Roads and Traffic Authority of NSW

Oxley Highway to Kempsey
Upgrading the Pacific Highway

Environmental Assessment

MAIN VOLUME

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14. Groundwater

This chapter describes the existing groundwater features in the locality of the Proposal, and assesses the potential impacts of the construction and operation of the Proposal. It also outlines measures to mitigate these potential impacts.

The Director-General's environmental assessment requirements identify surface and groundwater impacts to be a key issue. **Table 14-1** indicates where the aspects of the Director-General's environmental assessment requirements that relate to surface and groundwater are addressed, either in this chapter or in other chapters (in *italics*).

Table 14-1 Water quality

Environmental assessment requirements	Where addressed
Surface and Ground Water – including but not limited to:	
• Water quality taking into account impacts from both accidents and runoff and considering relevant environmental water quality criteria specified in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000.*	*Chapter 13 Water quality*
• Groundwater including cumulative impacts on regional hydrology. The assessment must consider: extent of drawdown; impacts to groundwater quality; discharge requirements; and implications for groundwater-dependent surface flows (including springs and drinking water catchments), groundwater-dependent ecological communities and groundwater users.	**Sections 14.3**, **14.4** and **14.5** *Chapter 15 Flora and fauna*
• Identifying changes to existing flood regimes, in accordance with the *Floodplain Development Manual* (former Department of Natural Resources, 2005), including impacts to existing receivers and infrastructure and the future development potential of affected land.	*Chapter 12 Hydrology*
• Demonstrating consideration of the effects of sea level rise, changes to rainfall frequency and/or intensity as a result of climate change on the project.	*Chapter 12 Hydrology* *Section 20.8*
• Waterways to be modified as a result of the project, including ecological, hydrological and geomorphic impacts (as relevant) and measures to rehabilitate the waterways to pre-construction conditions or better.	*Chapter 12 Hydrology*

14.1 Assessment approach

14.1.1 Data sources

Characteristics of the existing groundwater environment throughout the Proposal area have been established from several sources including:

- Licensed bore information from the NSW Office of Water (formerly Department of Water and Energy).
- *Pacific Highway Upgrade, Oxley Highway to Kempsey Project, Geotechnical Investigations for Preferred Route, Geotechnical Investigation Report* (Coffey Geosciences 2007a).

- *Pacific Highway Upgrade, Oxley Highway to Kempsey Project, Geotechnical Investigations for Preferred Route, Geotechnical Design Report* (Coffey Geosciences 2007b).
- *Pacific Highway Upgrade – Oxley Highway to Kempsey: Water Quality Assessment* (GHD 2006).
- *Pacific Highway Upgrade – Oxley Highway to Kempsey: Preliminary Hydrology and Hydraulics Report* (GHD 2005d).
- Available information relating to the catchments of the Hastings, Wilson and Maria rivers from Port Macquarie-Hastings and Kempsey Councils.
- Information obtained during the community consultation process.

