4. Highway upgrade strategy

Two upgrade approaches are being considered for the project:

- Arterial road standard (referred to as Class A). This would comprise two lanes in each direction (with a median wide enough to accommodate future upgrading to three lanes in each direction), 100 kilometres per hour posted speed, limited direct access to the roadway, and a grade-separated interchanges and some at-grade intersections.
- Motorway standard (referred to as Class M). This would comprise two lanes in each direction (with a median wide enough to accommodate future upgrading to three lanes in each direction), 110 kilometres per hour posted speed with controlled access to the roadway at grade-separated interchanges only.

The upgrade is expected to be completed in stages to meet traffic growth and as funding allows. Upgrading of some sections may initially be to arterial road standard followed by the ultimate upgrade to motorway standard. Upgrading to each of these road standards may also be completed on a staged basis, based on shorter lengths of highway. Thus, initial construction to arterial standard would be consistent with the ultimate motorway standard. There are a number of approaches that could be adopted in undertaking the upgrade to Class A or M and these will be further developed during the preparation of the environmental assessment and detailed design.

Chapter 4 outlines the strategy for building the highway upgrade to both a Class A and Class M standard, and includes details on the highway alignment, interchanges, and adjacent access roads. (The alignment of the highway is shown in the concept design drawings in **Appendix A**.)

4.1 Description of the highway alignment

4.1.1 Section 1 — Wells Crossing to Glenugie

This section is about 11 kilometres long.

It would begin at Bald Knob Road, about 23 kilometres south of Grafton, joining with the proposed Woolgoolga to Wells Crossing upgrade project.

The upgrade would be on the eastern side of the existing highway, within the Glenugie State Forest. Through this section, the road is outside the Clarence River (Coldstream basin) floodplain. Both carriageways would be generally at the same level, with relatively low grades and low cuts and fills.

Under an initial Class A upgrade, at-grade (that is, same level) intersections would be provided for Bald Knob Road and Franklins Road. In addition, a State Forest access track would be provided along the eastern side of the upgrade, connecting to the various fire trails and tracks within the forest.

Under a Class M upgrade, the existing highway would be retained as a service road and provide connection to Bald Knob Road and Franklins Road. An interchange would be located about 13 kilometres south of Grafton and just south of Eight Mile Lane (where the alignment of the upgrade would deviate from the existing highway) providing access to the south of Grafton.

4.1.2 Section 2 — Glenugie to Tyndale

This section of the upgrade is about 34 kilometres long and passes through a mix of open grazing land and remnant bush land.

This section would be built to Class M standard.

North of Eight Mile Lane, the upgrade would pass to the east of Grafton airport and turn north-east along Old Six Mile Lane. It would cross the Coldstream River north of Wants Lane and Sandy Crossing before crossing Wooli Road north of Eight Mile Lane. It would then turn north and run along the western side of the ranges to Tyndale.

The upgrade would be crossed by the following roads: Old Six Mile Lane, Avenue Road, Wooli Road, Firth Heinz Road, Bostock Road and Somervale Road. Access along these roads and property accesses would be maintained via underpasses or overpasses.

The upgrade would cross a number of waterways subject to both fast flows from smaller local catchments as well as higher but slower flows when the Clarence River floods. Major bridge structures are required at the Coldstream River and Pillar Valley Creek.

An interchange is proposed at Tyndale to provide access to the north of Grafton.

4.1.3 Section 3 — Tyndale to Harwood Bridge

This section would be about 17 kilometres long, of which about 14 kilometres would be located on the Clarence River floodplain.

Between Tyndale and Maclean, the upgrade would generally use the existing highway as the northbound carriageway, with some deviation to ensure that safety and design standards are maintained. North of Maclean, the upgrade would generally use the existing highway as the southbound carriageway.

Under a Class A standard upgrade, the existing highway could be retained as one carriageway, while under a Class M upgrade it would be replaced to provide a consistent alignment along the length of the project.

The upgrade would be located along the edge of the Clarence River South Arm and between the river and the Shark Creek flood basin. A large bridge is required to cross Shark Creek to maintain the effectiveness of the Shark Creek flood basin.

The existing highway between Cameron Street, Maclean and Yamba Road has restricted access and this will be maintained for both the Class A and Class M upgrades.

Two interchanges are proposed within section 3, with one at Goodwood Street, Maclean and one at Yamba Road. The Maclean interchange would provide access to Maclean from the south and Townsend. The Yamba Road interchange would provide access to Maclean from the north and Yamba.

This section of the upgrade may be initially built to Class A standard, with a series of at-grade intersections and short lengths of service road providing access to properties. When upgraded to Class M standard, the intersections would be removed and a full-length service road provided between Tyndale and Maclean. This road would also provide the alternative route south of Maclean.

4.1.4 Section 4 — Harwood Bridge to Iluka Road

This section would be about 10 kilometres long and follow the alignment of the existing Pacific Highway. The upgrade would be located across Harwood and Chatsworth islands, which are dominated by cane farms.

Initially, this section could be built from Harwood Bridge to Iluka Road to Class A standard. One new carriageway and one new bridge over the Clarence River would be required, with the existing bridge retained as the northbound carriageway. The new bridge crossing of the Clarence River would be located on the eastern side of the existing bridge and may be either a high-level, fixed bridge or a low-level opening bridge. Between Watts Lane and Carrolls Lane, the new carriageway would be located on the western side of the existing highway and constructed above the 20-year flood level. North of Carrolls Lane, the route would be located on the eastern side of the existing highway. An extra bridge crossing would be built over Clarence River North Arm at Mororo, on the eastern side of the existing Mororo Bridge.

At a time when traffic demand warrants it, an additional bridge would be built over the Clarence River as part of a further upgrade to Class M standard.

Under the Class A upgrade, a series of at-grade intersections and short lengths of service road would be built to provide access to properties. Under the later Class M upgrade, the intersections would be removed and a full-length service road built on the western side of the upgrade, which would also form part of the alternative route. Some additional service roads would also be required on the eastern side of the upgrade, mainly across Harwood Island and north of Carrolls Lane.

Due to the significant volume of water that crosses the islands during times of flood, numerous waterway openings would be provided in this section, in addition to large bridges at the Clarence River (Harwood Bridge), Serpentine Channel and the Clarence River North Arm (Mororo Bridge).

Two interchanges would be provided at:

- Watts Lane, providing accessing into Harwood and improving the cross-highway access for cane trucks along Watts Lane.
- Iluka Road, providing access to Iluka and properties north of the Mororo Bridge.

This section ties into the Iluka Road to Woodburn project at its northern end.

4.2 Access strategy

4.2.1 Grade-separated interchanges

The project would have a number of grade-separated interchanges. These would be built in the initial upgrades whether they are Class A or Class M standard. The main interchanges are described below. (Refer to **Figure 4-1** to **Figure 4-3** for an illustration of these interchanges and to **Appendix A** for the interchange design drawings.)

Glenugie interchange (refer drawings EN01810-C-116 and 338)

The Glenugie interchange would be located at the northern end of section 1, just south of Eight Mile Lane, to provide access to Grafton from the south. The interchange would have a split arrangement with south-facing ramps located south of Eight Mile Lane and north facing ramps located on Eight Mile Lane.

The south-facing ramps have been designed with a free-flowing arrangement for traffic to/from Grafton and would suit an interim safety upgrade to the existing highway, if required. The southern ramps would connect directly to the existing highway heading north, with the portion of the existing highway to the south of the interchange connecting at a T-junction.

The north-facing ramps would be located off Eight Mile Lane. Depending on the staging strategy adopted, these ramps may be constructed later than the south-facing ramps.

Tyndale interchange (refer drawings EN01810-C-126)

The Tyndale interchange would be located at the northern end of section 2 and provide access to Grafton from the north. A trumpet-style interchange layout has been adopted to provide free-flowing movements on all ramps.

Maclean interchange (refer drawings EN01810-C-344)

The Maclean interchange would be located on the southern side of Maclean. It would be a modified diamond arrangement with the southbound off-ramp located at Jubilee Street and the other ramps at Goodwood Street.

Figure 4.1 Section 1 At-Grade Intersections

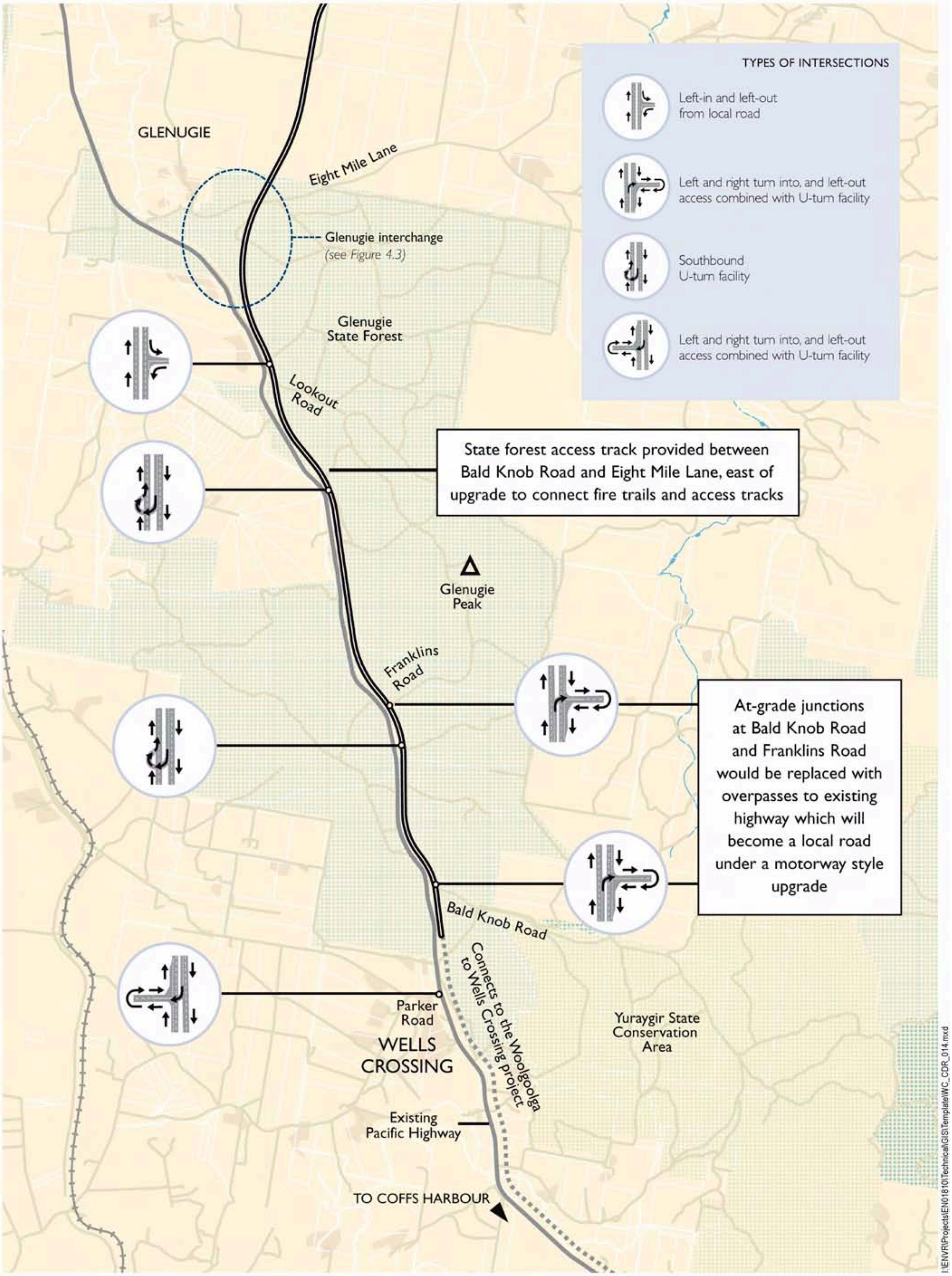


Figure 4.2 Location of at-grade intersections in Sections 3 and 4

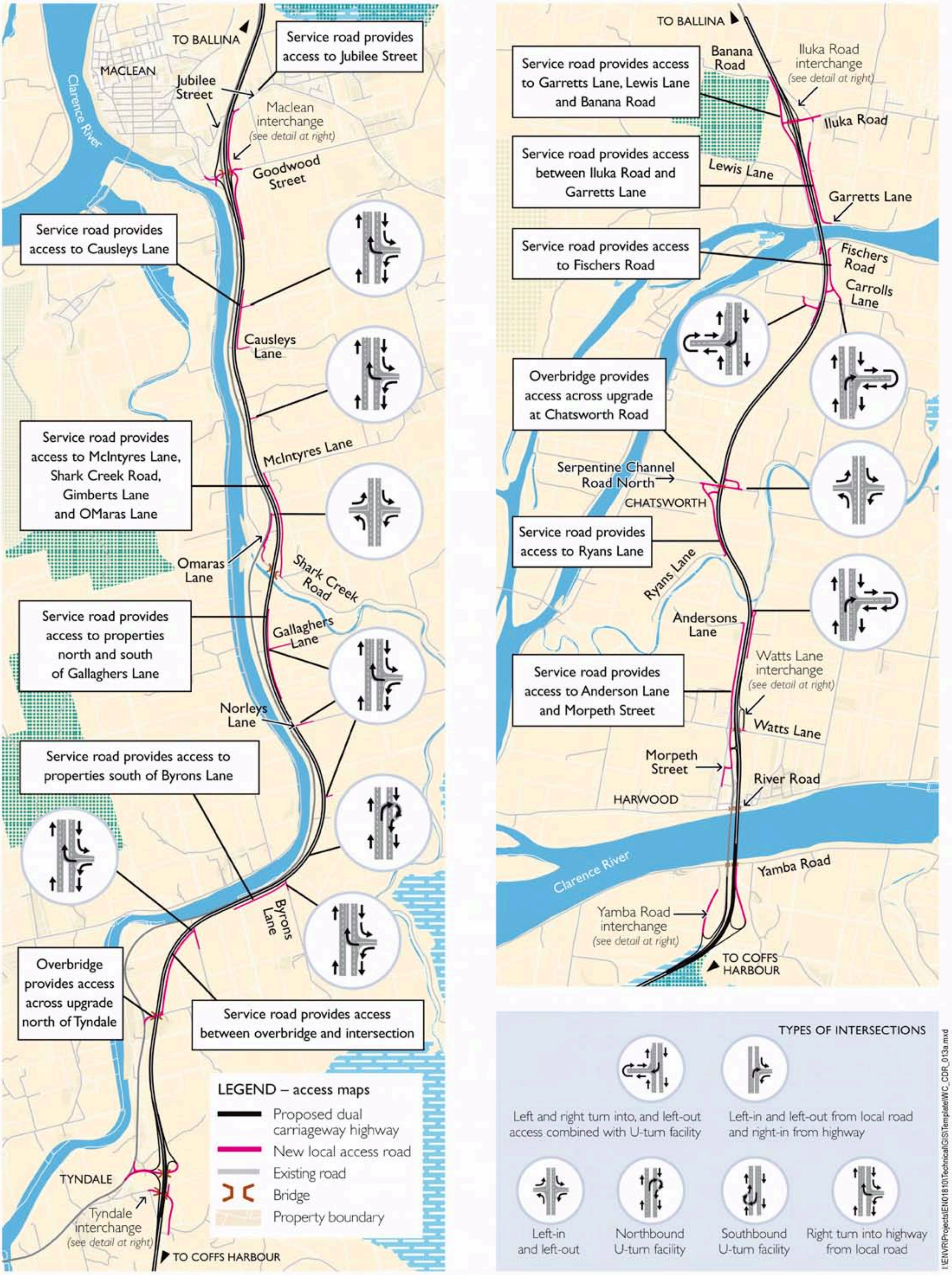


Figure 4.3 Glenugie and Tyndale Interchanges

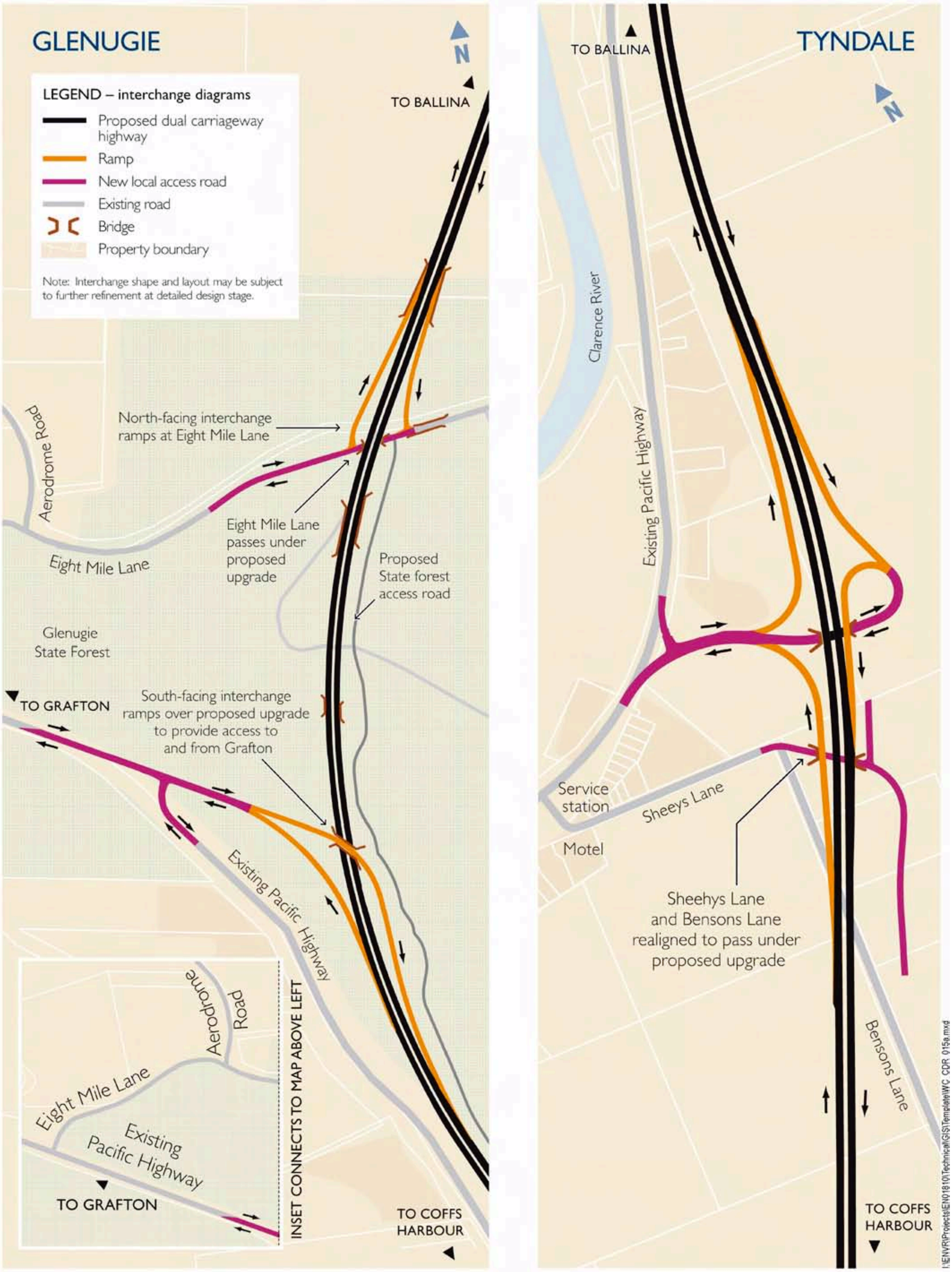
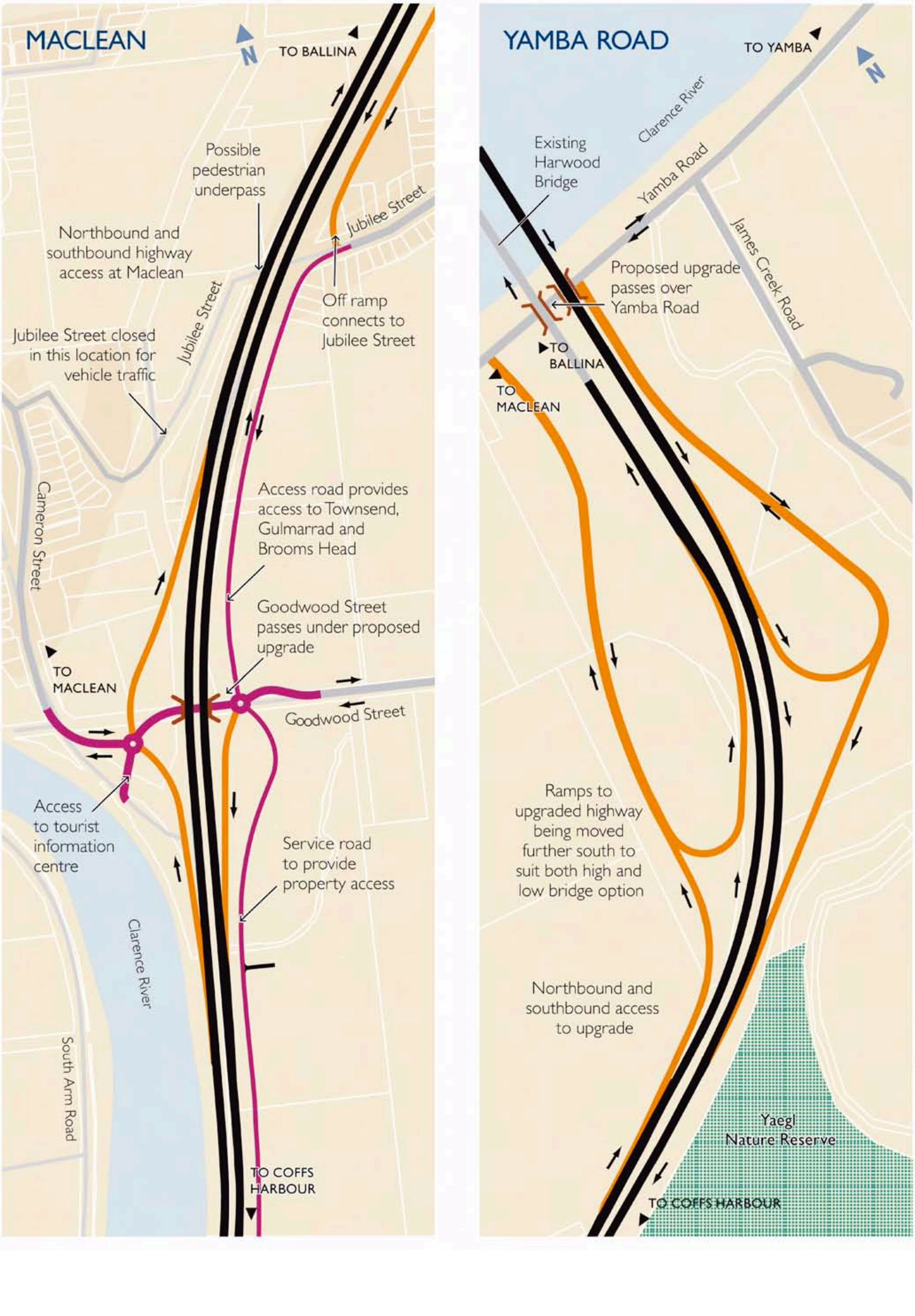
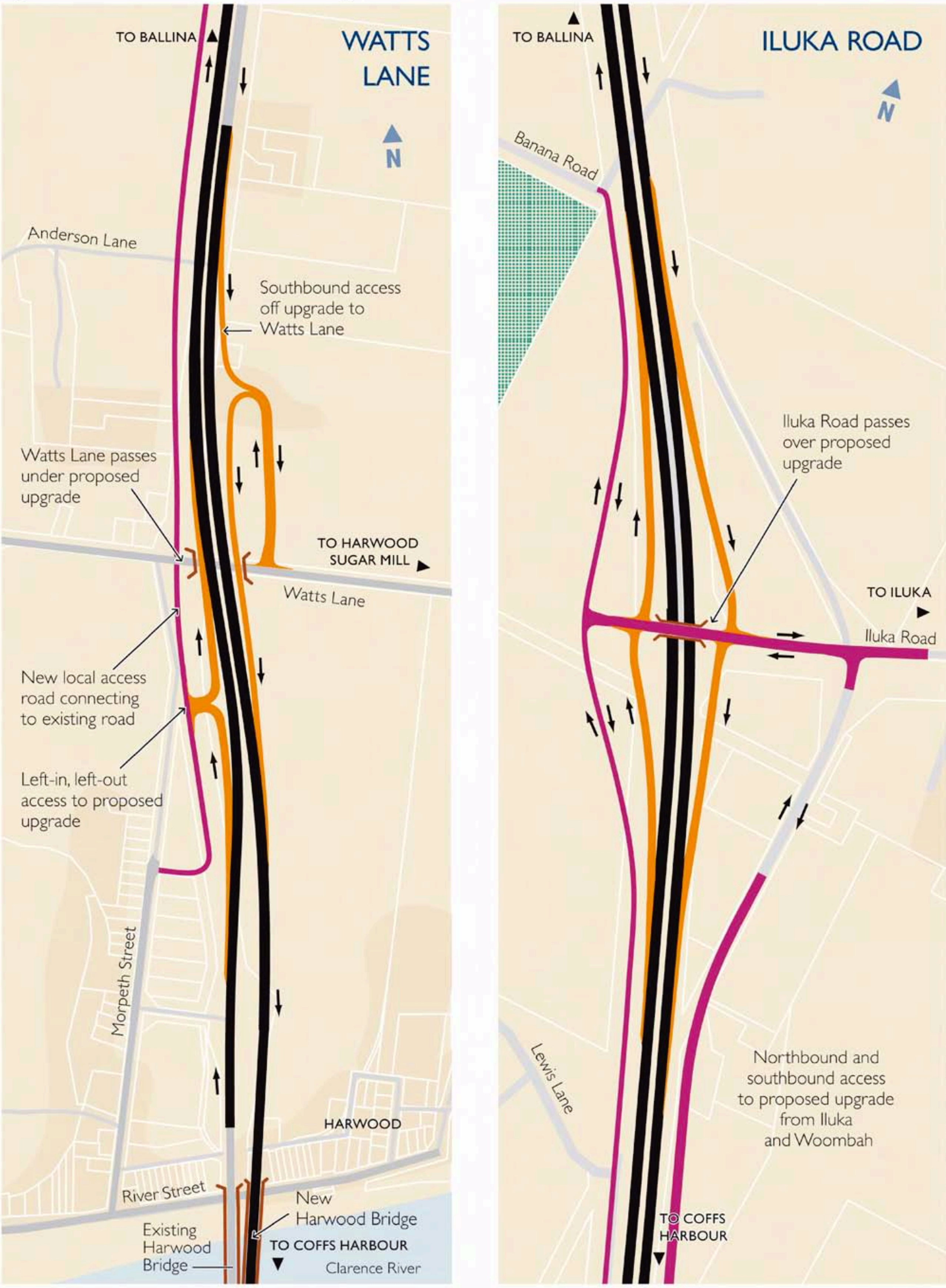


Figure 4.4 Maclean and Yamba Road Interchanges



I:\ENVR\Projects\EN01810\Technical\GIS\Template\WC_CDR_016.mxd

Figure 4.5 Watts Lane - Iluka Road Interchanges



I:\ENVR\Projects\EN01810\Technical\GIS\Template\WC_CDR_017.mxd

A local road connection would be provided between Jubilee Street and Goodwood Street, on the eastern side of the upgrade. The existing connection across the highway at Jubilee Street would be closed to vehicles. Goodwood Street would be raised to a level similar to the existing level at Cameron Street to maintain the current flood immunity (about 1 in 5 years).

An underpass would be provided along the alignment of the existing crossing of Jubilee Street below the highway, to maintain pedestrian and cycle access through this area.

Yamba Road interchange (refer drawings EN01810-C-346)

The Yamba Road interchange would be located at the northern end of section 3 and provide access to Maclean and Yamba. The proposed layout is similar to the existing interchange.

The location of the interchange would move slightly south of the existing arrangement to allow for longer ramps and for a future high-level or low-level bridge. The upgrade from Class A to Class M would require the modification of the northbound on-ramp to suit the inclusion of a third bridge across the Clarence River.

Watts Lane interchange (refer drawings EN01810-C-032)

The Watts Lane interchange would be located at the southern end of Section 4, just north of the Clarence River, and provide access to Harwood village and Harwood sugar mill. The layout has been designed to suit either a low-level or high-level bridge option over the Clarence River.

The interchange would incorporate on- and off-ramps for both northbound and southbound traffic. The ramps would intersect with parallel local roads either side of the upgrade. Connection beneath the upgrade would be provided at Watts Lane. A connection would also be provided between Watts Lane and Morpeth Street to allow access to Harwood Village.

Access to the service station north of Watts Lane (under a Class A upgrade) would need to be addressed due to the proximity to the southbound off ramp. It may be necessary to consider moving the diverge to the north to allow service station users access from the ramp. This would require a straight-through connection from the off-ramp to the on-ramp to allow highway traffic access back to the southbound carriageway.

Similar to the Yamba Road interchange, the subsequent upgrade from Class A to Class M standard would require the modification of the northbound off-ramp to suit the inclusion of a third bridge across the Clarence River.

Iluka Road interchange (refer drawings EN01810-C-035)

The Iluka Road interchange would be provided at the northern limit of the project to provide access to Iluka. The interchange would have a standard diamond arrangement with the Iluka Road connection over the upgrade.

On the western side of the interchange, connection would be provided to a north–south local road that provides access to Lewis Lane and Banana Road.

On the eastern side of the interchange, connection to Garretts Lane (to the south) would be provided via the Old Pacific Highway.

4.2.2 At-grade intersections

Under an initial Class A upgrade, a number of at-grade intersections would be built to provide access to local roads and/or properties. Under a subsequent Class M upgrade, these intersections would be removed and access provided through an extended local road network. The proposed at-grade intersections are listed in **Table 4-1** and shown in **Figure 4-1** and **Figure 4-2**. No at-grade intersections are proposed in section 2, as this section is away from the existing highway and would be built as Class M standard from the outset.

- **Table 4-1: At-grade intersections for the Class A upgrade**

Section	Chainage	Feature	Treatment
1	300	Bald Knob Road	Left-in — at intersection Left-out — at intersection Right-in — at intersection Right-out — use left-out and U-turn facility located at northern end of Woolgoolga to Wells Crossing upgrade project A U-turn facility would be incorporated into the intersection for northbound traffic.
	2500		U-turn facility for southbound traffic.
	3200	Franklins Road	Left-in — at intersection Left-out — at intersection Right-in — at intersection Right-out — use left-out and U-turn facility located at Ch 2500 A U-turn facility would be incorporated into the intersection for northbound traffic.
	6900		U-turn facility for southbound traffic.
	7900	Lookout Road	Left-in — at intersection Left-out — at intersection Right-in — use interchange at Ch 10000 to exit upgrade and perform a U-turn Right-out — use left-out and U-turn facility located at Ch 6900
3	45500	Lane adjacent Gregor Property	Left-in — at intersection Left-out — at intersection Right-in — use U-turn facility located at Ch 47400, then use left-in Right-out — at intersection
	46700	Byrons Lane	Left-in — at intersection Left-out — at intersection Right-in — use U-turn facility located at Ch 47400, then use left-in

Section	Chainage	Feature	Treatment
			Right-out — at intersection
	47400		U-turn facility for northbound traffic.
	47800	Cane Pad	Left-in — at intersection Left-out — at intersection Right-in — use intersection located at Shark Creek to exit upgrade, cross to other side and return Right-out — at intersection
	48700	Norleys Lane	Left-in — at intersection Left-out — at intersection Right-in — use intersection located at Shark Creek to exit upgrade, cross to other side and return Right-out — at intersection
	49700	Gallaghers Lane	Left-in — at intersection Left-out — at intersection Right-in — use intersection located at Shark Creek to exit upgrade, cross to other side and return Right-out — at intersection
	50600	Shark Creek Road and Gimberts Lane	Access via service road to Shark Creek at Ch 51300
	51000	O'Maras Lane	Access via service road to Shark Creek at Ch 51300
	51300	Shark Creek	Left-in and left-out provided either side of the upgrade Connection provided under upgrade at Shark Creek Road for both through traffic and access to the other side of the upgrade to cater for right-turning vehicles Access provided on and off upgrade for both northbound and southbound traffic Service road connections provided to Shark Creek Road, O'Maras Lane, McIntyres Lane and Gimberts Lane.
	51800	McIntyres Lane	Access via service road to Shark Creek at Ch 51300
	52400	Cane Pad	Left-in — at intersection Left-out — at intersection Right-in — u-turn at Maclean Interchange, then use left-in Right-out — at intersection
	53800	North of Causleys Lane	Left-in — at intersection Left-out —at intersection Right-in — u-turn at Maclean Interchange, then use left-in Right-out — at intersection
4	61700	River Road and Morperth Street	Access via Watts Lane Interchange at Ch 62700
	63900	Anderson Lane	Access via Watts Lane interchange at Ch 62700
	64000	Serpentine Channel Road South	Left-in — at intersection Left-out — at intersection Right-in — at intersection Right-out — use left out and U-turn through the Watts Lane Interchange A U-turn facility would be incorporated into the intersection for northbound traffic

Section	Chainage	Feature	Treatment
	64800	Ryans Road	Access via Chatsworth Road at Ch 65600 (opposite Serpentine Channel Road North)
	65600	Chatsworth Road / Serpentine Channel Road North	Left-in and left-out provided either side of the upgrade. Connection provided over the upgrade for both through traffic and access to the other side of the upgrade to cater for right-turning vehicles Provides access to Ryans Road
	68100	Carrolls Lane	An offset left-in-left-out and right-in (no right-out) provided either side of the upgrade U-turn facilities incorporated into the intersection on either side Right-out traffic would turn left, then do a U-turn about 200 m along the upgrade Provides access to Chatsworth Road and Fischers Lane
	68700	Chatsworth Road and Fischers Lane	Access via Carrolls Lane at Ch 68100
	69000	Garretts Lane	Access via Iluka Road interchange at Ch 70300
	69600	Lewis Lane	Access via Iluka Road interchange at Ch 70300
	70900	Banana Road	Access via Iluka Road interchange at Ch 70300

4.2.3 Service roads and access roads

Service roads would be built to connect the Pacific Highway to local roads, villages and properties. Service roads are sealed roads, suitable for accommodating all classes of vehicles except for oversized vehicles and B-doubles. They are designed to local council and/or Austroads standards and generally signposted at 80 kilometres per hour. Sections of the existing highway, which are planned to be retained for use as a service road, may have a speed limit of 100 kilometres per hour.

Access roads are roads that provide access to adjacent private property for residents and service vehicles. Access roads are connected to a local road or a service road. They are generally 'no through roads' and would be signposted at either 50 or 60 kilometres per hour.

Details of the proposed service road and access road arrangements for the Class A and Class M upgrade approaches are discussed below.

Class A upgrade

Section 1 — Wells Crossing to Glenugie

In section 1, the existing Pacific Highway would be maintained as a service road along the western side. This would provide an alternative route for the highway and a connection between Grafton and Halfway Creek. The existing highway would provide access to properties west of the highway.

Section 2 — Glenugie to Tyndale

Section 2 is proposed to be Class M from the outset.

Section 3 — Tyndale to Harwood Bridge

In section 3, the initial Class A upgrade would include nine at-grade intersections, and about 4.6 kilometres of service roads over six locations to limit the number of intersections. The at-grade intersections and service roads would be as follows:

- Lane at chainage 46 150 —intersection with service road provided back to crossover north of Tyndale village (about 1.2 kilometres).
- Byrons Lane —intersection with about 0.6 kilometres service road provided to the west for property access.
- Cane Pad at chainage 47 800 —intersection with no service road.
- Norleys Lane —intersection with no service road.
- Gallaghers Lane —intersection with service road provided both north and south for property access (about 1.1 kilometres).
- Shark Creek — intersection either side of upgrade with service road provided between Shark Creek Road and McIntyres Lane on eastern side of upgrade. Connection of Shark Creek Road below the upgrade would allow access both north and south on either side of the upgrade.
- Cane pad at chainage 52 450 —intersection with no service road.
- North of Causleys Lane —intersection with service road provided back to Causleys Lane (about 0.4 kilometres).
- Maclean interchange — about 350 metres of service road south of Goodwood Street for property access as well as a connection north of Goodwood Street to Jubilee Street.

The number of at-grade intersections could be further reduced by the inclusion of longer service roads.

Section 4 — Harwood Bridge to Iluka Road

In section 4, access would include a series of service roads and intersections as follows:

- Grade-separated access at Watts Lane, Chatsworth Road/ Serpentine Channel Road North and Iluka Road.
- Access from Watts Lane interchange back to Harwood village via Morpeth Street.
- Service road on the western side of the upgrade between Watts Lane and Andersons Lane.
- Intersection at Serpentine Channel Road South with gravel track access to the existing cane pad south of this road and the old Pacific Highway Bridge over Serpentine Channel.
- Service road on the western side of the upgrade between Ryans Road and Chatsworth Road.
- Intersections either side of upgrade at Chatsworth Road / Serpentine Channel Road North.
- Intersections either side of Carrolls Lane to allow access to upgrade and U-turn facilities.
- Service road on the eastern side of the upgrade between Carrolls Lane and Fischers Road.

