10. Drainage

The drainage system comprises the following key components: -

- Cross drainage, which can incorporate fauna crossings;
- Longitudinal drainage.
- Pavement / subsoil drainage.
- Water quality treatment where required.

This chapter identifies the design parameters on which the drainage design has been undertaken and details the results of the design and modelling. The water quality aspects of the design are addressed in Section 21.

The design is based upon the requirements of the Pacific Highway Upgrade Design Guidelines and the RTA Road Design Guide. In addition the requirements of Australian Rainfall and Runoff (1998) have been incorporated into the design.

Further information regarding the drainage assessment and design is provided in Updated Hydrology and Hydraulics Report – Working Paper (GHD, 2007). The concept drainage design is documented in the concept design drawings.

10.1 Design flood immunity

The RTA Pacific Highway Upgrade Design Guidelines provide the following guidance on the minimum allowable average recurrence intervals for the drainage design:

- Culverts where surcharge is allowable 50 years.
- Structures where surcharge is undesirable 100 years.
- Major storm event check for no property damage 100 years.
- Major storm event check for no structure damage 2000 years.

In addition specific hydraulic requirements for this project are:

- Provide flood immunity on at least one carriageway for:
  - A target of one in 100 year average recurrence interval flood event,
  - A minimum of at least one in 20 year average recurrence Interval immunity.

The flood immunity level has been defined as being the event for which the edge line of the outside lane has a 300 mm freeboard above the nominated flood level.

When designing the cross drainage, modelling has considered the impact of the new road on peak water levels and the impact upon inundation time. Where buildings may be affected, the criterion is more stringent and has usually been a maximum water level increase of 100 mm and a negligible impact upon the period of inundation.

10.2 Cross drainage design

10.2.1 Input data

A considerable amount of data was sourced from a number of organisations for the purpose of the design. This information is shown in the Table 10-1.

Table 10-1 Data source and comments

Type of data	Source	Comments on data
Bridges and culverts	Work as executed drawings from the RTA.	Work as executed drawings available for all the bridges, but drawings were not available for most of the culverts.
Plan and longitudinal section	Based upon design models described elsewhere in this report.	
Contours	NSW Department of Lands	10 m interval digital contours.
Digital terrain model	RTA	Aerial photogrammetry for 500 m width along the existing route.
Detailed survey at culvert locations	Blairlansky surveys	Existing culvert inverts and waterway cross sections for existing culverts along the highway alignment.

10.2.2 Site visit

An inspection of the site was completed between 15 November and 29 November 2006. The purposes of this site visit were to:

- Locate the existing waterway crossings.
- Generally evaluate the existing waterway crossings (eg culverts and bridges) and potential future waterway crossings.
- Approximately measure the dimensions of the existing drainage structures, particularly for culverts.

An electronic database was established containing site measurements and photos for each of the existing structures for future reference.

Approximate locations of the waterway structures were identified based on previous investigations of the route.

10.2.3 Existing land use

The existing land use of the identified catchments is comprised predominantly of rural dwellings, some industry, forest and cattle grazing land.

10.2.4 Hydrological analysis

A hydrological analysis of waterway crossings for the existing Pacific Highway route between Woolgoolga and Wells Crossing was undertaken to determine the design flow rates for the waterway structures (eg bridges and culverts). Some of the catchments that discharge through the waterway crossings are relatively large. These major waterway crossings are:

- Wells Crossing Creek.
- Halfway Creek.
- Cassons Creek.
- Blackadder Creek.
- Corindi River.
- Arrawarra Creek.

Of these, Cassons Creek, Blackadder Creek and Corindi River form part of the Corindi River floodplain, and are discussed briefly in Section 10.3 and discussed in detail in the Corindi River Flood Plain Preliminary Option Hydraulic Assessment (GHD, August 2007) – Working Paper. This working paper provides a notional preferred option for feasibility assessment and the actual arrangement to be constructed may vary form that described in this technical report.

