Hydraulic assessment report – final

Mona Vale Road upgrade – Drainage and utility investigations and concept design

89914065

Prepared for
NSW Roads and Maritime Services

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Cardno
Shaping the Future

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1 Introduction

This report provides the outcomes of the hydrological and hydraulic component of the drainage investigation for the Mona Vale Road Upgrade between McCarrs Creek Road, Terrey Hills to Powder Works Road, Ingleside and Manor Road, Ingleside to Foley Street, Mona Vale. This report focuses on the cross drainage structures, and identifies whether the existing capacity of these infrastructure are sufficient, or whether larger cross drainage structures will be required.

While the western part - between McCarrs Creek Road, Terrey Hills to Powder Works Road, Ingleside - of the study area was considered, limited cross drainage infrastructure were observed, which have been addressed in the drainage report. This report therefore targets the eastern part of the Mona Vale Road upgrade – from Manor Road, Ingleside to Foley Street, Mona Vale.

In accordance with the project brief, the hydrology and hydraulic component of the drainage investigation has the following objectives:

- Prepare a catchment plan of the study area.
- Investigate and locate any cross drainage within the study area and assess the cross drainage requirements (hydrological and hydraulic) and improvements required to cater for 1:100 ARI storm event.
- Determine the changes to the magnitude of flows that will occur under post road upgrade conditions for a range of design storm events.

The final report includes Roads and Maritime Services comments received 16/09/14 and comments from Roads and Maritime Staff during a meeting held on 22/09/14.

2 Available data

2.1 Topographical survey

Airborne Laser Scanner (ALS) is a form of survey that produces a dense amount of data points. The ALS data supplied by Pittwater Council in 2009 was used to define the topographic features in the Pittwater Overland Flow Flood Study and Mapping (Cardno, 2013). This ALS data was also adopted in the current study, with permission from Pittwater Council.

Generally, the accuracy of ALS data is +/- 0.15m to one standard deviation on hard surfaces.

2.2 Site visit

A site inspection of the study area was conducted on 3 July 2014. The site visit provided the opportunity to fine tune the modelling approach and to visually identify key features in the study area.

2.3 Council's data

The following Geographic Information System (GIS) data were provided by Pittwater Council for this study:

- The Pittwater LGA catchment plans with 2 metre and 10 metre contours,
- Existing pit and pipe layers,
- Cadastre,
- Category 1 and 2 flood extents as determined in previous flood studies,
- Digital ortho-rectified aerial images of the Pittwater LGA (2011 images).

2.4 Concept design

The concept design plans and the proposed terrain in 3D CAD drawings for the study area were provided by Roads and Maritime on 4 August 2014 and 29 September 2014 for the western and eastern portions respectively.

The adopted design iteration for the eastern portion of the Mona Vale Upgrade was received from Roads and Maritime with the naming convention "220914".

3 Study area

3.1 Regional catchments

3.1.1 East section - Manor Road to Foley Street

The east section of the Mona Vale Road upgrade crosses three main regional catchments:

> The south-western portion of the section bisects part of the upper catchment for Mullet Creek, a tributary of the Warriewood wetlands to the south-east, which in turn discharges into Narrabeen Lagoon.

> The central portion of the section bisects the upper catchment for the Narrabeen Creek catchment, another tributary of Warriewood wetland which flows through the middle of the suburb of Warriewood.

> The eastern portion of the section, between Emma Street and Foley Street approximately aligns with the ridgeline separating the Mona Vale catchment to the north and Narrabeen Creek catchments to the south.

The Narrabeen Creek and Mullet Creek catchments are both tributaries of Narrabeen Lagoon to the south-east, while the Mona Vale catchment discharges into the Pittwater estuary to the north.

Regional catchments and flowpaths sourced from Pittwater Council's GIS database are shown in **Figure 3-1**.

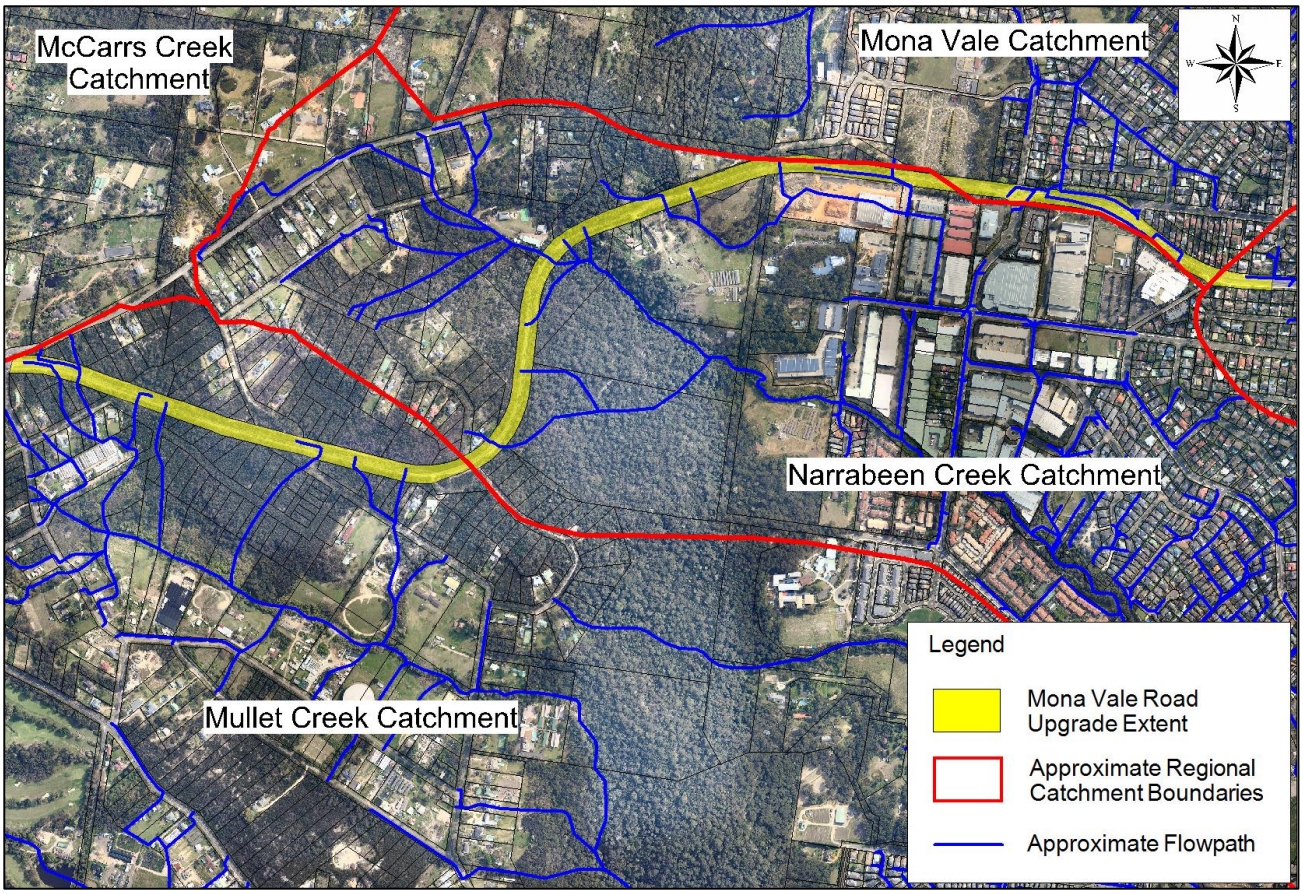


Figure 3-1 Regional catchments and flow paths for east Mona Vale Road.

3.1.2 West section - McCarrs Creek Road to Powder Works Road

The entire west section of the Mona Vale Road upgrade generally aligns with the ridgeline separating two regional catchments:

- McCarrs Creek catchment located to the north, which discharges to Pittwater Estuary.
- Deep Creek catchment to the south which is a tributary of Narrabeen Lagoon.

Regional catchments for Mona Vale Road west sourced from Pittwater Council's GIS database are shown in **Figure 3-2**.

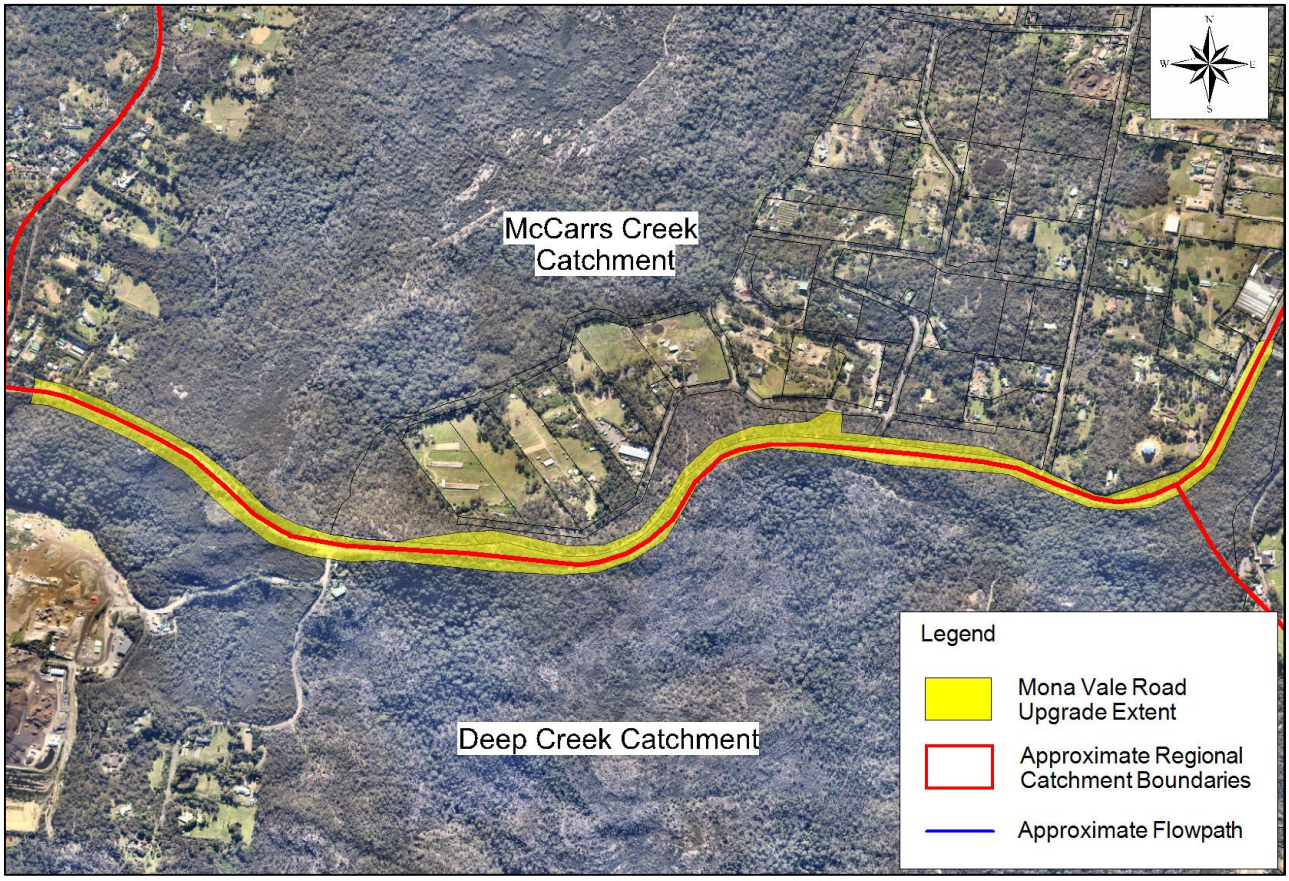


Figure 3-2 Regional catchments and flow paths for Mona Vale Road west.

While acting as a ridgeline for the most part, there are some minor external catchments that discharge onto Mona Vale Road. These areas are typically adjacent to the road reserve including rock outcrops and heavily vegetated bushland.

These catchments have been excluded from this assessment due to the following reasons:

- None of the catchments exceed 1.5 ha in size. Catchments of this size are not expected to generate significant volumes of flow, even in a 100 year ARI rainfall event.
- Due to these small catchments, there are no significant cross drainage structures within the west section of the Mona Vale Upgrade.