- Service road on the western side of the upgrade between Chatsworth Road and Banana Road.
- Service road on the eastern side of the upgrade between Garretts Lane and the Iluka Road interchange (via the old Pacific Highway).

The number of at-grade intersections could be further reduced by the inclusion of longer service roads.

Class M upgrade

The service roads to be included in the Class M upgrade would generally be an extension of those provided in the Class A upgrade.

Under the Class M upgrade, no at-grade intersections would be provided, so the service roads would be required to provide local access to the interchanges. For Sections 1, 3 and 4, service roads would be provided parallel and adjacent to the upgrade on at least one side. For Section 2, some relatively short service roads are required, with most accesses needed across the highway rather than along it.

Section 1 — Wells Crossing to Glenugie

The main change under the Class M upgrade would be the replacement of at-grade intersections at Bald Knob Road and Franklins Road with grade-separated crossings and connection of these through to the existing Pacific Highway, which is being maintained as a service road. The Bald Knob Road would pass over the upgrade route and Franklins Road would pass underneath. In addition, the intersection at Lookout Road would be removed. Access to this road would be provided via the State Forest access track running between Eight Mile Lane and Bald Knob Road.

The existing highway would be used along the western side of the upgrade route as a service road.

Section 2 – Glenugie to Tyndale

At the southern end of Section 2, the upgrade would run adjacent to a section of Old Six Mile Lane. Service roads would be provided on either side of the upgrade to maintain property access. A bridge provided on Old Six Mile Lane would pass over the upgrade at Ch 13300. The preferred route would be bridged over Avenue Road at Ch 16500. Both these crossings would provide connections at the eastern and western ends of this section of Old Six Mile Lane. Some realignment of Wants Lane, west of Avenue Road, is also required.

The upgrade runs along a short section of Firth Heinz Road, which would require reconstruction on the eastern side of the upgrade.

At the northern end of Section 2, access roads would be provided for property access on the eastern side of the upgrade. These would be about 500 metres south of the Tyndale interchange at Bensons Lane and about 300 metres north of the interchange off the alternative route crossover.

Connections across the upgrade through section 2 include:

- Ch 11000 — Eight Mile Lane under upgrade.
- Ch 13300 — Old Six Mile Lane over upgrade.
- Ch 16500 — Avenue Road under upgrade.
- Ch 20600 — Wooli Road over upgrade.
- Ch 23800 — property access under upgrade.
- Ch 26900 — Firth Heinz Road over upgrade.
- Ch 30550 — Bostock Road over upgrade.
- Ch 31950 — Somervale Road under upgrade.
- Ch 33700 — property access under upgrade.
- Ch 36100 — property access under upgrade.
- Ch 38700 — property access under upgrade.
- Ch 39950 — access to flood reserve over upgrade.
- Ch 41200 — access to flood reserve under upgrade.
- Ch 42200 — Bensons Lane under upgrade.
- Ch 44300 — alternative route over upgrade.

The alternative route for this section would be the existing highway between Glenugie and Tyndale, via Grafton.

Section 3 – Tyndale to Harwood Bridge

In section 3, the upgrade from Class A to Class M would require the removal of the at-grade intersections and provision of additional service roads to provide a full-length service road between Tyndale interchange and Maclean interchange.

Section 4 — Harwood Bridge to Iluka Road

In section 4, the upgrade from Class A to Class M would require the construction of a third bridge crossing of the Clarence River, with the existing highway becoming the local service road. This would require some adjustment to the interchange ramps on either side, as well as the connection of the local road network to the existing Harwood Bridge.

North of Watts Lane, a full-length service road would be provided on the western side of the upgrade between Watts Lane and Banana Lane. On the eastern side of the upgrade, a service road would be required between Watts Lane and Serpentine Channel Road South.

Grade-separated interchanges would be provided at Carrolls Lane to facilitate the removal of the at-grade intersections. Carrolls Lane would be built over the upgrade.

4.3 Improvements to the existing highway

As part of the upgrading of the Pacific Highway for this project, the RTA proposes to undertake a substantial package of improvements to the existing highway between Glenugie and Tyndale. These improvements could potentially include:

- Realigning curves that do not meet 100 kilometres per hour design standards.
- Widening road shoulders in some sections where they provide insufficient room for vehicles to pull off the carriageway.
- Upgrading major intersections (that is, where secondary roads intersect with the highway) to “seagull’ treatments.
- Providing additional overtaking lanes.
- Installing wire rope on the road edges or medians in areas where the potential for accidents involving head-on collisions or vehicles running off the road is highest.

5. Road design

In three of the four sections, the preferred route would initially be constructed to arterial road standard, with one section upgraded to motorway standard. It is proposed to ultimately upgrade the entire project route to motorway standard. Where an initial arterial upgrade is implemented, the design will be suitable to allow the future upgrade to motorway standard without substantial re-work.

Chapter 5 outlines the works proposed to upgrade the highway, and the parameters used in developing the concept design.

5.1 Design standards and guidelines

The standard for the concept design of this project is the RTA's *Upgrading the Pacific Highway — Upgrading Program beyond 2006 — Design Guidelines,* Issue 2.4 (RTA, 2006f). This is subsequently referred to as the *Pacific Highway Design Guidelines*. The RTA's *Road Design Guide* (RTA, 2000) and Austroads's *Guide to Traffic Engineering Practice* (Austroads, 2004) have also been used. The development of the environmental assessment and detailed design will need to consider any updating of the RTA's design standards subsequent to the concept design.

5.2 Design life

Infrastructure is designed to comply with the required design life outlined in Section 3.5 of the *Pacific Highway Design Guidelines*. These are listed in **Table 5-1**.

- **Table 5-1: Asset design lives**

Asset	Minimum design life (years)
Inaccessible drainage element	100
Drainage elements that are accessible for refurbishment, including sedimentation and detention ponds	20
Sign faces	10
Sign support structures and other roadside furniture	40
Fences, including fauna fences	20
Lighting and electrical equipment	20
Bridge structures, including underpasses and wildlife tunnels	100
Retaining walls, including reinforced soil walls	100
Dual carriageway and ramp pavements	40
Local road embankment and support structures	100
New local road pavement	20
Reconstructed local road pavements	10
Embankments, including reinforced embankments	100
Cut batters, including batter treatments	100

5.3 Highway design

5.3.1 Design and performance requirements

General

The engineering design criteria for the proposed upgrade are summarised in **Table 5-2**, and presented in more detail in the following sections.

- **Table 5-2: Concept design criteria**

Design parameters	Proposed upgrade
Design speed	110 km/h horizontal 100 km/h vertical
Minimum “K” value	95 (crest) / 35 (sag)
Stopping sight distance Horizontal Vertical Reaction time	 210 m 210 m 2.5 sec
Number of lanes	Two lanes per carriageway[1]
Traffic lane width	3.5 m
Outside shoulder widths	2.5 m — with no safety barrier 3 m — with safety barrier
Inside shoulder widths	0.5 m
Median width	12 m
Clear zone	11 m
Formation, drainage and road reserve widths	In accordance with Upgrading Program beyond 2006 — Design Guidelines, July 2005, Issue 2.4 (RTA, 2006f).
Minimum horizontal radius	1200 m desirable; 750 m minimum
Maximum superelevation	3%
Maximum vertical grade	4.5% desirable; 6.0% maximum[2]
Vertical clearance bridges to overhead	5.5 m desirable; 5.3 m minimum
Design vehicle	19.5 m semi-trailer / 25 m B-double
Flood immunity	One carriageway flood-free for the 20-year ARI event in designated areas, 100-year ARI elsewhere.

1 Consideration has been made for future widening to 3 lanes in each direction, when required.

2 Desirable maximum length for 6% grade is 500 m.

5.3.2 Sight distance

Sight distance requirements would be in accordance with the design guidelines, in particular:

- Stopping sight distance at all locations on the highway, including adjacent to barriers. The design includes widening of medians around the smaller radius bends to allow sufficient sight distance once the third lanes are added to each carriageway.

- As a minimum, safe intersection sight distance on the highway approaches to all at-grade intersections.
- Approach sight distance for 100 kilometres per hour at all at-grade intersections and, where possible, approach sight distance for 110 kilometres per hour.
- Headlight sight distance in sags.

Because of the large radius curves used in the design, benching of batters for sight distance is generally not required.

5.3.3 Cross-section

The highway cross-section would comprise a dual (divided) carriageway with:

- Two lanes per carriageway, with each lane 3.5 metres wide.
- A minimum median width of 12 metres between edge lines, suitable for future widening to three lanes in each direction.
- A left shoulder 2.5 metres wide generally, and 3 metres wide adjacent to barriers.
- A right shoulder 0.5 metres wide.

Typical road cross-sections are shown on the concept design drawings (see **Appendix A**). The superelevation (that is, the gradient between the inside and outside edges of the road) throughout the project would generally be limited to three per cent.

Across the floodplain, where long flat-grades have been adopted, consideration may be given at detailed design to the use of a four per cent cross-fall to help drain the pavement.

The cross-section includes allowance for cyclists on the shoulder in accordance with the *Pacific Highway Design Guidelines*.

5.3.4 Horizontal geometry

The proposed geometry for the horizontal alignment is shown on the concept design drawings (see **Appendix A**). In accordance with Clause 4.2b of the *Pacific Highway Design Guidelines*, the adopted desirable minimum horizontal radius is 1200 metres, with an absolute minimum of 750 metres. The locations where the horizontal radius would be less than 1200 metres, and reasons for these departures, are summarised **Table 5-3**.

Table 5-3: Departures from desirable minimum horizontal radii

Section	Chainage	Horizontal curve radius	Reason for departure
1	300 to 700	800 m	Alignment kept close to existing highway to minimise impacts on Glenugie State Forest and tie into Woolgoolga to Wells Crossing project.
	780 to 1430	1000 m	Alignment kept close to existing highway to minimise impacts on Glenugie State Forest.
2	13810 to 15530	1100 m	Minimise property impacts in the Old Six Mile Lane area.
3	44770 to 45770	1000 m	Minimise property impacts and severance. Alignment would allow for better use of existing highway asset in Class A upgrade.
	46490 to 48390	1100 m	Reduce deviation from existing highway and minimise property impacts.
	50880 to 51510	1000 m	Minimise property impacts and better tie-back to existing highway alignment.
	57880 to 58440	750 m	Tightly constrained corridor with Yaegl Nature Reserve on one side and cane farms on the other. Alignment would allow for better use of existing highway corridor.
	59850 to 60690	870 m	Tightly constrained corridor with Yaegl Nature Reserve on one side and endangered ecological communities on the other. Alignment would allow for better use of existing highway corridor.
4	63920 to 64610	950 m	Tie-in to existing Serpentine Channel bridge to allow for better use of existing highway asset in Class A upgrade.
	64740 to 65570	1100 m	Alignment would allow for better use of existing highway asset in Class A upgrade.

5.3.5 Vertical geometry

The proposed vertical geometry is shown on the concept design drawings (see **Appendix A**).

The desirable maximum grade of 4.5 per cent has not been exceeded, but a grade of six per cent could be adopted for the approaches to the high-level Harwood Bridge option.

Between Tyndale and Iluka Road, the road would have a flat grade through much of the floodplain.

The road has been designed to avoid aquaplaning — which is a loss of traction and vehicle control — which can occur when the road surface is covered by a flow deeper than five millimetres during storms.

Throughout the project, a cross-fall of three per cent would generally be adopted to direct water flow towards the road shoulders. This satisfies the *Austroads Guide to the Geometric Design of Rural Roads* (Austroads, 2002). For the two lane-configuration, the flow depth would be 2.3 millimetres, increasing to 3.2 millimetres for the three-lane configuration

Where superelevation transitions are located in the areas of low grade, further checks would be required during detailed design to confirm the flow depths do not exceed the levels allowed.

5.3.6 Future conversion to six lanes when required

The cross-section outlined in **Section 5.3.3** includes allowance for a median at least 12 metres wide, within which two additional lanes can be built should a future upgrade to a six-lane road be required. Allowance has been made within the width of the median to ensure sufficient sight distance is available once the additional lanes are built. In some locations, the median would be wider to allow sufficient sight distance adjacent to barriers, once the additional lanes are built.

5.3.7 Auxiliary lanes

There are no auxiliary lanes proposed for the upgrade.

5.3.8 Rest areas

The existing truck stops on the highway between Glenugie and Grafton, for both the northbound and southbound carriageways, would be retained in their current layout.

New rest areas could be located about 50 kilometres north of Halfway Creek, approximately 3.5 kilometres south of Tyndale village. As shown in the concept design drawings (see **Appendix A**), the proposed locations are:

- Northbound — Ch 38700 to Ch 39300.
- Southbound — Ch 38300 to Ch 37700.

The next set of rest areas are 4km (southbound) and 13km (northbound) north of the Iluka Road interchange, which are then about 45km to 55km north of the proposed rest areas on this project respectively.

In selecting these areas, key considerations included:

- Approach and departure grades.
- Potential property impacts, with the intention to use severed portions of properties where possible.
- Opportunities to win (rather than import) fill material, with the preference for the rest areas to be located in cut (or an area with a surplus of cut) to increase the potential fill material for sections to the north.

5.3.9 Truck stopping bays

Truck-stopping bays would be provided at about five-kilometre intervals in accordance with the *Pacific Highway Design Guidelines*.

Truck stopping bays for northbound and southbound traffic would be provided in conjunction with emergency crossovers, as outlined in **Section 5.3.10**.

5.3.10 Emergency U-turn bays, public U-turn bays and crossovers

Emergency U-turn bays have been provided to allow for U-turns to be executed by RTA, police and emergency vehicles in accordance with the *Pacific Highway Design Guidelines*. These would be spaced at about 2.5-kilometre intervals, although specific locations have not yet been determined.

Median crossovers would be provided to allow for switching of traffic flow between carriageways during emergencies or planned maintenance. The median crossovers would be combined with the emergency U-turn bays and truck stops, spaced at about five-kilometre intervals.

Public U-turn bays would be provided in some locations as part of at-grade intersections. In some locations, separate U-turn bays would be provided to facilitate movements not catered for at intersections. When the highway is upgraded from Class A to Class M, the public U-turn bays would be removed. The proposed locations of median crossovers and public U-turn bays are shown in **Table 5-4**.

Table 5-4: Emergency crossovers and U-turn bays

Section	Chainage	Road	U-turn direction [1]	Treatment
1	300	Bald Knob Road	Northbound	U-turn incorporated into at-grade intersection
	2500	Main highway	Southbound	Public U-turn
	3200	Franklins Road	Northbound	U-turn incorporated into at-grade intersection
	5000	Main highway		Emergency cross-over
	6900	Main highway	Southbound	Public U-turn
2	15700	Main highway	Both	Emergency cross-over
	20200	Main highway	Both	Emergency cross-over
	25700	Main highway	Both	Emergency cross-over
	31200	Main highway	Both	Emergency cross-over
	35500	Main highway	Both	Emergency cross-over
3	46200	Main highway	Both	Emergency cross-over
	47400	Main highway	Northbound	Public U-turn
	51500	Main highway	Both	Emergency cross-over
4	64000	Local access	Northbound	U-turn incorporated into at-grade intersection
	66800	Main highway	Both	Emergency cross-over
	68000	Local access	Southbound	U-turn incorporated into at-grade intersection
	68200	Local access	Northbound	U-turn incorporated into at-grade intersection

1 The listed direction refers to the direction in which the vehicle is travelling prior to performing a U-turn.

5.4 Service and access roads

5.4.1 Design criteria

Geometry

Service and access roads have been designed in accordance with the RTA's *Pacific Highway Design Guidelines* and *Road Design Guide*, and Austroads specifications. The design is based on the criteria in **Table 5-5**.

- **Table 5-5: Design criteria for service and access roads**

Design element	Service road design criteria	Access road design criteria
Horizontal alignment	80 km/h	70 km/h
Vertical alignment	80 km/h	70 km/h
Stopping sight distance (reaction time)	100 m (1.5 sec)	80 m (1.5 sec)
Lane width	3.5 m	3.0 m
Flood immunity	5-year ARI event across floodplain; 10-year ARI event elsewhere	10-year ARI event desirable

Sight distance

Sight distance on service and access roads would comply with the design guidelines. In particular, there would be:

- Stopping sight distance at all locations.
- Safe intersection sight distance on the approaches to all at-grade intersections.
- Headlight sight distance in sags.

5.4.2 Cross-section

Service roads would generally comprise two defined lanes, 3.5 metres wide, with:

- Sealed shoulders two metres wide where the road is deemed to be a cycle route (based on *Austroads Guideline Part 14* for an 80 kilometre per hour design speed).
- Sealed shoulders one metre wide elsewhere.
- No kerb and gutter.

Where service roads are parallel to the upgrade, a separation distance of 25 metres (edge line to edge line) would generally be adopted. This separation is based on the required clear zones for both the upgrade and the service road and provision of a five-metre planting (screening) zone between the clear zones. Reduced separation could be used if barriers or alternate screen methods were adopted.

Access roads would generally comprise two three-metre-wide lanes with 0.5-metre-wide unsealed shoulders and no kerb and gutter.

5.4.3 Cyclists and pedestrians

The design of the service road / alternate route through Sections 3 and 4 would allow two-metre-wide shoulders for cyclists.

5.5 Reuse of existing infrastructure

The existing highway represents a significant investment, and there are major benefits in maximising its reuse. **Table 5-6** lists the sections of the existing highway that could be reused.

Where the existing highway would be retained as part of the Class A upgrade (sections 3 and 4), it would be upgraded for inclusion in the Class M upgrade. This upgrade includes raising levels to achieve the required flood immunity and improving the alignment geometry and cross-section to meet current standards, as required.

Table 5-6: Re-use of the existing highway assets

Section	Chainage	Indicative reuse for existing highway
1	0 – 10100	Existing highway to be used as service road along western side of new highway.
2	10100 – 42600	Existing highway to be retained as alternate route between Glenugie and Tyndale interchanges, providing access to Grafton.
	42600 – 44400	Existing highway to be retained north of Tyndale interchanges as alternate route.
3	44400 - 45700	Existing highway to be retained for local access.
	45700 – 49600	Existing highway to be retained as northbound carriageway (under Class A).
	49600 – 51500	Existing highway to be retained for local access around Shark Creek.
	51500 – 55100	Existing highway to be retained as northbound carriageway (under Class A).
	56200 – 59900	Existing highway to be retained as southbound carriageway (under Class A).
	59900 – 60700	Existing highway not used (Yamba interchange).
4	60700 – 62100	Existing highway to be retained as northbound carriageway (under Class A) and as alternate route under Class M.
	63300 – 68100	Existing highway to be retained as southbound carriageway (under Class A).
	68100 – 70900	Existing highway not used other than existing southbound bridge at Mororo.

5.6 Grafton Airport

The upgrade route would pass to the south-east of Grafton Airport. The alignment (including allowances for vehicles) has been checked to confirm that the concept design satisfies the safe height limitation of the Grafton runway, (as provided by Clarence Valley Council). **Appendix B** shows a schematic drawing for the Grafton runway safe heights limitation.

5.7 Lighting

Lighting will be considered as part of the detailed design.

5.8 Barriers, signage and line marking

5.8.1 Barriers

Safety barriers would be provided at numerous locations in accordance with the RTA's *Road Design Guide*. Thrie-beam and W-beam rails are specified adjacent to bridges, while wire rope safety fence is specified as required in most other locations.

Safety barriers would be provided where fill batters are at a slope greater than 1V:4H and embankments are greater than two metres high. Safety barriers would be reduced across the floodplain through the use of 1V:4H batters.

Wherever wire rope safety fence is specified, the design is in accordance with the *Pacific Highway Design Guidelines*, Issue 2.4, RTA's *Road Design Guide* (RTA, 2006f) and standard RTA model drawings. In particular, in the design:

- The berm behind the safety fence is increased to 1.5 metres wide.
- The verge is widened at each terminal.
- There are standard transitions between the wire rope safety fence and W-beam.

5.8.2 Signposting policies

Signposting design will be undertaken as part of the detailed design. Regulatory, warning and directional signs shall be prepared in accordance with:

- *AS 1742 – Manual of uniform traffic control devices.*
- *Pacific Highway Design Guidelines*, *Upgrading Program Beyond 2006 – Design Guidelines*, Issue 2.4 (RTA, 2006f).
- RTA's *Road Design Guide* and model drawings.
- Austroads *Guide to Traffic Engineering Practice, Part 8 – Traffic Control Devices*.

In determining signposting requirements, sufficient and suitable signage shall be provided at the Glenugie and Tyndale interchanges in view of the long distance between these locations without the opportunity for exit.

5.8.3 Line marking

All line marking would comply with:

- *AS 1742 – Manual of uniform traffic control devices.*

- *Pacific Highway Design Guidelines, Upgrading Program Beyond 2006 – Design Guidelines, July* 2005, Issue 2.4 (RTA, 2006f).
- RTA's *Road Design Guide* and model drawings.

Line marking designs are included in the concept design drawings (see **Appendix A**).

5.9 Stage 2 road safety audit

The RTA conducted a Stage 2 Road Safety Audit[2] on the upgrade in March 2008. The concept design has been revised in response to the findings of this audit.

5.10 Occupational health and safety in design

An OHS in Design workshop was conducted on 29th March 2007. The workshop identified a series of issues and control measures covering a range of activities. During concept design, these issues were reviewed to ensure that they were designed out of the project, where practical and applicable.

5.11 Alternative options considered in the design

During the concept design, there were a number of areas where alternative designs were considered. These are presented below.

5.11.1 Glenugie interchange

A number of interchange options were considered for Glenugie, based on different locations and layouts. The locations considered included Eight Mile Lane, the point where the upgrade would leave the existing highway (about 1100 metres south of Eight Mile Lane), and adjacent to the Telstra tower (about 2900 metres south of Eight Mile Lane). The options are summarised below.

- Option 1 — a full diamond interchange with local road connection on the eastern side of the interchange to provide access to Glenugie State Forest. Eight Mile Lane to be bridged across upgrade on existing alignment.
- Option 1a — as per Option 1 but with Eight Mile Lane connected to the eastern side of the interchange instead of bridged across the upgrade.
- Option 2 — similar to Option 1 but with improved 'flow' between south facing-ramps and access to Grafton. The southbound off-ramp would become a loop to suit arrangements.
- Option 2a — as per Option 2 but with Eight Mile Lane connected to the eastern side of the interchange instead of bridged across the upgrade.
- Option 3 — a full diamond interchange at Eight Mile Lane. Eight Mile Lane to be upgraded between the interchange and the existing highway to cater for the increased traffic. Access to Glenugie State Forest to be provided from Eight Mile Lane.

---

[2] A Stage 2 Road Safety Audit is undertaken at the preliminary design stage of project development.

- Option 4 — a split interchange with south-facing ramps at Glenugie and north-facing ramps at Eight Mile Lane. The access to Glenugie State Forest would be from Eight Mile Lane to avoid creating conflict points on the interchange.
- Option 5 — a full diamond interchange located adjacent to the Telstra tower, closer to the existing highway.

Option 4 was preferred as:

- It would provide better traffic flows for the south-facing ramps.
- It would be a safer option through reducing the conflict points.
- The layout would have potential for a safety upgrade to the bends south of Eight Mile Lane.
- The location of the north-facing ramps off Eight Mile Lane would provide better access to the upgrade for traffic from Pillar Valley and Wooli to the east.

5.11.2 Tyndale interchange

For the interchange layout at Tyndale, locations were generally considered in the village and immediately north of the village. The major options were:

- Option 1 — a full interchange at Tyndale. The alternate route (from the north) would use the existing highway north of Tyndale then cross to eastern side of upgrade about two kilometres north of the interchange. Access would be from the interchange to properties on the eastern side of Tyndale.
- Option 2 — a full interchange at Tyndale. The alternate route (from the north) would continue along the eastern side of the upgrade to the interchange and also provide local road access. The existing highway north of the interchange would be a no through road.
- Option 3 — a full interchange at Tyndale. The alternate route (from the north) would cross the upgrade at the northern end of the range, clear of floodplain (about one kilometre north of the interchange). Local road access south of the interchange would connect at the interchange location. Local road access north of the interchange would be off the new alternative route. The existing highway north of the crossover point would be a no through road.
- Option 3a — similar to Option 3 but with north-facing ramps only at Tyndale and south-facing ramps south of Tyndale in the flood reserve.
- Option 4 — similar to Option 1 with local road access north of the interchange from the alternate route to the north, rather than from the interchange.
- Option 5 — a full interchange north of Tyndale. The interchange would be at a proposed cutting at the end of the range. The interchange would be used to cross an alternative route from the eastern side of the upgrade (north) to the western side (south). Local access road connections and ramps result in 5-way roundabouts either side of interchange. Local road access to east of upgrade, south of Tyndale to cross under the highway at Tyndale.

- Option 5a — similar to Option 5 but with north-facing ramps only at Tyndale and south-facing ramps located south of Tyndale in the flood reserve.

Following the development of a number of these options, Option 3 was selected as the preferred option, but modified from the original diamond layout to improve traffic flow for the north-facing ramps. The local road connection to Bensons Lane was also separated from the interchange to reduce conflict points. This option was selected because it would:

- Provide the most direct access from the existing highway to the upgrade, and improve traffic flow.
- Remove most of the traffic from the existing highway north of Tyndale, thus confining noise generation to one side only.
- Enable efficient use of existing infrastructure with inclusion of much of the existing highway into the project.
- Provide a better functional outcome by removing the need for a crossing over the upgrade on the floodplain (where there are soft soils) and reduce the impact to the hill to the east by eliminating the service road immediately north of the interchange.

5.11.3 Section 3 access options

Between Tyndale and Maclean, the need for access is driven mainly by the requirements for access to and from cane farms and pads. Along this section of the upgrade (about 11 kilometres), there are eight side roads, numerous property accesses and a number of cane pads with direct access to the existing highway.

With the sugar mill located to the north of this section of the highway, the desire line for the cane trucks is to turn right (north) onto the highway.

A number of cane growers work multiple properties through this section, which also generates traffic (mainly farm machinery). Much of this traffic currently uses farm tracks through various properties to access the required properties.

Due to the location of the upgrade, little cross-traffic is generated, although there is a need to provide for cross-movement at Shark Creek.

For this section, a number of access options were considered for the Class A upgrade:

- Option 1 — combination of eight seagull intersections and about 3.8 kilometres of service roads.
- Option 2 — combination of nine intersections with left-in, left-out and right-out, about 3.8 kilometres of service roads and four U-turn facilities.
- Option 3 — full-length service road between Tyndale and Maclean.

The inclusion of right-in movements instead of right-out movements was also considered for Option 2, with the need for additional U-turn facilities. This option was not adopted due to the adverse impacts on cane vehicle movements, which would have resulted in all cane needing to initially turn south onto the upgrade before undertaking a U-turn to head north to the Harwood Mill.

In considering the above options, it should be noted that the proposed Class M access strategy is to provide a full-length service road between Tyndale and Maclean, with no at-grade intersections. These options are further described in **Table 5-7**.

Table 5-7: Section 3 access options

	Option 1	Option 2	Option 3
Intersection Locations	Lane adjacent Gregor property — seagull Byrons Lane — seagull Cane pad south of Norleys Lane — seagull Norleys Lane — seagull Lane through Maloney property — seagull North of Shark Creek Road — seagull McIntyres Lane — seagull Causleys Lane — seagull	Lane adjacent Gregor Property — left-in, left-out and right-out Byrons Lane — left-in, left-out and right-out Cane Pad — left-in, left-out and right-out Norleys Lane — left-in, left-out and right-out Gallaghers Lane — left-in, left-out and right-out Shark Creek — left-in, left-out either side of upgrade Main Highway — left-in, left-out and right-out Cane Pad — left-in, left-out and right-out North of Causleys Lane — left-in, left-out and right-out	Nil — service road would connect to Tyndale interchange and Maclean interchange
U-Turn Locations	Nil	North of Tyndale Interchange North of Byrons Lane Shark Creek	Nil
Cross Highway Access	Shark Creek Road to cross below upgrade	Shark Creek Road to cross below upgrade	Shark Creek Road to cross below upgrade
Service Roads	Total of 4.6km of service road in 6 locations	Total of 4.6 km of service road in 6 locations	Total of 11.8 km of service road
Advantages	Provides for all movements at intersections	Removal of right turn-in would eliminate conflict point from the intersections.	Would remove all intersections, thus improving safety Would avoid construction of pavements at intersections that would later be removed. Separation of local and through / regional traffic would improve accessibility for farm machinery

	Option 1	Option 2	Option 3
			Would minimise the ultimate land-take as no additional area is required at intersections
Disadvantages	Right turn out impacts on safety	Would provide less direct access from south to side roads and properties	Would require full acquisitions under Class A Would increase initial construction cost

At this stage, Option 2 has been adopted. However, the RTA's Road Safety Section is conducting further studies on right-turn movements at intersections, which would need to be considered in the development of the final design for access through this section.

5.11.4 Maclean/ Yamba Road interchange options

As part of the preferred route announcement, a single interchange was included in the Maclean area. During the concept design phase, interchanges were considered at:

- Maclean — Cameron Street/ Jubilee Street.
- Yamba Road.

A number of strategic options were developed for this area including:

- Option 1 — full interchange at Yamba Road.
- Option 2 — full interchange at Cameron Street/ Jubilee Street.
- Option 3 — split interchange with south-facing ramps at Cameron Street/ Jubilee Street and north-facing ramps at Yamba Road.
- Option 4 — split interchange with south-facing ramps at Cameron Street/ Jubilee Street and north-facing ramps at Watts Lane.
- Option 5 — full interchange at Cameron Street/ Jubilee Street and Yamba Road.
- Option 6 — full interchange at Cameron Street/ Jubilee Street with south-facing ramps at Yamba Road.
- Option 7 — full interchange at Cameron Street/ Jubilee Street with north-facing ramps at Yamba Road.
- Option 8 — full interchange at Yamba Road with south-facing ramps at Cameron Street/ Jubilee Street.
- Option 9 — full interchange at Yamba Road with north-facing ramps at Cameron Street/ Jubilee Street.

Following an initial review of the strategic options, the following options were removed from further consideration:

- Option 3 — this would require a service road between Ferry Park and Yamba Road from initial construction. It would carry a significant volume of the local traffic, resulting in the upgrade being underutilised.
- Option 4 — this would require a service road between Ferry Park and Watts Lane from initial construction. It would carry a significant volume of the local traffic, resulting in the upgrade being underutilised.
- Option 6 — south-facing ramps at Yamba Road. This would require northbound traffic to initially head south and then undertake a U-turn. This proportion of traffic is significant and would not adequately meet community needs.
- Option 7 — this would require a service road between Ferry Park and Yamba Road from initial construction. It would carry a significant volume of the local traffic.
- Option 9 — north-facing ramps at Ferry Park would service the local cane trucks heading north not adequately meet community needs with regards to Maclean traffic heading south.

While a number of these options would provide the necessary connection and access to the highway, it was thought that other options would better cater for local traffic needs.

Further consideration of access in this area recommended that interchanges be included at Maclean and Yamba Road as well as Watts Lane, Harwood.

The Maclean interchange design was further developed, and the following options were considered:

- Option 1 — full diamond at Cameron Street.
- Option 2 — full diamond at Jubilee Street.
- Option 3 — split interchange with north-facing ramps at Jubilee Street and south-facing ramps at Cameron Street.
- Option 4 — split interchange with southbound off-ramp at Jubilee Street and other ramps at Goodwood Street.

The interchange option at Goodwood Street (Option 4) was preferred because:

- Its ramps would be located further away from the Clarence River than the Cameron Street option, making it easier to build.
- It would have a smaller footprint at Jubilee Street, where the main concentration of housing is located.

- It would provide an opportunity to improve the road alignment between Jubilee Street east of the upgrade and Cameron Street.
- The southbound off-ramp at Jubilee Street would provide improved travel efficiencies to Townsend and Gulmarrad from the north.

The Yamba Road interchange options considered included:

- Option 1 — diamond interchange located south of Yamba Road, adjacent the Yaegl Nature Reserve.
- Option 2 — interchange south of Yamba Road similar to the existing layout, with increased ramp lengths to suit current design standards.
- Option 3 — interchange south of Yamba Road (as above) but with connection on the eastern side of the upgrade to Yamba Road via James creek Road.

In considering these options, both the high-bridge and low-bridge options for the Clarence River crossing were taken into account. Option 2 was preferred because:

- It would enable the use of the existing highway south of the interchange as part of the upgrade.
- It would result in a lower impact to cane lands than Option 1.
- It would not require an overbridge (as in Option 1), which would likely provide significant savings.
- Option 3 would require two crossings of James Creek, which would increase the potential impact of the ramps and cost.
- Option 3 would potentially require an upgrade to Yamba Road to include sufficient turning lanes, thus increasing the costs.

5.11.5 Harwood Bridge

Two options were considered for Harwood Bridge, a low-level and a high-level bridge. These options are discussed in **Section 7.3**.

5.11.6 Watts Lane interchange

A Harwood interchange was not included as part of the preferred route. However, with the inclusion of only one new bridge under the Class A upgrade, access would have needed to have been provided. It was considered that having provided an interchange under the Class A upgrade, this should remain for the ultimate Class M upgrade.

In designing the Watts Lane interchange, the major considerations included:

- The need for east-west traffic movements along Watts Lane to access the Harwood Mill.
- The need for the design to cater for both the high- and low-bridge options.

- The need to provide access to Harwood village.

The options developed into variations on ramp layouts to suit the above needs, as well as consideration of Watts Lane crossing under or over the upgrade.

Due to the proximity of Watts Lane to Harwood Bridge, the option for the low bridge is different to that for the high bridge. In looking to avoid the construction of ramps on the Harwood Bridge, there is insufficient distance available between the northern end of a high-level bridge and Watts Lane for the construction of the interchange. Hence, the interchange has been designed with ramps north of Watts Lane. For the low bridge, sufficient distance is available between the northern end of the bridge and Watts Lane for the construction of the interchange. Hence, this location has been adopted due to the reduced distance to Harwood and the reduced impact on cane lands.

Another consideration for this interchange was the use of a diamond layout. This option was not further developed due to the overall area required once the additional service roads had been placed outside the diamond and sufficient separation provided between the intersections.

The design of Watts Lane under the upgrade was adopted in favour of it going over the upgrade, as it would be easier to build. By leaving Watts Lane at ground level, the construction of the upgrade can proceed without significant impact on the operation of Watts Lane.

5.11.7 Section 4 access arrangements

Across Harwood and Chatsworth Islands, most traffic is generated from cane farms. This includes cane haulage and machinery movements as well as other private trips. While cane haulage is directed to the south (Harwood Mill), there is a significant need for machinery movements both along and across the upgrade because cane growers work multiple properties.

The major traffic movements on the section north of Harwood are:

- Strong movement across the highway at Watts Lane, where there are cane haulage routes.
- Use of the old Pacific Highway Bridge over Serpentine Channel by cane growers for machinery and cane haulage.
- Movement across the highway at Chatsworth Road/Serpentine Channel North Bran Road by cane growers operating properties on either side of the highway.
- Movement across the highway at Fischers Road by cane growers operating properties on either side of the highway.
- Movement across Mororo Bridge by cane growers operating properties on either side of the Clarence River North Arm.

Other points of note include:

- One cane grower owns properties off both Ryans Road and Anderson Lane.
- Cane is not hauled through the villages of Harwood and Chatsworth.
- Cane trucks cannot turn left from Chatsworth Road into North Arm Drive due to the tight radius of the corner and the proximity of an existing residence.

Having reviewed the needs of cane growers in this area, the options for access include:

- Option 1 — combination of at-grade intersections with some service roads and U-turn facilities.
- Option 2 — full-length service road between Watts Lane and Iluka Road interchanges on the western side of the upgrade, along with additional service roads on the eastern side.

To reduce the amount of service roads required during the Class A upgrade, Option 1 was adopted. The final layout for this option involves:

- Grade separation of through movements for Watts Lane below the upgrade.
- Construction of a service road on the western side of the upgrade between Watts Lane and Andersons Lane.
- Construction of a service road on the western side of the upgrade between Ryans Road and Chatsworth Road.
- Construction of a left-in, left-out and right-in intersection at Serpentine Channel Road South with gravel track access to the existing cane pad south of this point and the old Pacific Highway Bridge over Serpentine Channel.
- Construction of a left-in, left-out intersections either side of upgrade at Chatsworth Road/Serpentine Channel Road North with grade separation of the cross movement over the upgrade.
- Construction of staggered left-in, left-out and right-in intersections either side of Carrolls Lane to allow access to upgrade and U-turn facilities with future grade separation of through movement at Class M upgrade.
- Construction of a service road on either the eastern side of the upgrade between Carrolls Lane and Fischers Road.
- Retention of the old Mororo Bridge as an access road between Fischers Road and Garretts Lane for movement of machinery.
- Construction of a service road on the western side of the upgrade between Garretts Lane to the Iluka Road interchange and north to Banana Road.
- Construction of a service road on the eastern side of the upgrade between Garretts Lane and the Iluka Road interchange (via the old Pacific Highway).