The catchment area for the remaining waterway structures is relatively small and these form the minor way crossings.

Flow rates for the large catchments were obtained from the hydrological model of the Corindi Floodplain Assessment (GHD, 2007) while the DRAINS program was used to determine the flows for all of the other catchments. Section 10.3 of this report contains a description of the Corindi River Flood Study results.

Flow estimation for catchments

Estimated peak design flow rates for all crossings, except the Corindi River floodplain, were determined using the DRAINS Version 2006.20 hydrological / hydraulic package. The modelling for the Corindi River is described in Section 10.3. The key parameters used in drains were as follows.

Table 10-2 DRAINS parameters

Parameter	Value	Comment
Paved and supplementary area depression storage	1 mm	Equates to Initial Loss
Pervious area depression storage	10 mm	Equates to Initial Loss
Soil type	3	Represents the typical soils in the catchment. In this case represents a slow infiltration rate.

Parameter	Value	Comment
Antecedent moisture content	3	Represents how wet the soil is at the start of the storm and is equivalent to initial loss – not actually true. It represents a wet soil with between 12.5 and 25 mm of rainfall in the preceeding five days to the storm event.

The rainfall intensities were obtained from Australian Rainfall and Runoff Volume 2 (Institute of Engineers Australia, 1998). The rainfall intensity data was entered directly into DRAINS and run for a number of different durations for the 5-year, 20-year and 100-year recurrence intervals. In the case of the major crossings, the 2000-year flows were determined using the procedures identified in Book VI of Australian Rainfall and Runoff.

Time of concentration (Tc) was determined using the procedures for Eastern NSW as described in Australian Rainfall and Runoff. The time of concentration for Wells Crossing was modified to account for the long narrow shape of the catchment.

Enquiries were made to the RTA in order to determine whether there were records of where the Pacific Highway had been closed in the past due to flooding. Minimal information was identified for this section of the highway, other than for the Corindi River floodplain.

A hydraulic analysis of existing waterway crossings was undertaken to determine the peak flood level, flow velocity and ponding times. The preliminary structures were then modelled to determine the required structure sizing that did not adversely affect nearby landowners

Major waterway crossings

The following waterway crossings with bridges were considered to be major waterway crossings:

- Corindi River (refer Section 10.3).
- Halfway Creek.
- Wells Crossing Creek.
- Redbank Creek.

Details of bridge geometry were obtained from work as executed drawings. The work as executed drawings for Halfway Creek and Wells Crossing also contained the highest recorded flood level. Table 10-3 summarises some critical information in relation to the bridges at Halfway Creek and Wells Crossing.

Table 10-3 Bridge details and existing flow area

Waterway and structure ID	Deck level (mAHD)	Soffit level (mAHD)	Existing flow area (m^2)	Recorded highest flood level (mAHD)*
Halfway Creek	59.84	58.4	86	58.3 (1940)
Wells Crossing	58	57.48	89.2	58.295 (1950)

*AHD = Australian Height Datum

Limited flooding immunity criterion for bridges was available from the RTA. Therefore bridges were designed were possible so that the post highway upgrade flood level was no more than 100 mm above the existing flood levels. In some isolated areas where residential property and buildings are unlikely to be impacted, the target criteria for the bridges and culverts was to not increase the flood level more than 600 mm.

The hydraulic analysis of the major waterway crossings was undertaken using HEC-RAS hydraulic model (USACE, 2003), except for the Corindi River, the modelling for which is detailed in Section 10.3.

The cross-section for each bridge was extracted from the work as executed drawings of each bridge. Additional cross-sections, upstream and downstream of each bridge were extracted from the combined digital terrain model of the strip along the highway alignment. The peak flow rates were obtained from DRAINS models of each structure, which were developed to determine the flows and to allow a check on the HEC-RAS results.