Therefore these minor catchments have been accounted for in the road drainage network as discussed in the Concept Drainage and Water Quality Design Report (Cardno, 2014).

3.2 Detailed catchment plan

Hydrological catchments have been delineated based on the topographical information summarised in **Section 2.1**. A summary of the catchment plan, and catchment areas for the major cross drainage networks is shown in **Figure 3-3** below.

As mentioned in **Section 3.1**, the west section – between McCarrs Creek Road to Powder Works Road, and the furthest east portion of the east section, from Emma Street to Foley Street, act as ridgelines and therefore have been excluded from this assessment.

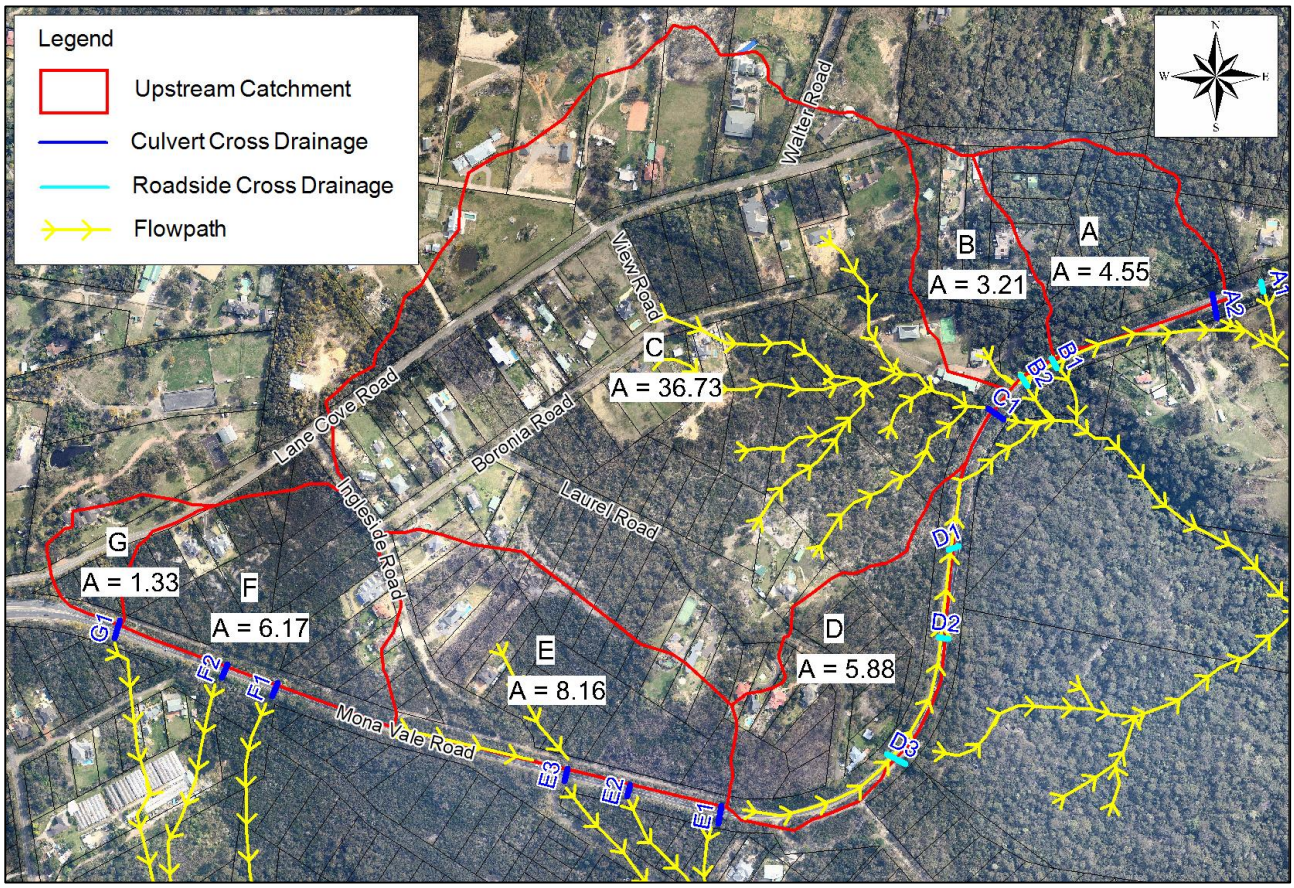


Figure 3-3 Detailed catchment plan.

3.3 Existing cross drainage

The dimensions, locations and inverts of cross drainage for the catchment were derived from the following data sources:

> Detailed ground survey of the existing site provided by Roads and Maritime.

> Pittwater Council's pit and pipe database.

Generally there was found to be good agreement between the data sets regarding the presence of cross drainage, however the exact location of the cross drainage was found to differ in some instances. The existence of cross drainage at most locations was also verified during the site visit.

For the purposes of this assessment cross drainage has been grouped into the following two general types:

> Culvert: Cross drainage with upstream inverts that are not at, or close to road level, but there is a regional "sag" point on the upstream side of the road crossing. This means that there is hydraulic "head" available such that if the cross drainage is designed appropriately there should be no overtopping of the road surface.

> Roadside: Where cross drainage inlets are level, or approximate to road level, which is further defined as flows sourced from the road surface or external catchments that interact with the road surface through

table drains or other roadside drainage. Capacity is likely derived from the inlet capacity of the "on-grade" pit inlets, however this has not been considered in the hydraulic model.

There is no significant cross drainage for the west section of the Mona Vale upgrade - between McCarrs Creek Road to Powder Works Road. In addition there is no cross drainage for the low lying section of the east section from Emma Street to Foley Street as Mona Vale Road acts as a local ridgeline.

The existing cross drainage network for the Mona Vale Road upgrade study area is shown in **Figure 3-3** above. The dimensions and inverts of these structures are summarised in **Table 3-1**.

Table 3-1 Existing cross drainage summary

Drainage ID	Chainage	Drainage Size (mm)	US Invert (m AHD)	DS Invert (m AHD)	Road Level (m AHD)	Drainage Length (m)	Type
A1	1870	450	71	69.65	71.45	12	Roadside
A2	1810	600	73.28	68.35	77.2	28	Culvert
B1	1620	450	94.25	93.1	95.35	14	Roadside
B2	1570	450	98.5	97.1	98.5	15	Roadside
C1	1520	2.75m W x 1.45m H	97.7	95.8	100.7	21	Culvert
D1	1360	450	115.7	114.87	116	13	Roadside
D2	1260	450	124.1	122.75	124.15	12	Roadside
D3	1100	525	136.25	132.93	136	25	Roadside
E1	890	750	139.05	136.74	142.1	21	Culvert
E2	780	750	143.04	142.15	144.65	14	Culvert
E3	700	750	146.8	146.6	148.3	15	Culvert
F1	350	525	152.13	149.9	153.5	17	Culvert
F2	290	525	150.35	149.35	152.95	17	Culvert
G1	150	450	156.1	155.2	157.9	22	Culvert

As can be seen in the table above, the pipe dimensions of "roadside" cross drainage does not exceed 450mm in diameter, with most inlet capacities assumed to be far less than the 100 year ARI design event based on observations made during the site visit.

These roadside drainage structures have nevertheless been modelled in the hydraulic model as 1D pipe elements. In lieu of available data on inlet capacity, unlimited inlet capacity has been assumed which is considered a conservative approach to the hydraulic modelling of these structures.

4 Hydrology and hydraulic modelling

4.1 Hydrology model

An XP-RAFTS hydrological model was established by Cardno for the study area which includes several regional catchments (as discussed in **Section 3.1**) to determine the catchment runoff. The hydrological model allows for the definition of runoff behaviour from the catchment, and is a key input to the hydraulic model. Runoff has been estimated for 1% AEP storm event.

4.1.1 Sub-catchment delineation

The catchment was divided into sub-catchments based on the topographic features, the likely flow paths, as well as the input requirements of the hydraulic model. The sub-catchment layout and impervious and pervious percentage for each sub-catchment are presented in **Appendix A.**

4.1.2 Hydrological model parameters

A number of parameters are required in the development of the RAFTS model. The important parameters include initial and continuing rainfall loss rates, and catchment roughness.

A split sub-catchment approach was applied to develop the RAFTS model. The initial and continuing rainfall loss rates for impervious/pervious areas are presented in **Table 4.1.**

Table 4-1: Rainfall loss rate

Rainfall loss rate	Impervious area	Pervious area
Initial loss (mm)	1.5	10
Continuing loss (mm/hr)	0	2.5

The adopted values of catchment roughness were 0.015 for impervious area, and 0.035 for pervious area.

4.1.3 Design rainfall

Design rainfall depths and temporal patterns for the 100 year ARI events were developed using standard techniques provided in Australian Rainfall and Runoff (AR&R) (Engineers Australia, 1999).

The design Intensity-Frequency-Duration (IFD) parameters applied are presented in **Table 4-2**.

Table 4-2. Design IFD parameters

Parameter	Value
2-Years ARI 1-hour Intensity	40.33
2-Years ARI 12-hours Intensity	9.19
2-Years ARI 72-hours Intensity	2.73
50-Years ARI 1-hour Intensity	83.99
50-Years ARI 12-hours Intensity	18.05
50-Years ARI 72-hours Intensity	5.82
Skew	0
F2	4.3
F50	15.88
Temporal Pattern Zone	1

4.2 Hydraulic model

A hydraulic model of the study area was developed in SOBEK, using a linked one- and two-dimensional modelling system to estimate flood behaviour. The one-dimensional component was utilised to define culverts in the study area, while the 2D component was utilised to define the overland flows. Catchment flows from the XP-RAFTS model were provided as inputs to the SOBEK model.

SOBEK elevation and roughness grids at 3m spacing were developed. The terrain data was defined utilising LiDAR survey data (supplied by council) which has a nominal vertical accuracy of +/- 0.15m on hard surfaces. The topographic grid was created using a 3m x 3m grid cell resolution which was sufficient to delineate the channel cross sections within the 2D domain. The extent of the model is shown in **Figure 4-1.**

In order to represent the design condition, the proposed road terrain provided by Roads and Maritime (refer **Section 2.4**) was incorporated into the model.

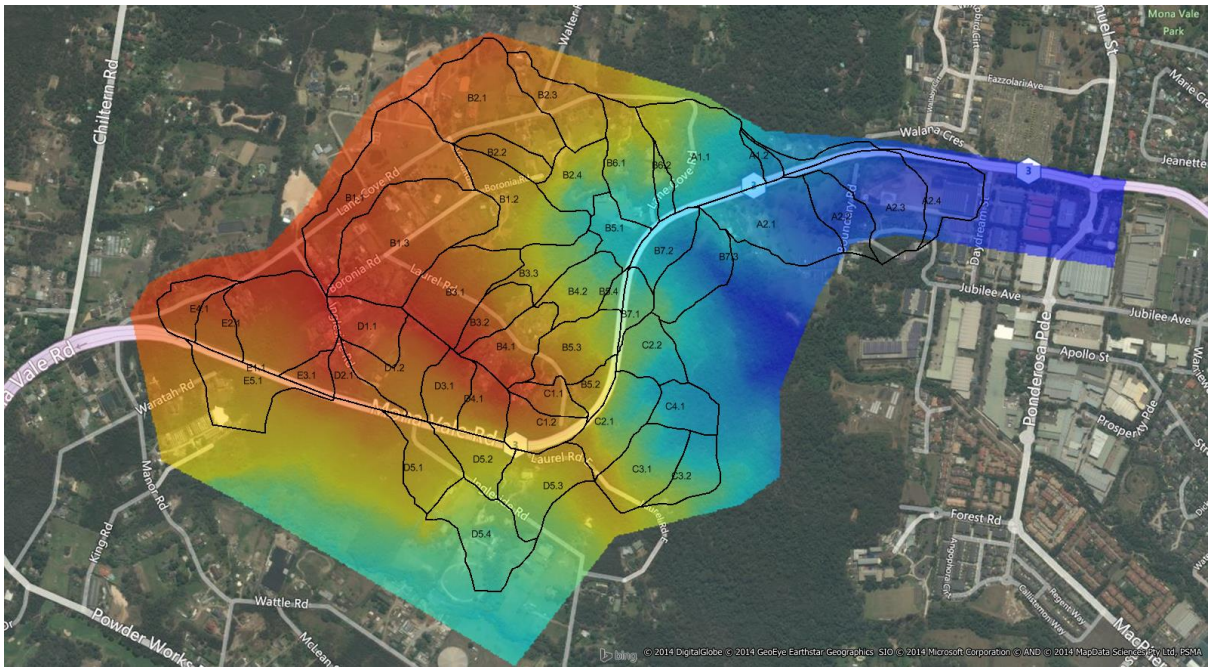


Figure 4-1 2D Model Extent.

