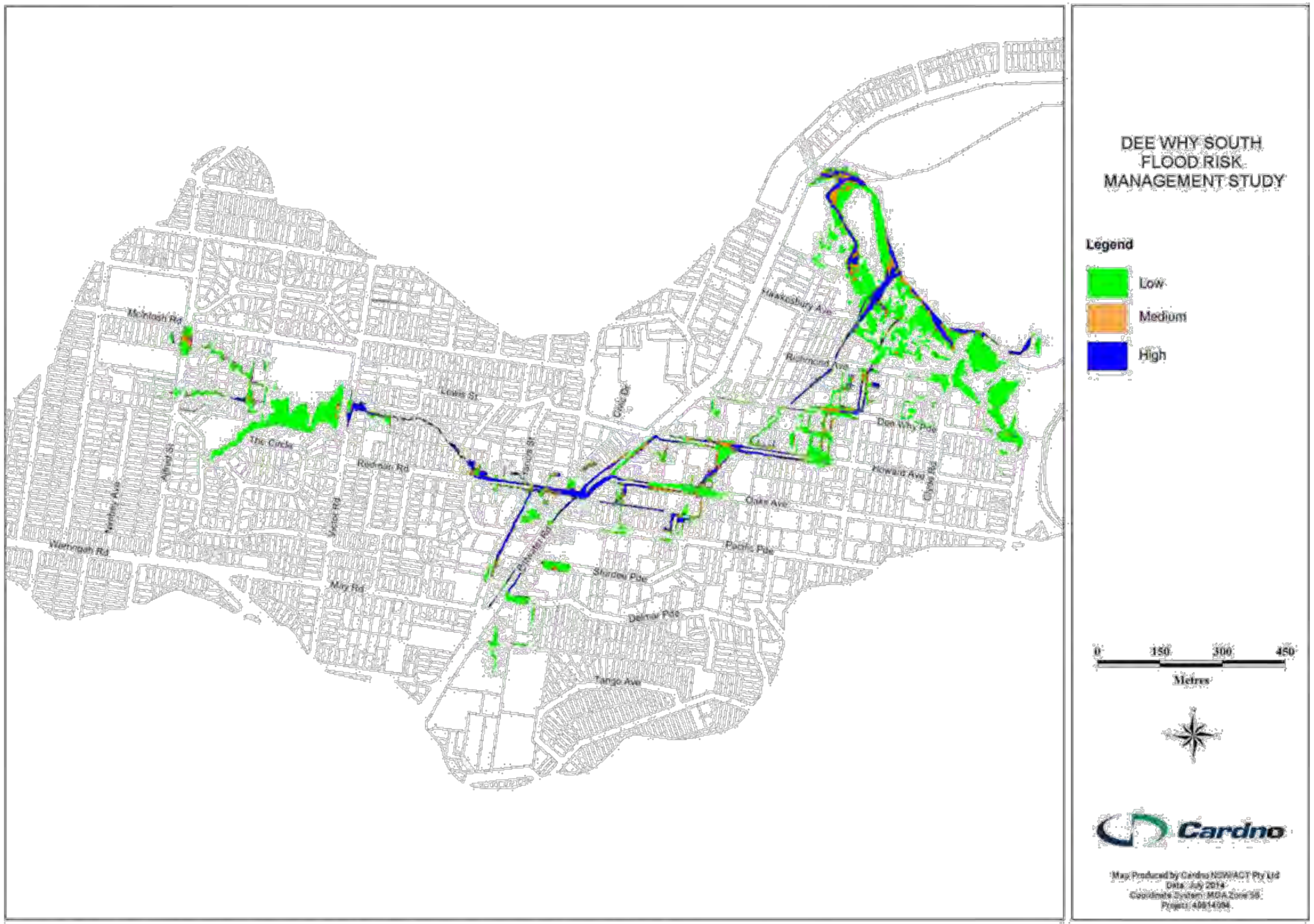


Figure 5-6 100 years ARI Provisional Flood Hazard – Existing Conditions

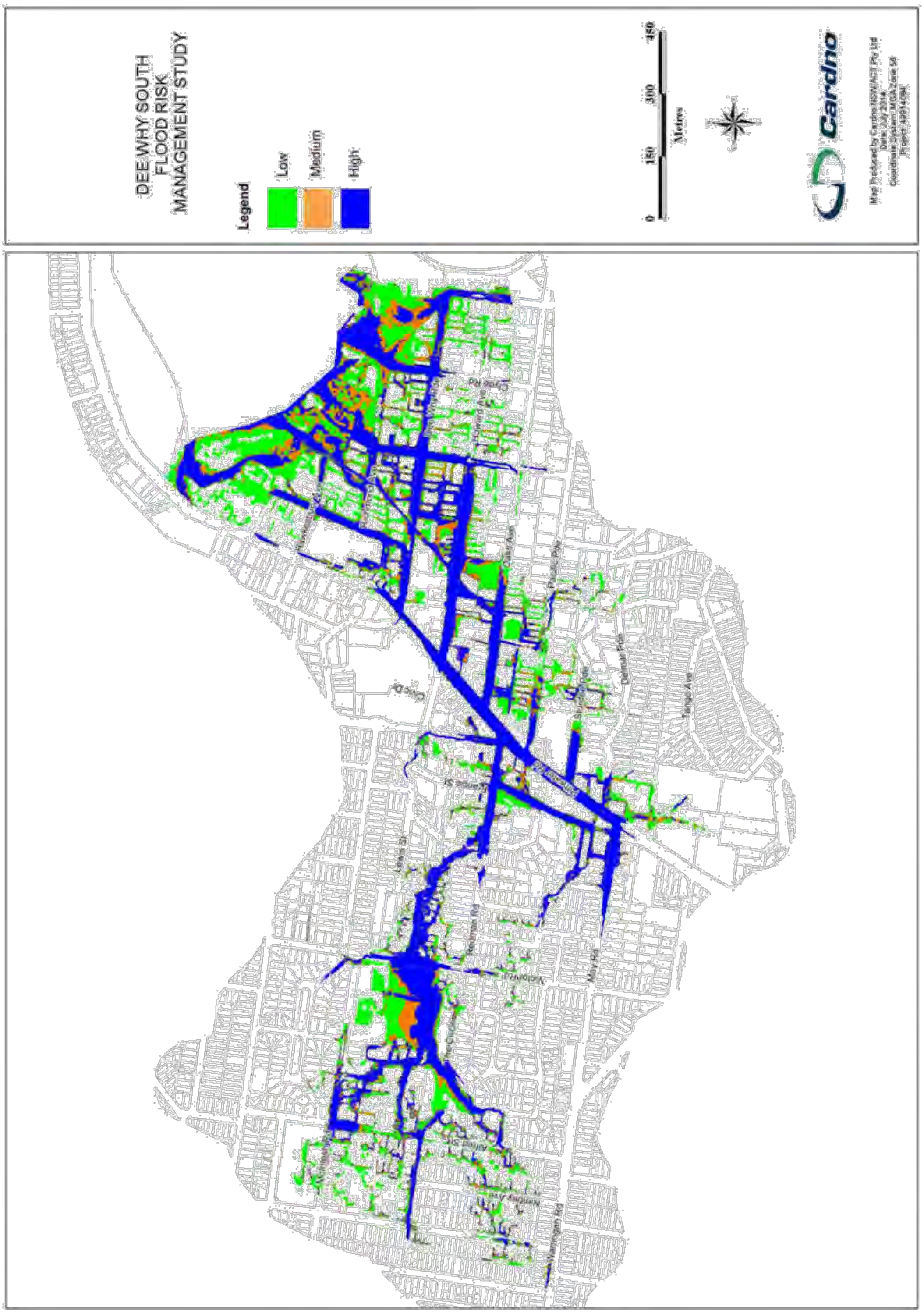


Figure 5-7 Probable Maximum Flood Provisional Flood Hazard – Existing Conditions

5.4.2 True Hazard

True flood hazard relates to a range of factors in addition to the hydraulic factors, as outlined in the *Floodplain Development Manual* (NSW Government, 2005):

> Size of the flood;
> Effective warning time;
> Flood readiness;
> Rate of rise of floodwaters;
> Duration of flooding;
> Ease of evacuation;
> Effective flood access; and
> Type of development in the floodplain.

Each of these factors has been considered with respect to defining true hazard for the Dee Why South Catchment.

Size of Flood

The size of a flood and the damage it causes varies from one event to another. In order to define the "true" flood hazard in varied magnitudes of storm events, the provisional flood hazard assessed for the PMF and 100 years ARI events (Cardno, 2013) forms the baseline for the incorporation of the other factors.

Effective Warning Time

The effective warning time is the actual time available prior to a flood during which people may undertake appropriate mitigation actions and is related to the time needed to pass the flood warning to people located in the floodplain and for them to begin effective property protection and/or evacuation procedures. Effective warning time is always less than the total warning time available to emergency service agencies. In general, the flood warning time needs to be in excess of 6 hours for an effective response to occur.

The Flood Study (Cardno, 2013) identified a critical duration of 1.5 hours for the Dee Why South Catchment. For the PMF event, the critical duration is 60 minutes. As all critical durations within the catchment for all events were significantly less than the 6 hours required for effective response, the warning time is not considered to modify the provisional flood hazard categorisation.

Flood Readiness

Flood readiness or preparedness can greatly influence the time taken by flood-affected residents and visitors to respond in an efficient pattern to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is prompt, efficient and effective.

A major flood event has not occurred in the Dee Why South Catchment for several years, thus awareness of potential flood impacts may be low. About 40% of respondents to the community questionnaire of the Flood Study (Cardno, 2013) indicated they were not aware of flooding in the catchment. The short duration before the onset of flooding in the catchment may result in flooding occurring when residents and business owners are not present when the flood event hits. Hence, even if they are organised to implement their site-specific flood plan, they may not have sufficient time to do so.

It is assumed that flood awareness of larger floods is likely to be relatively low and no particular part of the catchment is likely to be any more prepared for a flood than another, thus flood readiness does not modify the true hazard extents.

Rate of Rise of Floodwaters

During a flood event, the rate of rise of floodwaters indicates the time available for a person to evacuate to higher ground. In the event of flash flooding there is generally little to no lead time between the rainfall event and the flood event, and as such the risk of persons being caught in the flood event is increased.

The rate of rise of floodwaters affects the magnitude of the consequences of a flood event. Situations where floodwaters rise rapidly are potentially far more dangerous, and cause more damage, than situations where flood levels increase slowly. The rate of rise of floodwaters is affected by catchment and floodplain characteristics.

A rate of rise of 0.5 m/hr has been adopted as indicative of true high hazard. However, it is important to note that if an area has a rate of rise greater than 0.5 m/hr this does not automatically result in the area being categorised as high hazard. For instance, if the rate of rise is very high but flood depths only reach 0.2 m, this is not considered to pose any greater hazard than slowly rising waters. Therefore, peak flood depths were considered in conjunction with the rate of rise in defining areas affected by true high hazard.

A flood depth of 0.5 m was selected as the trigger depth for high hazard where the rate of rise was equal to or greater than 0.5 m/hr. A 0.5 m flood depth was adopted based on available information about vehicle instability, as this is the point when vehicles become unstable even when floodwaters do not have a velocity (Figure L1; NSW Government, 2005).

Duration of Flooding

The duration of flooding, or length of time a community, town or single dwelling is cut off by floodwaters, can have a significant impact on the costs and disruption associated with flooding. Flooding durations are generally less than a couple of hours in the Dee Why South Catchment (Cardno, 2013), and as such this factor is not considered to modify true hazard.

Ease of Evacuation

The degree of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation may be difficult due to a number of factors, including:

> The number of people requiring assistance;
> Mobility of those being evacuated;
> Time of day; and
> Lack of suitable evacuation equipment.

As previously discussed, the Dee Why South Catchment is subject to flash flooding with limited warning time and a short period of exposure; therefore evacuation may not be viable.

Effective Flood Access

The availability of effective access to and from flood affected areas can directly influence personal safety and potential damage reduction measures. Effective access implies that there is an exit route available that remains trafficable for sufficient time to evacuate people and possessions.

Flood access varies across the catchment. For this assessment, properties were identified as being in one of four flood access categories:

> Site is flooded and evacuation required through a high hazard flooded roadway;
> Site is flooded and evacuation is required through a flooded roadway;
> Site is flooded and evacuation is possible through a non-flooded roadway directly from site; and
> Site is flood free, however all road access is impeded by floodwaters.

To consolidate these categories and determine the implications of for true hazard categorisation, effective access was defined as a road which is flooded by less than 0.3 m of water. For the purposes of this assessment 300mm is the threshold depth at which vehicles become unstable, even at very low velocities.

In a 100 years ARI event, some roads are impacted by high provisional hazard due to high velocity flows, which results in some adjacent properties being impacted by limited effective access during a flood event (Cardno, 2013). Alternative road access that avoids roads subject to high hazard may be required to access some properties. Similarly, in the PMF event significant sections of the road network are identified as high provisional hazard, and many properties would have access issues. As a result, the high provisional hazard categorisations would be retained for these locations.

Type of Development

The degree of hazard to be managed is a function of the type of development and resident mobility. That is, where developments such as aged care facilities, schools and hospitals occur, evacuation and flood response is more challenging. Such areas may require re-categorisation from low provisional hazard to high true hazard on this basis. Similarly, the flood hazard mapping can assist authorities in planning new development so that it is sited in flood free or low hazard areas with flood free access and egress.

In the 100 years ARI event, two sites (and aged care facility and a child care centre) are affected by runoff and are categorised as true hazard. Of the utilities and service providers invited to participate in this FRMS, Sydney Water and Jemena assisted with the provision of mapping of their critical infrastructure. One Sydney Water pump station was located in the PMF extent and would have implications for true hazard.

True Hazard Mapping

Based on consideration of all these factors, the provisional hazard mapping (**Figures 5-6** and **5-7**) has been refined to show the true hazard mapping for the 100 years ARI and PMF events respectively (see **Figures 5-8** and **5-9**). Additional parts of the floodplain are classified as high true hazard in both storm events due to isolation by floodwaters and regional storages. The identified of true hazard areas in this study is relevant for consideration during urban development and land use planning.

5.4.3 Car Park Hazard

A site visit to investigate the current basement car parking arrangements within the Dee Why Town Centre was undertaken in February 2014. Recent developments are likely to have the flood immunity of the basement car parks at greater than 100 years ARI as current planning requirements specify an entrance at a minimum of the flood planning level. In more established regions of the Town Centre such as Howard Avenue, the basement entrance levels are significantly lower. Basements within these locations are likely to inundate in the 100 years ARI event.

Section 5.4.6 describes potential inundation and blockage of access roads and to basement car parks in a range of storm events for potential hazard based on depth and velocity-depth product criteria.

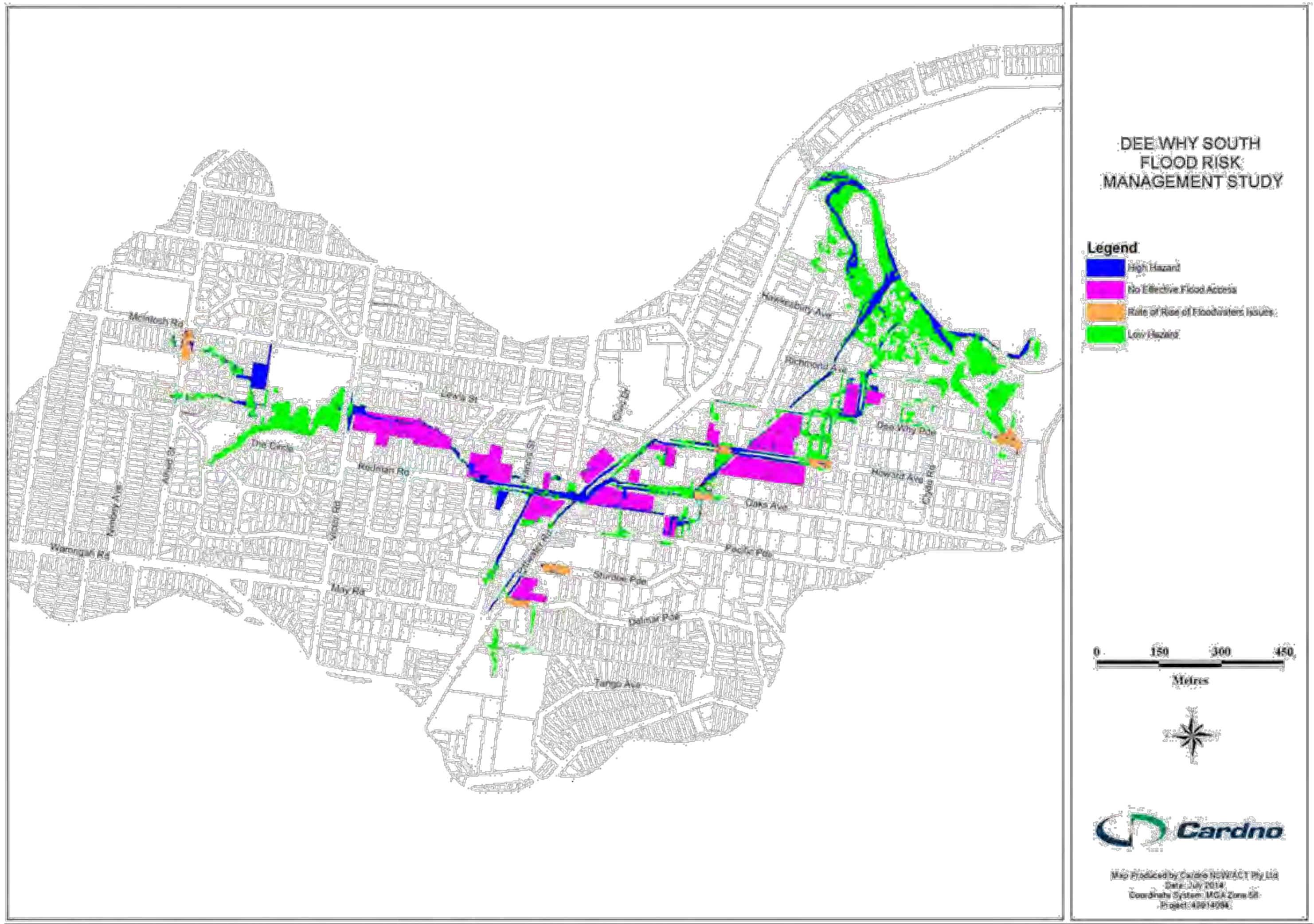


Figure 5-8 100 years ARI True Flood Hazard – Existing Conditions

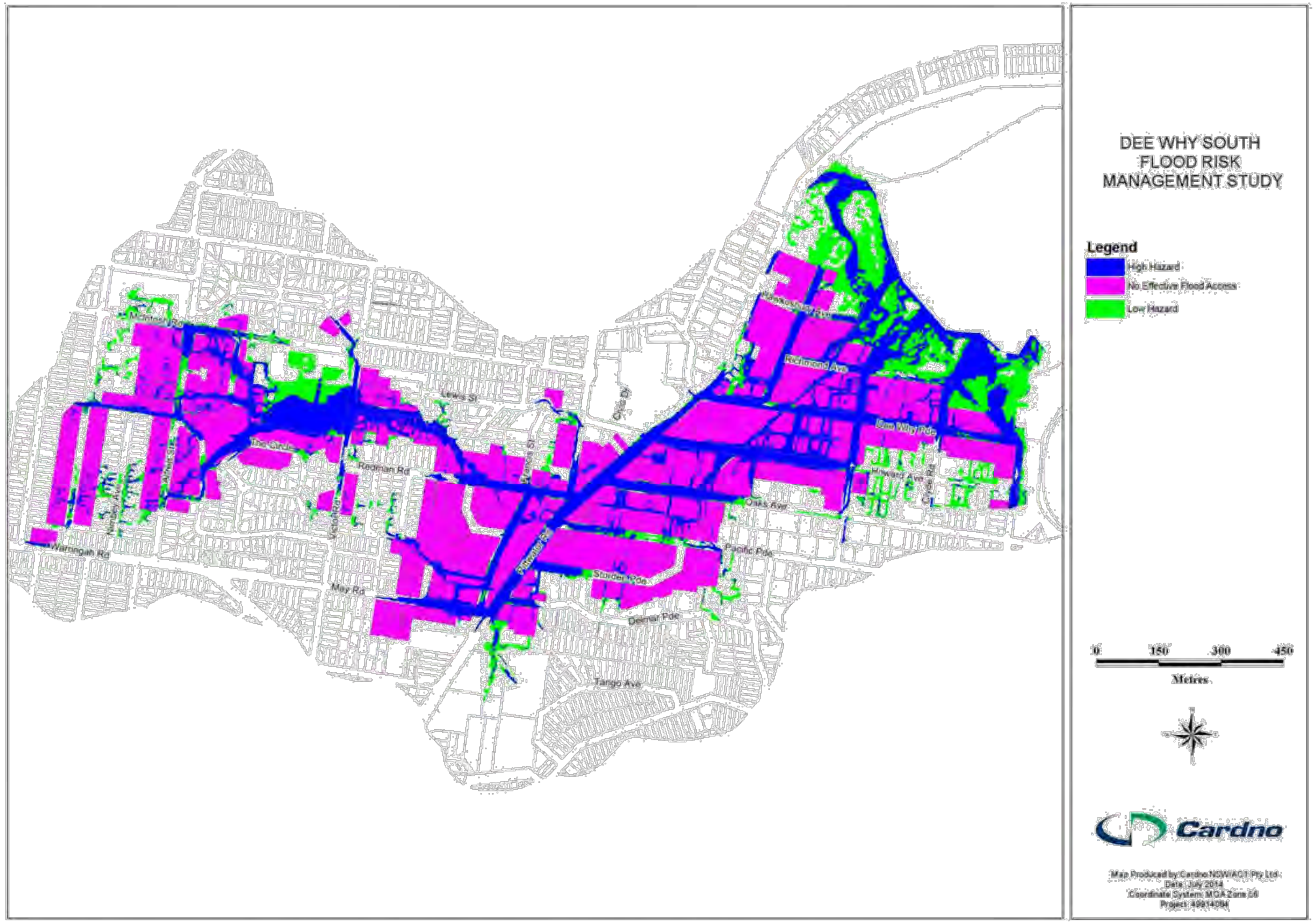


Figure 5-9 Probable Maximum Flood True Flood Hazard – Existing Conditions

5.4.4 Property Flooding

The number of properties affected by flooding (by inundation of at least the garden area) in the Dee Why South Catchment is shown for the modelled flood events in **Table 5-1**.

Table 5-1 Properties Currently Affected by Flooding

Flood Event	No. Flood Affected Properties
5 years ARI	1,219
10 years ARI	1,471
20 years ARI	1,626
100 years ARI	2,089
PMF	4,538

**Based on 0.15 m filtered extents from the Flood Study (Cardno, 2013). Note that if a property is subdivided this may be considered twice within the above calculation.*

5.4.5 Major Access Road Flooding

Several major access roads experience flooding in the Dee Why South Catchment (**Figure 2-2**) including:

- Redman Road;
- Mooramba Road;
- Pittwater Road;
- Oaks Avenue;
- Howard Avenue; and
- Dee Why Parade.

Redman Road is located immediately downstream of the open channel system running through properties on Lewis Street and Dela Close. At the end of the open channel, where it reconnects to the underground stormwater network, a significant reduction in flow capacity occurs. As a result, storm events greater than the 10 years ARI event will result in inundation of the local area.

Mooramba Road is located slightly off the main overland flow path; however, when the capacity of the underground pipes is exceeded, floodwater surcharges onto Mooramba Road and are conveyed north to Redman Road to join into the main overland flow path. Flows along Mooramba Road are predominantly contained within the roadway.

The main overland flow path is via Pittwater Road. Flows from the west of the catchment run down Redman Road and converge with flows from the southern portion of the catchment at the intersection of Pittwater Road and Redman Road. Significant road and property inundation occurs in events greater than the 5 years ARI. The main overland flow path splits off Pittwater Road into both Oaks Avenue and Howard Avenue.

Oaks Avenue is subject to flooding from both the main overland flow path and from overland flow originating at Pacific Parade. Significant inundation occurs to both roadway and properties during the 100 years ARI event. This flow is then conveyed down a drainage reserve opposite the Woolworths on Oaks Avenue.

Howard Avenue is significantly affected by floodwaters. The two main overland flow paths (from Pittwater Road and Oaks Avenue) re-converge at the drainage reserve at 29 Howard Avenue and then travels via the preferential overland flow path in an easterly direction, inundating 46-48 Howard Avenue. In low frequency ARI events the drainage reserve opposite 29 Howard Avenue is also subject to inundation.

Downstream of Dee Why Parade the drainage reserve is formalised into an open channel. Dee Why Parade is inundated primarily at the intersection of Avon Road, where the overland flow from the flow path west of Avon Road is present. In more frequent ARI events this flow is predominantly in the road, diverting down Avon Road to Dee Why Lagoon Wildlife Refuge at the downstream end of the catchment.

Peak depths and durations of inundation (greater than 0.15m depth) are summarised in **Table 5-2** for the critical access points shown in **Figure 5-10**.

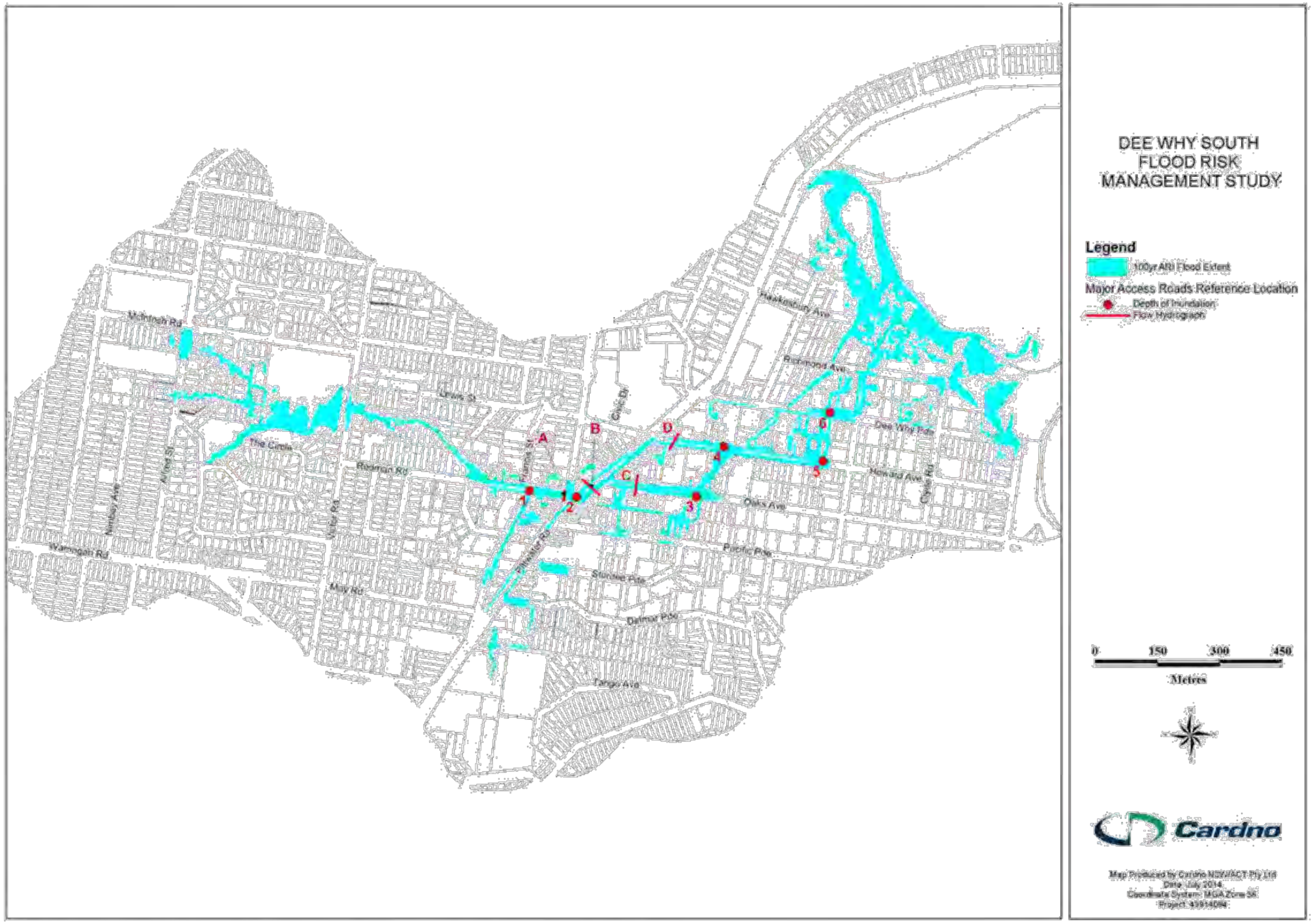


Figure 5-10 Major Access Road Flooding Showing Reference Locations

In order to evaluate the rate of rise, peak flow rates and the time to peak were assessed at the reference locations shown in **Figure 5-10**:

> A = Redman Road;
> B = Pittwater Road (north of Redman Road);
> C = Oaks Avenue (east of Pittwater Road); and
> D = Howard Avenue (east of Pittwater Road).

Figure 5-11 shows the time for runoff flows to occur at these locations in a 100 years ARI event (60 minute critical duration). As flow is a relationship between flow area and velocity, it can be assumed that as flow increases, the risk to life also increases. **Table 5-3** shows the average rate of rise at key locations. Note that the rate of rise shown is an estimate only, based on the time to peak flow and the peak depth achieved.

Table 5-2 Depth and Duration of Inundation – Major Access Roads

Location (as per Figure 5-10)	PMF*	100 yr ARI	20 yr ARI	10 yr ARI	5 yr ARI
Corner of Mooramba Road and Redman Road (1)					
Peak depth (m)	0.90	0.25	0.20	0.20	0.15
Duration (mins)	>90	55	25	25	20
Corner of Pittwater Road and Redman Road (2)					
Peak depth (m)	1.35	0.60	0.50	0.45	0.35
Duration (mins)	>90	60	30	30	25
Oaks Avenue Outside Woolworths (3)					
Peak depth (m)	1.30	0.55	0.45	0.45	0.45
Duration (mins)	>90	95	95	80	60
26 Howard Avenue (4)					
Peak depth (m)	1.35	0.50	0.35	0.30	0.20
Duration (mins)	>90	60	30	15	10
Howard Avenue west of Avon Street (5)					
Peak depth (m)	1.70	0.60	0.50	0.50	0.45
Duration (mins)	>90	55	40	25	20
Dee Why Parade west of Avon Street (6)					
Peak depth (m)	1.55	0.50	0.35	0.30	0.20
Duration (mins)	>90	55	30	15	10

**The PMF event critical duration is 90 minutes however the hydraulic model was not run for sufficient time to determine the drain time for the system.*

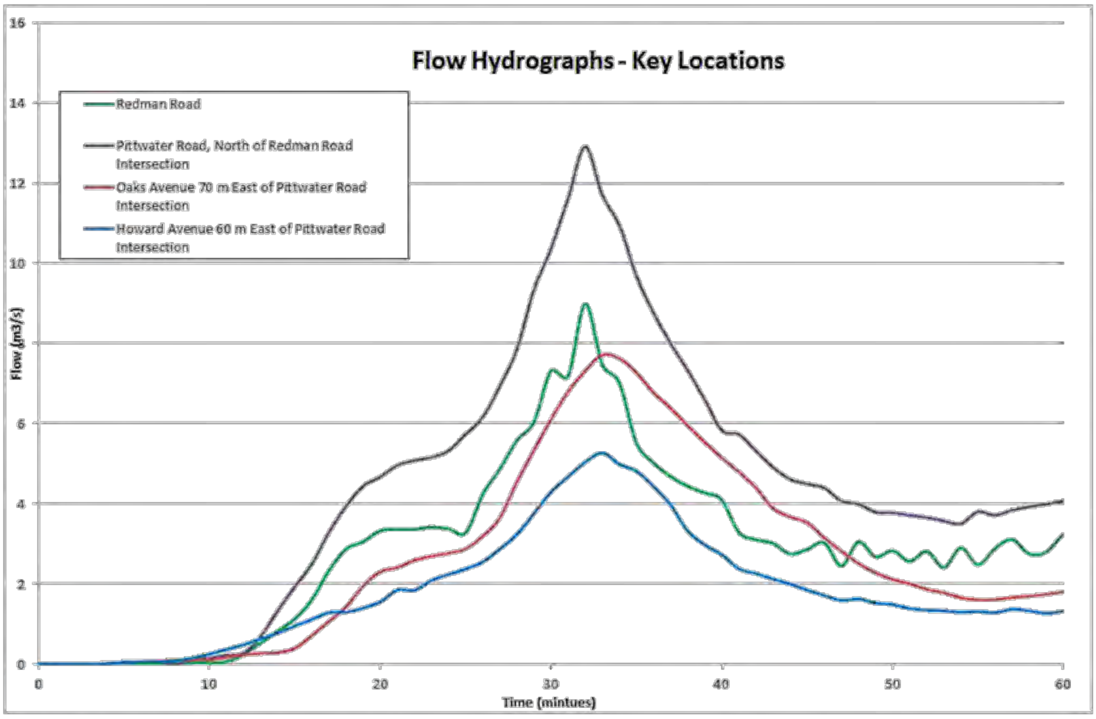


Figure 5-11 Flow Hydrographs at Major Access Roads – 100 years ARI Event

Table 5-3 Average Rate of Rise – 100 years ARI

Reference Location (as per Figure 5-10)	Average Rate of Rise (m/hr)
Corner of Mooramba Road and Redman Road (1)	0.60
Corner of Pittwater Road and Redman Road (2)	1.60
Oaks Avenue outside Woolworths (3)	1.40
26 Howard Avenue (4)	1.40
Howard Avenue west of Avon Street (5)	1.65

5.4.6 Evacuation Route Flooding

When considering the safety of people negotiating floodwaters or flooded streets, vehicle stability becomes a significant concern, along with loss of access / egress due to inundation of access roads.

To quantify dangerous overland flow conditions, Australian Rainfall and Runoff (ARR) guidelines (IEAust, 1987) state that "to prevent pedestrians being swept along streets and other drainage paths during major storm events, the product of velocities (V) and depths (D) in streets and major flow paths generally should not exceed D x V = 0.4 m^2/s". As such, provisional flood hazard (see **Section 5.4.1**) is a key consideration in evacuation planning.

ARR Project 10 "Appropriate Safety Criteria for People" Stage 1 Report (IEAust, 2010) lists guideline values for pedestrian safety based on the velocity-depth product of overland flows (**Figure 5-12**).

DV (m^2s^{-1})	Infants, small children (H.M ≤ 25) and frail/older persons	Children (H.M = 25 to 50)	Adults (H.M > 50)
0	Safe	Safe	Safe
0 – 0.4	Extreme Hazard; Dangerous to all	Low Hazard[1]	Low Hazard[1]
0.4 – 0.6		Significant Hazard; Dangerous to most	
0.6 – 0.8		Extreme Hazard; Dangerous to all	Moderate Hazard; Dangerous to some[2]
0.8 – 1.2			Significant Hazard; Dangerous to most[3]
> 1.2			Extreme Hazard; Dangerous to all

[1] Stability uncompromised for persons within laboratory testing program at these flows (to maximum flow depth of 0.5 m for children and 1.2 m for adults and a maximum velocity of 3.0 ms^{-1} at shallow depths).
[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})

**H.M = the product of the individuals height in metres and their weight in kilograms.*

Figure 5-12 Pedestrian Safety Criteria (after ARR Project 10; IEAust, 2010)

The safety and stability of people in floodwaters may also be compromised by other factors, including uneven and slippery obstacles, floating debris, waves generated by passing vehicles, low temperature, poor visibility, strong wind, clothing and footwear, as well as physique.

ARR Project 10 Appropriate Safety Criteria for Vehicles Stage 2 Report (IEAust, 2011) reviewed available experimental and analytical data for stationary vehicle stability. **Table 5-4** lists draft interim criteria for stationary vehicle stability (noting they are recommended for review following further testing).

Figures 5-13 to **5-16** show flood extents for roads that have a depth of inundation greater than 0.3 m in the 5 years ARI, 20 years ARI, 100 years ARI and PMF events. Similarly, **Figures 5-17** to **5-20** show roads inundated with a velocity-depth product and depth higher than the criteria presented in **Table 5-4**. These figures show locations where vehicle instability has potential to become an issue during a flood event.

These figures show that hazardous conditions that may result in vehicles becoming unstable occur even in small events like the 5 years ARI (**Figures 5-13** and **5-17**), and that large sections of roadway may become impassable in larger flood events such as the 100 years ARI (**Figures 5-15** and **5-19**). The lack of access and egress via these roadways represents a significant risk for people trapped in these areas, especially if they attempt to negotiate the floodwaters, whether by foot or in a vehicle. These locations would also be difficult for emergency services to access during a flood event.

Proposed *DRAFT INTERIM* criteria for stationary vehicle stability

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 = 3ms^{-1}; [3] at low depth

Table 5-4 Vehicle Stability (ARR Project 10; IEAust, 2011)