In the absence of any tailwater levels, the critical depth starting water level was adopted to determine the downstream boundary condition with a longitudinal grade of 0.001 m/m adopted. Based on the digital terrain model downstream of the bridges, this adopted longitudinal grade is considered to be relatively flat and hence is predicted to result in conservative flood levels upstream. The channel roughness was estimated based on vegetation observed during the site visit.

After the existing conditions were modelled, the preliminary new highway bridges were entered into the HEC-RAS model. The impact upon the crossing afflux was determined along with any change to the period of inundation and this was then assessed against the design criteria. If required the crossing was resized and then remodelled.

Minor structures

Minor structures were modelled in DRAINS and as with the major crossings, the existing conditions were modelled and then the proposed conditions modelled to determine the impact of the highway upgrade. If required the crossing configuration was then refined.

A key aspect of the design was the consideration of the fauna requirements. Many of the cross drainage culverts were upsized to allow for fauna passage. In addition the alignments of the crossings were refined to minimise the length of the crossings, as fauna is unlikely to utilise long crossings.

The configuration of minor structure crossings adopted for the purpose of modelling is shown in Table 10-4.

Table 10-4 Existing and indicative waterway crossings

Culvert	Chainage	Design Pipe(mm) RCBC(m)	Number of Cells
5	2325	2.4 x 0.9	9
6	2730	1.8 x 0.9	3
7	3400	2.4 x 1.2	3
8	3665	2.5 x 1.2	3

Culvert	Chainage	Design Pipe(mm) RCBC(m)	Number of Cells
9	3860	2.4 x 1.2	1
10	3980	2.5 x 1.2	1
11	4100	3 x 2.4	2
11a	5160	900	1
27	8780	2.4 x 1.5	2
28	9285	3 x 3	1
29	9410	1050	1
29a	10,500	1.2 x 0.9	2
29b	10,585	0.9 x 0.6	2
30	10,710	0.9 x 0.6	2
31	10,925	0.9 x 0.6	2
33	11,600	1050	1
33a	12,140	3 x 2.4	1
35	12,400	2.1 x 0.9	2
35a	12,800	3 x 3	1
36	13,150	750	1
36a	13,555	600	3
36b	13,825	600	2
36c	13,950	600	1
37	14,380	3 x 3	1
39	14,940	3 x 3	1
40	15,370	3 x 3	2
41	15,890	3 x 3	1
42	16,110	1350	2
43	16,240	750	1
44	16,335	3 x 3	1
49	19,775	600	1
50	20,145	1.8 x 1.2	3

Culvert	Chainage	Design Pipe(mm) RCBC(m)	Number of Cells
51	20,840	2.4 x 0.9	3
52	21,240	3 x 2.4	1
53	21,715	3 x 2.4	1
54	21,940	450	2
55	22,120	450	2
55b	22,480	675	1
58	22,935	3 x 1.8	1
59	23,350	3 x 3	1
61	24,870	1500	1
62	26,630	3 x 1.8	1
63	26,720	3 x 1.8	1

10.3 Corindi River floodplain

The Corindi River floodplain has been modelled separately to the other cross drainage structures due to the complexity of the floodplain hydrology and hydraulics. During the 100-year average recurrence interval flood event, three main flow paths have been identified across the Corindi River Floodplain. These are as follows:

- Corindi River main channel.
- The main floodplain.
- Cassons Creek.

The adopted hydraulic design criteria for the hydraulic assessment was:

- The maximum flow velocity across the floodplain must not exceed 2.5 m/s for all events up to the 100-year average recurrence interval, except locally around bridge abutments or piers where localised scour protection can be easily provided.
- The maximum change in water level must not exceed 100 mm for the 100-year average recurrence Interval event.
- The carriageway should be flood free for up to and including the 100-year average recurrence interval event.
- Undertake a hydraulic assessment of the preliminary, or indicative, option to determine flood levels for the 2000-year Average Recurrence Interval event and the probable maximum flood.

Given the targeted flood immunity is 100-year average recurrence interval for the Corindi River floodplain, several iterations were undertaken to balance afflux, velocity and time of inundation with the fill height and bridge lengths to ensure cost effective design.