14.1.2 Groundwater bores

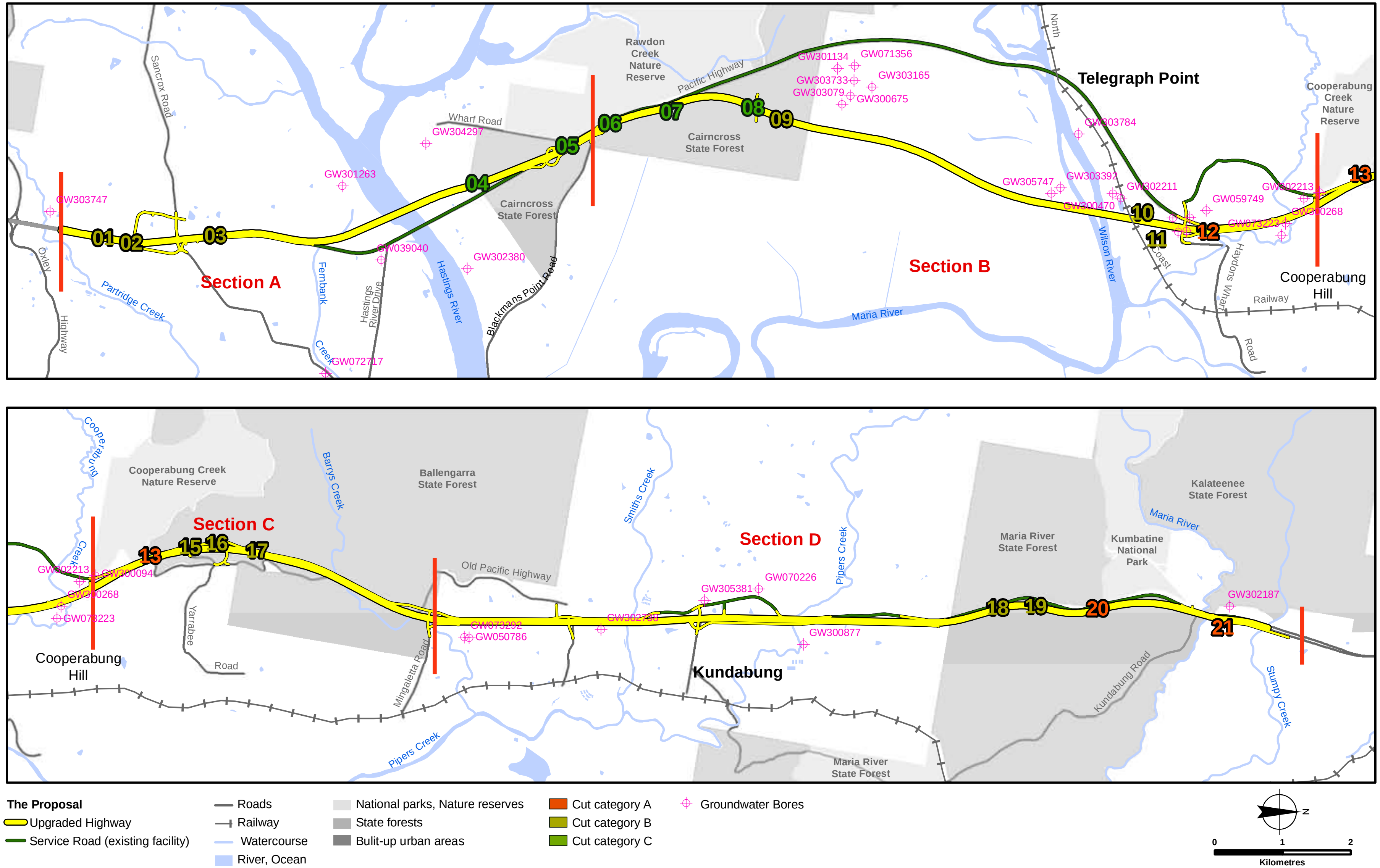
The Port Macquarie-Hastings *State of the Environment Report* (2007-2008) identified 1157 groundwater licences in the Port Macquarie-Hastings local government area. The Kempsey Shire Council *State of the Environment Report* (2004) identified 493 licensed groundwater bores in the Kempsey local government area. A review of data from the NSW Office of Water indicates the licensed groundwater bores located along the Proposal are primarily concentrated around housing areas at Kundabung and at the Hastings and Wilson rivers.

There are a number of bores that are located within 250 metres of the Proposal, as detailed in **Table 14-2** and shown in **Figure 14-1**.

Table 14-2 Licensed groundwater bores within 250 metres of the Proposal

Bore	Station	Distance from the Proposal	Relative location
GW 305747	15278.10	147.24 m	Wilson River floodplain
GW 303392	15393.74	255.16 m	Wilson River floodplain
GW 302211	16304.24	256.02 m	Wilson River floodplain
GW 303114	17109.24	110.75 m	Wilson River floodplain
GW 303077	17220.97	53.10 m	Wilson River floodplain
GW 302218	17338.35	23.25 m	Wilson River floodplain
GW 054292	17356.16	152.27 m	Wilson River floodplain
GW 073223	18688.13	205.35 m	Cooperabung Hill
GW 073608	18710.69	241.78 m	Cooperabung Hill
GW 300268	18784.98	52.27 m	Cooperabung Hill
GW 302213	19172.38	160.59 m	Cooperabung Hill
GW 300094	19430.63	126.25 m	Cooperabung Hill
GW 050786	25182.70	265.02 m	Maria River (hillside)
GW 073292	25105.60	110.75 m	Maria River (hillside)
GW 302738	27121.39	99.68 m	Adjacent to the Maria River
GW 302187	36452.80	147.24 m	Maria River (hillside)

