Roads and Maritime Services
PO BOX 9082
MOONEE BEACH NSW 2456

Job No. AM307

Attn: Mr Matthew Francisco

22 May 2012

Re: Review of Flooding in the vicinity of Arrawarra Beach Road, Arrawarra – Sapphire to Woolgoolga Pacific Highway Upgrade

Dear Sir

This letter sets out the findings of an investigation which was carried out by Lyall & Associates Consulting Water Engineers (LACE) on behalf of the Roads and Maritime Services (RMS) to assess the impact of the current Sapphire to Woolgoolga Pacific Highway Upgrade works (S2W) on local drainage patterns in the vicinity of Arrawarra Beach Road at Arrawarra. The investigation also deals with the impact that the proposed Arrawarra Rest Area would have on flooding in this area.

Figure 1 shows the route of the Pacific Highway upgrade west of Arrawarra Village and the drainage line along which local residents claim drainage patterns have been altered as a result of the road works (denoted herein as **Drainage Line A**).

S1 Key Findings and Conclusions

The impacts of the highway upgrade in terms of increases in peak flow in **Drainage Line A** are limited to storms with average recurrence intervals (ARI's) up to about 2 years. These increases have been shown to be relatively minor, in the order of 5-7% when compared to pre-upgrade conditions were RMS to decide not to build the Arrawarra Rest Area. It has also been shown that the impact of the highway upgrade on peak flows would reduce should RMS decide to build the Arrawarra Rest Area. This is because runoff from a portion of the catchment which presently contributes to flow in **Drainage Line A** would be diverted into an adjacent catchment.

The impacts of the highway upgrade in terms of increases in the volume of flow in **Drainage Line A** are also limited to storms with ARI's up to about 2 years. The degree to which the highway upgrade impacts on the volume of flow in **Drainage Line A** varies depending on the antecedent moisture condition of the catchment which lies to the west (upstream) of the highway corridor at the onset of runoff producing rainfall. For example, the volume of flow in **Drainage Line A** would be up to double that of pre-upgrade conditions for the case where the upstream catchment is in a rather dry condition at the onset of runoff producing rainfall (i.e. when antecedent moisture conditions in the catchment are relatively low), whereas the impact of the highway upgrade on the volume of flow in **Drainage Line A** is negligible for the case where the upstream catchment is in a rather wet condition at the onset of runoff producing rain (i.e. when antecedent moisture conditions in the catchment are relatively high).

It is important to note that the volumes of flow in **Drainage Line A** are an order of magnitude greater for the case where storms of up to about 2 year ARI occur on a rather wet catchment (when compared to a dry catchment) and that under these conditions the highway works will have negligible effect.

Whilst it has been demonstrated that the road works had only a minor impact on the rate (and volume) of runoff discharging to **Drainage Line A** during the recent 26 January 2012 storm event, observations by local residents of unprecedented flooding in the vicinity of Arrawarra Village during the event suggest that longer duration storms than those found to maximise peak flows in **Drainage Line A** (i.e. longer than about 1 hour) may be critical for maximising water levels in the area. This is because bursts of rainfall of between 3 and 6 hours embedded in the storm had equivalent ARI's which exceeded 100 years.

If it is the case that longer duration storms are critical for maximising water levels in the drainage lines east of the highway upgrade, this would suggest that flooding behaviour east of the highway is sensitive to changes in both the rate and volume of runoff. Given the lack of relief in the terrain and the limited conveyance capacity in the receiving drainage lines, it is possible that potentially large increases in the volume of runoff associated with the road works for storms with ARI's up to about 2 years could lead to nuisance flooding problems east (downstream) of the highway corridor.

Whilst difficult to determine, it is also possible that any nuisance flooding experienced by local residents is being exacerbated by construction activities, given the increased runoff potential associated with the large amount of clearing which has taken place in the corridor.

1. Introduction

The purpose of this present investigation is to address the concerns that have been raised by local residents regarding a perceived increase in the severity of flooding experienced in the vicinity of Arrawarra Village since the commencement of S2W construction activities on the adjacent section of highway in late 2011. Heavy rainfall and resultant flooding experienced in the area on 26 January 2012 has contributed to these concerns. The investigation also responds to residents' concerns that the Rest Area proposed on the eastern side of the upgraded highway adjacent to the Arrawarra Interchange will further exacerbate drainage and flooding issues in this area.

This letter presents the findings of an analysis of available rainfall data in the vicinity of Arrawarra Village to assess the approximate recurrence interval of the January 2012 event.

Hydrologic modelling was undertaken to assess changes in the hydrologic response of the catchments upstream (west) of Arrawarra for a number of construction scenarios. Impacts are described in terms of estimated changes to peak flow rates and volumes of runoff in the drainage line immediately north of Arrawarra Beach Road for a range of design and recorded rainfall events, including that of January 2012.

A site inspection was undertaken on 28 February 2012 to ground-truth existing drainage arrangements both within and downstream of the highway corridor.

2. Background to Flooding on 26 January 2012

Figure 1 provides an overview of Arrawarra Village and surrounding areas, including Arrawarra Beach Road and Eggins Drive. The extent of current highway upgrade works and the proposed Rest Area site are also shown on **Figure 1**.

Heavy rainfall on the morning of Thursday 26 January 2012 led to flooding of a number of properties and roads in the vicinity of Arrawarra Village. This followed several days of wet weather in the area, which extended to much of the mid-north coast of NSW. Whilst no reports of above-floor level inundation were made at Arrawarra Village, it is understood that several properties within the Village and along Arrawarra Beach Road experienced extensive flooding.

Floodwaters also covered sections of Arrawarra Beach Road and Eggins Drive, concentrated at the intersection of these two roads to a depth sufficient to close these roads to traffic. Resident reports suggest these roads remained impassable for several hours into the afternoon on 26 January. **Plate 1** in **Annexure A** shows floodwaters over the intersection, with heavy discolouration due to the sediment load from adjacent S2W upgrade works.

Note that flooding on 26 January was widespread and not limited to the general vicinity of Arrawarra Beach Road. **Plate 2** in **Annexure A** shows floodwaters over Eggins Drive approximately 2 km north of Arrawarra Beach Road, which lies beyond the extent of S2W upgrade works.

3. Drainage System in the Vicinity of Arrawarra Beach Road

Arrawarra Village and surrounds, including Arrawarra Beach Road and Eggins Drive, are located in a low-lying coastal area situated between the Pacific Highway and the ocean. The area is drained by a network of small unnamed drainage lines which ultimately flow into Arrawarra Creek and Yarrawarra Creek (refer **Figure 1**). These drainage lines have limited capacity to convey runoff due to their small size and flat grades, owing to the lack of relief in the terrain.

The drainage line that feeds runoff from the highway corridor into the intersection of Arrawarra Beach Road and Eggins Drive is shown on **Figure 1** as **Drainage Line A**.

3.1 Catchment Conditions Prior to Commencement of Highway Upgrade Works

Figure 1 shows the location of an existing cross drainage structure under the current two lane carriageway which comprises 5 off 2200 mm wide by 900 mm high reinforced concrete box culverts (RCBC's). This cross drainage structure has a waterway area of 9.9 m^2 and controls a 62.3 ha catchment which lies to the west of the highway corridor. The extent of this catchment is shown on **Figure 2**. The designers of the highway upgrade have assessed the hydrologic standard of this cross drainage structure to be greater than 100 year ARI.

Figure 1 also shows the location of a second cross drainage structure a short distance downstream (east) of the highway corridor where **Drainage Line A** crosses Eggins Road. This cross drainage structure comprises 4 off 750 mm diameter reinforced concrete pipes (RCP's) and has a waterway area of 1.8 m^2, which is approximately 18% of the waterway area available at the five cell box culvert system under the highway. The extent of the 7.8 ha catchment which contributed runoff to **Drainage Line A** at Eggins Road prior to the commencement of the highway upgrade is shown on **Figure 2**.

Downstream (east) of Eggins Road, **Drainage Line A** flows generally to the north, feeding a series of small water bodies which drain slowly to the north into Yarrawarra Creek. The Yarrawarra Creek system ultimately joins Arrawarra Creek at its outlet to the ocean (refer **Figure 1**).