Based on the observed main flow paths and the results of a cost analysis detailed in the Corindi River Flood Assessment, the general design approach for conveying the 100-year average recurrence interval flood flows across the proposed road alignment is to:

- Provide bridge spans across the main flow paths.
- Elsewhere use concrete box culverts.

The approach adopted to determine the proportion of bridge spans and culverts was as follows:

- The design criteria were initially achieved using bridge spans across the main flow paths only.
- The design was then optimised by replacing the outer bridge spans for each of the main flow paths with culverts, where the number of culverts that were required to still achieve the design criteria, cost less than the bridge span they were replacing (ie each bridge span could be replaced with fewer than six culverts cells).

10.3.1 Hydrological analysis

As part of the preliminary hydrology and hydraulic investigation of the Corindi River floodplain conducted by GHD in 2005 (GHD, 2005), a hydrological model of the Corindi River catchment was set-up using XP-RAFTS. Details of this XP-RAFTS model can be found in the GHD report (GHD, 2005). A revised version of this model was used to provide flow estimates for the hydraulic assessment for the Orange Route Option Road Alignment study (GHD, 2006). The hydrological analysis and the flow estimates adopted as part of the hydraulic assessment for the Orange Route Option Road Alignment have also been adopted for this assessment of the preliminary bridge and culvert arrangement.

Design flow hydrographs were required for the hydraulic modelling of the Corindi River. Table 10-5 presents the peak design flows adopted for the investigation.

Table 10-5 Peak design flows on the Corindi River at the upstream boundary of the investigation area

Average recurrence interval (years)	Peak duration[1] (hours)	Peak design flow (cumecs)
10	9	452
20	9	548
50	6	648
100	6	751
200	6	859
Probable Maximum Flood (~1:10,000,000 year Average Recurrence Interval)	4.5	3973

Note

[1] The peak duration represents the critical storm duration for each average recurrence interval

10.3.2 Hydraulic analysis

Hydraulic analysis was undertaken to determine the preliminary bridge/culvert arrangement of the Pacific Highway upgrade where it crosses the Corindi River floodplain, so as to comply with the criteria identified above.

As part of the Hydraulic Assessment for the Orange Route Option Road Alignment (GHD, 2006), an unsteady-state TUFLOW model of the Corindi River floodplain was set up. TUFLOW (WBM (2006) is a hydrodynamic model used for simulating one-dimensional (1D) and two-dimensional (2D) free surface flows. The model is based on the solution to the free-surface flow equations. It links 1D network domains to 2D network domains to represent the catchment terrain and its drainage system.

This TUFLOW model was used to assess the preliminary bridge and culvert arrangement. The model comprised two parts as follows:

- A 2D network representing the floodplain.
- A 1D network consisting of the Corindi River, as well as existing and future bridge and culvert structures.

Flows and boundary conditions

Inflow hydrographs (100 year average recurrence interval and probable maximum flood) derived using the XP-RAFTS model, as described above, were used for the Corindi River upstream boundary condition within the TUFLOW model.

In addition to the above inflow hydrograph at the upstream boundary of the TUFLOW model, inflows were also distributed across the 2D model to represent the runoff directly from within the study area.

Downstream boundary conditions were required within the TUFLOW model for the 2D network and the Corindi River (1D network). For both the 2D network and the Corindi River, the downstream boundary condition was assumed to be normal depth. This was determined within TUFLOW as being a slope of 0.004 (1 in 250).

The sensitivity of the modelled water levels to the assumed downstream boundary condition was investigated. This was undertaken by running the TUFLOW model with a downstream boundary condition at 0.3 m higher than normal depth. The results showed that just upstream from the existing alignment, the increase in the water level for the 100-year Average Recurrence Interval event was minimal, ie < 10 mm. It was therefore concluded that the model at the indicative alignment was not sensitive to the downstream boundary condition.