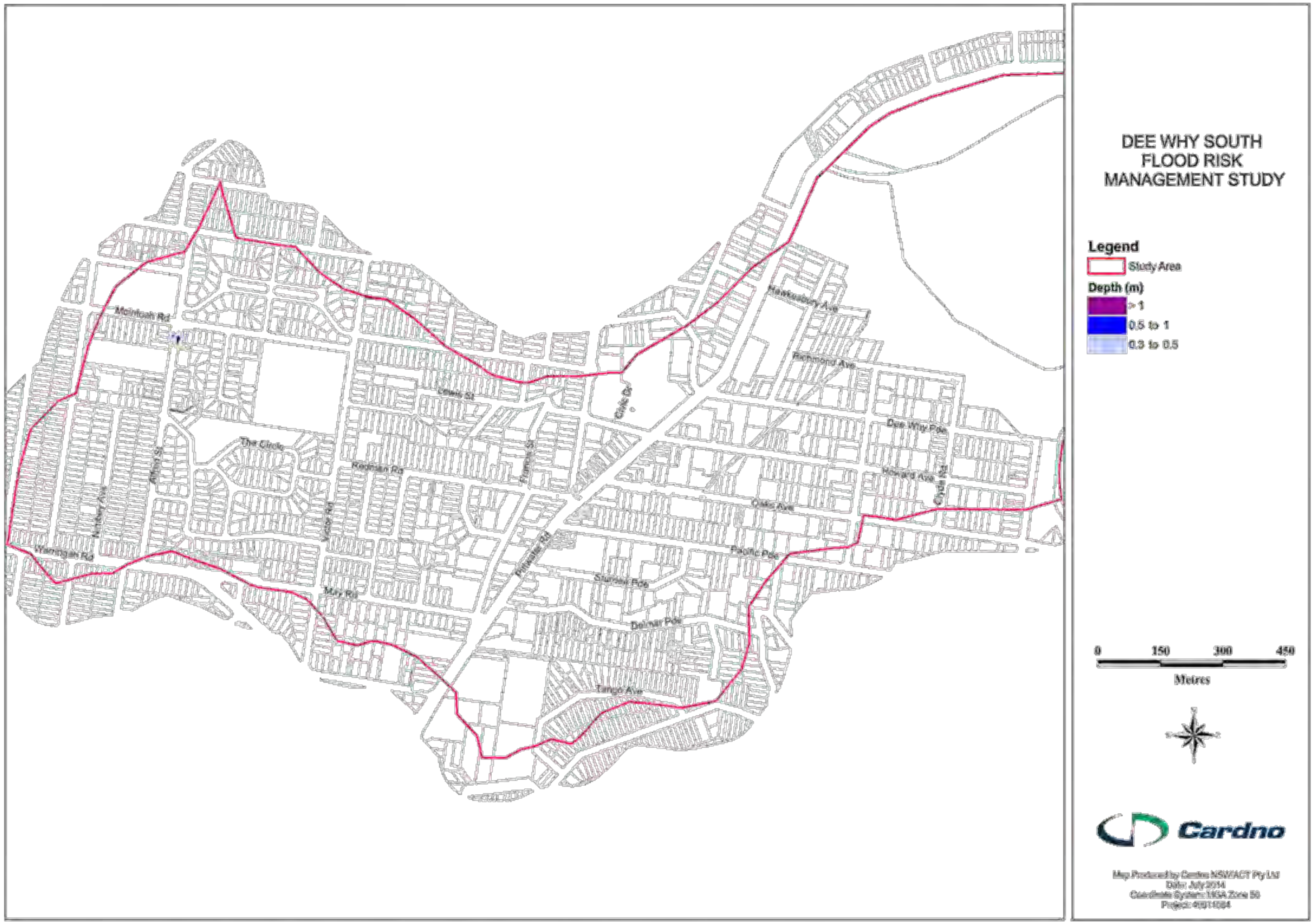


Figure 5-13 Inundation Depth for Access Roads – 5 years ARI

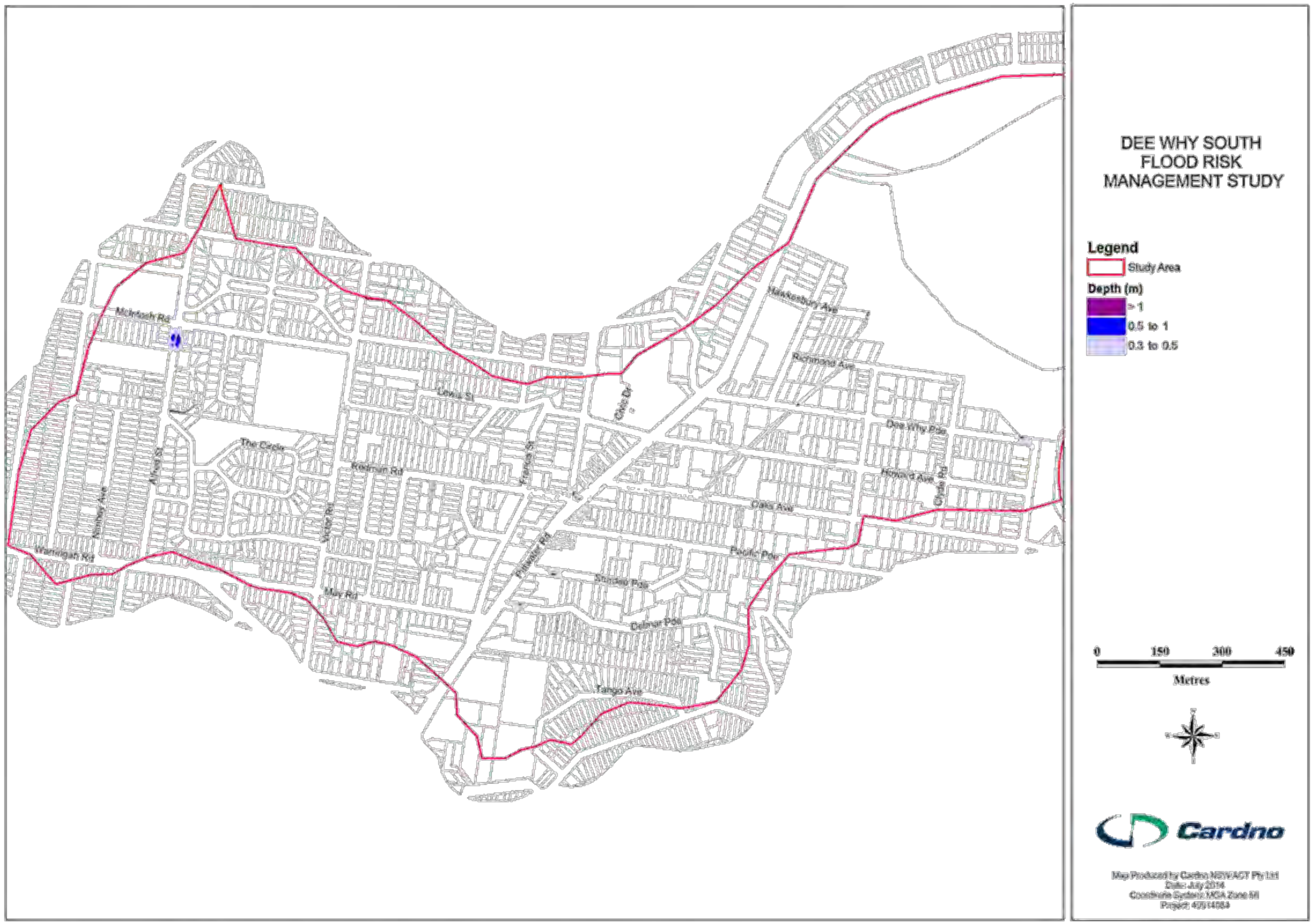


Figure 5-14 Inundation Depth for Access Roads – 20 years ARI

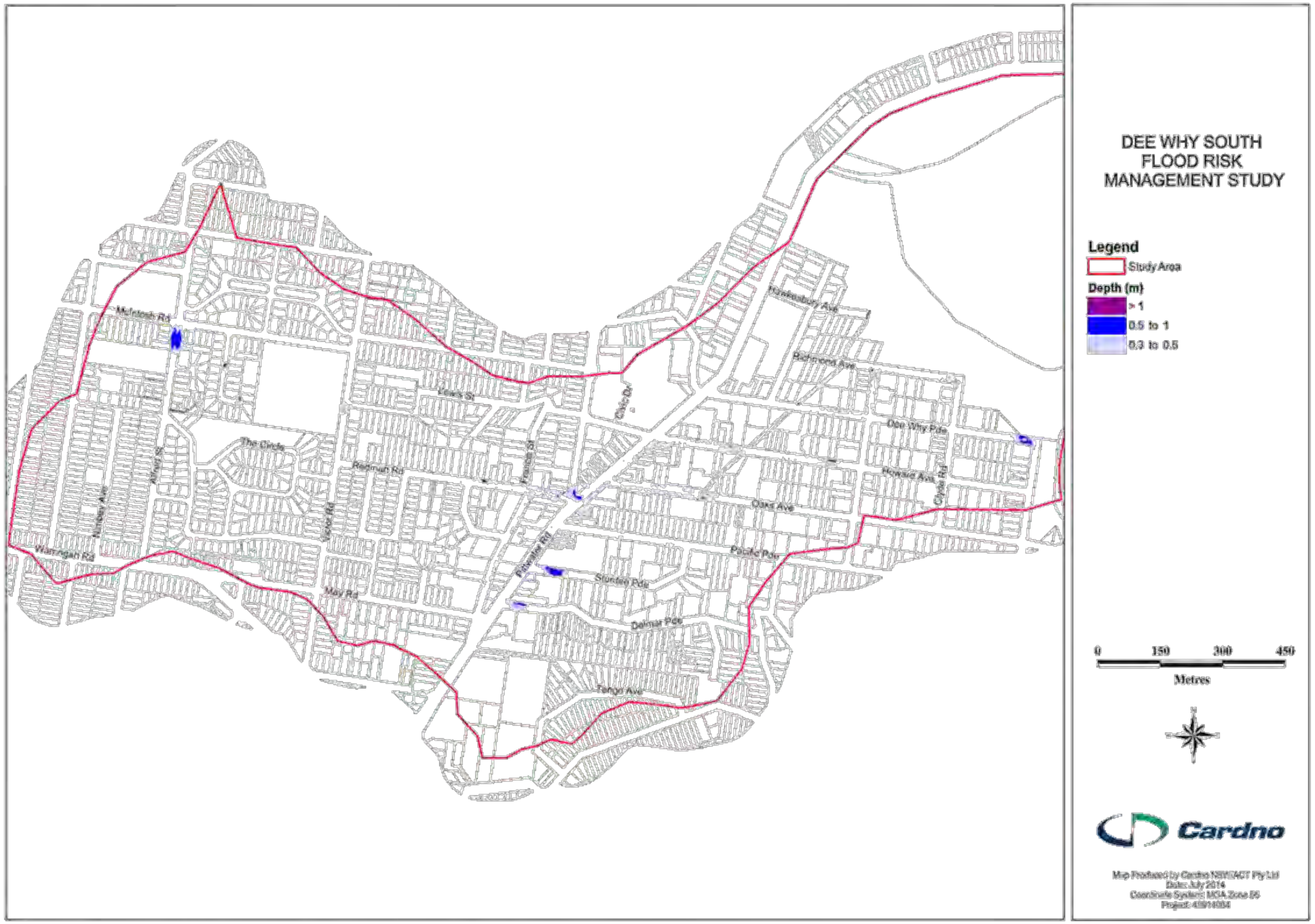


Figure 5-15 Inundation Depth for Access Roads – 100 years ARI

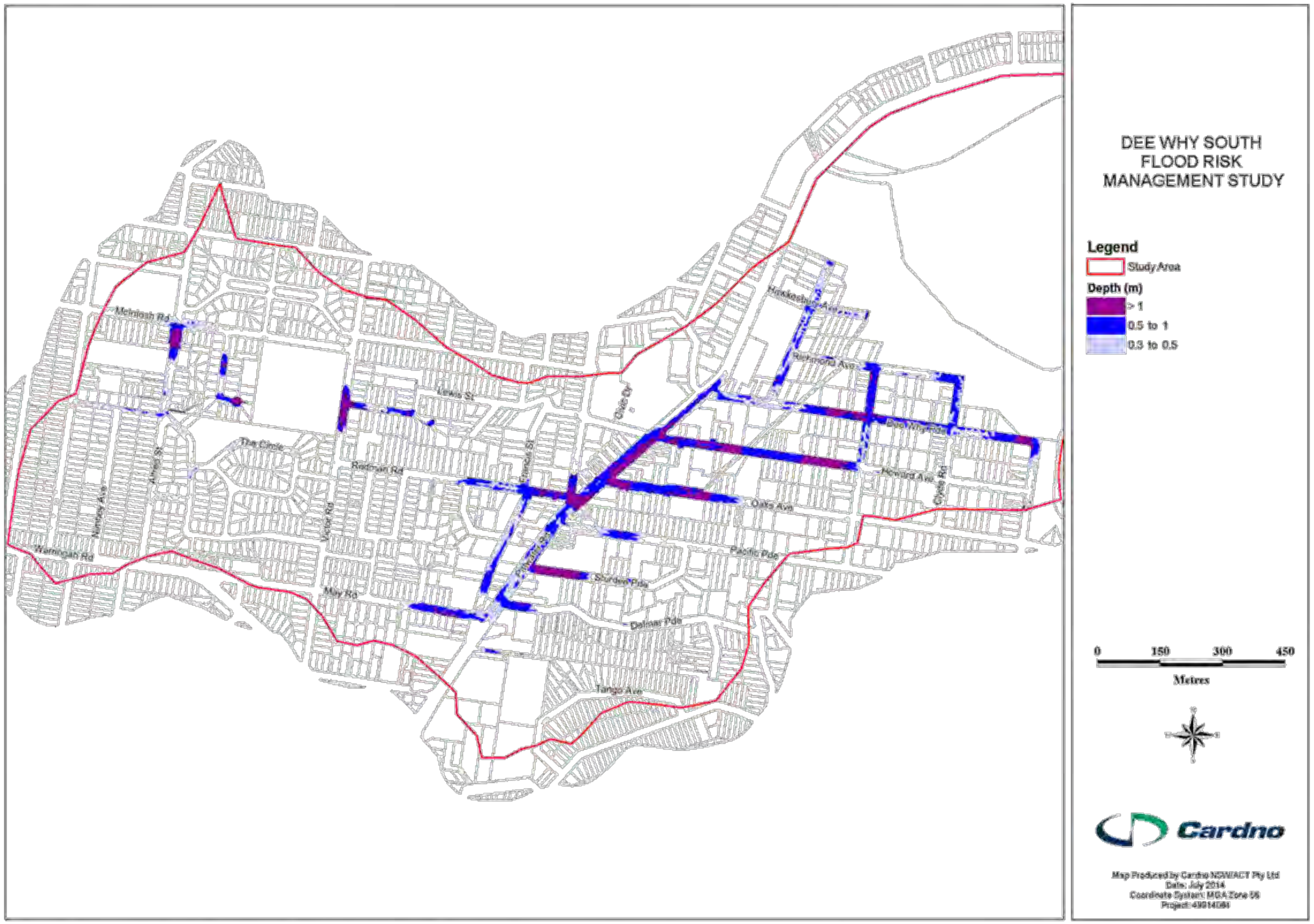


Figure 5-16 Inundation Depth for Access Roads – PMF

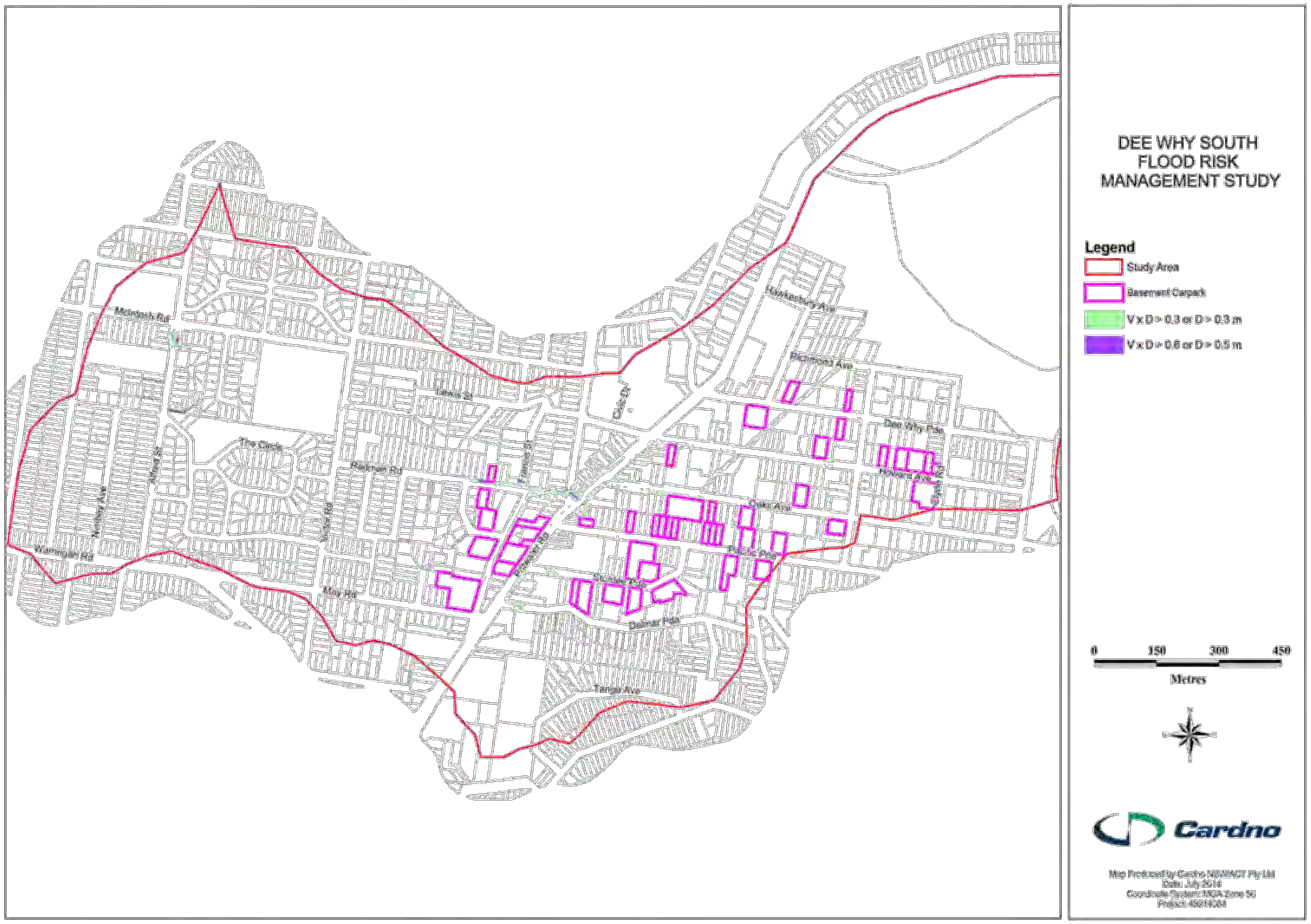


Figure 5-17 Velocity-Depth Product for Access Roads – 5 years ARI

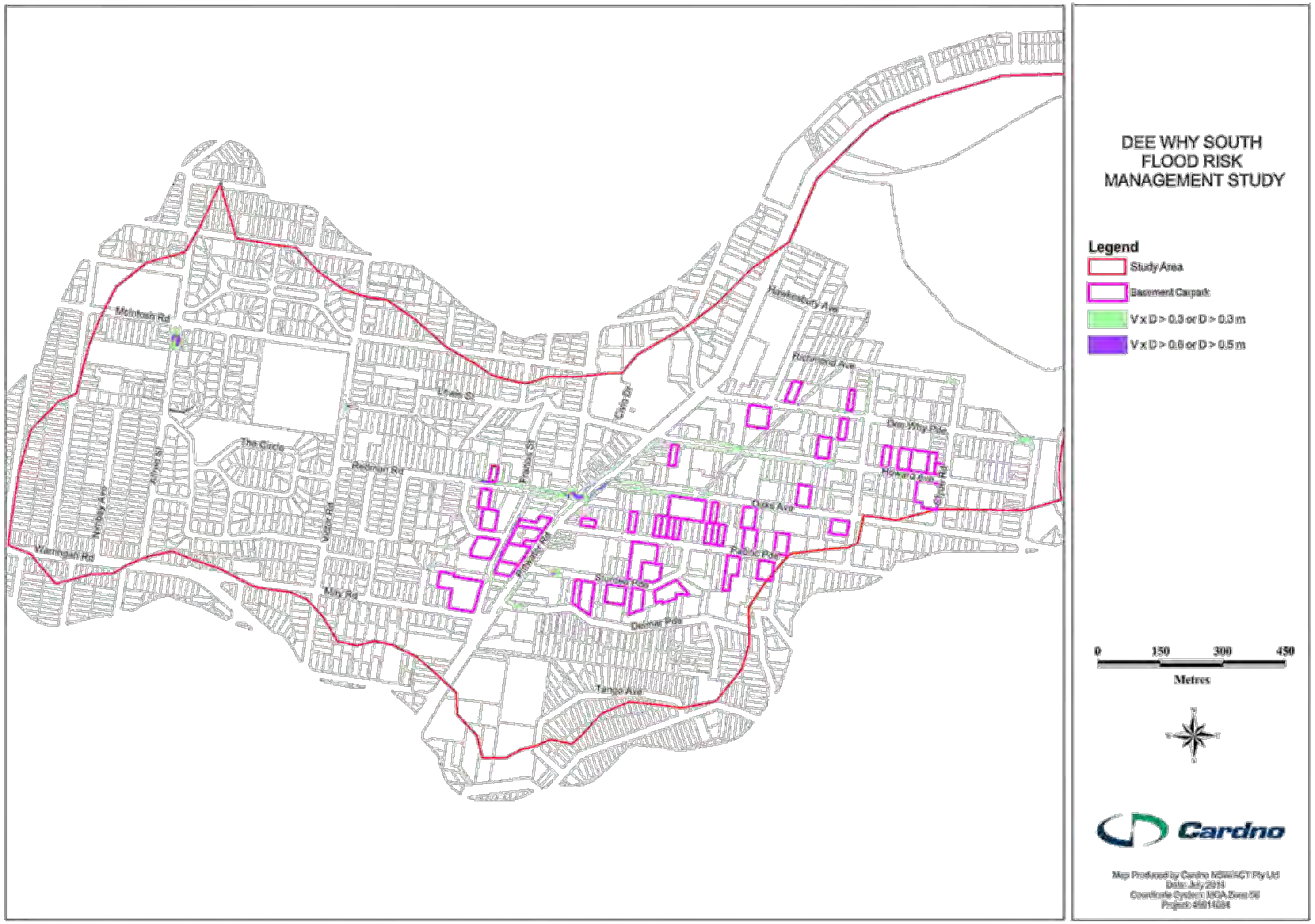


Figure 5-18 Velocity-Depth Product for Access Roads – 20 years ARI

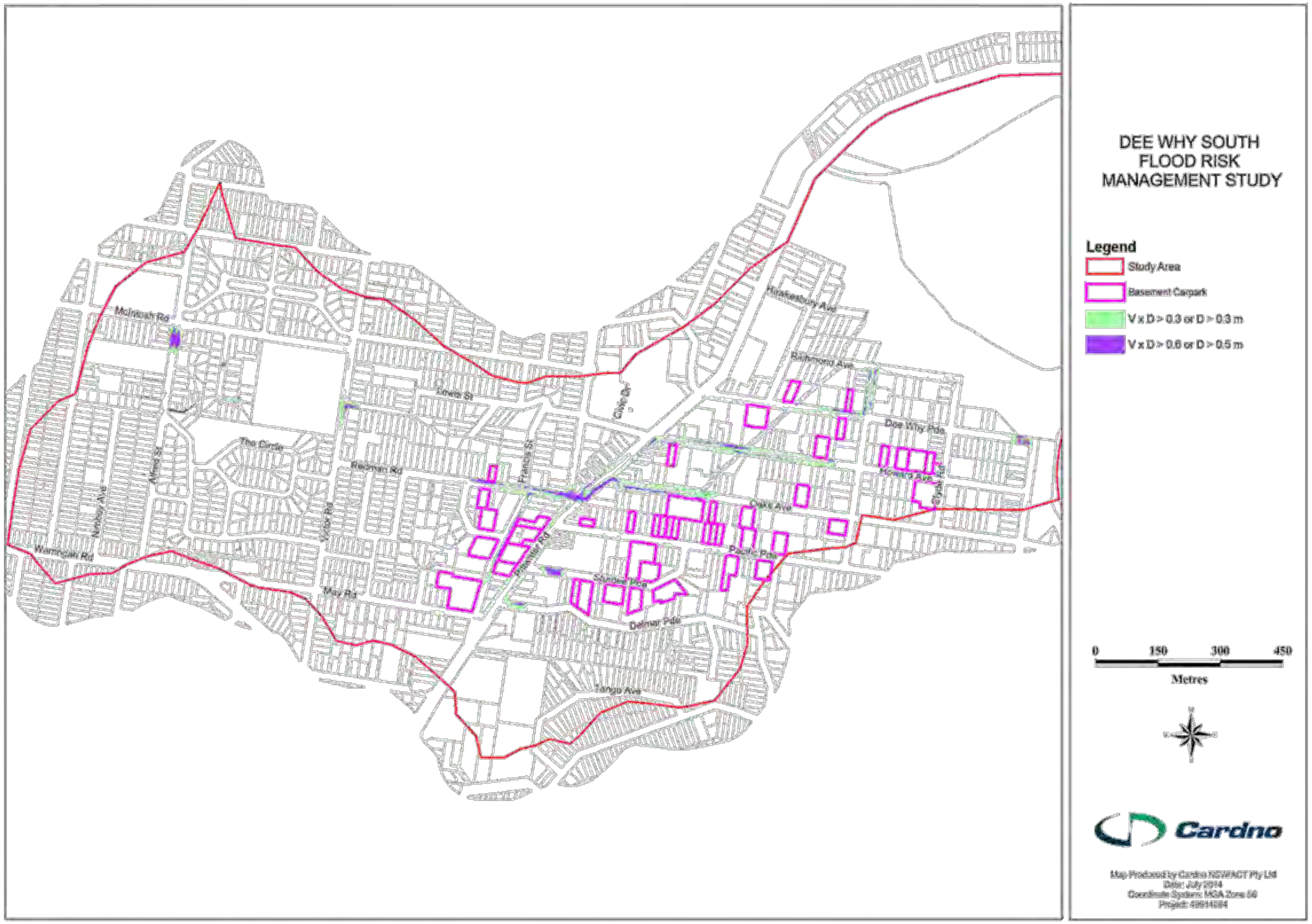


Figure 5-19 Velocity-Depth Product for Access Roads –100 years ARI

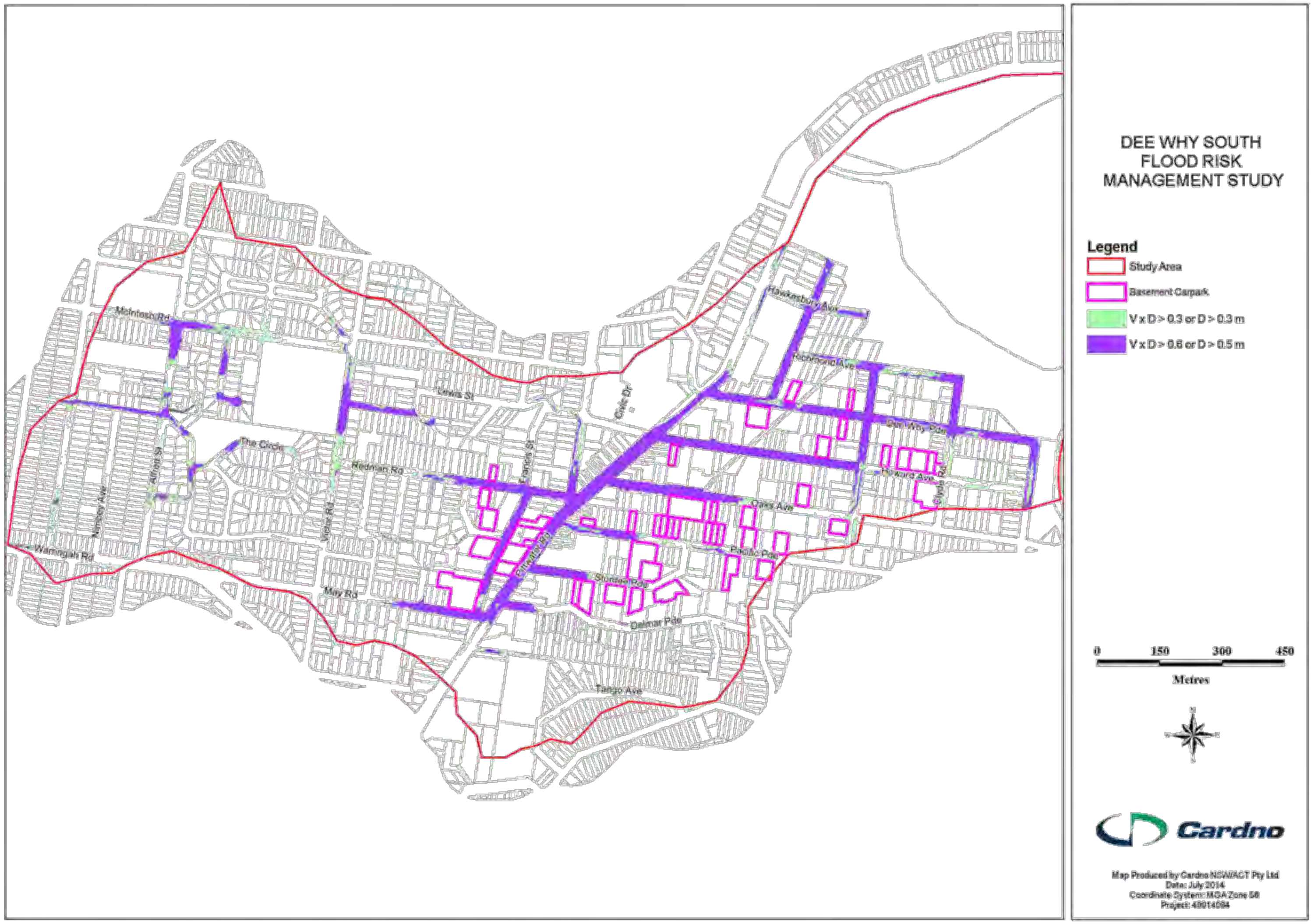


Figure 5-20 Velocity-Depth Product for Access Roads – PMF

Also of interest with respect to the depth of inundation is the prevalence of basement (i.e. below ground level) car parks, especially in the Dee Why Town Centre (see pink lines on **Figures 5-17** to **5-20**). There is potential for basement car parks to become inundated with floodwaters that drain from street level, and this can represent a hazard to any people using the car park, particularly in the event vehicles are destabilised and moved around by the floodwaters.

5.4.7 Critical Infrastructure

Critical infrastructure and vulnerable developments in the catchment that may have implications for the emergency response or require special attention during a flood event were identified based on a desktop review. Critical infrastructure includes utilities that are important to maintain, such as sewage pumping stations and electricity sub-stations. Vulnerable developments are those that may require additional effort in the case of an evacuation, including aged care facilities, schools and childcare centres. Facilities such as hospitals are particularly vulnerable as it there is a need to ensure ongoing service and access to medical facilities during a flood event, in addition to which they are very difficult facilities from which to affect an evacuation.

Figures 5-21 and **5-22** show the locations of these identified critical infrastructure and the modelled extent of the 100 years ARI and PMF events respectively. In the 100 years ARI flood event critical infrastructure and vulnerable developments are not located within the flood extent or cut off during a flood. However, an aged-care facility (on McIntosh Road) is shown with overland flooding through the site. Some of the sites unaffected by a 100 years ARI event are subject to overland flows in a PMF event. A significant proportion of access roads to the facilities are also inundated in a storm event of this magnitude. The net result is that many of these facilities would become inaccessible by road during a PMF event. Thus evacuation may not be possible and the best recommendation may be to seek refuge in the building (shelter-in-place). A detailed survey of individual properties would be required to evaluate the availability of refuges above the PMF level.

Sydney Water has several critical assets in the catchment. Of the assets identified by Sydney Water for purposes of this study, only one service is above ground and at risk of flooding; a pump station located at the northern end of Clarence Avenue (**Figures 5-21** and **5-22**). During the 100 year ARI event, the pump station is unaffected, however the site is subject to some inundation in the PMF event.

Jemena holds significant infrastructure within the Dee Why South Catchment; however no above-ground infrastructure was identified during a review of the information provided.

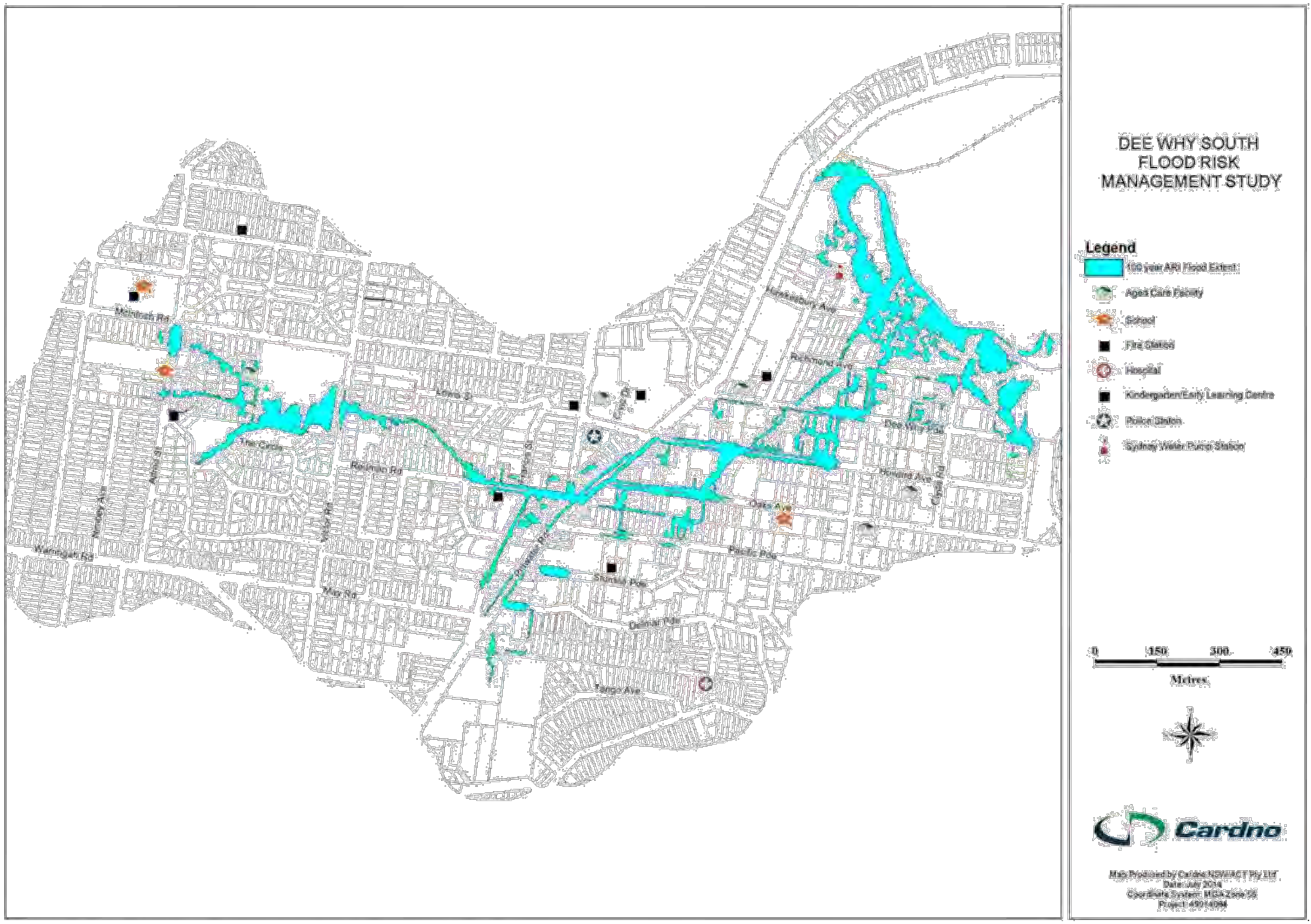


Figure 5-21 Critical Infrastructure – 100 years ARI Extent

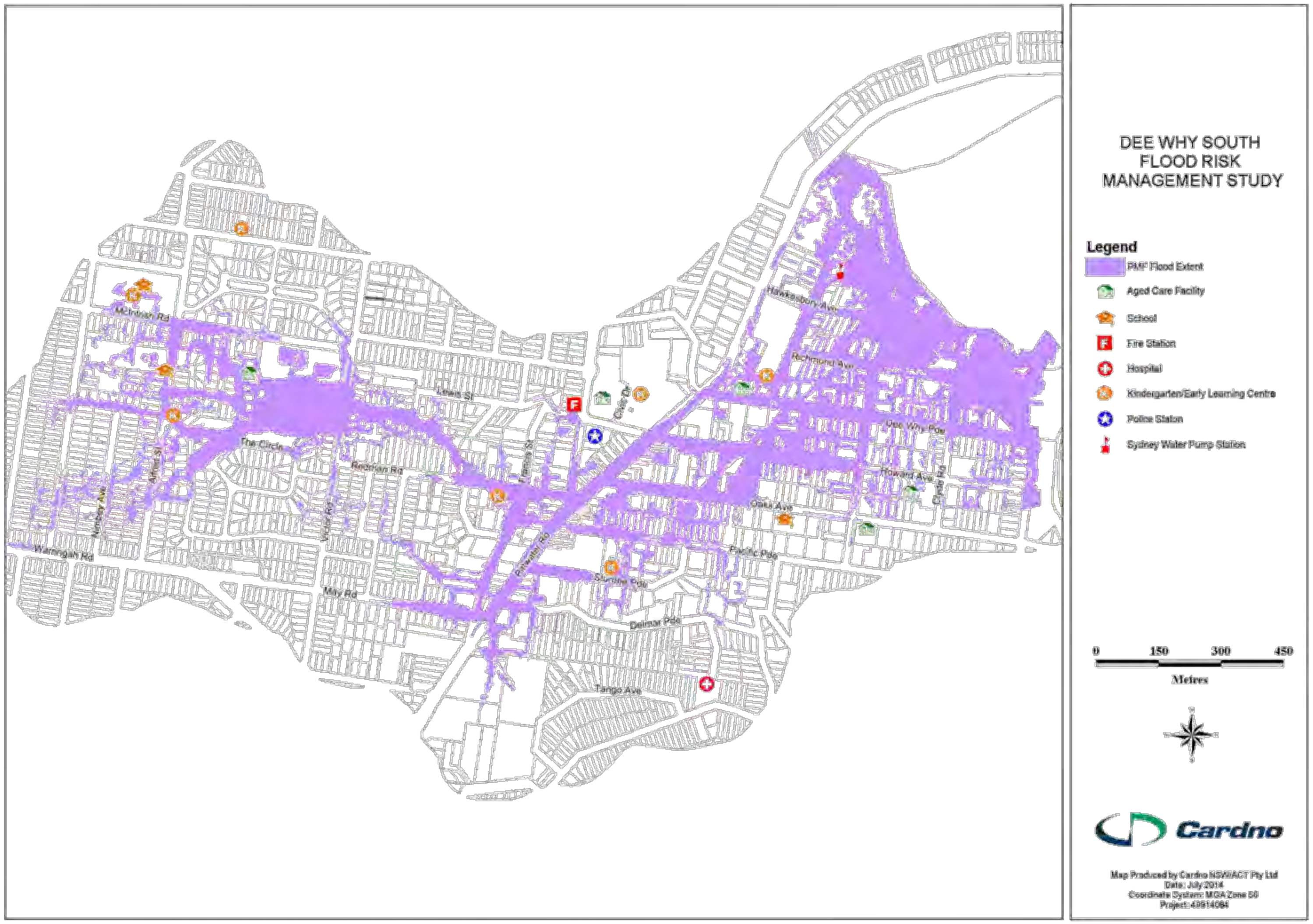


Figure 5-22 Critical Infrastructure – Probable Maximum Flood Extent

6 Economic Impact of Flooding

6.1 Background

In the past, flooding in the Dee Why South Catchment has caused property damage, blocked access and inconvenienced members of the community.

The economic impact of flooding can be defined by what is commonly referred to as "flood damages". Flood damages are classified into different categories, which are summarised in **Table 6-1**.

Table 6-1 Flood Damages Categories

Type of Flood Damage	Description
Direct	Building contents (internal) Structure (building repair and clean) External items (vehicles, contents of sheds etc.)
Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible	Social – increased levels of insecurity, depression, stress General inconvenience in post-flood stage

Direct damages, as indicated in the above table, are just one component of the entire cost of a flood event. There are also indirect costs. Both direct and indirect costs are referred to as 'tangible' costs. In addition there are also 'intangible' costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs, which are difficult to calculate in economic terms.

Flood damages can be assessed by a number of methods, including the use of computer programs such as FLDAMAGE or ANUFLOOD, or via more generic methods using spreadsheets. For the purposes of this project, generic spreadsheets have been used with assistance from the Office of Environment and Heritage (OEH) on the adoption of appropriate damage curves.

6.2 Floor Level and Property Survey

Floor level survey data utilised for the flood damages estimation comprises the survey data provided by Council (see **Section 3.2.3 and Figure 3-1**). The floor levels for 367 properties, defined by "FL" within the dataset, were extracted for use within this assessment. While all properties located within the catchment were not captured as part of the floor level survey, the available data is concentrated in the flood affected areas and is considered a sufficient sample size for the preliminary damages analysis.

Some modifications were made to floor level locations for calculation of the flood damages. For example, a slight offset was incorporated to allow the point to be intersected by the flood extent.

6.3 Damages Analysis

A flood damages assessment for the existing condition has been undertaken as part of the current study. It is based on damage curves that relate the depth of flooding on a property, and hence to the potential damage within that property.

Ideally, the damage curves should be prepared for the specific catchment for which the study is being carried out. However, this data is not available for most catchments and re-course is generally made to damage curves developed for other catchments. OEH has carried out research and prepared a draft methodology on developing damages curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties.

Whilst the OEH methodology is draft only, there are currently no strict guidelines regarding the use of damage curves in NSW, the OEH curves are typically adopted for such studies.

Sections 6.3.1-6.3.4 set out the methodology for the determination of damages within the Dee Why South Catchment.

Note: At time of writing of the report, the most up to date Average Weekly Earnings (AWE) used for the calculation within residential damage curves was November 2013. The most up to date Consumer Price Index (CPI) used within commercial and industrial damage curves was March 2014.

6.3.1 Residential Damage Curves

The draft *Floodplain Management Guideline No. 4 Residential Flood Damage Calculation* (DNR, 2004) was used in the creation of the residential damage curves. These guidelines include a template spreadsheet that determines damage curves for three types of residential buildings:

> Single storey, slab-on-ground;

> Two storey, slab-on-ground; and

> Single storey, high-set (i.e. on piers).

Two types of these properties were adopted for this study, including the single storey slab-on-ground and the two storey slab-on-ground. No single storey high-set houses were identified in the survey therefore no additional costs were apportioned based on these land uses. Apartment and multi-unit buildings are prevalent in the catchment, however no classification is included in the standard damage curves for such developments, and so apartment buildings are typically allocated to one of the two selected categories (noting that flooding would generally be confined to the ground floor).

Damages are generally incurred on a property prior to any over-floor flooding. The OEH curves allow for a damage of $11,048 (November 2013 dollars) to be incurred when the water level reaches the base of the house (the base of the house is estimated as 0.3 m below the floor level for slab on ground). Damages of this type are generally direct external damages (sheds, gardens), direct structural damages (foundational damage) or indirect damages (garden amenity and debris clean-up). According to the damage curves this amount of damages remains constant from the base of the house to the floor level of the house.

A nominal $1,000 of garden damage was assumed once overground flooding was present within a property. This amount is indicative that minor works may be required following a flood event, such repair to garden beds, mulch and plant replacement, damage to garden furniture, or minor fence repairs.

There are a number of input parameters required for the OEH curves, such as floor area and level of flood awareness. The following parameters were adopted:

> Based on interrogation of the aerial photos a value of 200 m^2 was adopted as a conservative estimate of the floor area for residential dwellings for the floodplain. With a floor area of 200 m^2, the default contents value is $82,500 (November 2013 dollars);

> The effective warning time has been assumed to be zero due to the nature of flooding (i.e. flash flooding) and absence of any flood warning systems in the catchment. A long effective warning time allows residents to prepare for flooding by moving valuable household contents (e.g. the placement of valuables on top of tables and benches); and

> The Dee Why South Catchment is located in a large metropolitan area, and as such post-flood inflation is unlikely. These inflation costs are generally experienced in remote areas, where re-construction resources are limited and large floods can cause a strain on these resources.

6.3.2 Average Weekly Earnings

The OEH curves are derived for late 2001, and were updated to represent November 2013 dollars. Generally OEH recommends adjusting values in residential damage curves by Average Weekly Earnings (AWE), rather than by the inflation rate as measured by the Consumer Price Index (CPI). OEH proposes that AWE is a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home. The most recent data for AWE from the Australian Bureau of Statistics at the time of the assessment was for November 2013. Therefore all ordinates in the residential flood damage curves were updated to November 2013 dollars.

While not specified, it has been assumed that the curves provided by OEH were derived in November 2001, which allows the use of November 2001 AWE statistics (issued quarterly) for comparative purposes. The November 2001 AWE is shown in Table D1 of the OEH guidelines, and the November 2013 AWE were taken from the Australian Bureau of Statistics website (www.abs.gov.au) (see **Table 6-2**). Based on this comparison, all ordinates on the OEH damages curves were increased by 65%.

Table 6-2 AWE Statistics for Residential Damage Curves

Month	Year	AWE (excl. GST)
November	2001	$676.40
November	2013	$1,115.40
Change	**65%**	

6.3.3 Commercial Damage Curves

Commercial damage curves have been adopted from the FLDamage Manual (Water Studies Pty Ltd, 1992), which allows for three types of commercial properties:

> Low value commercial;

> Medium value commercial; and

> High value commercial.

In determining the commercial damage curves, it has been assumed that the effective warning time is approximately zero, and the loss of trading days as a result of the flooding has been taken as 10 days.

These curves are determined based on the floor area of the property. The floor level survey provides an estimate of the floor area of the individual properties. For some commercial properties without the surveyed floor area, the floor area was estimated from aerial photographs.

The Consumer Price Index (CPI) was used to bring the 1990 data to March 2014 dollars obtained from the Australian Bureau of Statistics website (**Table 6-3**). Based on this comparison, damages have been increased by 83%. GST is not included in these values.

The commercial properties were not classified into different value categories (low, medium, or high) in the survey data provided to Cardno. Given the consumer based nature of the majority of commercial property (restaurants, domestic goods, etc.), medium value was assumed for all commercial properties.

Table 6-3 CPI Statistics for Commercial Damage Curves

Month	Year	CPI
June	1990	102.50
March	2014	188.43
Change	**83%**	

6.3.4 Damage to Vehicles

Damages to vehicles have been estimated through the Dee Why Town Centre in order to quantify the damage to parked vehicles during a flood event. The area between the Mooramba Road car park, Sturdee Parade, Pacific Parade, Oaks Avenue, Howard Avenue and Pittwater Road is considered to have a significant number of parked cars present regardless of the time of day at which flooding may occur. Hence it was assumed through this area that a parking rate of 25% was present.

Based on ANUFLOOD guideline, cars begin to float at depths >0.4 m. It is accepted that flood damaged cars are considered write-offs in most cases. For the purposes of this assessment, it was assumed that any location subjected to >0.5 m depth of inundation would result in irreparable car damage. It was assumed one car occupies an area of approximately 6 m^2.

There is limited literature available on the cost associated with vehicle replacement, so a nominal amount associated with car replacement has been selected. For this analysis a figure of $18,000 (excl. GST) per damaged vehicle was used, based on the average private vehicle net worth across all households in Australia reported by the Australian Bureau of Statistics.

6.4 Adopted Damage Curves

The adopted damage curves are shown in **Figure 6-1**. To normalise the damages for property size, the curves have been factored to account for floor area. The commercial damage curve is for a property with a floor area of 100 m^2.

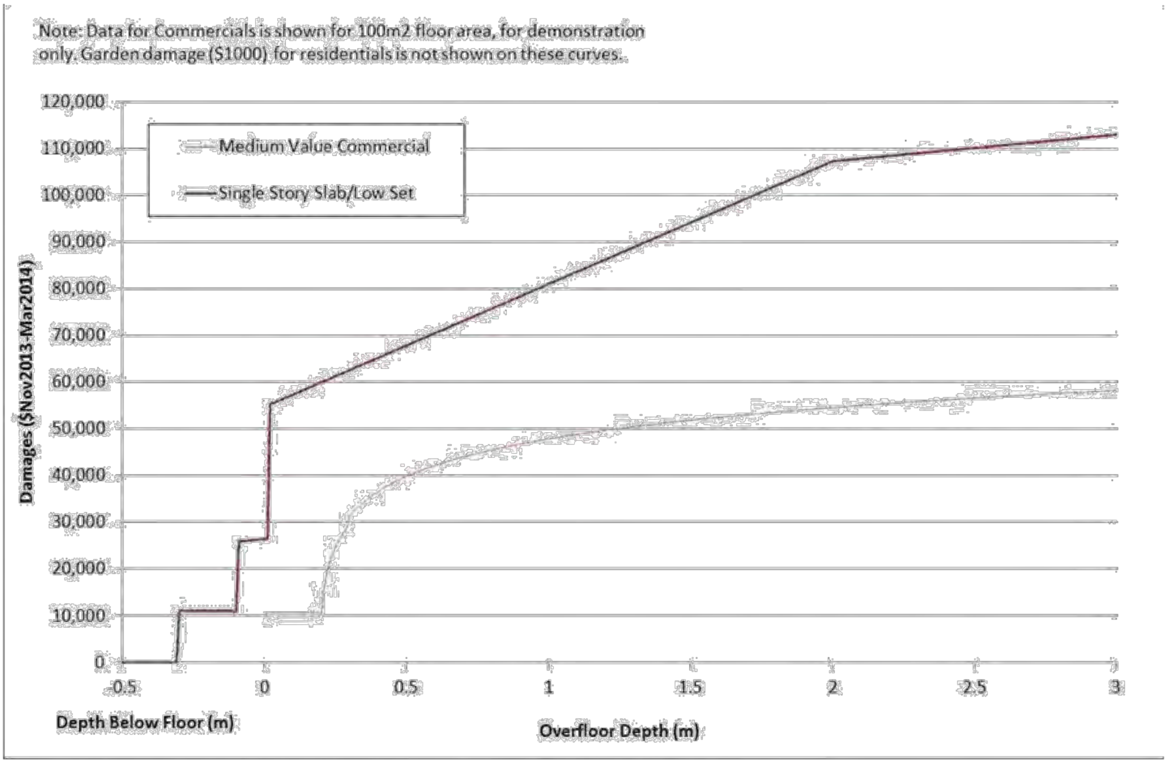


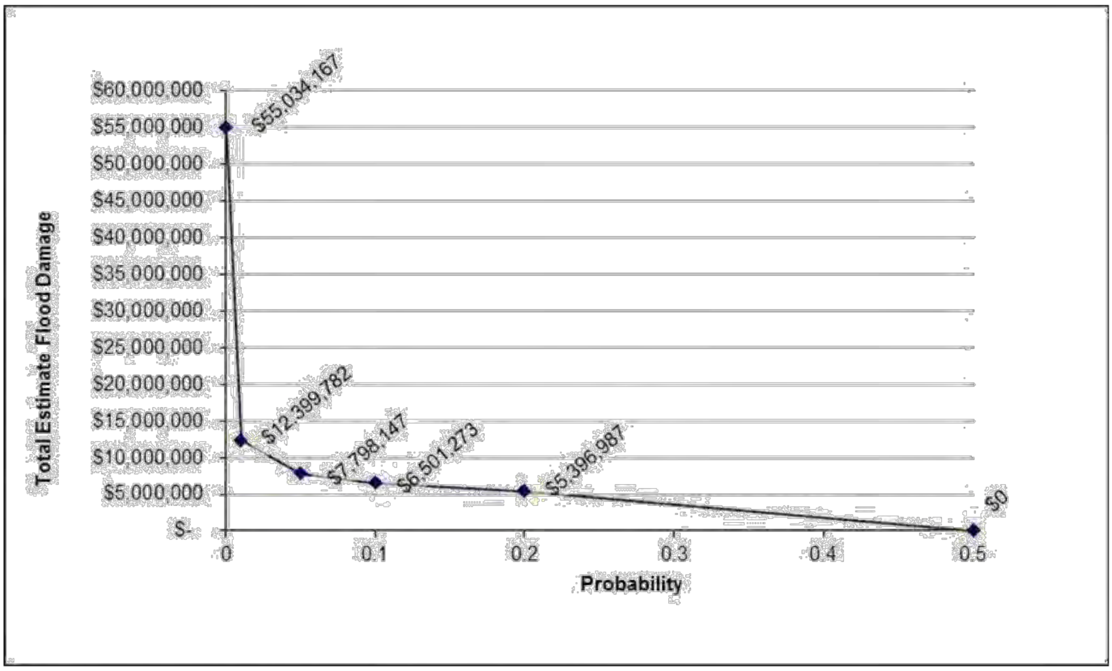
Figure 6-1 Damage Curves Developed for the Dee Why South Catchment

6.5 Average Annual Damages

Average Annual Damages (AAD) are calculated adopting a probabilistic approach, using the flood damages calculated for each design event. AAD is described in Appendix M of the *Floodplain Development Manual* (NSW Government, 2005) as the total damage caused by all floods over a long period of time divided by the number of years in that period. It is intended to quantify the flood damage that a floodplain would receive as an annualised value, that is, the damage on average during a single year.