3.2 Proposed Highway Upgrade Works

Figure 1 shows the extent of the S2W upgrade works in the vicinity of Arrawarra Beach Road. The S2W upgrade will include a range of permanent drainage works to manage runoff generated both upstream and within the highway corridor.

Because the existing five cell box culvert system has a hydrologic standard of at least 100 year ARI, the existing structure will be retained and simply extended at both ends to suit the widened dual carriageway configuration.

Scour protection measures, in the form of an energy dissipating outlet structure and dumped rock riprap, will be provided at the outlet of the lengthened cross drainage structure to reduce the risk of future scouring of **Drainage Line A** downstream (east) of the highway.

The lengthened cross drainage structure under the upgraded highway will also convey runoff captured by a new pavement drainage system within the widened highway corridor immediately to the south, extending over a length of approximately 150 m along the new dual carriageways and including the northbound entry ramp to the new Arrawarra Interchange and part of its southbound exit ramp.

Annexure B contains a series of design drawings for the highway upgrade that highlight the extent of the new pavement drainage systems that will contribute to runoff in **Drainage Line A**.

3.3 Proposed Arrawarra Rest Area

Figure 1 shows the site of the proposed Rest Area at Arrawarra, located on the eastern side of the upgraded highway between Arrawarra Interchange and Arrawarra Beach Road.

Runoff from the Rest Area would be controlled by a separate drainage system to that serving the adjacent section of upgraded highway. Runoff generated in the northern section of the Rest Area would be controlled by a series of swales, pits and piped drainage discharging to **Drainage Line A** immediately upstream (west) of Eggins Road.

Annexure C contains a design drawing for the proposed Rest Area that highlights the extent of the drainage system that would contribute to runoff in **Drainage Line A** (refer elements highlighted in blue). Note that for the purpose of this present investigation, it was assumed that the portion of drainage system upstream of pit **Z6/RA07/07** (refer **Annexure C** for location) would be directed south towards Arrawarra Creek based on advice from RMS.

Runoff generated in the southern section of the Rest Area, as well as the portion upstream of pit **Z6/RA07/07**, would be discharged to the eastern side of Eggins Drive adjacent to the proposed Arrawarra Interchange and drain generally to the south-east towards Arrawarra Creek, away from Arrawarra Beach Road.

3.4 Temporary Construction-Phase Drainage Arrangements

During construction of the highway upgrade, a range of temporary drainage arrangements will be utilised for the purpose of controlling runoff generated both upstream and within the highway corridor. These temporary drainage arrangements will involve the following:

- Works to control and capture sediment-laden runoff generated by surfaces within the highway corridor that are disturbed by construction activities.
- Works to divert ‘clean’ runoff generated upstream of the highway corridor through the construction site.

These arrangements are subject to ongoing modification as construction progresses to suit site requirements and to ensure compliance with environmental licensing obligations.

4. Analysis of Rainfall Data

The purpose of rainfall data analysis was to determine the approximate recurrence interval of the 26 January 2012 event.

Whilst RMS has requested this analysis be extended to the event occurring in June 2011, such assessment was prevented due to lack of suitable rainfall data for the earlier event. This is discussed in more detail in **Section 4.2** below.

4.1 January 2012 Event

Analysis of the recent January 2012 event was undertaken based on rainfall recorded by the Leighton Fulton Hogan Joint Venture's (LFHJV's) Woolgoolga weather station near Bark Hut Road, which is located approximately 4.5 km to the south of Arrawarra. Continuous rainfall data is available from this station at 5 minute intervals, with full coverage available for this particular storm event.

Table 1 shows the daily rainfall depths (24 hours to 9.00 am) which were recorded at Woolgoolga over the five day period between 23 and 27 January 2012. Whilst the largest rainfalls occurred on the calendar day of 26 January, **Table 1** shows that substantial rainfall also occurred over the preceding days.

TABLE 1
DAILY RAINFALL TOTALS FOR JANUARY 2012 EVENT
(mm)

Date	Rainfall depth for 24 hours to 9.00 am	
	LFHJV Station at Woolgoolga	Boyd property at Arrawarra
23 January 2012	28	27
24 January 2012	43	42
25 January 2012	16	13
26 January 2012	98	110
27 January 2012	195	164
Total 2-day rainfall depth (26 – 27 January 2012)	**293**	**274**
Total 5-day rainfall depth	**380**	**356**

Table 1 also shows corresponding rainfall depths reported by Arrawarra resident Lorraine Boyd for comparative purposes, which shows close agreement for both daily rainfall depths and the five day rainfall total. This indicates that rainfall at Woolgoolga over this period was reasonably consistent with that experienced at Arrawarra.

Figure 3 is a plot of cumulative rainfall depth for the calendar day of 26 January 2012, which shows that approximately 250 mm fell over the 21 hour period between midnight and 9.00 pm. **Figure 3** also shows that most of this rain occurred over a three hour period in the middle of the day when approximately 155 mm fell between 10.30 am and 1.30 pm. The heaviest burst during this period occurred around 11.00 am.

Figure 4 provides a graphical assessment of the ARI of the 26 January 2012 event for a range of storm durations between 5 minutes and 24 hours, based on design rainfall data derived for Arrawarra. This demonstrates that bursts of rainfall embedded in the overall event exceeded 100 year ARI for periods of between 3 and 6 hours. However, for a period of 2 hours the ARI of the storm reduced to below 50 years, falling further to approximately 15 years for a period of 1 hour.

4.2 June 2011 event

Review of continuous rainfall data recorded by LFHJV's Woolgoolga weather station for the June 2011 event shows a gap in the record, most likely due to instrument failure. Unfortunately this data gap coincides with the most intense bursts of rainfall experienced early on the morning of 14 June, which prevents any meaningful assessment of the ARI of this event.

Table 2 shows the daily rainfall depths (24 hours to 9.00 am) which were recorded at the Bureau of Meteorology's (BoM's) weather station located in Clear Place, Woolgoolga over the two day period of 13 – 14 June 2011. Whilst corresponding rainfall depths reported at the Boyd property are also provided in **Table 2**, comparison is limited by underestimation of rainfall at the Boyd property on 14 June due to overflow of the rain gauge.

TABLE 2
DAILY RAINFALL TOTALS FOR JUNE 2011 EVENT
(mm)

Date	Rainfall depth for 24 hours to 9.00 am	
	BoM Station at Woolgoolga (Clear Place)	Boyd property at Arrawarra
13 June 2011	121	142
14 June 2011	250	170 (1)
Total 2-day rainfall depth	**371**	**312** (1)

(1) Rainfall depth underestimated due to rain gauge overflow

4.3 Comparison of Historic Rainfall Events

Lack of continuous rainfall data for the June 2011 event prevents comparison of the ARI of this event with that of January 2012.

Whilst 24 hour and 48 hour rainfall depths were higher for the June 2011 event, peak flow rates in **Drainage Line A** at Eggins Road are maximised by bursts of rainfall occurring over a much shorter period, in the order of 1 to 2 hours. Note that further discussion of storm durations in the context of maximising peak flow rates is provided in **Section 5.3** below.

It is noted that resident reports suggest that the extent and depth of flooding along Arrawarra Beach Road was greater for the January 2012 event than in June 2011. However, without continuous rainfall records for both events that are representative of local conditions, no further conclusions can be drawn on the relative magnitude of the two flood events.

The closest location for which continuous rainfall data is available for both events is at the BoM's gauge in Coffs Harbour. However, review of daily rainfall totals for this gauge against the data in **Tables 1** and **2** above shows that both events were much smaller in terms of rainfall depths at Coffs Harbour and therefore not representative of conditions at Arrawarra.

5. Hydrologic Modelling

5.1 Methodology

Investigation of the impact the road works will have on peak flow rates and volumes of runoff entering **Drainage Line A** downstream (east) of the highway corridor and proposed Rest Area was undertaken using the DRAINS software. DRAINS is a simulation program which converts rainfall patterns to stormwater runoff and routes flows through networks of piped drainage systems, culverts, storages and open channels. It develops hydrographs and calculates hydraulic grade lines throughout the drainage network, enabling users to analyse the magnitude of overflows and stored water for established drainage systems. It is applicable to both rural and developed catchments, or any combination of the two, and is therefore well suited to this present investigation.