Some other options have been considered, such as continuation of the access road from Watts Lane to Chatsworth Road and adoption of an arrangement at Chatsworth Road/Serpentine Channel Road North similar to that for Carrolls Lane. However, it was agreed that the above arrangements would provide good value for money in the Class A stage.

5.11.8 Iluka Road interchange

The options considered for the Iluka Road interchange were all variations on the diamond layout, including:

- Option 1 — full diamond interchange with local road connection on the western side of the interchange.
- Option 2 — full diamond interchange with a local road connection on the western side of the interchange. Southbound ramps would use Old Pacific Highway, with the southbound on-ramp to extend from the local access road.
- Option 3 — similar to Option 1 but with a northbound on-ramp extending from the connection to Banana Road. This option would require a single intersection only on the western side of the intersection.
- Option 3a — combination of Option 3 and Option 2, in that southbound ramps would use Old Pacific Highway and the northbound on-ramp would extend from the connection to Banana Road.

In considering these options, Option 1 was preferred due to the safety benefits from separating local traffic and highway traffic. In adopting Option 1, the service road connections to the west could either include an intersection west of the interchange ramps or could connect to Iluka Road through a five-way roundabout. Both these options would require a similar footprint, and as such the final decision has been delayed until the detailed design.

6. Traffic

6.1 Existing traffic conditions

6.1.1 Pacific Highway traffic volumes

Traffic volume data was collected as part of the preliminary traffic assessment in October–November 2004. This was supplemented by data from the RTA's permanent count stations to allow expansion to annual average daily traffic volumes (AADT[3]) and to examine historical growth trends. **Table 6-1** shows recent AADT volumes for three Pacific Highway sites in the study area.

- **Table 6-1 Annual average daily traffic volume (vehicles[4])**

	South of Grafton (RTA Station 04.002)	South of Maclean (RTA Station 04.400)	South of Woodburn (RTA Station 04.233)
2001	6,700 (20% HV)	6,340 (20% HV)	5,760 (22% HV)
2004	8,520 (20% HV)	7,500 (20% HV)	7,480 (22% HV)
2007[5]	9,200 (20% HV)	8,100 (20% HV)	8,500 (22% HV)

The average daily traffic profile for the survey week in October–November 2004 is shown in **Figure 6-1**. This is for the Pacific Highway south of Grafton, but a similar pattern was observed at other Pacific Highway locations.

The survey shows there is a relatively consistent volume of heavy vehicles throughout the day and night. Late at night and early in the morning, heavy vehicles outnumber light vehicles, but between 4am and 9pm there are significantly more light vehicles on the road.

The Highway carries about 20 per cent heavy vehicles. Since 1978, traffic has grown at about 2.6 per cent per annum[6] (base year 2004), although the growth rate since 1998 (commencement of the Pacific Highway Upgrade Program) is 4.7 per cent (base year 2004), due largely to the increase in B-double traffic since the opening of the Yelgun to Chinderah bypass in 2002, which allowed these vehicles to switch from the New England Highway route.

---

[3] Annual average daily traffic — the number of vehicles passing a particular point during a calendar year, divided by the number of days in that year.

[4] RTA data has been converted from Axle Pairs to Vehicles based on surveys from October–November 2004. Heavy vehicle percentages are based on the same surveys.

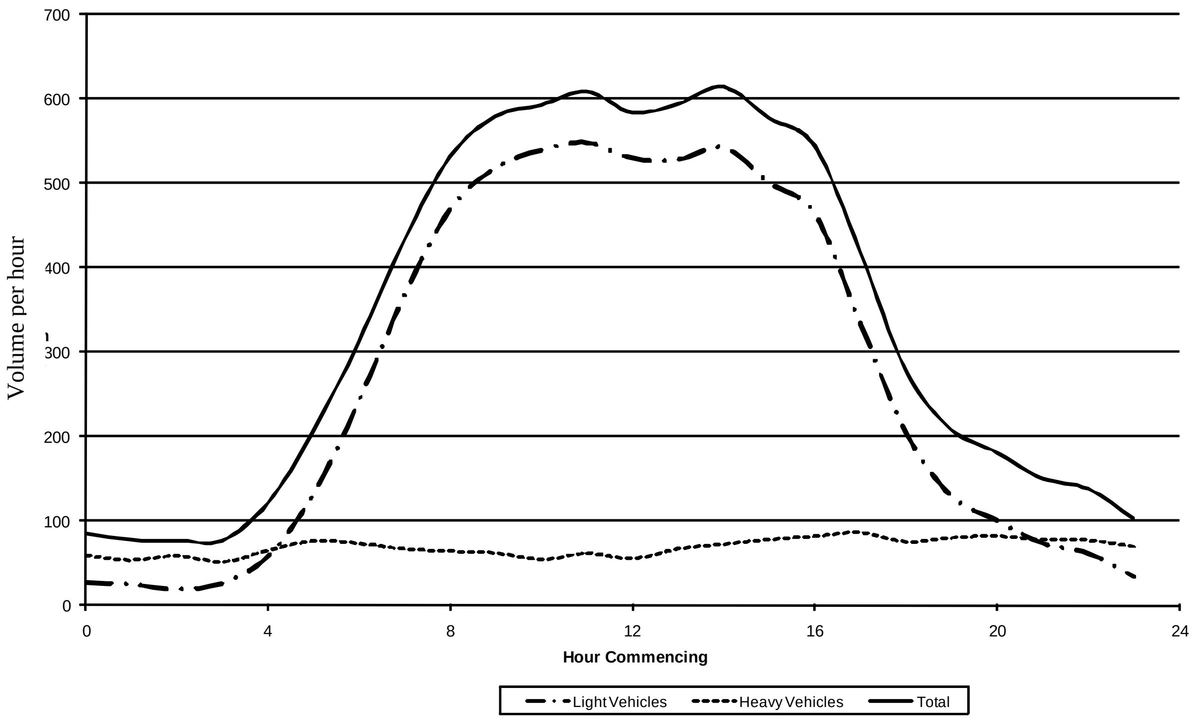
[5] Provisional RTA data

[6] South of Grafton

6.1.2 Travel times

Based on the posted speed limit, the travel time along the existing highway between Wells Crossing and Iluka Road (a distance of about 82 kilometres), is about 51 minutes, indicating an average speed of over 95 kilometres per hour. For the most part, a speed limit of 100 kilometres per hour applies to the highway, although there are lower speed limits through built-up areas such as South Grafton and Ulmarra.

- **Figure 6-1: Average daily traffic profile south of Grafton, October–November 2004**



6.1.3 Traffic patterns

To investigate traffic patterns within the study area, an origin–destination (O–D) survey was undertaken on Friday 29 October 2004**.** The number plates of white cars and all trucks were recorded at eight locations and subsequently matched to provide an indication of the origin and destination of traffic within the study area**.**

Traffic was recorded in both directions between 6am and 6pm. A classified tube count was undertaken at each of the survey sites to provide an indication of sample size and allow expansion to AADT volumes**.**

The largest volume of light vehicles was surveyed travelling to and from Grafton, with a similar volume travelling to and from the Maclean and Yamba areas**.** A similar pattern was observed for heavy vehicles, although a greater through-traffic component was recorded.

About 70 per cent of all trips recorded can be classified as internal or local trips, with both the origin and destination within the study area.

Through traffic, with both origin and destination outside the study area, made up 28 per cent (northbound) and 30 per cent (southbound) of all traffic entering the study area, with 37 per cent of through traffic being heavy vehicles.

6.1.4 Crash history and State Government targets

The crash history of the highway in the study area as recorded by the RTA has been analysed for the five-year period April 2000 to March 2005. The data shows:

- 334 crashes (average 67 per year).
- 12 fatal crashes (an average of 2.4 per year).
- 122 crashes resulting in injuries (average 24.4 per year).

Currently, on the Pacific Highway within the study area, crashes occur at a rate of almost 28 per 100 million vehicle kilometres travelled. This is almost twice the target rate for the Pacific Highway Upgrade Program (which is 15). There are almost 1.2 fatalities per 100 million vehicle kilometres traveled, which is almost twice the State Plan target of 0.7 fatalities per 100 million vehicle kilometres travelled[7].

6.2 Traffic assignment and forecast volumes

A comparison of the projected traffic for the proposed upgraded highway with the projected flows for the existing highway is shown in **Table 6-2**.

These forecasts are based on different growth rates being calculated for local, through and heavy vehicle traffic: local traffic is forecast to grow in line with local population growth (1.75 per cent per annum); light through traffic is forecast to grow at the observed post-1998 rate (4.7 per cent per annum); and heavy vehicle traffic is forecast to grow in line with Gross Domestic Product (four per cent per annum).

[7] State Plan Priority S7 (http://www.nsw.gov.au/stateplan/index.aspx?id=03d89116-1ab0-4e3d-b91c-c1968c8bec1c)

Table 6-2: Projected average annual daily traffic (vehicles)

Highway section	2004 (existing)	2011 (with upgrade)	2021 (with upgrade)
Wells Crossing to Eight Mile Lane (Section 1)	8,170 (20% HV)	9,840 (21% HV)	12,220 (22% HV)
Eight Mile Lane to South Grafton, Charles Street (existing highway)	8,170 (20% HV)	6,290 (15% HV)	7,570 (16% HV)
South Grafton, Charles Street to Tyndale (existing highway)	7,930 (21% HV)	6,270 (16% HV)	7,450 (17% HV)
Eight Mile Lane to Tyndale (upgraded highway Section 2)	n.a.	3,550 (32% HV)	4,660 (32% HV)
Tyndale to Harwood Bridge (Section 3)	7,930 (21% HV)	9,820 (23% HV)	12,110 (23% HV)
Harwood Bridge to Iluka Road (Section 4)	8,890 (18% HV)	10,580 (20%)	13,020 (21% HV)

6.3 Operational performance

6.3.1 Highway operation

The performance of a road during a particular hour can be measured with reference to the road's capacity and the volume using the road, to estimate a level of service (LOS). The LOS of a section of road varies from A (good) to E (poor), and describes the ease with which drivers are free to select their desired speed and manoeuvre within the traffic stream[8]. Reference is made to the 100th highest hourly volume, which is specified as the design hour. The 100th highest hourly volume is defined as the volume that is exceeded in only 99 hours per year and is about 10 per cent of AADT.

Under current conditions, the highway during the 100th highest hour is operating at LOS C, with the exception of south of Grafton, which is at LOS D. Without the highway upgrade, LOS during this hour would be D in all locations along the highway by 2021. It is anticipated that with the highway upgraded to a high-capacity dual-lane carriageway, LOS A would be attained well into the future (i.e. beyond 2020).

6.4 Intersection performance

The project objectives, as set by the RTA, include: "provide intersections designed to provide at least level of service C 20 years after opening for the 100th highest hourly volume". The proposed interchanges and intersections under Class A have been assessed and would provide a Level of Service C or better for the design hour.

[8] A roadway with Level of Service D is operating close to its limit of stable flow, with all drivers being severely restricted in their freedom to select their desired speed and to manoeuvre in the traffic stream. At Level of Service E traffic volumes are close to or at capacity and there is virtually no freedom to select desired speeds or manoeuvre in the traffic stream.

6.5 Distance and travel time savings

6.5.1 Distance

The length of the highway upgrade would be about 71 kilometres. The corresponding section of the existing highway is about 82 kilometres. This gives a distance saving of about eleven kilometres for through traffic. The estimated savings in vehicle kilometres travelled that would arise with the upgraded highway is shown in **Table 6-3**.

- **Table 6-3: Savings in vehicle kilometres travelled**

Year	Travel per year — existing conditions (million vehicle km)	Travel per year — with upgraded highway (million vehicle km)	Travel saving per year (million vehicle km)
2004	241.8	232.2	9.6
2021	356.8	341.9	14.9

6.5.2 Travel time analysis

The Pacific Highway Upgrade Program aims to reduce travel times. **Table 6-4** shows the design speeds and travel times (at design speeds) over the project length for through traffic. With the upgrade to motorway standard, through traffic would save 11 minutes per trip compared to the existing highway.

- **Table 6-4: Travel times for through traffic**

Scenario	Distance (km)	Speed limit (km/h)	Travel time (min)
Existing highway	82 km	50/60/80/100	51
Arterial standard upgrade	71 km	100	43
Motorway standard upgrade	71 km	110	39

6.6 Reduction in crashes

Crashes on the highway occur at the rate of about 28 per 100 million vehicle kilometres travelled (MVKT). Once the highway is upgraded, the number of fatal crashes in the corridor would decrease by over 30 per cent to approximately 0.7 per 100 million vehicle kilometres travelled. This is in line with the State Plan target for road safety improvements.

In particular, the upgraded highway would reduce crashes resulting from head-on collisions, vehicles hitting objects adjacent to the road and hitting animals. Combined, these crash types make up 44 per cent of the total crashes and 50 per cent of fatal crashes recorded on the highway. Improved safety would come from:

- The wide, vegetated median on the upgraded highway, which is expected to significantly reduce head-on accidents.

- The provision of sealed shoulders and removal of roadside objects, which is expected to greatly reduce accidents resulting from hitting off-road objects and animals.

The future upgrading of the arterial road sections to motorway standard would further reduce accident rates by removing all at-grade intersections.

6.7 Provisions for cyclists

The *Pacific Highway Design Guidelines* require a minimum nearside shoulder width of 2.5 metres with a minimum of three metres adjacent to the safety barrier. The RTA's *Bicycle Guidelines* (RTA, 2003) and *Austroads Guide to Traffic Engineering Practice – Part 14 Bicycles* (Section 4.4.2) suggest a 2.5 metre shoulder as desirable on freeways, with an absolute minimum width of two metres.

The Department of Planning is co-funding (with local government) a NSW Coastline Cycleway. The Department of Planning has identified a route for the Coastline Cycleway in conjunction with the Clarence Valley Council. Within the study area, the Coastline Cycleway would use the existing Pacific Highway between Wells Crossing and South Grafton, and then travel via Grafton, Lawrence and Maclean to Yamba.

Cycle lanes would be provided through at-grade intersections and crossing points on interchange ramps.

7. Bridges and other structures

Only sufficient design has been undertaken to provide ‘proof of concept’ for bridge structures. Many of the details of the proposed upgrade bridge structures may change during detailed design. The types and configurations of structures have been chosen on the basis of cost effectiveness and no detailed investigation of alternatives has been undertaken at this stage.

In general, scour has not been addressed for structures spanning waterways. It is expected that the flood velocities across the floodplains are low. They would increase, however, in some of the smaller waterways, so it will be necessary to investigate scour during the detailed design.

Specific details regarding access requirements to maintain structures have not been addressed in the concept design and will be determined as part of the detailed design.

7.1 Basis of design

Bridges located on separate carriageways shall be designed as stand-alone structures and must not be connected.

Each road bridge carrying traffic must be load rated against the SM1600 loading in accordance with AS 5100.7. Bridges shall be designed in accordance with the references outlined in **Section 17.6**.

The development of the environmental assessment and detailed design will need to consider any updating of design standards subsequent to the concept design.

7.2 Existing structures

7.2.1 Bridges

In Sections 1 and 2, the upgrade would be built away from the existing highway alignment, which would be retained as the alternate route. Therefore, the use of existing bridges along this portion of the highway would not be impacted by the upgrade.

In Section 3, the main bridge of note along the existing highway is at Shark Creek. This section of the upgrade includes a realignment of the existing highway, which would be retained as a service road, so the use of the existing bridge would not be impacted.

In Section 4, a number of bridges would be retained as part of the upgrade, including:

- Clarence River (Harwood Bridge) — this bridge would be incorporated as part of the northbound carriageway under the Class A upgrade, and become a service road under Class M.
- Serpentine Channel — this bridge would be incorporated as part of the southbound carriageway.
- Clarence River North Arm (Mororo Bridge) — the current northbound bridge would be retained as a service road, while the southbound bridge would be converted to a northbound bridge.

A structural assessment of the bridges to be retained will be undertaken closer to the time of the detailed design.

7.2.2 Drainage structures

In section 1, a number of fauna crossings are proposed in conjunction with the drainage structures. The corresponding structures below the existing highway would require upgrading in order to provide sufficient passage across the full road corridor. The locations of the combined fauna / drainage structures and the proposed upgrades are listed in **Table 7-1**.

- **Table 7-1: Existing structures to be upgraded**

Section	Chainage	Existing structure	Proposed structure (or equivalent)
1	2475	1 x ϕ300 pipe	2.4 m high clear passage either side of low-flow channel. Fauna passage to be raised above invert of low flow.
	4415	2 x 2.4 m wide x 2.4 high culvert	3 x 2.4 m wide x 2.4 high culverts with outer culverts raised 0.6 m above invert of middle culvert.
	5225	2.1 m wide x 1.5 high culvert	2.4 m wide x 2.4 high culvert
	5865	2 x ϕ1350 pipe	2.4 m wide x 2.4 high culvert
	6465	2.1 m wide x 2.1 high culvert	2.4 m wide x 2.4 high culvert

7.3 Proposed bridges

7.3.1 Harwood Bridge

The following information is taken from the *Harwood Bridge Options Working Paper* (RTA, 2008g). The existing bridge at Harwood is a two-lane, steel-truss, lift-span bridge, which opens to a height of 36.5 metres to allow the passage of yachts and other vessels further upstream. The proposed upgrade would involve duplicating the bridge immediately downstream (east) of the existing bridge, with a gap of 10 to 15 metres between each to provide room for construction as well as light penetration to the river below. The initial Class A upgrade would involve building one new bridge, with the existing bridge used as the northbound carriageway. Under a later Class M upgrade, an additional (third) bridge would be built, with the existing bridge used as part of the local road network. Two options are being considered for the new bridge(s), namely, a low-level bridge and a high-level bridge, as described below.

Low-level bridge

The opening span for the low-level bridge would be matched to the existing bridge with a span length of 38 metres and an opening height of 30 metres. The opening span would be comparable to the existing arrangement. The superstructure for a low-level bridge is dictated by the spans of the existing bridge. The concept design for the low-level bridge has nine 43.7-metre spans (393 metres) on the northern approach to the opening span and ten 43.7-metre spans (437 metres) on the southern approach. The likely methods of building the superstructure would be either ‘launched’ or span-by-span precast segmental construction.

High-level bridge

As with the low-level bridge options, the high-level bridge design is dictated by the spacing of the piers for the existing bridge, although various spacing arrangements have been considered. For the high-level bridge options it is considered that segmental precast or cast *in situ* balanced cantilever are both viable solutions for the main spans over the river and precast concrete T-girders are the most appropriate solution for the approach spans over the land. The viability of precast segmental construction is dependent on the volume of girders that are required for the project. Cast *in situ*, balanced cantilever construction is significantly slower than precast segmental construction but has lower set-up costs. Therefore, if the bridge is not on the critical path for the project, and only one bridge is being built, it is likely to be the most viable solution.

Bridge location options

Alternative alignments (to the east and west of the current bridge) were considered for the proposed bridges over the Clarence River. It was found that no real benefits would be gained from either the western or eastern alignments in terms of social, environmental and functional factors.

Functional, environmental, socio-economic and financial considerations

A comparative assessment was undertaken for the low-level and high-level bridge options in relation to interchange impacts, urban design and visual impacts, traffic and access, environmental impacts, social considerations, and cost. The results of this assessment are summarised in the *Harwood Bridge Options Working Paper* (RTA, 2008g).

Workshop and multi-criteria analysis

A site visit and risk assessment workshop was undertaken on 30 October 2007, attended by key representatives from the RTA and project team. As part of the workshop, a multi-criteria analysis (MCA) was undertaken, based on functional criteria, social and local economic criteria, natural environmental criteria and cost criteria. The workshop and MCA process highlighted key constraints and opportunities associated with the two bridge options and the need to build adequate flexibility into the concept design at this stage. Detail on the workshop and MCA process is provided in the *Harwood Bridge Options Working Paper* (RTA, 2008g).

7.3.2 Other bridges

A significant number of new bridges are included in the proposed upgrade, as shown in **Table 7-2**.

Table 7-2: Bridges required in the project

Section	Chainage	Description	No. of bridges	Nominal width	Approximate length
1	150	Bald Knob Road over upgrade (Class M Only)	1	10	60
	3000	Franklins Road under upgrade (Class M Only)	1	10	60
	9900	Glenugie interchange	1	10	65
	10280	Waterway crossing	2	11.5	35
2	10790	Waterway crossing	2	11.5	165
	10950	Glenugie Interchange Bridge at Eight Mile Lane	2	11.5	30
	11450	Waterway crossing	2	11.5	150
	13300	Old Six Mile Lane over upgrade	1	10	60
	14730	Waterway crossing	2	11.5	65
	16530	Avenue Road under upgrade	2	11.5	30
	17720	Waterway crossing for Coldstream River floodplain	2	11.5	75
	18400	Waterway crossing at Coldstream River	2	11.5	360
	18885	Waterway crossing for Coldstream River floodplain	2	11.5	175
	19105	Waterway crossing for Coldstream River floodplain	2	11.5	75
	20600	Wooli Road over upgrade	1	10	60
	21235	Waterway crossing for Pillar Valley Creek floodplain	2	11.5	80
	21380	Waterway crossing for Pillar Valley Creek floodplain	2	11.5	45
	21505	Waterway crossing at Pillar Valley Creek	2	11.5	95
	21650	Waterway crossing for Pillar Valley Creek floodplain	2	11.5	55
	21780	Waterway crossing for Pillar Valley Creek floodplain	2	11.5	120
	22220	Waterway crossing for Pillar Valley Creek floodplain	2	11.5	50
	22430	Waterway crossing for Pillar Valley Creek floodplain	2	11.5	55
	22800	Waterway crossing for Pillar Valley Creek floodplain	2	11.5	125
	24400	Waterway crossing	2	11.5	90
	24555	Waterway crossing	2	11.5	50
	25385	Waterway crossing	2	11.5	80
2	26950	Firth Heinz Road over upgrade	1	10	60
	27570	Waterway crossing at Chaffin Creek	2	11.5	80

Section	Chainage	Description	No. of bridges	Nominal width	Approximate length
	27650	Waterway crossing at Chaffin Creek	2	11.5	60
	29800	Waterway crossing	2	11.5	105
	30130	Waterway crossing	2	11.5	65
	30550	Bostock Road over upgrade	1	10	60
	31950	Somervale Road under upgrade	2	11.5	30
	32135	Waterway crossing at Champions Creek	2	11.5	80
	33760	Waterway crossing	2	11.5	70
	38700	Property access over upgrade	1	10	60
	40000	Flood Reserve access over upgrade	1	10	60
	42200	Bensons Lane under upgrade (includes additional bridges for interchange ramps)	2 2	11.5 7	25 25
	42450	Tyndale Interchange (includes additional bridge for northbound off ramp)	2 1	11.5 7	30 30
	44300	Alternative route over upgrade	1	10	65
3	45015	Waterway crossing	2	11.5	75
	50150	Shark Creek	2	11.5	830
	55360	Maclean interchange	2	11.5	30
	60650	Waterway crossing (ramp)	1	10	40
4	61400	Harwood Bridge (waterway crossing over Clarence River)	2	11.5	890 – low 1500 – high
	62650	Watts Lane interchange (includes additional bridges for interchange ramps)	2 2	11.5 7	30 30
	64200	Serpentine Channel (service road + n/b carriageway)	2	11.5	70
	65600	Chatsworth Road over upgrade	1	10	60
	68100	Carrolls Lane over upgrade	1	10	60
	68900	Mororo Bridge (s/b carriageway only) — waterway crossing over Clarence River North Arm	1	11.5	220
	70300	Iluka Road interchange	1	10	60

7.4 Other structures

7.4.1 Drainage culverts

Culverts would be used for smaller waterways and cross-drainage structures. Box culverts shall provide for fish passage and fauna passage as outlined in **Section 13.3**. The cross-drainage culverts to be included in the upgrade are detailed in **Section 8**.

Geotechnical design parameters for culvert footings and slabs would be determined in detailed design.

7.4.2 Property access

Where access to houses is required, a minimum vertical clearance of 4.6 metres would be provided. Elsewhere, a minimum 3.6 metres vertical clearance is required. A minimum clear width of 3.6 metres is required.

Property accesses would also provide for fauna passage. Where access tracks are provided through property access structures, a clear passage would be provided along the side for fauna. The fauna passage may be separated from the track by fencing or bollards.

Geotechnical design parameters for arch and culvert footings and slabs would be determined in detailed design.

7.4.3 Fauna crossings

The project would include various fauna crossings:

- Dedicated fauna crossings, where the sole purpose of the structure is for fauna crossing.
- Combined fauna crossings, where the fauna crossing would be provided in conjunction with a drainage and/or access crossing.
- Incidental fauna crossings, which are for drainage or access and include no specific fauna crossing measures.

The requirements for the dedicated fauna crossings and combined fauna crossings are listed in **Table 13-5**.

7.4.4 Noise structures

Specific noise mitigation measures would be identified as part of the environmental assessment and detailed design of the upgrade. Noise-mitigation options are described in **Section 13.4.3**.

In designing any noise structures, consideration must be given to their possible impacts on flooding, particularly in sections 3 and 4 as impermeable barriers created by noise walls or noise mounds have the potential to block flood flows and adversely impacts surrounding areas.

8. Flooding and drainage

The drainage system for the project would comprise the following key components:

- Cross–drainage (transverse drainage).
- Pavement drainage (longitudinal drainage).
- Subsurface drainage.
- New open channels.
- Existing channel and waterway diversions.
- Water quality treatment, where required.

Chapter 8 identifies the design parameters for the drainage design and details the results of the design and modelling. The water quality aspects of the design are addressed in **Section 13.7**.

The design is based on the requirements of the *Pacific Highway Design Guidelines* and the RTA's *Road Design Guide* (RTA, 2000). In addition, the requirements of *Australian Rainfall and Runoff* (Institution of Engineers Australia, 1998) have been incorporated into the design.

The development of the environmental assessment and detailed design will need to consider any updating of design standards subsequent to the concept design.

Further information regarding the flooding and drainage assessment and design is provided in the *Hydrology and Hydraulics Working Paper* (RTA, 2008e). The concept drainage design is documented in the concept design drawings (see **Appendix A**).

8.1 Cross-drainage

8.1.1 Design requirements (operational safety and efficiency)

The final design criteria would be derived from the outcome of the environmental assessment and detailed design. The information outlined below outlines the assumptions that have informed the concept design.

General

The *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.

The highway is designed to provide flood immunity as follows:

- A target of one carriageway above the one in 100-year average recurrence interval (ARI) flood event.
- A minimum one carriageway above the one in 20-year ARI immunity on major catchments.

The target immunity would be met, unless doing so could result in unacceptable environmental impacts. The flood immunity level has been defined as being the event for which the edge line of the outside lane is above the nominated flood level.

The concept design needs to provide sufficient bridges and culverts to minimise the changes to existing flood patterns (flood height, flood durations, flood flows and velocities). In determining acceptable changes to flood patterns, consideration is given to the risk / impact of the adverse effects of these changes. For example, a higher flood level at Grafton may cause overtopping of the existing levee, resulting in extensive flooding. In this case, stricter limits may be required. In the upper catchments of the various creeks, the impacts on the flood patterns are more localised, meaning that a higher impact would not create undue nuisance. Other considerations in determining limits relate to local issues, such as the duration of flooding being more important to the cane industry than the depth of flooding.

Bridge abutments are designed for a maintenance-free scour protection period of 50 years.

General criteria for design

While recognising that the upgrade has the potential to adversely affect the flow characteristics in upper catchments, the greatest risk is seen to be that associated with the floodplain. On this basis, the design criteria with regards to flooding are:

- Minimising the potential changes to the hydrological regime of the Clarence River and floodplain.
- Minimising the potential for increased impacts on properties, dwellings and existing road infrastructure.
- Minimising the potential for impact on the existing drainage systems and smaller more frequent flood events.

While bridges and culverts would be provided within the length of floodplain crossings to minimise the changes to existing flood patterns to an acceptable level, it is not possible to achieve zero impact in all areas of the floodplain. Localised changes to the flood patterns (levels, inundation times and flow paths) would occur as a result of design within the floodplain.

Specific Criteria

Given the above, the following impact criteria have been used for this stage of the project:

- Houses – less than 50mm increase in flood height for a any assessed flood event (less than 100 year ARI event).
- Cane land – less than 50mm increase in flood height for any assessed flood event (less than 100 year ARI event) and no more than 5% increase in the flood duration.
- Other agricultural lands (Section 2) – generally less than 250mm increase in flood height for any assessed flood event (less than 100 year ARI event).

Major flood events often dominate thinking during design. Local drainage patterns during smaller, more frequent storms must also be considered to ensure that potential adverse affects are minimised.

8.1.2 Hydraulics and hydrology

As outlined below, different types of cross-drainage structures would be built, largely based on the size of the catchment.

Clarence River and other major waterways

The location and size of cross-drainage structures within the floodplains of the Clarence River and other major waterways have been determined by comparing pre- and post-developed flood patterns in two-dimensional (2D) hydraulic models of the affected waterways.

For the concept design, five local catchment 2D flood models were used in addition to the Clarence River floodplain model.

Watercourses covered by the 2D flood models include the Clarence River, Shark Creek, Serpentine Channel, Pheasant Creek, Glenugie Creek, Coldstream River, Pillar Valley Creek, Chaffin Creek and Champions Creek.

Other waterways

Cross-drainage structures on waterways not covered by a 2D hydraulic model were sized using a number of different procedures. Catchments larger than one square kilometre had peak flowrates estimated using the hydrological model WBNM. Peak flow rates for smaller catchments were generally estimated by the probabilistic rational method as described in *Australian Rainfall and Runoff*, Institution of Engineers, 1987.

Sizing culverts and bridges in areas where the catchment is greater than one square kilometre and the waterway gradient was generally flat (less than one per cent), was done by providing an opening area sufficiently large to ensure flow velocities of less than 1.5 metres per second.

In steeper terrain, the required culverts were hydraulically modelled using SKM's in-house cross-drainage management (CDM) database and sized to ensure water depths at the culvert entrance would be within acceptable limits as described in **Section 8.1** above.

Where significant land reshaping is required to direct flow through a proposed cross-drainage structure, this work was modelled to ensure any land requirements or environmental consequences could be considered.

8.1.3 Proposed cross-drainage structures

A description of the cross-drainage structures in each of the four sections of the preferred route is outlined below.

Section 1

The route would cross a number of small creeks as well as the upper reaches of Glenugie Creek. All of these watercourses have relatively small catchments at the locations of the proposed crossings.

Minor drainage structures proposed in section 1 are listed in **Table 8-1.** They have been sized hydraulically.

- **Table 8-1: Section 1 — minor drainage structures and preliminary sizing**

Chainage	Catchment area (ha)	100-yr ARI flowrate (m^3/s)	Proposed structure
580	3.8	1.1	2 x ϕ0.75 pipe culvert
1015	0.9	0.35	ϕ0.6 pipe culvert
1450	1.9	0.64	ϕ0.9 pipe culvert
2475	5.9	1.6	2.4 m high x 3.6 m wide box culvert (fauna)
4415	210	27.9	3 x 2.4 m high x 2.4 m wide box culvert (fauna)
4890	27	5.3	2 x ϕ1.2 pipe culvert
5225	69	11.5	2.4 m high x 2.4 m wide box culvert (fauna)
5865	93	14.6	2.4 m high x 2.4 m wide box culvert (fauna)
6465	139	13.9	2 x 2.4 m high x 2.4 m wide box culvert (fauna)
7270	25	4.7	3 x ϕ1.050 pipe culvert
7395	34	6.7	3 x ϕ1.2 pipe culvert
7680	30	6.0	3 x ϕ1.2 pipe culvert
8780	2.1	0.7	2 x ϕ0.6 pipe culvert
9990	1.7	0.58	2 x ϕ0.525 pipe culvert (on ramp)
10040	102	15.7	4 x ϕ1.2 pipe culvert (on ramp)

- Note: ϕ indicates the diameter of a circular section in metres; (fauna) indicates possible increase in structure size to accommodate fauna crossing.

Major drainage structures proposed in section 1 are listed in **Table 8-2**. Sizes are based on the required opening area.

- **Table 8-2: Section 1 — major drainage structures**

Chainage	Description	Proposed structure
10280	Waterway crossing	35 m bridge (fauna)

Note: (fauna) indicates possible usage as a fauna crossing

Section 2 (south) – Glenugie to Firth Heinz Road

In section 2 (south), the route would cross Pheasant Creek (near Eight Mile Lane) and then pass along the southern edge of the Coldstream River basin. Clarence River backup flood levels are high (in the order of 5.1 metres AHD) and generally dictate the road levels in this area. However, the route would cross two large watercourses in the Coldstream River and Pillar Valley Creek. The highest velocity flows in these watercourses occur in shorter duration floods from these local catchments.

Minor drainage structures proposed in section 2 (south) are listed in **Table 8-3**. They have been sized hydraulically.

- **Table 8-3: Section 2 (south) — minor drainage structures and preliminary sizing**

Chainage	Catchment area (ha)	100-yr ARI flowrate (m^3/s)	Proposed structure
12160	37	6.6	2 x ϕ1.2 pipe culvert
12380	14	3.2	2 x 2.4 m high x 2.4 m wide box culvert (fauna)
12660	3.7	1.1	ϕ0.75 pipe culvert
12875	4.4	1.3	4 x ϕ0.6 pipe culvert
13125	4.5	1.3	2 x ϕ0.6 pipe culvert
13585	3.3	1.0	2 x ϕ0.6 pipe culvert
14145	13	3.1	2 x ϕ0.9 pipe culvert
15260	23	4.8	4 x ϕ0.75 pipe culvert
23815	33	6.4	3 x ϕ0.9 pipe culvert
23860	33	6.4	4.6m high arch (property access structure)
25175	40	7.3	2 x ϕ1.2 pipe culvert
25910	8.5	2.1	3 x ϕ0.6 pipe culvert
26510	51	9.2	2.4 m high x 3.0 m wide box culvert (fauna)

- Note: ϕ indicates the diameter of a circular section in metres; (fauna) indicates possible increase in structure size to accommodate fauna crossing.

Major drainage structures proposed in section 2 (south) are listed in **Table 8-4**. Sizes are based on the required opening area.

Table 8-4: Section 2 (south) — major drainage structures and preliminary sizing

Chainage	Description	Proposed structure
10790	Waterway crossing	165 m bridge
11450	Waterway crossing	150 m bridge
14730	Waterway crossing	65 m bridge
17720	Coldstream River floodplain	75 m bridge
18400	Coldstream River	360 m bridge
18885	Coldstream River floodplain	175 m bridge
19105	Coldstream River floodplain	75 m bridge
21235	Pillar Valley Creek floodplain	80 m bridge
21380	Pillar Valley Creek floodplain	45 m bridge
21505	Pillar Valley Creek	95 m bridge
21650	Pillar Valley Creek floodplain	55 m bridge
21780	Pillar Valley Creek floodplain	120 m bridge
22220	Pillar Valley Creek floodplain	50 m bridge
22430	Pillar Valley Creek floodplain	55 m bridge
22800	Pillar Valley Creek floodplain	125 m bridge
24400	Waterway crossing	90 m bridge
24555	Waterway crossing	50 m bridge
25385	Waterway crossing	80 m bridge

Section 2 (north) – Firth Heinz Road to Tyndale

In section 2 (north), the route would pass along the western edge of the Coldstream River basin. Similar to the southern part of section 2, Clarence River backup flood levels are high (in the order of five metres AHD) and dictate the proposed road levels in this area. However, the route would cross numerous small watercourses (such as Champion Creek and Chaffin Creek). The highest velocity flows in these watercourses occur in shorter duration floods from these local catchments.

Minor drainage structures proposed for section 2 (north) are listed in **Table 8-5**. They are sized hydraulically.

Table 8-5: Section 2 (north) — minor drainage structures and preliminary sizing

Chainage	Catchment area (ha)	100-yr ARI flowrate (m3/s)	Proposed structure
28790	64	11.0	3.6 m high x 3.6 m wide box culvert (fauna)
33305	80	13.0	2 x 0.9 m high x 3.0 m wide box culvert
34365	104	16.1	3.6 m high x 3.6 m wide box culvert (fauna)
35180	32	6.2	1.2 m high x 2.4 m wide box culvert
35895	130	19.1	3.6 m high x 3.6 m wide box culvert (fauna)
36895	138	18.9	3 x 0.9 m high x 2.1 m wide box culverts
36995	2.8	1.6	ϕ0.9 pipe culvert
37310	268	33.4	4 x 1.8 m high x 3.0 m wide box culverts
37900	19	4.3	2 x 0.9 m high x 2.4 m wide box culverts
38660	7.5	1.9	4 x ϕ0.6 pipe culvert
39010	9.3	2.4	2 x ϕ0.675 pipe culvert
39275	10	2.5	1.8 m high x 3.0 m wide box culvert
39585	115	10.7	3.6 m high x 3.6 m wide box culvert (fauna)
40570	25	5.2	3 x ϕ0.9 pipe culvert
41115	10	2.6	2 x ϕ0.9 pipe culvert
41300	17	3.8	0.75 m high x 2.1 m wide box culvert
42255	41	3.9	3 x ϕ0.9 pipe culvert
42470	38	7.0	2 x ϕ1.2 pipe culvert
42500	2.4	0.7	1 x ϕ1.2 pipe culvert
43060	12	2.9	2 x ϕ0.9 pipe culvert
43160	10	2.5	2 x ϕ0.75 pipe culvert
43515	13	3.0	4 x ϕ0.6 pipe culvert
43775	7.9	2.1	4 x ϕ0.6 pipe culvert
44055	13	3.2	4 x ϕ0.6 pipe culvert

- Note: ϕ indicates the diameter of a circular section in metres; (fauna) indicates possible increase in structure size to accommodate fauna crossing.