Flood damages (for a design event) are calculated by using the damage curves described in **Sections 6.3-6.4**. These damage curves define the damage experienced on a property for varying depths of flooding. The total damage for a design event is determined by adding damages incurred at all individual properties for that event.

Figure 6-2 is a probability curve based on the flood damages calculated for each design event. For example, the 100 years ARI design event has a probability of occurring of 1% in any given year, and as such the 100 years ARI flood damage is plotted at this point on the AAD curve (**Figure 6-2**). Other storm events and consequent damage are also plotted and AAD is then calculated by determining the area under this curve. Further information on the calculation of AAD is provided in Appendix M of the Floodplain Development Manual (NSW Government, 2005).



Note: The probability of the PMF occurring is assumed as 0.0001%

Figure 6-2 Average Annual Damages Curve for the Dee Why South Catchment

6.6 Results

Table 6-5 shows the results of the flood damages assessment for the 367 properties for which floor levels were available. Based on the analysis described in **Section 6.3**, the AAD estimated for the surveyed properties in the Dee Why South Catchment floodplain under existing conditions is approximately **$3,852,321** (excl. GST). Potential flood damages for the whole of the Dee Why South Catchment are likely to be higher as only a selection of properties have been surveyed.

As discussed in **Section 6.5**, the AAD reflects the likelihood of each design flood event in one year and the damages likely to occur as a result of that event. Whilst this is a useful tool for evaluating the benefit of flood management options and assessing the flood damage to an area over a long period of time, it is important to note the actual damages estimated to occur as a result of each design flood event. The cost to the community is not incurred as an average annual amount. The costs will be borne at one point in time due to the damage incurred by an individual flood event.

Financial and community attitude surveys and analysis undertaken in other areas of Sydney (e.g. the Hawkesbury Nepean Valley) (Gillespie et al., 2002) suggest that many people would have real difficulties dealing with the cost of recovering from severe flooding.

Table 6-4 Flood Damage Assessment Summary

Property Type	Properties with Overfloor Flooding	Average Overfloor Flooding Depth (m)	Max. Overfloor Flooding Depth (m)	Properties with Overground Flooding	Total Damages ($Mar 2013-May 2013) (ex. GST)
PMF					
Residential	48	1.27	2.73	99	$5,948,384
Commercial	205	1.48	2.86	195	$25,620,695
Public	11	1.38	1.9	11	$245,088
Cars	-	-	-	-	$23,220,000
Total	**264**			**305**	**$55,034,167**
100 years ARI					
Residential	19	0.94	2.56	57	$2,350,844
Commercial	90	0.95	2.53	109	$9,429,782
Public	8	1.04	1.33	8	$169,155
Cars	-	-	-	-	$450,000
Total	**117**			**174**	**$12,399,782**
20 years ARI					
Residential	12	0.98	2.55	44	$1,656,127
Commercial	62	0.73	1.7	93	$5,942,957
Public	6	0.98	1.19	6	$127,063
Cars	-	-	-	-	$72,000
Total	**80**			**143**	**$7,798,147**
10 years ARI					
Residential	9	1.01	2.54	40	$1,324,999
Commercial	55	0.65	1.67	79	$5,034,114
Public	6	0.95	1.16	4	$124,160
Cars	-	-	-	-	$18,000
Total	**70**			**123**	**$6,501,273**
5 years ARI					
Residential	8	1.09	2.52	32	$1,243,274
Commercial	43	0.65	1.37	68	$4,078,236
Public	6	0.48	1.13	4	$75,477
Cars	-	-	-	-	$0
Total	**57**			**104**	**$5,396,987**

7 Emergency Response Arrangements

7.1 Flood Emergency Response

Flooding in the Dee Why South Catchment is the result of flash flooding. That is, flood inundation characteristically occurs quickly resulting in rapid onset of increased flood levels that may be elevated for only short periods of time. The flooding occurs primarily due to runoff from the catchment, rather than inundation from Dee Why Lagoon. This flooding behaviour results in a limited time period in which to provide a flood warning or to arrange for evacuations. In most cases, to shelter-in-place by seeking refuge at a higher level within a building is a more appropriate action.

7.2 Flood Emergency Response Documentation

Flood emergency measures are an effective means of reducing the costs of flooding and managing the continuing and residual risks to the area. There are a number of documents relating to emergency preparedness and response for flood events, including:

> *New South Wales State Emergency Management Plan* (EMPLAN) (MPES, 2012);

> *New South Wales State Flood Sub-Plan* (SES, 2008);

> *State Flood Plan* – Consultation Draft (SES, 2014) – this document will, once finalised, supersede the Flood Sub-Plan (see above);

> NSW SES Region Capability Plan Risk Matrix - This document can be used to identify the level of risk, potential hazards or property damage and help to prioritise any control measures;

> *Guideline on Emergency Planning Response to Protect Life in the Event of Flash Floods* (AFAC, 2013);

> *Manly-Warringah-Pittwater Disaster Plan* (DISPLAN) (SES, 2005);

> *Manly-Warringah-Pittwater Flood Emergency Sub-Plan* (SES, 2013); and

> *North West Metropolitan Emergency Management District DISPLAN* (Interim) (SES, 2011).

Current flood emergency response arrangements for flooding in the Dee Why South Catchment are discussed with reference to the key documents below.

7.2.1 North West Metropolitan Emergency Management District Disaster Plan (DISPLAN)

The North West Metropolitan Emergency Management District covers many local government areas (LGAs) including Warringah, and incorporates areas from the Blue Mountains, Hawkesbury, and Parramatta to the Northern Beaches. The aim of the *North West Metropolitan Emergency Management District DISPLAN* (2011) is for a coordinated and efficient management of the prevention, preparation, response and recovery arrangements for emergencies within the District. It describes the arrangements and agency responsibilities and provides policy direction for the preparation of supporting plans.

The DISPLAN lists significant assets and risks within the District, including:

> Significant connecting Roads – Military / Spit / Pittwater and Barrenjoey Roads.

> Waterways – none.

> Water Storage Areas / Prescribed Dams – none.

> Correctional Centres – none.

> Industry and Critical Infrastructure (e.g. hospitals, universities, shopping complexes) none specifically listed. **Section 5.4.7** of this report discusses critical infrastructure in the catchment.

The primary hazards which could require district level response related to this Floodplain Risk Management Study are listed in **Table 7-1**.

Table 7-1 Primary Hazards

Hazard	Threat level			Comments
	Likelihood	Consequence	Risk Rating	
Severe Storms	Likely	Major	High	General threat throughout the District.
Flash Flood	Likely	Major	High	General threat throughout the District
Riverine Flood	Likely	Major	High	Refer to NSW SES Flood Plans

The agencies, organisations and/or committees with responsibilities to facilitate prevention and mitigation measures in potential flood disaster situations are listed in **Table 7-2**.

Table 7-2 Agencies Responsible for Flood Prevention and Mitigation

Hazard	Agency Responsible	Mitigation / Prevention Strategies
Flood	Local Councils	▪ Regulate property development & building construction through LEPs & DCPs ▪ Development & maintenance of flood mitigation works. ▪ Preparation of floodplain management plans.
	NSW Department of Finance and Services and the EPA	▪ Preparation of mitigation schemes and floodplain management studies and plans.

Responsibility for the conduct and coordination of public education in relation to flooding and severe storm is the NSW State Emergency Service (SES) as listed in **Table 7-3**.

Table 7-3 Agencies Responsible for Public Education on Flooding

Hazard	Agency Responsible
Flooding	NSW SES is responsible for ensuring that residents are aware of the flood threat and how to protect themselves against it.
Severe Storm	NSW SES is responsible for ensuring that the residents of their divisions are aware of the likely effects of storm impact and how to protect themselves against it.

Responsibility for the provision of warnings to the community, participating organisations and other agencies in relation to flood hazards or threats are listed in **Table 7-4**.

Table 7-4 Agencies Responsible for Provision of Warnings for Flood Hazards

Hazard	Agency Responsible	Warning Provided
Flooding	NSW SES Region Controllers	Local Flood Bulletins & Evacuation Warnings to: ▪ Flood affected communities via the electronic Media; ▪ the DEOCON; and ▪ relevant Agencies and Functional Areas.
	Bureau of Meteorology	Local Flood Advices and Warnings

The Standard Emergency Warning Signal (SEWS) is a nationally adopted distinctive sound which may be broadcast over radio or television immediately before an urgent public safety message. The SEWS is designed to attract the attention of the public to an urgent safety message. The NSW Government Ministry for Police and Emergency Services (MPES) advises "Following the signal there will be a message, pay immediate attention, listen to the announcement, and follow any instructions given. As part of a coordinated national emergency plan, an audio signal has been adopted to alert the community to an urgent safety message relating to an identified emergency such as a flood, fire, or earthquake aftershocks."

The MPES also advises of the Emergency Alert telephone warning system as "one of a number of ways we can warn the community of NSW about an emergency threat or emergency situation. If a decision is made to issue a warning via telephone during an emergency, an Emergency Alert would be sent to landline telephones based on the location of the handset, and to mobile phones based on the billing address within an area defined as under threat or affected by the situation. Emergency Alerts will only be used as a complement to other existing warning mechanisms such as door-knocking, broadcasts via local media outlets such as television, radio and newspapers and public address systems.

Evacuation of persons or animals from an area of danger or potential danger is a possible strategy in combating a flood event. **Table 7-5** is an extract from the DISPLAN (SES, 2012) and lists some individuals and organisations which have authority to order an evacuation of persons or animals and under which circumstances they have this authority. Disseminating warnings and advice to the public is generally through electronic media, but if urgently required, evacuation warnings will be reinforced by public address systems fitted to emergency services vehicles and door knocks of affected areas by evacuation teams (emergency services personnel and others as necessary). The Flood Sub-Plan (SES, 2013) does not list locations in (or near) the catchment recommended for use as flood evacuation centres.

Table 7-5 Extract from DISPLAN (Evacuation Authority)

Individual / Organisation	Circumstances	Authority
A member of the Police Force	If satisfied that there are reasonable grounds for doing so for the purpose of protecting persons from injury or death.	The protection of persons from injury or death whether arising from criminal acts or in any other way. (S 6 (3) (b) *Police Service Act*.
A Police officer, and all other members of emergency service organisations	Emergency operation related to flood or storm or when directed by SEOCON.	Recognise authority of the Director-General NSW SES and emergency officers acting under the orders of the Director-General, division controller or local controller (S. 21 - *State Emergency Services Act*).
The Commissioner, NSW SES; or "Emergency Service Officer" (as defined) when authorised by the Commissioner	Emergency related to flood or storm; or when directed by SEOCON	Direct a person to: leave premises and move out of an emergency area or part thereof; taking any persons in their care with them; and/or not to enter an emergency area or part thereof, including doing all such things as are reasonably necessary to ensure compliance, including use of reasonable force (S. 22 - *State Emergency Service Act*).

7.2.2 Manly-Warringah-Pittwater Flood Emergency Sub-Plan

The *Manly-Warringah-Pittwater Flood Emergency Sub-Plan* (SES, 2013) sits under the *Manly-Warringah-Pittwater DISPLAN* (2011) and covers preparedness measures, response operations and the coordination of immediate recovery measures from flooding within the three LGAs. It includes the Dee Why South Catchment area, comprising the suburbs of Dee Why and Narraweena.

The Plan lists responsibilities of emergency service organisations and supporting services, including the NSW SES, Bureau of Meteorology (BoM), Police, Roads and Maritime Services, and Warringah Council. The NSW SES is the legislated combat agency for floods with responsibilities including the control of flood operations and for damage control resulting from storm events. Responsibilities for dealing with flood events are categorised as Preparedness, Response and Recovery for the different stages of the flood event (**Section 7.4**).

The Plan does not list locations suitable for use as flood evacuation centres and identifies that no major water storage dams or reservoirs are located in the catchment.

7.3 Flood Warning Systems

Flooding in the catchment would result from local catchment overland flooding as properties are relatively unaffected by an increased flood level in Dee Why Lagoon. Overland flooding in the catchment is of a flash flooding nature, where the warning time is less than six hours. The time to a flooding event and potential response times limits the implementation of a flood warning system.

In the case of flash flood catchments, the BoM provides general warning services, including:

> Severe Thunderstorm Warnings;
> Severe Weather Warnings; and
> Flood Watches.

These services are typically issued for a much larger region, or catchment, that includes the local flash flood site. In some cases, two to three days advanced notice may be available (e.g. where an East Coast Low develops off Sydney). However, at other times it may only be possible to issue a flood warning a few hours in advance, if at all.

The Northern Beaches Flood Warning System is a joint partnership between Pittwater, Warringah and Manly Councils in collaboration with the OEH and the BoM. As described in Millener et. al. (2013), the five-year objective is to develop a basic flash flood warning system for the region's community by strategic installation of rainfall, water level and flow gauges. A publicly accessible webpage hosted by Manly Hydraulics Laboratory (MHL) (http://new.mhl.nsw.gov.au/users/NBFloodWarning/) is available to inform the public via real-time water level gauge data, advise of flood trigger levels, and to advise of where flooding may be occurring. Alarms and trigger levels on selected gauges will be applied to send an SMS to relevant personnel in NSW SES, Councils, or Roads and Maritime Services. The gauges of the system are envisaged to provide data for many years and the effectiveness of the overall system is dependent on the community reception and their response to warning messages.

7.4 Flood Event

The DISPLAN and Flood Emergency Sub Plan (**Section 7.2**) list responsibilities for organisations during a flood event. Actions during a flood event are undertaken in three core stages – Preparedness, Response and Recovery.

7.4.1 Preparedness

Tasks under this stage include - maintenance of the Plan, development of flood intelligence, development of warning systems, training and maintenance of resources.

7.4.2 Response

Response operations begin on receipt of a BoM flood warning or advice or when other evidence leads to an expectation of flooding. The primary response strategies of the NSW SES are information provision and warning, property protection, evacuation, rescue and re-supply.

When the immediate danger to life and property has passed the NSW SES will issue an 'all clear' message signifying that response operations have been completed.

In the Response stage, planning tasks include collating situational information (such as rainfall data and roads closed by flooding) and provision of flood information and warnings. Operational tasks include deployment of resources, road and traffic control, managing flood rescues, managing evacuation operations, managing resupply operations.

7.4.3 Recovery

The recovery committee will develop a Recovery Action Plan, coordinate the activities of agencies responsible for services during recovery, and ensure that stakeholders and the community are involved in the development and implementation of recovery strategies. A review of the response operation and organisations will be undertaken to identify further and future actions.

7.5 Access Road Flooding

Any flood response in the catchment must take into account the availability of flood free access and the ease in which movement may be accomplished. Movement may comprise evacuation from flood affected areas, emergency services personnel attempting to provide aid to flood affected people, or NSW SES personnel installing flood defences.

Flooding of major access roads in the Dee Why South Catchment is discussed in **Section 5.4.5**. Pittwater Road is the main road crossing within the catchment which is subject to flooding. In a 100 years ARI flood, the section of road between Redman Road and Oaks Avenue is subject to high hazard flooding. In a PMF event, many roads in the catchment, especially around Dee Why Town Centre, are subject to high hazard flooding preventing safe access from some properties to higher ground.

From the start of a storm event, limited warning time is available before of flood depth on roads start to increase, and inundation may be within one hour.

7.6 Flood Emergency Response Planning Classifications

7.6.1 Introduction

The NSW OEH *Flood Emergency Response Planning Classification of Communities* (FERPC) guideline was prepared in 2007 in conjunction with the NSW SES. It provides guidance on the classification of different areas of the community based on their relative vulnerability in flood emergency response.

The FERPC:

> Assists emergency managers with identifying the type and scale of information needed for emergency response planning; and

> Assists planners in identifying suitable areas for development.

A key point to note with the classifications is that they are intended for the planning phase and not for management of emergency response during the flood event. The response classification in its current form should be developed prior to a Flood Emergency Management Response Plan for the floodplain. The intention of the classification is to provide a rapid assessment methodology to highlight the key areas of concern. It can be used as a first pass system to enable emergency response classification to occur in catchments which do not have a fully robust Flood Emergency Response and Management Plan present.

One of the key strengths of the system as it currently stands is the ability to rapidly assess large areas of floodplain – this is due to the broad scale nature of the study, the limited data required and the simple logic path.

7.6.2 Definitions

The following are the classification definitions of communities within a flood affected region as described within the FERPC (DECC, 2007)

> **Flood Islands.** These are inhabited or potentially habitable areas of high ground within a floodplain linked to the flood-free valley sides by a road across the floodplain and with no alternative overland access. The road can be cut by floodwater, closing the only evacuation route and creating an island. Flood islands can be further classified as:

  - High Flood Island (the flood island contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground).
  - Low Flood Island (the flood island does not have enough flood free land to cope with the number of people in the area or the island will eventually become inundated by flood waters).

> **Trapped Perimeter Areas.** These would generally be inhabited or potentially habitable areas at the fringe of the floodplain where the only practical road or overland access is through flood prone land and unavailable during a flood event. The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped Perimeter Areas are further classified according to their evacuation route:

  - High Trapped Perimeter (the area contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground).
  - Low Trapped Perimeter (the area does not have enough flood free land to cope with the number of people in the area and will eventually become inundated by flood waters).

> **Areas Able to be Evacuated.** These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated.

- Areas with Overland Escape Route (access roads to flood free land cross lower lying flood prone land).
- Areas with Rising Road Access (access roads rise steadily uphill and away from the rising floodwaters).

> **Indirectly Affected Areas.** These are areas which are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.

> **Overland Refuge Areas.** These are areas that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas.

7.6.3 Application of the Guideline to Dee Why South Catchment

As the Dee Why South Catchment is subject to flash flooding as opposed to long duration riverine flooding, care has been taken when using the guideline to assess appropriate response measures. As the guideline's outcomes centre around evacuation response and re-supply, consideration of the available warning time, timing of peak water levels, and the applicability of these outcomes to the catchment is required.

7.6.4 Results of the FERPC Assessment

Figures 7-1 and **7-2** show the FERPC classifications for the 100 years ARI and PMF events respectively. Due to the high level of flood impacts present through the Dee Why Town Centre in the 100 years ARI flood event, the Town Centre is considered to be a high flood island. This implies that while significant inundation is present, there is sufficient land above the PMF extent to cater for the expected number of individuals present. Areas surrounding the Town Centre are considered as either rising road access or not flood affected, depending on their ability to seek higher ground or unaffected evacuation and resupply routes.

Table 7-6 outlines the response recommended in the *Flood Risk Management Guideline* (DECC, 2007) for different flood emergency response planning classifications. It is noted that although evacuation is recommended in these guidelines for both of the emergency response classifications, the catchment is primarily affected by short duration flash flooding and evacuation may not always be possible or safe in these circumstances. The classification should be used by emergency response providers to identify that these areas will potentially be isolated for a short period of time and appropriate response to this situation is required.

Table 7-6 Emergency Response Requirements (after: DECC, 2007)

Classification	Response Required		
	Resupply	Rescue / Medivac	Evacuation
High Flood Island	Yes	Possibly	Possibly
Low Flood Island	No	Yes	Yes
Area with Rising Road Access	No	Possibly	Yes
Area with Overland Escape Routes	No	Possibly	Yes
Low Trapped Perimeter	No	Yes	Yes
High Trapped Perimeter	Yes	Possibly	Possibly
Indirectly Affected Areas	Possibly	Possibly	Possibly

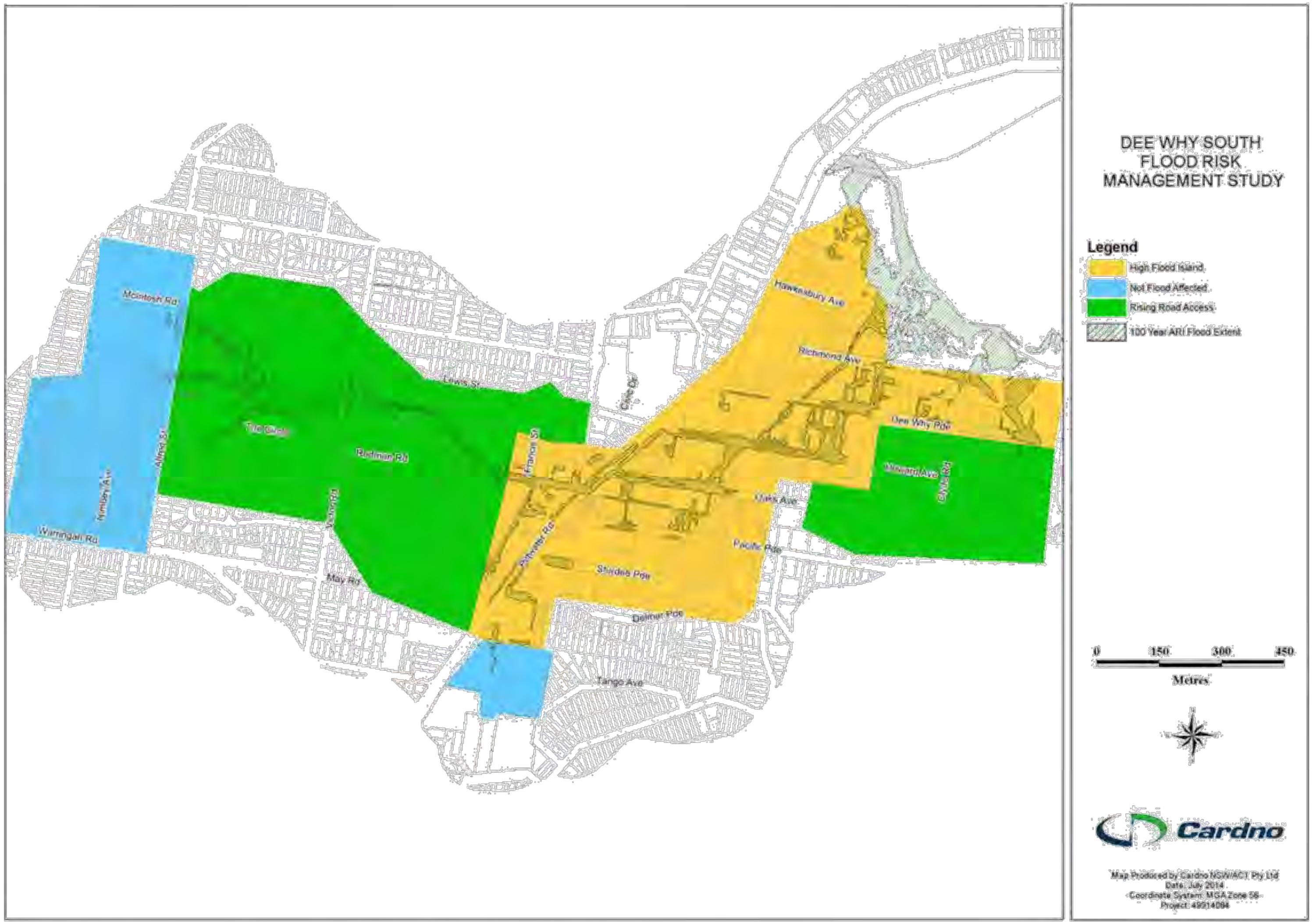


Figure 7-1 Emergency Response Classification – 100 years ARI Event

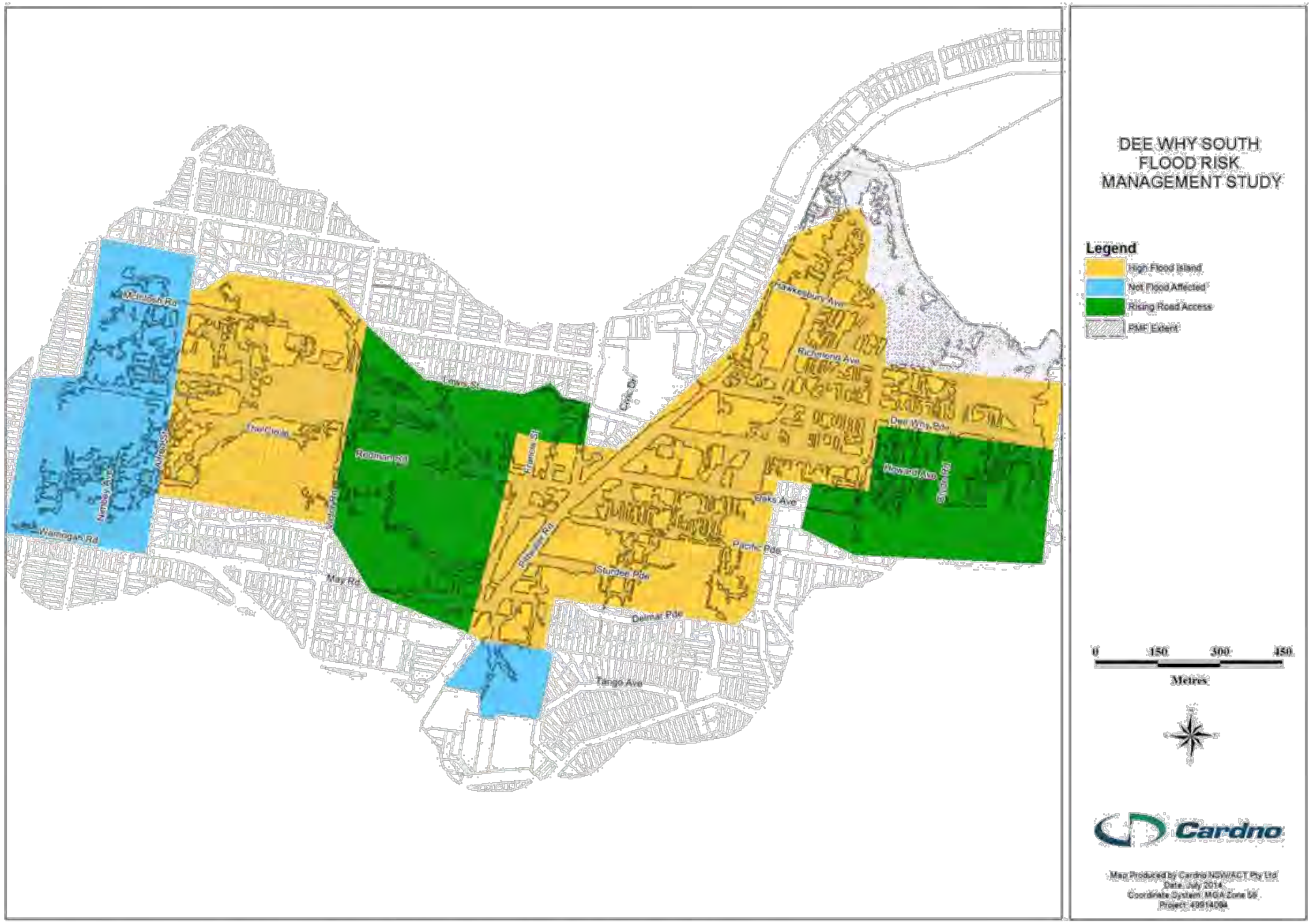


Figure 7-2 Emergency Response Classification – Probable Maximum Flood Event

7.7 Evacuation

Evacuation of persons or animals from an area of danger or potential danger is a possible strategy in combating a hazardous event. Flooding in this catchment is of a flash flooding nature resulting in limited warning time to prepare and respond for evacuation. **Section 7.2** summarises the relevant regional DISPLAN and local flood plan.

Demographic statistics for Dee Why and Narraweena indicate that 70% of the population are aged below 55 years and would generally not require assistance in the case of an evacuation (**Section 2.3**). Several schools and aged care facilities are located in the catchment, but are generally not inundated in the 100 years ARI flood event.

In a 100 years ARI event, potentially the best refuge is to shelter in place at higher levels of the building. This avoids risk from moving and driving on roads that may be hazardous in a storm event.

In a PMF event, properties may be inundated by floodwater with potential that the shelter in place option is less safe, particularly if vertical evacuation is not possible. However, many of the roads in the catchment would be inundated resulting in hazardous conditions.

8 Policies and Planning

8.1 Planning Instruments / Policy

The Dee Why South Catchment is located in the Warringah LGA where development is controlled through the Warringah LEP and *Warringah Development Control Plan 2011* (DCP). As discussed in **Section 2.2**, the LEP is a planning instrument which designates land uses and development in the LGA. The DCP regulates development with specific guidelines and parameters.

This section reviews flood controls covered by the LEP, DCP, policies and plans.

8.2 Warringah Local Environmental Plan 2011

8.2.1 Flood Controls

Section 6.3 (Flood Planning) of the LEP outlines control and objectives for land below the flood planning level (100 year ARI + 0.5m). The objectives of this section are:

> to minimise the flood risk to life and property associated with the use of land;

> to allow development on land that is compatible with the land's flood hazard, taking into consideration projected changes as a result of climate change; and

> to avoid significant adverse impacts on flood behaviour and the environment.

It is stated that development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

> is compatible with the flood hazard of the land;

> is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties;

> incorporates appropriate measures to manage risk to life from flood;

> is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses; and

> is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

8.3 Warringah Development Control Plan 2011

8.3.1 Background

A DCP is a non-statutory document that supports the LEP with more detailed planning and design guidelines. The flood related objectives of the Warringah DCP are to:

> to ensure the development is compatible with the flow regime of the waterway;

> to ensure that existing development is not adversely affected through increased flood damage and / or flood hazard as a result of new development;

> to provide for the safety of people and property;

> to provide a mechanism to control development on flood prone land; and

> to ensure a sustainable and holistic catchment wide approach is taken to development on flood prone land.

Land that is identified on the maps provided in the DCP are categorised according to flood behaviour as:

> High Flood Risk Planning Precinct;

> Medium Risk Planning Precinct; and

> Low Flood Risk Planning Precinct.

The DCP also provides guidance on preparing site specific flood studies, and outlines key flood management principles which development must adhere to (e.g. incorporation of flow paths, detention areas and upgraded culverts).

Specific flood planning levels (FPL) are documented for various development types. Further discussion on FPL is provided in **Section 9.**

8.3.2 Matrix Table Requirements

Tables 8-1 to **8-3** highlight the development requirements under the DCP for each of three flood risk planning precincts, and supporting information is provided below.

A - Floor Levels

1. Floor levels are to be equal to or higher than the FPL.

2. Floor levels are to be equal to or higher than the FPL. A Flood Risk Assessment is required to assess the risk to life and flood hazard of the site and determine if floor levels should be set at PMF level.

3. Floor levels are to be to be equal to or higher than the FPL when undertaking alterations or additions. The ceiling height of the existing building is to allow room for potential future raising of the floor level to the FPL. A flood risk assessment is required if this cannot be achieved.

4. Floor levels of balconies are to be set at a minimum of the FPL.

5. If the land use is changing to residential, all floor levels must be raised to the FPL.

6. The top of the swimming pool must be built to ground level (existing).

7. No net loss of flood storage is to occur. Compensation works may be permitted.

8. A Flood Risk Assessment is required to assess the risk to life and flood hazard at the site and determine if floor levels for the proposed development can be safely set at a minimum of the PMF level or FPL whichever is greater.

B - Building Components and Method

1. All structures to have flood compatible building components and/or withstand the hydraulic forces of 100 year velocities, up to the FPL.

2. All structures to have flood compatible building components up to the PMF level to withstand the hydraulic forces of the PMF at the site.

3. All services must be located above the PMF level.

4. Swimming pool fences are not to impede the flow of floodwaters.

C -Structural Soundness

1. A Flood Risk Assessment from a suitably qualified person is required to certify that any structure can withstand the forces of floodwater, debris and buoyancy up to the FPL.

2. Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to the FPL.

3. A Flood Risk Assessment from a suitably qualified person is required to certify that any structure can withstand the forces of floodwater, debris and buoyancy up to and including the PMF level plus a suitable freeboard specific to the site.

4. Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including the PMF level plus a suitable freeboard specific to the site.

Table 8-1 High Flood Risk Planning Precinct

		Essential Services & Infrastructure	Vulnerable Development	New Residential Accommodation	New Commercial & Industrial	Subdivision	Concessional Development	Residential Swimming Pools	Recreation Facility (Outdoor)
A	Floor Levels	8	8	8	8		3, 4, 7	6, 7	7
B	Building Components	2, 3	2, 3	1	2, 3		1 or 2	1, 4	1
C	Structural Soundness	3	3	1	3		1	1	1
D	Impact of Development	3	3	1	3	3	1	2	1
E	Evacuation	2, 3	2, 3	1, 3	2, 3	4	3		2, 3
F	Management & Design	3, 4	3, 4	3, 4	3, 4	1	2	4	4
G	Car Storage	2, 5	2, 4, 5	1, 3, 4, 5	2, 4, 5		1, 3, 4, 5		2

Table 8-2 Medium Flood Risk Planning Precinct

		Essential Services & Infrastructure	Vulnerable Development	New Residential Accommodation	New Commercial & Industrial	Subdivision	Concessional Development	Residential Swimming Pools	Recreational Facility (outdoor)
A	Floor Levels	8	8	1, 4, 7	2 or 5, 7		3, 4, 7	6, 7	7
B	Building Components	2,3	2,3	1	2, 3		1 or 2	1, 4	1
C	Structural Soundness	3	3	1	3		2	2	2
D	Impact of Development	3	3	1	3	1	2	2	2
E	Evacuation	2, 3	2, 3	1, 3	2, 3	4	3		2, 3
F	Management & Design	3, 4	3, 4	2	3, 4	1	2	4	4
G	Car Storage	2, 5	2, 4, 5	1, 3, 4, 5	2, 4, 5		1, 3, 4, 5		2

Table 8-3 Low Flood Risk Planning Precinct

		Essential Services & Infrastructure	Vulnerable Development	New Residential Accommodation	New Commercial & Industrial	Subdivision	Concessional Development	Residential Swimming Pools	Recreational Facility (outdoor)
A	Floor Levels	8	2, 7		2 or 5, 7		3, 4, 7		7
B	Building Components	2,3	2, 3		2		1 or 2		1
C	Structural Soundness	3	3		4		2		3
D	Impact of Development	3	3		3	2	2		2
E	Evacuation	2, 3	2, 3		2, 3	4	3		2, 3
F	Management & Design	3, 4	3, 4		3, 4	1	2		4
G	Car Storage	2, 5	2, 4, 5		2, 4, 5		1, 3, 5		2

D - Impact of Development

1. A Flood Risk Assessment from a suitably qualified person is required to certify that the development will not increase flooding or negatively impact on the velocities of the flood waters upstream or downstream in a 100 year flood event.

2. Applicant to demonstrate the structure will not cause increase in flooding, or negatively impact on the velocities of the flood waters upstream or downstream in a 100 year flood event.

3. A Flood Risk Assessment from a suitably qualified person is required to certify that the development will not increase flooding upstream or downstream in PMF event.

E -Evacuation

1. All new dwellings should contain an appropriate area to shelter in place above the PMF. Flood compatible materials should be used in the building materials up to the PMF.

2. Reliable access for pedestrians and / or vehicles is required above the PMF level or the FPL whichever is higher.

3. Existing and proposed developments shall be required to produce and maintain a Flood Emergency and Evacuation Plan that demonstrates that any occupants will be able to safely shelter in place in a PMF or have reliable access for pedestrians to evacuate safely above the PMF.

4. Applicant to demonstrate that evacuation of potential development is in accordance with this DCP.

F - Management and Design

1. The applicant must demonstrate that the development proposed as a result of the proposed subdivision can meet the relevant objectives and requirements of the Flood Prone Land section of the DCP.

2. The applicant must demonstrate that area is available to store goods (goods that may cause pollution or are potentially hazardous) above the FPL.

3. The applicant must demonstrate that area is available to store goods above the PMF level plus a suitable freeboard specific to the site.

4. There is to be no external storage of materials below the FPL which may cause pollution or be potentially hazardous during a flood. Any storage of such materials up to the PMF level is to be protected by bunds.

G - Car Storage

1. Car park floor levels (including stand-alone garages, multistorey and under building open areas) to be set at the 100 year flood level. The installation of movement devices may be required for protection against the movement of vehicles.

2. Car park floor levels (including stand-alone garages, multistorey and under building open areas) to be set so that floodwaters are no more than 200mm deep in a PMF. The installation of movement devices may be required for protection against the movement of vehicles in a PMF.

3. Where the garage is connected to the house, the garage floor level must be set at or above the 100 year flood level. The entrance from the garage into the dwelling must be set at the FPL. The height of the garage ceiling is to allow room for potential future raising of the floor level to the FPL.

4. The basement car park area must have a ramp set with a crest at the FPL to prevent floodwaters entering the car park. All potential water entry points are to be set at or above the FPL.

5. Carports are to have no more than 200mm depth of floodwater or 0.5 m/s velocity of floodwater flowing through in a 100 year flood event. The installation of movement devices may be required for protection against the movement of vehicles.

8.3.3 Recommendations

Currently basement car parks planned for several different types of developments have no planning levels under the current DCP. This includes subdivisions located in all risk zones and new residential developments located in low risk flood areas. The following change would be recommended to the DCP in this regard:

> In all Land Use areas, make the requirement to meet G(4) mandatory. This ensures all future basement levels are set to or are above the FPL.

City of Sydney Council in its *Draft Interim Floodplain Management Policy* (dated 16 July 2013) specifies a stricter requirement for basement car parks. The minimum entry level to a basement car park (being a vehicular entry, stairwell, lift shaft or other opening) is to be the higher of the FPL or PMF. Prior to this Policy, the requirement was for a review of the PMF.

A consideration in revision of the Warringah DCP should be the requirement for a minimum elevation of PMF level for entries to basement car parks. Potential implementation of flood proofing systems, such as automatic flood barriers and flood exclusion doors, should be considered if they are suitable for meeting flood exclusion requirements. A flood risk assessment may be recommended to define potential risk to persons and review of potential evacuation.

The NSW Government Department of Planning Circular of 31 January 2007 advises that unless there are exceptional circumstances, the 100 years ARI flood is to be adopted as the reference event in determination of the FPL.

8.4 Section 149 Certificates

8.4.1 Background

Section 149 Planning Certificates are issued in accordance with the *Environmental Planning & Assessment Act 1979*. They contain information on how a property may be used and the relevant restrictions on development.

Information to be disclosed on a Section 149 (2) Planning Certificate is specified under the *Environmental Planning and Assessment Regulation 2000* (Schedule 4) and includes development controls relevant to the following factors:

> Names of relevant planning controls (e.g. under the relevant LEP or DCP);

> Declared State Significant Developments;

> Zoning and land uses under the LEP;

> Critical habitat;

> Heritage Information;

> Land reserved for acquisition;

> Coastal protection;

> Mine subsidence;

> Road widening and road realignment;

> Council and other public authority policies on hazard risk restrictions;

> Section 94 Contributions Plans; and

> Matters arising under the *Contaminated Land Management Act 1997*

The Section 149 (5) Planning Certificate provides information (as opposed to imposing development controls as is described for part 2 of Section 149) on the last approved use and can also include additional information provided it has been endorsed by Warringah Council.

8.4.2 Flood Related Guidance

Clause 7A of Section 149 of the *Environmental Planning & Assessment Act 1979* relates to flooding and provides the following information:

(a) Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.

(b) Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls.

Advice provided is in the form of a yes or no answer to the above comments. Given the primary use of the Section 149 is to inform the current or future owner of the land on restrictions that may be in place on the site, the advice provided within the Section 149 is sufficiently detailed.

8.5 Dee Why Town Centre Masterplan

8.5.1 Dee Why Town Centre Masterplan Framework Overview

The final Dee Why Town Centre Masterplan (2013) has been developed to provide a vision for the urban renewal of Dee Why Town Centre. Chapter 4 of the Masterplan discusses the planning framework and amendments required to the Warringah LEP and DCP to progress the Masterplan. The other relevant planning policies and controls for the Dee Why Masterplan Development Area are:

> *Metropolitan Plan for Sydney 2036* (NSW Government, 2010), including the Sydney Metropolitan Transport Plan;

> *Draft Sydney North East Subregional Strategy* (NSW Government, 2007);

> Relevant State Environmental Planning Policies (SEPPs);

> S.117 Ministerial Directions; and

> *NSW State Infrastructure Strategy 2008 – 2018* (NSW Government, 2008).

This masterplanning framework is driving increased private investment within the Town Centre, providing unique opportunities for private infrastructure contributions to potentially assist in funding of floodplain management measures (i.e. structural works to alleviate flood risk). The Masterplan is now being implemented through a staged infrastructure upgrade process. By running this FRMS concurrently Council is seeking to identify opportunities for floodplain management options (such as drainage upgrades) to be incorporated into the wider road and streetscape upgrades, thereby achieving efficiencies in project delivery and minimising disruption to the community and businesses.

8.5.2 Flood Related Guidance

Of the texts referenced above in **Section 8.5.1**, only the *Draft Sydney North East Subregional Strategy* (NSW Government, 2007) provides guidance within Chapter 4: "Councils are to plan for land affected by flooding in accordance with the Government's Flood Prone Land Policy and Floodplain Development Manual (NSW Government, 2005). Floodplain risk management assessment needs to be undertaken strategically through the development of floodplain risk management studies and plans, which consider the flooding implications for existing and proposed development. Refer also Section 117 Direction No.15 Flood Prone Land and the Floodplain Development Manual."

This guidance is in accordance with Councils current strategies.

8.5.3 Recommended Modifications

The current document outcomes are in line with the Council's current philosophy on addressing Flood Prone Land. However, within the document, Section 117 Direction No. 15 Flood Prone Land and the *Floodplain Development Manual* (NSW Government, 2005) is mentioned, but not discussed. Under the heading Section 117 Directions a reference to this direction should be incorporated.

8.6 Infrastructure SEPP

The *SEPP - Infrastructure 2007* is relevant to the implementation stage where actions recommended in this FRMS are carried over to the FRMP. Under the Infrastructure SEPP, flood mitigation works "may be carried out by or on behalf of a public authority without consent on any land". These works include construction, routine maintenance and environmental management works which applies to most of the flood modification measures considered in this FRMS (see **Section 11.3**).

Although consent is not required, most flood modification measures will require further environmental assessment. The determining authority, in this case Warringah Council, is required to "examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity" complying with Section 111 of the *Environmental Planning and Assessment Act 1979*, most likely in the form of a Review of Environmental Factors.

When carrying out flood modification works, Council will be required to take out further permits, licenses and approvals such as:

> Flood modification works which emit into a water body will need an Environment Protection Licence complying with the *Protection of the Environment Operations Act 1997*;

> Any removal of vegetation and debris in the water body may need a Threat Abatement Plan complying with the *Fisheries Management Act 1994*; or

> A license to harm threatened species, population or ecological community or damage habitat under the *Fisheries Management Act 1994* or *Threatened Species Conservation Act 1995*.

Further details of the likely environmental considerations that will be required are presented in **Section 2**.

8.7 Proposed Changes to the NSW Environmental Planning Framework

The NSW environmental planning framework has been the subject of a reform process over the last two and a half years.

The White Paper "A new planning system for NSW" and draft planning legislation were released on 16 April 2013 and for public exhibition until 28 June 2013. The key changes to the planning framework are as follows:

> A shift to upfront evidence based strategic planning, with a focus on achieving sustainable development outcomes;

> A shift in focus to subregional planning jointly prepared by councils and the state, where there will be direct rezoning and supporting development guides for major precincts of state or regional significance;

> Infrastructure that is integrated with land use so that the community has confidence that areas of growth and change will be supported by transport, infrastructure and services;

> An innovative new approach to Local Plans focussed on outcomes not development controls in isolation;

> A partnership between the state, the community, local councils, agencies and the private sector to develop a shared vision for regions, subregions and local government areas;

> Clearly structured and transparent plans, with all development controls and zones accessible to the community and business in Local Plans whole of government requirements in strategic plans to improve planning outcomes and reduce the number of development applications that require multi agency concurrence, referral or approval;

> Strong performance monitoring and reporting to ensure that plans deliver on agreed objectives; and

> The transition of the relevant aspects of existing strategic plans and planning instruments to the new planning system.

Based on the commentary provided surrounding the proposed changes to Local Plans, in general there will be minimal alteration regarding advice to flood controls. As the *Warringah Local Environmental Plan 2011* currently has a FPL requirement of 100 years ARI + 0.5 m independent of the land use zone, the modifications proposed to the land use zoning as described within the framework will not alter the advice provided within the LEP.

8.8 Dee Why Lagoon Entrance Management Policy

Dee Why Lagoon is the downstream receiving water body for the Dee Why South Catchment. The entrance to the Lagoon lies midway between Dee Why and Long Reef Beach. A training wall has been constructed on the northern side of the entrance channel while rocks line the southern side (these are usually buried beneath the sand), with the purpose of restraining channel migration and erosion of sand dunes on the northern side of the entrance. The Lagoon is classified as an Intermittently Open and Closed Lake or Lagoon, meaning that it is periodically closed off from the sea due to the formation of an entrance berm, or sand bar across the mouth of the estuary.

Warringah Council has developed an Entrance Management Policy for Dee Why Lagoon to guide the management of the Lagoon entrance for purposes of flood mitigation. Whilst the entrance berm will naturally be overtopped and broken open during a flood event, the berm heights can reach as much as 2.4 m AHD (Cardno, 2013). The corresponding Lagoon water level would result in flood impacts on public lands surrounding the Lagoon, as well as properties upstream of Pittwater Road. For this reason, Council mechanically breaches the Lagoon entrance during a storm event when the water level reaches 2.3 m AHD.

The Entrance Management Policy includes guidance on the conditions under which the entrance should be breached, and how the works should be undertaken. A backhoe/excavator is driven into Long Reef Beach car park and then travels directly onto the sand through the access point at the end of the southern car park. Under the Entrance Management Policy, the alignment of the entrance channel is to be determined by lining up two white poles (markers) which are located on the northern side of the Dee Why Lagoon entrance.

The Policy provides the community with certainty as to Council's approach to management of the entrance berm with respect to flood management.