DRAINS models reflecting the following four scenarios were developed to assess the potential impact of both temporary construction-phase drainage arrangements and permanent drainage works proposed as part of the S2W upgrade:

- **Scenario 1** – under pre-highway upgrade conditions;
- **Scenario 2** – under post-highway conditions, without the proposed Arrawarra Rest Area;
- **Scenario 3** – under post-highway upgrade conditions, including the proposed Arrawarra Rest Area; and
- **Scenario 4** – during construction of the highway upgrade, circa 26 January 2012.

The DRAINS models incorporate the full extent of the catchment area that contributes to runoff in **Drainage Line A** at Eggins Road. A range of data was used in the development of the models, including:

- various DRAINS models developed as part of the detailed design for the new transverse and pavement drainage systems;
- ground survey data;
- highway upgrade design data and various design drawings; and
- observations and measurements made during site inspection.

In the absence of gauged streamflow data that could otherwise be used to calibrate the DRAINS models, peak flows arriving at the highway corridor were tuned as close as was practicable to peak flow estimates derived using the Probabilistic Rational Method (PRM).

It is understood that the highway corridor in the vicinity of Arrawarra Beach Road had been largely cleared of existing vegetation and subject to extensive earthworks prior to 26 January 2012. A conservative approach was therefore adopted for the purpose of assessing **Scenario 4**, whereby the full width of the highway corridor was assumed to be disturbed and generating runoff equivalent to a paved surface. This scenario can therefore be considered to represent an upper bound (i.e. worst case) in terms of the likely impact of temporary construction phase drainage arrangements on peak flows downstream of the highway corridor at the time of recent flooding in January 2012.

A range of rainfall events were analysed, including design storm events corresponding to the 1, 2, 5, 10, 20, 50 and 100 year ARI. The 26 January 2012 event was also analysed, whilst the June 2011 event was not due to lack of continuous rainfall data.

5.2 Change in Catchment Area Contributing Runoff to Drainage Line A

Table 3 provides a summary of the catchment area contributing runoff to **Drainage Line A** at Eggins Road for the above-mentioned scenarios.

TABLE 3
COMPARISON OF CATCHMENT AREA CONTRIBUTING RUNOFF TO DRAINAGE LINE A AT EGGINS ROAD
(ha)

Component	Scenario 1 Pre-highway Upgrade	Scenario 2 Post-highway Upgrade (no Rest Area)	Scenario 3 Post-highway Upgrade (with Rest Area)	Scenario 4 Construction Phase (circa 26 January 2012)
Paved Area	0.9	1.8	2.2	6.2
Grassed Area	69.2	68.4	66.2	64.4
Total Area	70.1	70.2	68.4	70.6

Whilst the total catchment area at Eggins Road will be essentially unchanged under post-highway upgrade conditions excluding the proposed Rest Area (i.e. **Scenario 2**), the paved proportion of this catchment will be doubled (i.e. from 0.9 ha to 1.8 ha).

The total catchment area at Eggins Road will be reduced by approximately 1.7 ha (i.e. from 70.1 ha to 68.4 ha) when compared to pre-highway upgrade conditions should the proposed Rest Area be constructed, with the balance of the area drained further to the south towards Arrawarra Creek, away from Arrawarra Beach Road. However, the paved proportion of the catchment will be increased by 1.3 ha.

Table 3 shows that under temporary construction phase conditions, the total catchment area at Eggins Road could be increased by up to 0.5 ha (i.e. from 70.1 ha to 70.6 ha), with a potential increase in effective paved area of up to 5.3 ha (i.e. from 0.9 ha to 6.2 ha). Note that this assessment corresponds to a worst case scenario, as described above in **Section 5.1**.

5.3 Impact on Peak Flows in Drainage Line A

Table D1 in **Annexure D** provides a comparison of estimated peak flows in **Drainage Line A** immediately downstream of Eggins Road for the above-mentioned scenarios and rainfall events.

Tables D2 and **D3** in **Annexure D** provide a comparison of estimated volumes of runoff in **Drainage Line A** immediately downstream of Eggins Road for the above-mentioned scenarios assuming initial losses from the pervious portion of the catchment of 5 and 20 mm, respectively. Note that an initial loss of 5 mm would be representative of a rather wet catchment (i.e. representative of a catchment where the antecedent moisture condition [AMC] is relatively high at the onset of runoff producing rainfall), whilst an initial loss of 20 mm would be representative of a rather dry catchment or relatively low AMC.

The following sections provide further interpretation and discussion of these results.

Note that peak flow rates downstream of Eggins Road were found to be maximised for design storm durations in the range of 1 to 2 hours for all four scenarios analysed.

5.3.1 Impact of S2W Upgrade excluding Rest Area (Scenario 2)

The results in **Table D1** in **Annexure D** demonstrate that the S2W upgrade excluding the proposed Rest Area (i.e. **Scenario 2**) will have only a minor impact on peak flows in **Drainage Line A**.

Peak flows for the smaller, more frequent storm events will be slightly increased, with the largest increase of approximately 7% for the 2 year ARI design event. However, peak flows for events larger than 2 year ARI will be slightly reduced as a result of the S2W upgrade.

For a rainfall event similar in magnitude to that experienced on 26 January 2012, the S2W upgrade is expected to have essentially no impact on peak flows downstream of Eggins Road.

Based on hydrologic modelling of the 26 January 2012 event undertaken as part of this present investigation, peak flows in **Drainage Line A** downstream of Eggins Road were equivalent to a storm of approximately 10 year ARI for all four scenarios analysed.

It is noted that this recurrence interval is more frequent, and therefore implies an event of lesser magnitude, than the 15 year ARI determined for the corresponding maximum rainfall depth occurring over a period of 1 hour (refer **Section 4**). This minor difference in recurrence interval can be attributed to a temporal distribution of rainfall that was slightly less 'peaky' for the 26 January 2012 event when compared to a design storm burst of 1 hour duration.

This is demonstrated in **Figure 5**, which provides a comparison of rainfall intensity over the peak 1 hour burst on 26 January 2012 against the 10 year ARI, 1 hour design storm event. The design storm contains three consecutive five minute periods with rainfall intensity greater than 90 mm per hour, peaking at 180 mm per hour, whereas the 26 January 2012 event contains an isolated five minute burst peaking at 150 mm per hour.

By comparison of the volumes given in **Tables D2** and **D3** in **Annexure D**, it can be seen that the volume of runoff in **Drainage Line A** will be increased as a result of the S2W upgrade. This effect is greatest for the larger initial loss value of 20 mm, where the volume of runoff in the drainage line could potentially be doubled for the more frequent, short duration events. Increases in volumes are generally less than 2% for storms with ARI's of 10 years and larger. For an initial loss of 5 mm, the increase in runoff volume associated with the more frequent, short duration events could be up to 3%, with increases generally less than 1% for storms with ARI's of 10 years and larger.

Note that whilst the higher initial loss value will generate greater impacts as a result of the highway upgrade, this case will also result in lower overall volumes of runoff entering **Drainage Line A**. For example, under post-highway upgrade conditions the 1 year ARI 1 hour duration event will result in:

- generation of 7,912 m^3 of runoff for an initial loss of 5 mm, which is a 3% increase relative to pre-highway upgrade conditions; or
- generation of 590 m^3 of runoff for an initial loss of 20 mm, which is a 102% increase relative to pre-highway upgrade conditions.

The difference in runoff volumes owing to the adopted initial loss value is lower for the larger, less frequent design storm events.

5.3.2 Impact of S2W Upgrade including Rest Area (Scenario 3)

The results in **Table D1** in **Annexure D** demonstrate that should the proposed Rest Area be constructed, the S2W upgrade (i.e. **Scenario 3**) will still have only a minor impact on peak flows in **Drainage Line A**.

Peak flows for design events up to 2 year ARI will be subject to a minor increase of approximately 1%. For design events larger than 2 year ARI, peak flows will be slightly reduced as a result of the S2W upgrade.

For a rainfall event similar in magnitude to that experienced on 26 January 2012, the S2W upgrade incorporating the proposed Rest Area would result in a minor reduction in peak flows downstream of Eggins Road.