Major drainage structures in section 2 (north) are listed in **Table 8-6**. Sizes are based on the required opening area.

- **Table 8-6: Section 2 (north) — major drainage structures and preliminary sizing**

Chainage	Description	Proposed structure
27600	Chaffin Creek	140 m bridge
29800	Waterway crossing	105 m bridge
30130	Waterway crossing	65 m bridge
32135	Waterway crossing	80 m bridge
33760	Waterway crossing	70 m bridge

Section 3

In section 3, the preferred route would follow the existing highway along the right bank of the Clarence River South Arm. The southern part of this section would also run along the edge of the Shark Creek basin. In the northern part of section 3, the route would separate the Clarence River from other smaller flood basins. **Table 8-7** lists the drainage structures proposed for section 3.

- **Table 8-7: Section 3 — drainage structures and preliminary sizing**

Chainage	Description	Proposed structure
45015	Floodplain crossing	75 m bridge
46140	Floodplain crossing	2 x 1.8 m high x 3.3 m wide box culvert
46765	Floodplain crossing	3 x 1.8 m high x 1.8 m wide box culvert
47740	Floodplain crossing	3 x 0.9 m high x 1.8 m wide box culvert
48100	Floodplain crossing	1.8 m high x 3.6 m wide box culvert
48915	Floodplain crossing	2 x 0.9 m high x 2.4 m wide box culvert
50150	Shark Creek	830 m bridge
50690	Floodplain crossing	2.4 m high x 3.6 m wide box culvert
51250	Floodplain crossing	3 x ϕ0.9 pipe culvert
51440	Floodplain crossing	0.9 m high x 2.1 m wide box culvert
51665	Floodplain crossing	1.5 m high x 2.4 m wide box culvert
52375	Floodplain crossing	3 x 2.4 m high x 3.0 m wide box culvert
52910	Floodplain crossing	1.8 m high x 3.6 m wide box culvert
53950	Floodplain crossing	2 x 0.9 m high x 2.4 m wide box culvert
54155	Floodplain crossing	0.9 m high x 2.4 m wide box culvert
54745	Floodplain crossing	2 x 0.9 m high x 2.4 m wide box culvert
55010	Floodplain crossing	4 x 2.4 m high x 3.0 m wide box culvert
55415	Floodplain crossing	ϕ0.9 pipe culvert
55740	Floodplain crossing	ϕ0.6 pipe culvert
56060	Floodplain crossing	2 x ϕ0.6 pipe culvert
56525	Floodplain crossing	ϕ0.9 pipe culvert
56650	Floodplain crossing	ϕ0.9 pipe culvert
56720	Floodplain crossing	ϕ0.6 pipe culvert
56860	Floodplain crossing	ϕ0.75 pipe culvert

Chainage	Description	Proposed structure
57140	Floodplain crossing	ϕ0.75 pipe culvert
57200	Floodplain crossing	2 x ϕ0.6 pipe culvert
57485	Floodplain crossing	2 x ϕ0.6 pipe culvert
57615	Floodplain crossing	2 x ϕ0.6 pipe culvert
57730	Floodplain crossing	2 x ϕ0.6 pipe culvert
57820	Floodplain crossing	ϕ0.6 pipe culvert
58225	Floodplain crossing	2 x 0.6 m high x 1.2 m wide box culvert
60075	Floodplain crossing	3 x 0.9 m high x 3.0 m wide box culvert
60285	Floodplain crossing	2 x 0.9 m high x 3.0 m wide box culvert
60520	Floodplain crossing	ϕ0.9 pipe culvert (on ramp)

- Note: ϕ indicates the diameter of a circular section in metres

Section 4

In section 4, the preferred route would follow the existing highway across Harwood and Chatsworth Islands. These islands are entirely within the floodplain and separated by Serpentine Channel, which is a tidal watercourse (about 50 metres wide). North of the Clarence River North Arm, the upgrade would cross a relatively short stretch (about 500 metres) of Clarence River floodplain before rising towards Iluka Road. **Table 8-8** lists the drainage structures proposed for section 4.

- **Table 8-8: Section 4 — drainage structures**

Chainage	Description	Proposed structure
61400	Clarence River	890 m low bridge or 1500 m high bridge
63400	Floodplain crossing	78 x 0.45 m high x 3.0 m wide box culvert
63610	Floodplain crossing	48 x 0.45 m high x 3.0 m wide box culvert
63870	Floodplain crossing	20 x 1.2 m high x 3.0 m wide box culvert
64200	Serpentine Channel	70 m low bridge
64770	Floodplain crossing	28 x 0.45 m high x 3.0 m wide box culvert
64870	Floodplain crossing	13 x 0.75 m high x 3.0 m wide box culvert
64960	Serpentine Channel	14 x 0.9 m high x 3.0 m wide box culvert
65105	Floodplain crossing	14 x 0.75 m high x 3.0 m wide box culvert
65270	Floodplain crossing	14x 0.75 m high x 3.0 m wide box culvert
65400	Floodplain crossing	25 x 0.75 m high x 3.0 m wide box culvert
65710	Floodplain crossing	30x 0.45 m high x 3.0 m wide box culvert
66040	Floodplain crossing	32 x 0.45 m high x 3.0 m wide box culvert
66260	Floodplain crossing	3 x 1.2 m high x 3.0 m wide box culvert
66570	Floodplain crossing	ϕ0.9 pipe culvert
66575	Floodplain crossing	10 x 0.75 m high x 3.0 m wide box culvert
66705	Floodplain crossing	10x 0.9 m high x 3.0 m wide box culvert
67060	Floodplain crossing	30 x 1.2 m high x 3.0 m wide box culvert

Chainage	Description	Proposed structure
67495	Floodplain crossing	25x 0.6 m high x 3.0 m wide box culvert
67595	Floodplain crossing	20x 0.6 m high x 3.0 m wide box culvert
67730	Floodplain crossing	19 x 0.9 m high x 3.0 m wide box culvert
67875	Floodplain crossing	24 x 0.75m high x 3.0 m wide box culvert
68000	Floodplain crossing	21 x 0.6 m high x 3.0 m wide box culvert
68150	Floodplain crossing	ϕ0.9 pipe culvert, 1.8m high x 3.0 m wide box culvert (on local road)
68200	Floodplain crossing	1.8m high x 3.0 m wide box culvert
68320	Floodplain crossing	1.8m high x 3.0 m wide box culvert (on local road)
68360	Floodplain crossing	33x 0.6 m high x 3.0 m wide box culvert
68900	Clarence River North Arm	220 m bridge
69215	Floodplain crossing	ϕ0.9 pipe culvert
69930	Floodplain crossing	4 x ϕ0.6 pipe culvert
70260	Floodplain crossing	2 x ϕ0.825, 2 x ϕ0.6, 4 x ϕ0.75 pipe culvert
70450	Floodplain crossing	6 x 0.6 m high x 3.0 m wide box culvert
70830	Floodplain crossing	0.6 m high x 3.0 m wide box culvert

- Note: ϕ indicates the diameter of a circular section in metres

Through Section 4, floodplain bridges may be used as an alternative to the use of culverts. The comparative waterway opening areas and flow widths (equivalent to bridge length) are shown in **Table 8-9**. The flow widths are approximately the same as the area for bridges needs to be higher due to the much higher Manning's n through the bridges (0.08) compared to that for the culverts (0.015). Hence, while the depths are higher for the bridge option, the velocities are slower and the areas are higher.

- **Table 8-9: Comparative bridge and culvert waterway areas in Section 4**

	Total Flow Area (m^2)	Total Flow Width (m)
Culverts option		
North of Serpentine Creek	599	774
South of Serpentine Creek	532*	529
Total	***1,131****	***1,303***
Bridges option		
North of Serpentine Creek	1,738	970
South of Serpentine Creek	677	380
Total	***2,415***	***1,350***
	* Includes Watt's Lane 55m wide, 5m high bridge	

In considering the various options, the following issues could affect the option selected:

- Construction on soft soils, including differential settlements between structures and embankments.
- Balancing the numbers of structures required against the afflux and velocity impacts on the surrounding areas.
- Impact of increasing the level of the highway in order to provide sufficient waterway area beneath the bridges and the subsequent impact on flood behaviours.

The selection of bridges or culverts across Section 4 will be undertaken following further hydrologic modelling through the environmental assessment and detailed design.

8.1.4 Further cross-drainage design issues

The cross-drainage would be further refined during the environmental assessment and detailed design. The following key issues must be considered in designing the cross-drainage structures:

- Significant channel regrading of Pheasant Creek is required around the Eight Mile Lane interchange (section 2 – Ch 11000) to ensure flood waters can be adequately managed in this area.
- The one in 100-year Clarence River flood level in the Coldstream Basin is RL 5.1.
- The concentration of flow through the bridges over the Coldstream River may require localised scour protection works on part of the creekbed and banks immediately downstream of the upgrade bridges.
- Floodgates on cane drains between Tyndale and Maclean are to be relocated to the eastern side of the upgrade (with the exception of the Shark Creek area) to provide safer access to the gates for maintenance and operation.
- The area around Ch 47600 in section 3 currently acts as a weir to regulate flow into the Shark Creek Basin during the one in 100-year flood event. Based on the road levels adopted in the concept design, an afflux of about 65 millimetres would be created on Woodford Island, opposite this point. During environmental assessment and detailed design, a bridge or culverts should be considered in this location to allow flows to enter the basin at this point, thus reducing the afflux.
- The existing highway south of Townsend is at a level of RL 3.5 (varying between RL 3.2 and RL 4.0 along this section). The upgrade would need to have a road crest of about RL 4.0 (varying between RL 3.9 and RL 4.2 along this section) to achieve the 20-year ARI flood immunity standard. Hence, there is little, if any, vertical distance available to construct culverts to help flood flows into the low lands above RL 3.5. If culverts were constructed under a road with a crest level of RL 4.2, this would result in substantially earlier and more frequent inundation of the low areas to the east.
- The design of the upgrade in section 4 is based on the edge of the lowest lane line being at the one in 20-year flood level. When the eventual three-lane carriageway is built, the crossfall over the carriageway would be sufficient to block the 100-year flood. (There would be a 315-millimetre

crossfall compared to around a 300-millimetre difference between the one in 20-year and one in 100-year flood levels) On this basis, the culverts have been designed to pass the one in 100-year flows. Consideration may be given in later design stages to raising the height of the road by around 300 millimetres to provide for one in 100-year flood immunity. The cost of this would equate to around 100,000–150,000 cubic metres of fill that would likely have to be imported.

- The cross drainage through the cane growing areas will need to provide for the existing cane drains and ensure flow paths are maintained.

8.2 Pavement drainage (longitudinal drainage)

The pavement drainage system includes gutters, pits, channels and pipes which, in turn:

- Collect stormwater safely from the road pavement in a gutter, a median drain, or in catch drains at the toe of the road embankment. (Pavement drainage would be designed as part of the detailed design of the upgrade).
- Convey the collected stormwater through a water-quality treatment device, where installed.
- Discharge the stormwater.

The pavement and sub-pavement drainage systems will be designed as part of the detailed design. Across the floodplain, a 1V:4H batter slope has been adopted to avoid the need for longitudinal drainage on the tops of the batters and, therefore, enable a float grade to be utilised. In adopting this approach, the slopes used in the medians would need to be varied to generate some longitudinal grades for drainage purposes.

8.3 Open channels

Open channels would be used to re-direct surface runoff away from the highway pavement and formation, direct road water runoff to water-quality treatment facilities, direct uncontaminated water around water-quality treatment facilities, and direct water to transverse culvert and bridge openings. In designing new open channels, the following design criteria must be adopted.

- Bank-full capacity of the channel is to be greater than or equal to a five-year ARI storm event.
- Consideration must be given to impacts in the event of channel overflows, with the channel capacity increased as necessary to manage the risk of adverse impacts. The channel capacity must be designed for a 100-year ARI storm event where overflows would affect the highway upgrade or adversely impact on adjoining properties.
- Median channels must be provided with a minimum longitudinal grade of 0.5 per cent.
- Median channels with a height difference between the channel invert and the edge of road of less than 250 millimetres shall be concrete-lined.
- Channels must be protected against erosion for storms up to the 20-year ARI storm event.

At this point, preliminary sizings have been undertaken for major catch drains along the length of the upgrade to ensure sufficient width is available within the project boundary. Final sizings and sizing of minor catch drains will be undertaken during detailed design.

8.4 Water quality basins

Basins have been designed for temporary (construction) and permanent (operational) phases of the project. Temporary and permanent basins have been designed in accordance with *Managing Urban Stormwater, Soils and Construction, Landcom, March 2004, 4th Edition* (the Blue Book), to allow adequate storage for 80% of the 5 day rainfall event. The following criteria were used to size the basins:

- Maximum internal and external side-slope grades of 1V:2H.
- Maximum ponding depth to the permanent water level of two metres.
- Generally, the basin crest shall be three metres wide. However, a narrower crest (minimum one metre) may be used where the fill height of the embankment is less than 0.75 metres and space constraints make a wider crest impractical.
- For water-quality ponds, a minimum 0.75 metres is to be provided between the permanent water level and the basin crest. For spill basins, a minimum 0.5 metres shall be provided.
- A spillway shall be provided to ensure overflows from the basins are managed to prevent damage to the basin, flooding on surrounding properties and scour. The spillway should be designed for the 100-year ARI event.
- Suitable access should be provided for maintenance purposes.

Temporary and permanent water-quality basins have been modelled into 12D in order to ensure any land requirements or environmental consequences of the basins could be considered. In sensitive environmental locations and where practicable, sedimentation basins installed for the construction phase would be converted to water-quality basins for the operation phase. Basin sizing for the construction phase was based on the revised universal soil loss equation (RUSLE) and the operation basins were provided a volume equal to 3.5 per cent of their catchment area. Basins that would be used for both phases have been sized according to which use demands the greater storage.

During the concept design, the initial sizing and location of the proposed water quality treatment devices has been undertaken. The design of the pipe system will be undertaken during environmental assessment and detailed design.

8.5 Final drainage design

The design of the final drainage system will be undertaken as part of the environmental assessment and detailed design. In preparing the detailed design, the following will be considered:

- Aquaplaning – to be less than five millimetres.
- Flow widths – in accordance with RTA design standards and not exceeding one metre in the travel lane.
- Maximum heights of fill embankments where sheet flow from pavements will occur.
- Pit and pipe specifications in accordance with RTA design standards.
- Catch drains – upstream of cut batters.
- Open channels.
- Sub-surface drainage including trench drains, intra-pavement drains and sub-pavement drains.
- Basins.

9. Earthworks

Since the announcement of the preferred route, geotechnical investigations have been carried out along the corridor to enable the design to define the concept design boundaries and inform the cost estimate. They have included 75 boreholes, 49 test pits, 20 piezocones, and six seismic locations. Further detailed geotechnical investigations would be required for the detailed design and construction of the upgrade.

Chapter 9 outlines geotechnical work undertaken to date.

9.1 Geotechnical units

The geotechnical units along the alignment comprise 11 soil units and 12 rock units. Soil units are initially characterised on the basis of genesis as fill, topsoil, thin transported soils and floodplain alluvium with further subdivision based on soil type and morphology. The rock units have been characterised initially on the basis of geological stratigraphy and then on the basis of strength and weathering. Although having soil properties, residual soil derived from bedrock is grouped together with extremely weathered rock. Highly and moderately weathered rocks are grouped separately from the slightly-weathered-to-fresh rock. The geotechnical units are outlined in **Table 9-1** and **Figure 9-1**

▪ **Table 9-1: Description of geotechnical units occurring along the alignment**

Unit	Description
Fill	▪ Generally road embankments and hardstand areas – imported sandstone or local soil fill.
Topsoil	▪ Organic and root-affected materials — thin topsoil layers (0.1–0.3 m thick).
Relatively thin transported soils	▪ Slopewash, outwash fans and colluvial deposits — clays and sands, sometimes clean coarse sands and gravels. ▪ Smaller channel valley deposits — stiff sandy clays and medium dense sands.
Clarence River floodplain sediments	▪ Desiccated surface soils (levees and plains) — stiff sandy clays and medium dense sands. ▪ Recent clean sands derived from channels and splays — loose to dense grey sands. ▪ Estuarine clays (muds) — dark grey silts and clays, very soft to firm, shells and peat. ▪ Estuarine sands — dark grey, loose to medium dense, shells and peat.
Clarence River floodplain sediments	▪ Pleistocene slays — grey, light grey and orange (often mottled) clay, stiff to hard. ▪ Pleistocene (sometimes estuarine) sands and clayey sands — clean grey sands and dark grey estuarine sands and clayey sands with shells and peat.

Unit	Description
	▪ Basement sand and gravel deposits — sandy gravels and cobbles overlying bedrock.
Grafton Formation — residual soil and weathered rock	▪ Residual soil and extremely weathered rock developed from Grafton Formation rocks — sandy clays and silty clays, medium to high plasticity. ▪ Highly and moderately weathered Grafton Formation rocks — siltstone, claystone, mudstone and sandstone. ▪ Slightly weathered and fresh Grafton Formation rocks — siltstone, claystone, mudstone and sandstone.
Kangaroo Creek Sandstone — residual soil and weathered rock	▪ Residual soil and extremely weathered rock developed from Kangaroo Creek Sandstone rocks — fine to coarse-grained sands and clayey sands. ▪ Highly and moderately weathered Kangaroo Creek Sandstone rocks — medium to coarse-grained quartz sandstone. ▪ Slightly weathered to fresh Kangaroo Creek Sandstone rocks — medium to coarse-grained quartz sandstone.
Walloon Coal Measures — residual soil and weathered rock	▪ Residual soils and extremely weathered rock derived from Walloon Coal Measure rocks — shale, minor coal and sandstone. ▪ Highly and moderately weathered Walloon Coal Measure rocks — shale, minor coal and sandstone. ▪ Slightly weathered to fresh Walloon Coal Measure rocks — shale, minor coal and sandstone.
Bundamba Group — residual soil and weathered rock	▪ Residual soil and extremely weathered rock derived from Bundamba Group rocks — coarse-grained sandstone, conglomerate and shale. ▪ Highly to moderately weathered Bundamba Group rocks — coarse grained sandstone, conglomerate and shale. ▪ Slightly weathered to fresh Bundamba Group rocks — coarse-grained sandstone, conglomerate and shale.

9.2 Cutting design

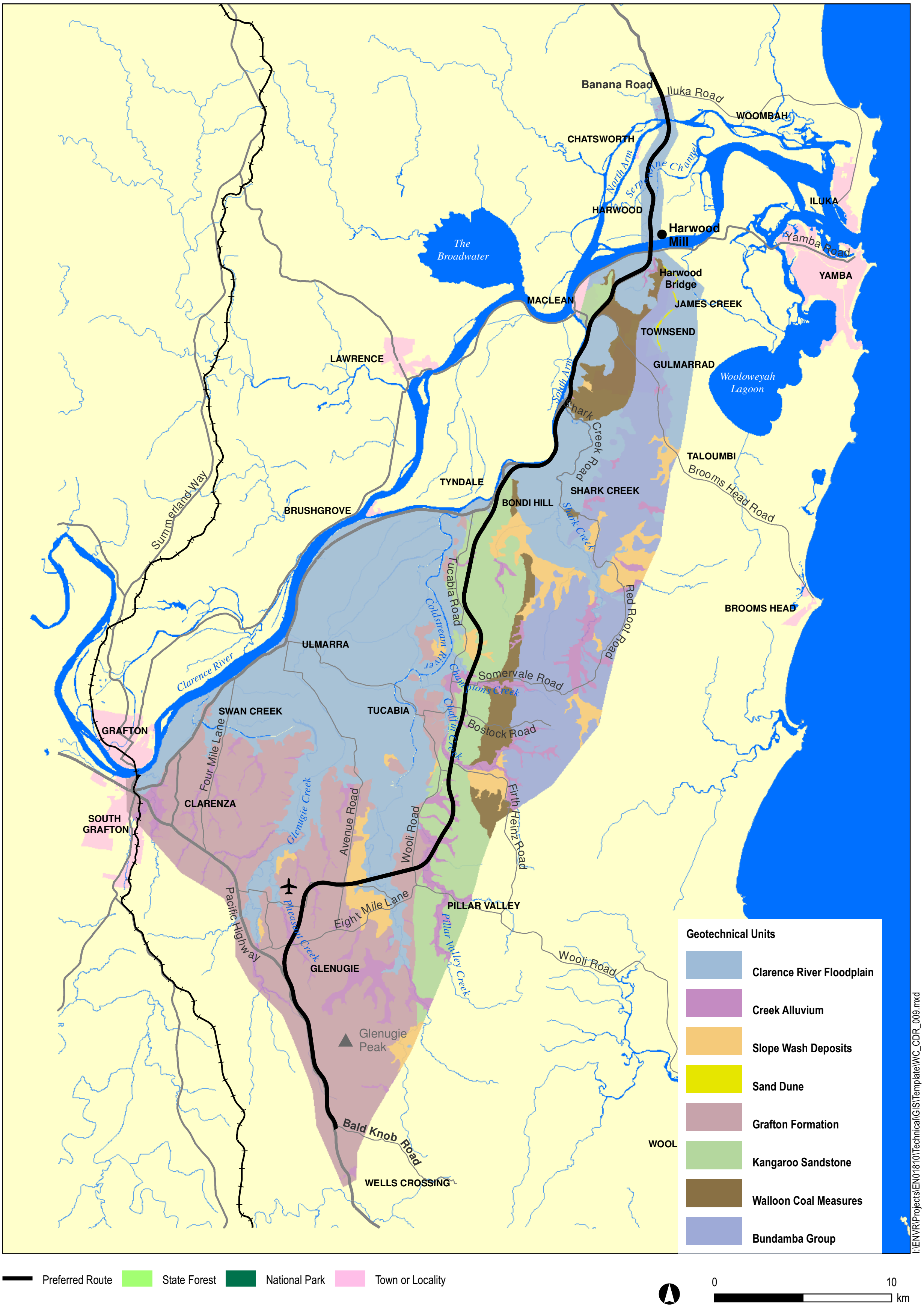
The cuttings along the proposed alignment would be located within three geological units:

- Grafton Formation — comprising shales, siltstones and interbeds of sandstone (sections 1 and 2).
- Kangaroo Creek Sandstone (section 2).
- Walloon Coal Measures — comprising shales with minor coal and sandstone beds (section 3).

9.2.1 Cuttings in the Grafton Formation

The summary geotechnical model for the Grafton Formation geological/bedrock environment is applicable to all road cuttings in section 1, and cuttings in section 2 between Ch 0 and about Ch 10200. The model is as follows:

Figure 9.1 Geotechnical Units



- The depth of residual soils and extremely weathered rock in the cuttings is expected to range from 0.5–4 metres.
- The highly weathered and slightly weathered rocks comprise interbedded mudstones, siltstones and sandstones of variable strength from very low to high, but typically of at least medium strength, at depths of six to 14 metres below existing ground levels. These units may also contain coal seams and laminations.
- Groundwater seepage is likely to be encountered within cuttings at the interface between residual soils and weathered rock, and within bedrock defects at depths of four to 14 metres below existing surface levels.

9.2.2 Cuttings in Kangaroo Creek Sandstone

The summary geotechnical model for the Kangaroo Creek Sandstone footslopes is applicable to section 2 road cuttings from about Ch 12400 to Ch 33800. The model is as follows:

- The thickness of slopewash overlying residual soils ranges from 0.2–1 metre on mid slopes and 1.5–3.7 metres on lower slopes, with the exception of boreholes 149 (Ch 29310) and 169 (Ch 16320), where there is shallow fill directly overlying sandstone bedrock. The slopewash typically comprises silty sands and sands of fine to coarse grain size, and of very loose to medium dense relative density.
- The thickness of residual soils and extremely weathered rock below the slopewash on hillsides is expected to range from 0.5–5 metres. However, deeper deposits of extremely weathered rock may be present at some locations to at least eight metres depth. At some locations, the extremely weathered rock contains low to medium strength bands.
- The bedrock units comprise medium to coarse-grained sandstone. The highly weathered material is typically of medium strength, but ranges from very low to high strength. The freshly weathered material is generally of medium to high strength with some very high strength.
- In hillsides, groundwater seepage is likely to be encountered at the interface between residual soils and weathered rock and within bedrock defects from depths between 1.5–11 metres below surface levels.

9.2.3 Cuttings in Walloon Coal Measures

Within section 3, the cuttings are located within the Walloon Coal Measures geological environment. A summary geotechnical model for each is provided below.

Green Hill footslopes

The geotechnical model for the three cuttings located within the Green Hill footslopes (north of Shark Creek) may be summarised as follows:

- The overall depth of residual soils and extremely weathered rock is expected to range from one to four metres, with residual soils comprising silty clay of low to high plasticity and very stiff to hard consistency that grade to extremely weathered rock with depth.
- Bedrock is expected to comprise interbedded bands of highly and moderately weathered fine-grained sandstone of typically low to medium strength.
- Groundwater seepage is likely to be encountered within cuttings at the interface between residual soils and weathered rock and within bedrock defects.

Maclean Hill footslopes

In general, the subsurface profile along the centreline of the upgrade across the Maclean Hill footslopes is seen as highly variable, comprising 5–15 m of residual soils and extremely weathered rock over highly weathered to moderately weathered shales and sandstones of the Walloon Coal Measures. In addition to residual soils, there may be localised deposits of slopewash soils. The residual soils are typically silty clays of medium to high plasticity. The weathered rocks comprise sandstones and siltstones typically of medium strength.

It is expected that groundwater seepage may occur at the residual soil/extremely weathered and highly to moderately weathered rock interface and form defects within the highly to moderately weathered bedrock.

In the vicinity of Jubilee Street, boreholes 121 and 122 indicate that there is a 20-metre difference in bedrock levels in a distance of seven metres across the downslope half of the proposed footprint, with bedrock on the downslope side of the footprint overlain by alluvium. This implies the presence of a steep alluvial channel or cliffline erosion surface.

9.2.4 Batter design criteria

In assessing proposed cut batters it was assumed that the following typical RTA requirements would apply:

- The cut batter slopes should maintain long-term stability to meet RTA Slope Risk Rating requirements (assumes low risk rating of ARL4 to ARL5) with limited maintenance to localised parts of a face or bench only.
- Limited failures during construction would be acceptable but should not extend beyond the width of one bench.
- The batters should be designed such that, where material may become detached, it is prevented from reaching the road shoulder.
- Plant and equipment access to the final batters would be provided to allow inspections, maintenance and installation of any treatment measure to be carried out.

- Where possible, the design should be in accordance with RTA specifications. Benches would be required where the vertical height of cut batters steeper than 1V:2H exceeds seven metres. For batters 1V:2H or flatter, benches are required at vertical intervals of 10 metres. A minimum bench width of four metres would be required to accommodate safe access for maintenance plant.
- All cut batters would be provided with open dish drains located behind the crest to minimise water flowing over the face and erosion of the cut face.
- Batter slopes of between 1V:1.5H and 1V:0.75H must be avoided.

9.2.5 Historical performance of existing batters in study area

As a background for making recommendations on batters for the concept design, the performance of local road cuttings and quarry batters was investigated. The following general trends were identified:

- Batters in extremely weathered Grafton Formation rock and soil — these are cut at about 1V:1.5H to 1V:1H, with erosion scours common. Some soil batters are graded at 1V:1.75H.
- Batters in less weathered Grafton Formation slope at about 1H:1V to 1V:0.75H — preferential weathering of siltstone seams within sandstone batters was evident together with spalling blocks in steeper batters (50–70º) of highly weathered bedrock.
- Batters in Walloon Coal Measures slope at about 1V:0.75H — significant erosion of surficial soils around concrete dish drains was observed in batters at the Maclean Pinnacle.
- Batters in better quality sandstone from Kangaroo Creek Sandstone slope — these are at about 1V:0.75H to 1V:0.5H.
- There is minimal protection on the soil batters, other than vegetation growth.

9.2.6 Recommendations for design

Indicative maximum slopes for permanent batters are given in **Table 9-2**.

Drainage should be provided at the top of each cutting to mitigate the risk of erosion of the batter faces. Based on the observations of existing batters, together with the results from laboratory testing, it is expected that dispersion and erosion should not be a significant issue where the recommended batters of residual soils and extremely weathered rock are adopted. However, where relatively flat batters are adopted in soil and weathered rock, it is recommended that hydro-mulching or erosion matting be used, together with the establishment of permanent vegetation, to reduce the potential for erosion.

Table 9-2: Indicative excavated batter slopes

Material	Geotechnical unit	Indicative batter slope without engineering protection [1,3]
Existing poor quality fill	Fill	1V:2H
Engineered fill	Fill	1V:2H
Grafton Formation [2]	Residual soil	1V:2H [4]
	Highly weathered	1V:1.5H
	Slightly weathered	1V:0.75H
Kangaroo Creek Sandstone	Residual soil	1V:2H [4]
	Highly weathered	1V:1.5H
	Slightly weathered	1V:0.75H
Walloon Coal Measures[2]	Residual soil	1V:2H [4]
	Highly weathered	1V:2H or 1V:1.5H
	Slightly weathered	1V:0.75H

1 Assumes 4 m wide benches at vertical heights of 7 m in batters steeper than 1V:2H.
2 Significant shale bands in the sandstone beds may require shotcrete protection against degradation.
3 Localised rock bolting may be required to stabilise rock wedges or blocks formed by unfavourably oriented defects.
4 For long batters in soil or extremely weathered rock (over 15 m long), a flatter batter of 1V:2.5H is recommended with energy dissipation bunds across the batter at 15 m intervals.

9.3 Excavated materials

It is expected that excavated residual sandy soils derived from Kangaroo Creek Sandstone and sandstone bedrock from Grafton Formation and Kangaroo Creek Sandstone would be suitable for reuse as engineered fill. However, all oversize or deleterious material should be removed, and rock should be crushed and graded to provide a suitably graded fill material.

Residual soils recovered from excavations of Grafton Formation and Walloon Coal Measures may be re-used as general engineered fill provided that all unsuitable, over-wet, oversize or deleterious material is removed and moisture content is strictly controlled.

It is expected that shales and siltstones recovered from the Grafton Formation and Walloon Coal Measures may readily break down to a silty clay following excavation and exposure to wetting and drying cycles. Therefore, these materials are only expected to be suitable for reuse as general engineered fill provided that all oversize material is removed and moisture content is strictly controlled.

Crushed Kangaroo Creek Sandstone does not meet the requirements for concrete aggregates and is marginal in relation for use as a pavement base or sub-base material. However, it is expected that fill derived from Kangaroo Creek Sandstone residual soils and excavated rock would be suitable for use as upper zone of formation (UZF) embankment fill (that is, CBR [California Bearing Ratio] > 5 per cent, PI [Plasticity] ≤ 25 per cent) and possibly as site-won select material (that is, CBR > 30 per cent, PI ≤ 15 per cent). However, a rigorous testing program would be required to assess if such materials could be excavated and/or crushed to meet RTA requirements for select materials and UZF fill.

9.4 Anticipated subgrade conditions for the floor of cuttings

It is understood that local RTA experience is that pavement subgrade in exposed residual soil or weathered rock from the Grafton Formation is usually pre-treated with a bridging layer of locally sourced crushed sandstone.

Pavement construction in the floor of cuttings with either a soil or rock subgrade would generally require a drainage blanket and sub-pavement drainage along both shoulders. For cuttings in soil or weathered rock, one option is to diagonally cross-rip the cutting floor to a depth of 300 millimetres to achieve the desired sub-pavement drainage effects. Where the floor of the cutting is in hard rock, the floor would have to be over-excavated by about 500 millimetres and a drainage layer provided. Drainage blankets and subsoil drains would have to discharge well beyond the pavement formation and may be incorporated into the road stormwater drainage systems.

In addition to sub-pavement drainage, surface catch drains should also be provided at the toe of all cuts. The gradient of the drains should be sufficient to allow self-cleaning.

9.5 Excavatability

Excavatability is the measure of whether a material can be excavated with conventional equipment, such as bulldozers, backhoes or scrapers. Materials that cannot be excavated with conventional excavation equipment are said to be non-rippable, and typically require pre-blasting or use of percussion hammers to facilitate excavation.

Excavatability of rock is largely dependent on the intact rock strength together with rock structure and defect spacing. General advice on excavatability for the various rock units is provided in **Table 9-3** below. It is expected that the more competent rock units, namely the slightly weathered to fresh rocks, would require larger plant such as Class 400C or larger crawler tractors (as defined in *AS2868 — 1986: Classification of machinery for earthmoving, construction, surface mining and agricultural purposes*, D10 or D375), 20-tonne or larger excavators fitted with impact hammers, and/or blasting. In particular, the less weathered massive sandstone beds of the Kangaroo Creek Sandstone can be substantially stronger than shale or siltstone beds and are anticipated to require blasting to achieve economical excavation rates.

- **Table 9-3: Summary of anticipated excavation requirements**

Material	Geotechnical unit	Anticipated excavation requirements
Grafton Formation	Residual soil and extremely weathered rock	Readily excavated by dozer blade and excavator bucket. Light ripping is expected to improve productivity in extremely weathered rock.
	Highly and moderately weathered rock	Ripping required. Detailed excavations by impact breaker for high strength bands.
	Slightly weathered and fresh rock	Marginal ripping with heavy plant. Blasting may be necessary in high strength rock.
Kangaroo Creek Sandstone	Residual soil and extremely weathered rock	Readily excavated by dozer blade and excavator bucket. Ripping of medium strength rock bands may be required. Light ripping is expected to improve productivity in extremely weathered rock.
	Highly and moderately weathered rock	Ripping required. Detailed excavations by impact breaker for harder rock bands.
	Slightly weathered and fresh rock	Marginal ripping with heavy plant. Blasting is expected to be necessary in very high strength rock and, possibly, high strength rock.
Walloon Coal Measures	Residual soil and extremely weathered rock	Readily excavated by dozer blade and excavator bucket. Light ripping is expected to improve productivity in extremely weathered rock.
	Highly and moderately weathered rock	Ripping required. Detailed excavations by impact breaker for harder rock bands.
	Slightly weathered and fresh rock	Marginal ripping with heavy plant. Blasting may be necessary in high strength rock.

9.6 Embankments

Embankments have been designed on a general principle of 1V:4H for embankments lower than about 2.5 metres. Higher embankments have a 1V:2H design slope, with the exception of embankments across the floodplain, where a 1V:4H slope has been adopted to assist in drainage of the formation.

9.7 Soft soils

9.7.1 Design objectives

The alignment extends across the Clarence River floodplain and marine delta area (sections 3 and 4) and would require construction of embankments over soft clay deposits for much of the floodplain surface. Therefore, embankment construction on these deposits would need to take into account the risk of embankment failure (short-term and long-term risk of slope instability) and short-term and long-term embankment settlement.

Treatment strategies for embankments on soft ground aim to meet the following objectives:

- Provide short-term and long-term stability.
- Attain a final level, with allowance for settlement, above the design flood level.

- Achieve post-construction settlement and differential settlement within tolerable limits for satisfactory performance in relation to drainage, riding comfort and safety, and in keeping with the normal maintenance regime for pavement repairs.
- Achieve post-construction differential settlements within tolerable limits at interfaces between pile-supported structures and embankments.
- Meet the construction time frame.
- Provide value for money.

To a large extent, the final choice of the soft ground treatment solution would be a balance between initial cost, whole-of-life costs, schedule and pavement performance. However, others issues, such as access and impacts on flooding, must also be considered. Where a long period of time is available, a conventional staged construction procedure with a minimum of ground improvement works may be feasible. In this case, the embankment would be raised relatively slowly to enable it to strengthen. The rate of consolidation and associated rate of embankment construction would depend on the thickness of the soft clay and could be increased by the use of vertical wick drains to shorten drainage paths.

In low embankment areas and in localised areas where soft estuarine clays (muds) are absent, it may be possible to adopt less expensive ground improvement methods and construct the embankments marginally above the design flood level to provide an allowance for settlement of the embankment and pavement maintenance over the pavement design life. This approach would limit initial capital cost, but may increase long-term maintenance costs. Soil reinforcement in the form of tensile fabric and, possibly, toe berms, may be required to facilitate the construction of low embankments on soft ground. For high embankments, ground improvement, load reduction or load transfer to stronger stratum would be required to stabilise the embankment and control post-construction settlement to within acceptable limits.

9.7.2 Soft soil properties

The main geotechnical properties governing the soft ground engineering for this project are associated with:

- Settlement — compressibility of the soft soils, including pre-consolidation pressures and coefficient of consolidation.
- Slope stability — undrained shear strength, and improvement of shear strength with consolidation pressure (for staged loading).

Slope stability and settlement are inter-related, particularly on sections of soft ground sites on the Wells Crossing to Iluka Road project. The timing for consolidation during staged construction has an important bearing on slope stability.

A detailed discussion on a range of soil properties is discussed in the draft Geotechnical Design Report.