Figure 14-1 Cuttings greater than 3 metres in depth



14.1.3 Geotechnical and groundwater investigations for the Proposal

As part of the geotechnical investigations for the Proposal, 67 boreholes (including seven over-water boreholes) were drilled along the Proposal route to depths of between 5 metres and 38 metres as part of the geotechnical investigations. In addition, standpipe piezometers (used for measuring groundwater levels) were installed in 11 boreholes to monitor groundwater levels along the Proposal route. Where encountered, groundwater levels were recorded in each of the boreholes.

14.1.4 Relevant design features for groundwater assessment

The construction and operation of the Proposal would involve earthworks that have the potential to impact groundwater. This would primarily be the use of fill material for embankments on floodplains and areas of soft soils; and the construction of cuttings (excavation) through hills and elevated terrain. The relevant design features of the Proposal in relation to embankments and cuttings are discussed below.

Embankments

Where embankments are proposed to be constructed on the floodplain, there is likely to be some interaction between the constructed road and the surrounding groundwater table. Areas where fill and de-watering is required will primarily be associated with the soft soils on the Hastings and Wilson river floodplains. The level of interaction between the areas of soft soils with an elevated water table and the constructed road corridor would depend on the type of soft soil treatment selected.

Cuttings

The Proposal would require a number of cuttings along its length. The main areas where cuts would interact with, and potentially impact, the groundwater would be through the Cooperabung Hill area and the Maria River State Forest. Cuttings that are greater than 3 metres in depth are described in **Table 14-3** and shown in **Figure 14-1**. Cuttings have been assigned a category based on their potential to intercept groundwater, which was determined by examining borehole results, specifically depth to groundwater, from the geotechnical investigations. A category was assigned based on this potential as follows:

- Category A cuttings are those that are likely to intercept groundwater.
- Category B cuttings are those that have minimal potential to intercept groundwater.
- Category C cuttings are those that are unlikely to intercept groundwater.

Note that the depths of cuttings in **Table 14-3** are based on the concept design and may be subject to change during the detailed design stage.

14.1.5 Methodology

The available data for the Proposal area, based on the geotechnical and groundwater investigations along with the information on licensed bores, was reviewed. This was carried out in conjunction with the findings of the geotechnical and hydrology assessments that have been undertaken for the Proposal. This provided an understanding of the groundwater characteristics along the Proposal route, and its interactions with surface water and geological conditions. This information also provided a basis for assessing potential impacts on groundwater associated with the Proposal.

Table 14-3 Cuttings along the Proposal

Cut no.	Length of cut	Maximum depth	Depth at which groundwater would be encountered	Assessed category
1	165 m	3.0 m	-	B
2	210 m	3.6 m	-	B
3	560 m	7.0 m	-	B
4	765 m	6.0 m	-	C
5	605 m	3.8 m	-	C
6	385 m	3.2 m	-	C
7	680 m	4.2 m	-	C
8	330 m	7.6 m	-	C
9	235 m	3.2 m	-	B
10	205 m	6.0 m	-	B
11	380 m	10.5 m	-	B
12	215 m	5.1 m	2 m	A
13	630 m	31.3 m	25 m to 29 m	A
14	105 m	4.0 m	-	C
15	145 m	6.0 m	-	B
16	320 m	9.2 m	-	B
17	470 m	13.1 m	-	B
18	475 m	4.6 m	-	B
19	230 m	7.0 m	-	B
20	360 m	12.0 m	7 m	A
21	285 m	7.1 m	2 m	A

14.2 Existing environment

14.2.1 Geology

The Proposal area comprises two distinct landforms. In the south are the wide floodplains of the Hastings River and Wilson River (including the Maria River floodplain). In the north, there is the Cooperabung Hill and the undulating landscape of the Maria River State Forest.

The Hastings and Wilson river floodplains are characterised by mixed and isolated sand, silt and clayey deposits with underlying siltstone, fine to medium grained sandstone and mudstone. A large portion of the floodplains on the Wilson and Hastings rivers have been cleared or drained for agricultural practices (livestock and plantations) with small to medium sized allotments scattered with rural homesteads and buildings. The thickness of the alluvial soil ranges from approximately 0.5 metres up to 15 metres.