The hydraulic roughness for the 1D cross sections and 2D model grid was determined using aerial photography. The 1D roughness value adopted for the channel/culverts was 0.015. The 2D roughness values are shown in **Figure 4-2.**

Table 4.3: Manning's roughness values

Description	Roughness (Manning's 'n')
Low Residential	0.05
Mona Vale Road	0.02
Open Space	0.08
Commercial	0.10
Road Reserve	0.02

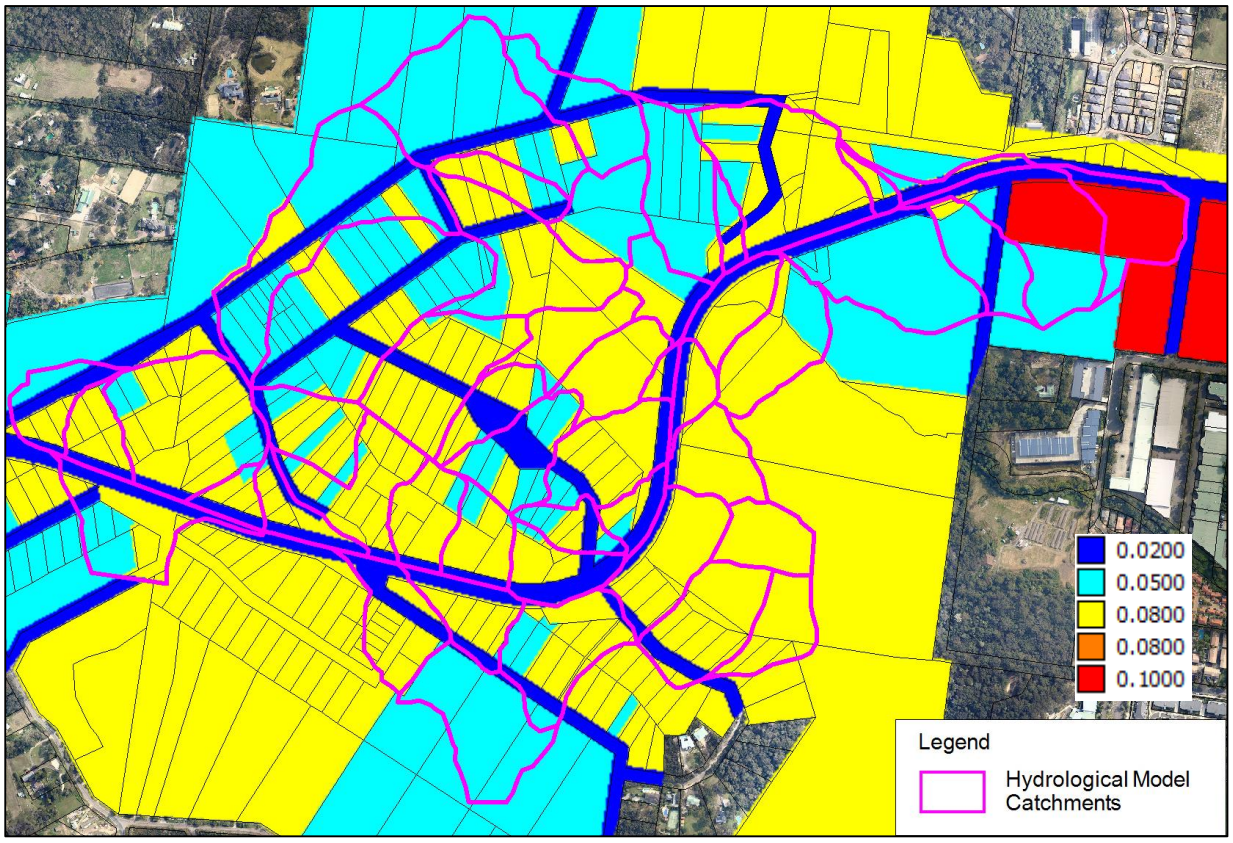


Figure 4-2 2D Model roughness.

5 Cross drainage assessment

5.1 Existing capacity

The existing capacity of the cross drainage networks has been assessed in the following sections for each of the seven catchments shown in **Figure 5-1**.

Each section provides a summary of the flow behaviour for the area, an assessment of the existing cross drainage capacity based on hydraulic model results, and a figure showing the following:

- Existing surface contours (0.5m intervals).
- Peak flood depth results from the 100 year ARI existing scenario hydraulic model.
- Cross drainage network.
- Catchment boundaries.
- Brief summary of key hydraulic performance details for the cross drainage.

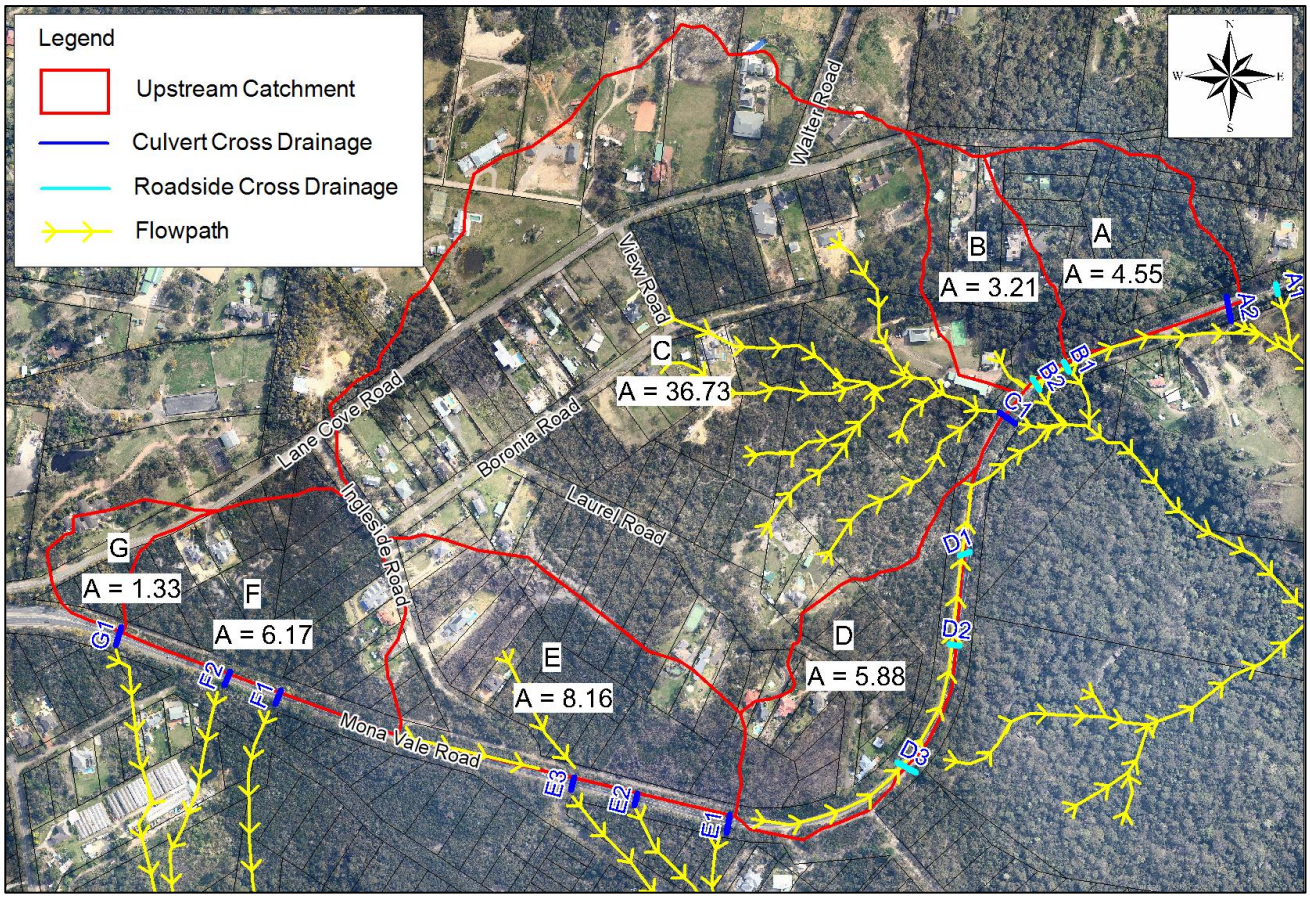


Figure 5-1 Cross Drainage Overview.

5.1.1 Catchment A

Summary of flow behaviour:

> The flow from the upstream catchment converges on a sag point with a low point of 73.3m AHD on the upstream side of Mona Vale Road.

> A 600mm diameter pipe (Drain A2 as shown in **Figure 5-1**) conveys flow under Mona Vale Road before discharging into rural properties downstream.

> At an elevation of 74.5m AHD, flow overtops Mona Vale Road and enters the road reserve, flowing east down the roadway.

Existing cross drainage capacity:

- *100 year ARI peak flow from catchment upstream = 2.6 m³/s.*
- *Drain A1 100 year ARI peak flow = 0.3m³/s*
- *Drain A2 100 year ARI peak flow = 2 m³/s.*
- *100 year ARI peak overtopping flow = 0.6 m³/s.*
- *100 year ARI minimum freeboard to road overtopping = -0.2 metres.*

Therefore the existing pipe network has insufficient capacity to convey the 100 year ARI peak flows.

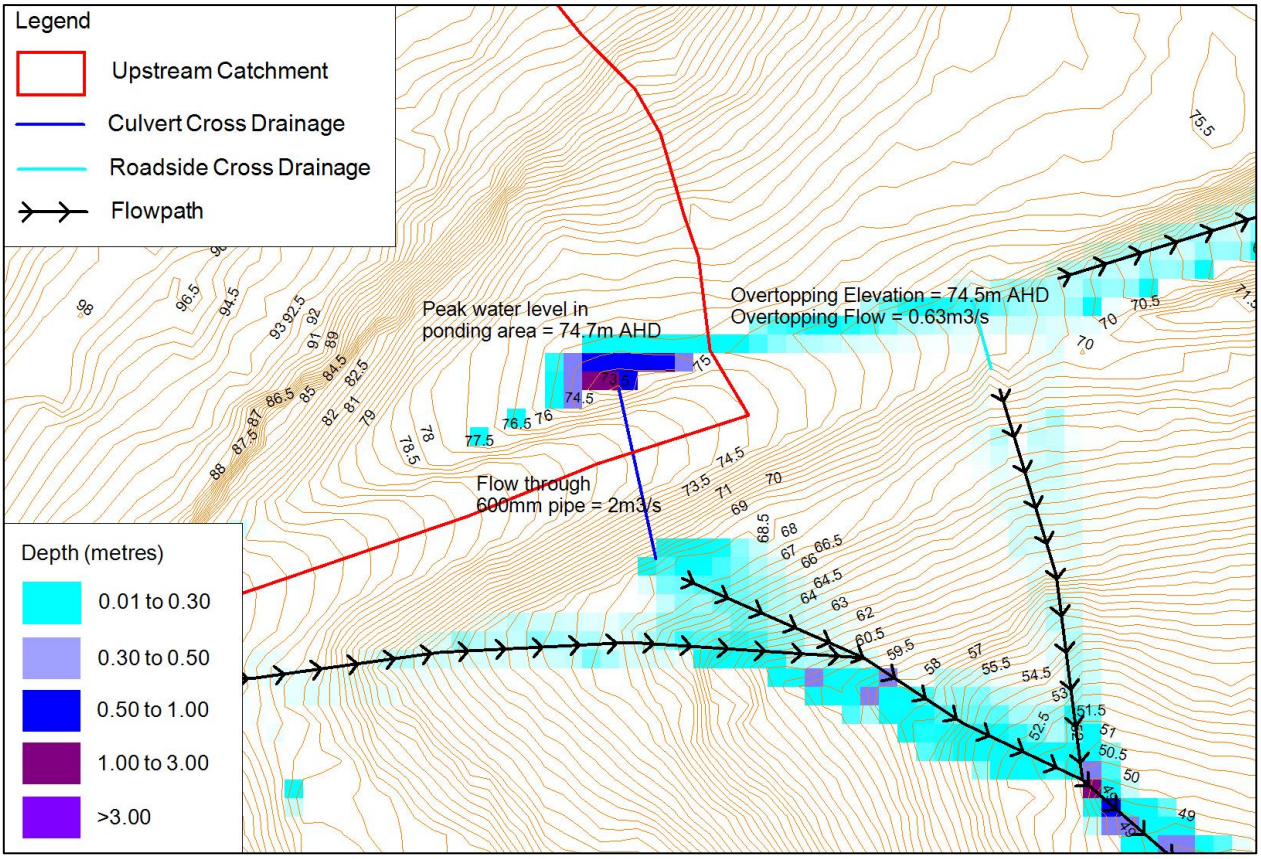


Figure 5-2 Existing cross drainage summary - catchment A.