A starting/initial water level of 9.30 m Australian Height Datum was applied in the 100-year average recurrence interval and probably maximum flood events over the 1D/2D networks.

Surface roughness

The surface roughness was represented within the model as a Manning's 'n' roughness coefficient. This was applied to the 2D network based on a land use type and to the 1D network based on channel characteristics.

Preliminary bridge and culvert arrangements that achieve the design criteria are presented in Table 10-6.

Table 10-6 Preliminary culvert and bridge arrangements

Chainage[1]	Arrangement[2]
5507.5 - 5592.5	1 bridge (85 m length, 1 No 35 m span and 2 No 25 m spans)
5900 - 6000	5 No. 2700 x 1200 Box Culverts
6025 - 6305	1 bridge (280 m length, 20 No. 14 m spans)
6380 - 6420	6 No. 2700 x 1200 Box Culverts
6715 - 6740	8 No. 2700 x 1200 Box Culverts

Note
[1] Chainage is based on road alignment chainage.
[2] Culverts are Reinforced Concrete Box Culverts with dimensions width (mm) x height (mm). The length of culverts to be installed has been assumed to be 50 m.

10.3.3 Flooding impact on Corindi Floodplain from proposed highway

100-year average recurrence interval event

Water surface levels and flood extents

Generally the 100-year average recurrence Interval event flood extent is similar to that under existing conditions. This is mainly due to the steep nature of the valley sides and channel bed of the Corindi River, which limits the lateral effect of any increase in water surface levels.

The main effects of the preliminary bridge and culvert arrangement on the existing 100-year average recurrence Interval event floodplain extents are:

- Immediately upstream from the indicative road alignment at the northern edge, the floodplain extent would be increased into a wooded area.
- Immediately downstream from the indicative road alignment at the northern edge, the floodplain would be reduced.
- Immediately downstream from the indicative road alignment at the southern extent of the floodplain, adjacent to Black Adder Creek the floodplain would also be reduced.

The preliminary bridge and culvert arrangement will increase the upstream 100-year Average Recurrence Interval event peak water surface levels generally along the upstream face of the indicative road alignment by approximately 100 mm to 500 mm. However due to the relatively steep gradient of the Corindi River channel bed and adjoining flood plain, this increase is limited to an area approximately within 200m upstream from the proposed road alignment. Further upstream from this, the hydraulic analysis shows that there is no further observed effect on peak water surface levels.

Flow velocities

Under existing conditions for the 100-year average recurrence Interval event, the analysis showed that the highest flow velocities generally occurred at:

- North bank of the Corindi River, approximately 500 m upstream from the proposed road alignment, where it appears that the main flood flows spill from the Corindi River on to the floodplain (2.5 m/s).
- Through the middle of the floodplain, where a slight depression exists that creates a defined flow path for flood flows across the floodplain (2 m/s).

The existing high flow velocity of 2.5 m/s on the north bank of the Corindi River is not changed by the proposed road alignment.

Duration of floodplain inundation

As part of the hydraulic assessment, the effect that the proposed alignment has on the duration of inundation of the floodplain was investigated. TUFLOW only models surface flow and does not model ground infiltration or evaporation. For the purpose of measuring the duration of inundation, the floodplain was considered inundated when water levels were greater than 100 mm. For the 100-year average recurrence Interval event, the floodplain with the existing road alignment was inundated to a level greater than 100 mm at a location immediately upstream from the proposed road alignment for approximately 13.5 hours. This duration was shown to increase to 16.5 hours for the proposed culvert and bridge arrangements for the preliminary option.

2000-year average recurrence interval event

The peak water surface levels for the 2000-year average recurrence Interval event and the 100-year average recurrence Interval event water levels for existing conditions and the preliminary option are presented in Table 10-7.