Cardno (2013) provided an assessment of the potential impacts of climate change on the Entrance Management Policy and procedures contained therein. The findings are summarised in **Sections 8.8.1** and **8.8.2**.

8.8.1 Impact of Increased Rainfall Intensity due to Climate Change on Opening Levels

Climate change is projected to increase the intensity of rainfall events by up to 32%, while at the same time reducing both the frequency of storm events and average annual rainfall.

The Dee Why South Catchment Flood Study (Cardno, 2013) estimated potential impacts of increased rainfall intensity on flooding within the catchment. Modelled results showed increased flood levels in the catchment, with only very limited increases to floods levels in Dee Why Lagoon.

Given the current scientific uncertainty regarding potential changes in rainfall intensity and frequency due to climate change, it is premature to comment on the implications on the Entrance Management Policy for Dee Why Lagoon. The most effective approach may be to monitor Lagoon water levels over time and consider these in light of the entrance management regime.

8.8.2 Impact of Increased Ocean Levels due to Climate Change on Opening Levels

As discussed in the Flood Study (Cardno, 2013), conservative projections of increases in mean sea level in the order of 0.9 m by 2100 have been widely adopted in accordance with the advice of the Chief Scientist and Engineer of NSW (2012).

The tidal range at the mouth of Dee Why Lagoon is approximately 0.5 m, and an estimated rise in mean sea level of 0.9 m by 2100 results in an average peak tidal level of approximately 1.15 m AHD (Cardno, 2013). This water level does not take into account any increases in water level resulting from meteorological conditions such as those that occur during storms such as East Coast Lows (e.g. inverse barometer effect). This is still considerably lower than the 2.3 m AHD trigger level currently specified for opening the Lagoon entrance under the Entrance Management Policy. The implication of higher ocean levels relates more to the frequency with which the trigger level is reached and the efficiency with which floodwaters are conveyed from the Lagoon to ocean (i.e. reduction in head difference).

8.8.3 Recommendations for the Dee Why Lagoon Entrance Management Policy

Currently the opening mechanism is primarily driven by rainfall within the Dee Why Lagoon catchment. The implications of climate change on the Lagoon Entrance Management are complex and still not fully understood. Due to the high level of uncertainty in the potential response of the entrance berm to climate change, it is recommended that ongoing monitoring of berm levels and lagoon water levels is undertaken and used to inform any changes to the current Entrance Management Policy.

9 Flood Planning Level Review

9.1 Background

The FPL for the majority of areas across NSW has been traditionally based on the 100 years ARI flood level plus a freeboard. The freeboard for habitable floor levels is generally set between 0.3 - 0.5 m. A new guideline on development controls for low risk areas states that unless there are 'exceptional circumstances', councils should adopt the 100 years ARI (plus an appropriate freeboard) for residential development (NSW Government, 2005).

As discussed in **Section 8.2.1**, Warringah Council currently adopts within the LEP an FPL of the 100 years ARI flood level plus 0.5 m freeboard, and maps all properties below this level.

A variety of factors are worthy of consideration in determining an appropriate FPL and whether 'exceptional circumstances' exist for the selection of an FPL other than the 100 years ARI. Most importantly, the flood behaviour and the risk posed to life and property in different parts of the need to be accounted for in the setting of an FPL.

The *Floodplain Development Manual* (NSW Government, 2005) identifies the following issues to be considered:

- risk to life;
- long term strategic plan for land use near and on the floodplain;
- existing and potential land use;
- current flood level used for planning purposes;
- land availability and its needs;
- FPL for flood modification measures (levee banks etc.);
- changes in potential flood damages caused by selecting a particular FPL;
- consequences of floods larger than the FPL;
- environmental issues along the flood corridor;
- flood warning, emergency response and evacuation issues;
- flood readiness of the community (both present and future)
- possibility of creating a false sense of security within the community;
- land values and social equity;
- potential impact of future development on flooding; and
- duty of care.

These issues are dealt with collectively in the following sections.

9.2 Likelihood of Flooding

As a guide, **Table 9-1** has been reproduced from the *Floodplain Development Manual* (NSW Government, 2005) to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life. The data indicates that there is a 50% chance of a 100 years ARI event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 100 years ARI flood event as the basis for the FPL. Given the social issues associated with a flood event and the non-tangible effects (such as stress and trauma), it is appropriate to limit the exposure of people to floods.

Table 9-1 Probability of Experiencing a Design Flood in an Average Lifetime (70 years)

Likelihood of occurrence in any given year (ARI)	Probability of experiencing at least one event in 70 years (%)	Probability of experiencing at least two events in 70 years (%)
1 in 10	99.9	99.3
1 in 20	97	86
1 in 50	75	41
1 in 100	50	16
1 in 200	30	5

Note that there still remains a 30% chance of exposure to at least one flood of a 200 years ARI magnitude over a 70 year period. This gives rise to consideration of the adoption of a rarer flood event (such as the 200 years ARI or up to the PMF) as the FPL for some types of development (e.g. aged care facilities and hospitals).

9.3 Land Use Planning

The hydrological regime of the catchment can change as a result of changes to the land use, particularly with an increase in the density of development. Removal of pervious areas in the catchment can increase the peak flow arriving at various locations, and hence the flood levels can increase. The impact of changes in land use has not been explicitly quantified as a sensitivity analysis was not undertaken during the Flood Study (Cardno, 2013), noting the majority of the Dee Why South Catchment is already highly urbanised.

Changes to the land use can also result in changes in the assumed roughness of the floodplain. This can lead to changes in discharge characteristics and consequently flood levels in the catchment. A number of sensitivity analyses of were conducted as a part of the Flood Study (Cardno, 2013) among which the effect of complete blockage of inlets. The results of this analysis showed that the highest increase in water level in the 100 years ARI event was greater than 0.5 m at a number of locations.

Consideration could be given to provide a freeboard based on the results of this sensitivity analysis.

As discussed in **Section 8.2.1**, the LEP states that habitable floor levels should be at a level of at least 0.5 m above the 100 years ARI flood level for all land-uses.

9.4 Damage Cost Differential Between Events

Based on the existing flood behaviour and the assessment of flood damages, the incremental difference in AAD for different recurrence intervals is shown in **Table 9-2**.

Table 9-2 Damage Differential Costs – All Damages

	Incremental AAD	Properties with Over-Floor Flooding	Average AAD per Property
Up to 5 Year ARI	$2,158,795	57	$5,882.00
5 Year to 10 Year	$594,913	70	$1,621.00
10 Year to 20 Year	$357,485	80	$974.07
20 Year to 100 Year	$403,959	117	$1,100.70
100 Year to PMF	$337,170	264	$918.72
AAD (Total)	**$3,852,321**		

Table 9-2 indicates that the largest incremental increase in AAD per property occurs up to the 5 years ARI event, followed by the differential cost between 5 and 10 years ARI events. Setting the FPL at the 5 years

ARI level would not be practical and would unnecessarily constrain development. Therefore the greatest savings in AAD per property (assuming that existing properties were replaced with similar properties set at the FPL) would be achieved if the FPL were set at the 20 years ARI at a minimum. The setting of the FPL at this level should not be considered solely on the basis of this AAD analysis as it is one of a number of factors for consideration.

9.5 Flood Depth Difference between Design Events

Consideration of the average height difference between various design flood levels can provide another measure for selecting an appropriate FPL.

Based on the existing flood behaviour (**Section 4** and Cardno, 2013), the incremental peak depth differences between events (as taken at the corner of Redman Road and Pittwater Road) are shown in **Table 9-3**.

Table 9-3 Differences in Design Event Flood Levels (Cardno, 2013)

Flood Event ARI	Recorded Flood Level (m AHD)
PMF	22.54
100 years	21.67
20 years	21.59
10 years	21.54
5 years	21.45

In this particular location, there is a significant increase to water levels in between the PMF event and the 100 years ARI event which is more than the freeboard allowance of 0.5 m. There is only a minor change (<0.3 m) between the 5 years ARI and the 100 years ARI. Based on these results, it is considered that adopting the PMF as the FPL would be overly conservative, and that adoption of the 100 years ARI plus 0.5 m freeboard as the FPL would be more appropriate.

9.6 Consequence of Adopting the PMF as the FPL

Analysis of the flood damages (**Section 9.4**) indicates that the choice of the PMF event over the 100 years ARI event as the FPL would result in significant economic benefits to the community. However, the difference in average flood levels between the 100 years ARI event and the PMF event (**Section 9.5**) indicates that the adoption of the PMF as the FPL would result in significantly higher levels (e.g. 0.86 m for properties at the corner of Redman and Pittwater Road), and as a result higher economic costs (i.e. cost of re-development). These economic costs may in fact outweigh the benefits of using the PMF event as the FPL. The use of the PMF level as the FPL may also conflict with other development controls adopted by Council.

The PMF is generally assigned a very low probability (reported to be of the order of 0.0001 - 0.000001% chance of occurrence each year; NSW Government, 2005). As such, the risk of exposure of buildings to the PMF remains, but is very low.

If the PMF were to be adopted as the FPL for all development, over 4,538 existing properties would be affected by this, as compared with 2,809 properties affected by adopting the 100 years ARI level for the FPL. This level of protection is considered likely to be an onerous task with regard to matters such as minor development and re-development to address what is evidently a relatively low level of risk to property and life. Given the very low probability of the event, the reduction in AAD associated with adopting the PMF as the FPL (through the re-development process and other programs such as house raising and voluntary purchase) is likely to be low.

However, given the risk of exposure outlined in **Table 9-1**, it is recommended that emergency response facilities be located outside of the floodplain and critical facilities (such as hospitals and facilities that are difficult to evacuate in response to flash flooding) be limited to areas outside of the floodplain. Other critical facilities are suggested to have a floor level at the PMF or the 100 years ARI plus 0.5 m, whichever is higher.

9.7 Environmental and Social Issues

FPLs minimise the tangible and intangible damages to a property and over time the ongoing process of re-development will ultimately result in all properties being raised to a suitable level and the risk to community will be significantly reduced. This can promote a feeling of security and reduce the emotional impacts of damages resulting from flooding.

Whilst FPLs are usually easily incorporated into the architectural designs for a property, the FPL can result in housing being placed higher than it otherwise would be. In areas where the flood level is considerably higher than the ground level, this can lead to a reduction in visual amenity for surrounding property owners, and may lead to effects on property values. In some cases, this may also lead to conflict with other development controls. For this reason, a lower FPL is generally preferred where risk to life and property is tolerable.

9.8 Readiness, Warning, Response and Evacuation

Given the short critical duration for the catchment (about 60 to 90 minute storm events), the potential for warning, response and evacuation is very limited. As such, the adoption of a FPL that is elevated and based on events that are rarer in occurrence, such as the PMF or 100 years ARI event, is an appropriate choice with regard to these factors. However, the PMF is an extremely rare event and its adoption as the FPL is highly unlikely. As such, the 100 years ARI event is a suitable choice for these factors.

Noting this recommendation, it is considered important that the community is reminded of the possibility of floods rarer than the FPL event occurring in the catchment. This is especially important when considering flood free evacuation routes. It is therefore important that suitable information for rarer floods (PMF) is provided to the community.

9.9 Climate Change – Sea Level Rise

The Chief Scientist and Engineer of NSW (2012) provide an estimate for projected sea level increases as a result of climate change to 2100 of 0.9 m. These estimates are produced from a range of scenarios. Engineers Australia (2004) also reports a central projected sea level rise for a 10 year planning period to be of the order of 0.1 m.

Thus the design flood level used in the assignment of FPLs should include a consideration of the potential impact of sea level rise on tailwater conditions and the resultant and the implications for water levels in Dee Why Lagoon.

A sensitivity analysis was undertaken within the Flood Study (Cardno, 2013) for variations in the Dee Why Lagoon level. The 100 years ARI Dee Why Lagoon flood level was increased by 20% (at the entrance to Dee Why Lagoon) under a 0.9 m sea level rise scenario. This translated into a maximum increase in flood levels of up to 0.1 m locally. This investigation identifies that flooding within the Dee Why South Catchment is not sensitive to the downstream water level condition.

10 Floodplain Risk Management Options

10.1 Managing Flood Risk

10.1.1 Overview of Available Measures

Flood Risk can be categorised as existing, future or residual risk:

> **Existing Flood Risk** – existing buildings and developments on flood prone land. Such buildings and developments by virtue of their presence and location are exposed to an 'existing' risk of flooding;

> **Future Flood Risk** – buildings and developments that may be built on flood prone land. Such buildings and developments would be exposed to a flood risk when they are built; or

> **Residual Flood Risk** – buildings and development that would be at risk if a flood were to exceed management measures already in place. Unless a floodplain management measure is designed to withstand the PMF, it may be exceeded by a sufficiently large event at some time in the future.

The alternate approaches to managing risk are outlined in **Table 10-1**.

Table 10-1 Flood Risk Management Alternatives (SCARM, 2000)

Alternative	Examples
Preventing / Avoiding risk	Appropriate development within the flood extent, setting suitable planning levels.
Reducing likelihood of risk	Structural measures to reduce flooding risk such as drainage augmentation, levees, and detention.
Reducing consequences of risk	Development controls to ensure structures are built to withstand flooding.
Transferring risk	Via insurance – may be applicable in some areas depending on insurer.
Financing risk	Natural disaster funding.
Accepting risk	Accepting the risk of flooding as a consequence of having the structure where it is.

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. There are three broad categories:

> **Flood modification measures** (see **Section 10.3**) – Flood modification measures are options aimed at preventing / avoiding or reducing the likelihood of flood risks. These measures reduce the risk through modification of the flood behaviour in the catchment.

> **Property modification measures** (see **Section 10.4**) – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than necessarily modify the flood behaviour, these measures aim to modify properties (both existing and future) so that there is a reduction in flood risk.

> **Emergency response modification measures** (see **Section 10.5**) – Emergency response modification measures aim to reduce the consequences of flood risks. These measures generally aim to modify the behaviour of people during a flood event.

10.1.2 Methodology for Identifying Options

Floodplain risk management options have the following objectives:

> The scope/design of the option was not to completely rid the catchment of flooding, but to reduce highly hazardous conditions in key locations in the catchment;

> To provide options that are feasible, both in terms of engineering and approvals but also with regard to Council's budgetary constraints as potentially the largest determinant of feasibility; and

> To not re-visit options previously investigated and disregarded, such as Beverley Job Park as a detention basin.

An initial assessment of all available management options was undertaken based on:

> Flood model results;
> Catchment site inspection;
> Historical information; and
> Engineering judgement.

Options development and shortlisting was also informed by workshops held with a diverse team involved in development of this FRMS, comprising representatives from Council's Environmental Strategy, Major Projects, Stormwater Assets, Parks Assets and Roads Assets teams, as well as the Working Group.

10.2 Existing Case

The existing flood behaviour in the Dee Why South Catchment is detailed in the Flood Study (Cardno, 2013). In order to assess the various management options, it is necessary to define a base case. This base case provides a reference to assess the effectiveness of various flood management options. The existing flood behaviour (see **Section 5**) as defined in the Flood Study (Cardno, 2013) will be used for these purposes.

10.3 Flood Modification Measures

Flood modification measures identified for assessment primarily comprise pipe upgrades, detention basins and other localised works. Through discussion with Council it has been identified that a flood modification measure involving an increase in storage at Beverley Job Park has been undertaken recently, as such this option has been omitted from this report.

The modification measures aim to reduce the areas with the highest risk, that is, those located within the Dee Why Town Centre. These measures are listed in **Table 10-2** with further discussion in the respective sub-sections. General locations for Options FM1 to FM9 are shown in **Figure 10-1**. Additional figures showing the general locations of measures as well as results are included in **Appendix C**. **Appendix C** is arranged in the order of the options including a figure for each of the depth, hazard, and depth difference (compared to existing) as well as showing the layout of the option.

Table 10-2 Flood Modification Measures

Option No.	Description	Report Section
FM1	Pipe upgrade between Pacific Parade and Oaks Avenue	**Section 10.3.1**
FM2	Increase drainage capacity along Oaks Avenue	**Section 10.3.2**
FM3	Drainage upgrades between Oaks and Howard Avenues plus Option FM2	**Section 10.3.3**
FM4	Daylighting of box culvert between Howard Avenue and Dee Why Parade	**Section 10.3.4**
FM5	Walter Gors Park detention basin plus Option FM2	**Section 10.3.5**
FM6	Replace open channel between Oaks Avenue and Pacific Parade with new pipe under Pittwater Road plus Options FM1 and FM2	**Section 10.3.6**
FM7	Raise level of Oaks Avenue and Howard Avenue plus Option FM2	**Section 10.3.7**
FM8	Storage basins at Mooramba Road car park and Redman Road	**Section 10.3.8**
FM9	Upgrade of Open Channel between Victor Road and Redman Road plus Option FM8	**Section 10.3.9**
FM10	Combination of Option FM2 and Option FM8	**Section 10.3.10**

It should be noted that the modelled dimensions and arrangements are utilised as proof in concept of the mitigation option. It is likely that with further detailed assessment that more efficient designs to cater for the required flows are possible, however the modelled designs are suitable determine the magnitude of the reductions expected.

Figure 10-1 Flood Modification Measures

The majority of options are contained within the lower catchment and the Dee Why Town Centre. There are a number of reasons for this, principally the Town Centre has a much higher degree of flood affectation with widespread high flood hazard. Combined with the higher housing density, pedestrian activity and car movements, this translates to a much higher level of flood risk to both life and property when compared to other parts of the catchment. The Dee Why Town Centre Masterplan, particularly the streetscape upgrades, offers an opportunity for stormwater infrastructure upgrades to occur in tandem with other works, thereby resulting in significant cost-savings. The trunk drainage in the Dee Why Town Centre has capacity at key commercial areas subject to overland flow, limiting the adverse flooding impacts of stormwater infrastructure installations or upgrades. Oaks Avenue, one of the major commercial streets within the Town Centre, currently has no stormwater infrastructure but is subject to high hazard overland flows, and additional stormwater pipes could partially alleviate this flow without impacting upon existing infrastructure.

The majority of the stormwater infrastructure in the upper catchment is undersized. Any upgrade to infrastructure would have adverse flooding impacts at the termination of the upgrade. To minimise this, an entire stormwater line would require upgrading terminating in Beverley Job Park, resulting in adverse impacts within the public open space. As this would require extensive upgrades at great cost to Council, and would benefit a relatively small number of properties, the resultant cost-benefit ratio would likely be low and not rank highly amongst other options. For this reason, structural flood management measures for the upper catchment were not considered in this FRMS.

10.3.1 FM1 - Pipe upgrade between Pacific Parade and Oaks Avenue

Description

Significant ponding and overland flow occurs along Pacific Parade and Oaks Avenue. Option FM1 aims to minimise ponding in the trapped low point on Pacific Parade, reduce flooding between Pacific Parade and the open drain, and alleviate flooding along Oaks Avenue. The Option 1 figure (**Appendix C**) shows the general layout of the system. The realignment of the pipe under this option locates the drainage system underneath a laneway proposed within the Dee Why Masterplan.

The option consists of a 0.9 x 0.9 m Reinforced Concrete Box Culvert (RCBC) running from the low point located in front of 20 Pacific Parade to 34 Pacific Parade. The culvert then increases in size to a 1.2 x 1.2 m RCBC to account for additional flow entering the system from an existing drainage line (existing pipe diameter 900 mm). This culvert runs along the western edge of 34 Pacific Parade north into 33 Oaks Avenue. At the boundary of these two properties the existing open channel which runs west to east from the back of 12 Pacific Parade connects to the culvert. To accommodate this additional flow a 3.6 x 1.2 m RCBC is utilised within 33 Oaks Avenue. As the existing culvert which runs underneath Oaks Avenue has limited cover, along Oaks Avenue the option utilises 2 x 2.7 x 1.2 m RCBC to tie into the existing network.

Modelling Results

Figures for Option FM1 in **Appendix C** show the performance of the mitigation Option FM1 for the 100 years ARI event. The option manages to reduce the level of ponding in Pacific Parade while also reducing the level of flooding downstream of the option by up to 0.1 m. The existing culvert which runs underneath Oaks Avenue is fully utilised under the proposed option arrangement. Due to additional downstream capacity there is slightly more capacity in the existing open channel. As a result, breakout flow from the channel occurring at 9 Oaks Avenue is reduced.

The option has little impact on the overall hazard associated within the affected area, however there are localised pockets where the maximum hazard within Oaks Avenue has been reduced from moderate to low.

Overall the option provides some property protection and some minor reductions in hazard within the area.

10.3.2 FM2 - Increase drainage capacity along Oaks Avenue

Description

Oaks Avenue is subject to significant inundation in the 100 years ARI event and Option FM2 aims to reduce flood depths along Oaks Avenue (see **Appendix C** figures). A large diameter pipe is proposed to run the length of Oaks Avenue, connecting into the main box culvert opposite 33 Oaks Avenue.

The option as modelled consists of an 825 mm Reinforced Concrete Pipe (RCP) running on the northern side of Oaks Avenue from 874 Pittwater Road to its connection with the existing culvert east of 28 Oaks Avenue. Two existing 600 mm diameter pipes convey drawing flow from the southern side of Oaks Avenue located in place at 7 Oaks Avenue and 23 Oaks Avenue. The culvert downstream of Oaks Avenue currently has a small amount of capacity available. It may be possible to increase the diameter of the mitigation option pipes and provide more flood alleviation in the area. This possibility should be investigated within the detailed design phase.

The design aims to introduce flows into the large downstream culvert system prior to the main flows concentrating at this location. By doing this, the overall extent of flooding on Oaks Avenue may be significantly reduced.

Modelling Results

Figures for Option FM2 in **Appendix C** show the modelling results for the 100 years ARI event. Flood modelling indicates a reduction in flood depths of up 0.22 m in Oaks Avenue, with further reductions between Oaks and Howard Avenues. Due to the significant reduction in overland flows along Oaks Avenue, substantial areas along the road are now classified as low hazard where previously they were moderate to high hazard.

By placing this overland flow underground, significant reductions in the overall extent of flooding downstream of the option occur, resulting in significant reductions in property damage as well as reductions in the expected hazard along the main overland flow path.

This option is extremely effective at reducing the overall hazard along Oaks Avenue and results in significant benefits to areas along the main flow path downstream of the option.

10.3.3 FM3 - Drainage upgrades between Oaks and Howard Avenues plus Option FM2

Description

Option FM3 introduces a new underground drainage system to build upon Option FM2 (**Section 10.3.2**) which runs along the laneway proposed in the Dee Why Town Centre Masterplan as shown in **Appendix C** figures. The intention of the diversion is to prevent to existing culvert from overloading with Option FM2 in place.

Option FM3 consists of the same arrangement as Option FM2 to its connection with the existing culvert at 28 Oaks Avenue. Option FM3 then continues further east along Oaks Avenue with a 1,200 mm RCP running from 28 Oaks Avenue to west of 46-50 Oaks Avenue. This pipe then turns north along the property edge until it reaches Howard Avenue. This pipe then is diverted back to the existing pipe network, connecting in front of 30 Howard Avenue.

Modelling Results

Option FM3 acts in a very similar way to option FM2 described above. There are slightly larger depth and hazard reductions associated with the option, however in general they are minimal and do not provide a significant benefit over Option FM2.

This result indicates that at present there is little value diverting flow around the existing culvert without also increasing the downstream pipe network capacity. As there is no additional capacity to be obtained downstream of Howard Avenue, the option provides little benefit over FM2 while requiring substantially more pipe drainage.

10.3.4 FM4 - Daylighting of box culvert between Howard Avenue and Dee Why Parade

Description

Option FM4 aims to improve visual amenity and maximise the capture of overland flows, while at the same time providing water re-use opportunities for proposed green open space areas. The **Appendix C** figures for Option FM4 show the general layout of the system.

Option FM4 consists of the removal of the existing culvert between Howard Avenue and Dee Why Parade and reinstating an open channel in its place. For the purposes of modelling a 2.4 x 2.4 m rectangular open channel was selected to assess the option.

This option is not designed to significantly reduce flooding impacts within the area; rather it investigates the possibility of improving the visual amenity of the area as per the Dee Why Masterplan vision without adversely affecting the flooding within the site.

Modelling Results

Figures for Option FM4 in **Appendix C** for the 100 years ARI event show that the option removes some localised flooding immediately around the opened culvert. The improved capacity in this channel upstream of Dee Why Parade results in more flow entering the existing open channel downstream of Dee Why Parade. This leads to a reduction in depths of up to 0.1 m east of the option along Dee Why Parade and also slight reductions to property flooding and flooding along Avon Road.

Slight increases in flood levels within the existing open channel occur under this option, with impacts of 0.08 m experienced on 13 Richmond Avenue. It is likely that these impacts could be appropriately managed with some minor channel works at this location.

The outcomes of this option highlight that if, for aesthetic reasons this channel was returned to an open channel state, there is unlikely to be significant unmanageable impacts while providing some positive environmental and social benefits along Dee Why Parade and Avon Road.

10.3.5 FM5 - Walter Gors Park detention basin plus Option FM2

Description

Option FM5 aims to improve visual amenity, maximise the capture of overland flows and reduce flood depths in Oaks Avenue and Dee Why Parade. The **Appendix C** figures of show the general layout of the option. Option FM5 utilises the pipe network upgrades of Option FM2 (**Section 10.3.2**) and provides an open basin of around 2,000 m^3 at Walter Gors Park. The basin would be slightly depressed (0.5 m to allow some storage) with raised edges on the southwest and east, to just below the adjacent Dee Why Parade levels to maximise the storage area.

A possible constraint of this option is the outlet condition for the basin and the interaction with the existing channel and pipe networks. For the assessment of this option it was assumed that the outlet for the basin would be located on the eastern edge and redirected back to the main channel through parkland.

Modelling Results

Figures for Option FM5 in **Appendix C** for the 100 years ARI event show this option results in little to no improvement over Option FM2. The minimal impacts associated with the option are because the system is too far down the catchment to have significant influence on the system.

In addition to its locale in the catchment, as the basin is to be built above the top level of the adjacent culvert, appropriate mechanisms to discharge into the basin without negatively affecting the upstream channel would require detailed investigation. It is possible that with significant investment into this analysis, a suitable discharge arrangement could be found which results in savings downstream of the basin. However, as there are few flood affected properties downstream, this is unlikely to provide a large overall benefit to the catchment.

10.3.6 FM6 – Replace open channel between Oaks Avenue and Pacific Parade with new pipe under Pittwater Road plus Options FM1 and FM2

Description

Option FM6 aims to reduce flood depths in Oaks Avenue and Pacific Parade. Removal of the channel will improve development opportunity. The Option 6 figures in **Appendix C** show the general layout of the system. This option is assessed in conjunction with Option FM1, and also incorporates Option FM2 (but with a larger pipe).

In order to successfully divert flow from the open channel, an underground network system will be required from 860 Pittwater Road, where the existing 4 x 900 mm RCP are present. A 1.5 x 0.9 m RCBC will run from this location north, turning east into Oaks Avenue. The culvert then runs along the north of Oaks Avenue, reconnecting to the existing culvert east of 28 Oaks Avenue. As previously discussed, Options FM1 and FM2 are incorporated within this option to alleviate excessive flooding to the south of the de-commissioned channel.

Modelling Results

Figures for Option FM6 in **Appendix C** for the 100 years ARI event show reductions in flood depths of up to 0.22 m downstream of Oaks Avenue and to the east of Oaks Avenue. The reduction in overall flood impact associated with the option is significant, and is due to both increased capacity in the underground drainage removing overland flow prior to it reaching Oaks Avenue, and the underground network effectively discharging local flows through the network prior to the main flood reaching the system.

As expected, due to the removal of the open channel, there are some localised increases in flood depth and hazard. These impacts are mainly due to the removal of the existing pipe connection from Pacific Parade, which results in substantially more overland flow entering the area through 18 Pacific Parade, travelling north and impacting 7 and 9 Oaks Avenue. This results in greater depths of flooding and increased hazard through this section of Oaks Avenue.

If this option was to be implemented, additional investigation into appropriate measures to alleviate the local impacts would be required.

10.3.7 FM7 - Raise level of Oaks Avenue and Howard Avenue plus Option FM2

Description

Option FM7 aims to divert flow that currently runs along Howard Avenue and Oaks Avenue along Pittwater Road to Dee Why Parade as shown in the **Appendix C** figures for Option FM7. The concept behind the option is to activate more floodplain area to reduce the overall hazard present for the area.

The option involves increasing the road level across Howard Avenue and Oaks Avenue to be flush with the kerbing (raise approximately 0.25 m). It is noted that given the current grades and entrance levels from Pittwater Road that this may not be feasible without significant intersection works. However, in order to identify the effectiveness of the option these are the parameters that were considered.

Modelling Results

Figures for Option FM7 in **Appendix C** for the 100 years ARI event show increased flood depths of up to 0.3 m along Pittwater Road as additional flow is re-directed down this street. The additional flow overtops along Howard Avenue as the raised levels are insufficient to move flows further along Pittwater Road, as the hazard is already high along some of Pittwater Road, the increased water level does not have a significant impact on the resultant hazard for the area.

Oaks Avenue sees significant reductions in both hazard and flow velocity, as well as depth reductions of 0.3 m. The raised level across Oaks Avenue and Howard Avenue has effectively created a small storage area along Pittwater Road. While this has resulted in some negative impacts locally, it has eased the pressure on the overloaded main drainage system and allowed more widespread reductions downstream.

While this option may not be feasible due to the increased water levels and hazard experienced along Pittwater Road, it highlights the improvements possible with minimal upstream storage within this system. Due to the flash flooding nature of the area, small storage areas intelligently placed through the catchment may result in significant reductions in flood impact.

10.3.8 FM8 - Storage basins at Mooramba Road car park and Redman Road

Description

Option FM8 aims to reduce peak flows crossing Pittwater Road and provide suitable locations for water re-use and treatment. The concept is to prevent as much flow as possible from crossing Pittwater Road into the Town Centre. The two areas used for storage have been earmarked for re-development in the Dee Why Town Centre Masterplan. Option FM8 figures in **Appendix C** show the option layout.

To assess the impacts of storage, 1,850 m^3 tanks were modelled at this location. In order to ensure that both systems filled to capacity at relatively the same time, a 600 mm diameter RCP was used to join the two tanks. The Mooramba Road tank is located above the main drain, so the system was designed to surcharge into the tank. The Redman Road tank is located along the main overland flow path. Large pits to intercept flow upstream of the tank were placed along Redman Road to fill this tank.

Modelling Results

Figures for Option FM8 in **Appendix C** for the 100 years ARI event show reductions in hazard and flood depth along Pittwater Road and throughout the Dee Why Town Centre. This option shows significant potential with very large reductions in flood depth and flow velocity occurring for significant periods downstream of the basins.

As previously discussed, this catchment, especially through the Dee Why Town Centre area, is highly reactive to upstream storages.

10.3.9 FM9 - Upgrade of Open Channel between Victor Road and Redman Road plus Option FM8

Description

Option FM9 aims to reduce the presence of hazard along the open channel between Redman Road and Victor Road. Currently this drainage section exhibits significant hazard in the 100 years ARI event. The drainage system is a mix of open drains of varying sizes and pipes. The option comprises a standardised open section with pipes used to convey flow over what previously were defined as "waterfalls". Option FM9 figures in **Appendix C** show the proposed configuration.

The channel through this reach was re-sized to a consistent cross-section. It comprised a trapezoidal shape 3 m deep with a 4 m wide base and 5 m wide surface width through areas with low grade. The existing channel varies in cross-section, generally being about 0.4 m to 1.7 m deep and 2.1 m to 5.7 m wide. In areas that have significant grade, such as the waterfalls, large diameter pipes were used to convey flow from top to bottom. This system was selected to minimise the energy loss associated with the drop.

As this option is likely to result in a significantly higher peak flow being present at Redman Road, the two storage basins defined in Option FM8 (refer **Section 10.3.8**) were also incorporated within the option to offset this increased peak flow.

Modelling Results

Figures for Option FM9 in **Appendix C** for the 100 years ARI event show that the increased flow could not be contained within the proposed storages at Redman Road and Mooramba Road. As a result significantly greater impacts occur downstream than in the existing conditions.

As the outcomes of this assessment are primarily negative, this option has not been pursued any further. From the results it is apparent that in order to safely direct the increased flows from Redman Road to the Dee Why Lagoon outlet a whole of system infrastructure upgrade would be required.

10.3.10 FM10 – Combination of Option FM2 and Option FM8

Description

Option FM10 is a combination of Options FM2 and FM8, and comprises underground storage tanks in Mooramba Road (FM8) and additional drainage capacity in Oaks Avenue (FM2). In combination, the two measures aim to reduce flooding prior to Pittwater Road and on Oaks Avenue.

Modelling Results

Option FM8 results in reductions to flood levels at Pittwater Road and also on Oaks Avenue and downstream. Option FM2 reduces overland flood depths on Oaks Avenue and Howard Avenue in particular.

Option FM10 does not provide net cumulative benefit equivalent to the sum of the benefits associated with Options FM2 and FM8. This is due to the fact that each of the individual options has an overlap in the parts of the catchment for which they provide a benefit.

In the 5 years and 10 years ARI Option FM10 does provide some improvement over Option FM2 on its own due to reduction in flood impacts for areas upstream of Oaks Avenue along Pittwater Road. It does not, however, provide significant benefit over Option FM8 for these events.

In the less frequent events, such as the 100 years ARI, Option FM10 provides a significant reduction in flood impact because the option captures flow from upstream and temporarily detains floodwaters at the Mooramba Road car park, resulting in significant reductions in flood levels along Oaks Avenue and Howard Avenue. As a result, Option FM10 removes almost all the high hazard areas along and downstream of Oaks Avenue.

10.3.11 Velocity-Depth Product Effects

As discussed in **Section 5.4.6**, rather than simply trying to reduce overland flooding in the 100 year ARI event, Council's objective for flood mitigation is to reduce the areas subject to potentially hazardous flow conditions. This includes overland flows such as those that result in vehicle instability and are hazardous to pedestrians, specifically where the velocity-depth product (VxD) is greater than $0.4m^2/s$.

Table 10-3 lists the total area and percentage reduction in the area exposed to a VxD greater than $0.4m^2/s$ for the modelled options.

Table 10-3 Mitigation Measures Velocity-Depth Product Effects

Scenario	Area of VxD ≥0.4 m^2/s (m^2 – to nearest hundred)	% Reduction Over Existing
Existing	185,800	N/A
Option FM1	163,700	12%
Option FM2	170,100	8%
Option FM3	173,300	7%
Option FM4	175,700	5%
Option FM5	169,600	9%
Option FM6	120,700	35%
Option FM7	131,000	30%
Option FM8	167,500	10%
Option FM9	183,700	1%
Option FM10	156,600	16%

Reductions in VxD are highest for Options FM6 and FM7, followed by FM10 and FM1. However, FM6 and FM7 also show an increase in peak depths compared to existing conditions. The reduction for FM10, which is a combination of FM2 and FM8, is not a sum of the two reduction percentages as the options may result in benefits at similar locations.

The reduction in this parameter is not the only factor in assessing the feasibility of measures, and other factors such as cost will also be assessed. **Section 12** details the assessment of the measures for a broader range of criteria.

10.4 Property Modification Measures

Property modification measures are aimed at preventing and reducing the consequences of flood risks by modifying properties (both existing and future). Council's current LEP and DCP (discussed in **Section 8**) are planning instruments which provide specific guidelines for how land may be used and developed.

Table 10-4 lists the property modification options reviewed for this Study.

Table 10-4 Property Modification Measures

Option No.	Description	Section Reference
PM1	House raising	**Section 10.4.1**
PM2	Voluntary purchase	**Section 10.4.2**
PM3	Land swap	**Section 10.4.3**
PM4	Flood proofing	**Section 10.4.4**

10.4.1 PM1 - House Raising

House raising is a measure to reduce the incidence of over-floor flooding of properties. However, whilst house raising can reduce the occurrence of over-floor flooding other issues related to this approach include:

> Difficulties in raising some houses, such as slab on ground buildings. For some slab on ground houses it may be possible to install a false floor, although this is limited by the ceiling heights;

> The potential for damage to items on a property other than the raised dwelling (such as gardens, sheds, garages, etc.) are not reduced;

> Unless a dwelling is raised above the level of the PMF, the potential for over-floor flooding still exists (i.e. there will still be a residual risk);

> Evacuation may be required during a flood event for a medical emergency or similar, even if no over-floor flooding occurs, and this evacuation is likely to be hampered by floodwaters surrounding a property;

> The need to ensure the new footings or piers can withstand flood-related forces; or

> There is potential for conflict with height restrictions imposed for a specific zone or locality within the LGA.

In a 5 years ARI event, the flood damages analysis (**Section 6**) identified that 57 properties are inundated to over-floor levels between Pittwater Road and Dee Why Lagoon. The majority of buildings in this area, excluding those fronting Pittwater Road, are multi-storey residential units. Viability of a house raising scheme in this catchment is therefore limited. Several publicly owned buildings on Howard Avenue are single storey and identified with over-floor flooding in a 5 years ARI event, but are located within the re-development area of the Dee Why Town Centre Masterplan. A house-raising scheme may not be applicable to commercial properties on Pittwater Road as they depend on customer access being near ground level.

Although Option PM1 is not viable for this catchment, it is considered for the purpose of providing a comprehensive options assessment.

10.4.2 PM2 - Voluntary Purchase

The voluntary purchase of existing flood affected properties is an alternative to the construction of flood modification measures for properties where house raising is not possible. Option PM2 would free both residents and emergency services personnel from the hazard of future floods by removing the risk. This can be achieved by the purchase of properties and the removal and demolition of buildings. Properties could be purchased by Council at an equitable price and only when voluntarily offered. Such areas would then need to be re-zoned under the LEP to a flood compatible use, such as recreation or parkland, or possibly re-developed in a manner that is consistent with the flood hazard.

However, due to the significant expense associated with purchase of properties in the study area, this measure should be considered only after other, more practical measures have been investigated and exhausted.

Potential criteria to determine properties that are eligible for voluntary purchase are:

> Located in the high hazard zone for the 100 years ARI flood event; and

> Occurrence of over-floor flooding in the 5 years ARI flood event; and

> Economic value of damages for a particular property is comparable to the property market value.

The OEH has prepared guidelines for voluntary purchase schemes that detail the objectives, eligibility criteria, funding and implementation procedure.

There are no residential properties with over-floor flooding in the 5 years ARI event which result in property damages greater than $160,000, even in the PMF. Therefore, no properties have been identified for voluntary purchase in the catchment. In addition to this, as the OEH budget for the acquisition of land is $1 million annually, it is unlikely that any blocks of land could be purchased within this budget considering the higher than average house prices in this area and this option has only been considered for purposes of providing a comprehensive options assessment.

10.4.3 PM3 - Land Swap

An alternative to voluntary purchase is the consideration of a land swap program whereby Council swaps a parcel of land outside of the flood prone area, such as an existing park, for a parcel of flood prone land with the appropriate transfer of any existing facilities to the acquired site. After the land swap, Council would then arrange for demolition of the building and have the land re-zoned under the LEP to open space.

Several publicly owned buildings on Howard Avenue are single storey and identified with over-floor flooding in a 5 years ARI event, but are located within the re-development area of the Dee Why Town Centre Masterplan. Thus, a land swap arrangement may not be appropriate as alternative arrangements for the facilities may be proposed within the Masterplan.

10.4.4 PM4 - Flood Proofing guidelines

Flood proofing involves undertaking structural changes and other procedures in order to reduce or eliminate the risk to life and property, and thus the damage caused by flooding. Flood proofing of buildings can be undertaken through a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding. It is primarily suited to industrial or commercial properties.

The *Floodplain Development Manual* (NSW Government, 2005) advises that flood proofing is an additional measure to other measures. It is noted that flood proofing may minimise structural and contents damage but the occupants may still experience social and economic disruption caused by flooding.

Potential flood proofing measures include modifications or adjustments to building design, site location or placement of contents. Measures range from elevating or relocating a building and temporary flood barriers to the intentional flooding of parts of the building during a flood in order to equalise pressure on walls and prevent them from collapsing.

Option PM4 provides for the development of guidelines on flood proofing measures that may be considered for properties located within the floodplain. These guidelines could be included as an attachment to the DCP.

Examples of proofing measures include:

> All structural elements below the FPL shall be constructed from flood compatible materials;

> All structures must be designed and constructed to ensure structural integrity for immersion and impact of debris up to the 100 years ARI flood event. If the structure is to be relied upon for shelter-in-place evacuation then structural integrity must be ensured up to the level of the PMF; and

> All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the FPL.

The NSW SES *Flash Flood Tool Kit* (SES, 2012) provides businesses with a template to create a flood-safe plan and to be prepared to implement flood proofing measures.

In addition to flood proofing measures that are implemented to protect a building, temporary / emergency flood proofing measures may be undertaken prior to or during a flood to protect the contents of the building. These measures are generally best applied to commercial properties.

These measures should be carried out according to a pre-arranged plan and may include:

> Raising belongings by stacking them on shelves or taking them to a second storey of the building;

- Securing objects that are likely to float and cause damage;
- Re-locating waste containers, chemicals and poisons well above floor level; and
- Installing any available flood proofing devices, such as temporary levees and emergency water sealing of openings.

Flood proofing barriers ranging from single door entries and car park entries to whole building frontages have been installed to new buildings and retrofitted to existing buildings. The systems vary in design, operation and their aesthetic impact. They include:

- Flood proof doors – being a normal use pedestrian door or bi-fold flood barriers that recess into a wall cavity (potentially for a double-door shop front);
- Flood proof roller doors – typical roller doors in appearance which seal at the frame edges to exclude water ingress;
- Manual flood barriers – generally removable panels that slot into a frame installed across the opening (a single person operation);
- Automatic flood barriers – a solid barrier that rises from a recess in the ground. The barriers can raise automatically using float switches / water level sensors and utilise battery backup / uninterruptable power supplies; and
- Temporary levees – a temporary levee wall created by planks installed within guideposts or tilt-up panels.

A significant advantage of these systems is that they can be retrofitted to existing buildings where permanent flood protection systems not reliant on mechanical or manual input. The manual flood barrier systems rely on persons to install the components, however a flood event may occur at a time when the property is unoccupied, thereby relying on pre-emptive installation of the system prior to leaving the premises.

Automatically operated systems require regular maintenance and testing to ensure they will operate to specifications. Training on installation and operation of the devices would also be required. Some devices also preclude access as they are designed as barriers to be impermeable to flood water. Flooding in the catchment is primarily of short duration and rapid rise, meaning the flood proofing systems must be installed quickly but that they may not be required to be installed for extended periods.

Building Entries

Flood proof doors are designed as functional systems and may impact on aesthetics and accessibility. For example, some doors may be more suited as fire-exits rather than shop entries where they may be too obtrusive. Slot in barriers may be the most applicable method for flood proofing entries to commercial buildings. Care in storage of the barriers and ready access to them in case of a flood event will also be required.

Basement Car Parks

Flood proof roller doors may be suitable to replace existing roller doors to exclude flood waters from inundation of garages. Automatic flood barriers rising from the ground are potentially applicable to retrofit existing entry ramps into basement car parks to provide flood proofing to the required level.

The ability of these flood proofing measures to exclude inundation of flood water is dependent on the installation and maintenance. Systems not properly installed or maintained will compromise their effectiveness at providing barriers to flooding. A flood proofing strategy will need to be developed to assess the applicability of measures for specific locations in the catchment and acceptance / operation of the systems by users and property owners.

10.5 Emergency Response Modification Measures

Emergency response modification measures aim to reduce the consequences of flood risks generally by modifying the behaviour of people during a flood event. Improved emergency response, warning measures and increased community awareness are specific outcomes. **Table 10-5** lists the options reviewed for this Study.

Table 10-5 Emergency Response Modification Measures

Measure Reference	Description	Detailed in Report Section
EM1	Information transfer to the NSW SES	**Section 10.5.1**
EM2	Flood warning systems	**Section 10.5.2**
EM3	Public awareness and education	**Section 10.5.3**
EM4	Flood warning signs	**Section 10.6.4**
EM5	Event data collection	**Section 10.7.5**

10.5.1 EM1 - Information Transfer to the NSW SES

The findings of the Flood Study (Cardno, 2013) and this FRMS are an important source of catchment-specific information for the NSW SES and Council. Details of flood risks at specific locations are important for planning of operational tasks and for the future review of the *Manly-Warringah-Pittwater Flood Emergency Sub-Plan* (due no later than January 2018).

10.5.2 EM2 - Flood Warning Systems

The implementation of a flood warning system in this catchment is limited due to the short time interval between the onset of a storm and flood impacts, and response times are very limited. For a flash flood warning systems to be effective it must provide accurate real time data. The application and accessibility of the data is important. People must be able to understand the information available, potential implications of the event, and appropriate responses to any warnings.

The Northern Beaches Flood Warning System implemented by the local Councils (Pittwater, Warringah and Manly) is also described in **Section 7.3**. The system is part of a five-year plan to develop a basic flood warning system for the region. The aim of the system and associated webpage is to provide actual rainfall and water level data in real time to the community, NSW SES and The Councils for reducing the risk to life and property from flooding.

The system is primarily a simplistic flood warning network. It involves the installation and maintenance of a number of rainfall, water level and flow gauges with data recorded in near real time on a purpose built web page. Event data is frequently updated on the interactive webpage hosted by Manly Hydraulics Laboratory (MHL) (http://new.mhl.nsw.gov.au/users/NBFloodWarning).

Previous flood studies in Northern Beaches catchments identified that inundation and flood impacts may occur when a 2-5 years ARI event occurs. The following trigger levels were adopted for setting alarms on the six rainfall gauges:

> 20 mm in 1 hour;

> 70 mm in 3 hours; or

> 150 mm in 24 hours.