By comparison of the volumes given in **Tables D2** and **D3** in **Annexure D**, it can be seen that the volume of runoff in **Drainage Line A** will generally be increased as a result of the S2W upgrade for the more frequent storm events up to an ARI of 2 years. This effect is greatest for the larger initial loss value of 20 mm, where the volume of runoff in the drainage line could potentially be increased by almost 150% for the more frequent, short duration events. For an initial loss of 5 mm, the increase in runoff volume associated with the more frequent, short duration events could be up to 2%. **Tables D2** and **D3** demonstrate that for storms with ARI's of 10 years and larger, the volume of runoff in **Drainage Line A** will generally be reduced as a result of the S2W upgrade for either initial loss value.

Note that whilst the higher initial loss value will generate greater impacts as a result of the highway upgrade for the more frequent, short duration events, this case will also result in lower overall volumes of runoff entering **Drainage Line A**. For example, under post-highway upgrade conditions including the proposed Rest Area, the 1 year ARI 1 hour duration event will result in:

- generation of 7,803 m^3 of runoff for an initial loss of 5 mm, which is a 2% increase relative to pre-highway upgrade conditions; or
- generation of 721 m^3 of runoff for an initial loss of 20 mm, which is a 147% increase relative to pre-highway upgrade conditions.

The difference in runoff volumes owing to the adopted initial loss value is lower for the larger, less frequent design storm events.

5.3.3 Impact of Temporary Construction Phase Drainage Arrangements (Scenario 4)

The results in **Table D1** in **Annexure D** demonstrate that peak flows in **Drainage Line A** could be increased during construction of the highway upgrade for events up to and including 20 year ARI, with peak flows unchanged for larger events. The impact on peak flows is greatest for the smaller, more frequent events, with a maximum increase of up to 31% for the 1 year ARI event. The impact is reduced for larger events, with an increase in peak flow of up to 11% for the 20 year ARI event.

For a rainfall event similar in magnitude to that experienced on 26 January 2012, the impact of temporary construction phase drainage arrangements on peak flows downstream of Eggins Road is minor, with an estimated increase of up to 1%.

Note that this analysis assumes that the highway corridor is fully disturbed and that the runoff characteristics of the disturbed area are similar to a fully paved surface. In reality this is not the case, and the impact of the highway construction works on peak flows would be less than that given in **Table D1**.

For example, in the case where half the highway corridor was assumed to be behaving as a fully paved surface, peak flows in **Drainage Line A** would be increased by up to 15% for the 1 year ARI, and by up to 8% for the 20 year ARI. Given the changing nature of temporary landforms, surface treatments and progressive rehabilitation within the highway corridor during construction, it is not possible to put a finer point on likely impacts during the construction phase.

By comparison of the volumes given in **Tables D3** in **Annexure D**, it can be seen that the upper limit of potential increases in the volume of runoff in **Drainage Line A** could be as high as 600% for a 1 year ARI event of 60 minutes duration.

We trust that the findings of this investigation will assist RMS in its understanding of the impact the S2W upgrade, and proposed Rest Area, will have on flooding in the vicinity of the intersection of Arrawarra Beach Road and Eggins Road at Arrawarra. If we can be of any further assistance, please do not hesitate to contact the undersigned.

Yours faithfully
Lyall & Associates Consulting Water Engineers

Scott Button
Principal

Attachments

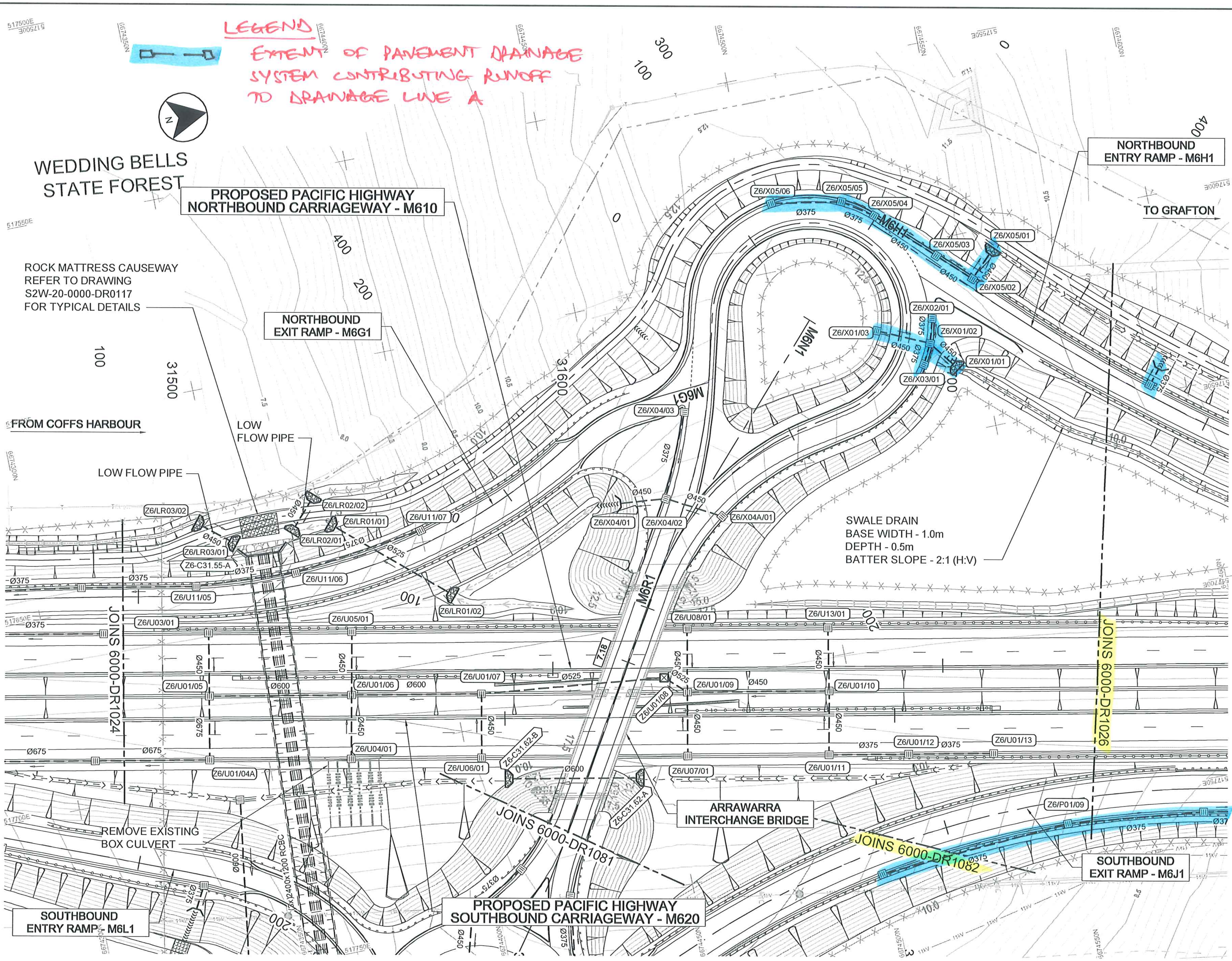
Figure 1	Location Plan
Figure 2	Catchment Plan – Pre-Highway Upgrade Conditions
Figure 3	Cumulative Rainfall for 26 January 2012 Event
Figure 4	Comparison of 26 January 2012 Event with Design Rainfall Data
Figure 5	Comparison of 26 January 2012 Peak Rainfall Burst with Design Storm Event
Annexure A	Photographs of 26 January 2012 Flooding
Annexure B	Design Drawings for S2W Upgrade
Annexure C	Design Drawings for Proposed Rest Area
Annexure D	Summary of DRAINS Model Results

ANNEXURE A
PHOTOGRAPHS OF 26 JANUARY 2012 FLOODING

Plate 1
View looking east along Arrawarra Beach Road towards intersection with Eggins Drive, showing floodwaters over the intersection and extending east along Arrawarra Beach Road

Plate 2
View towards the northern end of Eggins Drive from Pacific Highway exit (approximately 2 km north of Arrawarra Beach Road), showing floodwaters over Eggins Drive