5.1.2 Catchment B

Note that this catchment does not have any significant cross drainage structures, only two roadside 450mm diameter pipes.

However this analysis has been used to assist the road drainage design summarised in the Concept Drainage and Water Quality Design Report (Cardno, 2014).

Summary of flow behaviour:

> The flow from the upstream catchment enters the Mona Vale Road reserve as sheet flow from the driveway to the north.

> There are two roadside cross drainage pipes, both 450mm in size (Drain B1 and B2 as shown in **Figure 5-1**). These have been included in the hydraulic model as pipe networks with a pit inlet on the upstream side with unlimited capacity.

This is seen as a conservative approach as the inlets observed seemed to have limited capacity.

> A proportion of the flow overtops the road and flows down the embankment before converging with Narrabeen Creek, the remaining flows remain in the Mona Vale Road reserve in a north-east direction.

Existing cross drainage capacity:

- *100 year ARI peak flow from catchment upstream = 2.0 m³/s*
- *Drain B1 100 year ARI peak flow = 0.3 m³/s*
- *Drain B2 100year ARI peak flow = 0.5m³/s*

When the system is modelled with unlimited inlet capacity, the pipes are not able to convey the flows from the upstream catchment as the flows act as sheet flow and do not converge on one location.

At this location flows entering the road reserve are to be treated within the road drainage network.

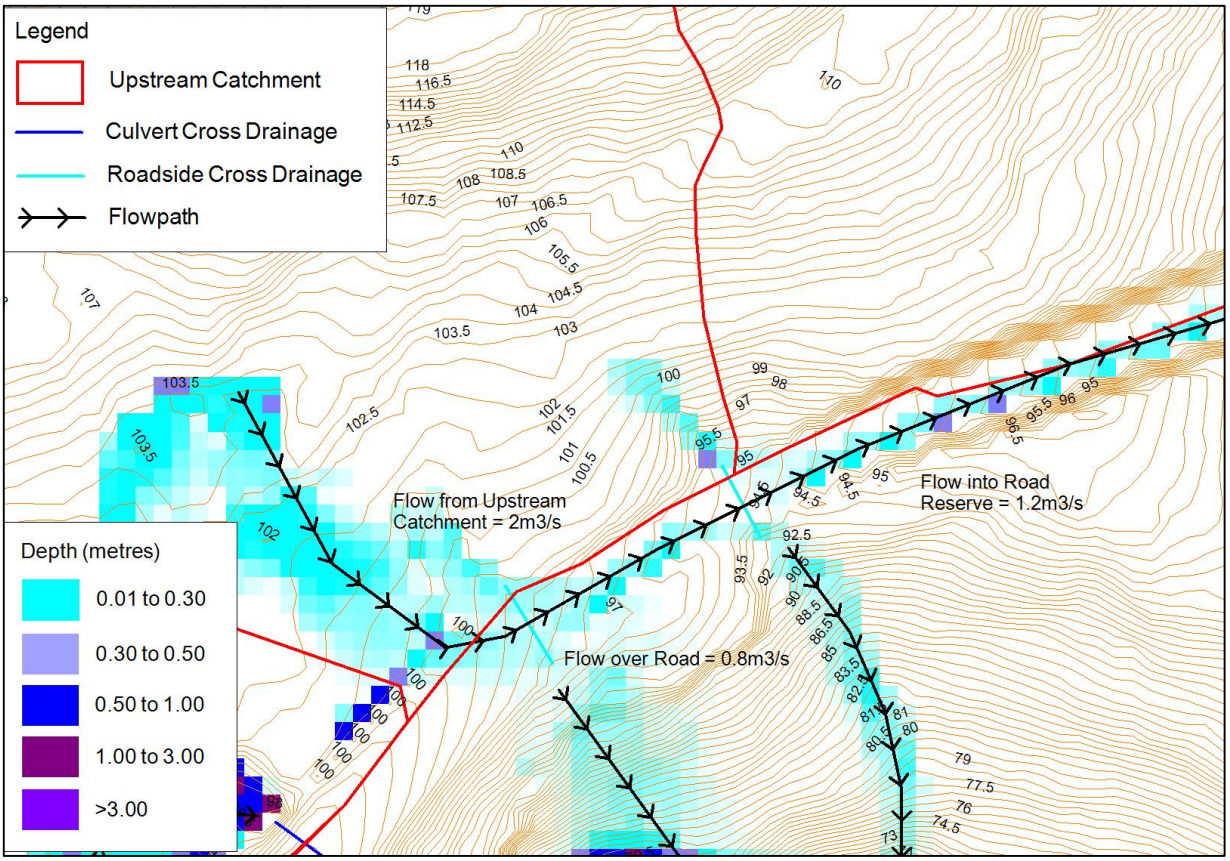


Figure 5-3 Existing cross drainage summary - catchment B.

5.1.3 Catchment C

Summary of flow behaviour:

> The flow from the large upstream catchment converges to Narrabeen Creek which forms upstream of Mona Vale Road crossing.

> Narrabeen Creek crosses Mona Vale Road via a 2.75m wide x 1.5m high sandstone lined culvert (Drain C1 as shown in **Figure 5-1**).

> The minimum road surface in the area is 100.7m AHD, with the creek invert on the upstream side of the road at 97.7m AHD. Therefore the road surface is 3m above the creek invert with earth embankment for the road forming a ponding area on the upstream side of the road crossing.

> 25m downstream of the Mona Vale Road crossing, Narrabeen Creek flows over a 12m high escarpment, resulting in no tailwater conditions downstream of the crossing.

Existing cross drainage capacity:

- *100 year ARI peak flow from catchment upstream = 21.9 m³/s.*
- *100 year ARI peak existing culvert flow = 21.9 m³/s.*
- *100 year ARI peak upstream water level = 99.7m AHD.*
- *100 year ARI minimum freeboard to road overtopping = 1.0 metres.*

The above hydraulic model results suggest that the road embankment leads to ponding upstream of Mona Vale Road. Peak flow depths of approximately 1 metre upstream are less than the 1.5 metre height of the culvert section. This suggests the culvert is not at full capacity, and that it does not act as a flow constriction for the 100 year ARI event.

The existing culvert has sufficient capacity to convey the 100 year ARI peak flows.

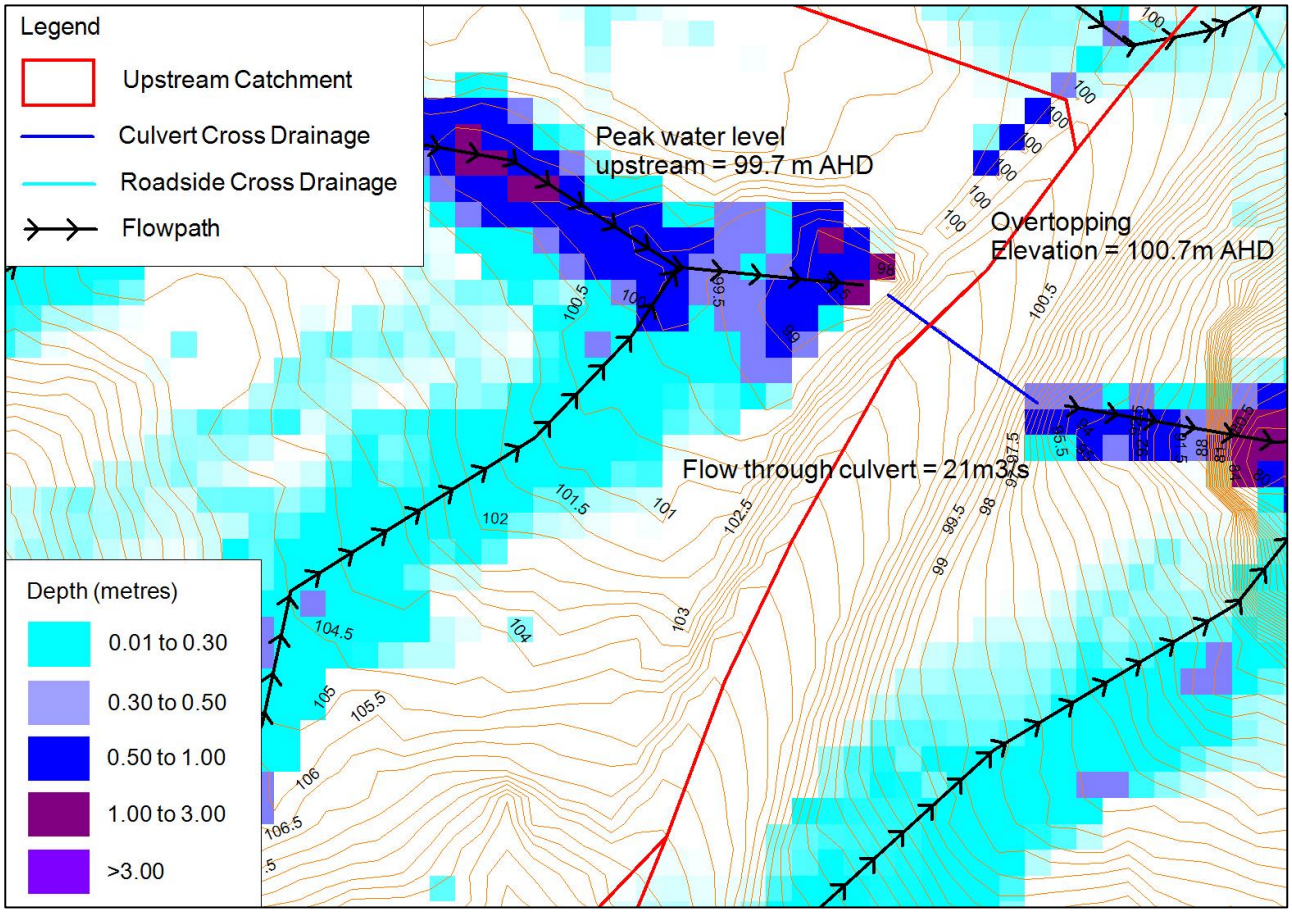


Figure 5-4 Existing cross drainage summary - catchment C.

5.1.4 Catchment D

Note that this catchment has three roadside cross drainage networks conveying flow under Mona Vale Road and discharging to the east. This analysis has been used to assist the road drainage design summarised in the Concept Drainage and Water Quality Design Report (Cardno, 2014).

Summary of flow behaviour:

> The flow from the upstream catchment enters the Mona Vale Road reserve as sheet flow along the roads length spilling down elevated rock outcrops.

> As flow enters the road corridor, the existing road surface contours divert flow to the western kerb into a table drain that conveys flow north.

> There are three roadside cross drainage pipes, the furthest upstream is 525mm in diameter (Drain D3) while the other two are 450mm in diameter (Drain D1 and D2 as shown in **Figure 5-1**), which divert flow to the east under Mona Vale Road before discharging on the eastern embankment. These pipes have been included in this assessment as pipe with unlimited inlet capacity. This is seen as a conservative approach as the inlets observed seemed to have limited capacity

> As the road nears the Narrabeen Creek crossing, the road diverts flow across Mona Vale Road to the east, before spilling down the eastern embankment to converge with Narrabeen Creek downstream of Mona Vale Road.