Currently, rainfall alarms are to be sent to trained personnel only in Council and the NSW SES.

During subsequent contracts, a more sophisticated flood warning system may be implemented as technology improves. The warning system of gauge infrastructure and the associated webpage could be enhanced as discussed below. It is noted that the effectiveness of the system is dependent on the community reception and their response to warning messages.

The NSW SES, along with Manly, Warringah and Pittwater Councils, developed the Northern Beaches Flood and Coastal Storms Education Strategy in 2012. A survey of residents for this strategy identified that specific warning messages were preferably disseminated directly to them via SMS messages and door knocks by the NSW SES. SMS messages are used by other agencies as it is considered effective to advise of impacted residents of potential danger. Appropriate trigger levels (such as rainfall and Lagoon levels) for issuing of alerts and potential recipients in flood affected locations will need to be developed. MHL have advised that the capability within their systems exists for this to occur. However, currently the water level alarms are not set at levels which indicate flooding but thresholds which facilitate entrance management decisions.

A second potential improvement is that although there is IP telemetry in most of the gauges and the older infrastructure is in the process of having this installed, the data still goes to MHL's servers where it is uploaded onto the webpage. This often creates a delay from rainfall occurring to data on the webpage of around 30 mins. In a flash flood environment such as the Northern Beaches, this may be too long to provide any meaningful flood warning. Regular maintenance and monitoring of the gauges and system is required to ensure it is functioning correctly and any breakdown in gauges or telemetry failure is quickly corrected.

The existing gauges of the warning system may be combined with live vision from webcams located in key areas, such as the Dee Why Lagoon entrance. This will enable remote monitoring and thus more regular checking of the conditions to enable specific actions to be undertaken if required, such as opening the Lagoon entrance.

Electronic message boards could be installed at key locations in the catchment where flooding occurs, such as around Pittwater Road and Dee Why Town Centre. These message boards could be used to prevent residents and vehicles moving into affected areas, and to evacuate affected areas with the aim to prevent injury and reduce property losses.

Information from the flood studies (available on Council's website) could be expanded onto the event webpage as a predictive tool to advise of potential flooding trouble spots based on the received gauge information.

Effectiveness of the warning system is dependent on the understanding and use of the system. Therefore, ongoing education of Council staff and the community is required.

10.5.3 EM3 - Public Awareness and Education

Flood awareness is an essential component of flood risk management for people living in the floodplain. The affected community must be made aware of, and remain aware of, their role in the overall floodplain management strategy for their area. This includes preparations to reduce the risk of damage, the defence of their property and their evacuation (if required) during the flood event.

Flood awareness campaigns need to be an ongoing process and requires the continuous effort of related organisations (e.g. Council and NSW SES). A major factor determining the degree of awareness within the community is the frequency of moderate to large floods in the recent history of the area. For effective flood emergency planning, it is important to maintain an adequate level of flood awareness during the extended periods when flooding does not occur. A continuous awareness program needs to be undertaken to ensure new residents are informed, awareness among long-term residents is maintained, and to allow for changing flood behaviour and new developments.

In May 2012, a community survey was undertaken by the three Councils and NSW SES to determine the level of understanding and awareness of flood preparedness and response to flooding and coastal erosion on the Northern Beaches. It was found that there is a very low level of concern regarding flooding by the Northern Beaches community (Micromex, 2012).

NSW SES, Manly, Warringah and Pittwater Councils developed the Northern Beaches Flood and Coastal Storms Education Strategy in 2012. The strategy has been developed to identify actions that will be undertaken by the Northern Beaches Councils to raise awareness of the mechanism and potential impacts of natural hazards and encourage appropriate emergency response behaviours. It aims to improve community knowledge, attitudes and actions towards flooding and coastal storms on the Northern Beaches by implementing a participatory, tailored and ongoing education program that builds disaster resilience within the Northern Beaches community. It lists a series of actions to be undertaken by the organisations within the 2012-2016 period.

The current actions identified in the Strategy encourage a rather ad-hoc approach to education. For example, attendance at events and distribution of material where available being examples of two such actions. A better approach may be to develop a holistic education campaign that is rigorously planned and identifies required resources (both staff and financial) for implementation, as well as defining objectives and how the education campaign will be evaluated against those objectives. The Micromex survey which was undertaken prior to the development of the Strategy identified hazard 'appetite' through awareness of various parameters. Future surveys need to be designed to include questions which assess baseline scenarios relating to an objective, follow up surveys can then somewhat objectively assess the results of the education campaign.

Council's website has both general and specific information on flooding in the LGA. Completed flood studies and FRMSs are available as well as general information and a Flood Safe Warringah Brochure which provides general information on flooding in the LGA, preparation in case of a flood, as well as flood response and recovery.

The Northern Beaches Flood and Coastal Storm Education Strategy compliments the Northern Beaches Flood Warning Network (discussed in **Section 10.5.2**) by identifying actions to regularly promote the MHL webpage. The following methods were identified:

> NSW SES Flash Flood Guide for Pittwater LGA (and shortly Manly LGA);
> Links on each Council webpage;
> Regular social media updates by each Council to the webpage, especially during large rain events;
> Council newsletters;
> Presentations by NSW SES in schools;
> Local newspaper (i.e. the Manly Daily);
> Attendance by NSW SES at festivals and events; and
> Provision of information to local businesses through the Chamber of Commerce.

Review of the demographic characteristics of the catchment (**Section 2.3**) identified that languages other than English are used by the community. Therefore, education programs and the publication of outcomes of this Study will need to address the prevalent languages used in the community.

Ongoing education should promote the webpage and awareness of flooding, however it is likely that a significant flood will also achieve the same result, although most likely after the event.

10.5.4 EM4 - Flood Warning Signs

Flood warning signs are commonly located in locations that are periodically inundated and present a traffic or pedestrian hazard. A number of public places and roads in the catchment experience high hazard flooding in the 100 years ARI event. It is therefore important that appropriate flood warnings signs are posted at these locations. These signs may contain information on flooding issues, or be depth gauges to inform residents of the flooding depth over roads and paths.

Potential locations for flood warning signs (based on the existing 100 years ARI extent) include:

> Intersection of Pittwater Road, Redman Road, and Fisher Road;
> Victor Road, near Lewis Street; and
> Howard Avenue, east of Pittwater Road near the open channel.

In a PMF event, high hazard flow conditions are shown in more locations, some of which may benefit from provision of warning signs dependent on potential risk and effectiveness for pedestrians / drivers.

10.5.5 EM5 - Event Data Collection

Post-flood event data is useful to further develop understanding of flood behaviour in the catchment, to estimate potential future flood extents, and guide the application of mitigation measures and plans. This measure comprises development of a strategy for the collection of data following a flood event, including a data collection form, methodology, and resourcing to facilitate the task. This may comprise detailed ground survey of flood extents and depth marks on buildings and properties. Specific data collected within the catchment has increased as Council has installed rainfall gauges and flow gauges in drainage channels.

11 Economic Assessment of Options

11.1 Preliminary Costing of Options

Preliminary cost estimates have been prepared for the flood modification measures (**Table 11-1**), being those options that allow for an economic assessment via consideration of the cost of implementation and the associated reduction in flood damages. For other measures, broad cost estimates were made for the purpose of comparison in the multi-criteria assessments detailed in **Section 12**.

As discussed in **Section 10.3.9**, Option FM9 is not technically feasible in and a detailed cost estimate and modelling to assess the change in AAD have not been undertaken.

Prior to a measure proceeding, it is recommended that in addition to detailed analysis and design of the measure, that these costs be revised prior to budget allocation to allow for a more accurate assessment of the overall cost. Detailed rates and quantities will also be required at the detailed design phase. A cost breakdown is provided in **Appendix D.**

Table 11-1 Cost Estimates for Quantitatively Assessed Measures

Option No.	Description	Capital Cost (excl. GST)	Ongoing (Annual) Costs (excl. GST)
FM1	Pipe upgrade between Pacific Parade and Oaks Avenue	$3,512,933	$3,710
FM2	Increase drainage capacity along Oaks Avenue	$1,158,473	$1,900
FM3	Drainage upgrades between Oaks and Howard Avenues plus Option FM2	$2,256,887	$4,120
FM4	Daylighting of box culvert between Howard Avenue and Dee Why Parade	$1,367,700	$1,250
FM5	Walter Gors Park detention basin plus Option FM2	$2,090,423	$10,950
FM6	Replace open channel between Oaks Avenue and Pacific Parade with new pipe under Pittwater Road plus Options FM1 and FM2	$4,948,201	$6,610
FM7	Raise level of Oaks Avenue and Howard Avenue plus Option FM2	$1,254,023	$2,200
FM8	Storage basins at Mooramba Road car park and Redman Road	$4,355,963	$21,000
FM9	Upgrade of Open Channel between Victor Road and Redman Road plus Option FM8	*Not costed.*	
FM10	Combination of Option FM2 and Option FM8	$5,499,435	$22,900

11.2 Annual Average Damages Assessment

An assessment of AAD for the existing condition was presented in **Sections 6.5 and 6.6**. As the flood management options selected are predominantly concerned with the reduction of local flood impacts, rather than assess the catchment wide damages, the reduction in damages resulting from local decreases in flood depths and extents has been considered. The results (all excl. GST) are summarised in **Table 11-2**, noting that the AAD under existing conditions is $3,852.321 (excl. GST).

Table 11-2 Reduction in Damages Associated with Each Option

Option No.	Description	Reduction in Damages for 100 years ARI	Total Reduction in AAD
FM1	Pipe upgrade between Pacific Parade and Oaks Avenue	$629,166	$581,166
FM2	Increase drainage capacity along Oaks Avenue	$787,827	$445,378
FM3	Drainage upgrades between Oaks and Howard Avenues plus Option FM2	$807,768	$440,600
FM4	Daylighting of box culvert between Howard Avenue and Dee Why Parade	$14,852	-$121,014
FM5	Walter Gors Park detention basin plus Option FM2	$772,673	$426,673
FM6	Replace open channel between Oaks Avenue and Pacific Parade with new pipe under Pittwater Road plus Options FM1 and FM2	$205,678	$368,461
FM7	Raise level of Oaks Avenue and Howard Avenue plus Option FM2	$221,272	$143,733
FM8	Storage basins at Mooramba Road car park and Redman Road	$3,223,939	$1,140,478
FM9	Upgrade of Open Channel between Victor Road and Redman Road plus Option FM8	*Not costed.*	
FM10	Combination of Option FM2 and Option FM8	$4,618,594	$1,196,201

11.3 Benefit Cost Ratio of Options

The economic evaluation of each modelled measure was assessed by considering the reduction in the amount of flood damages incurred for the design events and by then comparing this value with the cost of implementing the measure.

The existing condition (or the 'do nothing' option) was used as the base case to compare the performance of modelled options (FM1-FM10). Inputs for the assessment include those data derived from the floor levels and property survey along with damage curves for other similar areas. The flood extents for all the design events were considered for this evaluation. The preliminary costs of each measure were used to undertake a benefit-cost analysis of each measure on a purely economic basis.

Table 11-3 summarises the results of the economic assessment of each of the flood management options. The indicator adopted to rank these measures on economic merit is the benefit-cost ratio (B/C), which is based on the net present worth (NPW) of the benefits (reduction in AAD) and the costs (of implementation), adopting a 7% discount rate and an implementation period of 50 years.

The benefit-cost ratio provides an insight into how the damage savings from a measure, relate to its cost of construction and maintenance:

> Where the benefit-cost is greater than 1 the economic benefits are greater than the cost of implementing the measure;

> Where the benefit-cost is less than 1 but greater than 0, there is still an economic benefit from implementing the measure but the cost of implementing the measure is greater than the economic benefit;

> Where the benefit-cost is equal to zero, there is no economic benefit from implementing the measure; and

> Where the benefit-cost is less than zero, there is a negative economic impact of implementing the measure.

Table 11-3 Summary of Economic Assessment of Flood Management Options

Option No.	NPW of Reduction in AAD (excl. GST)	NPW of Cost of Implementation (excl. GST)	B/C Ratio	Economic Ranking
FM1	$8,582,000	$3,567,000	2.41	6
FM2	$6,577,000	$1,186,500	5.54	1
FM3	$6,506,300	$2,317,700	2.81	4
FM4	-$1,787,000	$1,386,200	-1.29	9
FM5	$6,300,600	$2,252,100	2.80	5
FM6	$5,441,000	$5,045,800	1.08	8
FM7	$2,122,500	$1,286,500	1.65	7
FM8	$16,841,200	$4,666,100	3.61	2
FM9	*Not costed.*		*N/A*	*N/A*
FM10	$17,664,100	$5,837,600	3.03	3

The top three highest ranking flood management options are:

> Option FM2 - Increase drainage capacity along Oaks Avenue;

> Option FM8 - Storage basins at Mooramba Road car park and Redman Road; and

> Option FM10 - Combination of Option FM2 and Option FM8.

Option FM2 has the highest economic benefit cost ratio due to the relatively low cost of implementation, which is around one fifth of the economic benefit derived from the reduction in AAD.

Option FM4 has a negative economic benefit cost ratio due to the resultant increase in AAD and consequently falls last in the rankings.

It is noted that the economic analysis has only incorporated changes to economic damages to properties, and does not consider social factors, risk to life and environmental factors. These types of benefits are difficult to quantify in dollar terms. The multi criteria analysis (**Section 12**) incorporates some of these non-quantifiable impacts into the decision making process.

12 Multi-Criteria Options Assessment

12.1 Overview

A multi-criteria (matrix-based) assessment MCA has been adopted for the comparative assessment of all the options identified. The matrix effectively provides a quadruple-bottom line assessment (economic, social, environmental, governance) of the options using a similar approach to that recommended in the *Floodplain Development Manual* (NSW Government, 2005). It uses a subjective scoring system to assess the relative merits of various options developed in this FRMS.

The principal merits of such a system are that it allows direct comparison of very different types of options using common criteria. In addition, it makes the assessment methodology more methodical and transparent. However, it is noted that this approach does not provide an absolute "right" answer as to what should be included in the FRMP and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

12.2 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the outcome of the economic assessment (**Section 11**) and the background information on the nature of the catchment (**Section 2**), and the other relevant information provided in **Sections 7-10**.

Each measure is given a score for the specific criteria listed in **Table 12-1**.

Table 12-1 MCA Scoring System

Criteria	Score				
	1	2	3	4	5
Economic					
Benefit Cost Ratio*	< 0	0 - 2	2 - 4	4 - 6	6+
Risk to Property	Major increase in AAD	Slight increase in AAD	No improvement	Slight decrease in AAD	Major decrease in AAD
Critical Infrastructure	Highly negative impact	Slight negative impact	No impact	Some benefit	Considerable benefit
Capital Cost	> $5 million	> $3 million	> $2 million	> $1 million	< $1 million
Ongoing Costs	> $20,000	$15,000 - $20,000	$10,000 - $15,000	$5,000 - $10,000	$0 - $5,000
Social					
Risk to Life	Major increase in risk to life	Slight increase in risk to life	No change in risk to life	Slight reduction in risk to life	Major reduction in risk to life
Social Disruption	Major increase in social disruption	Slight increase in social disruption	No change to social disruption	Slight reduction of social disruption	Major reduction of social disruption
Compatibility with Council Policies & Plans	Completely incompatible	Slightly incompatible	Neutral	Slightly compatible	Completely compatible
Community & Stakeholder Support**	Strong disagreement	Disagreement	Neutral	Support	Strong support
Environmental					
Water Quality Objectives	Completely incompatible	Slightly incompatible	Neutral	Slightly compatible	Completely compatible

Criteria	Score				
	1	2	3	4	5
Water Re-use Schemes	Completely incompatible	Slightly incompatible	Neutral	Slightly compatible	Completely compatible
Fauna & Flora Impact – incl. street trees	Strong negative impact	Slight negative impact	No impact	Slight positive impact	Considerable positive impact

See **Table 11-3. **This criterion has not been scored but will be completed pending community consultation during the public exhibition phase.*

The assignment of a score for each criterion for each option is shown in its entirety in the complete matrix in **Appendix E**. The total score of each option was calculated by equally weighting each criteria and summing the total.

Each of the options was then ranked against each other based on the total scores, allowing identification of the preferred options, namely those that provide the greatest benefit to the community. These total scores and rankings are also shown in **Appendix E**.

The rankings are proposed as the basis for selecting management options for inclusion in the FRMP, and for prioritising their implementation. It must be emphasised that the scoring and rankings shown in **Appendix E** are not final and must be subject to careful as part of the process of preparing the FRMP, pending the outcomes of the stakeholder and community consultation during the public exhibition phase.

It is noted that both structural (flood modification) and non-structural (property modification and emergency response) options have been considered separately. Generally, it is difficult to directly compare these types of measures. Furthermore, funding sources and implementation timeframes for the two different types of measures are typically different. Therefore, they have been considered separately and ranked as such.

12.3 Summary of Options Assessment Outcomes

Table 12-2 provides a ranked list of management options for consideration for inclusion in the FRMP. The options selected for inclusion in the Plan should be based on both their likely benefits and the available funding available from Council and the State Government.

If Option FM10 (being a combination of the two most cost-effective options, FM2 and FM8) is the only structural option implemented, the total cost of implementation would be $5,565,435 (excl. GST). Furthermore, it is noted that due to the proposed re-development of the Mooramba Road car park, there is potential make cost savings in implementing Option FM10 (or Option FM2 on its own, if Council chooses not to proceed with Option FM8) concurrently with the proposed site development.

Table 12-2 Summary of MCA Evaluation for Options

Option No.	Description	Total Score	Overall Rank	Rank (Structural / Non-Structural)
EM3	Public Awareness and Education	41	1	NS-1
FM2	Increase drainage capacity along Oaks Avenue	40	2	S-1
PM4	Flood Proofing guidelines	40	2	NS-2
EM4	Flood Warning Signs	40	2	NS-2
EM1	Information transfer to NSW SES	39	5	NS-4
EM2	Flood Warning System	39	5	NS-4
FM3	Drainage upgrades between Oaks and Howard Avenues plus Option FM2	38	7	S-2
FM1	Pipe upgrade between Pacific Parade and Oaks Avenue	37	8	S-3

Option No.	Description	Total Score	Overall Rank	Rank (Structural) / Non-Structural)
FM7	Raise level of Oaks Avenue and Howard Avenue plus Option FM2	36	9	S-4
FM8	Storage basins at Mooramba Road car park and Redman Road	36	9	S-4
EM5	Event Data Collection	36	9	NS-6
FM4	Daylighting of box culvert between Howard Avenue and Dee Why Parade	35	12	S-6
FM10	Combination of Option FM2 and Option FM8	35	12	S-6
FM5	Walter Gors Park detention basin plus Option FM2	34	14	S-8
FM6	Replace open channel between Oaks Avenue and Pacific Parade with new pipe under Pittwater Road plus Options FM1 and FM2	33	15	S-9
FM9	Upgrade of Open Channel between Victor Road and Redman Road plus Option FM8 – not feasible (see **Section 10.3.9**)	N/A	N/A	N/A
PM1	House Raising – not viable (see **Section 10.4.1**)	N/A	N/A	N/A
PM2	Voluntary Purchase – not viable (see **Section 10.4.2**)	N/A	N/A	N/A
PM3	Land Swap – not viable (see **Section 10.4.3**)	N/A	N/A	N/A

12.4 Potential Funding Sources

The NSW Government has established the Floodplain Management Program to provide financial support to Local Government for the implementation of the Flood Prone Land Policy, as described in the *Floodplain Development Manual* (NSW Government, 2005). The primary objective is "to reduce the impacts of flooding and flood liability on communities as well as the private and public losses resulting from floods, using ecologically positive methods wherever possible".

Floodplain management grants from the NSW Government are available for implementation of actions listed in FRMPs, which include (but are not limited to), the following:

> structural works, such as levees, detention basins, flood gates and improved flow conveyance;

> flood warning systems;

> evacuation management; and

> voluntary purchase or house raising.

This grant program is administered by the OEH.

13 Recommendations and Conclusions

This FRMS for the Dee Why South Catchment follows on from the Flood Study prepared by Cardno in 2013. Further assessment of the existing flood behaviour has provided improved definition of parts of the catchment that are particularly hazardous to pedestrians and vehicular travel (**Section 7**). In addition, flood damages have been estimated to be in the order of $3.9 million in ADD for the properties examined (**Section 6**).

This knowledge of the flood hazard and flood behaviour, along with the information on the catchment characteristics (**Section 2**), existing emergency management arrangements (**Section 7**) and development controls relevant to flooding (**Section 8**) was used by the project team to develop a range of flood mitigation options for further assessment based on their relative costs and benefits (see **Sections 10 to 12**).

Based on review of the analysis results, multi-criteria assessment and review of the feasibility of the options, a preliminary shortlist of options has been recommended (see **Table 13-1**). An alternative could be to replace Option FM2 and/or Option FM8 with Option FM10 (a combination of the two), depending on Council's preferred approach.

Table 13-1 Recommended Flood Management Options

Option No.	Description	Capital Cost (excl. GST)	Ongoing Cost (excl. GST)
EM3	Public Awareness and Education	$0	$5,000
PM4	Flood Proofing guidelines	$15,000	$1,500
EM4	Flood Warning Signs	$12,000	$1,000
EM1	Information transfer to NSW SES	$4,000	$1,000
EM2	Flood Warning System	$30,000	$7,000
EM5	Event Data Collection	$5,000	$5,000
FM2	Increase drainage capacity along Oaks Avenue	$1,158,473	$1,900
FM8	Storage basins at Mooramba Road car park and Redman Road	$4,355,963	$21,000
	TOTAL COST (excl. GST)	**$5,565,436**	**$43,400**

It is recommended that this FRMS be placed on public exhibition by Council to enable final comment by key stakeholders and the community.

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Dee Why South Catchment
Floodplain Risk Management Study

APPENDIX A
SITE VISIT PHOTOS

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Image 1 – Mooramba Road Carpark

Image 2 Open Channel Upstream of Redman Road

Image 3 – Culvert under Redman Road

Image 4 - End of Redman Road, Pittwater Road end

Image 5 - Pittwater Road Looking Down Pacific Parade

Image 6 - Sturdee Parade – Basement Entrance to Dee Why Grand

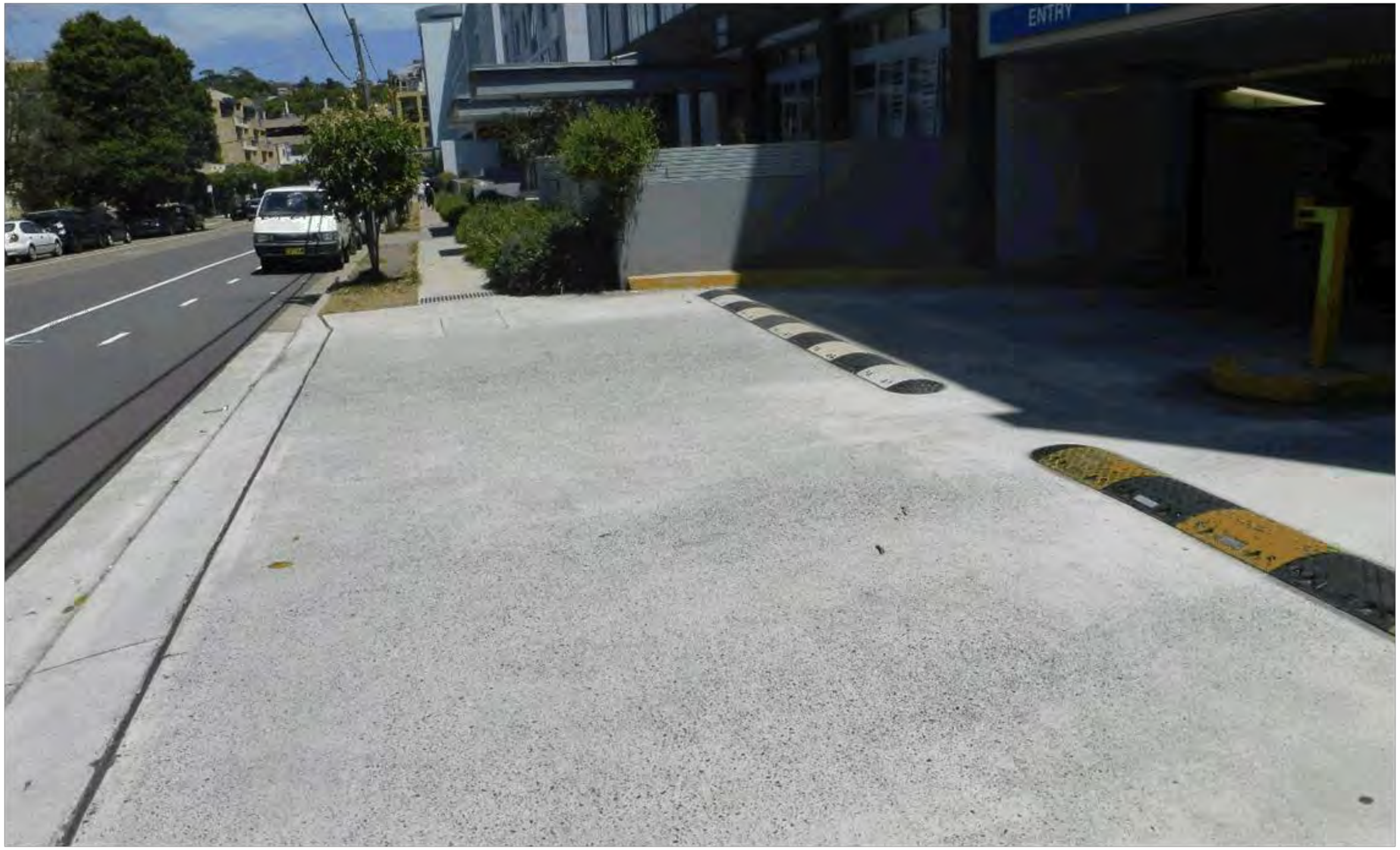

Image 7 - Pacific Parade – Basement Entrance to Dee Why Grand

Image 8 - Corner of Pittwater Road and Oaks Avenue looking north

Image 9 – Dee Why Medical Centre Basement Entrance, Howard Avenue

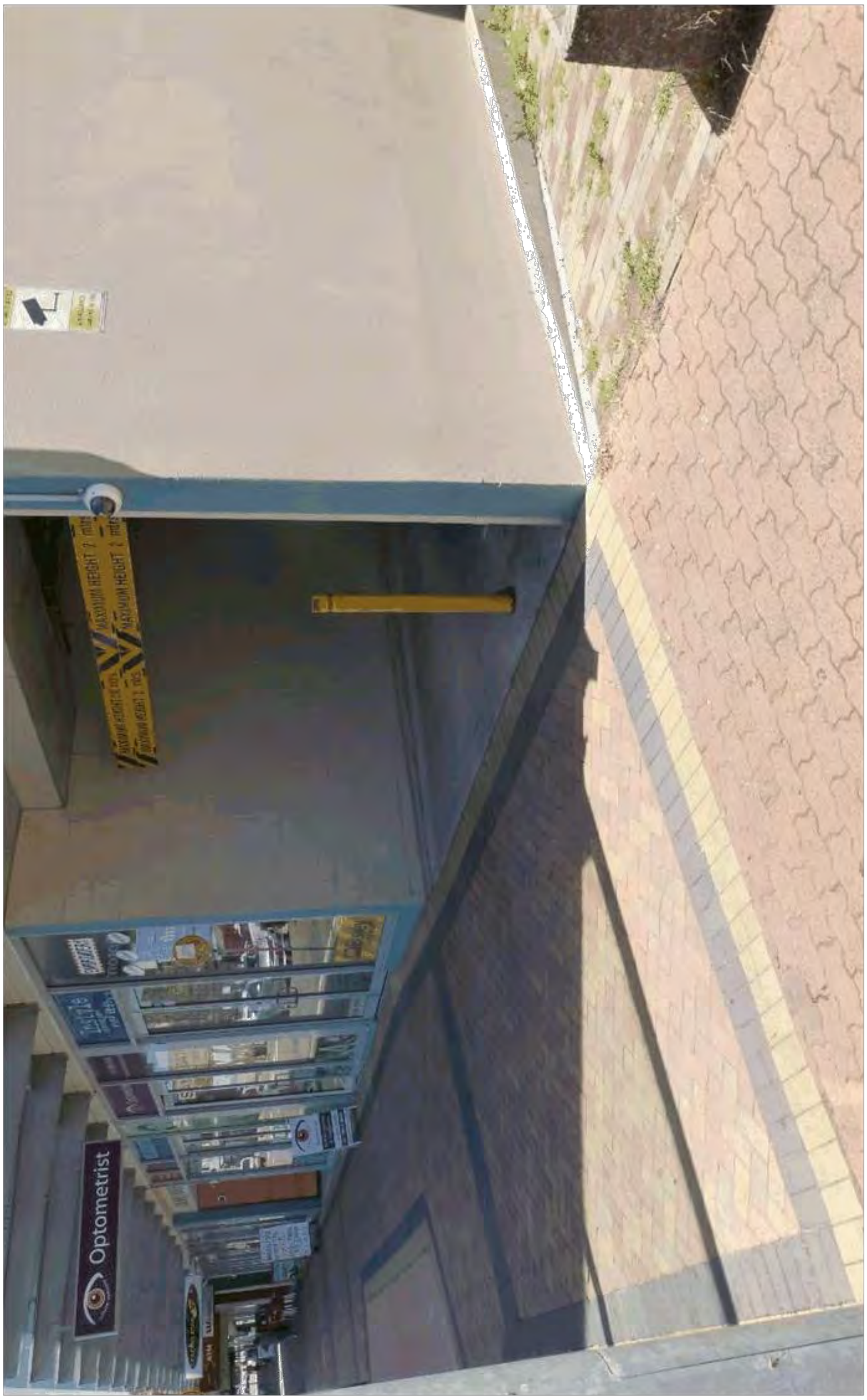

Image 10 - Basement Entrance – 12 Howard Avenue

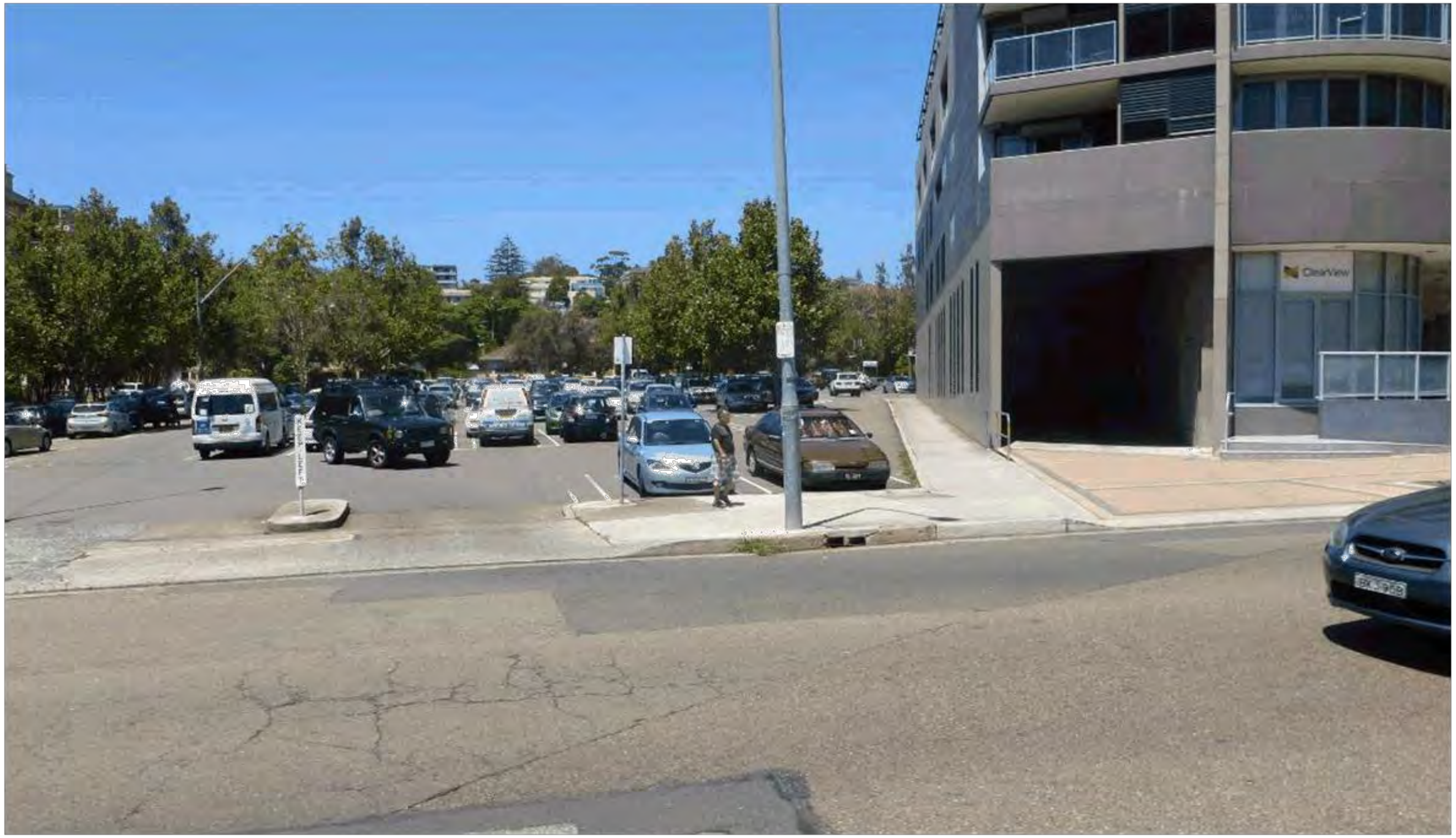

Image 11 - Basement Entrance – 29 Howard Avenue

Image 12 - Walter Gors Park – Looking South to Howard Avenue

Image 13 - Open Channel DS of Dee Why Parade

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APPENDIX B
DATABASE SEARCH RESULTS

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Appendix B

Table B.1 Threatened Flora Species (NSW Bionet Wildlife Atlas and EPBC Protected Matters Search Tool, 2014)

Scientific Name	Common Name	Legal Status (TSC Act)	Legal Status (EPBC Act)
Acacia terminalis subsp. terminalis	Sunshine Wattle	E1,P	E
Asterolasia elegans			E
Caladenia tessellata	Thick-lipped Spider-orchid, Daddy Long-legs		V
Callistemon linearifolius	Netted Bottle Brush	V,P,3	
Chamaesyce psammogeton	Sand Spurge	E1,P	
Cryptostylis hunteriana	Leafless Tongue-orchid		V
Darwinia biflora		V,P	
Epacris purpurascens var. purpurascens		V,P	
Eucalyptus camfieldii	Camfield's Stringybark	V,P	V
Eucalyptus nicholii	Narrow-leaved Black Peppermint	V,P	
Genoplesium baueri	Yellow Gnat-orchid		E
Hibbertia superans		E1,P	
Melaleuca biconvexa	Biconvex Paperbark		V
Melaleuca deanei	Deane's Melaleuca		V
Microtis angusii	Angus's Onion Orchid	E1,P,2	E
Pelargonium sp. Striatellum	Omeo Stork's-bill		E
Persoonia hirsuta	Hairy Geebung	E1,P,3	
Persoonia hirsuta	Hairy Persoonia		E
Pimelea curviflora var. curviflora		V,P	V
Prostanthera junonis	Somersby Mintbush	E1,P	
Prostanthera marifolia	Seaforth Mintbush	E4A,P,3	CE
Streblus pendulinus	Siah's Backbone, Sia's Backbone, Isaac Wood		E
Syzygium paniculatum	Magenta Lilly Pilly	E1,P	V
Tetratheca glandulosa		V,P	

CE – Critically Endangered, E- Endangered, V – Vulnerable, P – Protected.

Table B.2 Threatened Fauna Species (NSW Bionet Wildlife Atlas and EPBC Protected Matters Search Tool, 2014)

Scientific Name	Common Name	Legal Status (TSC Act)	Legal Status (EPBC Act)
Anthochaera phrygia	Regent Honeyeater	E4A,P	E
Botaurus poiciloptilus	Australasian Bittern	E1,P	E
Burhinus grallarius	Bush Stone-curlew	E1,P	
Calidris alba	Sanderling	V,P	
Calidris ferruginea	Curlew Sandpiper	E1,P	
Calidris tenuirostris	Great Knot	V,P	
Callocephalon fimbriatum	Gang-gang Cockatoo	V,P,3	
Calyptorhynchus lathami	Glossy Black-Cockatoo	V,P,2	
Carcharias taurus	Grey Nurse Shark		CE
Carcharodon carcharias	Great White Shark		V
Caretta caretta	Loggerhead Turtle		E
Cercartetus nanus	Eastern Pygmy-possum	V,P	
Chalinolobus dwyeri	Large-eared Pied Bat, Large Pied Bat		V

Scientific Name	Common Name	Legal Status (TSC Act)	Legal Status (EPBC Act)
Charadrius leschenaultii	Greater Sand-plover	V,P	
Charadrius mongolus	Lesser Sand-plover	V,P	
Chelonia mydas	Green Turtle	V,P	V
Daphoenositta chrysoptera	Varied Sittella	V,P	
Dasyornis brachypterus	Eastern Bristlebird		E
Dasyurus maculatus	Spotted-tailed Quoll	V,P	E
Dermochelys coriacea	Leatherback Turtle	E1,P	E
Diomedea epomophora epomophora	Southern Royal Albatross		V
Diomedea epomophora sanfordi	Northern Royal Albatross		E
Diomedea exulans	Wandering Albatross	E1,P	V
Diomedea exulans antipodensis	Antipodean Albatross		V
Diomedea exulans exulans	Tristan Albatross		E
Diomedea exulans gibsoni	Gibson's Albatross		V
Epinephelus daemelii	Black Rockcod, Black Cod, Saddled Rockcod		V
Eretmochelys imbricata	Hawksbill Turtle		V
Esacus magnirostris	Beach Stone-curlew	E4A,P	
Eubalaena australis	Southern Right Whale	E1,P	E
Fregetta grallaria grallaria	White-bellied Storm-Petrel		V
Glossopsitta pusilla	Little Lorikeet	V,P	
Gygis alba	White Tern	V,P	
Haematopus fuliginosus	Sooty Oystercatcher	V,P	
Haematopus longirostris	Pied Oystercatcher	E1,P	
Heleioporus australiacus	Giant Burrowing Frog	V,P	V
Isoodon obesulus obesulus	Southern Brown Bandicoot (eastern)	E1,P	E
Ixobrychus flavicollis	Black Bittern	V,P	
Lathamus discolor	Swift Parrot	E1,P,3	E
Litoria aurea	Green and Golden Bell Frog	E1,P	V
Macronectes giganteus	Southern Giant Petrel	E1,P	E
Macronectes halli	Northern Giant-Petrel	V,P	V
Megaptera novaeangliae	Humpback Whale	V,P	V
Miniopterus australis	Little Bentwing-bat	V,P	
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	V,P	
Mormopterus norfolkensis	Eastern Freetail-bat	V,P	
Myotis macropus	Southern Myotis	V,P	
Natator depressus	Flatback Turtle		V
Ninox connivens	Barking Owl	V,P,3	
Ninox strenua	Powerful Owl	V,P,3	
Onychoprion fuscata	Sooty Tern	V,P	
Pandion cristatus	Eastern Osprey	V,P,3	
Petrogale penicillata	Brush-tailed Rock-wallaby		V
Petroica boodang	Scarlet Robin	V,P	
Phascolarctos cinereus	Koala		V
Physeter macrocephalus	Sperm Whale	V,P	
Potorous tridactylus tridactylus	Long-nosed Potoroo		V
Pristis zijsron	Green Sawfish, Dindagubba, Narrowsnout Sawfish		V
Prototroctes maraena	Australian Grayling		V
Pseudomys novaehollandiae	New Holland Mouse, Pookila		V
Pseudophryne australis	Red-crowned Toadlet	V,P	
Pterodroma leucoptera leucoptera	Gould's Petrel		E

Scientific Name	Common Name	Legal Status (TSC Act)	Legal Status (EPBC Act)
Pterodroma neglecta neglecta	Kermadec Petrel		V
Pteropus poliocephalus	Grey-headed Flying-fox	V,P	V
Ptilinopus magnificus	Wompoo Fruit-Dove	V,P	
Ptilinopus superbus	Superb Fruit-Dove	V,P	
Rhincodon typus	Whale Shark		V
Rostratula australis	Australian Painted Snipe		E
Scoteanax rueppellii	Greater Broad-nosed Bat	V,P	
Sternula albifrons	Little Tern	E1,P	
Sternula nereis nereis	Australian Fairy Tern		V
Thalassarche bulleri	Buller's Albatross, Pacific Albatross		V
Thalassarche cauta	Shy Albatross	V,P	V
Thalassarche cauta salvini	Salvin's Albatross		V
Thalassarche cauta steadi	White-capped Albatross		V
Thalassarche eremita	Chatham Albatross		E
Thalassarche melanophris	Black-browed Albatross	V,P	V
Thalassarche melanophris impavida	Campbell Albatross		V
Tyto novaehollandiae	Masked Owl	V,P,3	
Varanus rosenbergi	Rosenberg's Goanna	V,P	

CE – Critically Endangered, E- Endangered, V – Vulnerable, P – Protected.