9.7.3 Slope stability assessment

The assessment of embankment stability for short-term and long-term conditions has been carried out for the embankments at selected floodplain locations. For embankment stability, the adopted design minimum factors of safety (FOS) are:

- 1.3 for short-term conditions.
- 1.5 for long-term conditions.

Both short-term (undrained) and long-term (drained) stability analyses have been carried out for embankments two, four and six metres high, with side slopes of 1V:4H, at a selected number of floodplain areas through section 3 and. For concept design, a 1V:4H batter for fill embankments has been adopted. At two locations along section 4, analyses were also undertaken for a steeper side slope of 1V:2H.

The results generally indicate that under long-term (drained) conditions, embankments have adequate FOS for overall stability. Under rapid drawdown conditions, there is an increased risk of slope instability, in particular for the steeper six-metre-high batter slopes where at some locations the stability becomes marginal.

In order to increase the FOS for short-term (undrained) conditions, it may be necessary to construct the higher embankments in stages to allow for strength gain in the clay layers or to incorporate toe berms. The time required to construct each stage would be based on the required dissipation of pore pressures from the previous stages to maintain a minimum FOS of 1.3.

At bridge abutment locations, depending on the embankment geometry and thickness of the underlying soft soil, there is potential for the embankment to fail along the longitudinal direction. In these locations, it may be necessary to adopt a piled embankment solution or to reinforce the embankments using geogrids or geotextiles. Alternative ‘hard’ ground support systems adjacent to the bridge abutments could include deep soil mixing, installation of stone columns, dynamic replacement or similar ground treatment measures.

9.7.4 Settlement assessment

Settlement analyses and preload concept design have been carried out for the soft clay areas within the low-lying portions of the preferred route. The geotechnical models, design parameters and design approach are discussed in the draft Geotechnical Design Report

For concept design purposes the following limits have been adopted:

- At bridge abutments — not more than 50 millimetre total settlement (assuming that a relieving slab would be installed at bridge abutments).
- Away from bridge abutments — total settlement limit increasing from 50 millimetres to 100 millimetres over a distance of 50 metres (this is equivalent to a uniform differential settlement of 0.1 per cent).
- Beyond 50 metres from bridge abutments — total settlement limit of not more than 100 millimetres.

Post-construction settlement may be limited by pre-loading with surcharge fill or other ground treatment methods, such as deep soil mixing and vacuum consolidation; or combinations of these methods could be used. A 90 per cent degree of consolidation has been adopted as the target at the end of the preloading period.

Settlement of the soft soils is related to numerous factors including:

- Soft soils material type (and parameters such as co-efficient of settlements).
- Material type in adjoining layers.
- Thickness of soft soils.

Table 9-4 summarises the required wick drain spacing for various coefficients of consolidation (C_v) values to achieve the target 90 per cent degree of consolidation after one and two years of preloading. This analysis assumes wick drain penetration over the full depth of compressible layers.

- **Table 9-4: Required wick drain spacing for various C_v values and preload periods**

C_v (m^2/yr)	1-year preload period	2-year preload period
3	1.4 m wick drain spacing	2.0 m wick drain spacing
4	1.7 m wick drain spacing	2.3 m wick drain spacing
10	2.6 m wick drain spacing	3.5 m wick drain spacing

9.7.5 Soft soil construction strategy

Due to the variability of these factors and the limited extent of investigations to date, a standard treatment has been adopted for the concept design cost estimate, as follows:

- The construction of embankments is based on the use of traditional methods, including preload and wick drain installation.
- The spacing of wick drains is based on that needed for a one-year settlement period, with the expectation that construction would be undertaken in a two-staged approach. This would allow for partial construction of embankments and therefore allow sufficient waterway area to allow the passing of any major floods during construction. This is particularly important in section 4.

- The staged construction approach enables embankments to be constructed across areas where culverts would be ultimately installed. This would induce settlement in these locations prior to the removal of the embankment and installation of the culverts (between the two stages of the embankment construction). This method has been adopted as the settlements in section 4 are expected to be up to 1 metre, significantly increasing the costs of using over-sized culverts as well as increasing the risks associated with differential settlements.
- The amount of additional fill materials required for settlement and preload is based on adoption of an allowable 100-millimetre post-construction settlement.
- Drainage blankets, geotextiles and tensile fabric would be installed below the embankments.
- Timber piling would be used below embankments either side of bridges. The length of the piles would be reduced as they move further from the bridges, in order to reduce differential settlements.
- A plain concrete pavement would be used through the soft soil areas.

Alternatives to the above could be considered. These include (but should not be limited to):

- Use of vacuum consolidation in place of preloading and wick drains. This would allow settlement of the soils in section 4 without construction of the embankment, and therefore avoid adverse impacts on flooding. The disadvantages of this option are the cost of vacuum consolidation and the performance of this technique. It is noted that this technique does not work in all soil conditions and further testing would be required to ensure ground conditions are appropriate.
- Construction of a flexible pavement in place of the plain concrete pavement. On similar past projects, plain concrete pavements have been used with success and these pavements generally have a better whole-of-life costing than flexible pavements.
- A series of floodplain bridges could be built in place of the culverts in section 4. This option would result in an increased afflux and increased water velocities through the waterway openings, which could have an adverse impact on the cane. In addition, the introduction of bridges would require a change in the vertical grading of the alignment to cater for drainage on the bridges. This would result in an alignment with a series of high points and low points along its length.
- Due to the expected time between concept and detailed design, it is acknowledged that new and improved techniques and/or equipment may be developed which could change the proposed construction methodology across the soft soils.

9.8 Acid sulphate soils

Sections 2 to 4 would include construction across alluvial valleys where acid sulphate soils (ASS) have been mapped or could be anticipated.

Based on the findings of the geotechnical assessment, further deeper acid sulphate soils investigations would need to be undertaken during the detailed design stage. It is anticipated a project specific Acid

Sulphate Soils Management Plan (ASSMP) would need to be prepared prior to commencement of earthworks.

Further details on ASS are provided in the draft Geotechnical Design Report.

9.9 Contaminated soils

A Preliminary Phase 1 Environmental Site Assessment (ESA) was undertaken to identify lands that may potentially be impacted by widespread contamination and to identify Areas of Environmental Concern (AEC), which are sites along the route that are used or have been used for potentially contaminating activities.

A review of historical aerial photographs and available records provided information on changes in use through time and sites that may have been used for contaminating activities. Limited fieldwork was carried out which involved site walkovers of selected sites, and collecting a limited number of surface soil samples for analysis of potential contaminants of concern.

Soil samples were collected from sites within each of the four sections to provide an initial assessment of background levels of contaminants in the different environments and types of land use.

The Preliminary Phase 1 ESA identified 15 AECs that are within or near the proposed alignment. A more detailed Phase 2 investigation at each of these AEC is recommended at the environmental assessment and detailed design stage.

9.10 Quantities of earthworks

Section 1 of the upgrade has been designed with an approximate earthworks balance (slightly more cut than fill) based on the bank volumes.

Section 2 of the upgrade has been designed to produce a surplus of material for use in sections 3 and 4 to the north. Further refinement of the vertical alignment may be required at the detailed design stage to produce additional surplus material and an improved balance of materials across the project. Should the staging of the project be such that this surplus material is not required, a revised vertical profile could be considered to give a more suitable earthworks balance.

In Sections 3 and 4, the earthworks are driven by the need to keep the upgrade above the one in 20-year flood level. This has resulted in the need for a substantial amount of fill being required. This material may be available from section 2 or from the Iluka Road to Woodburn project to the north. The amount of fill required in these sections would need to be further increased above the raw figures by the need to cater for preload and settlement materials.

The approximate bank earthworks volumes are shown in **Table 9-5** and subject to further refinement during the environmental assessment and detailed design. The earthworks volumes are based on:

- Sections 1 and 2 — pavement thickness of 710 millimetres, and topsoil stripping depth of 150 millimetres.
- Sections 3 and 4 — pavement thickness of 710 millimetres, and topsoil stripping depth of 0 millimetre.

- **Table 9-5: Concept design bank earthworks volumes**

Section	Cut volume	Fill volume	Balance
1 – Class A	990,000 m^3	910,000 m^3	80,000 m^3
1 – Class M	990,000 m^3	990,000 m^3	0 m^3
2 – Class M	5,670,000 m^3	3,860,000 m^3	1,810,000 m^3
3 – Class A	380,000 m^3	1,410,000 m^3	- 1,030,000 m^3
3 – Class M	380,000 m^3	1,530,000 m^3	- 1,150,000 m^3
4 – Class A	130,000 m^3	790,000 m^3	- 660,000 m^3
4 – Class M	140,000 m^3	870,000 m^3	- 730,000 m^3

10. Pavements

10.1 Design criteria

Pavements are to be designed in accordance with:

- *Pavement Design — A Guide to the Structural Design of Road Pavements* (Austroads, 2004) — referred to as the *Austroads 2004 Guide*.
- *Supplement to the Austroads Guide to the Structural Design of Road Pavement* Draft Version 16 (RTA, August 2006) — referred to as the *RTA Draft Supplement Version 16*.

The pavements for the project have been designed in response to the geotechnical conditions and predicted traffic volumes. They would be heavy duty, low-maintenance pavements, designed for a 40-year life. The final pavement design would be undertaken as part of the detailed design.

10.2 Traffic volumes

Traffic volumes adopted for pavement designs are based on the parameters outlined in **Chapter 7** of this report. Updated traffic data may, however, be required for detailed design depending on when construction begins.

10.3 Preliminary pavement design

For the purposes of the concept design, the following pavements have been adopted:

- Pacific Highway carriageways — plain concrete pavement:

  260 millimetre plain concrete base.

  150 millimetre lean mix concrete sub-base.

  300 millimetre selected material.

  Subgrade CBR (bearing ratio) of three per cent.
- Interchange ramps — plain concrete pavement as per carriageways.
- Service and access roads — flexible granular pavement:

  50 millimetre asphalt.

  400 millimetre granular material — consisting of dense graded base (DGB) material and dense graded sub-base (DGS) material.

During environmental assessment and detailed design, these designs will need to be further developed with considerations given to operational issues, including the use of low noise pavements, and maintenance requirements.

11. Urban design

Chapter 11 presents information drawn from the Landscape and Visual working paper, compiled as part of the Preferred Route Report (RTA, 2006b).

A more detailed urban design proposal and corresponding landscape and visual assessment would be developed as part of the future environmental assessment process.

11.1 The visual environment

There are three main features that form the local landscape within the study area:

- The pronounced ranges of coastal hills.
- The wide floodplain of the Clarence River and its South Arm.
- The water bodies of the river system.

Although some parts of these are outside the study area, they contribute strongly to its character and scenic quality (**Figure 11.1**).

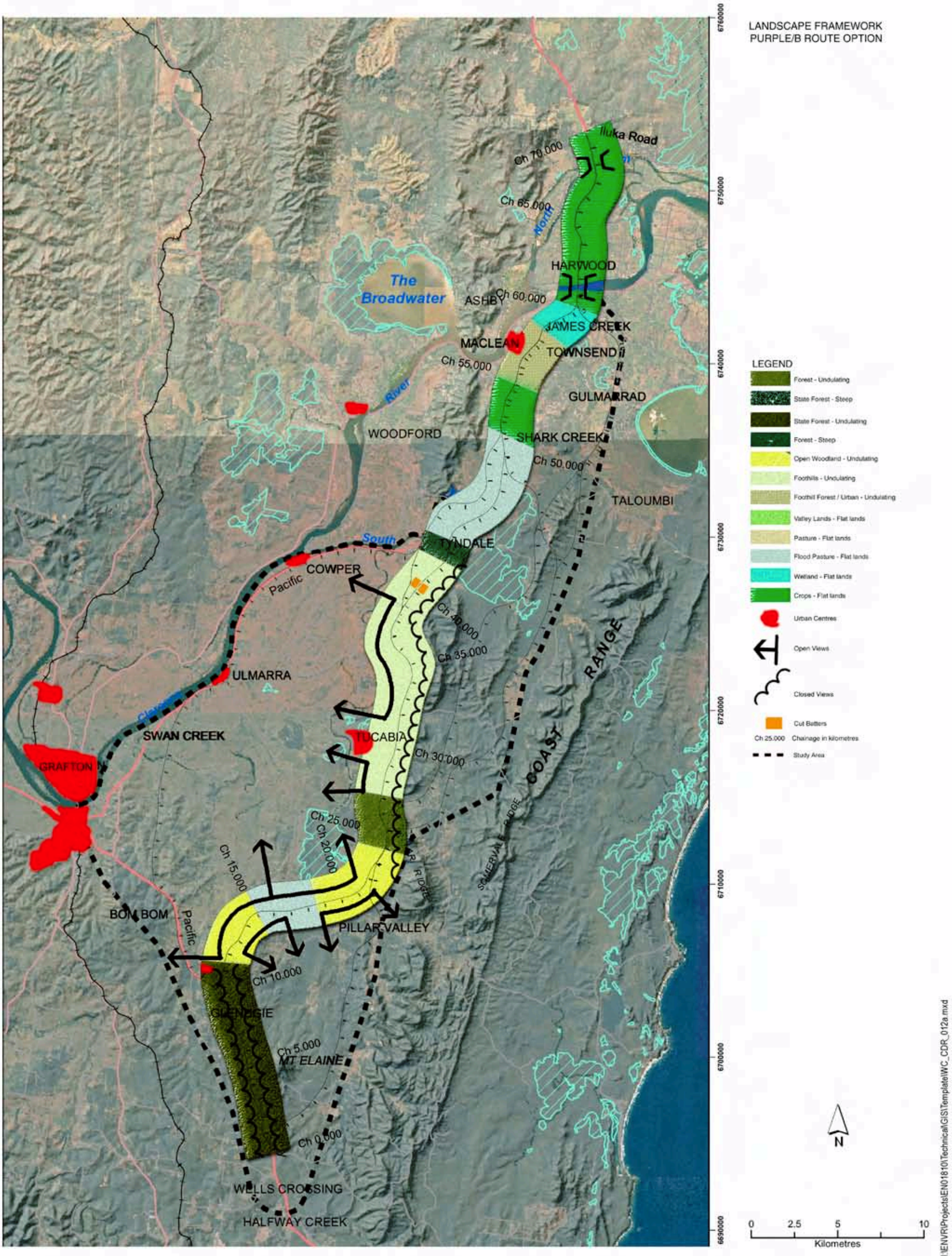
The principal coastal hill peaks range in height from 127 metres at Shark Creek to 316 metres at Mt Elaine (Glenugie Peak). Their edges to the floodplain are characterised by gentle hill slopes and the valleys that penetrate them.

The floodplain of the Clarence River, located generally below an altitude of five metres, is characterised by many meandering creeks, former watercourses and swamps. The banks of the Clarence River and South Arm, being subject to flooding, are generally raised above the level of the immediately surrounding land. Hence, although important features of the area, the rivers are really only visible from elevated locations.

Natural woodlands, mostly located on higher or steeper land, cover almost half of the study area and dominate the southern and eastern parts of the broader area. These woodlands are generally dry, open forest. In various locations on the more gentle sloping foothills the forest has been partially cleared.

Within the cleared plains, there is a high degree of visual diversity created by the constantly changing pattern of open grassed areas, small and/or large treed areas, intervening riparian strips along drainage lines, soaks, creeks and rivers, as well as vegetation associated with various swamps within the floodplain. Within this mosaic, sugar cane is a distinctive feature and exhibits significant changes in character with the growing cycles. A backdrop of forested hills is common to many views within the floodplain areas.

Figure 11.1 Scenic Quality and Views Map



In terms of settlements, the study area features:

- Intensive cropping, including sugar cane, to the north of the study area, particularly along the Clarence River and South Arm and the existing highway.
- Areas of existing and intensifying rural residential development in the Shark Creek/Gulmarrad area.
- A number of the towns and villages located on the highway, including Glenugie, South Grafton, Ulmarra, Brushgrove, Cowper, Tyndale, Maclean, Townsend and Harwood, which help to define the visual character of the existing highway and broader environment.

11.2 Urban design framework

The *Pacific Highway Urban Design Framework* (RTA 2005c) provides guidelines for urban design considerations to be incorporated into all stages of the highway upgrade. The *Urban Design Framework* emphasises the importance of considering urban design early in the project, at the route selection stage.

The starting point is the RTA's vision for the Pacific Highway Upgrade Program:

> *' A sweeping, green highway, providing panoramic views to the Great Dividing Range and the forests, farmlands, and coastline of the Pacific Ocean. The route is punctuated by the presence of distinctive settlements, rivers, mountains and bridges.'*

Within the context of the *Urban Design Framework*, the project needs to consider the specific landscape and development considerations of the study area so that the project can be integrated into the landscape. In this regard, the following objectives espoused by the framework are relevant.

Objective 1: Flowing and responsive.

> "*Provide a flowing road alignment that is responsive and integrated with the landscape*."

To implement this objective, the design should seek to:

- Achieve an aesthetically pleasing road alignment by following the edges of landscape units, skirting the edges of the valley, following the interface between pasture and bush land and being responsive to the topography.
- Integrate road embankments into the adjacent landscape through the use of variable batter slopes.
- Consider the use of split carriageways that enable greater responsiveness to topography, particularly in steep terrain or in the foothills where this could reduce cut and fill.
- Integrate the road landscape into existing vegetation patterns. For example, avoid linear strip planting of trees and shrubs along the highway that do not fit into the landscape.

Objective 2: Well-vegetated and natural.

> "*Provide a well vegetated, natural road reserve*."

To implement this objective, the design should seek to:

- Select vegetation that responds to that adjoining the road corridor.
- Select planting that reflects the developed and cultural planting of the area to which the highway is connecting, where it passes through or connects to populated areas. Special landscape treatments may be appropriate at interchanges, where cultural or native plantings may be used.
- Select median planting that is responsive to the vegetation community through which the road travels.
- Design rest areas so they provide an environment that is conducive to rest. They should incorporate shade plantings and shelter, and provide a visual connection to the passing traffic to provide a sense of security.
- Highlight creek and river crossings by using plantings that reflect naturally-occurring species that distinguish them from other areas.
- Use revegetation works that respond to ecological constraints and controls. Adjacent to traffic lanes, or where there are no fauna fences, plant species should be selected that do not attract fauna species that are prone to straying onto roads.

Objective 3: Enjoyable journey.

> "*Provide an enjoyable, interesting highway with varied views and vistas of the landscape and pleasant restful places to stop*."

To implement this objective, the design should seek to:

- Create a varied sequence of views and enclosure. The corridor passes through a number of landscape types and these should be acknowledged.
- Make the alignment responsive to the topography, with curves responding to topographic constraints and straight sections used sparingly and in harmony with terrain.
- Locate rest areas in places with views of the surrounding landscape.

Objective 4: Community benefit.

"*Value the communities and towns along the road*."

To implement this objective, the design should seek to:

- Provide advance views of, or visual markers to, Grafton and Maclean and their outskirts, which would be bypassed by the proposed road alignments with limited opportunity for viewing from the highway.
- Provide distinctive planting at off-ramps leading to towns.
- Achieve a net improvement to the public spaces in the town or settlement where public spaces (street paths, park, etc) are affected by the highway.
- Consider reducing the scale of the existing highway in bypassed towns, through road narrowing and planting.
- Consider local access to the highway alignment.
- Consider access needs at a regional and local context, to facilitate easy movement of locals within their local region as well as connecting to the wider hinterland and beyond. This consideration of access should assess the issue of flooding, and the ability of people and livestock to escape from flood waters.
- Avoid or minimise and mitigate against adverse visual impacts on towns and communities, where possible.

Objective 5: Consistency with variety.

"*Provide consistency with variety in road elements*."

To implement this objective, the design should seek to:

- Consider the bridges as part of the same design family and part of the suite of unified elements. Particular care should be paid to the Clarence River crossing due to the distinctive and historic character of the existing bridge and the need to duplicate it. Reference should be made to the *RTA, 2005: Bridge Aesthetics Design Guidelines* (RTA, 2005d) during the route selection and concept development process.
- Make the flood bridges slim in profile to minimise visual bulk and reduce their visual impact.
- Make the new bridge at Harwood complement the existing bridge. Extreme care is needed in the concept design to address the potential for misalignment of bridge decks and contrasting

construction techniques. The Clarence River crossing is a significant visual element and the arrangement of the bridge could alter the way the river is viewed. The installation of a new bridge also provides the opportunity to improve the relationship of Harwood to the river, which would help offset some of the impact of the proposal.

Objective 6: Simplicity and refinement.

"*Provide a simplified and unobtrusive road design*."

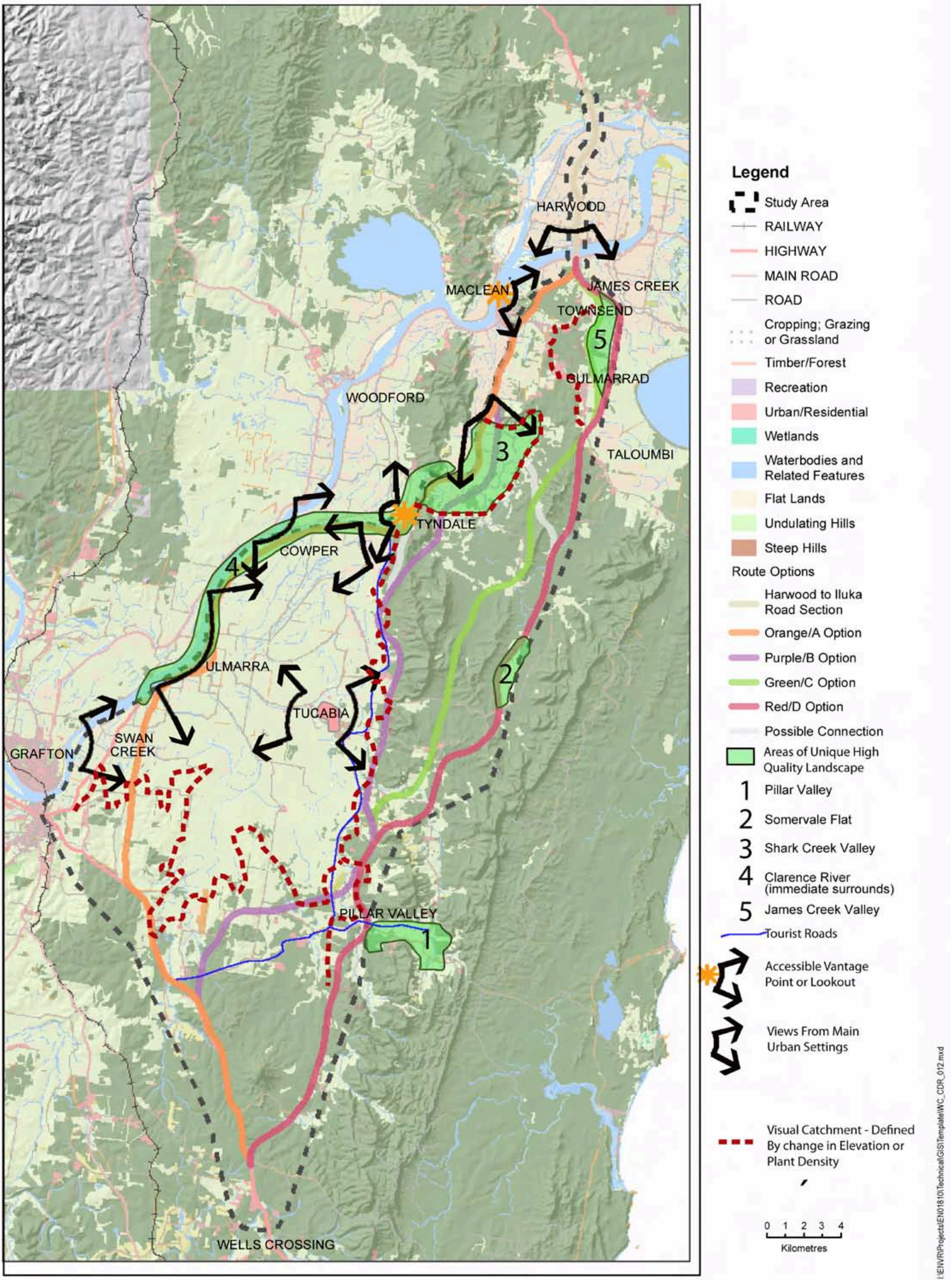
To implement this objective, the design should seek to:

- Integrate the piers for bridges that cross over the highway into the overall design of the structure, either through the use of columns without pier caps (headstocks) or wall type piers.
- Use spill-through 'open' abutments on bridges over the upgrade.
- Design safety screens, where required, as an integral part of the bridge and site them in accordance with RTA policy.
- Neatly connect bridge barriers with road and safety barriers as an integrated system.
- Provide noise walls (if required) that are plain, simple structures with no patterns or images on their surface in accordance with the *RTA, 2005: Pacific Highway Urban Design Framework* (RTA, 2005c). Preference should be given to integrating noise treatments within the earthworks of the project or to provide architectural treatments.

11.3 Landscape framework

The landscape framework is shown in **Figure 11-2**. It provides a structural layout for the future landscape design of the project. The framework is responsive to the urban design strategies, with particular reference to Objective 2 — "*Well vegetated and natural*". The framework defines the three key landscape types, namely, flat lands, undulating lands and steep lands, and makes general recommendations regarding the treatments of these types. The landscape treatment for the upgrade is described in the following sections.

Figure 11.2 Landscape framework - Purple / B Route Option



11.3.1 Landscape types

Flat lands

Flat lands are defined by the floodplain of the Clarence River; they are low lying, flat and expansive in scale. The following landscape types are contained within this zone and need to be reflected in the landscape design: croplands, pasture, wetlands, forests and valley lands:

- Croplands are characterised primarily by sugar cane crops. The character of this zone changes as crops are harvested and fields fallowed according to crop rotation, creating an alternating cycle of open and closed views. The road structure within the flat lands is characterised by being raised three to five metres on either embankment or viaduct.
- Pasture is characterised by exotic grasses, and this zone forms the primary vegetation type of the floodplain. The expanse of pasture is broken only by the occasional feature tree such as fig trees, primarily close to the river, or scattered clumps of eucalypts or casuarinas. The road would be located on embankment or viaduct and should be integrated into its surrounds by using flatter batter slopes and re-vegetating to generally match the surrounds.
- Generally, SEPP14 wetlands and other regionally significant wetlands would be avoided by the route. Wetlands are environmentally sensitive areas that are of visual interest. Embankment batters should be designed to limit the extent of impact on the adjacent vegetation, where possible and desirable. To achieve this, steeper batters (1:2) or vertical walls are suggested. Revegetation should be undertaken using the dominant vegetation type, such as *Allocasuarina*, *Casuarina* and *Melaleuca*.
- Forest within the flat lands is distinct from the other landscapes and has a specific vegetation and character. By traversing the floodplain, the road would generally not impact on forest, as much of it has been cleared for agriculture.. To minimise impacts, steeper batters (max. 1:2) are preferable subject to geotechnical constraints. These should be re-vegetated to match the adjacent community.
- The valley lands are a unique landscape within the study area and are located to its eastern edge between the coast and Shark Creek Ranges. This landscape combines a number of different attributes including pasture, foothills and open woodland, and has a sense of enclosure and containment. In order to minimise impacts, care needs to be taken to reduce the scale of the road within this landscape. This could be done by using split carriageways, following the valley edge, and using planting that restricts but does not eliminate views.

Undulating lands

Undulating lands are the transitional zone between the ridges and plains. They are characterised by rolling hills of gentle gradients (6–15 per cent), which are either cleared, partially cleared or forested. Undulating lands comprise the following landscape types: foothills, open woodland, forest and State Forest, as follows:

- Foothills cover a relatively limited extent of the study area. They occur at the intersection of the floodplain and the coastal ranges and are the transitional landscape between floodplain and ridge. The vegetation cover reflects this transitional nature, having pasture, open woodland and forest. The landscape design should respond to this varying character and reflect this mix. Batter slopes should also vary to reflect the flatter and steeper terrain of this zone. Views should be opened and closed to provide interest and to emphasise the vistas that are special or important.
- Open woodland comprises cleared or partially cleared lands and varies from scattered clumps/clusters of trees to continuous, but open woodland. This landscape provides opportunities for views, and also opportunities to screen. The design should use the qualities of woodland to provide interest along the route as well as mitigate the impacts of the roadway.
- The forest is a relatively undisturbed landscape composed of groundcovers, understorey and canopy vegetation, creating a strong sense of enclosure. The road formation should respond to this by minimising its footprint and, thereby, minimising impact on this landscape.
- Although State Forest is essentially similar in character and attributes to forest, the planting and structure is more controlled and regimented, composed of one dominant canopy species of relatively similar age rather than the mixed canopy of the natural forest. This creates its own distinct feel. The proposed design should respond to this regimented character.

Steep lands

Steep lands are the least common landscape type and are concentrated to the eastern edge of the study area with localized areas in the southwest. Steep lands are characterized by steep gradients (15 per cent or greater) and a relatively high elevation. The steep topography of this terrain has seen the natural vegetation communities largely retained. There are two landscapes: forest and State forest.

- Forest reflects a relatively undisturbed landscape composed of groundcovers, understorey and canopy vegetation, creating a strong sense of enclosure. The road formation should respond to this by minimising its footprint and, thereby, minimising impact on this landscape.
- As outlined above (undulating lands), State Forest has a structure and feel that is distinct from forest, and the road design should respond to this regimented character.

Because of the steeper terrain of the steep lands landscape, the project is likely to result in deeper cuts. These cuts are likely to encounter rock that may be unable to be re-vegetated. The nature of the rock needs to be established early in the design process so that final treatments can be determined. These treatments include near vertical rock batters, reinforced in-situ concrete walls, or earth walls. Any of these treatments may result in a significant increase in visual impact.

11.3.2 Landscape treatments

In implementing landscape treatments, a number of issues that affect the physical appearance of the road should be addressed, including species mix, ground conditions and stabilisation methods.

In addition to these soft landscape parameters, there are a number of hard landscape elements that contribute to the character of the road. These include fences and other built elements.

Key principles and approaches to aid the assessment process are outlined below.

Species mix

The species mix for the road corridor can be broken into two distinct categories: ecological and agricultural/cultural plantings.

Ecological plantings are those which reflect the natural communities of the site; while agricultural/cultural plantings are responsive to the altered landscape. Agricultural/cultural plantings reflect crops or pasture types or the dominant character of the urban landscape. Grafton, for example, is synonymous with Jacaranda trees.

The general plant species likely to be used in the respective landscapes are listed below. This list is indicative only. Final species selection should reflect the communities adjacent to the proposed highway and be finalised as part of the environmental assessment phase. Landscapes and respective species are:

- Pasture/floodplain.
  - Species of pasture grasses, Ficus obliqua, Casuarina glauca and Melaleuca quinquinervia.
- Wetlands.
  - Trees: Melaleuca quinquinervia, Casuarina glauca and Melaleuca linariifolia.
  - Groundcover: Baumea articulata and Carex spp.
- Forest/woodlands.
  - Trees: Eucalyptus pilularis, Corymbia intermedia, Eucalyptus eugenoides, Eucalyptus microcorys, Eucalyptus propinqua and Eucalyptus siderophloia.
  - Shrubs: Acacia spp, Allocasuarina torulosa, Allocasuarina littoralis, Melaleuca sieberi, Banksia oblongifolia and Melaleuca linariifolia.
  - Groundcover: Imperata cylindrical, Pteridium esculentum, Lomandra longifolia and Entolasia stricta.

Ground conditions and stabilisation methods

Ground conditions would have a strong impact on the success of the landscape design and the visual character of the route. Cuttings would provide the greatest risk in terms of impacts on landscape character as they would expose the underlying geology of the route.

In a number of instances, a weak stratum may be encountered which is not stable in its natural state and is unable to support vegetation. Options to address this include:

- Introducing walls.
- Flattening the slope and over-excavation to enable introduction of soil for landscape.
- Treatment or rock armouring.
- Shotcrete as a selective stabilisation method. However, this should be avoided if possible.

Fence types

Fencing can have a strong influence on the character to the road. Critical to minimising the impacts are the relationship of the fence to the road, and the type of fencing used. A range of fencing types are likely to be used, including:

- Agricultural fence — five-strand fence.
- Fauna fence — floppy top fence.
- 'People-proof' fence — 1.8-metre-high chain mesh fence (black finish).

Built elements

Built elements refer primarily to the bridge structures associated with the road. The design of bridges should be guided by the following principles:

- Bridges should generally belong to the same design family and should be considered as part of the suite of unified elements.
- Bridges should be of similar design to bridges in adjoining upgrade sections of the highway.
- Piers for bridges over the highway should be integrated into the overall design of the structure. This may be through the use of either a column without pier caps (headstocks) or wall type columns. Generally, spill-through 'open' abutments, finished in local stone and laid over a blinding slab, should be employed.
- Bridge balustrades should be constructed of pre-cast concrete and double bridge-rails and drainage pipes should be concealed.
- Safety screens, hand rails and noise barriers, where required, should be designed as integral parts of the bridge balustrade.

12. Public utilities

Chapter 12 presents the findings of investigations into public utilities in the study area.

12.1 Investigation of existing utilities

A 'Dial-Before-You-Dig' investigation was undertaken as part of the concept design. Moreover, visible surface utilities were located as part of the ground survey process. Contact was also made with Country Energy to obtain information on their assets throughout the area.

These investigations found there are a significant number of services in the area of the proposed upgrade alignment, including communications, electricity, water and sewer, but no gas services or major electrical transmission lines. The public utilities within the study area are summarised in **Table 12-1**.

- **Table 12-1: Utilities with the area**

Utility class	Authority	Service description
Communication	Telstra	Optical fibre — location along the route from the Telstra Tower in Section 1 (Ch 8200) to Eight Mile Lane. Optical fibre — located along the route north of Maclean. Cable crosses the route at a number of locations. Local distribution networks — located throughout the area.
Electrical	Country Energy	Local distribution networks — located throughout the area.
Water	Clarence Valley Council	Water main — located along the route between Tyndale and Shark Creek (Section 3 — Ch 47500 and Ch 49700).
Sewer	Clarence Valley Council	Sewer rising main — crosses the route at Goodwood Street, Maclean.

12.2 Utilities potentially affected by the project

This section outlines the considerations related to utilities affected by the proposed upgrade. The concept design drawings (**Appendix A**) indicate the locations of the public utilities. Utilities that need to be relocated or protected would be confirmed during detail design, following the confirmation of the concept design and further consultation with the authorities.

12.2.1 Communication

Due to the extent of Telstra's local network, there are numerous locations where the upgrade crosses the network throughout the length of the project.

Telstra has two main lengths of fibre optical cable within the project area:

- Connection to tower in section 1.
- Sydney–Brisbane optical fibre cable located north of Maclean to Iluka Road (and beyond).

Table 12-2 summarises the impacts that the project would have on the Telstra network.

- **Table 12-2: Major Telstra utilities affected by the project**

Section	Chainage	Impacts	Adjustment / protection required
1	Ch 9200	Route crosses over Fibre Optic Cable.	Cable to be protected below fill embankment.
	Ch 10100	Connection to existing highway crosses over Fibre Optic Cable.	Cable to be protected below fill embankment.
3	Ch 58100 – Ch 60000	Fibre Optic Cable located below northbound carriageway.	Cable alignment to be relocated clear of formation.
4	Ch 62700 – Ch 64000	Fibre Optic Cable located below northbound carriageway then crosses to eastern side of upgrade.	Cable alignment to be relocated clear of formation with protection provided at crossing point.
	Ch 64400 – Ch 64700	Fibre Optic Cable located below fill batter from southbound carriageway.	Cable alignment to be relocated clear of formation (protection may be possible subject to negotiations with Telstra).
	Ch 64700 – Ch 65500	Fibre Optic Cable located at toe of batter.	May require some protection over full or partial lengths.
	Ch 68200 – Ch 68800	Fibre Optic Cable located below southbound carriageway then crosses to western side of route.	Cable alignment to be relocated clear of formation with protection provided at crossing point.
	Ch 69000 – Ch 69900	Fibre Optic Cable located at toe of batter.	May require some protection over full or partial lengths.
	Ch 69900 – Ch 70900	Fibre Optic Cable located below interchange and local road.	Cable alignment to be relocated clear of formation.

12.2.2 Electricity

Country Energy maintains a network of aerial cables across the project area, and these would be crossed by the preferred route at numerous locations. Allowance is made for some relocations in the concept design estimate.

12.2.3 Water

A water main is located along the western side of the existing highway between Tyndale and Shark Creek (section 3 — Ch 47500 to Ch 49700). Allowance is made in the concept design estimate for some protection or adjustment of this asset.

12.2.4 Sewerage

A sewer rising main has recently been constructed along Goodwood Street at Maclean, which is the site of the proposed Maclean interchange. As part of the construction of the interchange, the level of Goodwood Street is proposed to be raised. Allowance is made in the concept design estimate for some protection or adjustment of this asset.

13. Mitigation of issues and impacts of concept design

The project would have a number of impacts, both positive and adverse, on the local environment and the community. Chapter 13 presents a summary of the key issues and proposed mitigation measures.

13.1 Cane industry assessment

A detailed assessment of the potential impacts of the upgrade on the cane industry was undertaken for the concept design phase (*Cane Industry Working Paper* [RTA, 2008a]). The main aim of the assessment was to quantify potential impacts on individual cane farmers and the wider cane industry and identify the mitigation measures that would minimise these impacts.