Existing cross drainage capacity:

- *100 year ARI peak flow from catchment upstream = 3.0 m³/s*
- *Drain D1 100 year ARI peak flow = 0.2 m³/s*
- *Drain D2 100 year ARI peak flow = 0.6 m³/s*
- *Drain D3 100 year ARI peak flow = 0.9 m³/s*

These hydraulic model results suggest the sheet flow within the road reserve is high velocity, low depth flow, with limited capacity to be detained and conveyed through cross drainage.

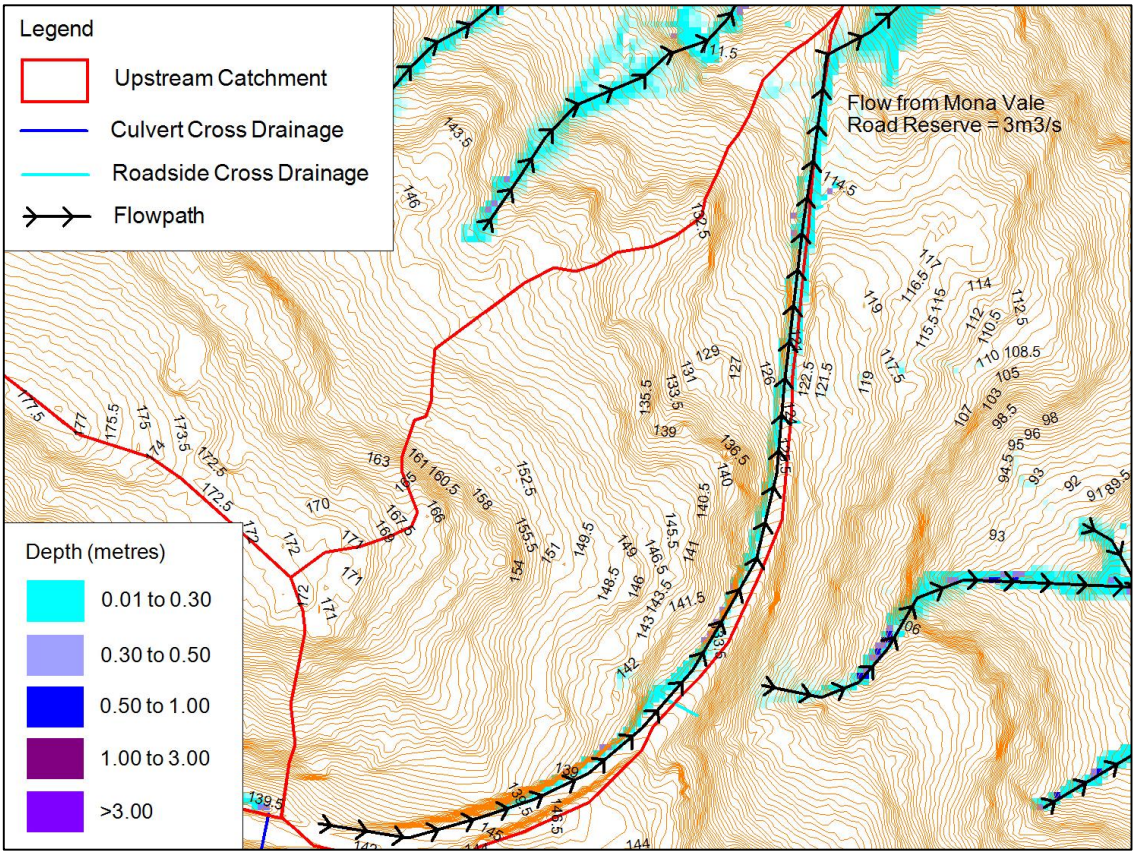


Figure 5-5 Existing cross drainage summary - catchment D.

5.1.5 Catchment E

Summary of flow behaviour:

> The flow from the upstream catchment converges to a shallow overland flowpath adjacent to Mona Vale Road to the north.

> Flow enters three 750mm diameter pipes (Drain E1, E2, and E3 as shown in **Figure 5-1**) that cross Mona Vale Road and discharge on the downstream embankment to the south.

> Downstream of this crossing there is sheet flow through rural properties before flows converge with Mullet Creek downstream.

Existing cross drainage capacity:

- *100 year ARI peak flow from catchment upstream = 4.9 m³/s.*
- *100 year ARI peak existing culvert flow = 1.0 + 1.5 + 1.8 = 4.3 m³/s.*
- *100 year ARI peak upstream water level = 146.0m AHD (this is variable along the roads length however this is at the point closest to overtopping).*
- *100 year ARI minimum freeboard to road overtopping = 0 metres.*

The shallow overland flowpath that runs adjacent to Mona Vale Road is at full capacity in the 100 year ARI existing scenario, with flow nearly overtopping the road.

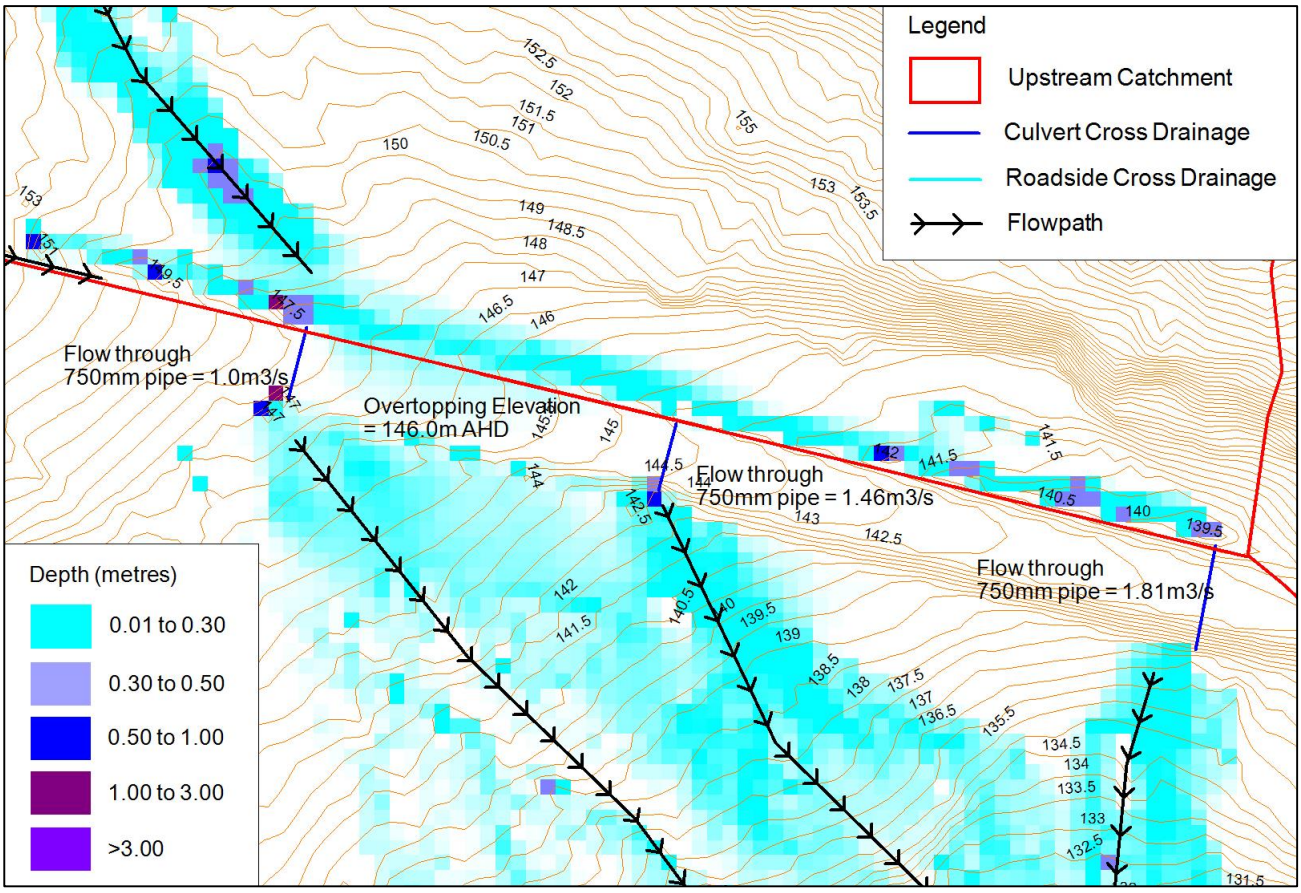


Figure 5-6 Existing cross drainage summary - catchment E.

5.1.6 Catchment F and catchment G

Summary of flow behaviour:

> The flow from catchment G to the north-west converges in an overland flowpath that is parallel to Mona Vale Road on the upstream side.

> Flow from catchment G enters a 450mm diameter pipe (Drain G1 as shown in **Figure 5-1**) that crosses Mona Vale Road and discharge on the downstream embankment to the south.

> The overland flowpath continues east entering a local sag point on the upstream side of Mona Vale Road where flows from Catchment F converge.

> The flow is conveyed under Mona Vale Road through two 525mm diameter pipes (Drain F1 and F2 as shown in **Figure 5-1**) that discharge on the downstream embankment of the road.

> There is a low point in the road surface adjacent to the sag point with excess flows overtopping Mona Vale Road.

Existing cross drainage capacity:

Catchment F:

- *100 year ARI peak flow from catchment upstream = 3.6 m^3/s.*
- *100 year ARI peak existing culvert flow = 1.2 + 0.8 = 2.0 m^3/s.*
- *100 year ARI peak upstream water level = 152.9m AHD.*
- *100 year ARI peak overtopping flow = 1.6 m^3/s.*
- *100 year ARI minimum freeboard to road overtopping = -0.1 metres.*

Based on these hydraulic model results the capacity of the cross drainage system for Catchment F is insufficient to convey the 100 year ARI peak flows.

Catchment G:

- *100 year ARI peak flow from catchment upstream = 0.8 m^3/s.*
- *100 year ARI peak existing culvert flow = 0.6 m^3/s.*
- *100 year ARI peak existing flow in overland flowpath = 0.2 m^3/s.*

The majority of flows are conveyed under Mona Vale Road through the existing 450mm diameter pipe, with the remaining flows carried within the overland flowpath that runs adjacent to the road. As there is no overtopping of the road in the 100 year ARI event, the existing cross drainage network is considered to have sufficient capacity.

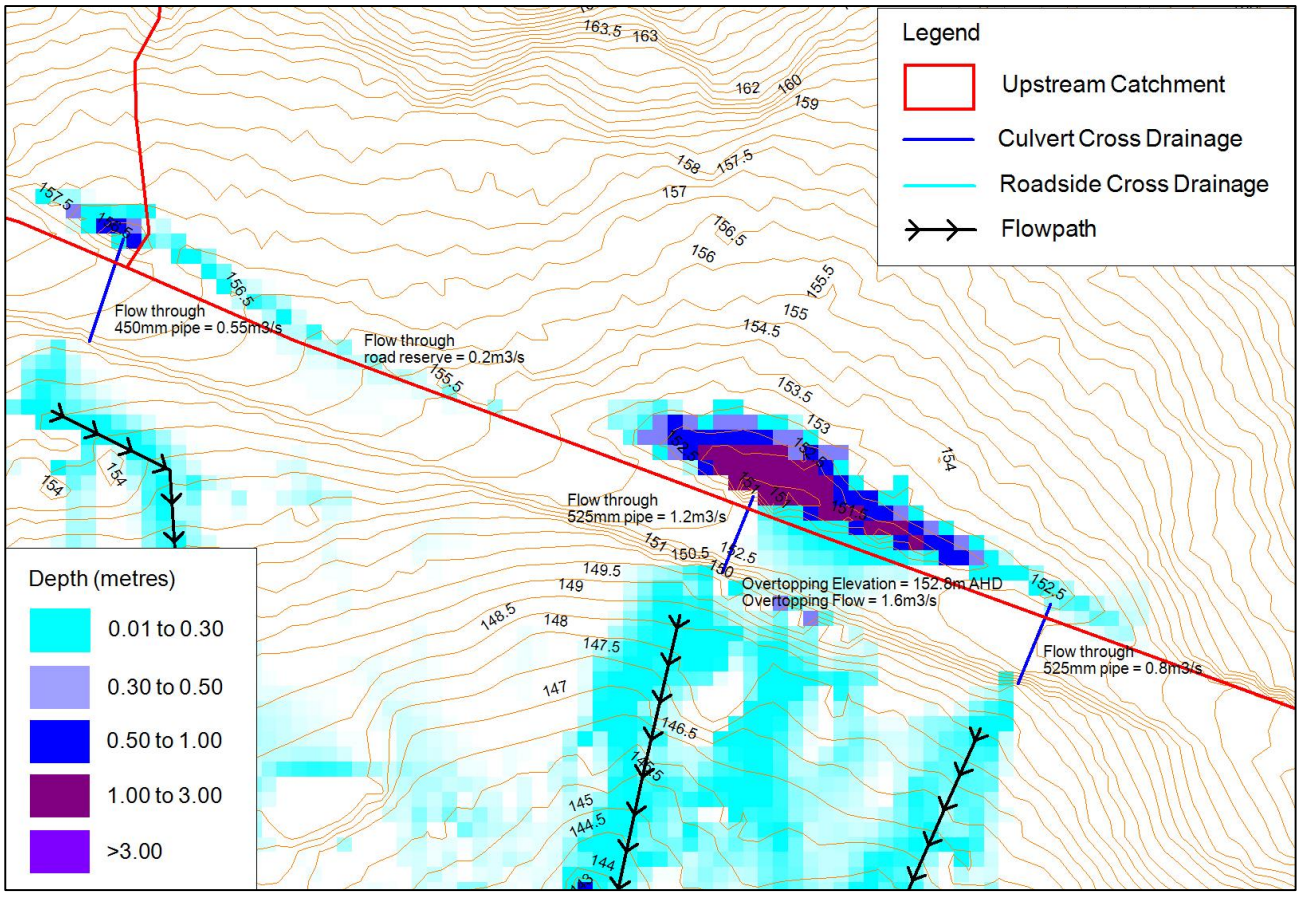


Figure 5-7 Existing cross drainage summary - catchment F and catchment G.