The ridgelines and hills across the northern portion of the Proposal area, including Cooperabung Hill and the Maria River State Forest areas, are typically characterised by hard residual clay and silty clay underlain by siltstone, fine to coarse-grained sandstone and mudstone. The thickness of the soil in these areas ranges from approximately 0.5 to 5 metres deep.

Acid sulfate soils:

Are waterlogged soils that are rich in iron sulfides (pyrite). If the sediments are exposed to air, the pyrite could be oxidised and generate sulfuric acid.

Acid sulfate soil or acidic soil has been identified in the upper 1 metre of soil across the Hastings and Wilson river floodplains at concentrations exceeding the NSW *Acid Sulfate Soils Manual* (Stone, Ahern and Blunden 1998) action criterion. There is a high risk of occurrence of ASS at depths greater than 1 metre.

Further detail in relation to geology and acid sulfate soils is provided in **Section 20.3**.

14.2.2 Regional groundwater context

The Proposal area is located within the Hastings River catchment (further detail is provided in **Chapter 12 Hydrology**). As groundwater catchments are generally consistent with surface water catchments, the Hastings River catchment provides the appropriate regional context for groundwater.

The Hastings River catchment is not covered by a water sharing plan under the *Water Management Act 2000 for either surface water or underground.*

The Hastings and Wilson rivers flow from forested areas in the west, down the Hastings Valley through state forest and onto floodplains. The Maria River is a tributary of the Wilson River. The floodplains of the Hastings and Wilson rivers and tributaries of the Maria River typically have ground surface elevations of less than 3 metres above sea level. Large areas have been cleared for agriculture. Groundwater in the area generally follows the river systems down onto these floodplains.

Australian Water Resources 2005, an initiative of the National Water Commission, contains water resource assessments for specific water management areas/units in Australia. The Proposal area is located within the Hastings River surface water management unit, and there are two groundwater management units within: Hastings River alluvium and Hastings River coastal sands. These management units only cover part of the Hastings River catchment, and no comprehensive data groundwater exists for the entire catchment.

The sustainable yield of groundwater identified for the Hastings River alluvium in 2004-2005 was estimated at 16,442 megalitres, while the total groundwater extraction (estimated from licence volume) for the same period was 1368 megalitres (National Water Commission 2007).

The sustainable yield of groundwater identified for the Hastings River coastal sands in 2004-2005 was estimated at 24,796 megalitres, while the total groundwater extraction (estimated from licence volume) for the same period was 1033 megalitres (National Water Commission 2007).

14.2.3 Local groundwater conditions

Based on the geological investigations and measurement of groundwater levels, semi-confined bedrock aquifers and unconfined alluvial aquifers have been identified throughout the Proposal area. Bedrock aquifers have been identified in the Cooperabung Hill area and the Maria River State Forest area. Alluvial aquifers have been identified under the floodplains of the Hastings and Wilson rivers, and to a lesser extent adjacent to other waterways such as Cooperabung Creek, Smiths Creek, Pipers Creek and the Maria River.

Aquifer:

Is an area that contains enough groundwater to be pumped to the surface and used for drinking water, irrigation, industry or other uses.

Bedrock aquifers

The bedrock aquifers are semi-confined aquifers within the sandstone and siltstone layers underlying the Proposal area. These aquifers generally follow the elevated terrain across the Cooperabung Hill area, and the Maria River State Forest area. Groundwater within the bedrock aquifer in the Cooperabung Hill area generally follows the slope of the bedrock towards areas of lower elevation, primarily towards the Hastings and Wilson rivers. Vertical movement is likely to occur through porous sections and rock fractures.

The pattern of groundwater flow suggests that groundwater divides are likely to occur at several locations across the Proposal area, typically at higher elevations. It is likely that recharge to the bedrock aquifer occurs at these locations.

Based on available licensed borehole data from the NSW Office of Water, groundwater yields generally range from about 0.5 to 1.5 litres per second, with a small number of boreholes reporting yields of between 3 and 40 litres per second. The high yield borehole (40 litres per second) is located 300 metres to the east of the Pipers Creek crossing.

Alluvial aquifers

Alluvium (or alluvial floodplains):

Soil or sediments deposited by a river or other running water. Alluvium is typically made up of a variety of materials, including fine particles of silt and clay and larger particles of sand and gravel.