ANNEXURE B
DESIGN DRAWINGS FOR S2W UPGRADE



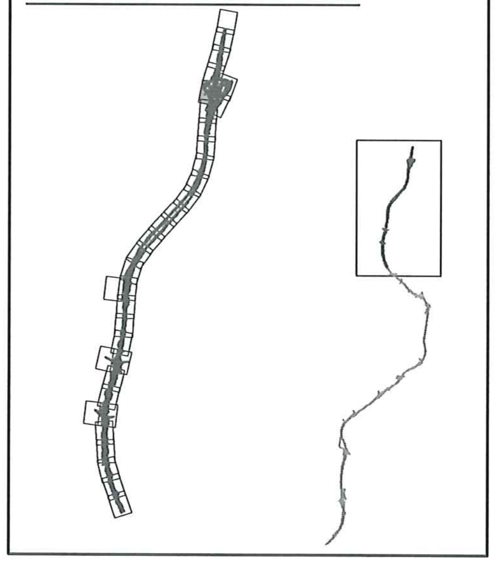
LEGEND

	HEADWALL WITH ROCK MATRESS OR RIP-RAP ARPON
	HEADWALL WITH CONCRETE APRON
	HEADWALL WITH TYPE A DISSIPATOR U.N.O.
	HEADWALL WITH ROCK VEGETATED APRON
Ø450/600x450 RCBC	PIPE/BOX CULVERT AND FLOW DIRECTION
Ø450/D450	EXISTING PIPE/BOX CULVERT
	SWALE - VEGETATED
	CATCH DRAIN - VEGETATED (TYPE 'A' UNO)
	CATCH DRAIN - ENKAMAT (TYPE 'A' UNO)
	CATCH DRAIN - CONCRETE (TYPE 'A' UNO)
	CHANNEL - VEGETATED
	CHANNEL - CONCRETE UNO
	BERM DRAIN - VEGETATED UNO
	BERM DRAIN - CONCRETE UNO
	TABLE DRAIN - VEGETATED
	TABLE DRAIN - CONCRETE UNO
Z6-C15.56-A	TRANSVERSE DRAINAGE TAG
Z6/NBA1/1	PAVEMENT DRAINAGE TAG
B01	STORMWATER PIT / BATTER DRAIN

NOTES

1. FOR GENERAL NOTES AND ADDITIONAL LEGEND REFER TO DRAWING DR0021.

KEYPLAN - ZONE 6000



FOR CONSTRUCTION

DRAWING FILE LOCATION / NAME
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DESIGN MODEL FILE(S) USED FOR DOCUMENTATION OF THIS DRAWING
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REV	DATE	AMENDMENT / REVISION DESCRIPTION	LOT SEQ. No	APPROVAL
A	12.08.2011	ISSUED FOR CONSTRUCTION	060A	SL

DESIGNERS SITE NOTE
REF. No(s):

CO-ORDINATE SYSTEM: MGA ZONE 56
HEIGHT DATUM: A.H.D.

SCALES AT A3 SIZE DRAWING
1 : 1000 FULL SIZE A3

CONTRACTOR: LEIGHTON, Fulton Hogan
DESIGNER: AECOM, SMEC
PROJECT: LEIGHTON, Fulton Hogan