5.2 Concept design assessment

A preliminary hydraulic assessment of the concept design for the Mona Vale Road upgrade has been conducted using surface contours received from Roads and Maritime (see **Section 2.4** for further details). These surface contours for the proposed road upgrade were integrated into the hydraulic model, and the culverts adjusted to represent the additional length in the road.

As identified in **Section 5.1**, a number of the culverts in their current form provide sufficient capacity to convey the flows without overtopping of the road in the 100 year ARI event. A further check has been provided for the additional length of the culverts for the upgraded road, and it has been identified that the culverts perform in a similar manner to the existing scenario.

5.2.1 Catchment A:

Two design options have been identified to address the existing issues with capacity for the cross drainage for catchment A flows:

- Design option 1: Increase Drain A1 pipe size to 750mm diameter pipe (existing 600mm diameter pipe).
- Design option 2: Increase flood storage volume upstream of Mona Vale Road through construction of a bund near Mona Vale Road verge.
- Design option 3: Increase flood storage volume upstream of Mona Vale Road through excavation of ponding area upstream

A summary of the two design options is provided in **Figure 5-8**.

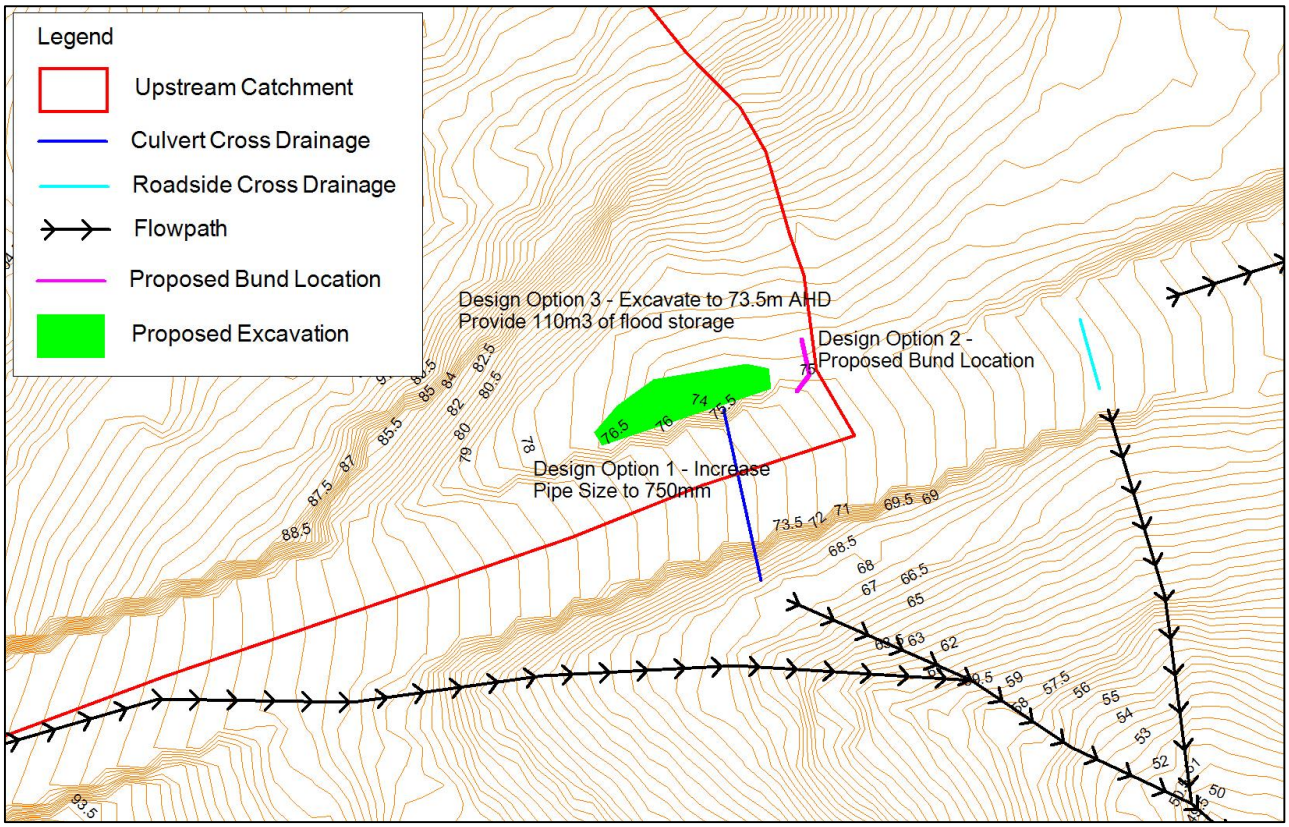


Figure 5-8 Catchment A design options summary.

The hydraulic performance of the two design options has been summarised in **Table 5-1**.

Table 5-1 Hydraulic impacts of design options for catchment A

	Existing Scenario	Design Option 1	Design Option 2	Design Option 3
Peak culvert flow (m^3/s)	2.0	2.8	2.0	2.0
Peak water level upstream of road (m AHD)	74.7	73.9	75.25	74.7
Peak flow overtopping road (m^3/s)	0.6	0	0	0
Minimum Freeboard (m)	-0.2	1.4	0	0.6

All design options result in no overtopping of Mona Vale Road, however option 1 (the pipe upgrade) results in a 0.8m^3/s increase in peak discharges from the pipe. This represents a 40% increase in flows. With a large lot residential area immediately downstream of the crossing including a pig farm at the pipe discharge as observed during the site visit, these increases are considered to be unacceptable.

Alternatively, option 2 (construction of bund) results in no increases in pipe discharge, however does result in a 0.55 metre increase in water levels upstream of Mona Vale Road.

This will increase the flood level and as a result impact the minimum floor level requirements for neighbouring developments and therefore is not an ideal outcome.

Option 3 does not result in increases in peak flow from the cross drainage or increases in water level upstream, however does require excavation of the land upstream as follows:

- Excavation of land to an invert of approximately 73.5m AHD upstream of the expanded Mona Vale Road reserve,
- Provision of 110m^3 of flood storage volume upstream of Mona Vale Road to not result in overtopping of the road surface.

While this option requires works to be conducted in currently privately owned property it has the best hydraulic performance of all options and therefore is recommended.

5.2.2 Catchment C

A second culvert is proposed to be constructed next the existing Drain C1 with identical inverts and dimensions (2.75m W x 1.5m H Box Culvert).

This has potential to increase the peak discharges from the Mona Vale Road crossing which may have impacts for Narrabeen Creek downstream.

In addition in the existing scenario, flows from catchment D are conveyed within the road corridor before being diverted north-east and discharge in Narrabeen Creek downstream of the Moan Vale Road crossing (see **Section 5.1.4** for further details).

As outlined in the Concept Drainage and Water Quality Design Report (Cardno, 2014), the concept road drainage design proposes to divert flows in the proposed scenario to the north-west, upstream of the Mona Vale Road crossing.

This diversion of flow also has potential to increase the flow through Drain C1.

The hydraulic impact of the second culvert and diversion of Catchment D flows have been assessed in the hydraulic model with the hydraulic impacts summarised in **Table 5-2**.

Table 5-2 Hydraulic impacts of second culvert for Drain C1 and diversion of catchment D

	Existing Scenario	Proposed Scenario	Difference
Peak flow from catchment upstream of Drain C1 (m^3/s)	21.9	23.3	+1.4
Peak culvert flow for Drain C1 (m^3/s)	21.9	22.0	+0.1
Peak flow downstream of waterfall (m^3/s)	25.2	25.3	+0.1
Peak upstream water level (m AHD)	99.2	99.3	+0.1
Minimum freeboard to road overtopping (m)	1.5	1.4	-0.1

Note that the peak discharge from the upstream catchment has been increased by 1.4m^3/s due to the diversion of Catchment D. This, coupled with the inclusion of a second culvert only results in 0.1m^3/s increase in peak discharge from Drain C1.

This result suggests that the existing culvert does not act as a constriction of flow as doubling the conveyance area of the culvert system does not increase peak discharges.

The flow entering Narrabeen Creek from the road overtopping of Catchment D has been reduced, therefore the cumulative impact of the diversion is to have a negligible impact downstream of the Mona Vale Road crossing.

Further downstream of the crossing, below the waterfall, the impact of the diversion is negligible with a 0.1m^3/s increase in peak flows from the existing scenario.

The water level impacts show a minor reduction in peak water levels (less than 0.1 metres) resulting from the diversion for the areas immediately downstream of Mona Vale Road, with minor water level increases upstream (less than 0.1 metres), particularly along the new flowpath formed by the diversion.

Therefore the diversion of catchment D flows and construction of a second culvert to act as a fauna crossing is considered appropriate as:

- It does not result in overtopping of Mona Vale Road, with a minimum freeboard of 1.4 metres.
- Results in negligible impacts on flow and water levels downstream of Mona Vale Road.

5.2.3 Catchment E

While the existing three 750mm pipes for Catchment E have been found to have sufficient capacity to convey flow from the catchment upstream (refer to **Section 5.1.5**), there is no freeboard to road overtopping in the 100 year ARI event at this location.

Therefore a design option was modelled with a 0.5m deep channel running adjacent to Mona Vale Road as shown in **Figure 5-9** below.

The proposed design surfaces provided have been lowered by 0.5m to account for this channel in the hydraulic model in the area shown below.