Groundwater movement through alluvium generally involves water continually moving from points of recharge to points of discharge. The normal movement of groundwater in the alluvium is downstream and towards a stream or river. Generally, the greatest recharge into alluvium is through land surface area from rainfall and the greatest discharge is into a stream or river. The alluvial aquifers in the Proposal area are recharged by direct rainfall and discharge into the adjacent waterways.

Several unconfined and discontinuous aquifers exist within the alluvium throughout the study area, mainly in the Hastings and Wilson river floodplains, with smaller aquifers in the vicinity of Cooperabung Creek, Smiths Creek, Pipers Creek and the Maria River.

Geotechnical investigations have revealed that groundwater levels within the alluvial aquifers associated with the Hastings and Wilson rivers are generally less than 1.5 metres below ground level. Depths to groundwater within the other smaller alluvial aquifers appear to be greater, at up to 5 or 6 metres below ground level due to the steeper banks of these waterways. Due to the variable nature of the alluvium, it is unlikely that the alluvial aquifers are saturated throughout their entire thickness below groundwater level.

Based on available licensed borehole data, groundwater yields generally range from about 0.5 to 1.5 litres per second, with a small number of boreholes reporting yields of between 3 and 5 litres per second. There is evidence that the groundwater is tidally affected in the coastal floodplains.

14.2.4 Groundwater quality

Limited groundwater quality data (salinity) is available from the NSW Office of Water licensed borehole database. Reported salinity concentrations within the bedrock aquifer in the Cooperabung Hill and Maria River State Forest areas range from 350 milligrams per litre (fresh) to 3000 milligrams per litre (brackish). Groundwater with a salinity of 3000 milligrams per litre is generally only useful for livestock watering and some industrial applications. More information on the suitable uses for groundwater is available on the NSW Office of Water database. Based on the available information, there does not appear to be any spatial trends in salinity.

Salinity concentrations between 500 (fresh) and 3800 (brackish) milligrams per litre have been reported within the alluvial aquifers. However there is great variability in the quality of the groundwater in the alluvium. There are some wells within 300 metres from the Hastings and Wilson rivers that yield relatively fresh water, while brackish groundwater has been reported at greater distances from these rivers and the groundwater in the estuarine reach downstream of Rawdon Island, located approximately 2 kilometres upstream of the existing Hastings River crossing, can be characterised as predominantly saline. Local geological conditions produce this scenario.

The pH (a measure of acidity) of the groundwater on the floodplains of the Maria River and parts of the Hastings and Wilson rivers is impacted by acid sulfate soils. There is evidence of low pH (acidic) in these areas, particularly in the lower reaches of the Maria River where drains across agricultural land have been identified as releasing acidic groundwater into the catchment (Thor Aasø 2000). Discharges of acidic water have been identified from Fernbank Creek, Partridge Creek and low lying areas around Rawdon Island (Tulau 1999).

To address this acidification, remediation projects have been implemented to mitigate acidic groundwater from agricultural practices across the floodplains. Additionally large parts of the floodplains in the Hastings River catchment are under voluntary agreements for acid sulfate soil management to manage runoff from the floodplain (Thor Aasø 2000). The remediation projects have included involvement from the NSW Government and Port Macquarie Hastings Council as part of the Acid Sulfate Soils Hot Spots Remediation Program overseen by the Acid Sulphate Soil Management Advisory Committee.

14.2.5 Groundwater use

Groundwater is utilised in the Port Macquarie-Hastings local government area for a number of uses including:

- Commercial.
- Domestic.
- Farming.
- Industrial.
- Irrigation.
- Stock watering.

Groundwater use across the Proposal area is primarily located around the areas of the Hastings River, Kundabung and the Wilson River. These bores are used for a range of purposes including commercial, domestic, farming irrigation and stock watering.

14.2.6 Drinking water

The sources of drinking water supplies for the region are located upstream of the Proposal.

Water extraction for Kempsey is located to the north in the Macleay River sands alluvium. The Kempsey Water Supply Scheme derives its source water from the Sherwood borefield. The borefield is on the low lying flats within 200 metres of the Macleay River to the north and south of the Sherwood Bridge (Kempsey Shire Council 2004). This is 20 kilometres to the north-west of the Proposal.