Table 10-7 Water surface levels at the upstream faces of the proposed bridges on Corindi Floodplain (mAHD)

Location	Road chainage (m)	Existing condition (100-yr)	Preliminary option (100-yr)	Preliminary option (2000-yr)
Corindi River Bridge	5550	10.84	11.04	11.24
Main Floodplain Bridge (north abutment)	6305	10.39	10.67	11.02
Main Floodplain Bridge (at centre)	6165	10.54	10.73	11.07
Main Floodplain Bridge (south abutment)	6025	10.78	11.07	11.42

10.3.4 Proposed flood mitigation works

No flood mitigation works are proposed for the Corindi River, as no properties are impacted by the increased flood levels adjacent to the proposed highway.

10.4 Other structures

As part of the drainage design, longitudinal catch drains are required to capture water that may cause damage to fill embankments and to cut batters. These drains will be located within the road corridor and will be sized to convey the 5-year Average Recurrence Interval flow as required by the Pacific Highway Design Guidelines, Upgrading Program Beyond 2006 – Design Guidelines, July 2005, Issue 2.1.

10.5 Fauna passage design in cross drainage structures

A key element of the design of the cross drainage structures has been the provision of fauna passage capacity. In the case of the proposed bridges, the openings have natural cross-sections with a base flow channel and a dry weather bank thereby providing good fauna passage. However, the culverts do not generally have natural cross-sections. Since culverts are required for relatively smaller waterways, which make up the majority of crossings, provision of fauna passage is required where the fauna survey indicates the likelihood of fauna usage.

A key aspect of this design has been the retention where possible of suitable existing structures (suitable hydraulic size and suitable structural condition) however some of the existing culverts in the study area are not considered to provide an adequate fauna passage and as a result may be replaced or else augmented.

Where possible culverts that have been identified as being suitable for fauna passage, have been given an indicative sizing based upon fauna usage in the area, as shown in Table 16.1.

For long culverts, provision of a light entrance to the culvert may be allowed for in the median, depending on species using the culvert.

10.6 Fish passage

The majority of Australian native fish species are adapted to a mobile lifestyle and need to be able to move up and down waterways or even between waterways in order to access food, shelter or breeding grounds. Fish also need to be able to move throughout a waterbody during low flows to access food and shelter. Therefore roads and the cross drainage structures must be designed to allow fish passage during both high and low flow conditions to maximise movement options.

In the case of Woolgoolga to Wells Crossing, ecologists have made an assessment of the creek ecology and on this basis a number of the cross drainage structures have been upsized to provide for fish passage. The structures are a minimum of 3 m wide and will contain a “natural” invert that will be partially dry and partially wet to allow for fauna and fish passage.

10.7 Scour protection

Since culverts are hydraulically efficient, the velocity of flow through a culvert is greater than the velocity of flow in a natural channel of the same slope. When this high velocity flow exits the culvert, a scour problem may develop. Scour holes at culvert outlets develop because of the need to dissipate excess energy. These scour holes may undermine the culvert headwall and endanger the structure or damage the embankment. Therefore, the potential for scour at all culvert outlets should be investigated.

In general, an existing streambed, which is old and well seasoned, will withstand much higher velocities than will a channel, which has been newly constructed. This is because erosion has been taking place in the natural channel for many years and the material forming the channel lining tends to be coarse and stable. Therefore, allowable outlet velocities at culvert outlets, which discharge into a natural stream, tend to be higher than the velocities allowed in new roadside channels.

If it is determined that culvert outlet protection is needed and the calculated outlet velocity is greater than 2 m/s and 4 m/s or less, then a rock lining should be provided. The minimum thickness of the rock layer shall be 1.5 times the maximum stone diameter for D_{50} of 400 mm or less; and 1.2 times the maximum stone size for D_{50} greater than 400 mm. The D_{50} rock size shall be determined at detailed design phase in accordance with RTA design requirements.