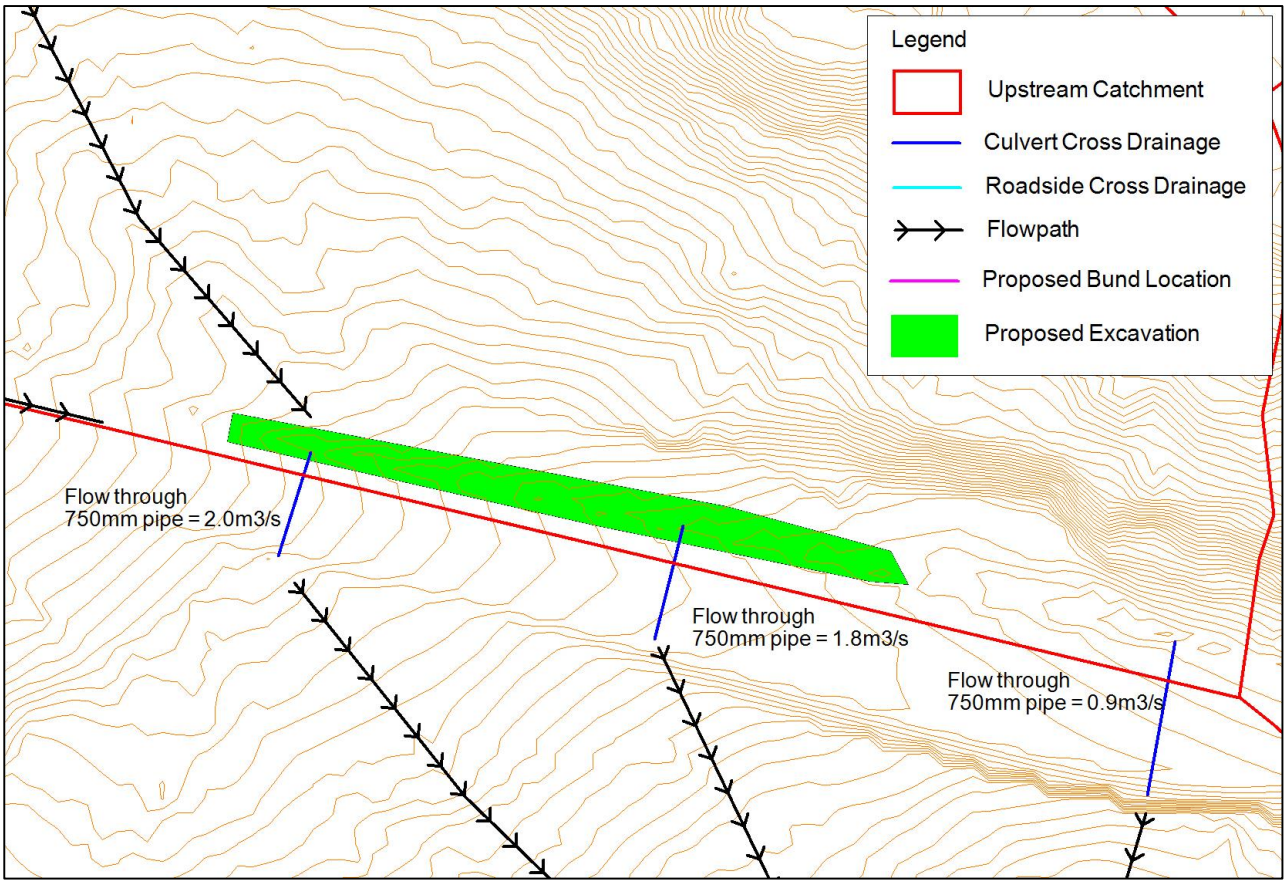


Figure 5-9 Proposed location of small capacity channel adjacent to Mona Vale Road for Catchment E

Table 5-3 Hydraulic impacts of proposed cross drainage design for Catchment E

	Existing Scenario	Proposed Scenario
Peak culvert flow (m^3/s)	4.3 (1.8 + 1.5 +1.2)	4.7 (0.9 + 1.8 + 2.0)
Peak water level upstream of road (m AHD)	145.6	145.3
Road Crest Level (m AHD)	145.6	145.6
Minimum Road Level (m AHD)	145.5	145.3
Peak Road Overtopping Depth (m)	0.1	0

The inclusion of this 0.5m deep channel is effective in ensuring flows do not enter the road reserve, and provides a freeboard of 0.3 metres to overtopping of the road crest at the Mona Vale Road centreline.

The minor increase in peak flows ($0.4m^3/s$) from the cross drainage results in peak water level increases of less than 0.05 metres for an area of existing sheet flow downstream of Mona Vale Road.

These water level increases are considered negligible therefore the minor increase in discharge is considered acceptable.

Therefore it is recommended that a 0.5m deep roadside channel be installed adjacent to Mona Vale Road for Catchment E to better contain 100 year ARI flows and exclude them from the road reserve.

5.2.4 Catchment F

The conveyance capacity of the existing pipe network at Catchment F crossing was found to be as such:

> The 525mm pipe for Drain F1 is oversized as it conveys only a small portion of roadside drainage from the western portion of Catchment F, therefore it is proposed to be downgraded to a 450mm pipe,

> The 525mm pipe for Drain F2 conveys the majority of flows as it is located at the existing sag point on the upstream side of Mona Vale Road. As shown in **Section 5.1.6** there is overtopping of the road in the 100 year ARI event meaning the pipe is undersized.

Therefore the proposed pipe at this location is proposed to 900mm in diameter.

In addition, due to the extension of the Mona Vale Road reserve to the north in the proposed design, there is insufficient ponding area on the upstream side of Mona Vale Road.

Therefore a portion of land (shown in **Figure 5-10** below) adjacent to Mona Vale Road is proposed to be lowered by 1 metre to provide additional flood storage.

The results of the hydraulic modelling for Catchment F upgrades are summarised in **Table 5-4** below.

Table 5-4 Hydraulic impacts of proposed cross drainage design for Catchment E

	Existing Scenario	Proposed Scenario
Peak culvert flow (m^3/s)	2.0 (0.8 + 1.2)	3.7 (0.4 + 3.3)
Peak Overtopping Flow (m^3/s)	1.6	0
Peak water level upstream of road (m AHD)	152.9	152.1
Road Crest Level (m AHD)	152.8	153.0
Minimum Road Level (m AHD)	152.7	152.7
Peak Road Overtopping Depth (m)	0.2	0

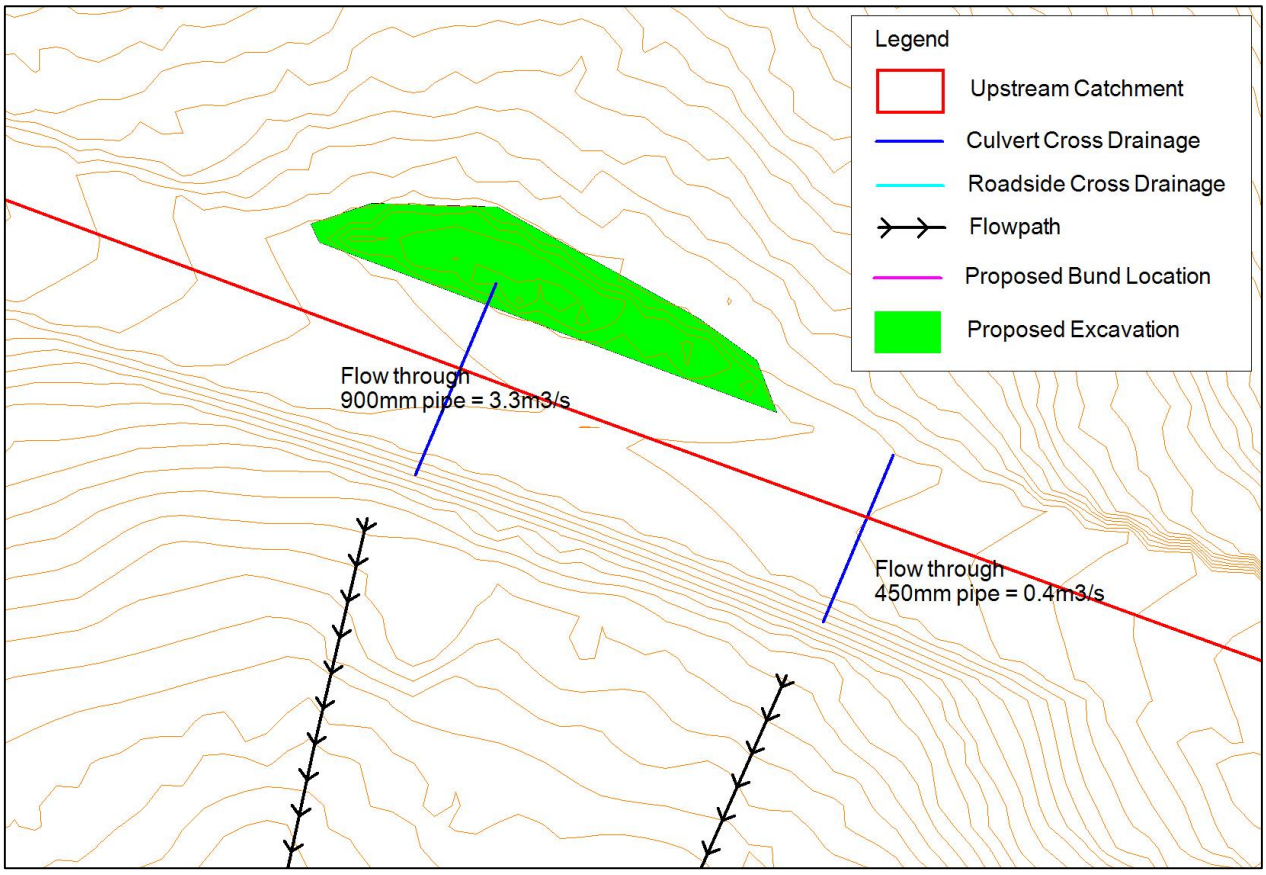


Figure 5-10 Proposed excavation and cross drainage upgrades for catchment F.

The excavation upstream and pipe upgrade for Drain F2 results in no overtopping of Mona Vale Road in the proposed scenario, and provides freeboard of 0.6 metres to road overtopping.

The peak flows for the proposed scenario are 0.1 m^3/s higher than in the existing scenario which results in water level increases of less than 0.05 metres in an existing area of sheet flow downstream.

This is considered a negligible impact therefore the design is considered acceptable.

6 Summary

A detailed analysis of the 100 year ARI was undertaken for the key cross drainage structures in the eastern part of the study area, as summarised in **Section 5.1**.

Note that the existing dimensions of the culverts are generally sufficient to cope with the cross drainage flows, with the exception of the following:

- Catchment A has road overtopping, to address this it is recommended that a flood storage area be excavated upstream of Mona Vale Road with no increase in cross drainage size;
- Catchment E has inundation within road reserve therefore a 0.5m deep channel is recommended to be constructed on the upstream side of Mona Vale Road with no increase in cross drainage size;
- Catchment F has road overtopping therefore a flood storage area is proposed to be constructed on the upstream side of Mona Vale Road with an increase in Drain F2 from 525mm to 900mm.

In all other locations existing cross drainage is sufficient to convey flows.

For catchment C, a second culvert is proposed for construction to act as a fauna crossing, with the impacts of this found to be negligible on peak flows downstream of Mona Vale Road.

The existing and proposed cross drainage structures and 100 year ARI peak flows are shown in **Table 6-1**.