PROJECT DOCUMENT NUMBER: S2W-DRG-20-6000-DR1025
REVISION: A

HIGHWAY No 10 SAPPHIRE TO WOOLGOOLGA UPGRADE CITY OF COFFS HARBOUR

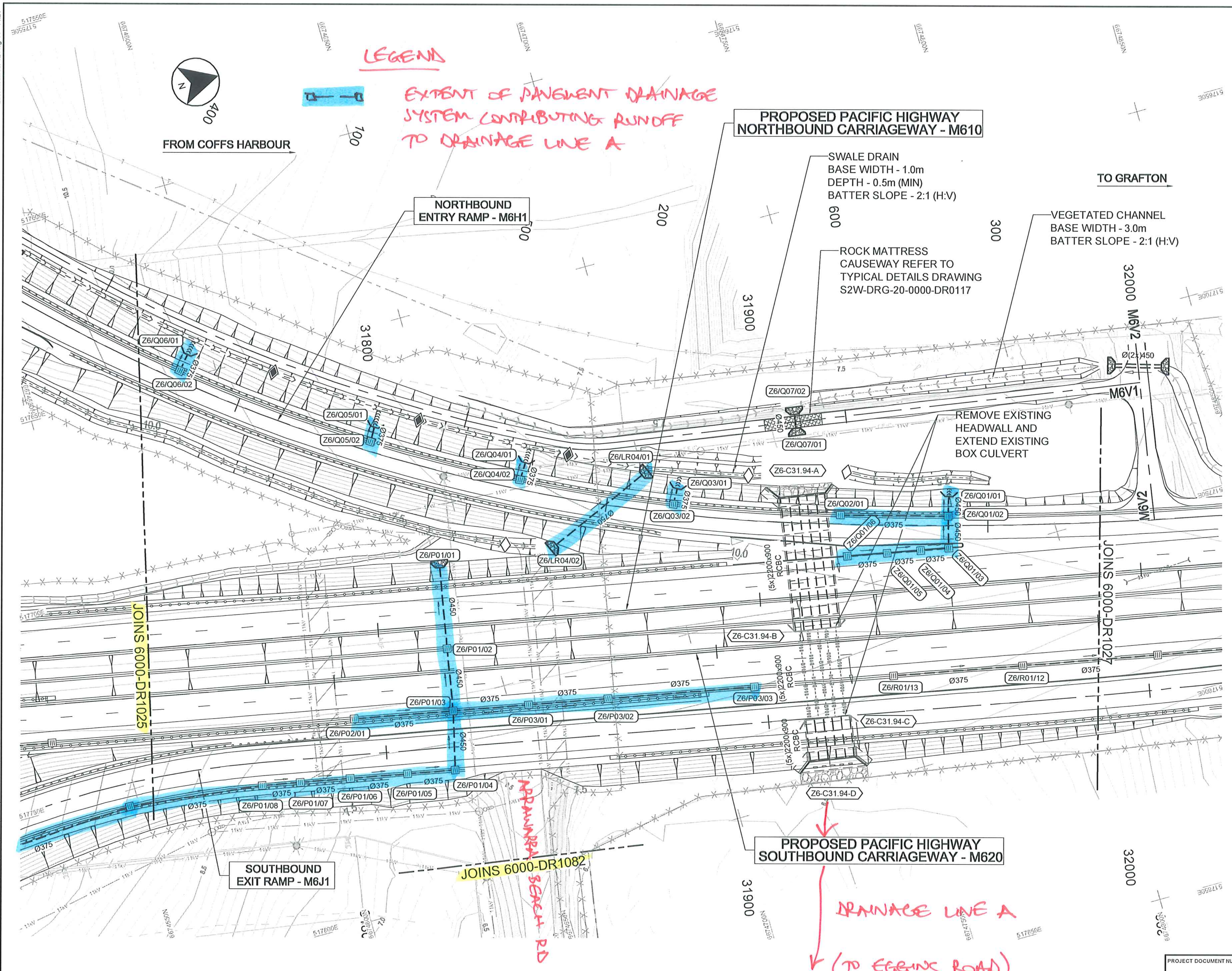
ZONE 6000
DRAINAGE
PLAN
SHEET 25

RTA PLAN REGISTRATION No OF PLANS: 0010.110RC4207

ISSUE STATUS: FOR CONSTRUCTION
SHEET No
ISSUE

Last modified: 12 Aug 11 - 11:25

150 mm ON ORIGINAL



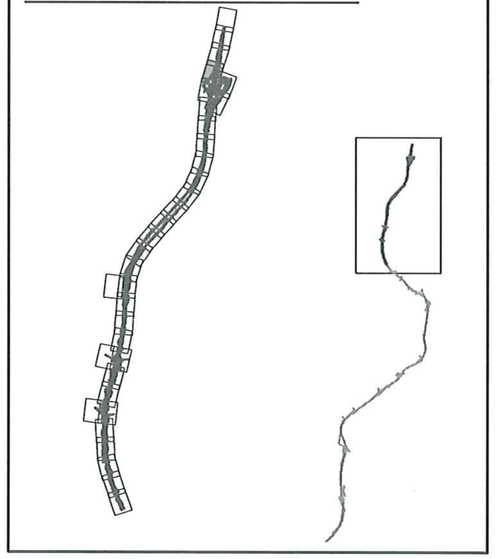
LEGEND

- HEADWALL WITH ROCK MATRESS OR RIP-RAP ARPON
- HEADWALL WITH CONCRETE APRON
- HEADWALL WITH TYPE A DISSIPATOR U.N.O.
- HEADWALL WITH ROCK VEGETATED APRON
- Ø450/600x450 RCBC — PIPE/BOX CULVERT AND FLOW DIRECTION
- Ø450/D450 — EXISTING PIPE/BOX CULVERT
- SWALE - VEGETATED
- CATCH DRAIN - VEGETATED (TYPE 'A' UNO)
- CATCH DRAIN - ENKAMAT (TYPE 'A' UNO)
- CATCH DRAIN - CONCRETE (TYPE 'A' UNO)
- CHANNEL - VEGETATED
- CHANNEL - CONCRETE UNO
- BERM DRAIN - VEGETATED UNO
- BERM DRAIN - CONCRETE UNO
- TABLE DRAIN - VEGETATED
- TABLE DRAIN - CONCRETE UNO
- Z6-C15.56-A — TRANSVERSE DRAINAGE TAG
- Z6/NBA1/1 — PAVEMENT DRAINAGE TAG
- B01 — STORMWATER PIT / BATTER DRAIN

NOTES

1. FOR GENERAL NOTES AND ADDITIONAL LEGEND REFER TO DRAWING DR0021.

KEYPLAN - ZONE 6000



FOR CONSTRUCTION

DRAWING FILE LOCATION / NAME	Cad ref: C:\Projects\S2W\5. CADD\5.3 Working\Drg\20_Detailed\6000\DR_Drainage\S2W-DRG-20-6000-DR1026.dwg
DESIGN MODEL FILE(S) USED FOR DOCUMENTATION OF THIS DRAWING	S2W-MOD-20-6000-RD_DES_20110718-FC-A.TXT; S2W-MOD-20-6000-DR_DES_COMB_20110812-FC-A.12da

REV	DATE	AMENDMENT / REVISION DESCRIPTION	LOT SEQ. No	APPROVAL
A	12.08.2011	ISSUED FOR CONSTRUCTION	060A	SL

DESIGNERS SITE NOTE — REF. No(s): ---------

CO-ORDINATE SYSTEM: MGA ZONE 56
HEIGHT DATUM: A.H.D.

SCALES AT A3 SIZE DRAWING — 1:1000 — FULL SIZE A3

CONTRACTOR: LEIGHTON, Fulton Hogan
DESIGNER: AECOM, SMEC
PROJECT: LEIGHTON Fulton Hogan

PROJECT DOCUMENT NUMBER: S2W-DRG-20-6000-DR1026 — REVISION: A

HIGHWAY No 10 — SAPPHIRE TO WOOLGOOLGA UPGRADE — CITY OF COFFS HARBOUR

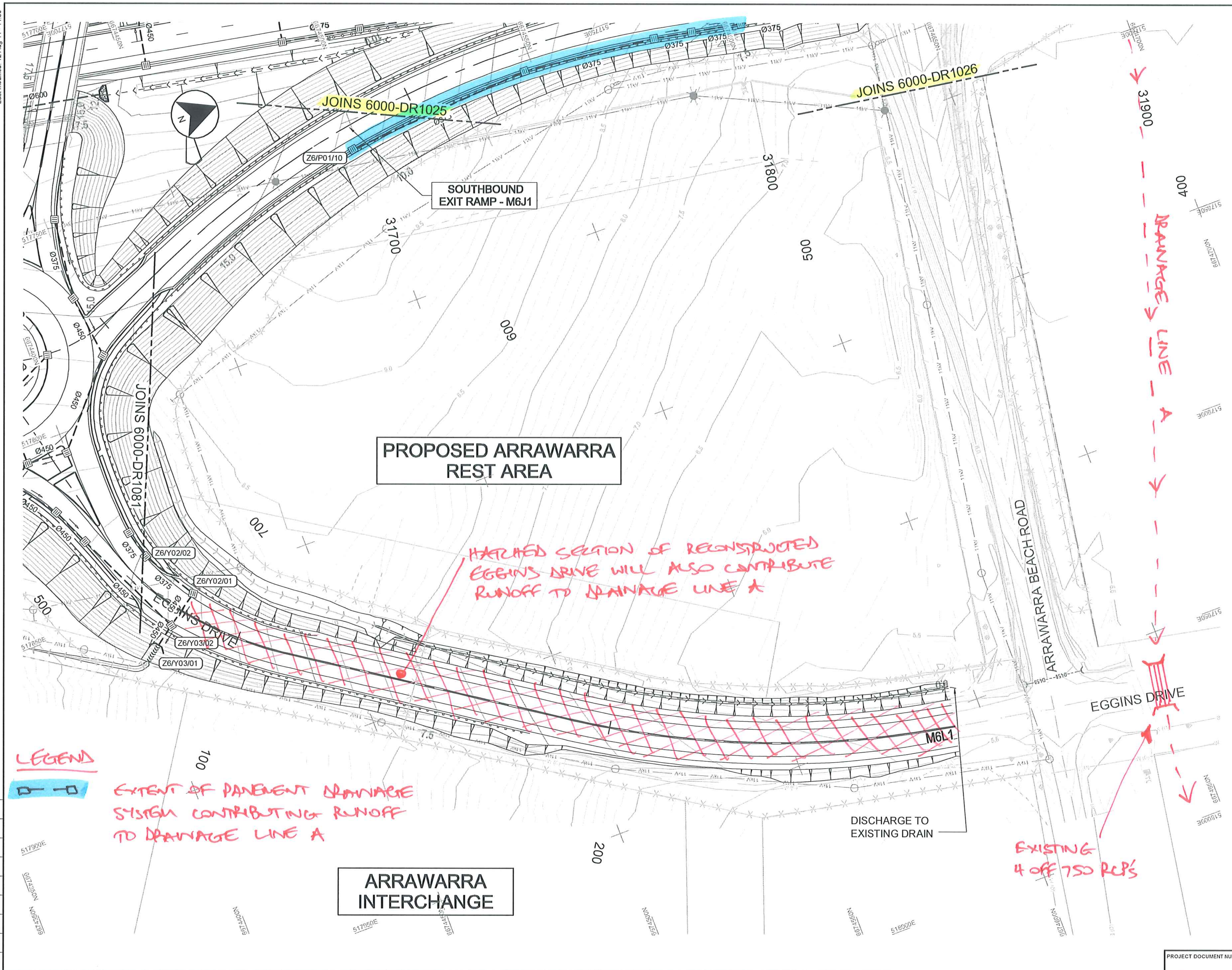
ZONE 6000
DRAINAGE
PLAN
SHEET 26

RTA PLAN REGISTRATION No OF PLANS: 0010.110RC4207

ISSUE STATUS: FOR CONSTRUCTION — SHEET No — ISSUE

Last modified: 12 Aug 11 - 11:26

150 mm ON ORIGINAL



LEGEND

- HEADWALL WITH ROCK MATRESS OR RIP-RAP ARPON
- HEADWALL WITH CONCRETE APRON
- HEADWALL WITH TYPE A DISSIPATOR U.N.O.
- HEADWALL WITH ROCK VEGETATED APRON
- Ø450/600x450 RCBC — PIPE/BOX CULVERT AND FLOW DIRECTION
- Ø450/Ø450 — EXISTING PIPE/BOX CULVERT
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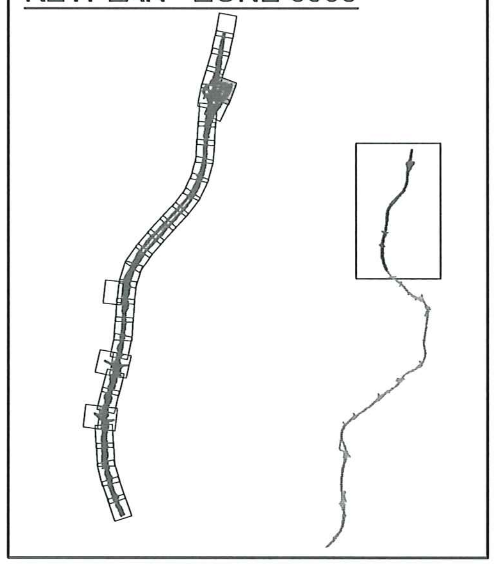
- CATCH DRAIN - VEGETATED (TYPE 'A' UNO)
- CATCH DRAIN - ENKAMAT (TYPE 'A' UNO)
- CATCH DRAIN - CONCRETE (TYPE 'A' UNO)
- CHANNEL - VEGETATED
- CHANNEL - CONCRETE UNO
- BERM DRAIN - VEGETATED UNO
- BERM DRAIN - CONCRETE UNO
- TABLE DRAIN - VEGETATED
- TABLE DRAIN - CONCRETE UNO
- Z6-C15.56-A — TRANSVERSE DRAINAGE TAG
- Z6/NBA1/1 — PAVEMENT DRAINAGE TAG
- B01 — STORMWATER PIT / BATTER DRAIN