For outlet velocities greater than 4 m/s, an energy dissipator such as internal baffle, an impact type energy-dissipating headwall or a culvert outlet flume will be required. The type of energy dissipator chosen depends on site characteristics, however where possible dissipators using rock lining will be used. Internal energy dissipators should be used only in situations where debris is not considered a problem. Rock lined stilling basins (pre-formed scour holes) can be used where the expected scour hole is acceptable and there is no nuisance effect. Impact-type dissipators and stilling basins are used where the scour hole is not acceptable and/or debris is present. Impact-type dissipators are effective when outlet velocities are moderate and the Froude number is less than 3.0. Stilling basins can be used for higher velocities and Froude numbers greater than 3.0.

10.8 Longitudinal drainage

Pavement surface drainage is required to ensure that water does not pond on the surface resulting in a safety hazard. A pavement drainage system is also required to allow water to be captured and treated in water quality control systems.

The key design criteria that has been used is as follows:

- Bridge drainage is connected to the road drainage system.
- Longitudinal drainage is placed within the median of cuttings.
- The drainage design separates cross drainage systems from pavement drainage systems.
- Runoff from ramps or turning roadways must not flow beyond noses and across the main carriageway for a one in two year storm event.
- Oil and chemical spill collection and treatment has been provided at water crossings that are environmental sensitive areas on a case-by-case basis as advised by an ecologist.

- Drainage of pavement wearing surfaces is designed for a one in 10 year average recurrence interval. The one in 100 year average recurrence interval has been modelled and a check made of flow levels to ensure that nuisance flooding is avoided. In particular the drainage system is designed so that:
  - Gutter flow spread limited to width of shoulder 10 years
  - Piped system (including pits) 10 years
- For the 50 mm per hour rainfall design event, the maximum:
  - Water depths at any point on the pavement are not more than 5 mm in the through lanes, including pavements at intersections and on the auxiliary lanes on the approaches to interchanges and intersections.
  - Change in the depth of flow does not increase at a rate greater than 0.5 mm per metre.
- Drainage pipes are designed in accordance with the following requirements:
  - RTA Specification R11.
  - Pipe classifications and installations as set out in the Concrete Pipe Association's "Concrete Pipe Selection and Installation" guide.
  - A minimum 450 mm diameter for longitudinal and transverse drainage pipes.
  - Depths of drainage pipes that provide for connection of subsoil drainage systems.
  - Classes of pipe and cover requirements to suit construction traffic conditions.

As a result of discussions with the RTA and Department of Environment and Climate Change as described in Section 21, road runoff in areas of medium and low sensitivity will generally be allowed to flow directly off the road formation. In all cuttings, runoff will be captured and conveyed out of the cutting by a series of pipes and pits.

10.9 Sub-surface drainage

The subsoil drainage system has been designed to comply with the following requirements:

- A subsoil drainage system has been provided in cuttings, including false cuttings such as earth mounds.
- All cuttings have a trench drain installed on each side of the pavement. The drains are designed to be a minimum of 150 mm below the design floor level and have been designed to drain the pavement and/or to act as a means to intercept seepage from the cutting.
- In rock cuttings the subsoil drainage includes a free draining rock layer. The drainage layer discharges into subsoil drains installed to a minimum depth of 150 mm below the underside of the drainage layer.
- Where drainage blankets are required and longitudinal grade is greater than 3 per cent, intra-pavement drains have been provided at a maximum spacing of 100 m.
- In cuttings, other than rock cuttings or cuttings, which are wet, subsoil drainage has been designed to consist of subsoil drains installed to a minimum depth of 150 mm below the design floors of cuttings or the base of ripped or loosened material.
- The maximum outlet spacing has been designed in accordance with the RTA Model Drawings.

The sub-pavement drainage system has been designed to comply with the following requirements:

- A sub-pavement drainage system has been provided for all pavements.
- Edge drains have been designed to be installed at the sides of rigid pavements to drain the interface between the base and sub-base. The maximum outlet spacing of edge drains has been indicated as being less than 80 m.
- A sub-pavement drain has been designed at all interfaces between different pavement types, including interfaces with existing pavements.