The assessment process and key findings are presented below.

13.1.1 Investigations

A meeting between the Clarence Cane Industry Committee and the project team was held on 16 March 2007 in Maclean. Representatives from the Clarence Cane Growers, NSW Sugar Milling Cooperative and the Harwood Sugar Mill were present at the meeting. The meeting provided the cane industry with an opportunity to outline its concerns, discuss the potential impacts of the project on their operations, and highlight the important features of their activities that would need to be considered during the design and construction phases.

Following the meeting, interviews were held with individual cane growers (29 interviews) to ascertain the location of residential dwellings, farm sheds, cane pads, farm tracks and roadways, drainage patterns and existing flood mitigation measures on 66 affected cane-growing properties. The Clarence Cane Growers office provided farm maps to help determine the total landholding and calculate the potential impacts on individual farms. Access arrangements to cane farms, cane pads and the sugar mill were also identified. The extent of the impact was calculated, including a consideration of the residual lots created. The locations of the farm drains and access tracks that need to be retained or replaced to lessen the impacts of the upgrade were also identified.

An overview of the initial findings was then presented at a meeting with the Clarence Cane Industry Committee on 8 August 2007. To discuss the impacts on the cane industry and potential measures to minimise these impacts, four precinct meetings were also held on 21 and 22 August, 2007. The precincts were based on the following boundaries:

- Tyndale to McIntyres Lane.
- McIntyres Lane to Harwood Bridge.
- Harwood Bridge to Serpentine Bridge.
- Serpentine Bridge to Iluka Road.

13.1.2 Potential impacts during construction and operation

The cane industry study identified the following potential impacts of the project:

- Direct loss of cane land (particularly highly productive land located to the south of Maclean).
- Creation of residual lots.
- Loss of cane production and associated income.
- Impacts on cane pads, farm sheds and residential dwellings.
- Loss or restriction of access between properties and to cane pads.
- Loss or restriction of access from cane pads to the sugar mill.
- Alterations to farm drainage and the flooding regime.

Loss of land

North of Harwood Bridge, 6 of the 14 cane farmers would have over 5 percent of their total holdings (property holdings comprise the entire cane land area owned by an individual farmer and may contain more than one cane farm) affected by the proposal. The average loss of holdings is 5.8 percent.

The impact on cane growers south of Harwood Bridge would be greater, with 13 of the 15 farmers having over 5 percent of their total holdings affected by the proposal. The average percentage of total holdings lost as a result of the preferred route is 12.4 percent.

The land acquisition resulting from the upgrade would also require cane growers to reduce the row lengths within many cane farms. This would decrease the efficiency of farming operations, and increase farming and harvesting costs.

Creation of residual lots

The project would result in the creation of residual lots, especially south of Harwood Bridge. The area of the residual lots that can be retained for cane production would depend on the level of investment required to re-level the property and build adequate drainage features.

The productivity of some of the residual lots would be diminished as a result of the shortened row lengths. If all the residual lots created by the upgrade were lost to cane production, a total of 36 hectares of cane land would be lost. There is, however, potential for residual lots to be amalgamated with other cane paddocks so they are retained for cane production. It is expected that only about 10 hectares of residual land would not be retained for cane production, which is equivalent to a loss of about 1500 tonnes of cane per annum.

From the estimates made to calculate the loss in cane production and associated income, the project could potentially result in an annual revenue loss of $476,050. This revenue loss is based on the direct loss of land. The impact of the upgrade could be greater than this if the residual lots cannot be maintained as cane land. In addition, this analysis does not take into account the inefficiencies in farming and harvesting caused by shorter row lengths.

Impacts on access

There is a need to maintain suitable access within and between cane properties and between cane pads and the sugar mill to ensure the ongoing viability and efficiency of cane harvesting and farming operations. The *Cane Industry Working Paper* (RTA, 2008a) describes the transfer routes used from each cane pad to the sugar mill and the tonnes of cane hauled and number of truck movements during the 2007 harvest period. Each truck movement with a load of cane destined for the sugar mill has a corresponding truck movement with an empty cane bin to the same or a nearby cane pad.

Impacts on cane pads and farm sheds

The project would directly affect nine cane pads, all of which are required to enable cost-effective harvesting and would need to be relocated. Construction costs for a new cane pad could range between $40,000 and $100,000, depending on the length of access road and quantity of fill required (RTA, 2008a). It was estimated that $750,000 may be required to reconstruct the nine cane pads.

In addition, four farm sheds around Tyndale and Shark Creek cannot be relocated from their existing low-impact flood site to less elevated sites without large investments in fill and access road construction. Depending on whether the new locations of these structures are convenient for servicing the cane farms, this may lead to ongoing increased harvesting costs due to the extra travel distance between sheds, properties and cane pads.

Impacts on farm drainage

If inappropriately designed and managed, the project could affect the drainage patterns of individual paddocks, properties and the wider locality directly. The impact on paddock layout and associated drainage would also compromise the overall drainage pattern for the cane lands. Many of the drains along the ends of paddocks that are adjacent to the existing road reserve would need replacing.

Preliminary drainage design has been addressed as part of the concept design phase. More detailed drainage design would be addressed during the detailed design and environmental assessment phase of the project and care should be taken to maintain the functionality of farm drains, main drains, flood mitigation drains and floodgates. Otherwise, the result would be yield reduction, cane death and impediment of farming and harvesting operations.

13.1.3 Recommended mitigation measures prior to and during construction and operation

During the interviews and meetings held with individual farmers and the cane industry, mitigation measures were suggested and documented (refer to *Cane Industry Working Paper* [RTA 2008a]). The main impacts that can be mitigated through design include those that relate primarily to flooding, drainage and access within and between properties (including residual plots), cane pads, property infrastructure and Harwood Mill.

The concept design incorporates a range of management measures aimed at minimising the project's impacts on individual cane farmers and the viability of the cane industry in the Clarence Valley.

Mitigation measures: severance and residual lots

To reduce severance and the creation of residual lots, where possible, the route would follow the existing road corridor. Although the area north of Bondi Hill and the Shark Creek area would be severed by the project, it is anticipated that the residual lots could be amalgamated into a single workable lot.

Mitigation measures: drainage

In minimise drainage impacts, the project proposes measures that seek to maintain the current times of inundation, limit the flow velocities through the cane, and maintain the current cane drainage systems. In section 3 of the alignment (Tyndale to Harwood Bridge), water would flow into and out of the Shark Creek Basin in a pattern similar to the existing flows. In section 4 (Harwood Bridge to Iluka Road), the design includes a series of culverts across Harwood and Chatsworth Islands to maintain flood patterns similar to the existing flood pattern. In addition, culverts and floodgates would be provided to maintain current drainage systems.

Mitigation measures: access

To minimise access issues in sections 3 and 4, the project proposes measures that respond to the requirements for the haulage of cane and machinery movements as well as private vehicle trips. (Options considered are detailed in **Sections 5.11.3** and **5.11.7)**.

Access would be provided to all properties and cane pads along the highway. While direct access from properties to the route would be removed under both the Class A and Class M upgrades, local roads would be provided to maintain local access. Under the Class A upgrade, the local roads would connect to a series of at-grade intersections along the highway, while under the Class M upgrade, access would be provided at interchanges only (refer **Sections 0**).

The at-grade intersections for the Class A upgrade would provide convenient movement for cane trucks to Harwood Mill, thus limiting the need for back-tracking and U-turns. The inclusion of an interchange at Watts Lane with free-flow for the cross-highway traffic would improve access to Harwood Mill. Cross-highway access would be provided at the following locations:

- Shark Creek Road (under highway).
- Goodwood Street (under highway).
- Yamba Road (under highway).

- Watts Lane (under highway).
- Chatsworth Road / Serpentine Channel Road North (over highway).
- Carrolls Lane (at-grade intersections in Class A; over highway in Class M).
- Iluka Road (over highway).

13.2 Terrestrial ecology

Terrestrial ecology assessments were undertaken for the route selection (2004-07) and concept design phases (2007). The current assessment builds on the information gathered from the previous stages of the project, and provides further insight into the potential nature and extent of the terrestrial ecological impacts likely to be associated with the project.

The principal aim of the assessment is to identify, describe and map the ecological features of the preferred route corridor to help evolve the concept design and provide baseline data for future environmental assessment phases of the project. The assessment also has preliminary mitigation measures for incorporation into the concept design. The full terrestrial ecology assessment can be found in the *Terrestrial Ecology Working Paper* (RTA, 2008b). Biodiversity issues will be outlined in the Environmental Assessment.

13.2.1 Investigations

During the route option phase, a list of threatened flora and fauna species was compiled to determine the potential presence of threatened biodiversity in the study area.

General landscape and habitat data were also collected across the Clarence River floodplain east of the river through to Yuraygir National Park, which included the escarpments and western footslopes of the Shark Creek Range, Pillar Valley Range and McCraes Knob.

For the concept design, detailed field surveys during winter and spring (July to October) 2007 served to gather quantitative and qualitative data on flora and fauna species richness, vegetation associations and habitats. The data contributed to a detailed understanding of the vegetation communities, fauna habitat types, high conservation value areas and wildlife corridors throughout the landscape surrounding the corridor, and provided key information to the concept design process. Consultation also occurred with Professor Stephen Davies, Emu specialist from the University of Curtin, regarding potential impacts on the coastal Emu population and relevant mitigation strategies.

13.2.2 Potential impacts on terrestrial ecology

Endangered ecological communities

There are no nationally endangered ecological communities as listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) located along the preferred route corridor. However, the following endangered ecological communities listed in NSW under the *Threatened Species Conservation Act 1995* (TSC Act) occur in the area of the preferred route corridor:

- Subtropical Coastal Floodplain Forest.
- Swamp Sclerophyll Forest on Coastal Floodplains.
- Swamp Oak Floodplain Forest.
- Lowland Rainforest.
- Freshwater Wetlands on Coastal Floodplains.

The project would result in direct impacts on about 84 hectares of endangered ecological communities.

Threatened flora

Threatened flora species identified in or along the preferred route corridor are listed in **Table 13-1**, along with their conservation status, distribution and abundance.

- **Table 13-1 Threatened flora species**

Species	Conservation status			Distribution, abundance and potential impacts
	Cwlth	NSW	RoTAP	
Moonee Quassia (*Quassia sp.* Moonee Creek)	E	E	-	A single specimen identified on a sandstone ridge to the east of the preferred route corridor in section 2 near McCraes Knob. Outside of the corridor.
Sandstone Rough-barked Apple (*Angophora robur*)	V	V	2RC-	This species is relatively abundant within and adjacent to the preferred route corridor in Dry Sclerophyll Forest on elevated sandy soils through section 2 from Firth Heinz Road north to Pine Brush State Forest. Based on a 150 metre-wide corridor, it is estimated that 3000-6000 individual trees out of an estimated population of 100,000 could be directly affected by the upgrade. *Angophora robur* hybridises with another closely related species *Angophora subvelutina,* which is also abundant in the area although occurring on lower elevated sites and seasonally waterlogged areas. Hybrids were present on lower slopes where the two species were found to intergrade, making it difficult to estimate the total population size and number of individual trees potentially affected by the upgrade (refer to **Table 13-3**re proposed mitigation).

Species	Conservation status			Distribution, abundance and potential impacts
Square-fruited Ironbark (*Eucalyptus tetrapleura*)	V	V	2VCa	A large sub-population of *Eucalyptus tetrapleura* was identified in section 1 within Glenugie State Forest predominantly in the area between Lookout Road and Reserve Road. The population is estimated to comprise between about 30,000–40,000 individual trees. Of these about 2000–3000 individual trees are estimated to be directly impacted (6-8 per cent of the sub-population) for the proposed highway upgrade based on a 150 m wide road footprint. The population is estimated to occur over an area of 307 ha in which *Eucalyptus tetrapleura* forms a dominant to subdominant component of the vegetation community; however within some pockets of this area it is absent or occurs in low abundance. *Eucalyptus tetrapleura* was also recorded to the south of preferred route corridor, appearing to occur in similar densities to the population within the corridor, although trees in this location were not quantified. There are also subpopulations within Pine Brush State Forest and to the south within Newfoundland State Forest.
Four-tailed Grevillea (*Grevillea quadricauda*)	V	V	3VC-	This species was identified within two separate locations adjacent to riparian vegetation west of McRaes Knob in section 2. It occurs in low abundance with both populations totalling only 20 individual trees. These populations are within the preferred route corridor and may potentially be affected by the proposal.
Slender Screw Fern (*Lindsaea incisa*)	-	E	-	A localised population was identified within a drainage swale supporting dense sedges and shrubs on private property in section 2 (about 500 m east of Tucabia-Tyndale Road). This population is located to the west of the preferred route corridor and has potential to be indirectly affected from altered hydrological regimes.
Weeping Paperbark (*Melaleuca irbyana*)	-	E	-	This species was recorded on private property west of the proposed crossing of the Coldstream River in section 2. About 30 individual trees were identified within an open paddock and adjoining Swamp Forest community. This species occurs outside of the preferred route corridor and is unlikely to be indirectly impacted by the proposal.

V= vulnerable E= endangered RoTAP= Rare or Threatened Australian Plant
2RC-= geographic range < 100km, rare but not yet threatened, reserved, reserved population not currently known.
2VCa= geographical range < 100km, vulnerable, reserved, with 1000 plants or more known to occur within the conservation reserve.
3VC-= geographic range > 100km, vulnerable, reserved, reserved population not currently known.

Threatened fauna

There is potential for 67 threatened fauna species to occur along the preferred route corridor. The fauna surveys within the preferred route corridor recorded 20 of those vertebrate fauna species of conservation significance. These are listed in **Table 13-2**.

Table 13-2 Threatened fauna species

Species	Status		Distribution and abundance
	Cwlth	NSW	
Black-chinned Honeyeater (*Melithreptus gularis gularis*)		V	Small population located on private property between Glenugie State Forest and Six Mile Lane. Potential habitat in section 1 and southern end of section 2.
Black-necked Stork (*Ephippiorhynchus asiaticus*)		E1	Recorded in several locations throughout the study area. Present in all sections, favoured open swamps, wetlands, reedlands, dams and adjacent paddocks. At least three nest sites have been identified in the study area, although none of these is located within the preferred route corridor.
Brolga (*Grus rubicundus*)		V	Pair recorded in Ellis Swamp, west of Wooli Road.
Brown Treecreeper (*Climacteris picumnus*)		V	Small population located on private property between Glenugie State Forest and Six Mile Lane. Potential habitat in section 1 and the southern end of section 2.
Eastern Cave Bat (*Vespadelus troughtoni*)		V	Recorded from single bat call recording, in dry sclerophyll forest habitat on sandy soils west of McCraes knob
Eastern False Pipistrelle (*Falsistrellus tasmaniensis*)		V	One individual spotlighted resting on tree trunk in dry sclerophyll forest habitat on sandy soils west of McCraes Knob.
Emu (*Dromaius novaehollandiae*)		E2	Recorded in several locations throughout the study area, predominantly within sections 2 and 3. Local population comprises up to 100 individuals. Recorded in variety of habitats from grassy floodplain to swamp and dry sclerophyll forest.
Glossy Black-Cockatoo (*Calyptorhynchus lathami*)		V	Pair of adult birds recorded in dry sclerophyll forest habitat on sandy soils west of McCraes Knob. Abundance of *Allocasuarina torulosa* (food resource) and large tree hollows also present.
Grey-crowned Babbler (*Pomatostomus temporalis temporalis*)		V	Recorded in several locations in the vicinity of the preferred route corridor favouring forest habitats with open understorey, grassy paddocks, urban fringes, road reserves and small remnant forest patches. Moderately common along the preferred route corridor.
Grey-headed Flying-Fox (*Pteropus poliocephalus*)	V	V	Recorded sparsely in dry open sclerophyll forest.
Hoary Wattled Bat (*Chalinolobus nigrogriseus*)		V	Recorded from single bat call recording, in dry sclerophyll forest habitat on sandy soils west of McCraes Knob.
Koala (*Phascolarctos cinereus*)		V	Recorded in section 2. Low population expected based on evidence of scats. Favours forests dominated by Tallowood.
Little Bentwing-Bat (*Miniopterus australis*)		V	Three individuals captured within Glenugie State Forest, dry sclerophyll forest on clay soils. Also recorded in Dry Sclerophyll Forest on sandy soils near Tucabia and McCraes Knob via several recorded bat calls.
Magpie Goose (*Anseranas semipalmata*)		V	Pair recorded in TSR wetland at Sandy Crossing on the eastern side of Wants Lane.
Osprey (*Pandion haliaetus*)		V	Recorded flying over Tucabia within large expanse of dry sclerophyll forest in section 2. Also commonly recorded in the floodplain and estuarine habitats in the vicinity of the upgrade.

Species	Status		Distribution and abundance
	Cwlth	NSW	
Powerful Owl (*Ninox strenua*)		V	One bird (sex unknown) heard calling in section 2, near Tucabia, during spotlighting survey.
Rufous Bettong (*Aepyprymnus rufescens*)		V	On the basis of historic and current records, a population of Rufous Bettong occupies habitat from within Glenugie State Forest up to and around the Coldstream River. The majority of the records are associated with the Pheasant Creek and upper Coldstream areas, and numerous road kills have been reported along Six Mile Lane and Airport Road. At least three individuals were observed during spotlighting surveys between Eight Mile Lane and Pillar Valley.
Squirrel Glider (*Petaurus norfolcensis*)		V	A total of six individuals captured, predominantly in swamp sclerophyll forest or adjacent dry sclerophyll forest. Recorded between Pillar Valley and McCraes Knob, in section 2 of the upgrade. Populations likely to be widespread although potentially restricted by populations of Sugar Gliders which were also recorded and the distribution and density of tree hollows.
Stephens' Banded Snake (*Hoplocephalus stephensii*)		V	One individual recorded on crown land, east of the Tyndale-Tucabia Road (section 2) in dry sclerophyll forest on sandy soils. Population expected to be restricted to mature open forests with dense understorey and high structural diversity.
Yellow-bellied Glider (*Petaurus australis*)		V	Recorded near Eight Mile Lane within Dry Sclerophyll Forest on clay soils (section 2) via spotlighting single individual. Scar tree (evidence of sap feeding) observed near Tucabia in Dry Sclerophyll Forest on sandy soils. Populations likely to be widespread although potentially restricted by the distribution and density of tree hollows.

V= vulnerable species E1= endangered species E2= endangered population

Wildlife corridors

The Department of Environment and Climate Change (DECC) key habitats and corridors project identifies regional fauna key habitats and linking habitat corridors (DEC, 2003). The data, along with a review of local fauna movement corridors specific to the study area, show trends in fauna activity and likely movements in relation to two main corridors:

- An east-west corridor from Yuraygir National Park across Wooli Road to the Coldstream River wetlands and intersecting a portion of section 2 of the route.
- A south-north corridor linking Glenugie State Forest and Pine Brush State Forest also affecting a portion of section 2. This corridor crosses Eight Mile Lane, Wooli Road, Firth Heinz Road, Bostocks Road and Somervale Road. The project would cross this corridor at the Coldstream River and continue north, parallel to the corridor.

Evidence from a number of community surveys undertaken by the Grafton office of DECC on the local Emu population suggests that ecotonal areas of forest adjoining open sugar cane farms are particularly important post-breeding. This factor, along with the local wetlands associated with Shark

Creek, Tyndale Swamp and the Coldstream River, account for the majority of movements of Emu from Yuraygir National Park into the study area.

The location of significant wildlife corridors as they relate to the project are illustrated in **Figure 13-1.**

13.2.3 Recommended terrestrial flora and fauna mitigation measures

General

The terrestrial ecology assessment indicates that particular care and consideration is required to minimise threats and conserve areas of conservation value to flora and fauna.

Measures to avoid and/or mitigate impacts on threatened flora and threatened fauna are listed **Table 13-3** and **Table 13-4** respectively.

- **Table 13-3 Impacts, avoidance and mitigation measures for threatened flora**

Threatened species	Avoidance and mitigation measures
Angophora robur	Considering the widespread distribution of this species and its intersection across portions of the preferred route corridor, it is not possible to avoid direct impacts to a small percentage of the population. However, the preferred route is located such that the large majority of the population would remain outside the corridor and upslope from the development. Investigate the avoidance of the footslope and higher elevated slopes where this species has been identified in producing the final design. During the environmental assessment phase undertake surveys to allow identification of *A robur*, *A subvelutina* and the hybrids. Investigate opportunities to minimise clearing through the identified location of the population. Where this species occurs downslope of the proposal, potential indirect impacts would need to be managed during construction and operation.
Eucalyptus tetrapleura	Considering the widespread distribution of this species and its intersection across portions of the preferred route corridor, it is not possible to avoid direct impacts to a small percentage of the population. Aim to minimise impacts by placing the pavement as close as possible to the existing highway (i.e. western extent of the designated corridor) where the population has been identified. Collect and propagate local seed for use in revegetation associated with the project.
Grevillea quadricauda	Up to 20 individuals have been located within the 150 metre-wide preferred route corridor. Consider opportunities to avoid impacts on all of these individuals in the concept design. Minimise impacts on remaining individuals during construction. Collect and propagate local seed for use in revegetation associated with the project.
Lindsaea incise	This species is present downslope of the preferred route corridor along a drainage swale and is therefore vulnerable to altered hydrology regimes, additional nutrients and sedimentation associated with construction. Manage potential indirect impacts during construction and operation.

Figure 13.1 Key habitats and fauna corridors

- **Table 13-4: Avoidance and mitigation measures for threatened fauna**

Threatened species	Avoidance and mitigation measures
Forest fauna species	Investigate opportunities to minimise clearing through forest habitats particularly on elevated or sandy soils during the final design and construction. Identify significant features such as hollow-bearing trees and nest sites during environmental assessment and avoid these features where possible in producing the final design to further minimise impacts. Provide dedicated and incidental fauna crossing structures at key locations identified to target the range of large, medium and smaller species.
Floodplain fauna	Minimise direct and indirect impacts on creek lines and wetland fringes through the final design and construction. Re-survey and identify nest locations for Osprey, Black-necked Stork and Brolga as part of the environmental assessment. Manage indirect impacts on hydrology regimes

Fauna crossing structures

Fauna crossing structures would be an important part of the mitigation measures. When designing for their location and placement, the following issues should be considered:

- In section 1, fauna crossing points are required to allow passage for the identified population of Rufous Bettong which inhabits the northern parts of Glenugie State Forest near Pheasant Creek and extends north into section 2. Box culverts as small as 2.4 x 1.2 metres are considered suitable — a male Rufous Bettong is 385 millimetres in height and weighs up to 3.5 kilograms.
- In section 2, fauna crossing points are required to accommodate Emus and small-to-large mammals. Large mammals (such as Eastern Grey Kangaroo) require much wider and higher areas for daily movements. Typically, the provision of box culverts 3 x 3 metres is considered a sufficient opening for large macropods and 2.4 metres is considered appropriate for smaller macropods. It has been suggested that structures intended to facilitate the movement of Emus may need to be higher, but there is no empirical evidence to inform the height. Accordingly, for the concept design, crossings points intended to accommodate Emu's have be sized in accordance with the standard property access culvert (vertical height of 3.6 m), and the height requirements would require further investigation during the environmental assessment and detailed design stages of the project.
- Factors that are considered to deter larger terrestrial fauna from using underpass structures include stumps blocking the entrance and long, narrow (and therefore dark) passages.
- With all terrestrial fauna, security from predators is important. This can be accommodated by providing a clear line of sight to light and vegetation at both ends of the crossing. For smaller species, providing protective cover and structures such as ledges or horizontal logs that are designed to restrict access by larger predators would aid their security. For larger species such as emus, open areas, which provide a clearer line of sight, would be appropriate.

Terrestrial fauna require exclusion fencing to guide them through the crossing structure and to prevent access to the carriageway.

- Given the diversity and abundance of arboreal mammals recorded through section 2 (that is, Greater Glider, Squirrel Glider, Sugar Glider, Feathertail Glider, Koala, Common Brushtail and Common Ringtail Possum), consider installing one or two fauna overpasses (such as rope bridges) in the area between the Wooli Road crossing in the south up to Tyndale.
- To allow the successful movement of arboreal fauna, it is desirable to allow easy passage between upper canopy layers both over and adjacent to the overpass. Large, dedicated underpasses should also use elevated furniture to encourage use by arboreal fauna such as koalas and gliders.
- More terrestrial fauna species use bridge underpasses than culvert underpasses, where possible bridge structures have been designed to assist fauna passage. Large ground-dwelling mammals, especially macropods, generally prefer bridge underpasses (which provide more open and better illuminated spaces) and natural base materials. These would also be suitable for emus.
- Where multiple culverts are placed side-by-side, one outer cell may be raised so that, during low-flow conditions, fauna could stay dry.
- Approaches to the structure should allow good visibility and not be obscured by dense vegetation.
- Impacts on emus through road strike should be managed through the provision of exclusion fencing across the required length of section 2 from Eight Mile Lane north to the Tyndale intersection. Fencing is necessary to help guide emus to the crossing structures. A suitable emu fence is a minimum of 1.5 metres chain mesh. Standard RTA floppy-top fences are considered appropriate.
- Bridges should be designed with a minimum 3.6 metres clearance[9] and allow clear passage on either side of the top of the bank, which should be suitable for emus to use as passageways.
- Emus are reported to prefer to be able to see well ahead of them, ideally one kilometre, so it would be important to have clear, straight leads up to the crossing points and equally important to shield these routes from as much traffic noise, light and movement as possible.

Placement is the single most important factor affecting the success of passage structures. It is essential that these are not too widely spaced. The strategy provides opportunities for various fauna passage structures along the route. A summary of the proposed fauna crossing structures relevant to each section and their requirements is in **Table 13-5.**

---

[9] Upon consultation with an emu specialist it was indicated that the specific height requirements for emu crossings were unknown at this stage. In terms of the concept design, it has been decided to size the emu crossings at a 3.6-metre vertical height, except where the height of the crossing is higher due to other considerations, such as where there is a local road.

Table 13-5: Summary of recommendations for fauna crossing structures

Section	Chainage				Type	Concept Design Culvert Cells	Concept Design Height / Diameter	Concept Design Width / Bridge Length	Comments
		Concept Design Dedicated (D) ; Combined (C) or Potential Combined (PC) Fauna Crossings	Concept Design Incidental Crossing						
			Road / Access	Waterway					
1		580 PC			Pipe	2	0.75		Crossing for small to medium sized fauna.
1				1015	Pipe	1	0.6		Crossing for small to medium sized fauna.
1		1450 PC			Pipe	1	0.9		Crossing for small to medium sized fauna.
1		2475 C			Box	1	2.4	3.6	2.4 m high clear passage in culvert either side of low flow channel. Underpass to extend across existing highway.
1		4415 C			Box	3	2.4	2.4	Glenugie Creek Bridge - dry passage retained along both banks for fauna passage targeting Rufous Bettong. Underpass to extend across existing highway.
1		4890 C			Pipe	2	1.2		Crossing for small to medium sized fauna.
1		5225 C			Box	1	2.4	2.4	Fauna passage targetting Rufous Bettong. Underpass to extend across existing highway.
1		5865 C			Box	1	2.4	2.4	Fauna passage targetting Rufous Bettong. Underpass to extend across existing highway.
1		6465 C			Box	2	2.4	2.4	Dry passage retained along both banks for fauna passage targeting Rufous Bettong. Underpass to extend across existing highway.
1		7270 C			Pipe	3	1.05		Crossing for small to medium sized fauna.
1		7395 C			Pipe	3	1.2		Crossing for small to medium sized fauna.
1		7680 C			Pipe	3	1.2		Crossing for small to medium sized fauna.
1				8780	Pipe	2	0.6		Crossing for small to medium sized fauna.
1				9990	Pipe	2	0.525		Crossing for small to medium sized fauna (on ramp).

Section	Chainage				Type	Concept Design Culvert Cells	Concept Design Height / Diameter	Concept Design Width / Bridge Length	Comments
		Concept Design Dedicated (D) ; Combined (C) or Potential Combined (PC) Fauna Crossings	Concept Design Incidental Crossing: Road / Access	Concept Design Incidental Crossing: Waterway					
1		10040 C			Pipe	4	1.2		Crossing for small to medium sized fauna (on ramp).
1		10280 C			Bridge			35	Crossing for larger fauna.
2		10790 C			Bridge			130	Crossing for larger fauna.
2		11050 C			Bridge			90	Crossing for larger fauna.
2		11450 C			Bridge			150	Pheasant Creek - dry passage retained along both banks for fauna passage targeting Rufous Bettong.
2		12160 C			Circular	2	1.2		Crossing for small to medium sized fauna.
2		12380 C			Box	2	2.4	2.4	Small to medium sized fauna including Rufous Bettong. Fauna passage provided in culvert either side of low flow channel.
2		12660 PC			Circular	1	0.75		Crossing for small to medium sized fauna.
2				12875	Circular	4	0.6		Crossing for small to medium sized fauna.
2				13125	Circular	2	0.6		Crossing for small to medium sized fauna.
2				13585	Circular	2	0.6		Crossing for small to medium sized fauna.
2		14145 PC			Circular	2	0.9		Crossing for small to medium sized fauna.
2		14730 C			Bridge			65	Crossing for larger fauna..
2		15260 PC			Circular	4	0.75		Crossing for small to medium sized fauna.
2		16530 C			Bridge	2		30	Fauna passage provided along both sides of existing road under bridge. Minimum vertical clearance of 3.6 m for emus.
2		17720 C			Bridge			75	Coldstream River Floodplain Minimum vertical clearance of 3.6 m for emus.
2		18400 C			Bridge			360	Coldstream River - dry passage retained along both banks for fauna passage. Minimum vertical clearance of 3.6 m for emus.

Section	Chainage				Type	Concept Design Culvert Cells	Concept Design Height / Diameter	Concept Design Width / Bridge Length	Comments
		Concept Design Dedicated (D) ; Combined (C) or Potential Combined (PC) Fauna Crossings	Concept Design Incidental Crossing						
			Road / Access	Waterway					
2		18885 C			Bridge			175	Coldstream River Floodplain. Adequate clearance for emus.
2		19105 C			Bridge			75	Coldstream River Floodplain. Adequate clearance for emus.
2		21235 C			Bridge			80	Pillar Valley Creek Floodplain. Adequate clearance for emus.
2		21380 C			Bridge			45	Pillar Valley Creek Floodplain. Adequate clearance for emus.
2		21505 C			Bridge			95	Pillar Valley Creek – dry passage provided along both banks for fauna passage. Minimum vertical clearance of 3.6 m for emus.
2		21650 C			Bridge			55	Pillar Valley Creek Floodplain. Adequate clearance for emus.
2		21780 C			Bridge			120	Pillar Valley Creek Floodplain. Adequate clearance for emus.
2		22220 C			Bridge			50	Pillar Valley Creek Floodplain. Adequate clearance for emus.
2		22430 C			Bridge			55	Pillar Valley Creek Floodplain. Adequate clearance for emus.
2		22800 C			Bridge			125	Pillar Valley Creek Floodplain – dry passage provided for fauna passage. Minimum vertical clearance of 3.6 m for emus.
2		22850 PC			Arch	1	4.6		Adequate clearance for emus.
2		23815 PC			Circular	1	0.9		Crossing for small to medium sized fauna.
2		23860 C			Box	1	4.6	6	Fauna passage provided in conjunction with local access. Minimum vertical clearance of 3.6 m for emus.
2		24400 C			Bridge			90	Adequate clearance for emus.
2		24555 C			Bridge			50	Dry passage provided for fauna passage. Minimum vertical clearance of 3.6 m for emus.
2		25175 C			Circular	2	1.2		Crossing for small to medium sized fauna. Consider raising one cell for fauna.

Section	Chainage				Type	Concept Design Culvert Cells	Concept Design Height / Diameter	Concept Design Width / Bridge Length	Comments
		Concept Design Dedicated (D) ; Combined (C) or Potential Combined (PC) Fauna Crossings	Concept Design Incidental Crossing						
			Road / Access	Waterway					
2		25385 C			Bridge			80	Dry passage provided along both banks for fauna passage. Minimum vertical clearance of 3.6 m for emus.
`2				25910	Circular	3	0.6		Crossing for small to medium sized fauna.
2		26510 C			Box	1	2.4	3.0	Dry passage provided along both banks for fauna passage.
2		27570 C			Bridge			80	Chaffin Creek. Adequate clearance for emus.
2		27650 C			Bridge			60	Chaffin Creek. Adequate clearance for emus.
2		28790 C			Box	1	3.6	3.6	Dry passage provided along both banks for fauna passage. Minimum vertical clearance of 3.6 m for emus.
2		29800 C			Bridge			105	Adequate clearance for emus.
2		30130 C			Bridge			65	Adequate clearance for emus.
2		32125 C			Bridge			80	Champions Creek – dry passage provided along both banks for fauna passage. Minimum vertical clearance of 3.6 m for emus.
2		33305 PC			Box	2	0.9	3.0	Crossing for small to medium sized fauna.
2		33760 C			Bridge			70	Crossing for larger fauna.
2		34365 C			Box	1	3.6	3.6	Dry passage provided along both banks for fauna passage. Minimum vertical clearance of 3.6 m for emus.
2		35180 C			Box	1	1.2	2.4	Crossing for small to medium sized fauna.
2		35895 C			Box	1	3.6	3.6	Dry passage provided along both banks for fauna passage. Minimum vertical clearance of 3.6 m for emus.
2		36120 C			Arch	1	4.6		Crossing for small to medium sized fauna.
2		36895 C			Box	3	0.9	2.1	Crossing for small to medium sized fauna.

Section	Chainage				Type	Concept Design Culvert Cells	Concept Design Height / Diameter	Concept Design Width / Bridge Length	Comments
		Concept Design Dedicated (D) ; Combined (C) or Potential Combined (PC) Fauna Crossings	Concept Design Incidental Crossing: Road / Access	Concept Design Incidental Crossing: Waterway					
2		36995 C			Circular	1	0.9		Crossing for small to medium sized fauna.
2		37310 C			Box	4	1.8	3.0	Crossing for small to medium sized fauna.
2		37900 C			Box	2	0.9	2.4	Crossing for small to medium sized fauna.
2				38660	Circular	4	0.6		Crossing for small to medium sized fauna.
2				39010	Circular	2	0.675		Crossing for small to medium sized fauna.
2		39275 C			Box	1	1.8	3.0	Crossing for small to medium sized fauna.
2		39585 C			Box	1	3.6	3.6	Dry passage provided along both banks for fauna passage. Minimum vertical clearance of 3.6 m for emus.
2		40570 C			Circular	3	0.9		Crossing for small to medium sized fauna.
2		41115 C			Circular	2	0.9		Crossing for small to medium sized fauna.
2		41270 C			Box	1	3	3.6	Crossing for small to medium sized fauna.
2		41300 PC			Box	1	0.75	2.1	Crossing for small to medium sized fauna.
2		42255 PC			Circular	3	0.9		Crossing for small to medium sized fauna.
2		42470 C			Circular	2	1.2		Crossing for small to medium sized fauna.
2		42500 C			Circular	1	1.2		Crossing for small to medium sized fauna.
2		43060 PC			Circular	2	0.9		Crossing for small to medium sized fauna.
2		43160 PC			Circular	2	0.75		Crossing for small to medium sized fauna.
2				43515	Circular	4	0.6		Crossing for small to medium sized fauna.
2				43775	Circular	4	0.6		Crossing for small to medium sized fauna.
2				44055	Circular	4	0.6		Crossing for small to medium sized fauna.

Section	Chainage				Type	Concept Design Culvert Cells	Concept Design Height / Diameter	Concept Design Width / Bridge Length	Comments
		Concept Design Dedicated (D) ; Combined (C) or Potential Combined (PC) Fauna Crossings	Concept Design Incidental Crossing						
			Road / Access	Waterway					
3		45015 C			Bridge			75	Shark Creek Floodplain Bridge. Crossing for larger fauna.
3		46140C			Circular	2	1.8	3.3	Crossing for small to medium sized fauna.
3		46765 C			Box	3	1.8	1.8	Crossing for small to medium sized fauna.
3		47740 PC			Box	3	0.9	1.8	Crossing for small to medium sized fauna.
3		48100 C			Box	1	1.8	3.6	Crossing for small to medium sized fauna.
3		48915 PC			Box	2	0.9	2.4	Crossing for small to medium sized fauna.
3		50150 C			Bridge			830	Shark Creek Bridge. Crossing for larger fauna.
3		50690 C			Box	1	2.4	3.6	Crossing for small to medium sized fauna.
3		51250 C			Circular	3	0.9		Crossing for small to medium sized fauna.
3		51440 C			Box	1	0.9	2.1	Crossing for small to medium sized fauna.
3		51665 C			Box	1	1.5	2.4	Crossing for small to medium sized fauna.
3		52375 C			Box	3	2.4	3.0	Crossing for small to medium sized fauna.
3		52910 C			Box	1	1.8	3.6	Crossing for small to medium sized fauna.
3		53950 PC			Box	2	0.9	2.4	Crossing for small to medium sized fauna.
3		54155 PC			Box	1	0.9	2.4	Crossing for small to medium sized fauna.
3		54745 PC			Box	2	0.9	2.4	Maclean Interchange Bridge. Crossing for small to large sized fauna.
3		55010 C			Box	4	2.4	3.0	Crossing for small to medium sized fauna.
3		55410 PC			Circular	1	0.9		Crossing for small to medium sized fauna.
3				55740	Circular	1	0.6		Crossing for small to medium sized fauna.