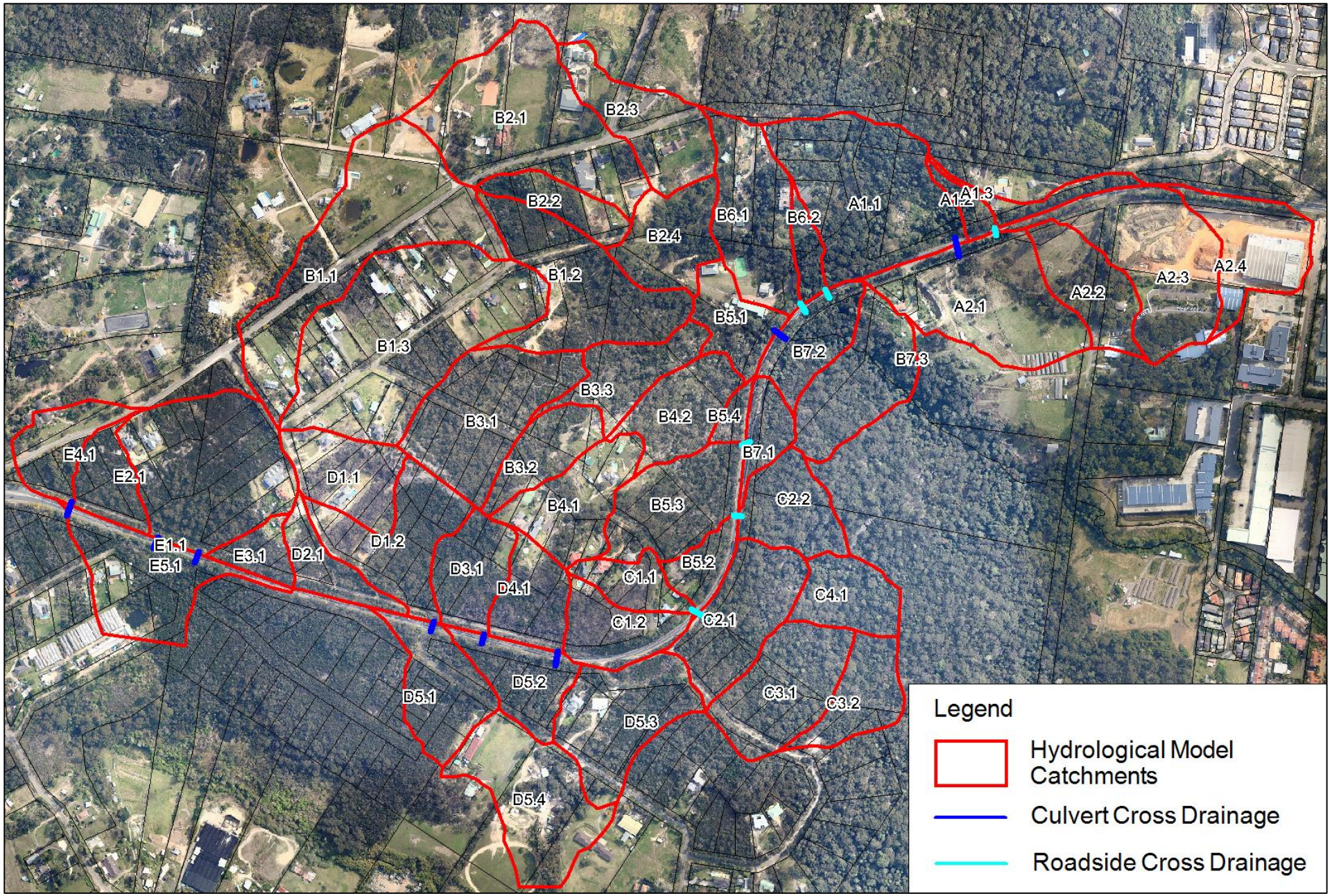
Table 6-1 Summary of Cross Drainage Structure Dimensions

Culvert	Chainage	Existing Dimensions	Existing Peak Flow (m^3/s)	Proposed Dimensions	Proposed Peak Flow (m^3/s)	Comments
A1	1870	450mm pipe	0.3	450mm pipe	0.1	Cross drainage is ineffective in this area, roadside drainage is to be utilized (**Section 5.1.1)**
A2	1810	600mm pipe	2	600mm pipe	2	Excavation of additional flood storage area upstream of Mona Vale Road is recommended (**Section 5.2.1**)
B1	1620	450mm pipe	0.3	-	-	Cross drainage is ineffective in this area, roadside drainage is to be utilized (**Section 5.1.2**)
B2	1570	450mm pipe	0.5	450mm pipe	0.1	
C1	1520	2.75m W x 1.5m H Box Culvert	21.9	Twin 2.75m W x 1.5m H Box Culvert	22.0	Second culvert for fauna crossing does not result in increase in flows downstream
D1	1360	450mm pipe	0.2	450mm pipe	0.4	Diversion of flows from road reserve to the west of Mona Vale Road has no impact on peak flows downstream
D2	1260	450mm pipe	0.6	450mm pipe	0.5	
D3	1100	525mm pipe	0.9	525mm pipe	0.9	
E1	890	750mm pipe	1.8	750mm pipe	0.9	Excavation of 0.5m channel upstream of Mona Vale Road proposed to provide freeboard to road overtopping
E2	780	750mm pipe	1.5	750mm pipe	1.8	
E3	700	750mm pipe	1	750mm pipe	2	
F1	350	525mm pipe	0.8	450mm pipe	0.4	Excavation of flood storage area upstream of Mona Vale Road and upgrade of Drain F2 from 525mm to 900mm
F2	290	525mm pipe	1.2	900mm pipe	3.3	
G1	150	450mm pipe	0.6	450mm pipe	0.6	No alteration of cross drainage required

APPENDIX A

HYDROLOGICAL CATCHMENT SUMMARY

Cardno
Shaping the Future


B2.1
B2.3
B2.2
B2.4
B6.1
B6.2
A1.1
A1.2
A1.3
B1.1
B1.2
A2.4
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A2.2
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B5.1
B1.3
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B3.1
B4.2
B5.4
B7.1
E4.1
E2.1
D1.1
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B4.1
B5.3
C2.2
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D4.1
C4.1
C1.2
C2.1
D5.2
D5.1
C3.1
C3.2
D5.3
D5.4
Legend
Hydrological Model Catchments
Culvert Cross Drainage
Roadside Cross Drainage

ID	Area (all in ha)						Impervious % and Areas			Slope			
	Open Space	Road Reserve	Low Res	Comm	Mona Vale Rd	Total	Imp %	Perv Area (ha)	Imperv Area (ha)	US_Elev (m AHD)	DS_Elev (m AHD)	Distance (m)	Slope (%)
A1.1	3.50	0.00	0.61	0.00	0.44	4.55	5.6%	4.30	0.25	138.1	73.5	319.3	20%
A1.2	0.22	0.00	0.07	0.00	0.09	0.38	11.0%	0.34	0.04	104.6	73.2	134.1	23%
A1.3	0.11	0.00	0.16	0.00	0.34	0.61	21.8%	0.48	0.13	106.0	49.9	356.7	16%
A2.1	0.00	0.02	3.31	0.00	0.44	3.78	21.3%	2.98	0.81	96.5	38.5	320.9	18%
A2.2	0.10	0.25	1.33	0.00	0.03	1.71	22.0%	1.33	0.38	71.0	35.6	200.7	18%
A2.3	0.02	0.16	1.44	1.47	0.55	3.65	42.5%	2.10	1.55	57.9	31.2	275.6	10%
A2.4	0.01	0.00	0.22	1.49	0.37	2.08	57.4%	0.88	1.19	47.0	27.7	247.8	8%
B1.1	0.82	1.01	3.54	0.00	0.00	5.37	20.7%	4.26	1.11	180.1	152.8	558.8	5%
B1.2	2.57	0.30	0.60	0.00	0.00	3.47	6.9%	3.23	0.24	157.3	119.1	292.0	13%
B1.3	1.56	1.01	4.08	0.00	0.00	6.65	18.3%	5.43	1.22	180.0	146.5	455.8	7%
B2.1	0.38	0.49	4.13	0.00	0.00	5.00	20.4%	3.97	1.02	166.5	140.8	374.6	7%
B2.2	0.68	0.10	0.26	0.00	0.00	1.04	8.8%	0.94	0.09	157.8	140.5	217.6	8%
B2.3	0.17	0.40	1.65	0.00	0.00	2.21	22.1%	1.72	0.49	160.4	138.2	260.3	9%
B2.4	0.31	0.02	1.48	0.00	0.00	1.80	16.8%	1.50	0.30	139.8	104.9	163.2	21%
B3.1	2.75	0.29	0.28	0.00	0.00	3.32	5.2%	3.15	0.17	177.0	139.2	281.1	13%
B3.2	0.84	0.35	0.13	0.00	0.00	1.32	12.5%	1.15	0.16	178.0	138.7	220.2	18%
B3.3	1.44	0.00	0.08	0.00	0.00	1.52	1.0%	1.50	0.02	157.6	105.0	304.4	17%
B4.1	0.40	0.45	1.22	0.00	0.00	2.07	20.4%	1.65	0.42	177.5	137.4	255.0	16%
B4.2	1.67	0.00	0.03	0.00	0.01	1.72	0.6%	1.71	0.01	141.2	104.5	181.5	20%
B5.1	0.48	0.00	0.56	0.00	0.21	1.25	14.0%	1.08	0.18	109.4	98.1	147.7	8%
B5.2	0.31	0.01	0.11	0.00	0.35	0.78	16.8%	0.65	0.13	150.5	124.5	187.3	14%
B5.3	1.75	0.18	0.25	0.00	0.22	2.40	7.8%	2.21	0.19	167.6	116.7	291.3	17%
B5.4	0.15	0.00	0.00	0.00	0.18	0.33	16.2%	0.28	0.05	131.8	109.3	130.6	17%
B6.1	0.14	0.01	2.48	0.00	0.05	2.68	19.2%	2.17	0.52	148.5	99.3	376.0	13%
B6.2	0.19	0.00	0.27	0.00	0.06	0.53	14.0%	0.45	0.07	130.5	95.1	168.1	21%
B7.1	0.44	0.00	0.00	0.00	0.32	0.77	12.7%	0.67	0.10	123.0	103.3	189.1	10%
B7.2	1.00	0.00	0.00	0.00	0.45	1.45	9.3%	1.32	0.13	107.9	67.5	156.3	26%
B7.3	1.72	0.00	0.70	0.00	0.01	2.43	5.9%	2.29	0.14	116.8	41.2	224.4	34%

ID	Area (all in ha)						Impervious % and Areas			Slope			
	Open Space	Road Reserve	Low Res	Comm	Mona Vale Rd	Total	Imp %	Perv Area (ha)	Imperv Area (ha)	US_Elev (m AHD)	DS_Elev (m AHD)	Distance (m)	Slope (%)
C1.1	0.33	0.16	0.39	0.00	0.02	0.91	16.6%	0.76	0.15	172.0	136.3	185.7	19%
C1.2	0.68	0.06	0.13	0.00	0.60	1.47	15.6%	1.24	0.23	171.9	136.6	305.1	12%
C2.1	2.01	0.09	0.00	0.00	0.30	2.41	5.3%	2.28	0.13	145.1	90.4	254.7	21%
C2.2	1.52	0.00	0.00	0.00	0.14	1.65	2.5%	1.61	0.04	124.0	86.5	183.7	20%
C3.1	2.28	0.24	0.00	0.00	0.00	2.52	3.9%	2.43	0.10	143.1	87.5	236.7	23%
C3.2	1.41	0.01	0.00	0.00	0.00	1.42	0.2%	1.42	0.00	130.0	86.8	223.1	19%
C4.1	1.41	0.00	0.00	0.00	0.00	1.41	0.0%	1.41	0.00	111.8	79.1	157.1	21%
D1.1	1.02	0.14	0.63	0.00	0.00	1.79	10.1%	1.61	0.18	180.0	156.4	224.2	11%
D1.2	1.94	0.15	0.26	0.00	0.08	2.43	5.6%	2.29	0.14	174.5	147.8	257.9	10%
D2.1	0.54	0.15	0.04	0.00	0.30	1.03	15.3%	0.87	0.16	175.0	151.0	231.6	10%
D3.1	1.29	0.00	0.13	0.00	0.11	1.52	3.8%	1.47	0.06	177.9	144.0	208.4	16%
D4.1	0.97	0.00	0.26	0.00	0.15	1.38	7.1%	1.29	0.10	174.4	139.3	240.3	15%
D5.1	1.34	0.39	0.02	0.00	0.24	1.98	11.6%	1.75	0.23	153.5	129.7	266.9	9%
D5.2	0.88	0.15	0.03	0.00	0.48	1.54	13.7%	1.33	0.21	147.0	124.6	222.8	10%
D5.3	1.62	0.30	0.74	0.00	0.04	2.69	10.4%	2.41	0.28	146.0	116.5	234.1	13%
D5.4	0.03	0.07	3.03	0.00	0.00	3.13	20.3%	2.49	0.63	132.6	107.6	269.7	9%
E1.1	3.35	0.12	0.75	0.00	0.17	4.39	5.7%	4.14	0.25	180.0	151.5	231.3	12%
E2.1	0.86	0.02	0.03	0.00	0.19	1.10	6.4%	1.03	0.07	172.5	152.3	247.4	8%
E3.1	0.38	0.00	0.07	0.00	0.23	0.68	12.3%	0.60	0.08	174.6	153.8	120.9	17%
E4.1	0.43	0.40	0.42	0.00	0.08	1.33	20.2%	1.06	0.27	173.0	156.4	231.5	7%
E5.1	1.02	0.09	0.86	0.00	0.67	2.65	15.5%	2.24	0.41	157.1	140.4	182.5	9%

Land Use	Impervious %	
Open Space	0%	
Road Reserve	40%	20m wide road reserve with either 6 or 9m road widths (average 8m)
Low Res	20%	*Assumption made visually
Commercial	70%	*Assumption made visually
Mona Vale Road	30%	40m wide road reserve with 12m wide road (4 lanes)