NOTES

1. FOR GENERAL NOTES AND ADDITIONAL LEGEND REFER TO DRAWING DR0021.

KEYPLAN - ZONE 6000



FOR CONSTRUCTION

Last modified: 12 Aug 11 - 11:30

DRAWING FILE LOCATION / NAME
Cad ref: C:\Projects\S2W5. CADD\5.3 Working\Drg\20_Detailed\6000\DR_Drainage\S2W-DRG-20-6000-DR1082.dwg

DESIGN MODEL FILE(S) USED FOR DOCUMENTATION OF THIS DRAWING
S2W-MOD-20-6000-RD_DES_20110718-FC-A.TXT
S2W-MOD-20-6000-DR_DES_COMB_20110812-FC-A.12da

REV	DATE	AMENDMENT / REVISION DESCRIPTION	LOT SEQ. No	APPROVAL
A	12.08.2011	ISSUED FOR CONSTRUCTION	060A	SL

DESIGNERS SITE NOTE — REF. No(s):

CO-ORDINATE SYSTEM: MGA ZONE 56
HEIGHT DATUM: A.H.D.

SCALES AT A3 SIZE DRAWING: 1 : 1000 FULL SIZE A3

CONTRACTOR: LEIGHTON, Fulton Hogan
DESIGNER: AECOM, SMEC
PROJECT: LEIGHTON Fulton Hogan

PROJECT DOCUMENT NUMBER: S2W-DRG-20-6000-DR1082 — REVISION: A

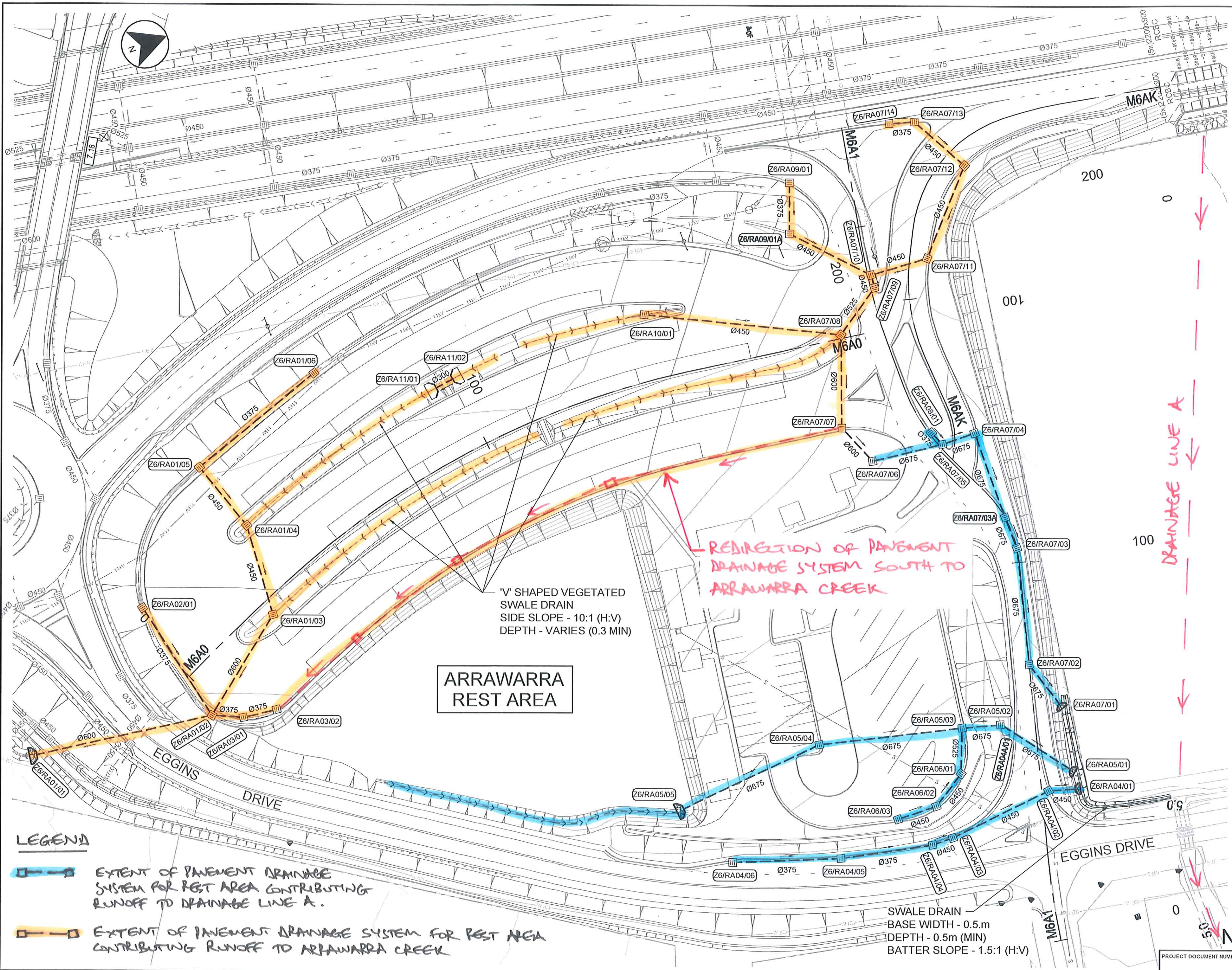
HIGHWAY No 10 — SAPPHIRE TO WOOLGOOLGA UPGRADE — CITY OF COFFS HARBOUR

ZONE 6000
DRAINAGE
PLAN
SHEET 33

RTA PLAN REGISTRATION No OF PLANS: 0010.110RC4207

ISSUE STATUS: FOR CONSTRUCTION

ANNEXURE C
DESIGN DRAWINGS FOR PROPOSED REST AREA



LEGEND

- HEADWALL WITH ROCK MATRESS OR RIP-RAP ARPON
- HEADWALL WITH CONCRETE APRON
- HEADWALL WITH TYPE A DISSIPATOR U.N.O.
- HEADWALL WITH ROCK VEGETATED APRON
- Ø450/600x450 RCBC — PIPE/BOX CULVERT AND FLOW DIRECTION
- Ø450/Ø450 — EXISTING PIPE/BOX CULVERT
- SWALE - VEGETATED
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- CATCH DRAIN - CONCRETE (TYPE 'A' UNO)
- CHANNEL - VEGETATED
- CHANNEL - CONCRETE UNO
- BERM DRAIN - VEGETATED UNO
- BERM DRAIN - CONCRETE UNO
- TABLE DRAIN - VEGETATED
- TABLE DRAIN - CONCRETE UNO
- Z6/RA01/1 — PAVEMENT DRAINAGE TAG
- STORMWATER PIT

NOTES

1. FOR GENERAL NOTES AND ADDITIONAL LEGEND REFER TO DRG GE6021.

KEYPLAN - ZONE 6000

NOT FOR CONSTRUCTION

Last modified: 21 Oct 11 - 15:39

150 mm ON ORIGINAL

DRAWING FILE LOCATION / NAME
Cad ref: C:\Projects\S2W5. CADD\5.3 Working\Drg\20_Detailed\6000\GE_General\S2W-DRG-20-6000-GE6201.dwg

DESIGN MODEL FILE(S) USED FOR DOCUMENTATION OF THIS DRAWING
S2W-MOD-20-6002-RD_DES_20111020-FD-02.TXT
S2W-MOD-20-6002-DR_DES_20111020-FD-02.12da

REV	DATE	AMENDMENT / REVISION DESCRIPTION	LOT SEQ. No	APPROVAL
01	16.09.2011	ISSUED FOR PRELIMINARY DETAILED DESIGN	810A	SL
02	21.10.2011	ISSUED FOR FINAL DESIGN	810A	SL

DESIGNERS SITE NOTE
REF. No(s): ---------

CO-ORDINATE SYSTEM: MGA ZONE 56
HEIGHT DATUM: A.H.D.