Section	Chainage				Type	Concept Design Culvert Cells	Concept Design Height / Diameter	Concept Design Width / Bridge Length	Comments
		Concept Design Dedicated (D) ; Combined (C) or Potential Combined (PC) Fauna Crossings	Concept Design Incidental Crossing						
			Road / Access	Waterway					
3				56060	Circular	2	0.6		Crossing for small to medium sized fauna.
3		56525 PC			Circular	1	0.9		Crossing for small to medium sized fauna.
3		56650 PC			Circular	1	0.9		Crossing for small to medium sized fauna.
3				56720	Circular	1	0.6		Crossing for small to medium sized fauna.
3		56860 PC			Circular	1	0.75		Crossing for small to medium sized fauna.
3		57140 PC			Circular	1	0.75		Crossing for small to medium sized fauna.
3				57200	Circular	2	0.6		Crossing for small to medium sized fauna.
3				57485	Circular	2	0.6		Crossing for small to medium sized fauna.
3				57615	Circular	2	0.6		Crossing for small to medium sized fauna.
3		57720 D			Box	2.4	2.4		Yaegl Nature Reserve. Crossing for larger fauna.
3				57730	Circular	1	0.6		Crossing for small to medium sized fauna.
3				57820	Circular	2	0.6		Crossing for small to medium sized fauna.
3				58225	Box	2	0.6	1.2	Crossing for small to medium sized fauna.
3		60075 PC			Box	3	0.9	3.0	Crossing for small to medium sized fauna.
3		60285 PC			Box	2	0.9	3.0	Crossing for small to medium sized fauna.
3		60520 PC			Circular	1	0.9		Crossing for small to medium sized fauna (on ramp)
3		60550 C			Bridge	1		40	Crossing for small to medium sized fauna (on ramp).
4		61400 C			Bridge			1500 (high) 890 (low)	Clarence River Bridge. Crossing for larger fauna.
4		62650 C			Bridge			30	Watts Lane Interchange Bridge. Crossing for larger fauna.
4				63400	Box	78	0.45	3.0	Crossing for small to medium sized fauna.

Section	Chainage				Type	Concept Design Culvert Cells	Concept Design Height / Diameter	Concept Design Width / Bridge Length	Comments
		Concept Design Dedicated (D) ; Combined (C) or Potential Combined (PC) Fauna Crossings	Concept Design Incidental Crossing						
			Road / Access	Waterway					
4				63610	Box	48	0.45	3.0	Crossing for small to medium sized fauna.
4		63870 C			Box	20	1.2	3.0	Crossing for small to medium sized fauna.
4		64200 C			Bridge			70	Serpentine Channel Bridge. Crossing for larger fauna.
4				64770	Box	28	0.45	3.0	Crossing for small to medium sized fauna.
4		64870 PC			Box	13	0.75	3.0	Crossing for small to medium sized fauna.
4		64960 PC			Box	14	0.9	3.0	Crossing for small to medium sized fauna.
4		65105 PC			Box	14	0.75	3.0	Crossing for small to medium sized fauna.
4		65270 PC			Box	14	0.75	3.0	Crossing for small to medium sized fauna.
4		65400 PC			Box	25	0.75	3.0	Crossing for small to medium sized fauna.
4				65710	Box	30	0.45	3.0	Crossing for small to medium sized fauna.
4				66040	Box	32	0.45	3.0	Crossing for small to medium sized fauna.
4		66260 C			Box	3	1.2	3.0	Crossing for small to medium sized fauna.
4		66570 PC			Circular	1	0.9		Crossing for small to medium sized fauna.
4		66575 PC			Box	10	0.75	3.0	Crossing for small to medium sized fauna.
4		66750 C			Box	10	0.9	3.0	Crossing for small to medium sized fauna.
4		67060 C			Box	30	1.2	3.0	Crossing for small to medium sized fauna.
4				67495	Box	20	0.6	3.0	Crossing for small to medium sized fauna.
4				67595	Box	20	0.6	3.0	Crossing for small to medium sized fauna.
4		67730 C			Box	19	0.9	3.0	Crossing for small to medium sized fauna.
4		67875 PC			Box	24	0.75	3.0	Crossing for small to medium sized fauna.

Section	Chainage				Type	Concept Design Culvert Cells	Concept Design Height / Diameter	Concept Design Width / Bridge Length	Comments
		Concept Design Dedicated (D) ; Combined (C) or Potential Combined (PC) Fauna Crossings	Concept Design Incidental Crossing						
			Road / Access	Waterway					
4				68000	Box	21	0.6	3.0	Crossing for small to medium sized fauna.
4		68200 C			Box	1	1.8	3.0	Crossing for small to medium sized fauna.
4				68360	Box	33	0.6	3.0	Crossing for small to medium sized fauna.
4		68900 C			Bridge			220	Mororo Bridge. Crossing for larger fauna.
4		69215 C			Circular	1	0.9		Crossing for small to medium sized fauna.
4				69930	Circular	4	0.6		Crossing for small to medium sized fauna.
4		70260 PC			Circular	2	0.825		Crossing for small to medium sized fauna.
4				70450	Box	6	0.6	3.0	Crossing for small to medium sized fauna.
				70830	Box	1	0.6	3.0	Crossing for small to medium sized fauna.

General notes:

- The location and design of the fauna structures (dedicated, combined, potential combined) and incidental use culverts presented here should be regarded as preliminary only and would be refined during in the environmental assessment and detailed design stage, in developing drainage design, considering new fauna issues/ information and enabling innovation.
- The bridge lengths presented here are only indicative at this stage and would require further consideration during the environmental assessment/ detailed design.
- All property accesses will be refined during environmental assessment and detailed design and may change from that outlined here.
- Crossings points intended to accommodate emu's have be sized in accordance with the standard property access culvert (vertical height of 3.6 m). The height of emu these structures will be reviewed during the environmental assessment and detailed design taking into account bridge structure height for flood flow, embankment heights/ earthworks volumes and heights, urban design, cost etc
- Walkway widths and opportunities under bridges will be further developed in the environmental assessment and detailed design stage.
- There may be opportunities to provide for fauna access at several of road accesses under the new highway, and this would be considered further in environmental assessment and detailed design, taking into consideration feasibility and safety issues.
- Where multicell structures are involved, consideration would be given during the environmental assessment and detailed design stage to raising one cell for fauna passage in the. Furthermore, where reasonable and feasible consideration would also be given to combining several smaller structures into a single larger structure better suited to fauna and fish.

13.3 Aquatic ecology

The aquatic ecology assessment, documented in the *Aquatic Ecology Working Paper,* provides detailed information on aquatic habitats, macroinvertebrates, fish and water quality; assesses potential impacts of the upgrade on aquatic ecology components; and recommends measures to minimise these impacts (RTA 2008c). The study also assesses the likely presence of protected aquatic species, and considers impacts on endangered populations, ecological communities and key threatening processes.

13.3.1 Field investigations

The study area is located within the Clarence River Catchment and the upgrade crosses a number of watercourses. Field investigations, concentrating on macroinvertebrates, were conducted from 5 – 8 June 2007, while fish sampling took place from 25 – 29 June 2007. Sampling times were chosen in the autumn period to satisfy the requirements of the 'AusRivAS' sampling protocol. Habitat assessments and water quality measurements were also taken on both occasions.

Investigations were undertaken at 18 sites covering 16 different waterways including the Clarence River (main channel, South Arm, North Arm), Shark Creek and Serpentine Channel (tributaries of the Clarence River), Coldstream River, Chaffin Creek, Pillar Valley Creek, Pheasant Creek, Champions Creek and Glenugie Creek. Investigation sites were selected where the upgrade would either cross these watercourses or may impact on an adjacent aquatic habitat. At every site, a general habitat description, RCE (Riparian, Channel and Environmental Inventory) habitat assessment and fish habitat assessment was made and water quality measurements recorded. Sampling for macroinvertebrates was carried out at six sites by Rapid Assessment methods. Fish surveys were carried out at eight sites using electrofishing, bait trapping and gill nets.

Of the sites assessed, Chaffin Creek, Pillar Valley Creek, Pheasant Creek and Champion Creek contained habitats of greatest ecological value within the study area, indicated by relatively higher RCE scores compared with other sites. Results of AusRivAS analyses showed that all sites sampled except Pillar Valley Creek were significantly impaired in terms of expected macroinvertebrate communities. Ten species of fish were recorded over the whole survey, with Shark Creek and Pheasant Creek having the greatest abundance and species diversity. No threatened or protected species were found during the survey.

13.3.2 Potential impacts of the project

Road crossings over waterways, such as bridges and culverts, are likely to have impacts on the passage of fish, long-term water quality, and habitat stability. These aspects are discussed below.

Impacts on the passage of fish

An inappropriate design or type of waterway crossing may impede or prevent fish from travelling within their natural range. Barriers to fish passage can prevent the breeding or repopulation of waterways by restricting access of fish to breeding partners and spawning grounds. Forcing fish to negotiate causeways or culverts can cause excessive energy loss resulting in the re-absorption of their gametes to replenish lost energy reserves. This can result in the loss of a spawning season and, in the long term, population decline. Barriers to fish passage are a problem for both migrating and non-migrating species by inhibiting access to food, shelter or habitat and obstructing local movement away from predation or adverse physical conditions. For migratory species, local extinction may occur in circumstances where fish are prevented from completing their breeding cycle altogether.

Impacts on water quality

Roads and waterway crossings also have implications for long-term water quality and may facilitate surface run-off of contaminants or sediment from surrounding land into aquatic habitats in times of high rainfall.

Impacts on habitat stability

The long-term impacts of removing existing riparian vegetation, and/or input of in-stream structures, can result in increased erosion of banks and stream beds, leading to habitat instability.

13.3.3 Recommended aquatic habitat mitigation measures

Specific guidelines for the design and construction of waterway crossings to maintain fish passage are outlined in *Guidelines and Policies for Aquatic Habitat Management and Fish Conservation* (NSW Fisheries, 1999) and *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull and Witheridge 2003). The minimum recommended crossing requirements for each site is summarised in **Table 13-6** and the *Aquatic Ecology Working Paper* (refer to RTA 2008c).

Table 13-6 Minimum recommended crossing requirements

Name of Waterway	Fish Habitat Class	Minimum Recommended Crossing Type
North Arm, Clarence River	1	Bridge, arch structure or tunnel
Serpentine Channel	1	Bridge, arch structure or tunnel
Harwood Bridge, Clarence River	1	Bridge, arch structure or tunnel
James Creek	1	Bridge, arch structure or tunnel
Melaleuca Swamp	3	Culvert or ford
Maclean Intersection (Clarence River)	1	Bridge, arch structure or tunnel
Edwards Creek	2	Bridge, arch structure, culvert or ford
Shark Creek	1	Bridge, arch structure or tunnel
South Arm (Clarence River) at Tyndale	1	Bridge, arch structure or tunnel
McPhees Swamp Ford	4	Culvert, causeway or ford
Champion Creek	2	Bridge, arch structure, culvert or ford
Chaffin Creek	1	Bridge, arch structure or tunnel
Horseshoe Waterhole (Pillar Valley Creek)	1	Bridge, arch structure or tunnel

Name of Waterway	Fish Habitat Class	Minimum Recommended Crossing Type
Black Snake Hole (Pillar Valley Creek)	1	Bridge, arch structure or tunnel
Coldstream River	1-2	Bridge, arch structure, tunnel or culvert
Coopers Creek, Chevally Lane	4	Culvert, causeway or ford
Pheasant Creek	3	Culvert or ford
Glenugie Creek	2-3	Bridge, arch structure or culvert

Key recommendations include:

- The use of bridges rather than arch structures, culverts, fords and causeways (in this order) as they cause the least disturbance to flow or the aquatic habitat of a waterway. Where practical, bridge piers should be placed outside the main channel of the waterway to avoid formation of turbulence and bed erosion, and abutments should be placed away from the bank.
- Reducing the impacts on fish passage by culverts, where these are considered the suitable crossing type. Fish passage may be maintained by minimising changes to the natural flow, channel width and water depth through the culvert cells (recommended to have a minimum water depth range of 0.2–0.5 metres). Additionally, culvert designs should consider flow rates and installing artificial substratum that may facilitate fish movement and provide resting areas.
- Taking into account the following considerations during detailed design and environmental impact assessment:
  - Long-term water quality, particularly in relation to stormwater and surface water runoff, acid sulphate soil management, and pollution resulting from the design and construction of causeways.
  - Habitat instability relating to habitat loss, changes in sediment transport and natural tidal exchange.
  - Erosion of beds, banks and channels.

13.4 Noise

The noise and vibration working paper prepared for the Preferred Route Report forms the basis for assessment at this concept stage (RTA, 2006d). A more detailed noise investigation would form part of the future environmental assessment process.

13.4.1 Noise goals

Road noise goals are determined by the Environmental Criteria for Road Traffic Noise (ECRTN) guideline (DEC, 1999). The appropriate noise goals for the proposed upgrade of the Pacific Highway are listed in **Table 13-7**. The assessment methodology and application of the noise criteria are taken from the RTA's *Environmental Noise Management Manual* (RTA, 2001).

- **Table 13-7: Base criteria for road traffic noise**

Road category	Daytime levels	Night-time levels
New freeway	LAeq (15 hour) 55 dB (A)	LAeq (15 hour) 50 dB (A)
Redevelopment of an existing freeway	LAeq (15 hour) 60 dB (A)	LAeq (15 hour) 55 dB (A)

In Table 13.10:

- The 'new freeway' category is used for residences that are currently unaffected by road noise, or where the direction of noise is to change as a result of a new road development. It is anticipated that this category would apply to most of the study area.
- The 'redevelopment of an existing freeway' category is used where upgrading is on / adjacent to the existing highway. This category recognises the existing noise levels experienced at residences adjacent to existing roads.

Where the criteria are already exceeded, the ECRTN requires that new roads should be designed so as not to increase existing noise levels by more than 0.5 dB. For a road development, noise levels should not increase above the existing by more than 2 dB. In both cases the ECRTN states that consideration should be given to reducing noise levels to meet the base criteria through the use of mitigation measures.

13.4.2 The existing noise environment

An important issue for this project is the notable variation in existing noise conditions within the study area. Residences and other sensitive land uses along the current Pacific Highway are currently subject to high levels of road traffic noise. Many of these areas have been settled for a long period of time and traffic volumes as well as the size and number of heavy vehicles has grown incrementally over time. This has resulted in increasing levels of noise exposure for many residents. Conversely, areas away from the highway are typically less densely settled.

It must also be recognised that these residents currently enjoy an environment that is relatively free of road traffic noise, and a new road would result in substantial changes to the ambient noise regime. Even where dwellings are predicted to experience new noise levels below the criteria, the extent of change in noise levels has the potential to cause annoyance to residents.

13.4.3 Recommended noise mitigation measures

A range of noise mitigation measures could be employed to manage road traffic noise at nearby sensitive receivers. Specific noise mitigation measures would be identified as part of the environmental assessment and detailed design of the upgrade. Where appropriate, taking into consideration the procedure detailed in the RTA's *Noise Management Manual*, the following specific mitigation measures (in no particular order) would be considered for the project, as part of the overall plan to manage road traffic noise:

- *Acoustic treatment of existing dwellings:* Treatments may be considered in certain cases, such as window glazing upgrades or the installation of air-conditioning or mechanical ventilation systems so that windows and doors may be kept closed.
- *Acoustic design in future developments:* Councils may elect to impose appropriate conditions on the construction of future developments to ensure that occupants have a suitable internal acoustic environment. The ECRTN guideline provides for councils to impose conditions on future developments in close proximity to arterial or sub-arterial road reserves to ensure compliance with the guidelines (DEC, 1999).
- *Pavement surfacing in noise sensitive areas:* Different road surfaces result in different noise emissions from roadways, particularly at higher traffic speeds, and low-noise-emission pavements can be used in noise-sensitive areas.
- *Noise mounds and/or roadside barriers:* Landscaped noise mounds and/or roadside barriers are common on many Australian road networks. The required location and height of mounds and barriers is determined, in part, by the prevailing noise levels, the topography of the immediate area, and the number of receivers that would benefit.

13.5 Indigenous heritage

A cultural heritage assessment was undertaken for the concept design. The full assessment can be found in the *Cultural Heritage Working Paper* (RTA 2008d). Aboriginal sites and places of known or potential heritage significance have been identified, and the potential impact of highway construction on those sites has been assessed at this early concept stage. This has been undertaken with the participation of representatives of the local Aboriginal communities.

13.5.1 Engagement of Aboriginal stakeholders

The study area falls within the area of interest of five local Aboriginal organisations comprising the:

- Grafton-Ngerrie Local Aboriginal Land Council (LALC).
- Yaegl LALC.
- Yaegl Native Title Group.
- Yarrawarra Aboriginal Corporation (including the Garby Elders).
- Burra:way Wa:jad Traditional Owners group.

Aboriginal consultation was undertaken in accordance with the DECC *Interim Community Consultation Requirements for Applicants* (2004) and the RTA's *Draft Procedures for Aboriginal Cultural Heritage Consultation and Investigations (2007)*.

Representatives from each of the above organisations attended an Aboriginal Focus Group meeting on 6 September 2007 to discuss the proposed methodology for the next stage of the Aboriginal cultural heritage assessment. This was the fifth meeting held with representatives from local Aboriginal community organisations to discuss various aspects of the proposed upgrade since May 2005. The group also met in September 2008 to further discuss the Cultural Heritage working paper which was prepared to assist with the development of the concept design.

13.5.2 Fieldwork

The fieldwork aimed to identify and define Aboriginal archaeological artefacts, sites and areas of archaeological potential within the preferred route corridor. The field strategy involved a team comprising an archaeologist, assistant and representatives of the relevant Aboriginal groups, walking across the sample areas and looking for Aboriginal heritage sites. The survey was conducted over a two-week period from 26 November to 7 December 2007.

The LALC representatives operated within their LALC boundaries, and the Yarrawarra Aboriginal Corporation operated in the southern section of the upgrade, generally south of Tucabia. Although not within the study area, the Birrigan Gargle LALC is situated immediately east of it. While that LALC was not involved in fieldwork for the route selection study or the upgrade assessment, the LALC has participated in consultation activities for some years, including attendance at focus group meetings and discussions of indigenous heritage sites and areas of significance within the wider study area.

13.5.3 Impacts on Indigenous heritage

No Aboriginal sites, places or objects were identified along the length of the upgrade corridor. Eight potential archaeological deposits (PADs) were recorded during the study.

Based on consultation conducted to date, there have been no references to or identification of specific places or sites with Aboriginal cultural values, except for those values associated with the PADs identified during this investigation. All Aboriginal participants in the field component of the study were of the view that all potential Aboriginal archaeological remains should be fully investigated and subject to an appropriate form of recovery (salvage) so that artefacts would not be destroyed during construction works and could be managed according to community wishes and in consultation with DECC.

The following clarification is provided in relation to the potential impact of the proposed upgrade on the PADs:

- Five PADs - WX2I PADs 3, 4, 6, 7 and 8 - are considered to have high archaeological potential and it is recommended that subsurface testing be undertaken in order to confirm the presence, extent and integrity of Aboriginal objects in the identified areas. This investigation should be conducted prior to construction. If the project is not approved under Part 3A of the EP&A Act 1979 then subsurface testing would require a section 87 permit from the DECC.
- Due to property access constraints, two PADs - WX2I PADs 1 and 5 - require further field survey to confirm their status as PADs. It is recommended that the fieldwork be undertaken at both locations following receipt of relevant property access approvals and before commencement of construction activities. If field survey confirms the areas as PADs with high archaeological potential then it is recommended that subsurface testing be undertaken in order to confirm the presence, extent and integrity of Aboriginal objects in the identified areas. If the project is not approved under Part 3A of the EP&A Act 1979 then subsurface testing would require a section 87 permit from the DECC. If field survey determines they are not PADs, then no further action is required with regard to the areas.
- One (WX2I PAD 2) is considered to have low potential. No further action is required for this PAD.

13.6 Non-Indigenous heritage

13.6.1 Fieldwork

The objective of the survey strategy for non-indigenous heritage was to obtain the most comprehensive assessment possible of the heritage sites within the preferred route corridor.

Any heritage-listed items were first identified through heritage register searches, including the relevant local environmental plans, the NSW State Heritage Register and Inventory, RTA Section 170 Register, the Register of the National Estate and the Register of the National Trust (NSW). These were then inspected in the field. Additional potential heritage sites were identified by members of the local community, identified from topographic maps and through observation along the existing highway and secondary roads within the study corridor.

The field survey was conducted concurrently with the indigenous heritage assessment (refer Section 13.10). Any areas of historic interest were recorded in the field.

13.6.2 Impacts on matters of non-Indigenous heritage

One historical heritage site, WIH3, a nineteenth-century private residence, No. 12 (A & B) River Street, Harwood, and one potential historical heritage site, Harwood Bridge, were identified within the preferred route study corridor. The former is not listed on the Maclean LEP 2001 as a heritage item of local significance but is included in a proposed heritage conservation area identified for the Harwood Village (Maclean Shire Community-Based Heritage Study 2006). The latter is also identified in that study as having potential heritage item.

The current concept design affects the residence as it is would be acquired and demolished as part of the highway upgrade proposal. That design also affects Harwood Bridge due to duplication of the highway. It will be necessary to undertake an archival record of the residence in accordance with NSW Heritage Office guidelines, and it may be necessary to undertake a similar archival record of the bridge depending on the outcome of further assessment of it.

13.7 Water quality

A water quality assessment was undertaken to provide information on surface water quality under both wet and dry conditions. The information was used for the concept design and to provide baseline data for future environmental assessment. The study is presented in the *Water Quality Working Paper* (RTA 2008f). A summary of the report is presented below.

13.7.1 Water quality investigations

Fifty-one sites were assessed for water quality and sampling events were considered ‘wet’ or ‘dry’ subject to the volume of rainfall in the preceding 48 hours. The water quality of waterways potentially impacted by construction and operation of the project is outlined below.

Section 1

In section 1, water quality improved with wet weather, complying with all parameters measured. During dry weather, water quality did not comply with the guidelines for pH, turbidity or dissolved oxygen. This poor water quality result is likely to be due to the low flow and stagnant nature of the waterway in addition to excessive macrophyte growth and oxidation of organic matter, which may also explain the high turbidity measured. Heavy rainfall prior to and during the wet weather sampling event appears to have flushed the system, resulting in improved water quality.

Section 2

In section 2, water quality differed little between wet and dry sampling events. However, conductivity was regularly below the lower guideline limit for the protection of lowland aquatic ecosystems during wet weather. This can be attributed to the antecedent heavy rainfall which probably diluted the waterways. Turbidity was elevated at a small number of sites, mostly following wet weather. While rainfall can flush and clean a system, excessive rainfall may also lead to run off, bank erosion and re-suspension of sediment in the water column, which all contribute to increased turbidity.

In addition, while section 1 would run through Glenugie State Forest, many parts of section 2 would run through and adjacent to grazing pastures. The reduced vegetation and increased farmland along this section may also contribute to poorer water quality. Dissolved oxygen and pH were below the lower guideline limit at the majority of sites, quite possibly due to the presence of acid sulphate soils within the region. However, in addition to acid sulphate soils, low pH values during wet weather may also be explained by the heavy antecedent rainfall, which may have reduced levels due to the slightly acidic nature of the rain.

Section 3

In section 3, there was no clear distinction between wet and dry conditions in terms of exceeding water quality guidelines.

However, many sites were measured either only during wet weather or during dry weather with no comparative data between the two conditions available. Turbidity, pH and dissolved oxygen regularly did not comply with the guidelines, with pH and dissolved oxygen values often low and turbidity elevated, regardless of wet or dry sampling events. Acid sulphate soils are widespread along this section of the preferred route and may be responsible for the low pH values recorded.

Shark Creek upstream of the preferred route had poor water quality, most likely due to the nearby floodgate and surrounding land use. Edwards Creek also performed poorly for pH and dissolved oxygen during dry weather, which is attributed to its highly modified channels, exotic weeds, drainage from sugar cane fields and lack of flow.

Water quality would be expected to improve after flushing with heavy rainfall. However, construction impacts may exacerbate the poor water quality without appropriate control measures in place, especially due to the route’s close proximity to South Arm and the distance it runs adjacent to this waterway.

Section 4

Water quality was generally good throughout section 4, with the exception of Serpentine Channel and Nyrang Creek. Non-compliance with the guidelines for turbidity usually occurred following wet weather with the guidelines occasionally exceeded for pH during dry weather.

Serpentine Channel and Nyrang Creek did not comply with the guidelines for pH, turbidity of dissolved oxygen during either wet or dry weather.

The Clarence River and North Arm generally showed good water quality results with the exception of occasional non-compliance for pH during dry weather and turbidity during wet weather. Elevated turbidity levels during wet weather are likely to result from runoff, erosion and resuspension of sediment in the water column. Salinity, ORP (oxidation reduction potential which reflects the antimicrobial potential of the water) and conductivity were considerably lower during wet weather, due to dilution by large volumes of rain.

13.7.2 Potential impacts on water quality

Construction and operation of the project presents a potential moderate risk to water quality from:

- Exposure of soils during earthworks. This would require erosion and sedimentation control measures to minimise the increase of suspended solids and pollutants running off into the surrounding waterways.

- Disturbance of acid sulphate soils (ASS), which may result in water quality deterioration through increased dissolved metal concentrations, a reduction in dissolved oxygen and a drop in pH.

Additional impacts are also possible, such as groundwater and surface water contamination, changes to groundwater recharge and discharge, and hydrologic and hydraulic disturbances.

The physical and chemical changes to the water quality of surrounding creeks and streams that would result from the construction and operation of the highway may include:

- Increased sediment loads — these can reduce light penetration through the water column, impacting on aquatic flora and fauna.
- Decay of organic matter and some hydrocarbons — these can decrease dissolved oxygen levels.
- Increased nutrients (nitrogen and phosphorus) — these can stimulate the growth of algae and aquatic plants.
- Exposed ASS — these can cause acidic pH, low dissolved oxygen, excess sulphate and iron stains.
- Heavy metals (including aluminium and iron) from vehicle wear, accident spills or ASS — these are toxic to aquatic biota and fish.
- Silting of waterways — this can smother aquatic flora and fauna.
- Accidental spills of chemicals — these can impact aquatic (and terrestrial) ecosystems.
- Litter, oil and grease — these can pollute waterways and are unsightly and can cause water quality problems.

13.7.3 Design options to maintain water quality

Ultimately, the key to minimising water quality impacts lies in ensuring that the detailed design adequate addresses the water quality considerations. This is especially applicable to the construction phase. Measures are outlined below and aim to mitigate the water quality and water quantity issues highlighted above. These would need to be further considered during the environmental assessment and detailed design and incorporated as appropriate.

Treatment of stormwater and road runoff

Existing drainage lines should be identified in design and construction drawings and protected using appropriate measures, such as sedimentation barriers, grassed areas, swale drains, buffer strips and the use of wetlands.

To minimise the quantity of water requiring treatment, clean water should be diverted around or away from the site along stable diversion drains, banks or bunds to avoid areas of soil or loose material.

A bunded and impermeable wash area, with collection and treatment systems, should be installed for washing plant and equipment. The contents should be pumped out.

Measures to minimise erosion and sedimentation

To minimise the effects of erosion and sedimentation:

- Stormwater drainage pipes should be installed to control stream and gully erosion.
- Sediment fencing or litter screens should be installed near inlets to prevent blockage of pipes.
- Energy dissipaters or scour protection devices should be used to prevent erosion at outlets.
- Work should be staged, if practicable, to minimise the disturbance area.
- Disturbed soil should be covered and protected with vegetation cover, mulch or erosion-resistant material.
- Buffer zones of dense vegetation should be established along watercourses.

Erosion control and water treatment measures used during the construction phase may be retained for the ongoing operation of the highway. The primary design options include:

- Swale drains.
- Sediment basins.
- Wetlands.

The proposed measures outlined above would be subject to further consideration during the detailed design and environmental assessment phase of the project.

13.7.4 Mitigation measures during construction and operation

Prior to commencement of construction, it would be necesary to prepare:

- A soil and water management plan (SWMP) — to document controls to minimise erosion and transportation of sediment into the waterways.
- An acid sulphate soil management plan (ASSMP) — to outline strategies to manage the potential impacts where road construction works are likely to disturb ASS. During the operation of the upgrade no further exposure of ASS is expected, although mitigation and management measures should be immediately executed in the event of ASS exposure in order to reduce the probability of water quality being adversely affected.

The detailed design should include options to minimise water quality degradation of SEPP14 Wetlands, and these options should be carried through to the construction phase. As a minimum, water quality should be maintained at current levels.

During operation of the project, measures should be considered to maintain or improve water runoff entering the SEPP 14 Wetlands. These measures include minimising the amount of litter, oils and greases, nutrients and sediment that can enter the wetlands. The retention of swale drains and sediment basins (as treatment ponds or wetlands) at these sensitive sites following the construction phase would treat stormwater, while gross pollutant traps or similar devices would reduce the volume of gross litter from entering the waterways.

Measures to minimise impacts on water quality would be further detailed and assessed during detailed design and environmental assessment.

14. Impacts on property

Chapter 14 presents potential impacts of the project on properties, and outlines the land acquisition process.

14.1 Determining the road boundary

The route alignment would affect properties in private and public ownership. The alignment was selected to maximise the use of the existing highway corridor, where possible, with deviations required to address environmental, functional, social and economic constraints and requirements.

The following provisions were made in establishing the proposed road boundary that forms the basis for property acquisition:

- A road corridor sufficiently wide to allow the construction of the highway carriageway for both the arterial and motorway upgrades.
- Sufficient area for access roads and service roads for the both the arterial and motorway upgrades.
- Sufficient area for sediment basins, drainage structures, noise structures and fauna crossings.

The property acquisition boundary does not include provisions for batch plants and stockpiles. It is assumed that these sites would be leased or purchased from adjacent property owners prior to construction, if required. These sites do not form part of the proposed road corridor.

14.2 Land acquisition process

The RTA acquires land under the terms of the *Roads Act 1993*. Payment for land is assessed in accordance with the provisions of the *Land Acquisition (Just Terms Compensation) Act 1991*. One aim of the Act is to encourage the purchase of land by negotiation, rather than using the compulsory acquisition process.

Prior to construction, owners of properties affected by the road proposal are notified in writing of the RTA’s intention to acquire the land and to commence negotiations to purchase the property.

The RTA may give consideration in special circumstances to purchasing a property ahead of the construction phase, where the owner of the land to be acquired can show that a delay in this acquisition will cause hardship, as defined by the Act.

Further details on the land acquisition process can be found in the RTA’s Land acquisition policy statement, RTA 1999.

14.3 Acquisition and adjustment requirements

The acquisition and adjustment requirements for individual properties shall be determined as part of the environmental assessment and detailed design. Based on initial assessments and consultation undertaken prior to the display of the concept design, preliminary access arrangements have been included in the design. The proposed local access roads are described in **Sections 0**, while proposed access for individual property owners is described in **Section 7.4.2.**

In acquiring the necessary property for the construction of the upgrade, the area would be based on the largest land take from either the Class A or Class M acquisitions so that all property ultimately required for the upgrade, interchanges and other associated infrastructure is provided for. For example, in sections 3 and 4, the acquisitions would be based on the inclusion of a full-length service road, even though this may not be initially constructed under Class A.

15. Construction

Chapter 15 presents construction issues, including constructability, timeframes, staging, resources and temporary infrastructure.

15.1 Constructability

The concept design takes into account the constructability (that is, the ease of construction) of the highway upgrade — to both arterial (Class A) and motorway (Class M) standard. Areas of major concern are outlined in the following sections.

15.1.1 Flooding

Flooding is a major factor to consider in the project design. In addition to the large, slow-moving Clarence River floods, many of the catchments through sections 1 and 2 experience smaller, rapid-flowing floods. During construction, consideration must be given to maintaining floodways in creeks and rivers, as well as overland flow in floodplain areas. Across the floodplains, embankments should be built either in stages or with sufficient culverts and bridges in place to ensure flood flows are maintained at all times.

15.1.2 Soft soils

Much of the construction in sections 3 and 4 would occur across the Clarence River floodplain, which contains soft soils that are also likely to be acid sulphate soils. A soft soil construction strategy is outlined in **Section 9.7.5**. Construction in these areas must consider:

- Soft soil treatments — traditional methods using wick drains and preloading are assumed in the concept design.
- Settlements — up to one metre through parts or section 4.
- Consolidation times — a staged approach has been assumed with an overall consolidation timeframe of about two years.
- Flooding — the possibility of flooding is considered in the staged construction approach.
- Acid sulphate soils — treatment must be considered for piles and groundwater extracted as part of the consolidation process.
- Proximity to existing assets — potential consolidation impacts on the existing highway as well as nearby structures must be considered.
- Working under traffic — construction of embankments alongside the existing highway would limit the availability of working space.

15.1.3 Construction within the existing highway corridor

In sections 3 and 4, the project would be built using the existing highway as one carriageway under Class A. Much of section 3 would use the existing highway as the northbound carriageway. This would switch north of the Maclean interchange then switch back at Yamba Road. Similarly, much of section 4 would use the existing highway as the southbound carriageway, with switches at Watts Lane and north of Carrolls Lane.

The project is designed so that the construction of one new carriageway would be clear of the existing highway, allowing sufficient space for construction and operation. Some traffic management would be required to ensure the safe separation of construction and highway traffic is maintained.

Switching has been limited where possible, although a number are still required. These switches would require construction and traffic management to cater for:

- Highway traffic.
- Access for construction equipment.
- Construction of the route at a higher level to the existing.
- Preloading requirements for soft soils.

Careful consideration of sequencing and some temporary works would be required during detailed design and construction, but overall the requirements are not outside what would normally be included in construction of similar projects.

15.1.4 Tie-in at Glenugie and Tyndale interchanges

Construction of the Glenugie and Tyndale interchanges would be predominantly away from the existing highway, simplifying the construction process. The tie-in to the existing highway would require careful consideration of sequencing during the detailed design, although the requirements are not outside what would be normally included in construction of similar projects.

15.1.5 North-facing ramps on Eight Mile Lane

As part of the construction of the north-facing ramps at Eight Mile Lane, the existing road alignment would be straightened to improve sight distances at the new intersections. This would also provide a benefit in allowing for the construction of the new bridge over Eight Mile Lane to be undertaken away from the existing roadway.

Once the deviation and bridge have been constructed, local traffic can be diverted onto the new section of Eight Mile Lane, allowing construction of the upgrade embankment to continue to the north.

15.1.6 Maclean interchange and construction along Maclean Hill

The major portion of the Maclean interchange and the upgrade along Maclean Hill would be built within the existing highway corridor, requiring considerations as described in **Section 15.1.3**.

The following issues would also need to be considered:

- The level of Goodwood Street, which would be raised between the interchange and Cameron Street, with the highway over to be similarly raised.
- The local access from Jubilee Street to Cameron Street would need to be maintained.
- The use of the existing highway would switch from the northbound carriageway, south of the interchange, to the southbound carriageway, north of the interchange.

15.1.7 Yamba Road interchange and Harwood Bridge

The bulk of the Yamba Road interchange would be built within the existing highway corridor, requiring considerations as described in **Section 15.1.3**. The Harwood Bridge would be constructed alongside the existing bridge. The following issues would also need to be considered:

- Local access along Yamba Road would need to be maintained.
- Operation of the existing interchange would need to be maintained.
- The use of the existing highway would switch from the southbound carriageway, south of interchange, to the northbound carriageway, north of interchange.
- Access for water traffic would need to be maintained along the Clarence River.

15.1.8 Watts Lane interchange

The Watts Lane interchange would be built predominantly within the existing highway corridor, requiring considerations as described in **Section 15.1.3**. The following issues would also need to be considered:

- Local access along Watts Lane, River Street and to Harwood village would need to be maintained.
- The use of the existing highway would switch from the northbound carriageway, south of the interchange, to the southbound carriageway, north of the interchange.

15.1.9 Iluka Road interchange

A significant portion of the Iluka Road interchange would be built within the existing highway corridor, requiring considerations as described in **Section 15.1.3**. The following issues would also need to be considered:

- Local access along Iluka Road to the east, and local roads to the west, would need to be maintained.
- Poor matching of the existing alignment to the proposed upgrade may lead to the provision of side tracks to allow construction of the upgrade.

15.1.10 Local access

A number of local roads cross the proposed route alignment. Throughout construction, local access would need to be maintained, with particular consideration given to the movement of cane during harvest season. This activity has a high intensity (24-hour operation) but generally over a short period (days or weeks in individual locations). It is expected that some side tracks would be required to maintain local roads and access tracks through the construction period.

15.1.11 Traffic management

As the project is a combination of duplication of the existing highway, realignment of the existing highway and construction of off-line[10] sections, there would be specific areas that require particular attention with regard to traffic management. These areas, such as large portions of sections 3 and 4, would require constant traffic management, which would impact on the cost of the project as well as safety, and cause delays for road users.