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APPENDIX C
MITIGATION OPTION FIGURES

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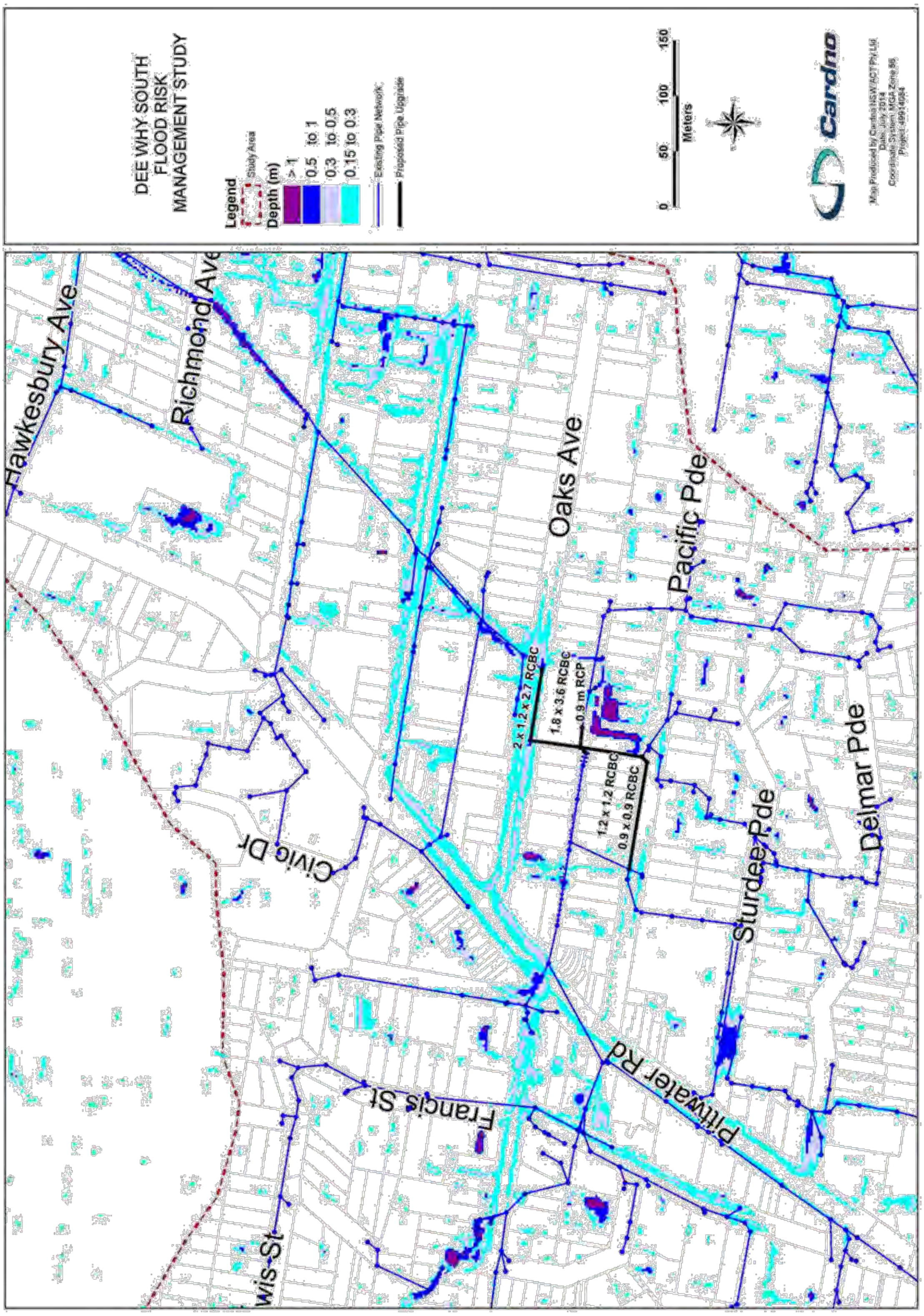