SCALES AT A3 SIZE DRAWING
1 : 1000 — FULL SIZE A3

CONTRACTOR: LEIGHTON, Fulton Hogan
DESIGNER: AECOM, SMEC
PROJECT: LEIGHTON, Fulton Hogan

PROJECT DOCUMENT NUMBER: S2W-DRG-20-6000-GE6201
REVISION: 02

HIGHWAY No 10 — SAPPHIRE TO WOOLGOOLGA UPGRADE — CITY OF COFFS HARBOUR

ZONE 6000
ARRAWARRA REST AREA
DRAINAGE
PLAN

RTA PLAN REGISTRATION No OF PLANS: 0010.110RC4207

ISSUE STATUS: FINAL DESIGN

ANNEXURE D
SUMMARY OF DRAINS MODEL RESULTS

TABLE D1
COMPARISON OF PEAK FLOWS [(1)] IN DRAINAGE LINE A
IMMEDIATELY DOWNSTREAM OF EGGINS ROAD

Event	Scenario 1 Pre-highway Upgrade	Scenario 2 Post-highway Upgrade (without Rest Area)			Scenario 3 Post-highway Upgrade (including Rest Area)			Scenario 4 Construction Phase (circa 26 January 2012)		
	Peak flow	Peak flow	Difference [(2)]		Peak flow	Difference [(2)]		Peak flow	Difference [(2)]	
	(m^3/s)	(m^3/s)	(m^3/s)	(%)	(m^3/s)	(m^3/s)	(%)	(m^3/s)	(m^3/s)	(%)
1 year ARI	2.93	3.07	0.14	5%	2.95	0.02	1%	3.85	0.92	31%
2 year ARI	5.28	5.64	0.36	7%	5.32	0.04	1%	6.49	1.21	23%
5 year ARI	9.20	9.08	-0.12	-1%	8.96	-0.24	-3%	10.2	1.0	11%
10 year ARI	11.8	11.6	-0.2	-2%	11.5	-0.3	-3%	12.5	0.7	6%
20 year ARI	15.3	15.1	-0.2	-1%	14.9	-0.4	-3%	17.0	1.7	11%
50 year ARI	19.9	19.7	-0.2	-1%	19.4	-0.5	-3%	19.9	0	0%
100 year ARI	23.3	23.0	-0.3	-1%	22.7	-0.6	-3%	23.3	0	0%
26 January 2012	11.7	11.7	0	0%	11.5	-0.2	-2%	11.8	0.1	1%

(1) Peak flows are quoted to more than one decimal place for ease of comparison only, where flows are relatively small

(2) Note that a positive difference represents an increase in peak flow as a result of the S2W upgrade works. Differences for all scenarios are shown relative to pre-highway upgrade conditions (i.e. Scenario 1).

TABLE D2
COMPARISON OF RUNOFF VOLUMES IN DRAINAGE LINE A IMMEDIATELY DOWNSTREAM OF EGGINS ROAD PERVIOUS AREA INITIAL LOSS = 5 mm

Event		Scenario 1 Pre-highway Upgrade	Scenario 2 Post-highway Upgrade (without Rest Area)			Scenario 3 Post-highway Upgrade (including Rest Area)			Scenario 4 Construction Phase (circa 26 January 2012)		
ARI	Duration	Volume	Volume	Difference (1)		Volume	Difference (1)		Volume	Difference (1)	
		(m^3)	(m^3)	(m^3)	(%)	(m^3)	(m^3)	(%)	(m^3)	(m^3)	(%)
1 year	1 hour	7,683	7,912	229	3.0%	7,803	120	1.6%	8,910	1,227	16%
	3 hour	11,848	12,171	323	2.7%	12,005	157	1.3%	13,748	1,900	16%
	6 hour	13,797	14,231	434	3.1%	14,066	269	1.9%	16,374	2,577	19%
2 year	1 hour	14,363	14,617	254	1.8%	14,321	-42	-0.3%	15,662	1,299	9.0%
	3 hour	21,892	22,231	339	1.5%	21,805	-87	-0.4%	23,905	2,013	9.2%
	6 hour	26,365	26,835	470	1.8%	26,355	-10	0.0%	29,128	2,763	11%
10 year	1 hour	28,846	29,135	289	1.0%	28,532	-314	-1.1%	30,276	1,430	5.0%
	3 hour	43,551	43,913	362	0.8%	42,951	-600	-1.4%	45,767	2,216	5.1%
	6 hour	53,301	53,802	501	0.9%	52,662	-639	-1.2%	56,395	3,094	5.8%
100 year	1 hour	52,482	52,852	370	0.7%	51,840	-642	-1.2%	54,094	1,612	3.1%
	3 hour	79,042	79,522	480	0.6%	77,678	-1,364	-1.7%	81,552	2,510	3.2%
	6 hour	98,420	98,990	570	0.6%	96,699	-1,721	-1.7%	101,957	3,537	3.6%
26 January 2012 (24 hours)		115,464	116,395	931	0.8%	113,807	-1,657	-1.4%	120,881	5,417	4.7%

(1) Note that a positive difference represents an increase in runoff volume as a result of the S2W upgrade works. Differences for all scenarios are shown relative to pre-highway upgrade conditions (i.e. Scenario 1).

TABLE D3
COMPARISON OF RUNOFF VOLUMES IN DRAINAGE LINE A
IMMEDIATELY DOWNSTREAM OF EGGINS ROAD
PERVIOUS AREA INITIAL LOSS = 20 mm

Event		Scenario 1 Pre-highway Upgrade	Scenario 2 Post-highway Upgrade (without Rest Area)			Scenario 3 Post-highway Upgrade (including Rest Area)			Scenario 4 Construction Phase (circa 26 January 2012)		
ARI	Duration	Volume	Volume	Difference (1)		Volume	Difference (1)		Volume	Difference (1)	
		(m^3)	(m^3)	(m^3)	(%)	(m^3)	(m^3)	(%)	(m^3)	(m^3)	(%)
1 year	1 hour	292	590	298	102%	721	429	147%	2,037	1,745	598%
	3 hour	1,464	1,902	438	30%	2,064	600	41%	4,083	2,619	179%
	6 hour	3,414	3,964	550	16%	4,127	713	21%	6,704	3,290	96%
2 year	1 hour	3,972	4,331	359	9.0%	4,373	401	10%	5,997	2,025	51%
	3 hour	11,501	11,958	457	4.0%	11,860	359	3.1%	14,235	2,734	24%
	6 hour	15,975	16,566	591	3.7%	16,412	437	2.7%	19,460	3,485	22%
10 year	1 hour	18,451	18,859	408	2.2%	18,564	113	0.6%	20,610	2,159	12%
	3 hour	33,170	33,647	477	1.4%	33,009	-161	-0.5%	36,106	2,936	8.9%
	6 hour	42,926	43,539	613	1.4%	42,719	-207	-0.5%	46,736	3,810	8.9%
100 year	1 hour	42,089	42,586	497	1.2%	41,851	-238	-0.6%	45,451	3,362	8.0%
	3 hour	68,659	69,235	576	0.8%	67,750	-909	-1.3%	71,893	3,234	4.7%
	6 hour	88,041	88,765	724	0.8%	86,782	-1,259	-1.4%	92,301	4,260	4.8%
26 January 2012 (24 hours)		105,479	106,511	1,032	1.0%	104,244	-1,235	-1.2%	111,591	6,112	5.8%

(1) Note that a positive difference represents an increase in runoff volume as a result of the S2W upgrade works. Differences for all scenarios are shown relative to pre-highway upgrade conditions (i.e. Scenario 1).