Particular attention has been given to minimising the switches in duplication from one side of the highway to the other, in order to minimise traffic switches through the construction phase. However, a number of switches would be required as part of the construction phasing. Areas of likely concern are:

- Maclean interchange.
- Yamba Road interchange.
- Watts Lane interchange.
- North of Carrolls Lane.

The construction sequence would depend largely on the staging of the project and the delivery method adopted. The construction sequence would be finalised once the delivery method has been determined, the preferred method and project staging finalised, and the construction contractor appointed. An indicative construction sequence for each section of the route would be:

- Property acquisition.
- Utility protection and/or relocations.
- Pre-clearing investigations for flora and fauna.
- Site establishment (compounds, etc).
- Installation of traffic controls (ongoing throughout project).
- Clearing/grubbing.
- Installation of sediment and erosion controls.
- Establishment of stockpile areas.
- Topsoil stripping.
- Cross-drainage, including fauna crossings.
- Earthworks.

---

[10] Sections that are independent of the existing highway.

- Construction of service roads and access roads.
- Establishment of concrete batch plant(s).
- Bridge construction.
- Subgrade and pavement construction.
- Topsoil, revegetation and landscaping.
- Noise mitigation measures.
- Linemarking and signage, including service and access roads and existing highway.
- Lighting at intersections.
- Finishing works.

15.2 Construction timeframes

The concept design adopts traditional methods for the treatment of soft soils in sections 3 and 4, including preloading and installing wick drains. This technique would result in a settlement period of up to two years and a construction period of potentially four to five years. The use of other techniques to shorten the overall construction timeframe would likely result in an increase to the construction cost.

The construction of sections 1 and 2 would not require the consolidation of soft soils, so the construction timeframes can be reduced to three or four years.

15.3 Staging

With four project sections, and more options within each section and when construction of adjoining projects are considered, the possibilities for staging are extensive.

The sourcing of fill would be an important consideration in the staging process.

The earthworks balance for the upgrade is such that section 1 is about balanced, section 2 has the opportunity for an excess in cut materials and sections 3 and 4 require a high volume of fill for the construction of embankments across the floodplain. In developing the concept design, consideration was given to hauling excess cut material from section 2 to section 3 while fill material for section 4 could be hauled from the Iluka Road to Woodburn upgrade project. Accordingly, the upgrade could be economically constructed as a separate contract for section 1, single contract for sections 2 and 3, and then an integrated contract for section 4 with the Iluka Road to Woodburn project.

Construction of section 3 prior to section 2 would need to consider the sources of available fill. This material could be imported, resulting in the need to balance the earthworks in section 2, or could be sourced by opening borrow pits in the northern end of section 2.

No decisions have yet been made on the project staging.

15.4 Construction resources

The availability of raw and manufactured materials and prefabricated components would significantly impact on the delivery of this project. Preliminary estimates of raw materials for construction have been generated as part of the concept design. A preliminary study was undertaken to identify existing and potential sources of quarry materials in and around the study area and the effect of depletion of resources on the broader community, in particular in terms other construction projects in the region.

The project's significant number of bridges and culverts would result in the need for a large amount of prefabricated items. As many of the bridges are across floodplains, it is anticipated that multiple, shorter spans could be used to improve construction efficiencies[11]. Prefabricated items are likely to include:

- Bridge beams — concrete planks or Super-Ts.
- Bridge headstocks and abutments.
- Box culverts.
- Drainage pipes.
- Drainage pits.
- Drainage headwalls.
- Noise walls.

15.4.1 Presence of selected materials within proposed earthworks

As much material as possible will be derived from the area of the roadworks. Along the upgrade route, crushed sandstone suitable for use as selected material can be derived from the Grafton Formation (mudstone, siltstone and sandstone), Maclean Sandstone and Kangaroo Creek Sandstone. **Table 15-1** gives approximate chainages where various rock units are anticipated to be encountered and their potential for reuse as a selected material zone (SMZ).

The majority of quarries in the study area are contained within the Kangaroo Creek Sandstone. The upper five metres of the Kangaroo Creek Sandstone is generally highly to extremely weathered. Less weathered material below this is typically used for pavement sub-base and base material.

- **Table 15-1: Anticipated rock units along the upgrade route**

Section	Approximate chainage		Formation	Potential for reuse as SMZ
	From	To		
1	0	10700	Grafton Formation	Y[1]

[11] The concept design has recognised that shorter spans lengths may be necessary to facilitate construction efficiencies, although this will ultimately be informed by the detailed design.

Section	Approximate chainage		Formation	Potential for reuse as SMZ
	From	To		
2	0	22700	Grafton Formation	Y[1]
	22700	44400	Kangaroo Creek Sandstone	Y
3	44400	44600	Kangaroo Creek Sandstone	Y
	44600	55600	Alluvium	N
	55600	58000	Walloon Coal Measures	N
	58000	61000	Alluvium	N
4	61000	70900	Alluvium	N

[1] Sandstone portions of formation

Estimates of the volume of selected material that can be obtained from the cuts within the Grafton, Maclean and Kangaroo Creek Formations are given in **Table 15-2**.

- **Table 15-2: Estimated SMZ volumes**

Source	Volume
Estimated volume of SMZ from cut	600,000 m^3
Imported volume of SMZ	100,000 m^3

15.4.2 Imported quarry materials

The volumes of materials likely to be required are given in **Table 15-3**.

- **Table 15-3: Likely volumes of imported construction materials**

Material	Volume
General fill	750,000 m^3
Selected material	100,000 m^3
Drainage blanket	500,000 m^3
Concrete aggregate	2,100,000 m^3

The bulk of the general fill that is required to be imported is in the northern sections and the project. Depending on the overall upgrade program, general fill may be available from the Iluka Road to Woodburn project, located immediately to the north. It is expected that this project would provide sufficient general fill, although this is subject to confirmation during environmental assessment and detailed design.

15.4.3 Available and potential quarry materials

Existing quarry sites

Pavement sub-base gravels, select material and drainage layer rock

It is not expected that material for use as drainage rock or pavement aggregate would be reliably obtained from cuts along the upgrade route and all such materials would need to be sourced from quarries. Throughout the study area, there are a number of quarry sites located in areas underlain by the Grafton Formation and Kangaroo Creek sandstones. The majority of these quarries produce products that meet RTA specifications for the supply of selected fill and sub-base materials. Known active quarries are listed in **Table 15-4** and indicated in **Figure 15-1**.

Little testing data is available for the Kangaroo Creek Sandstone, in which most of the quarries within the project area are situated. Available data suggests that the wet-dry strength variation of the material is highly variable, with values between 20 and 70 per cent. RTA specification requires that material for DGB20 (road base) and drainage rock should have aggregate strengths with a wet-dry strength variation not exceeding 35 per cent. Based on discussions with operators of the quarries in the study area, many quarry products do not always pass specifications for base quality material due to variations and seams within the sandstone. Hence, any material obtained from these quarries would need to be tightly controlled to produce road base product.

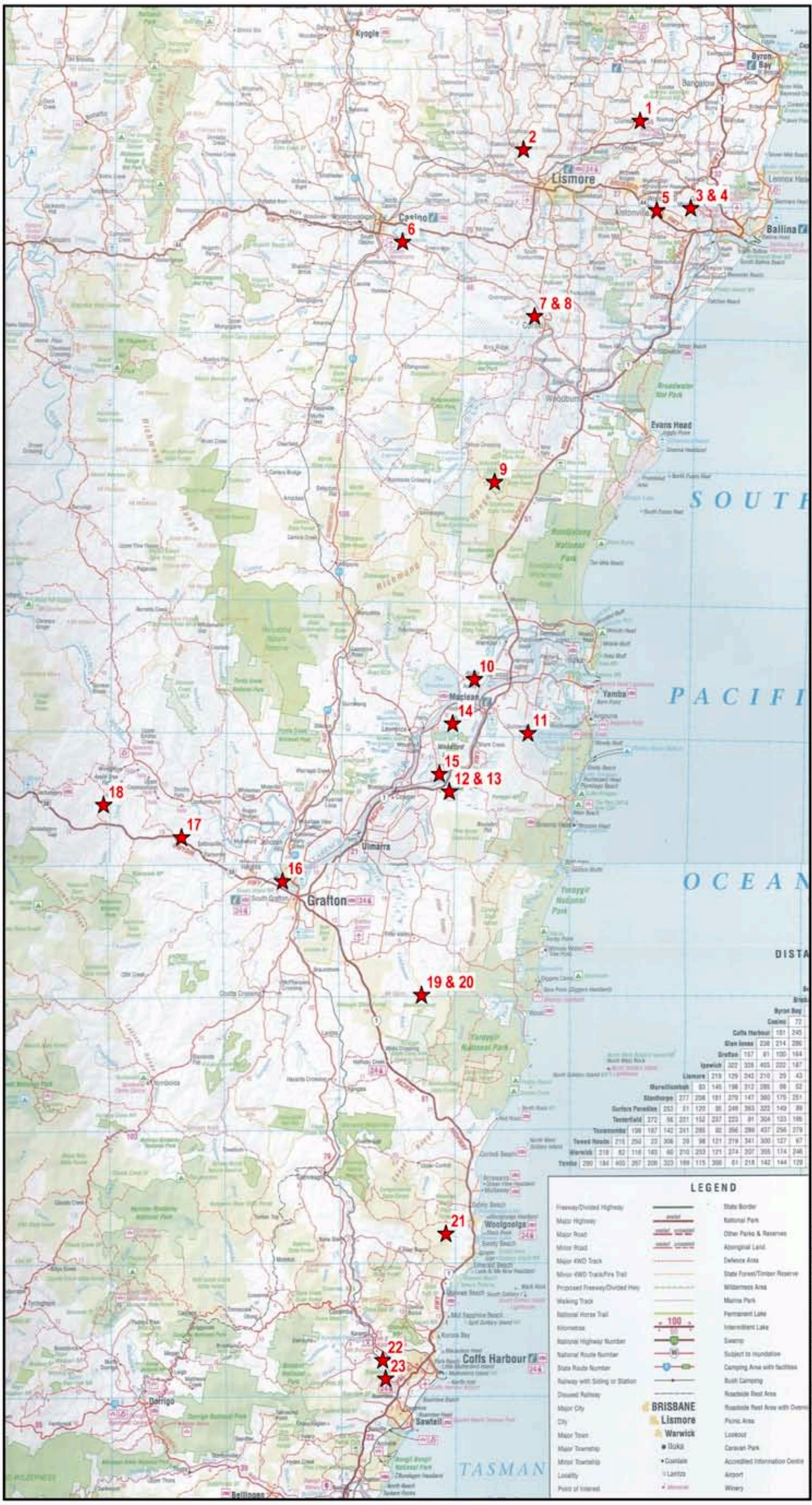
Based on current extraction volumes, over 300,000 cubic metres per year of selected and sub-base quality material can be supplied by existing sandstone quarries in and near to the project without disruption of local supply. Many of the quarry operators produce material to satisfy local demand and do not reach the limits of resource consent. It is likely that many of these quarries would be able to increase the production limits if demand made this a viable option.

Concrete aggregates

Concrete aggregates require a ‘hard rock’ source and consistent product that meets tight quality controls on grading and aggregate strength. The sandstone units within the study area do not meet the requirements of a hard rock source for concrete aggregate supply. Only one quarry close to the project area meets requirements for concrete and sealing aggregates. This is Boral’s Susan Island facility in the Clarence River where river gravels are quarried and crushed for local concrete aggregate supplies.

Quarries producing concrete aggregate are located to the north of the project area in the areas surrounding Casino, Lismore, Ballina, and Coraki. To the south of the project area, concrete aggregates can be sourced from Woolgoolga and to the west of Coffs Harbour.

Figure 15.1 Location of active quarries within the study area



I:\ENVR\Projects\EN01810\Technical\GIS\Template\WC_CDR_010.mxd

Table 15-4: Quarries for sourcing construction materials

No	Quarry name	Location	Distance to project[‡] (km)	Quarried material	Base material	Sub-base material	Selected material	Sand	Concrete aggregate	Anticipated supply volumes
1	Corndale	Corndale	115	Basalt	Y	Y	Y		Y	?^
2	Northern Rivers	Blakebrook	110	Basalt	Y	Y	Y		Y	130 m^3/hr
3	Teven	Teven	105	Basalt and Argillite	Y	Y	Y		Y	?[#]
4	Foxes	Teven	105	Argillite and Dolerite	Y	Y	Y		Y	?[#]
5	Gap Road	Alstonville	105	Basalt	Y	Y	Y		Y	65 m^3/hr
6	Clovass	Casino	105	Basalt	Y	Y	Y		Y	470 m^3/hr
7	Peterson	Coraki	85	Basalt	Y	Y	Y		Y	16,500 m^3/yr
8	Kelly's	Coraki	85	Basalt	Y	Y	Y		Y	67,000 m^3/yr*
9	Tullimorgan	Tabbimobile	55	Sand and Sandstone	Y	Y	Y	Y		150,000 m^3/yr
10	Wilcox	Ashby	30	Sandstone	Y	Y	Y	?		30-55,000 m^3yr
11	Shark Creek	Shark Creek	15	Sandstone	?	Y	Y			43,000 m^3/yr
12	Corbett	Tyndale	<5	Sandstone		Y	Y	?		67,000 m^3/yr*
13	Tyndale	Tyndale	<5	Sandstone	Y	Y	Y	Y		?*
14	Causley's	Woodford Island	20	Sandstone	?	?	?	?		n/a
15	Clares	Woodford Island	15	Sandstone	Y	Y	Y			15,000 m^3/yr
16	Susan Island	Grafton	30	Alluvium	?	?	?	Y	Y	?
17	Jacky's Creek	Ramornie	50	Ironstone and Ridge gravel		Y	Y	Y		?[+]

No	Quarry name	Location	Distance to project‡ (km)	Quarried material	Base material	Sub-base material	Selected material	Sand	Concrete aggregate	Anticipated supply volumes
18	Main creek	Jackadgery	60	Ironstone and Ridge gravel	Y	Y	Y	Y		?+
19	Sullivan	Pillar Valley	30	Sandstone		Y	Y	Y		20,000 m^3/yr
20	Jones	Pillar Valley	30	Sandstone	Y	Y	Y	?		?^
21	Woolgoolga	Woolgoolga	65	Argillite	Y	Y	Y	Y	Y	20,000 m^3/yr
22	Lucas	Coffs Harbour	105	Greywacke					Y	?#
23	Boambee	Coffs Harbour	115	Greywacke					Y	?~

Notes:

- Volumes in the future could change from those indicated above subject to the findings of the detailed design
- Use of the sites indicated above would be subject to the findings of the environmental assessment and detailed design

Key:

‡ All distances are measured to the project are approximate from the quarry site to Tyndale (about the mid point of the project)

^ Quarry operator could not be contacted

\# Quarry operator contacted, but indicative supply volumes not provided

* Quarry not operational at the present time

\+ Quarry near production limits

~ Production only limited by truck availability

Other than the Susan Island facility, Boral also operates hard rock quarries at Teven and at Coffs Harbour. No indicative quantities for supply were given by Boral, which is understood to be one of the major suppliers in both areas.

Readymix operates aggregate facilities at both Teven and Coffs Harbour. Again no supply volumes were provided by Readymix; however, it was indicated that supply would only be limited by truck availability. Production of aggregate from Kelly's Quarry at Coraki is indicated at 65,000 cubic metres per year once it is operational.

Potential for borrow sites

Bondi Hill at Tyndale represents the greatest potential for a borrow site within the project area. This site contains at least two quarries, both of which are currently inactive.

The Golf Links Pit adjacent to Causley's Quarry was previously operated by the RTA. This quarry is currently not in operation, but there may be some potential for it to become operational again.

Potential borrow sites in Kangaroo Creek Sandstone are located in the ranges to the east of the proposed alignment and access can be obtained along Somervale and Bostock Roads to the east of Tucabia, and Mitchell or Firth Heinz Roads to the south of Tucabia.

Any proposed borrow areas would need to be assessed as part of the environmental assessment and detailed design.

15.4.4 Implications of quarry resource depletion to the broader community

Boral and Readymix did suggest they could meet the project demands.

The Newman's Quarry operator (at Tullimorgan) has indicated that its sandstone quarry resource will last for many years at current production rates for general fill, road base, sub-base and select material products. Newman's Quarry currently has a production limit of 200,000 cubic metres per year and produces about 50,000 cubic metres per year to meet demand. Newman's Quarry has also indicated that resource consent to increase its production limit has been discussed with local authorities previously. It is therefore likely that any exhaustion of resources at other local quarries is likely to be taken up by Newman's Quarry.

Wilcox Quarry at Ashby indicated that, at current production rates, the resource within the consent area will last for about 40 years and there is more resource outside the consent area. Wilcox Quarry has the infrastructure to increase production to twice the current output, but is dependent on new planning approval to do so.

15.4.5 Other raw materials

Cement

Sources of cement are likely to be Sydney, Newcastle or Brisbane, requiring transportation to the site via road or rail. It is expected that storage silos would be constructed on site adjacent any temporary batch plants.

Bitumen

Requirements for bitumen would depend on the pavement type selected for the upgrade, with plain concrete pavements adopted for the concept design. As a minimum, bitumen would be required at the top of the SMZ and for local and service roads.

Water

Water would be required for concrete batching and earthworks, including dust suppression and compaction. Water for the manufacture of concrete would be subject to quality controls.

Extraction of water from rivers and streams would require planning approvals and would require further appraisal as part of the environmental assessment.

Prefabricated materials

Supply of pre-cast drainage items could be sourced from various locations — depending on the suppliers — and include Sydney, Brisbane, Kempsey and Tamworth.

Supply of bridge units could be from a variety of sources along the east coast. Individual construction contractors may adopt different sources. At the time of the concept design, a pre-casting yard was proposed for development at Macksville, which may supply many of the units required.

15.4.6 Environmental approvals

The specific sources of materials, as well as site access and supply routes, would be assessed as part of the environmental assessment for the project. Where appropriate material may also be sourced from existing legally operating quarries.

15.5 Temporary infrastructure and work compounds

During construction, the contractor would require temporary infrastructure and work compounds for a range of construction-related facilities, logistics and activities.

It is expected that the contractors would refine their requirements in accordance with the environmental assessment to be prepared, detailed design, construction methodology and staging.

15.5.1 Temporary infrastructure requirements

Temporary infrastructure would be for the exclusive use of the project. Once the facilities are no longer required, they would be removed and areas restored to acceptable conditions.

Temporary infrastructure would include site compounds, batching plants, access roads and earthworks, as outlined below. These would generally be located within the road corridor or in cleared areas nearby.

Site compounds

Potential site compounds would be required for:

- Offices and workshops.
- Parking facilities for cars, trucks and construction equipment.
- Workforce facilities including toilets, first aid and lunchrooms.
- Covered and open storage areas for construction materials.

Temporary site compounds would be generally located close to interchange, intersection and overpass construction sites. To minimise traffic movements, it is expected that the contractor would utilise multiple site compounds along the route in line with construction staging. The location of these compounds would depend on the detailed design, project delivery method and staging. General site compounds should:

- Allow safe and easy access to the work site.
- Be located on relatively flat ground with good drainage, but allow for containment and treatment of runoff.
- Be located above an acceptable flood level (the level of acceptability depends on the contractor's level of risk).
- Allow for water, electricity and phone services to be available or able to be provided without additional environmental impact.

Batching plants

The supply of concrete and asphalt are essential ancillary works. On-site concrete and asphalt batching plants are a cost-effective and more environmentally sustainable approach to supplying concrete and asphalt for the project.

Temporary access roads

Temporary access roads may be required for access to site compounds and batching plants, or to provide improved access to different areas of the construction area. These roads would generally be of a low standard and controlled to restrict access by members of the public.

Earthworks

Earthworks activities would require temporary infrastructure, including:

- Crushing plant — may be required to process cut materials into general fill, selected material zone (SMZ), etc.

- Stockpile areas — required for processing materials, topsoil, mulch and other materials. Long-term stockpile areas may be required if section 2 is built before section 3.
- Spoil disposal areas — required for disposal of unsuitable materials.

15.5.2 Potential locations

While a number of potential sites have been identified, the contractor in consultation with the RTA would be responsible for selecting sites for each type of activity according to the final design, construction methods and staging proposed.

All work undertaken on temporary sites would be subject to satisfying site-specific environmental criteria, mitigation measures, and the requirements of Clarence Valley Council and relevant State government authorities. It would be the contractor's responsibility to obtain approvals for temporary facilities, and to consider all requirements relating to noise, dust, storage, environment and waste management.

In considering possible locations for temporary infrastructure facilities, a range of constraints need to be considered. In particular, the site should be:

- Central to a substantial portion or specific location of the works.
- Located with ready access to the local road network.
- Of adequate size to provide for the effective operation of the infrastructure.
- In close proximity to water sources.
- Relatively level.
- Within the road reserve or in areas where land use is permitted.
- Separated from the nearest residence by at least 200 metres, unless it can be demonstrated that no adverse impact would occur at the nearest residence.
- Selected so that the use of construction facilities does not affect land use of adjacent properties.
- Not within 100 metres of SEPP 14 wetlands.
- Not within 100 metres of any drain that discharges into the wetland, unless mitigation measures are to be provided.
- Not within a one in 100-year floodplain.
- Of low conservation significance for flora and fauna.

15.5.3 Environmental controls

Assessment of the environmental controls would be undertaken prior to construction and as part of the environmental assessment.

15.6 Managing road user delays

A key objective of the overall Pacific Highway Upgrade Program is to limit delays to motorists during construction. The need for traffic management measures along the four sections of the route, during construction and maintenance, is outlined below.

15.6.1 Traffic management during construction

Section 1: Wells Crossing to Glenugie

In section 1, due to the separation of the preferred route from the existing highway, it is expected that construction works would not impose significant delays on highway motorists.

Where the interchange is to be constructed, it is standard practice that a 'construction speed zone' would be implemented at the tie-in point, reducing travel speeds to provide a safe working environment. Through effective construction staging and traffic management, delays to traffic could be minimised.

Section 2: Glenugie to Tyndale

In section 2, the project route would cross a number of local roads including:

- Eight Mile Lane.
- Old Six Mile Lane.
- Avenue Road.
- Wooli Road.
- Firth Heinz Road.
- Bostock Road.
- Somervale Road.
- Bensons Lane.

The potential for delays at these locations would be minimised by providing an alternative route or allowing traffic to pass through the work area.

At Tyndale an interchange with the existing highway alignment would be provided. The interchange would be located to the east of the existing highway, minimising delays during construction.

Section 3: Tyndale to Harwood Bridge

Between Tyndale and Maclean, the existing highway would form the northbound carriageway under the Class A upgrade. This arrangement would maintain access for through traffic while the southbound carriageway is built. Similarly, between Jubilee Street and Yamba Road, the existing highway would form the southbound carriageway under the Class A upgrade.

The route could be built one carriageway at a time, allowing traffic to be switched from one carriageway to another. Although traffic would be restricted to a single lane in each direction, delays should be minimal.

In addition, the upgrade would cross a number of local roads and property accesses. The potential for delays at these locations would be minimised by providing an alternative route or allowing traffic to pass through the work area.

Section 4: Harwood Bridge to Iluka Road

The construction of section 4 would be similar to that of section 3, with use of the existing highway in the Class A upgrade, some traffic switching and the need to maintain access for local roads.

Haulage of materials

It would be necessary to haul materials required for earthworks, drainage, bridging and paving. The specific requirements would be determined at the time of the environmental assessment and would be subject to the staging arrangements adopted.

When haulage is necessary, the route would be carefully selected to minimise possible delays to road users, particularly for vehicles on the existing highway and trucks hauling cane to the Harwood Mill.

15.6.2 Maintenance considerations

Pavement considerations

Design policy for the upgrading of the Pacific Highway specifies a high-strength 10-metre-wide pavement (comprising a 2.5-metre outside shoulder, two 3.5-metre travel lanes and 0.5-metre inside shoulder). The pavement design requires that the same pavement be used under the road shoulders as on the trafficable lanes. As such, the wider shoulders can accommodate future traffic loading, if required, during maintenance activities or when the third lanes are built.

When pavement design parameters are being established, the likely delay costs during future routine maintenance must be identified and estimated. This would ensure that project decisions consider the delay cost impact during both construction and maintenance.

Design considerations

During detailed design, consideration should be given to minimising the need to occupy any areas of the existing trafficked roadway during the lifecycle of the road. This would ensure that thought is given to avoiding unnecessary traffic delays during both construction and maintenance.

In addition, reference should be made to the *RTA Guidelines for Road User Delay Management* which specify that all briefs for detailed design work should contain the following considerations:

- Whenever economically feasible, the final alignment is to avoid encroaching on the existing trafficked roadway.
- Construction staging plans must be developed, where necessary, to ensure the capacity of the roadway is maximised.
- Consideration must be given to the future maintenance of traffic control devices and roadside furniture to ensure that potential road occupancy and road user delays are minimised.

Bridge considerations

Narrow clearances associated with bridge structures have the potential to present a serious impediment to diverted traffic during maintenance activities, and to cause significant additional future costs when road widening is required.

During the detached design of the bridge structures, the costs associated with providing sufficient width on a highway bridge or sufficient lateral clearance of an overbridge to accommodate vehicular access during future maintenance activities and possible future widening, will be estimated.

All new bridges constructed for project would adhere to the standards established by the RTA for Pacific Highway Upgrade projects. Stringent quality management during both the concept and final design stages would ensure continual compliance with RTA standards.

16. Outstanding issues

16.1 Value engineering workshops

As part of the concept design process, value engineering workshops (VEW) were held, as follows:

- VEW 1 (12 September 2007) — section 1.
- VEW 2 (14 November 2007) — section 4.
- VEW 3 (12–13 February 2008) — sections 2 and 3.

Workshop participants were drawn from across the RTA, and brought expertise in road design, road safety, bridge design, geotechnical considerations, urban design, environmental management, heritage management, property services and maintenance. The objective of these workshops was to:

- Obtain a common understanding of the project and its status.
- Review the concept design for the specific sections as they was completed, and highlight issues, concerns and potential improvements.
- Identify a way forward to resolve any issues raised.

An overview of the key issues raised, and how these have been addressed, is provided in **Table C–1** (**Appendix C**). A brief summary of these is provided below.

16.2 Issues to be addressed

The value engineering process identified other issues to be considered or addressed during the environmental assessment and detailed design processes. These issues are the need to:

- Develop guidelines for landowner discussions regarding property access to ensure consistency.
- Undertake trials to confirm the height requirements for emu crossings.
- Refine options for minimising/ rationalising the use of fauna fencing.
- Refine the combination of functions for overpasses, underpasses and culverts (drainage, fauna movement access *etc*) to maximise wildlife connectivity.
- Review the locations for emergency access along the route in consultation with Emergency Services and Police.
- Refine the soft soil/pavement strategy.
- Undertake further investigation of cane pads in terms of need, access, relocation, etc.
- Ensure allowance for extra fill to allow for surcharge of wick drains.
- Provide an allowance for the importation of specialised material.
- Review the implications of changing batter slopes in section 2 to 1:3, to win more fill for section 3.
- Ensure appropriate legible signage is put in place to avoid drivers missing the turn-off to Grafton.

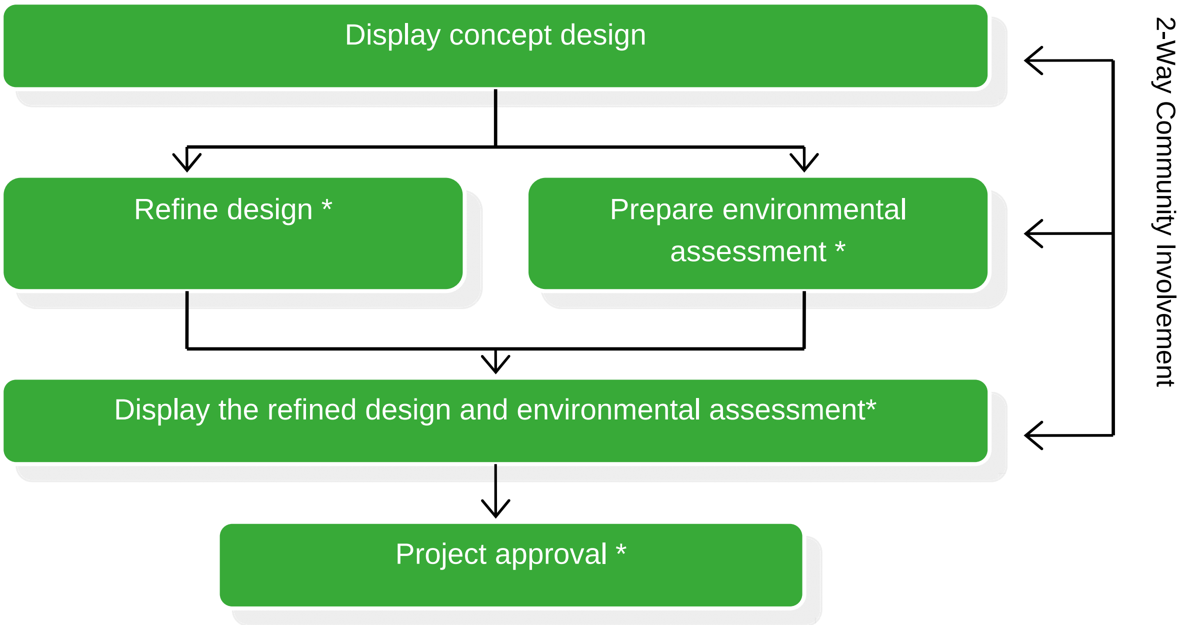
- Review local property access under the carriageway near the Tyndale interchange, to consider the use of a number of short culverts rather than one long culvert under the carriageway.
- Determine how much of the existing highway asset needs rework if is to be reused.
- Investigate having the flood gates on the farm side of the road (eastern side).
- Review the construction of the southbound carriageway south of Shark Creek at a level below the one in 20-year flood level, taking into account flooding, level of service, access, geotechnical considerations and cut/ fill balance issues.
- Review the implications of noise attenuation in terms of the concept design and costing.
- Review the need for noise walls near residences east and north of the Maclean interchange and confirm that these can be accommodated.
- Define an acceptable level of impact with respect to flooding (with respect to afflux, duration, velocity of flow, etc).
- Ensure that the cane drains remain operational during construction and that access to cane farms is maintained during construction and cane harvesting.
- Review the implications of constructing more of the service road in section 3 under Class A in order to reduce the number of intersections required to access the cane pads.
- Develop a management plan for the treatment and avoidance of acid sulfate soils.
- Consider the replacement of many small culverts with a few larger, longer culverts in soft soils.
- Give effect to the proposed strategy for addressing settlement, flooding and drainage across the floodplain.
- Identify potential fill sources from highway upgrade projects to the north.

An overview of the key issues raised, and how these have been addressed, is provided in **Table C–1** (**Appendix C**).

17. The next steps

Following the display of the preferred concept design, the Roads and Traffic Authority (RTA) will consider issues raised in any comments. Clarence Valley Council will then be approached to have the corridor formally reserved in its local planning instrument. The boundaries of the corridor will be based on the final concept design.

- **Figure 17-1: Steps following display of the concept design**



* Note: timing of next steps dependent on future funding

Timing for construction will depend on funding availability. Once this is determined, the environmental assessment will commence and planning approval will then be sought, as outlined in **Figure 17-1**.

18. References

18.1 General reference

The following documents were used in the compilation of this concept design report:

- Clarence Valley Council, 2006, *Maclean Shire (former) Community Based Heritage Study, Coordinators Report*. Clarence Valley Council, Grafton.
- Roads and Traffic Authority, 2005a, *Wells Crossing to Iluka Road, Route Options Development Report*, Roads and Traffic Authority, Grafton.
- Roads and Traffic Authority, 2006a, *Wells Crossing to Iluka Road, Upgrading the Pacific Highway, Preferred Route Report*, Roads and Traffic Authority, Grafton.
- Roads and Traffic Authority, 2008h, *Wells Crossing to Iluka Road*, *Preferred Route Submissions Report*, Roads and Traffic Authority, Grafton.
- Roads and Traffic Authority, 2006f, *Value Management Workshop Report*, Roads and Traffic Authority, Sydney.

18.2 Working paper references

The following working papers where compiled as input into the concept design and were used in the compilation of this report:

- Roads and Traffic Authority, 2008a, *Wells Crossing to Iluka Road Concept Design: Cane Industry Working Paper*, Roads and Traffic Authority, Grafton.
- Roads and Traffic Authority, 2008b, *Wells Crossing to Iluka Road Concept Design: Terrestrial Ecology Working Paper*, Roads and Traffic Authority, Grafton.
- Roads and Traffic Authority, 2008c, *Wells Crossing to Iluka Road Concept Design: Aquatic Ecology Working Paper*, Roads and Traffic Authority, Grafton.
- Roads and Traffic Authority, 2008d, *Wells Crossing to Iluka Road Concept Design: Cultural Heritage Working Paper*, Roads and Traffic Authority, Grafton.
- Roads and Traffic Authority, 2008e, *Wells Crossing to Iluka Road Concept Design: Hydrology and Hydraulics Working Paper*, Roads and Traffic Authority, Grafton.
- Roads and Traffic Authority, 2008f, *Wells Crossing to Iluka Road Concept Design: Water Quality Working Paper*, Roads and Traffic Authority, Grafton.
- Roads and Traffic Authority, 2008g, *Wells Crossing to Iluka Road Concept Design: Harwood Bridge Options Working Paper*, Roads and Traffic Authority, Grafton.

18.3 Highway design references

The following documents have been used in the development of the highway design:

- Austroads, 2002, *Guide to the Geometric Design of Rural Roads*, Austroads, Sydney.
- Austroads, 2004, *Guide to Traffic Engineering Practice*, Austroads, Sydney.
- Roads and Traffic Authority, 2000, *Road Design Guide*, Roads and Traffic Authority, Sydney.
- Roads and Traffic Authority, 2003, *NSW Bicycle Guidelines*, Roads and Traffic Authority, Sydney.

18.4 Pavement design references

The following documents have been used in the development of the pavement design:

- Austroads, 2004, *Austroads Pavement Design — A Guide to the Structural Design of Road Pavements*, Austroads, Sydney.
- Austroads, 2006, *Guide to the Structural Design of Road Pavement Draft Version*, Austroads, Sydney.

18.5 Urban design references

The following documents have been used in the urban design review:

- Roads and Traffic Authority, 2006f, *Upgrading the Pacific Highway — Upgrading Program beyond 2006 — Design Guidelines, Issue 2.4*, Roads and Traffic Authority, Grafton.
- Roads and Traffic Authority, 2005c, *Pacific Highway Urban Design Framework*, Roads and Traffic Authority, Grafton.
- Roads and Traffic Authority, 2005d, *Bridge Aesthetics Design Guidelines*, Roads and Traffic Authority, Sydney.
- Roads and Traffic Author, 2005e, *Pacific Highway Urban Design Framework - Urban Design Guidelines for the SH10 from Hexham to Tweed Heads*, Roads and Traffic Authority.
- Roads and Traffic Authority, 2006b, *Wells Crossing to Iluka Road, Landscape and Visual Working Paper*, Roads and Traffic Authority, Grafton.

18.6 Structures design references

The following documents have been used in the development of the design of the bridge structures:

- Roads and Traffic Authority, 2002 *Technical Direction TD 2002/RS02 (Policy for Safety Screening of Bridges)*, Roads and Traffic Authority, Sydney.
- Roads and Traffic Authority, 2005d, *Bridge Aesthetics Design Guidelines*, Roads and Traffic Authority, Sydney.

- Standards Australia 2004, *AS 5100-2004: Bridge design — Scope and general principles*, Standards Australia, Sydney.

18.7 Noise design references

The following documents have been used in the noise component of the concept design:

- Roads and Traffic Authority, 2001, *Environmental Noise Management Manual,* Road and Traffic Authority, Sydney.
- Roads and Traffic Authority, 2006d, *Wells Crossing to Iluka Road, Noise and Vibration Working Paper,* Roads and Traffic Authority, Grafton.
- Roads and Traffic Authority, 2006e, *Noise Wall Design Guideline - Design guidelines to improve the appearance of noise walls in NSW*, Roads and Traffic Authority, Sydney.

18.8 Ecological references

The following documents have been used in the ecological component of the concept design:

- DEC, 2003. *Key Habitats and Wildlife Corridors in North East New South Wales*. http://maps.nationalparks.nsw.gov.au/keyhabs/default.htm.
- Fairfull, S. and Witheridge, G., 2003. *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings*, NSW Fisheries, Cronulla.
- Smith, A. K. and Pollard, D. A, 1999, *Policy and Guidelines Aquatic Habitat Management and Fish Conservation: 1999 Update,* NSW Fisheries, Port Stephens Research Centre.

18.9 Water quality references

The following documents have been used in the water quality component of the concept design:

- Landcom, 2006, *Managing Urban Stormwater: Soils and Construction*, In: Main Road Construction, Volume 2, Book 4.
- Wong T., Breen P., and Lloyd S, 2000, *Water Sensitive Road Design — Design Options for Improving Stormwater Quality of Road Runoff,* Cooperative Research Centre for Catchment Hydrology, Technical Report 00/1, Melbourne