Figure C1 – Mitigation Option FM1 100 year ARI Depth Plot

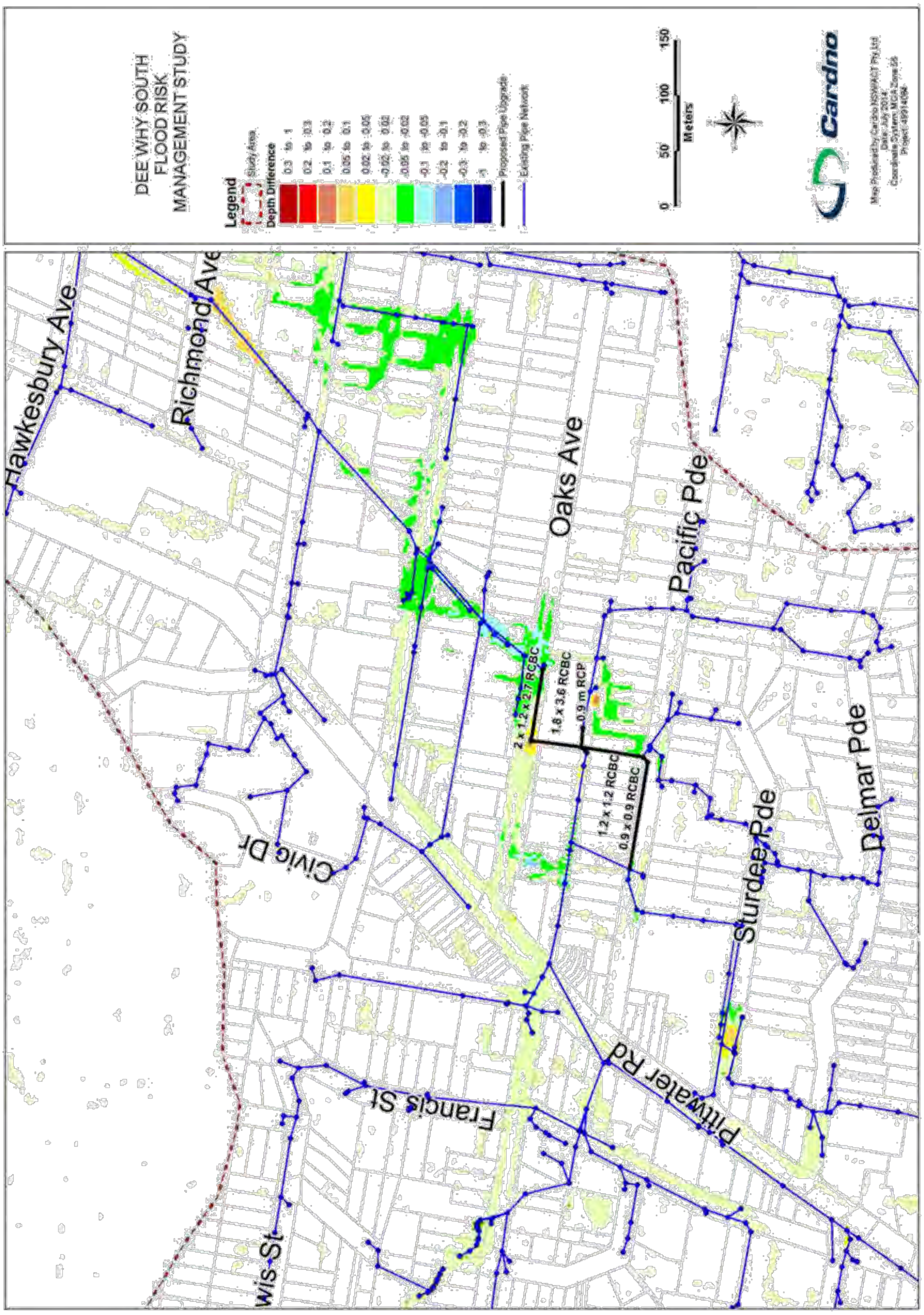

Figure C2 – Mitigation Option FM1 100 year ARI Depth Difference Plot

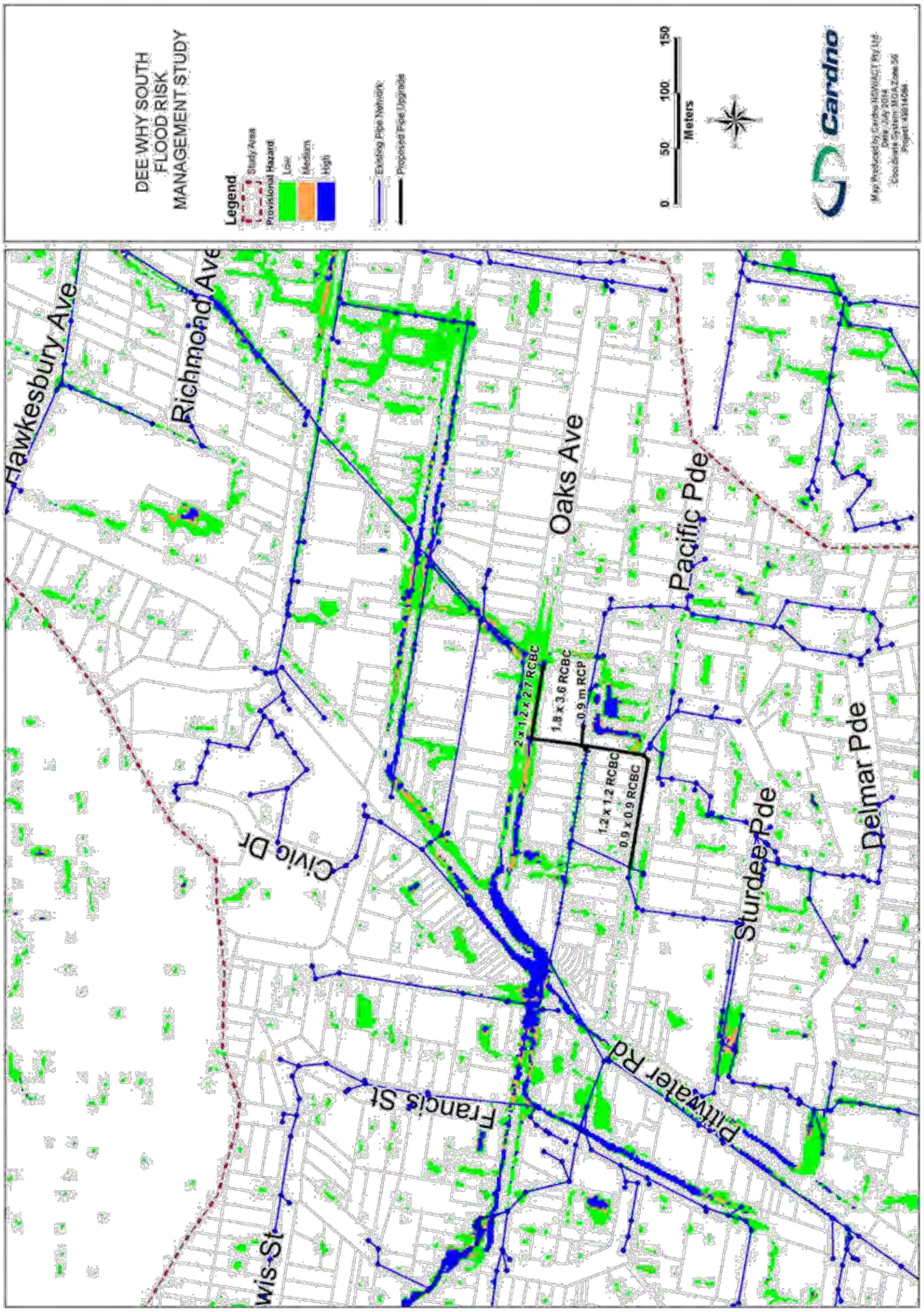

Figure C3 – Mitigation Option FM1 100 year ARI Hazard Plot

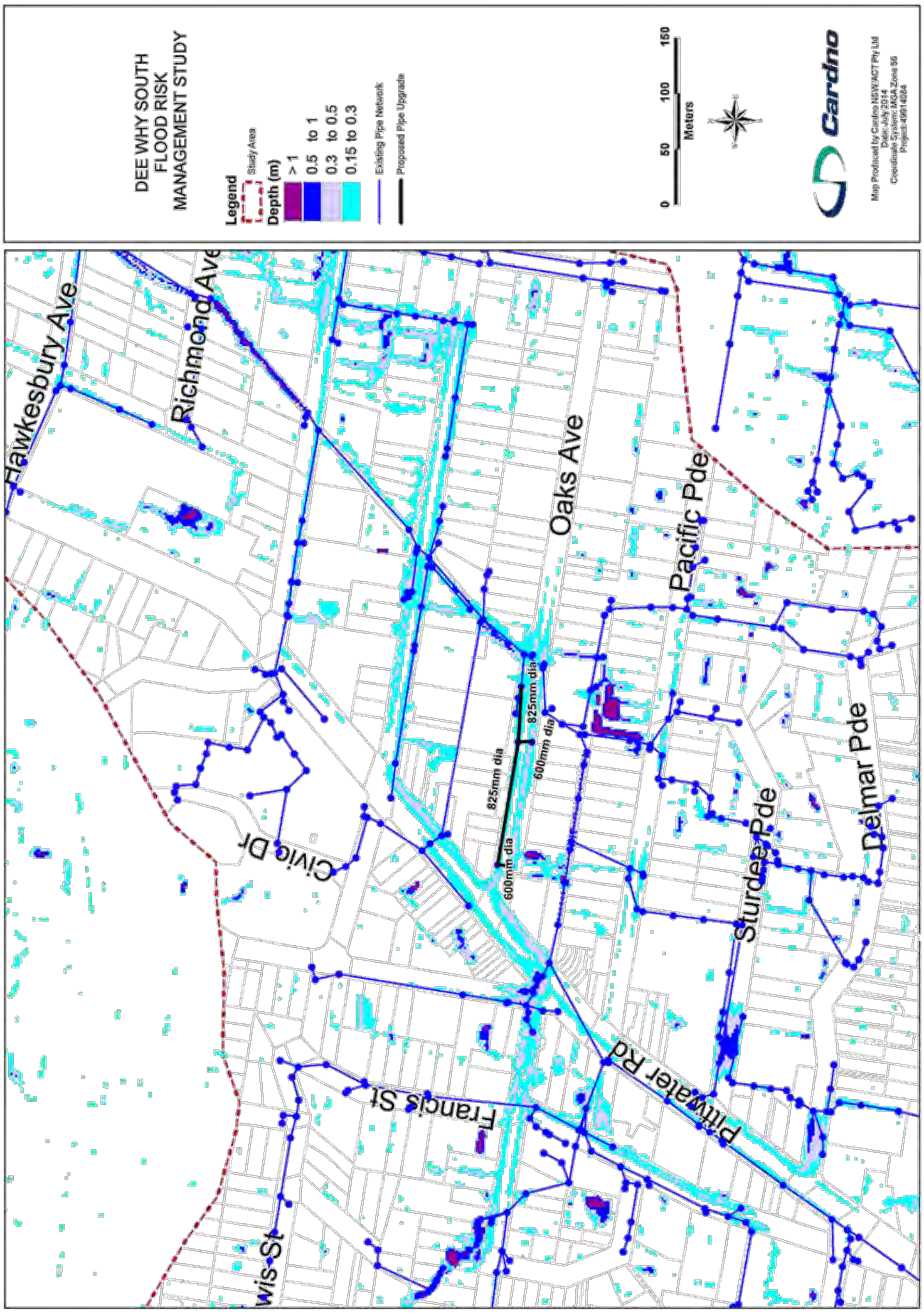

Figure C4 – Mitigation Option FM2 100 year ARI Depth Plot

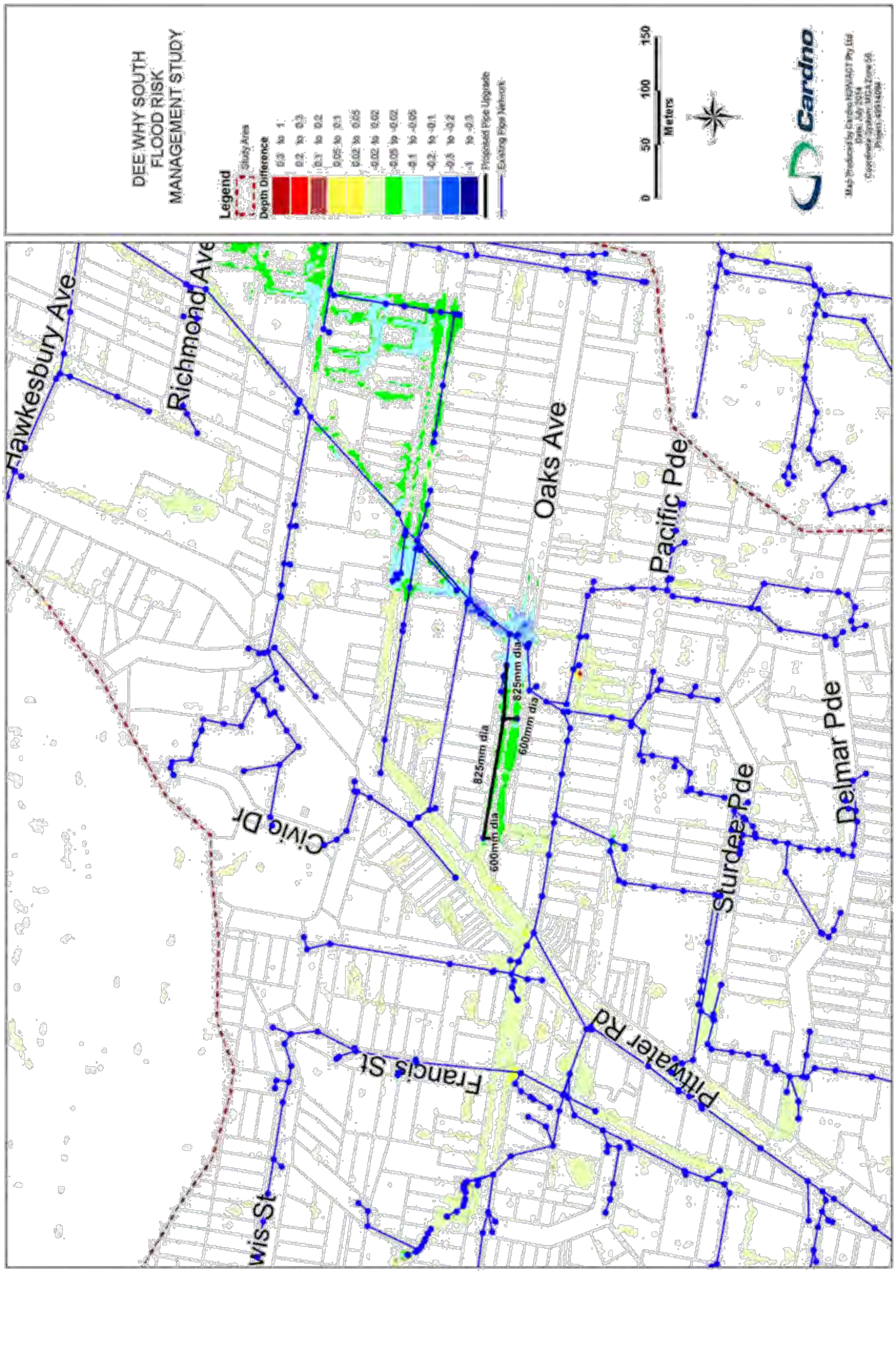

Figure C5 – Mitigation Option FM2 100 year ARI Depth Difference Plot

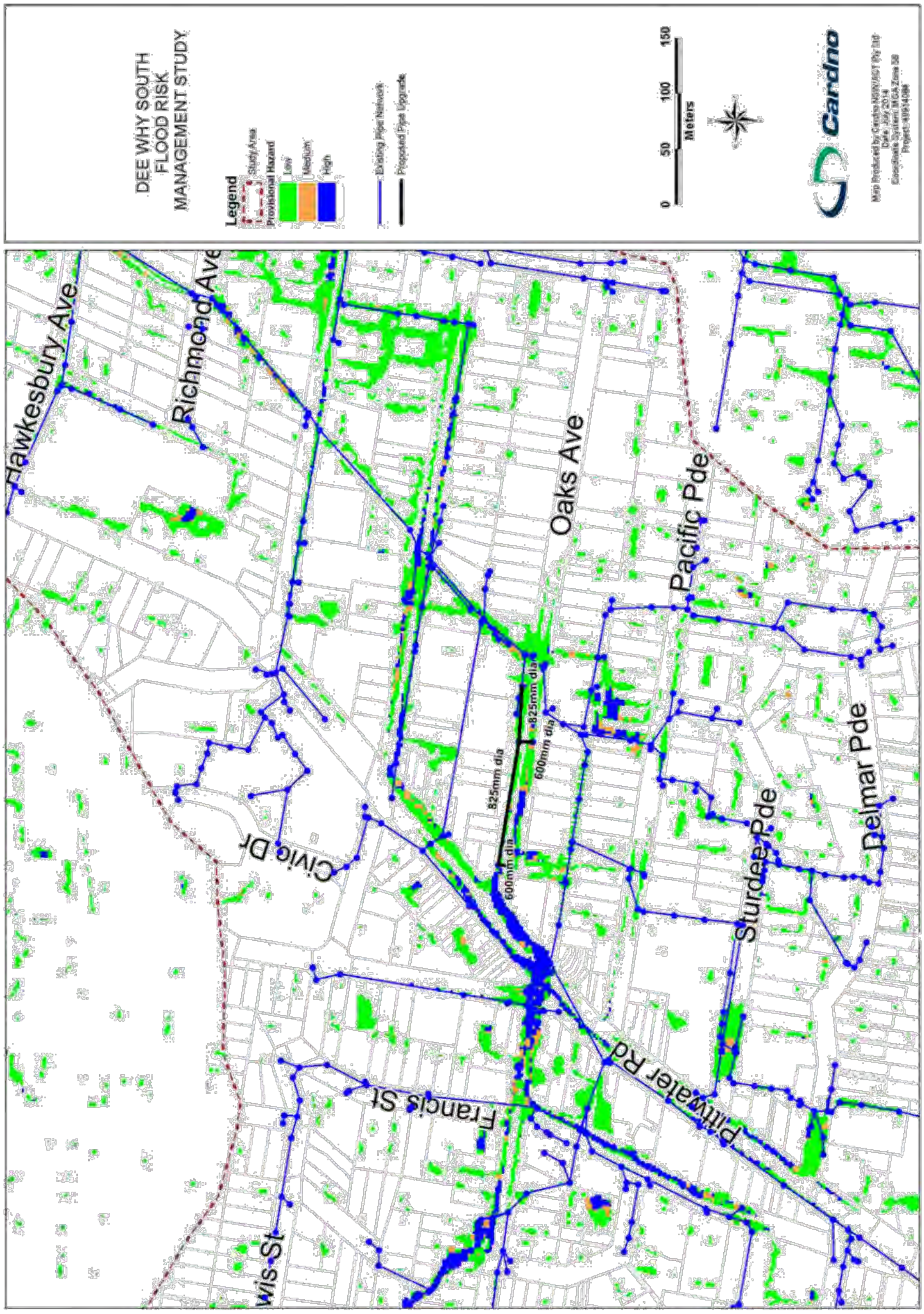

Figure C6 – Mitigation Option FM2 100 year ARI Hazard Plot

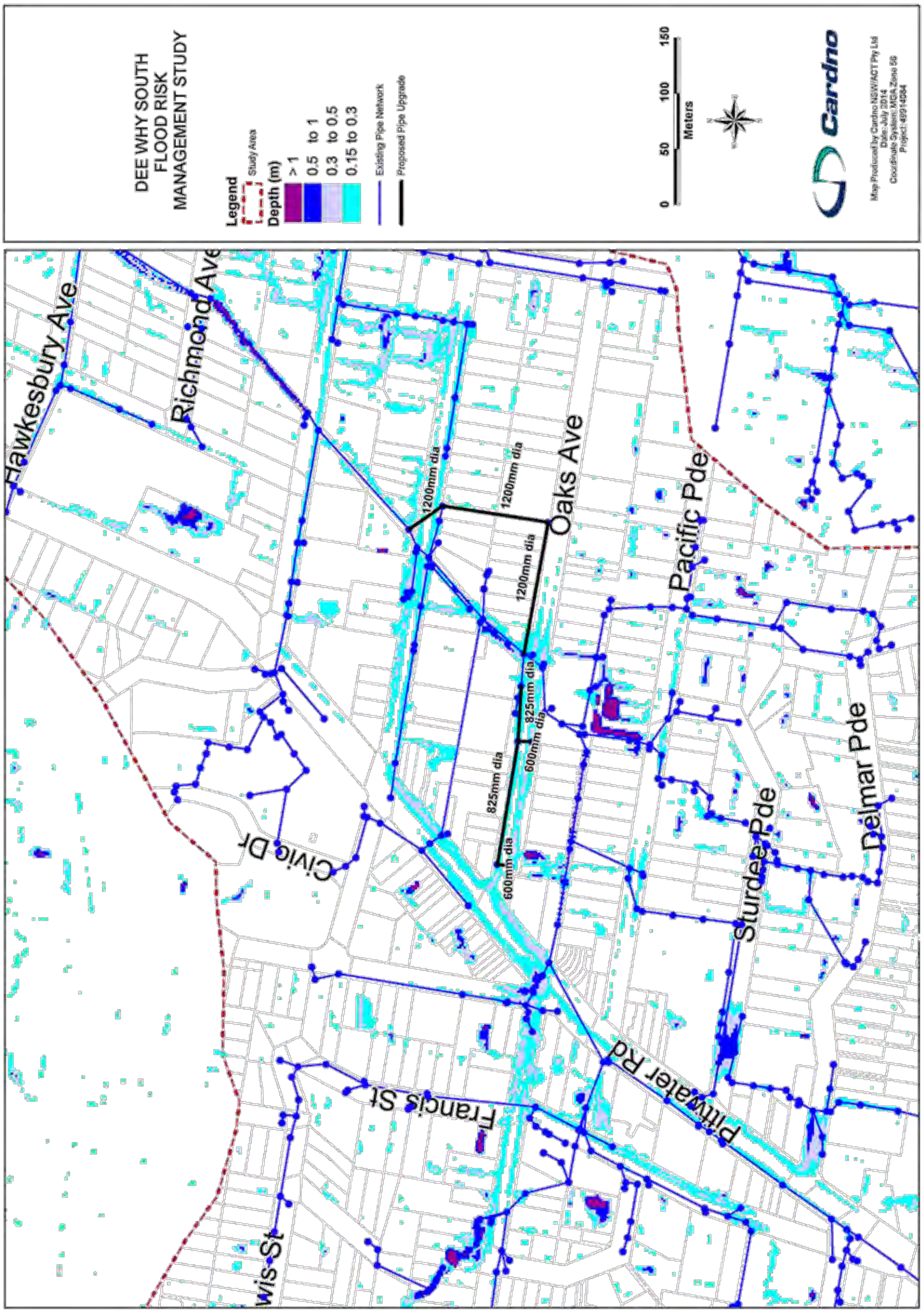

Figure C7 – Mitigation Option FM3 100 year ARI Depth Plot

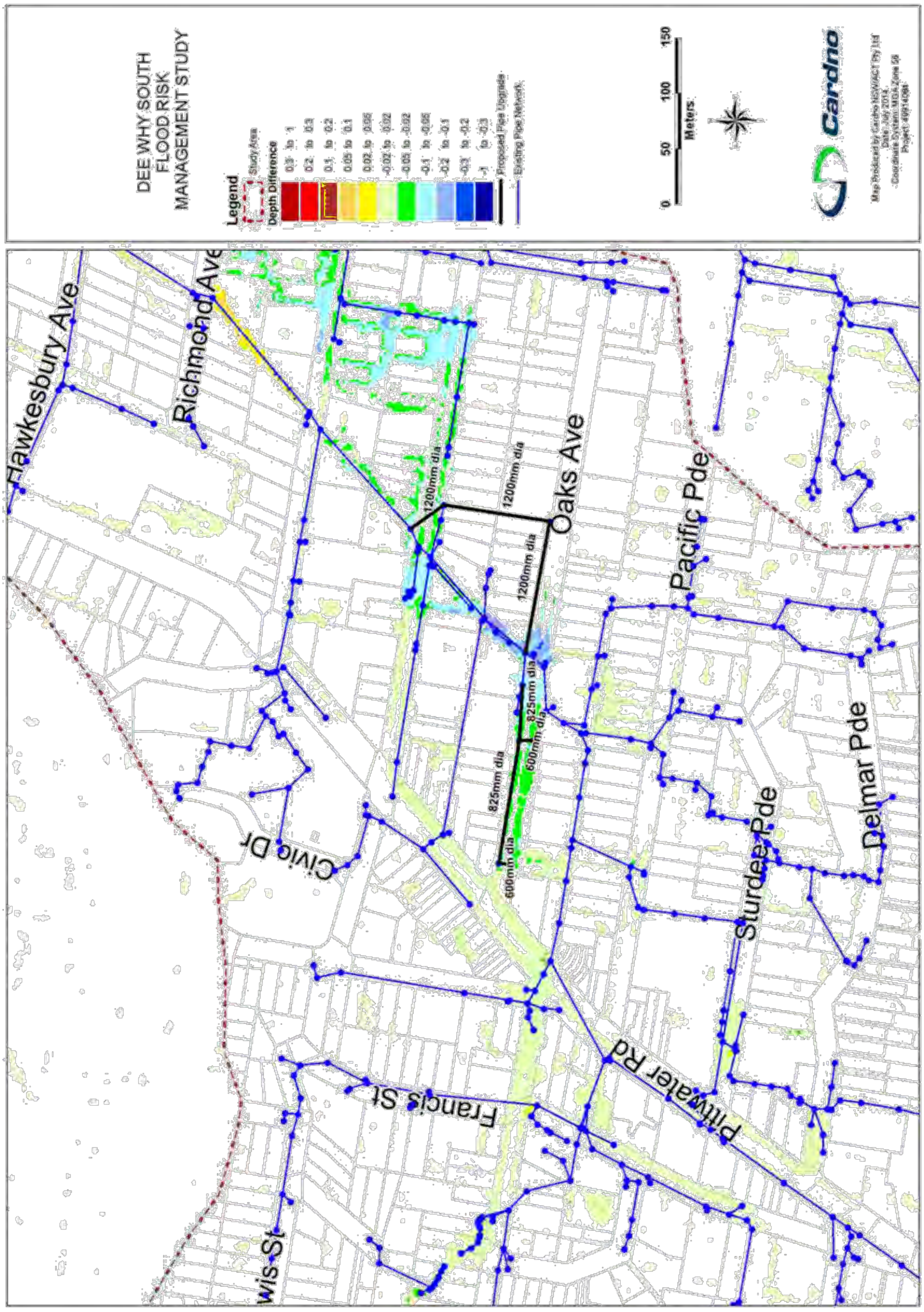

Figure C8 – Mitigation Option FM3 100 year ARI Depth Difference Plot

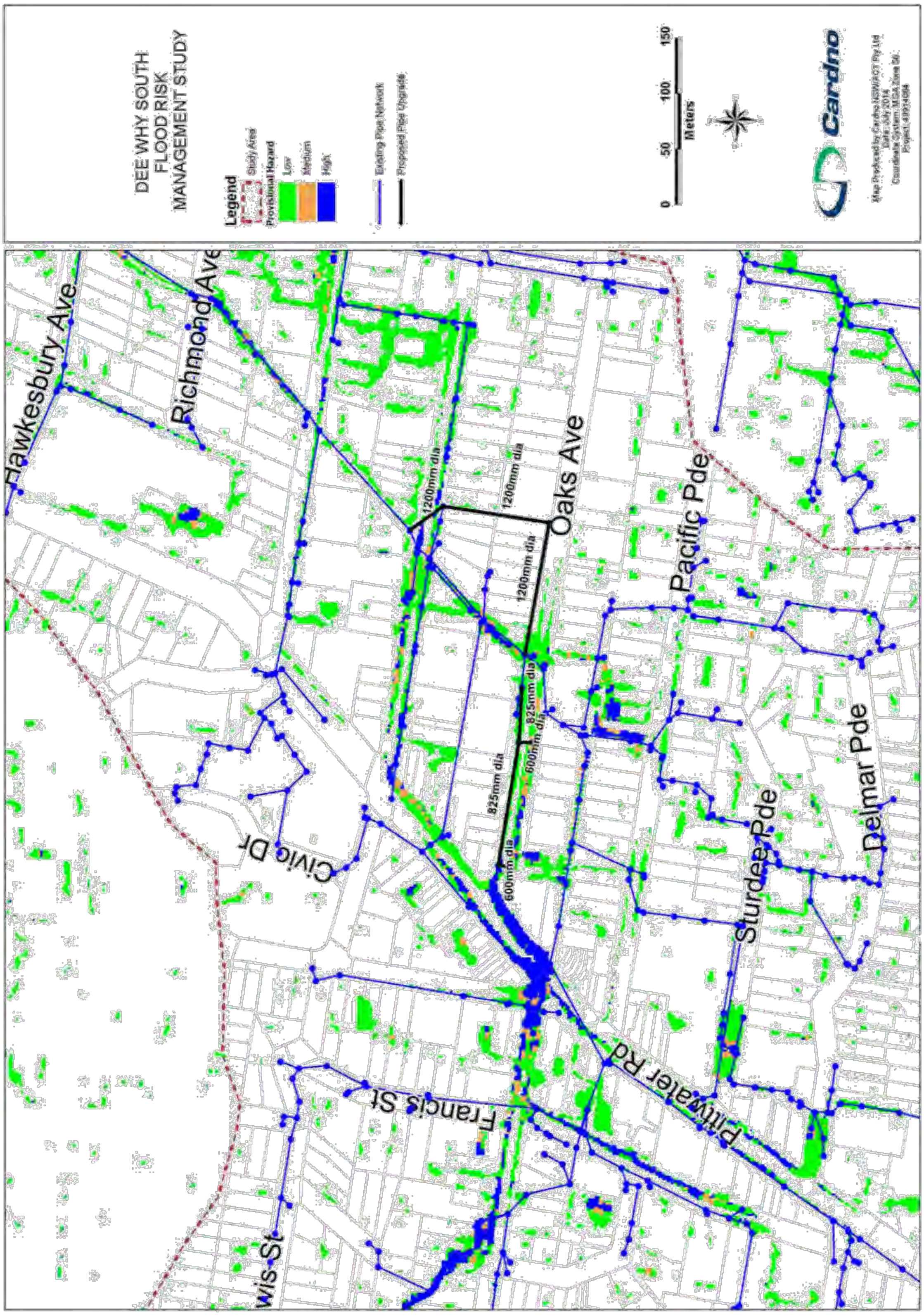

Figure C9 – Mitigation Option FM3 100 year ARI Hazard Plot

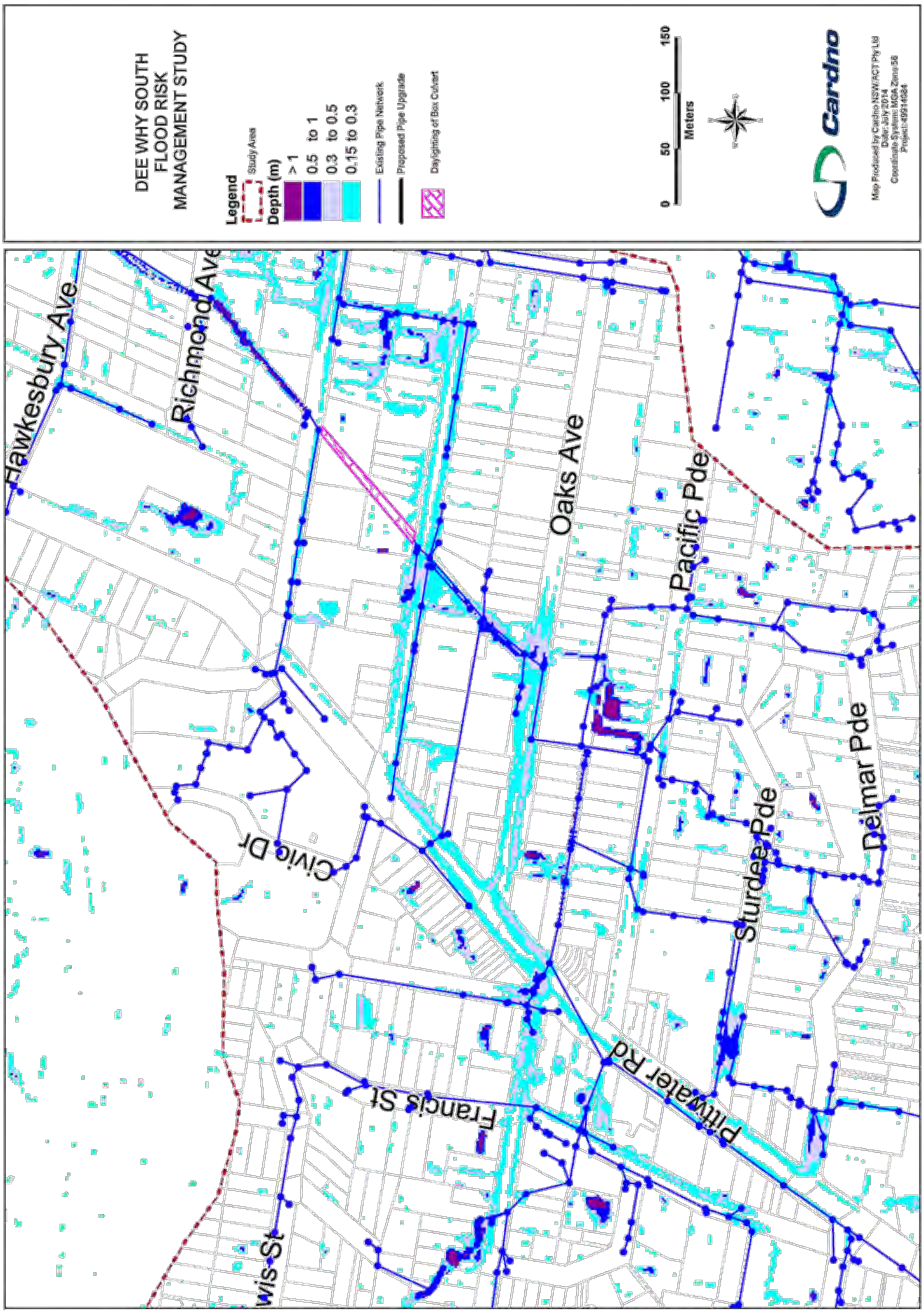

Figure C10 – Mitigation Option FM4 100 year ARI Depth Plot

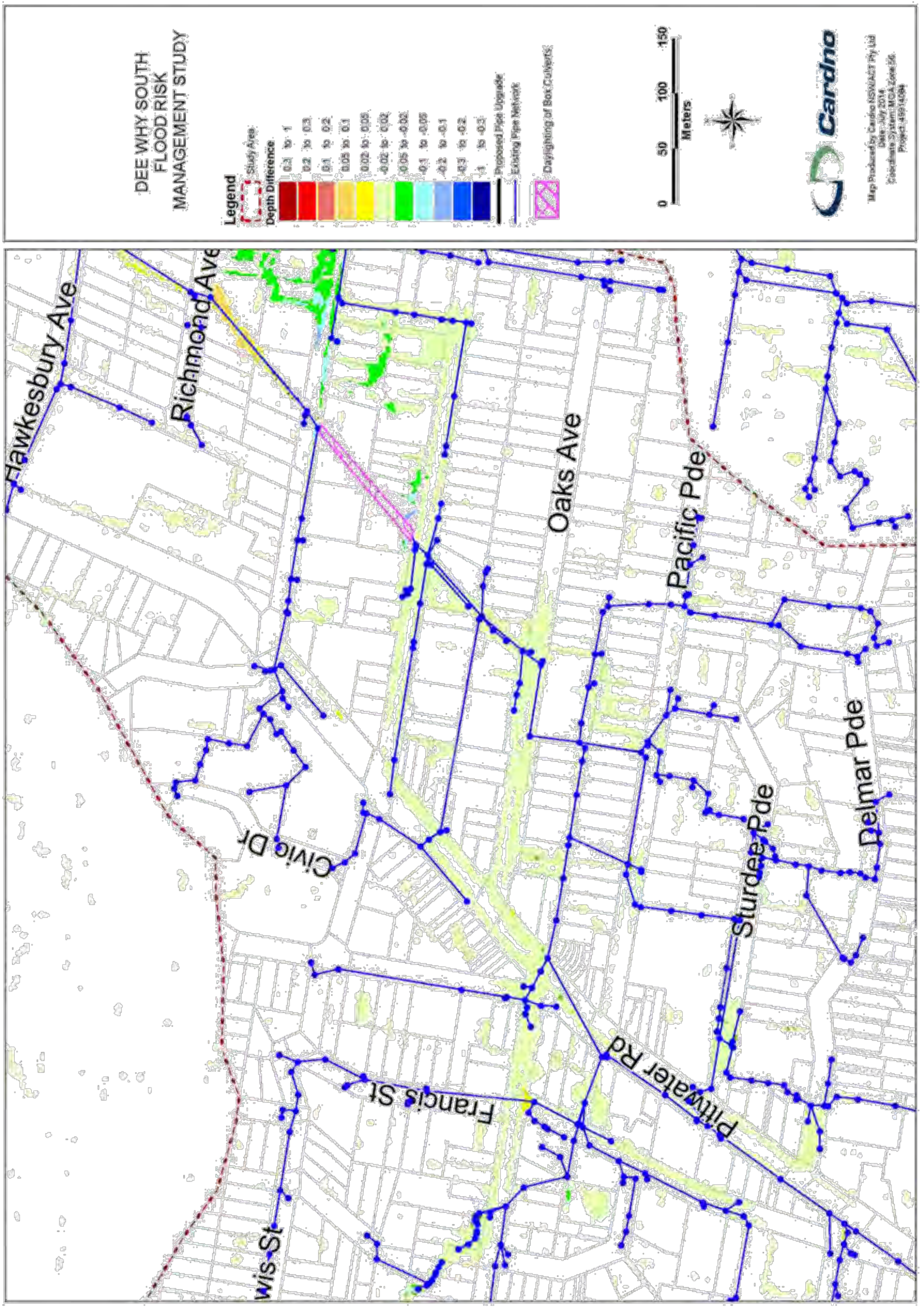

Figure C11 – Mitigation Option FM4 100 year ARI Depth Difference Plot

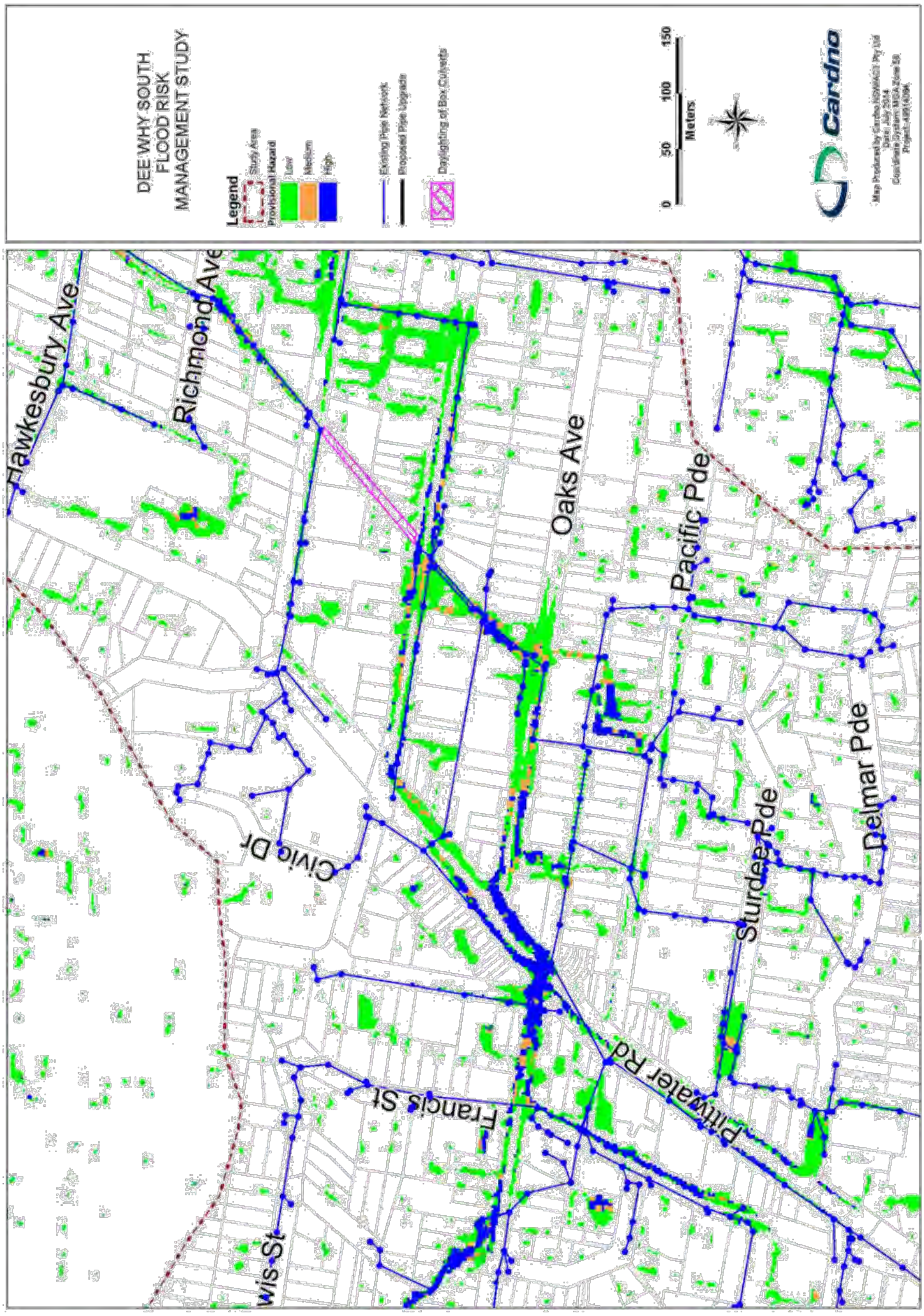

Figure C12 – Mitigation Option FM4 100 year ARI Hazard Plot

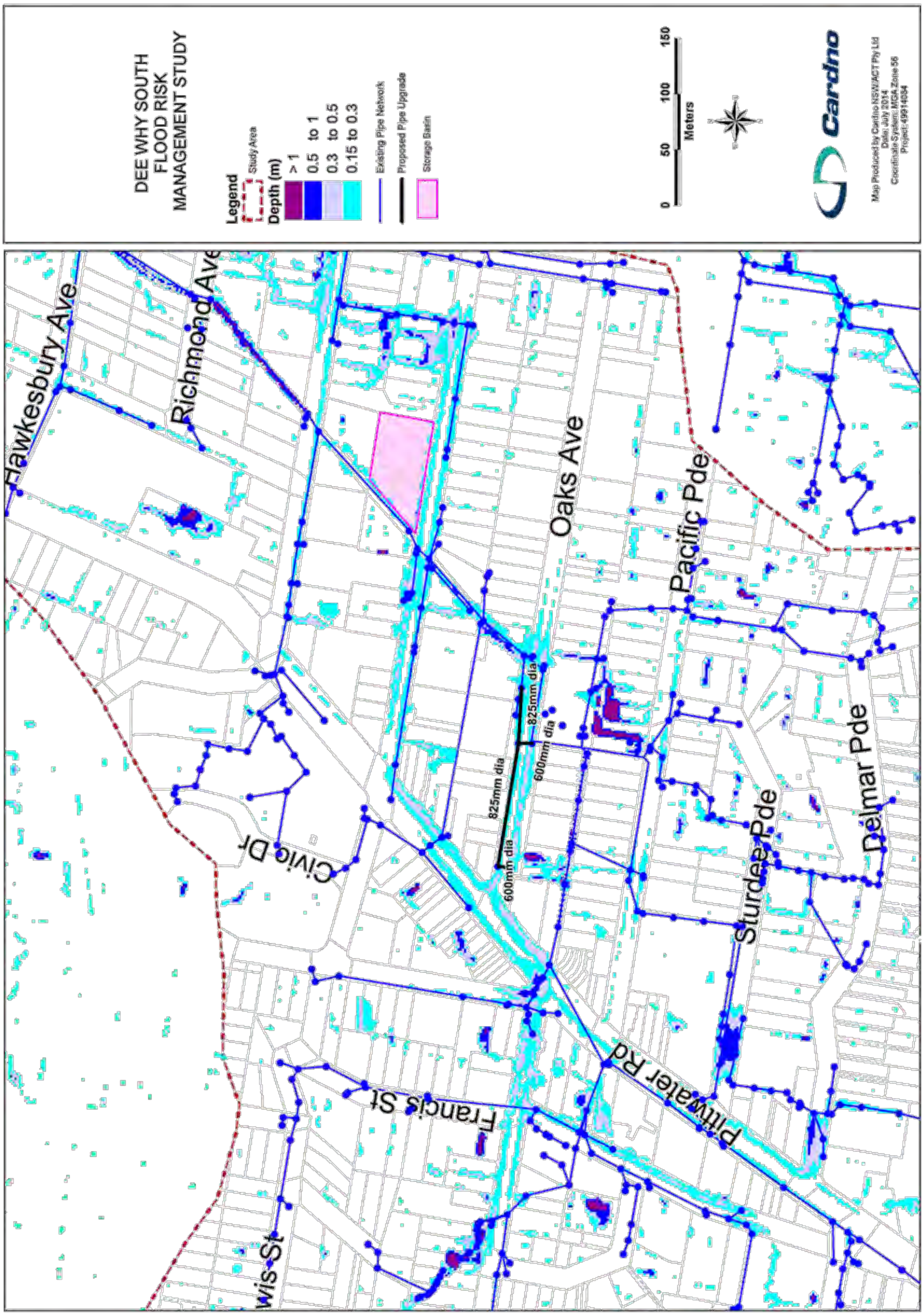

Figure C13 – Mitigation Option FM5 100 year ARI Depth Plot

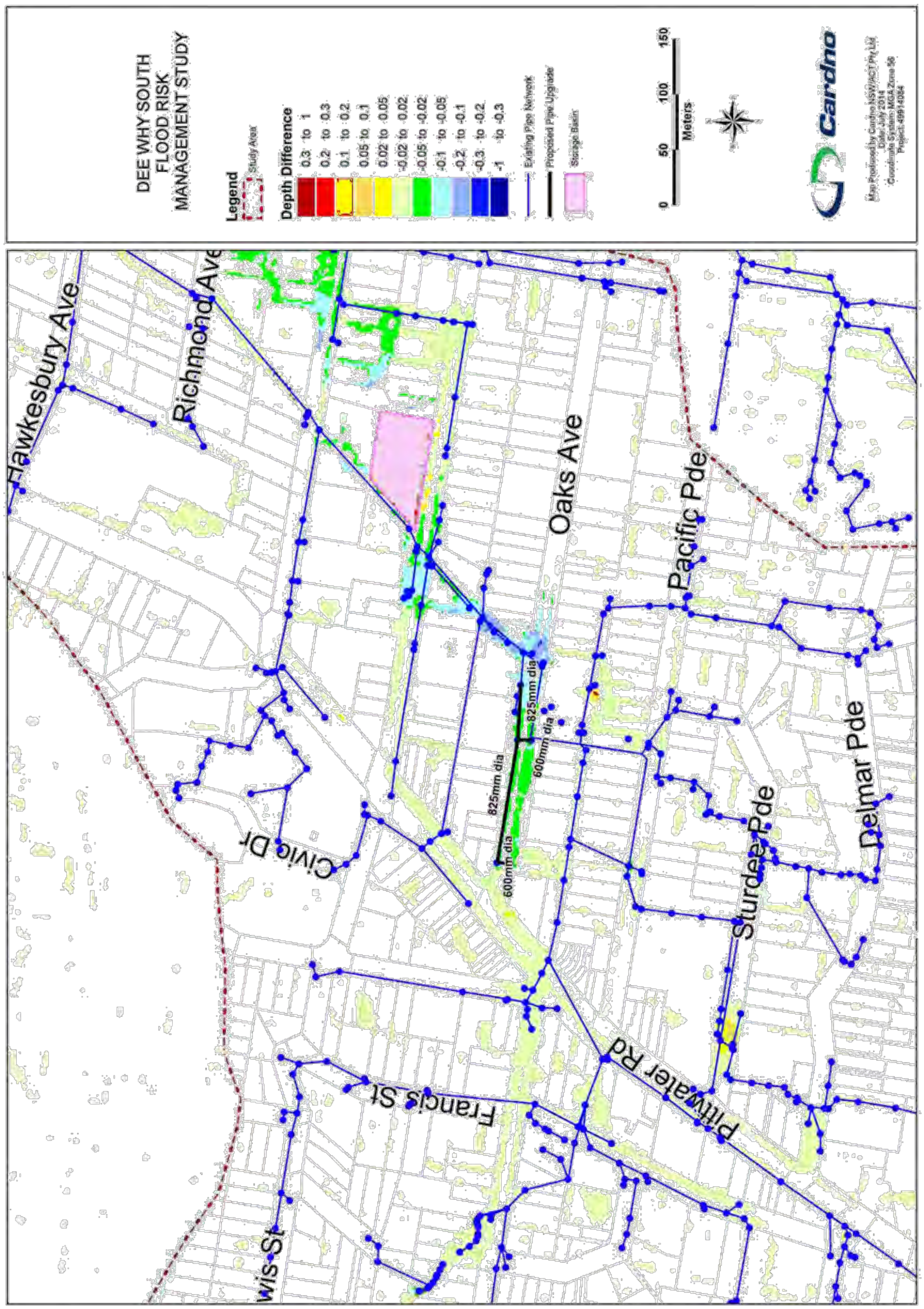

Figure C14 – Mitigation Option FM5 100 year ARI Depth Difference Plot

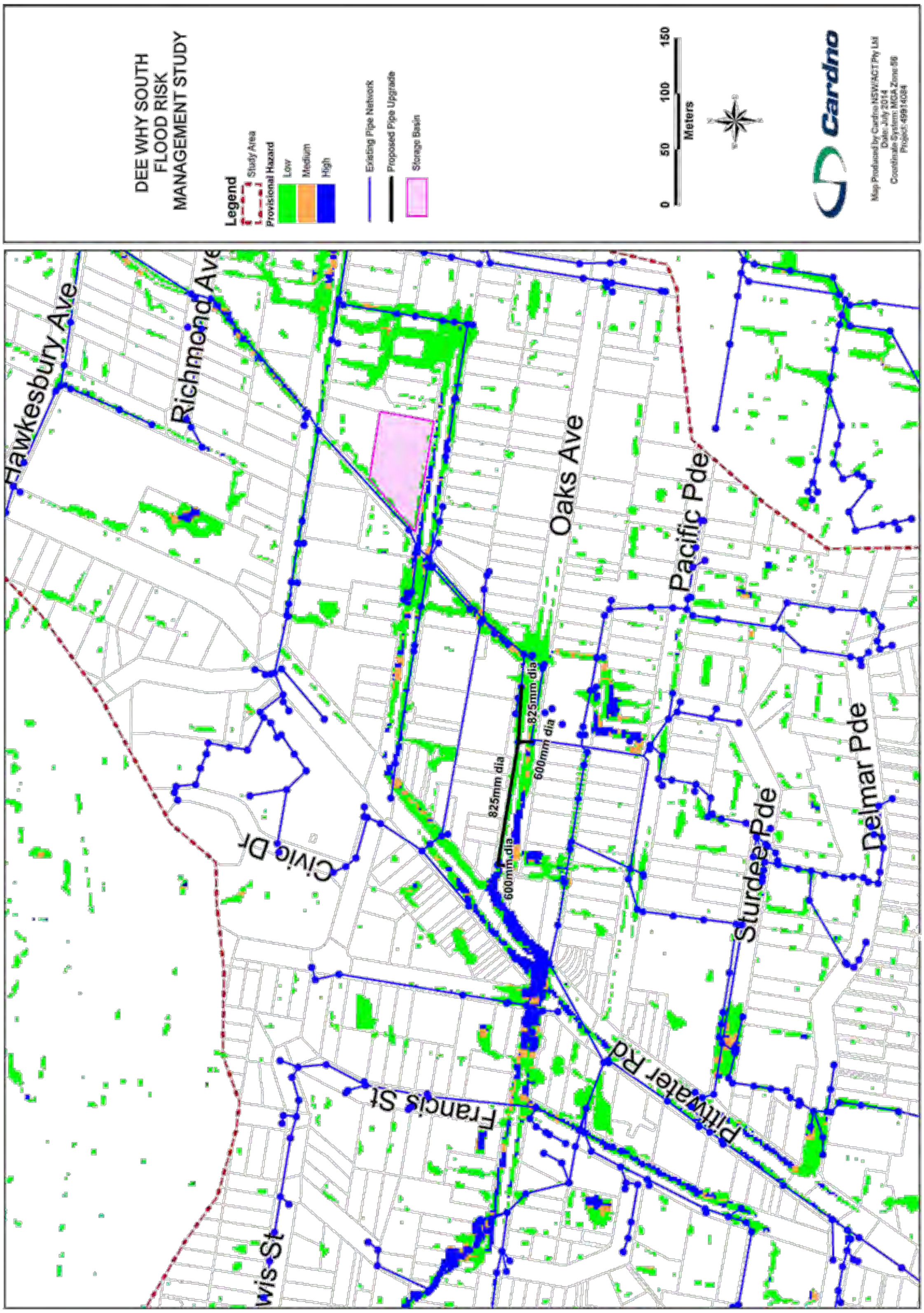

Figure C15 – Mitigation Option FM4 100 year ARI Hazard Plot

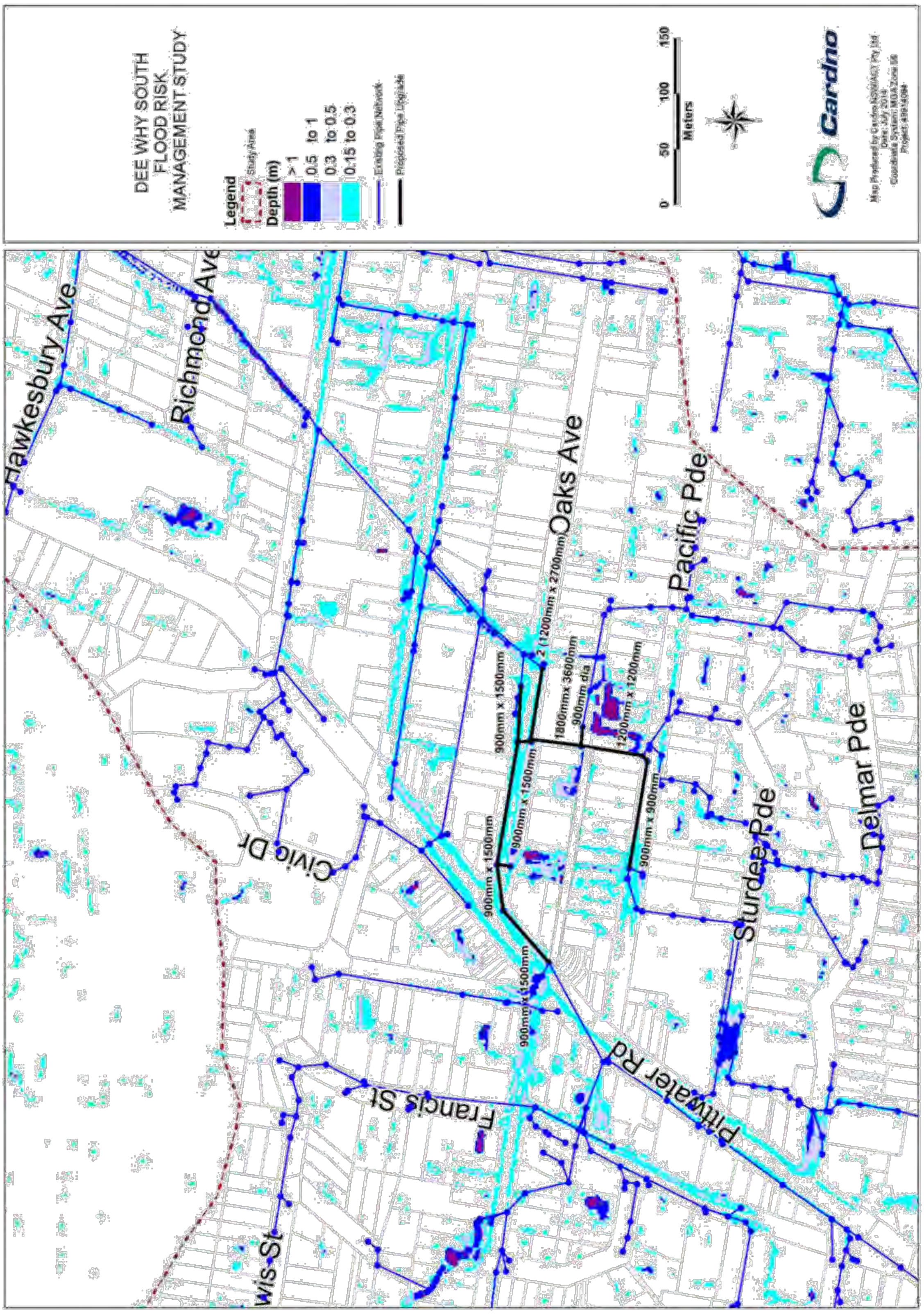

Figure C16 – Mitigation Option FM6 100 year ARI Depth Plot

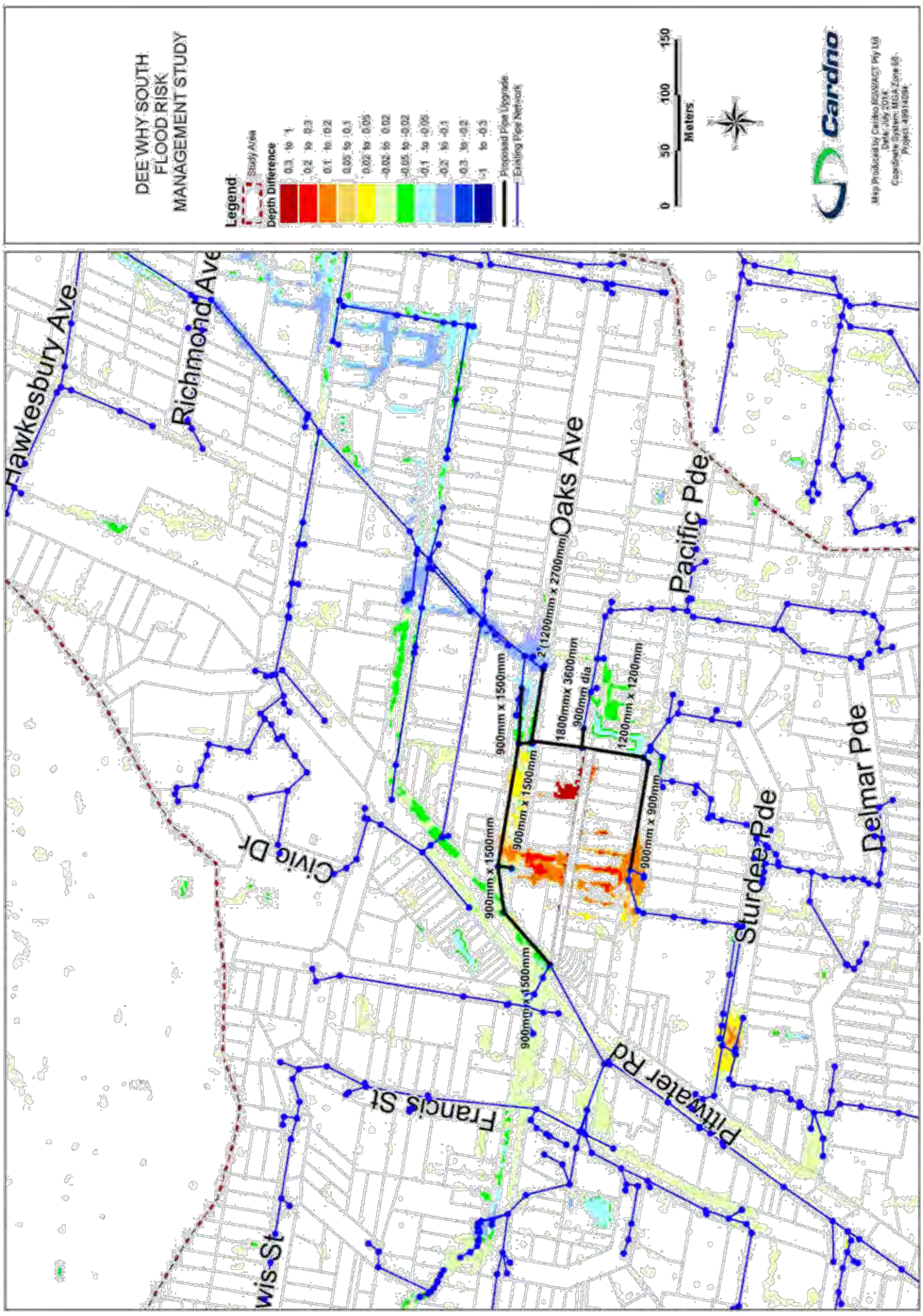

Figure C17 – Mitigation Option FM6 100 year ARI Depth Difference Plot

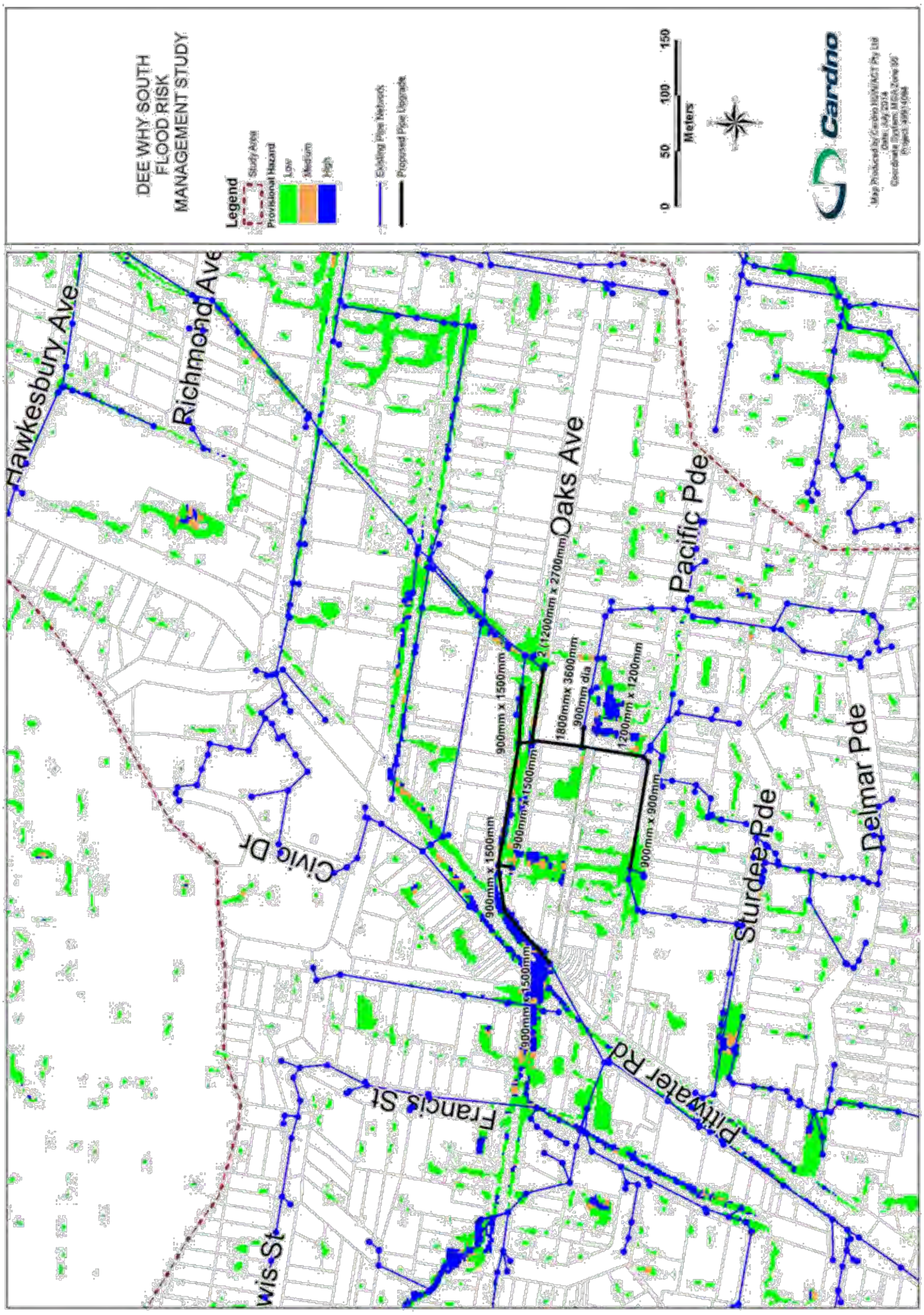

Figure C18 – Mitigation Option FM6 100 year ARI Hazard Plot

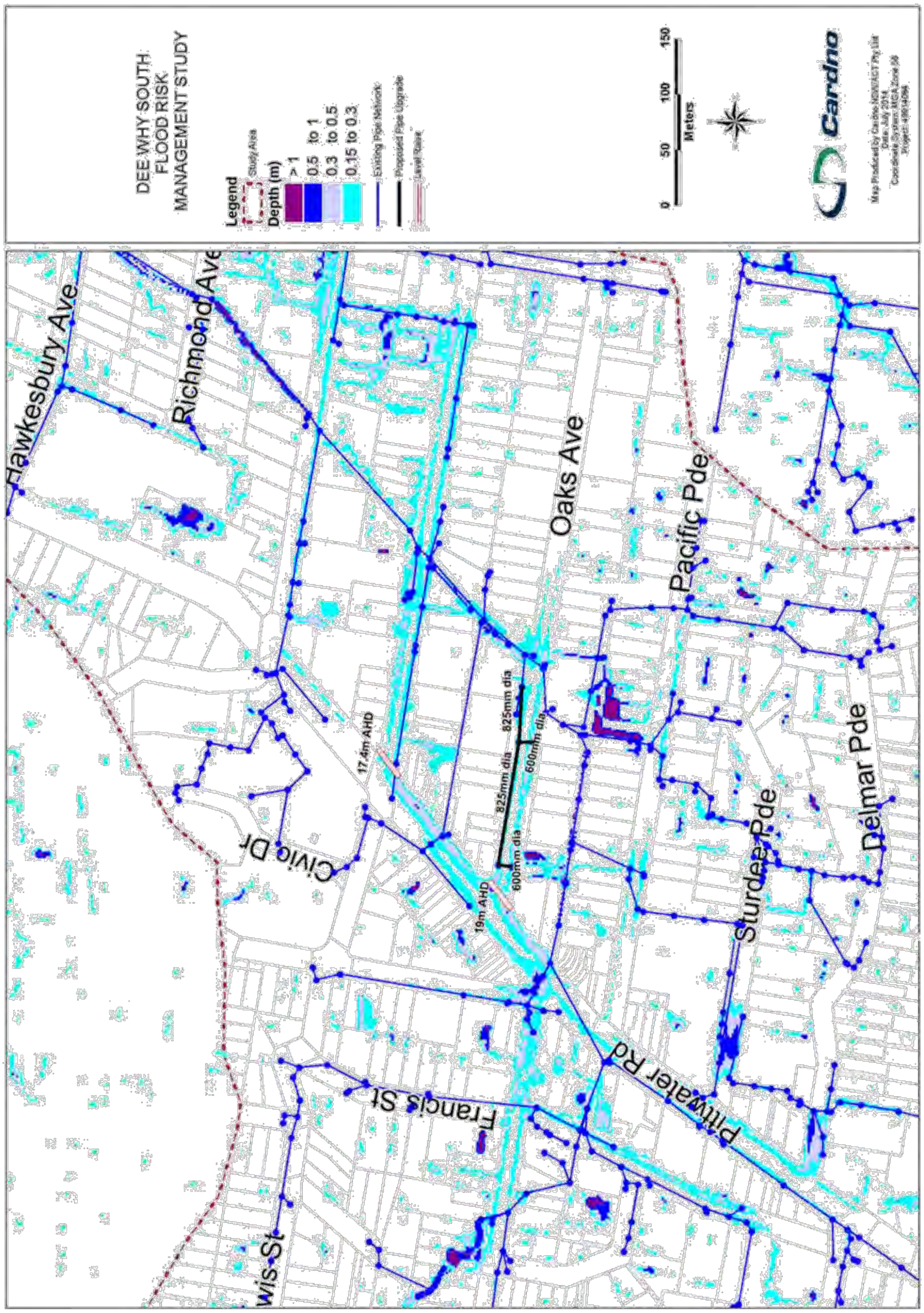

Figure C19 – Mitigation Option FM7 100 year ARI Depth Plot

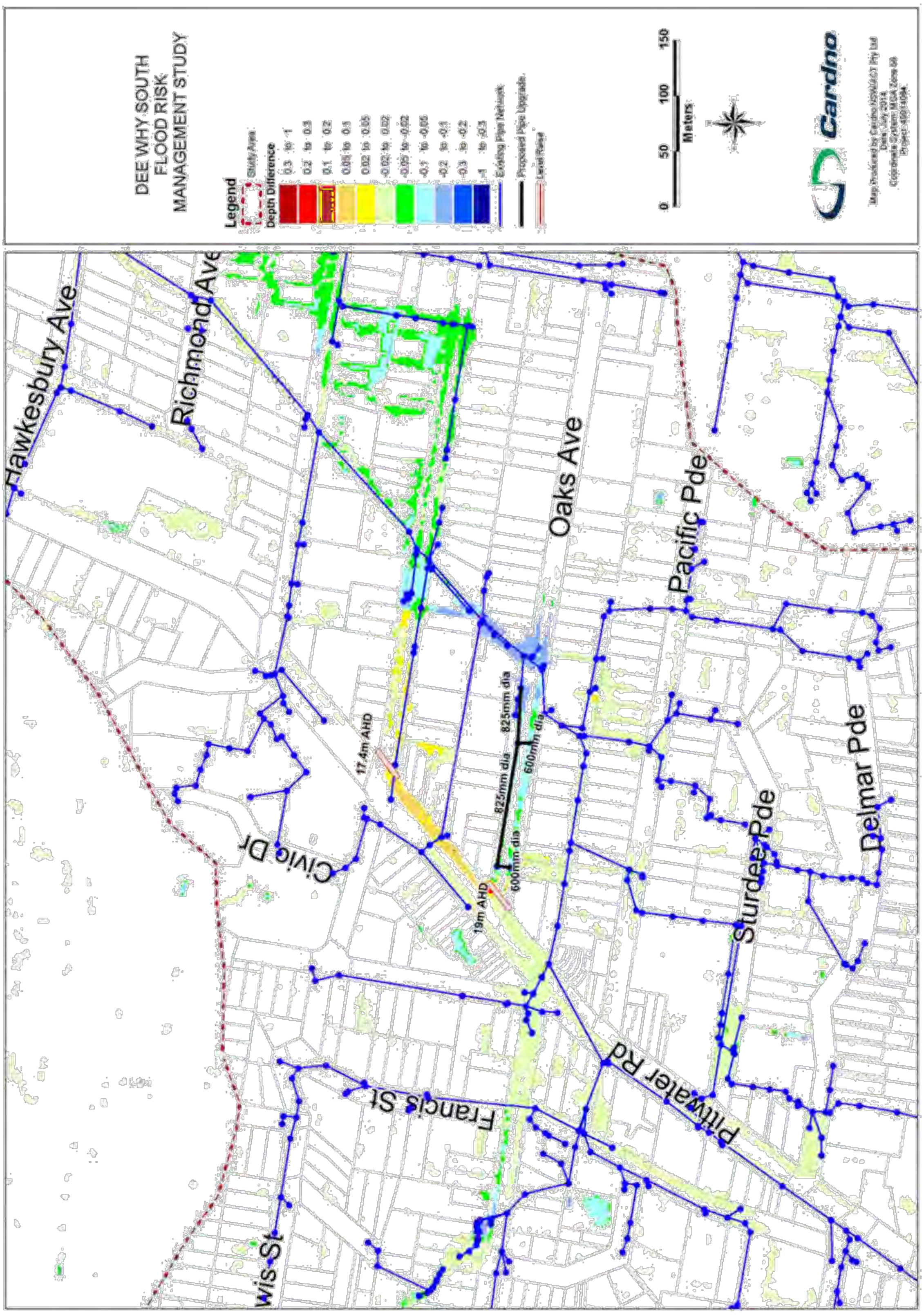

Figure C20 – Mitigation Option FM7 100 year ARI Depth Difference Plot

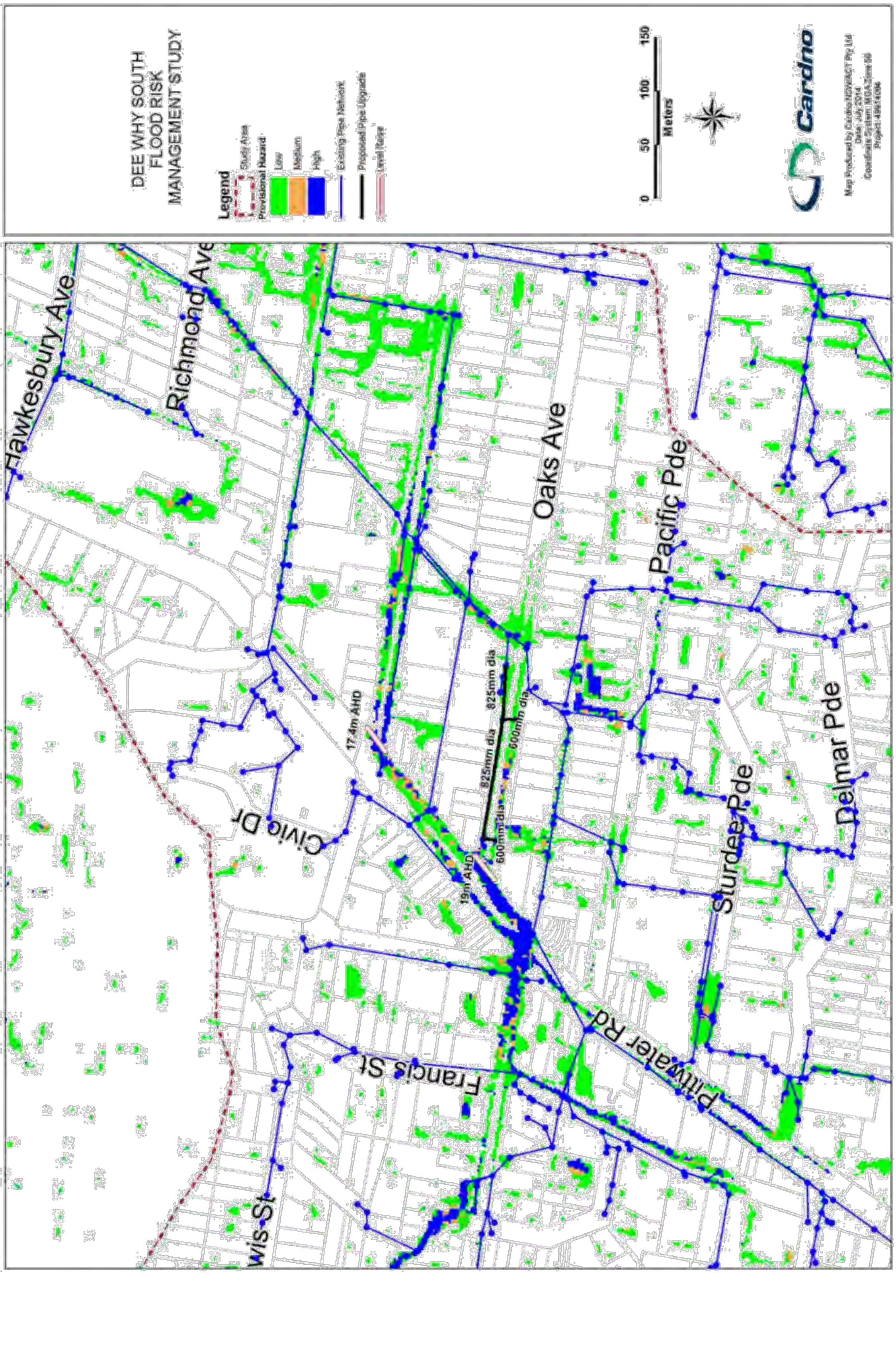

Figure C21 – Mitigation Option FM7 100 year ARI Hazard Plot

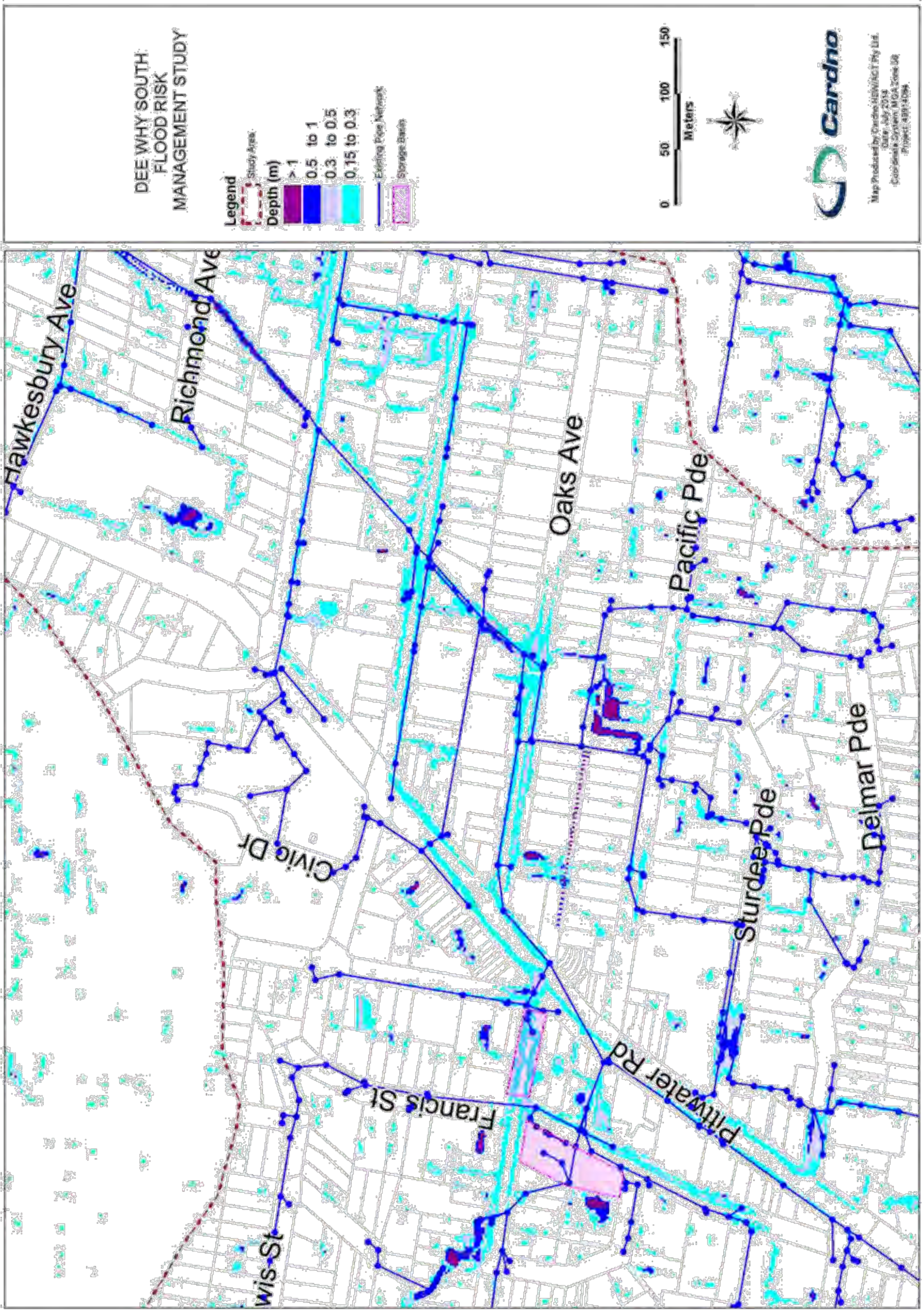

Figure C22 – Mitigation Option FM8 100 year ARI Depth Plot

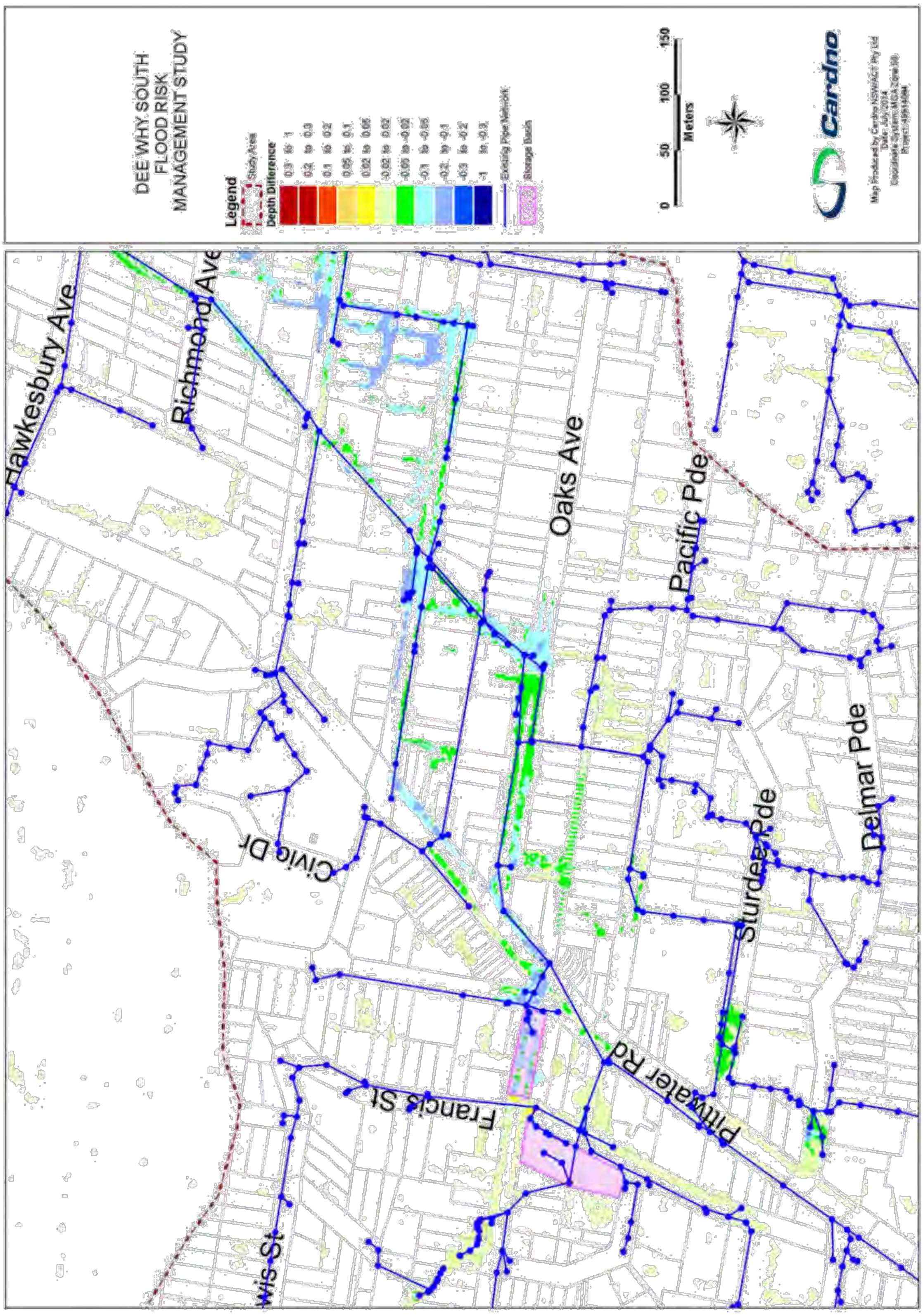

Figure C23 – Mitigation Option FM8 100 year ARI Depth Difference Plot

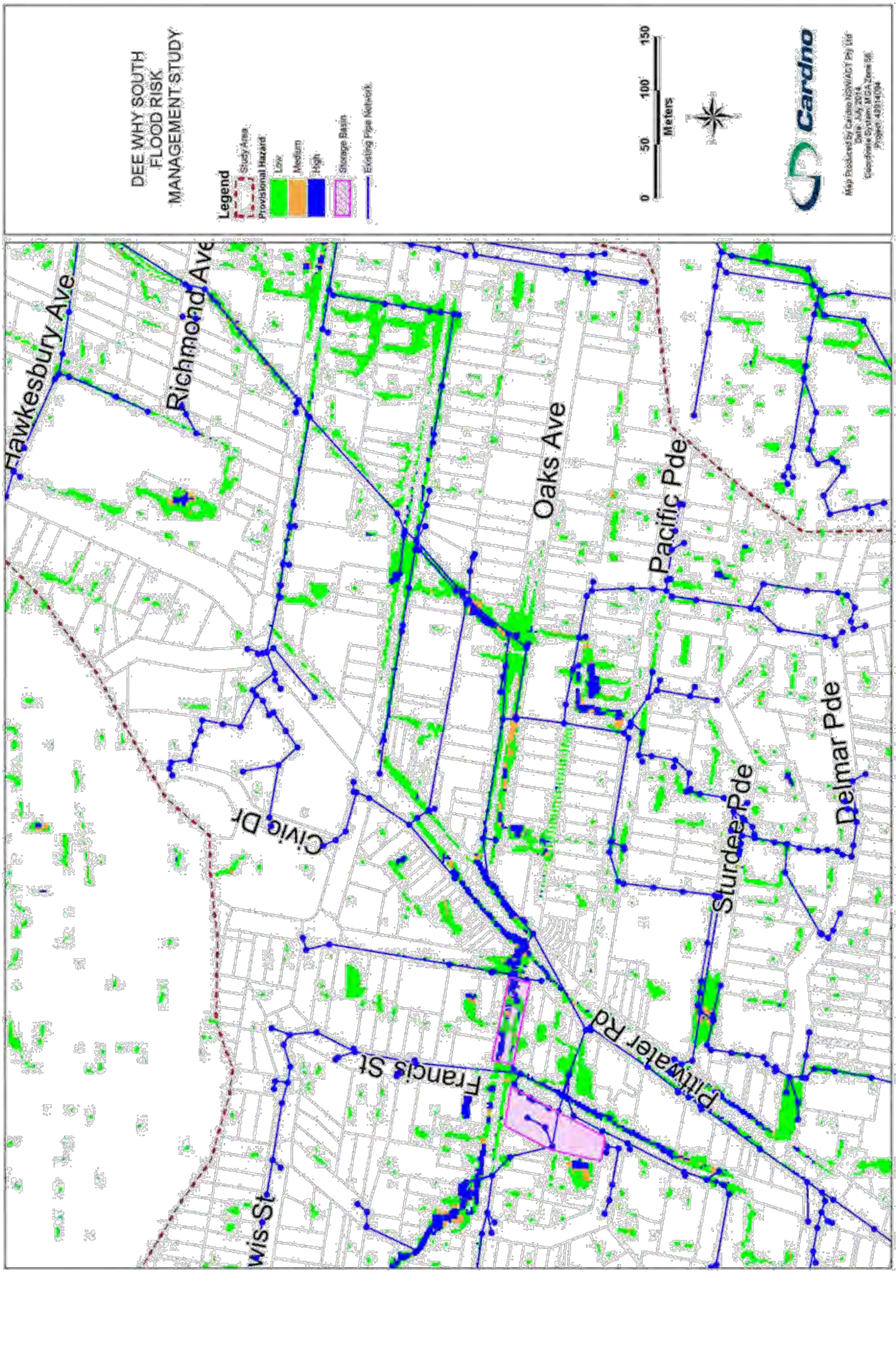

Figure C24 – Mitigation Option FM8 100 year ARI Hazard Plot

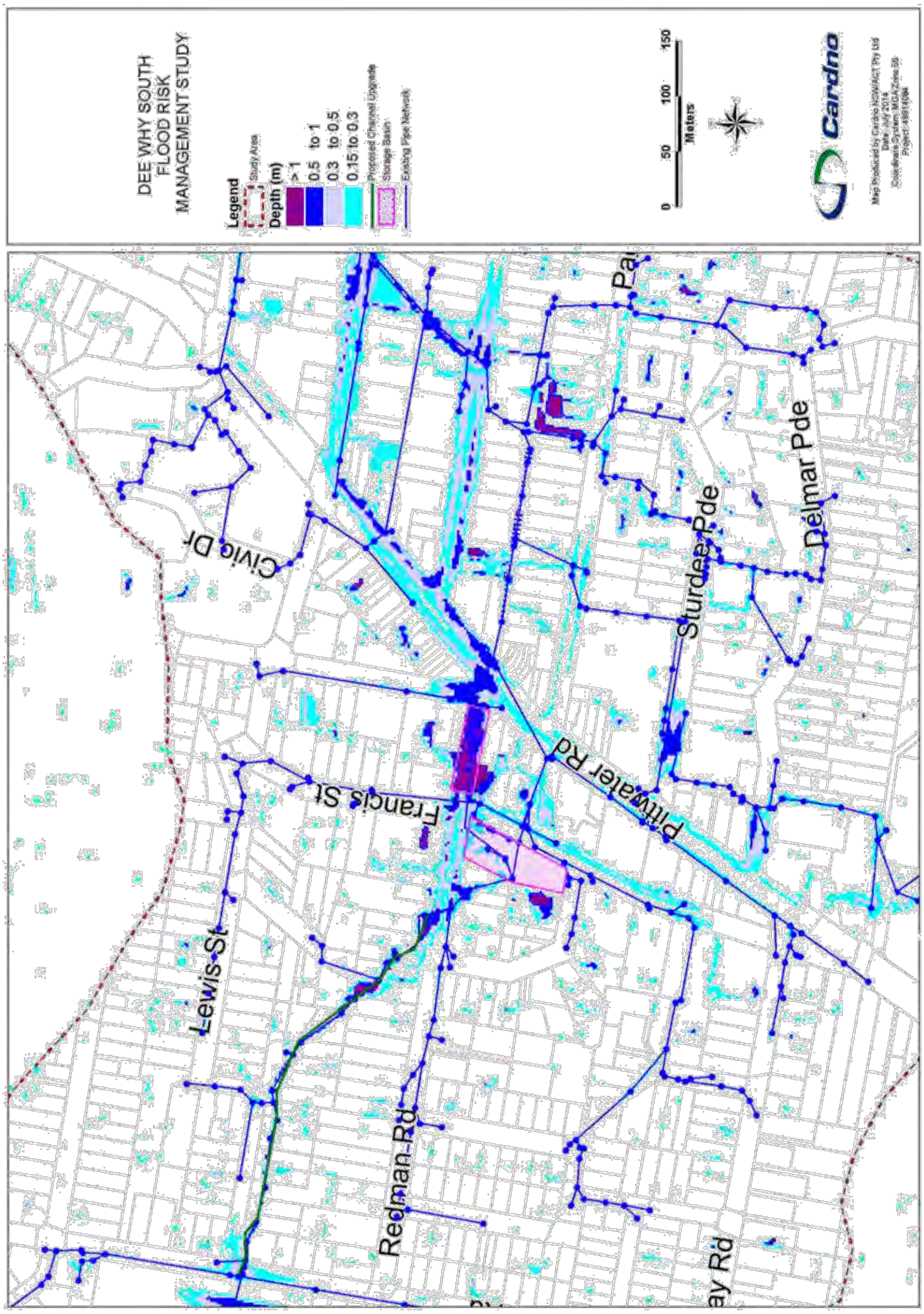

Figure C25 – Mitigation Option FM9 100 year ARI Depth Plot

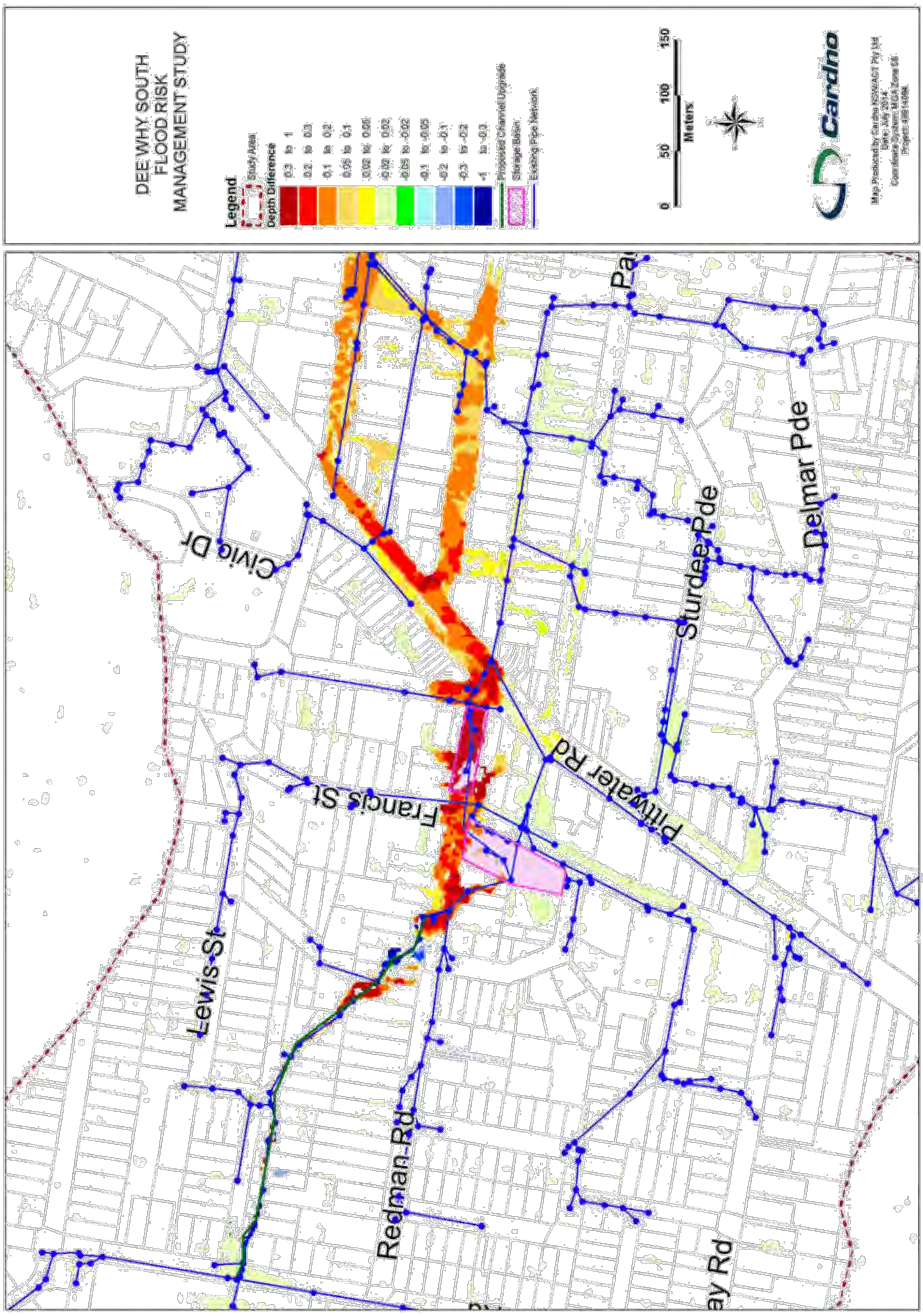

Figure C26 – Mitigation Option FM9 100 year ARI Depth Difference Plot

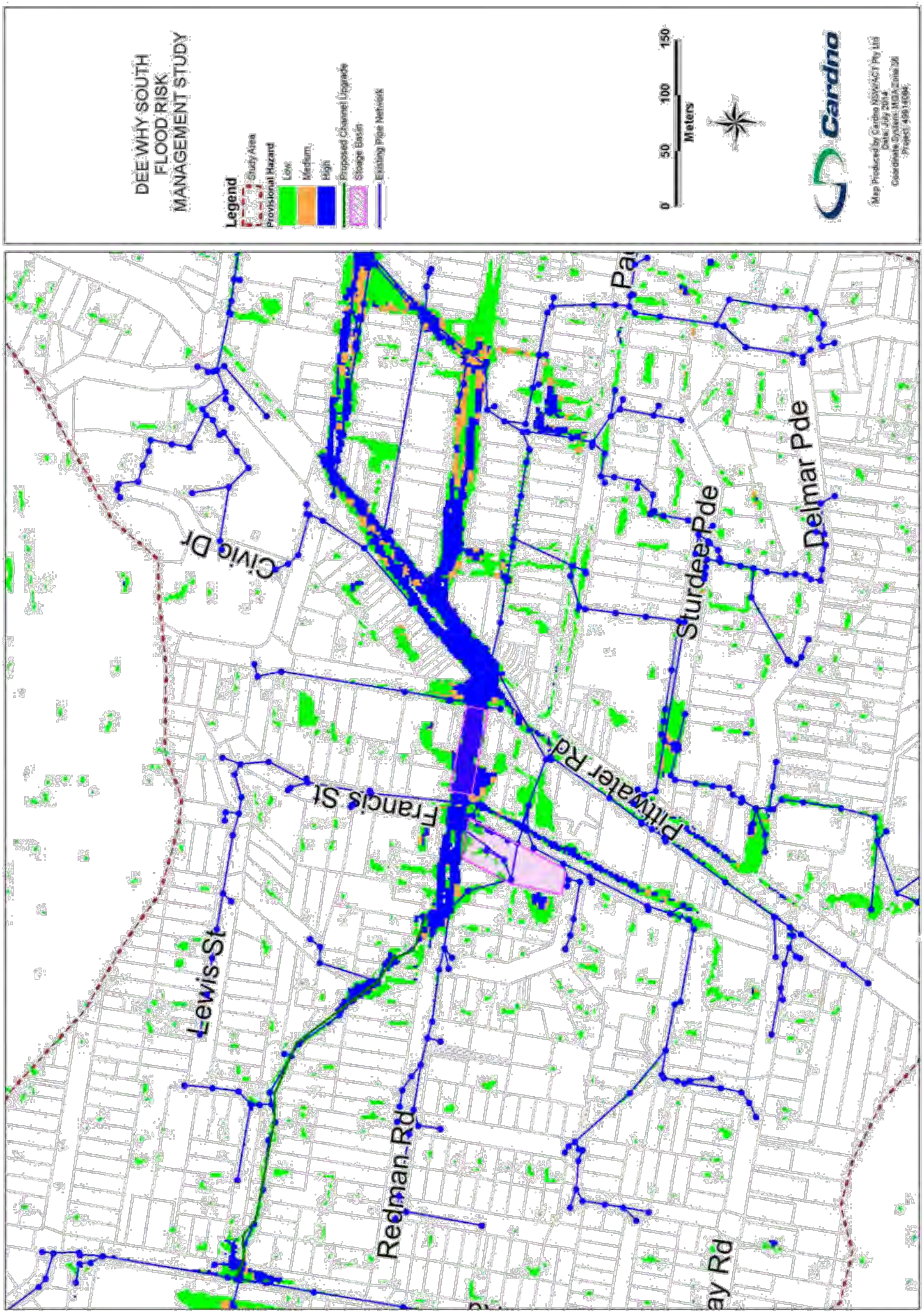

Figure C27 – Mitigation Option FM9 100 year ARI Hazard Plot

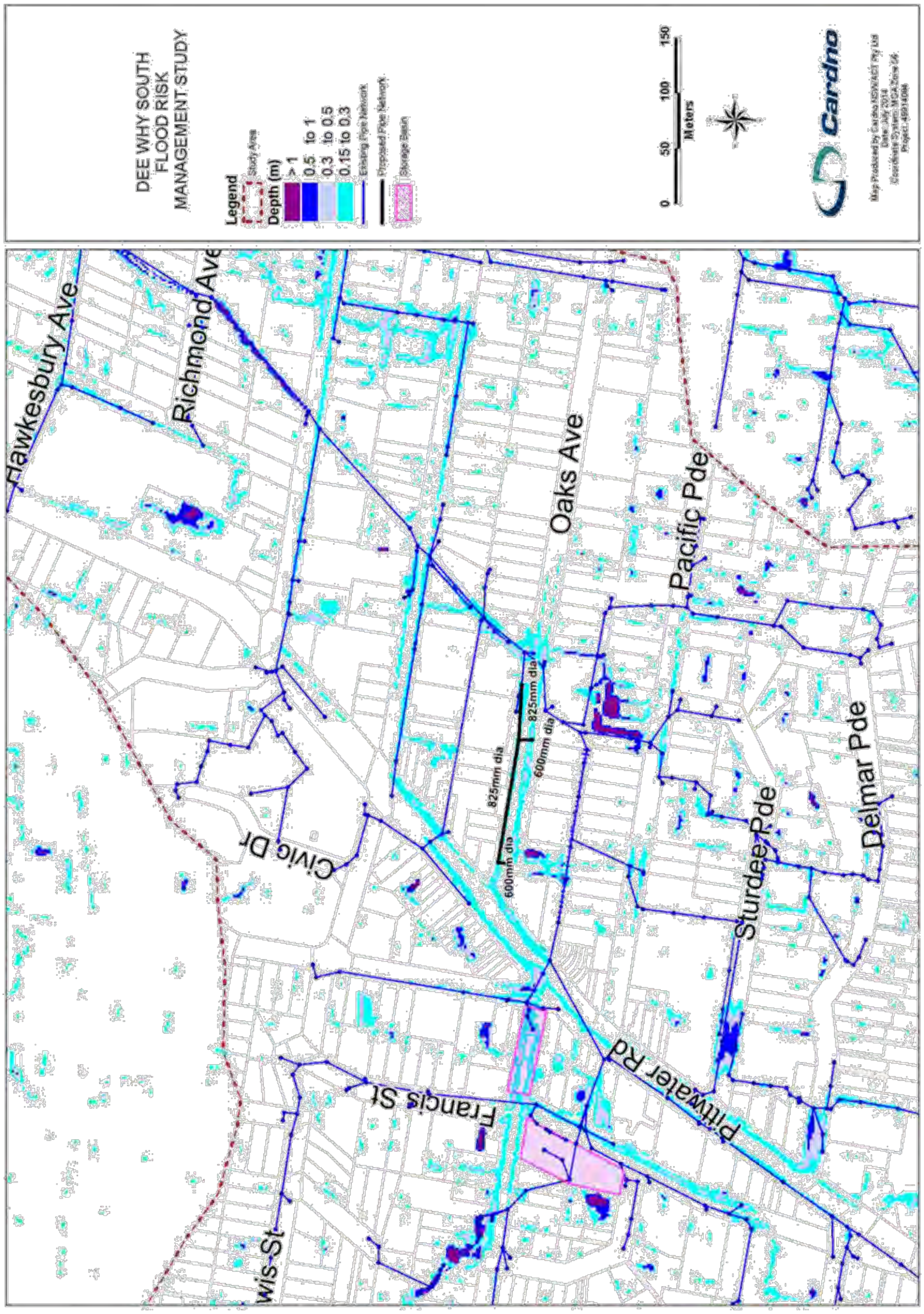

Figure C28 – Mitigation Option FM10 100 year ARI Depth Plot

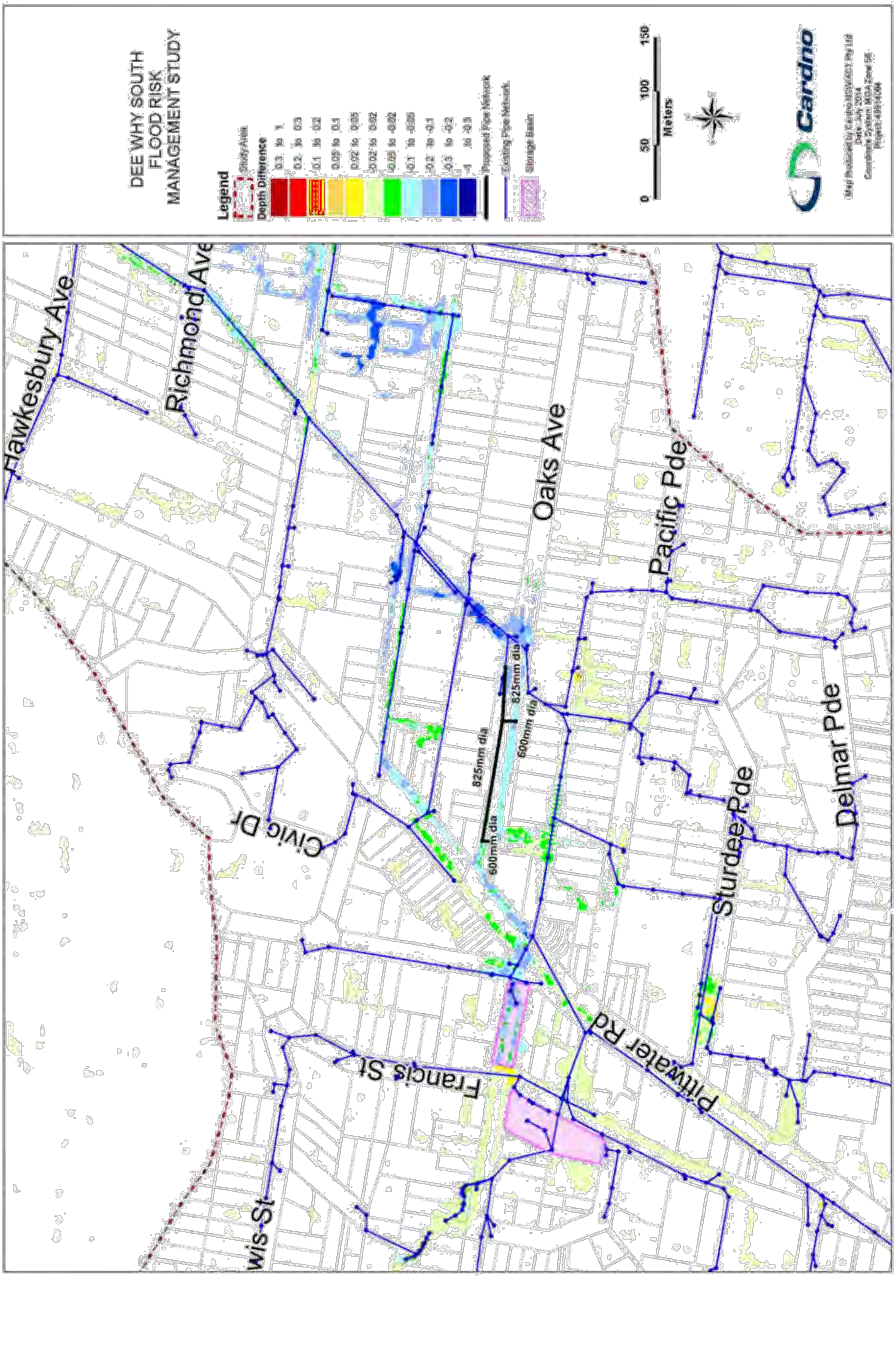

Figure C29 – Mitigation Option FM10 100 year ARI Depth Difference Plot

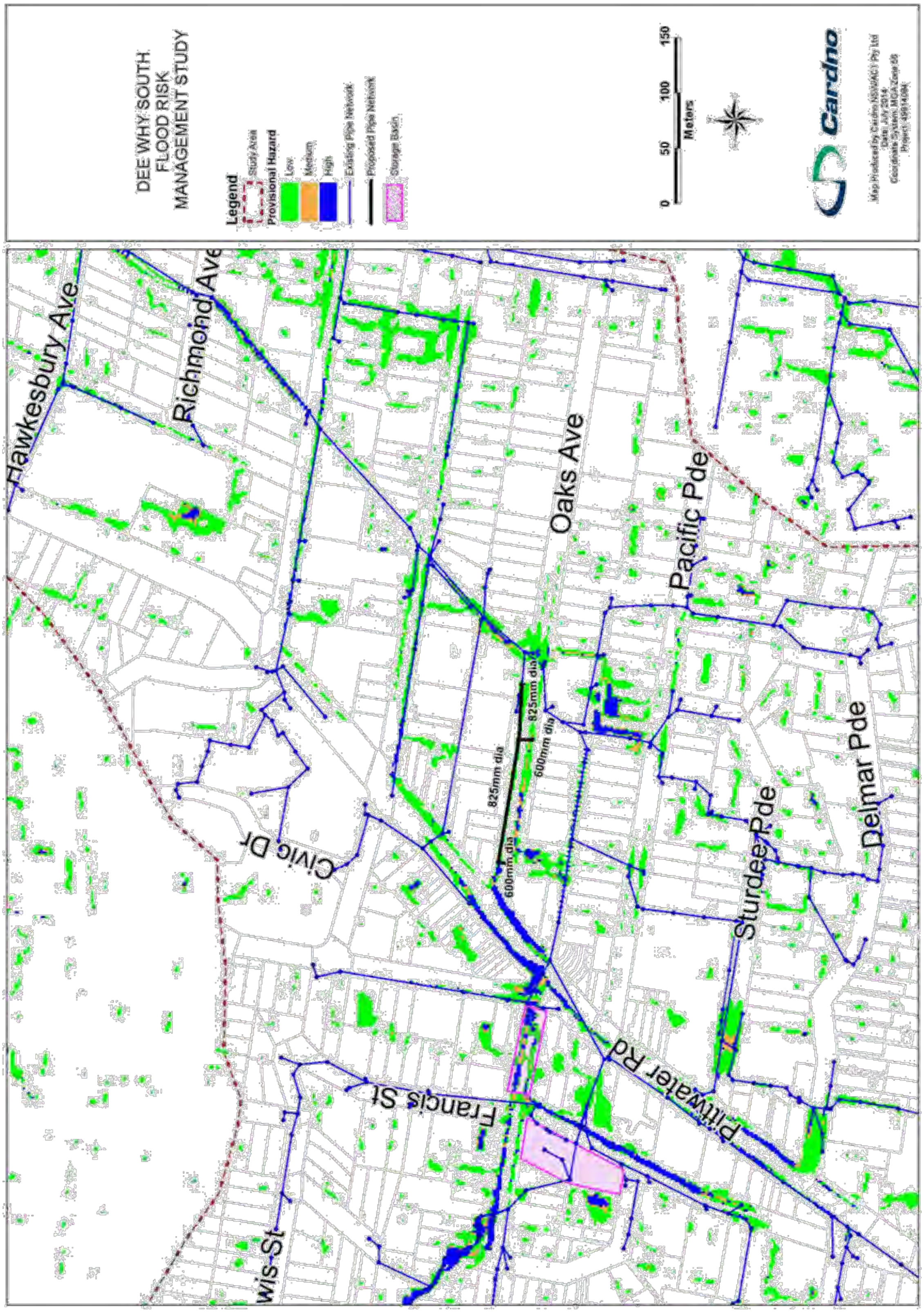

Figure C30 – Mitigation Option FM10 100 year ARI Hazard Plot

Dee Why South Catchment
Floodplain Risk Management Study

APPENDIX D
MITIGATION OPTION COSTINGS

Cardno
Shaping the Future

59914084 - Dee Why FRMS

Cardno Shaping the Future

Cost Estimate
Opt: FM 1
Pipes upgrade between Sturdee Pde and Oaks Ave

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
1.6	Cost Associated with easment (ass $1,000,000 median house (400m2) price 40m2 required)	1	item		100,000
	SUBTOTAL (Assumed as 15% of works cost)				**389,200**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of vegatated areas (nominal allowance)	1,000	sq. m	10	10,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	150	cu. m	25	3,750
2.3	Dispose of excess topsoil (nominal 10% allowance)	15	cu. m	60	900
2.4	Pull up and dispose existing road surface	1680	sq.m	35	58,800
	SUBTOTAL				**73,450**
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.9m x 0.9m culvert	100	lin.m	1900	190,000
	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.9m x 0.9m culvert	7	lin.m	1900	13,300
4.2	Supply, excavate, bed, lay, joint, backfill and provide connections for 1.2m x 1.2m culvert	58.09	lin.m	2400	139,416
4.3	Supply, excavate, bed, lay, joint, backfill and provide connections for 3.6m x 1.5m culvert	7.52	lin.m	6600	49,632
4.4	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.9m dia. Pipe	18.42	lin.m	1200	22,104
4.5	Supply, excavate, bed, lay, joint, backfill and provide connections for 3.6m x 1.8m culvert	45.99	lin.m	7050	324,230
4.6	Supply, excavate, bed, lay, joint, backfill and provide connections for 2.4m x 1.5m culvert	67.37	lin.m	4000	269,480
4.7	Supply, excavate, bed, lay, joint, backfill and provide connections for 2.4m x 1.5m culvert	67.37	lin.m	4000	269,480
4.8	Install new drainage / junction pit	8	each	4000	32,000
4.9	Install new oulet structure, including erosion protection as required	1	each	6000	6,000
4.1	Adjustment of exsiting services (nominal allowance) (assumed 10% of drainage installation cost)	1	item	131,564	131,564
	SUBTOTAL				**1,447,206**
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	1680	sq. m	120	201,600
	SUBTOTAL				**201,600**
6.0	**TRAFFIC CONTROL**				
6.1	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	371	lin.m	500	185,500
	SUBTOTAL				**185,500**
7.0	**MINOR LANDSCAPING**				
7.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	1,000	sq. m	20	20,000
	SUBTOTAL				**20,000**
8.0	**Additional Assessment**				
8.1	Undertake Environmental Impacts Assessment	1	item	25000	25,000
	SUBTOTAL				**25,000**
	CONSTRUCTION SUB-TOTAL				**2,341,956**
8.0	**CONTINGENCIES**				
8.1	50% construction cost				**1,170,978**
	CONSTRUCTION TOTAL, excluding GST				**3,512,933**
	GST				**351,293**
	CONSTRUCTION TOTAL, including GST				**3,864,227**
	CONSTRUCTION TOTAL, rounded				**3,864,300**

DISCLAIMER:

1. This estimate of cost is provided in good faith using information available at this stage. This estimate of cost is not guaranteed.

Cardno (NSW) will not accept liability in the event that actual costs exceed the estimate.

NOTES:

1. Estimate does not include Consultant's fees, including design or project management
2. Estimate / rates in 2010 dollars and does not allow for inflation

59914084 - Dee Why FRMS

Cardno
Shaping the Future

Cost Estimate
Opt: FM 2
Increase drainage capacity along oaks Ave

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	GENERAL AND PRELIMINARIES				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				97,500
2.0	DEMOLITION, CLEARING AND GRUBBING				
2.1	Clearing & grubbing of vegatated areas (nominal allowance)	1,000	sq. m	10	10,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	150	cu. m	25	3,750
2.3	Dispose of excess topsoil (nominal 10% allowance)	15	cu. m	60	900
2.4	Pull up and dispose existing road surface	1680	sq.m	35	58,800
	SUBTOTAL				73,450
4.0	DRAINAGE				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	12	lin.m	975	11,700
4.2	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	12	lin.m	975	11,700
4.3	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.825m dia. Pipe	115	lin.m	1125	129,375
4.4	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.825m dia. Pipe	51	lin.m	1125	57,375
4.7	Install new drainage / junction pit	5	each	4000	20,000
4.8	Install new oulet structure, including erosion protection as required	1	each	6000	6,000
4.9	Adjustment of exsiting services (nominal allowance) (assumed 10% of drainage installation cost)	1	item	23,615	23,615
	SUBTOTAL				259,765
5.0	PAVEMENTS				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	1680	sq. m	120	201,600
	SUBTOTAL				201,600
6.0	TRAFFIC CONTROL				
6.1	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	190	lin.m	500	95,000
	SUBTOTAL				95,000
7.0	MINOR LANDSCAPING				
7.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	1,000	sq. m	20	20,000
	SUBTOTAL				20,000
8.0	Additional Assessment				
8.1	Undertake Environmental Impacts Assessment	1	item	25000	25,000
	SUBTOTAL				25,000
	CONSTRUCTION SUB-TOTAL				772,315
8.0	CONTINGENCIES				
8.1	50% construction cost				386,158
	CONSTRUCTION TOTAL, excluding GST				1,158,473
	GST				115,847
	CONSTRUCTION TOTAL, including GST				1,274,320
	CONSTRUCTION TOTAL, rounded				1,274,400

DISCLAIMER:

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NOTES:

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2. Estimate / rates in 2010 dollars and does not allow for inflation

59914084 - Dee Why FRMS

Cardno Shaping the Future

Cost Estimate
Opt: FM 3
Increase drainage capacity along oaks Ave, divert main drain to the east, reconnect to existing drain at Howard St

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				193,000
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of vegetated areas (nominal allowance)	4,000	sq. m	10	40,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	600	cu. m	25	15,000
2.3	Dispose of excess topsoil (nominal 10% allowance)	60	cu. m	60	3,600
2.4	Pull up and dispose existing road surface	1680	sq.m	35	58,800
	SUBTOTAL				117,400
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	12	lin.m	975	11,700
4.2	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	12	lin.m	975	11,700
4.3	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.825m dia. Pipe	115	lin.m	1125	129,375
4.4	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.825m dia. Pipe	51	lin.m	1125	57,375
4.5	Supply, excavate, bed, lay, joint, backfill and provide connections for 1.2m dia. Pipe	124	lin.m	1650	204,600
4.6	Supply, excavate, bed, lay, joint, backfill and provide connections for 1.2m dia. Pipe	98.56	lin.m	1650	162,624
4.7	Install new drainage / junction pit	9	each	4000	36,000
4.8	Install new oulet structure, including erosion protection as required	1	each	6000	6,000
4.9	Adjustment of exsiting services (nominal allowance) (assumed 10% of drainage installation cost)	1	item	61,937	61,937
	SUBTOTAL				681,311
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	1680	sq. m	120	201,600
	SUBTOTAL				201,600
6.0	**TRAFFIC CONTROL**				
6.1	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	412.56	lin.m	500	206,280
	SUBTOTAL				206,280
7.0	**MINOR LANDSCAPING**				
7.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	4,000	sq. m	20	80,000
	SUBTOTAL				80,000
8.0	**Additional Assessment**				
8.1	Undertake Environmental Impacts Assessment	1	item	25000	25,000
	SUBTOTAL				25,000
	CONSTRUCTION SUB-TOTAL				1,504,591
8.0	**CONTINGENCIES**				
8.1	50% construction cost				752,296
	CONSTRUCTION TOTAL, excluding GST				2,256,887
	GST				225,689
	CONSTRUCTION TOTAL, including GST				2,482,576
	CONSTRUCTION TOTAL, rounded				2,482,600

DISCLAIMER:

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NOTES:

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59914084 - Dee Why FRMS

Cardno
Shaping the Future

Cost Estimate
Opt: FM4
Daylight Existing Culvert

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**115,700**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of vegatated areas (nominal allowance)	1,000	sq. m	10	10,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	150	cu. m	25	3,750
2.3	Dispose of excess topsoil (nominal 10% allowance)	15	cu. m	60	900
2.4	Pull up and dispose existing road surface	50	sq.m	35	1,750
	SUBTOTAL				**16,400**
4.0	**DRAINAGE**				
4.1	2.4m culvert	125	lin.m	4200	525,000
4.7	Install new drainage / junction pit	9	each	4000	36,000
4.8	Install new oulet structure, including erosion protection as required	1	each	6000	6,000
4.9	Adjustment of exsiting services (nominal allowance) (assumed 10% of drainage installation cost)	1	item	56,700	56,700
	SUBTOTAL				**623,700**
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	50	sq. m	120	6,000
	SUBTOTAL				**6,000**
6.0	**TRAFFIC CONTROL**				
6.1	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	50	lin.m	500	25,000
	SUBTOTAL				**25,000**
7.0	**LANDSCAPING**				
7.1	Provide safe landscaping to accommodate the open channel within the current towncentre	1,000	sq. m	100	100,000
	SUBTOTAL				**100,000**
8.0	**Additional Assessment**				
8.1	Undertake Environmental Impacts Assessment	1	item	25000	25,000
	SUBTOTAL				**25,000**
	CONSTRUCTION SUB-TOTAL				**911,800**
8.0	**CONTINGENCIES**				
8.1	50% construction cost				**455,900**
	CONSTRUCTION TOTAL, excluding GST				**1,367,700**
	GST				**136,770**
	CONSTRUCTION TOTAL, including GST				**1,504,470**
	CONSTRUCTION TOTAL, rounded				**1,504,500**

DISCLAIMER:

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NOTES:

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2. Estimate / rates in 2010 dollars and does not allow for inflation

59914084 - Dee Why FRMS

Cardno
Shaping the Future

Cost Estimate
Opt: FM 5
FM2 + Addition of a detention basin in Walter Gors Park

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**130,000**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of Walter Park (nominal allowance)	5,000	sq. m	10	50,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	750	cu. m	25	18,750
2.3	Dispose of excess topsoil (nominal 10% allowance)	75	cu. m	60	4,500
2.4	Pull up and dispose existing road surface	2000	sq.m	35	70,000
	SUBTOTAL				**143,250**
3.0	**Earthworks**				
3.1	Excavation of park and oval detention basins	4,000	cu.m	45	180,000
3.2	Disposal of excess cut (assuming 80% of total excavation)	3,200	item	60	192,000
	SUBTOTAL				**372,000**
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	12	lin.m	975	11,700
4.2	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	12	lin.m	975	11,700
4.3	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.825m dia. Pipe	115	lin.m	1125	129,375
4.4	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.825m dia. Pipe	51	lin.m	1125	57,375
4.7	Install new drainage / junction pit	10	each	4000	40,000
4.8	Install new oulet structure, including erosion protection as required	2	each	6000	12,000
4.9	Adjustment of exsiting services (nominal allowance) (assumed 10% of drainage installation cost)	1	item	26,215	26,215
	SUBTOTAL				**288,365**
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	2000	sq. m	120	240,000
	SUBTOTAL				**240,000**
6.0	**TRAFFIC CONTROL**				
6.1	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	190	lin.m	500	95,000
	SUBTOTAL				**95,000**
7.0	**MINOR LANDSCAPING**				
7.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	5,000	sq. m	20	100,000
	SUBTOTAL				**100,000**
8.0	**Additional Assessment**				
8.1	Undertake Environmental Impacts Assessment	1	item	25000	25,000
	SUBTOTAL				**25,000**
	CONSTRUCTION SUB-TOTAL				**1,393,615**
8.0	**CONTINGENCIES**				
8.1	50% construction cost				**696,808**
	CONSTRUCTION TOTAL, excluding GST				**2,090,423**
	GST				**209,042**
	CONSTRUCTION TOTAL, including GST				**2,299,465**
	CONSTRUCTION TOTAL, rounded				**2,299,500**

DISCLAIMER:

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NOTES:

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2. Estimate / rates in 2010 dollars and does not allow for inflation

59914084 - Dee Why FRMS

Cardno Shaping the Future

Cost Estimate
Opt: FM 6
Decommission the channel +FM1+FM2

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
1.6	Cost Associated with easment (ass $1,000,000 median house (400m2) price 40m2 required)	1	item		100,000
	SUBTOTAL (Assumed as 15% of works cost)				427,000
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of vegatated areas (nominal allowance)	1,000	sq. m	10	10,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	150	cu. m	25	3,750
2.3	Dispose of excess topsoil (nominal 10% allowance)	15	cu. m	60	900
2.4	Pull up and dispose existing road surface	1680	sq.m	35	58,800
	SUBTOTAL				73,450
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.9m x 0.9m culvert	100	lin.m	1900	190,000
4.2	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.9m x 0.9m culvert	7	lin.m	1900	13,300
4.3	Supply, excavate, bed, lay, joint, backfill and provide connections for 1.2m x 1.2m culvert	58.09	lin.m	2400	139,416
4.4	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.9m dia. Pipe	18.42	lin.m	1200	22,104
4.5	Supply, excavate, bed, lay, joint, backfill and provide connections for 3.6m x 1.8m culvert	45.99	lin.m	7050	324,230
4.6	Supply, excavate, bed, lay, joint, backfill and provide connections for 2.4m x 1.5m culvert	67.37	lin.m	4000	269,480
4.7	Supply, excavate, bed, lay, joint, backfill and provide connections for 2.4m x 1.5m culvert	67.37	lin.m	4000	269,480
4.8	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	12	lin.m	975	11,700
4.9	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	12	lin.m	975	11,700
5.0	Supply, excavate, bed, lay, joint, backfill and provide connections for 1.5m x 0.9m culvert	65	lin.m	2600	169,000
5.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 1.5m x 0.9m culvert	42	lin.m	2600	109,200
5.2	Supply, excavate, bed, lay, joint, backfill and provide connections for 1.5m x 0.9m culvert	115	lin.m	2600	299,000
5.3	Supply, excavate, bed, lay, joint, backfill and provide connections for 1.5m x 0.9m culvert	51	lin.m	2600	132,600
4.8	Install new drainage / junction pit	13	each	4000	52,000
4.9	Install new oulet structure, including erosion protection as required	1	each	6000	6,000
4.1	Adjustment of exsiting services (nominal allowance) (assumed 10% of drainage installation cost)	1	item	201,921	201,921
	SUBTOTAL				2,221,130
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	1680	sq. m	120	201,600
	SUBTOTAL				201,600
6.0	**TRAFFIC CONTROL**				
6.1	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	661.24	lin.m	500	330,620
	SUBTOTAL				330,620
7.0	**MINOR LANDSCAPING**				
7.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	1,000	sq. m	20	20,000
	SUBTOTAL				20,000
8.0	**Additional Assessment**				
8.1	Undertake Environmental Impacts Assessment	1	item	25000	25,000
	SUBTOTAL				25,000
	CONSTRUCTION SUB-TOTAL				3,298,800
8.0	**CONTINGENCIES**				
8.1	50% construction cost				1,649,400
	CONSTRUCTION TOTAL, excluding GST				4,948,201
	GST				494,820
	CONSTRUCTION TOTAL, including GST				5,443,021
	CONSTRUCTION TOTAL, rounded				5,443,100

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NOTES:

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59914084 - Dee Why FRMS

Cardno Shaping the Future

Cost Estimate
Opt: FM 7
Raise levels of Oaks Ave and Howard St + FM2

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				105,800
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of vegetated areas (nominal allowance)	1,000	sq. m	10	10,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	150	cu. m	25	3,750
2.3	Dispose of excess topsoil (nominal 10% allowance)	15	cu. m	60	900
2.4	Pull up and dispose existing road surface	1680	sq.m	35	58,800
	SUBTOTAL				73,450
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	12	lin.m	975	11,700
4.2	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	12	lin.m	975	11,700
4.3	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.825m dia. Pipe	115	lin.m	1125	129,375
4.4	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.825m dia. Pipe	51	lin.m	1125	57,375
4.7	Install new drainage / junction pit	5	each	4000	20,000
4.8	Install new oulet structure, including erosion protection as required	1	each	6000	6,000
4.9	Adjustment of exsiting services (nominal allowance) (assumed 10% of drainage installation cost)	1	item	23,615	23,615
	SUBTOTAL				259,765
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	2000	sq. m	120	240,000
	SUBTOTAL				240,000
6.0	**TRAFFIC CONTROL**				
6.1	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	220	lin.m	500	110,000
	SUBTOTAL				110,000
7.0	**MINOR LANDSCAPING**				
7.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	1,100	sq. m	20	22,000
	SUBTOTAL				22,000
8.0	**Additional Assessment**				
8.1	Undertake Environmental Impacts Assessment	1	item	25000	25,000
	SUBTOTAL				25,000
	CONSTRUCTION SUB-TOTAL				836,015
8.0	**CONTINGENCIES**				
8.1	50% construction cost				418,008
	CONSTRUCTION TOTAL, excluding GST				1,254,023
	GST				125,402
	CONSTRUCTION TOTAL, including GST				1,379,425
	CONSTRUCTION TOTAL, rounded				1,379,500

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NOTES:

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59914084 - Dee Why FRMS

Cardno Shaping the Future

Cost Estimate
Opt: FM 8
Storage Basin at Mooramba Rd carpark and at the east end of Redman Rd

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				345,200
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing for Storage basin (nominal allowance)	2,500	sq. m	10	25,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	375	cu. m	25	9,375
2.3	Dispose of excess topsoil (nominal 10% allowance)	37.5	cu. m	60	2,250
2.4	Pull up and dispose existing road surface	1680	sq.m	35	58,800
	SUBTOTAL				95,425
3.0	**Earthworks**				
3.1	Excavation for storage basin(2 sites)	2,500	cu.m	45	112,500
3.2	Disposal of excess cut (assuming 80% of total excavation)	2,000	item	60	120,000
	SUBTOTAL				232,500
4.0	**DRAINAGE / STORAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	100	lin.m	975	97,500
4.2	Inclusion of Basin (x2) - total storage area = 5000 m3	2	item	600000	1,200,000
4.3	Install new drainage / junction pit	5	each	4000	20,000
4.4	Install new oulet structure, including erosion protection as required	1	each	6000	6,000
4.5	Adjustment of exsiting services (nominal allowance) (assumed 10% of drainage installation cost)	1	item	132,350	132,350
	SUBTOTAL				1,455,850
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	5000	sq. m	120	600,000
	SUBTOTAL				600,000
6.0	**TRAFFIC CONTROL**				
6.1	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	100	lin.m	500	50,000
	SUBTOTAL				50,000
7.0	**MINOR LANDSCAPING**				
7.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	5,000	sq. m	20	100,000
	SUBTOTAL				100,000
8.0	**Additional Assessment**				
8.1	Undertake Environmental Impacts Assessment	1	item	25000	25,000
	SUBTOTAL				25,000
	CONSTRUCTION SUB-TOTAL				2,903,975
8.0	**CONTINGENCIES**				
8.1	50% construction cost				1,451,988
	CONSTRUCTION TOTAL, excluding GST				4,355,963
	GST				435,596
	CONSTRUCTION TOTAL, including GST				4,791,559
	CONSTRUCTION TOTAL, rounded				4,791,600

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NOTES:

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59914084 - Dee Why FRMS

Cardno Shaping the Future

Cost Estimate
Opt: FM 10
Storage Basin at Mooramba Rd & east Redman Rd with Oaks Ave augmentation

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				442,700
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing for Storage basin (nominal allowance)	3,500	sq. m	10	35,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	525	cu. m	25	13,125
2.3	Dispose of excess topsoil (nominal 10% allowance)	52.5	cu. m	60	3,150
2.4	Pull up and dispose existing road surface	3360	sq.m	35	117,600
	SUBTOTAL				168,875
3.0	**Earthworks**				
3.1	Excavation for storage basin(2 sites)	2,500	cu.m	45	112,500
3.2	Disposal of excess cut (assuming 80% of total excavation)	2,000	item	60	120,000
	SUBTOTAL				232,500
4.0	**DRAINAGE / STORAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	124	lin.m	975	120,900
	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.825m dia. Pipe	166	lin.m	1125	186,750
4.2	Inclusion of Basin (x2) - total storage area = 5000 m3	2	item	600000	1,200,000
4.3	Install new drainage / junction pit	10	each	4000	40,000
4.4	Install new outlet structure, including erosion protection as required	2	each	6000	12,000
4.5	Adjustment of exsiting services (nominal allowance) (assumed 10% of drainage installation cost)	1	item	155,965	155,965
	SUBTOTAL				1,715,615
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	6680	sq. m	120	801,600
	SUBTOTAL				801,600
6.0	**TRAFFIC CONTROL**				
6.1	Control of traffic during works (nominal allowance) (assumed $500 per lin.m)	290	lin.m	500	145,000
	SUBTOTAL				145,000
7.0	**MINOR LANDSCAPING**				
7.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	6,000	sq. m	20	120,000
	SUBTOTAL				120,000
8.0	**Additional Assessment**				
8.1	Undertake Environmental Impacts Assessment	1	item	40000	40,000
	SUBTOTAL				40,000
	CONSTRUCTION SUB-TOTAL				3,666,290
8.0	**CONTINGENCIES**				
8.1	50% construction cost				1,833,145
	CONSTRUCTION TOTAL, excluding GST				5,499,435
	GST				549,944
	CONSTRUCTION TOTAL, including GST				6,049,379
	CONSTRUCTION TOTAL, rounded				6,049,400

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NOTES:

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Dee Why South Catchment
Floodplain Risk Management Study

APPENDIX E
MULTI CRITERIA ASSESSMENT

Cardno
Shaping the Future

Option No.	Description	Capital Cost (excl. GST)	Ongoing (Annual) Costs (excl. GST)	NPW of Cost	Reduction in Damages - 100 years ARI	Total Reduction in AAD	NPW of Reduction in AAD	B/C Ratio	B/C Rank	Economic: Economic B/C	Economic: Risk to Property	Economic: Critical Infrastructure	Economic: Capital Cost	Economic: Ongoing Cost	Social: Risk to Life	Social: Social Disruption	Social: Planning Framework	Social: Community Support*	Environmental: Water Quality Objectives	Environmental: Water Re-use Objectives	Environmental: Flora & Fauna Impact	Total Score	Overall Rank
EM3	Public Awareness and Education	$0	$5,000	NC	NC	NC	NC	N/A	N/A	2	3	3	5	4	5	5	5		3	3	3	41	1
FM2	Increase drainage capacity along Oaks Avenue	$1,158,473	$1,900	$1,186,500	$787,827	$445,378	$6,577,000	5.54	1	4	4	4	4	5	4	4	3		3	3	2	40	2
PM4	Flood Proofing guidelines	$15,000	$1,500	NC	NC	NC	NC	N/A	N/A	2	3	3	5	5	4	4	5		3	3	3	40	2
EM4	Flood Warning Signs	$12,000	$1,000	NC	NC	NC	NC	N/A	N/A	2	3	3	5	5	4	4	5		3	3	3	40	2
EM1	Information transfer to NSW SES	$4,000	$1,000	NC	NC	NC	NC	N/A	N/A	2	3	3	5	5	4	3	5		3	3	3	39	5
EM2	Flood Warning System	$30,000	$7,000	NC	NC	NC	NC	N/A	N/A	2	3	3	5	4	4	4	5		3	3	3	39	5
FM3	Drainage upgrades between Oaks and Howard Avenues plus Option FM2	$2,256,887	$4,120	$2,317,700	$807,768	$440,600	$6,506,300	2.814	4	3	4	4	3	5	4	4	3		3	3	2	38	7
FM1	Pipe upgrade between Pacific Parade and Oaks Avenue	$3,512,933	$3,710	$3,567,000	$629,166	$581,166	$8,582,000	2.41	6	3	4	4	2	5	4	4	3		3	3	2	37	8
FM7	Raise level of Oaks Avenue and Howard Avenue plus Option FM2	$1,254,023	$2,200	$1,286,500	$221,272	$143,733	$2,122,500	1.65	7	2	4	4	4	5	3	3	3		3	3	2	36	9
FM8	Storage basins at Mooramba Road car park and Redman Road	$4,355,963	$21,000	$4,666,100	$3,223,939	$1,140,478	$16,841,200	3.61	2	3	5	4	2	1	4	4	3		4	4	2	36	9
EM5	Event Data Collection	$5,000	$5,000	NC	NC	NC	NC	N/A	N/A	2	3	3	5	4	3	3	4		3	3	3	36	9
FM4	Daylighting of box culvert between Howard Avenue and Dee Why Parade	$1,367,700	$1,250	$1,386,200	$14,852	-$121,014	-$1,787,000	-1.29	9	0	2	4	4	5	3	3	3		4	3	4	35	12
FM10	Combination of Option FM2 and Option FM8	$5,499,435	$22,900	$5,837,600	$4,618,594	$1,196,201	$17,664,100	3.03	3	3	5	4	1	1	4	4	3		4	4	2	35	12
FM5	Walter Gors Park detention basin plus Option FM2	$2,090,423	$10,950	$2,252,100	$772,673	$426,673	$6,300,600	2.80	5	3	4	4	3	3	3	3	3		3	3	2	34	14
FM6	Replace open channel between Oaks Avenue and Pacific Parade with new pipe under Pittwater Road plus Options FM1 and FM2	$4,948,201	$6,610	$5,045,800	$205,678	$368,461	$5,441,000	1.08	8	2	4	4	1	4	4	4	3		2	3	2	33	15
FM9	Upgrade of Open Channel between Victor Road and Redman Road plus Option FM8 – not feasible (see **Section 10.3.9**)	NC	NC	NC	NC	NC	NC	N/A	N/A	Not technically feasible												N/A	N/A
PM1	House Raising – not viable (see **Section 10.4.1**)	NC	NC	NC	NC	NC	NC	N/A	N/A	Not feasible for this catchment												N/A	N/A
PM2	Voluntary Purchase – not viable (see **Section 10.4.2**)	NC	NC	NC	NC	NC	NC	N/A	N/A	Not feasible for this catchment												N/A	N/A
PM3	Land Swap – not viable (see **Section 10.4.3**)	NC	NC	NC	NC	NC	NC	N/A	N/A	Not feasible for this catchment												N/A	N/A

*NC = Not costed. N/A = Not applicable. *Pending submissions received during public exhibition period.*