Water for the Port Macquarie area is sourced from Hastings River at Koree Island, approximately 5 kilometres south-west of Wauchope. This is a significant distance upstream from the Proposal. Port Macquarie-Hastings Council does not utilise groundwater as part of its water supply but has investigated the use of an emergency groundwater bore supply in the sand beds between Bonny Hills and North Haven (Scott 2003). This is located 15 kilometres to the south-east of the Proposal area.

14.3 Potential groundwater impacts as a result of construction

The potential impacts on groundwater as a result of construction would be:

- A reduction in groundwater availability to existing users.
- Groundwater drawdown.
- Impediment to groundwater flow or changes to groundwater flow patterns.
- Groundwater quality impacts, including groundwater acidification.
- Discharge of excess groundwater to the surrounding environment.
- Impacts on groundwater dependent ecosystems.
- Impacts on groundwater dependent surface flows.

Each of these potential impacts is discussed below.

14.3.1 Reduction in groundwater availability

The availability of groundwater for existing users may be reduced as a result of:

- Direct removal of existing groundwater wells.
- Groundwater drawdown associated with cuttings through hills.
- De-watering during construction.
- Extraction of groundwater for use during construction.

Direct removal of existing groundwater wells is likely to be limited to one property on the southern floodplain of the Hastings River near Fernbank Creek. This bore was identified during the community consultation process, although it is not currently a licensed bore. A review of the NSW Office of Water licensed borehole database did not reveal any other existing bores that may require removal as a result of the Proposal.

Groundwater drawdown would occur in a small number of locations as a result of excavations for cuttings in the Cooperabung Hill and Maria River State Forest areas. An assessment of the likely drawdown determined that impacts would generally be localised in the immediate vicinity of the cuttings, and that surrounding aquifers would not be impacted to the level that groundwater for existing users would be reduced. More detail on potential groundwater drawdown impacts is provided in **Section 14.3.2**.

De-watering would be required during the construction of cuttings through the Cooperabung Hill and Maria River State Forest areas, and for the construction of fill embankments across the Hastings and Wilson river floodplains. In the cutting areas, groundwater that is intercepted would be diverted along surface flow paths, and would re-enter the environment. There are a number of construction techniques available for de-watering the floodplain and soft soil areas. The selected technique would be determined at the detailed design and construction stage. Generally, provided the extracted water is not acidic and would not contribute to the potential acidification of soils, the water would be pumped and discharged to adjoining surface areas where it would either recharge to groundwater in other locations, or follow surface drainage paths. An assessment of potential acidification would be undertaken to assist in determining the appropriate treatment method.

The use of groundwater for construction purposes is one option available for the construction contractor. The requirements for water usage during construction are outlined in **Section 7.5.2**. Generally, the use of groundwater for construction would be limited to that groundwater taken from the floodplain areas during de-watering as part of the construction of the fill embankments and bridge structures. The volumes of groundwater used for construction would not generally exceed the volume from de-watering and would not contribute to any reduction in groundwater availability for existing users.

Any reduction in groundwater availability has the potential to impact on the surrounding environment. Potentially affected elements of the surrounding environment include groundwater dependent ecosystems and groundwater dependent surface flows. These are discussed in **Sections 14.3.6** and **14.3.7** respectively.

Any reduction in groundwater availability also has the potential to impact on drinking water supplies. However, as described in **Section 14.2.6**, drinking water in the catchment is not sourced from groundwater aquifers. Therefore the Proposal would not impact the region's supply of drinking water.

14.3.2 Groundwater drawdown

Groundwater drawdown of both the bedrock aquifer and alluvial aquifer is likely to occur to some degree throughout the construction period. Works most likely to result in drawdown of the alluvial aquifer would include:

- Installation of wick drains to accelerate the consolidation of soft soils.
- De-watering during bridge pile construction and box culvert installation.
- The potential extraction of groundwater for use during construction.

Drawdown of the alluvial aquifer is more likely along the floodplains of the Hastings and Wilson rivers, and in the vicinity of the proposed bridges over Cooperabung Creek, Smiths Creek, Pipers Creek and the Maria River. Further investigations and groundwater modelling of the Hastings and Wilson river floodplains may be undertaken during the detailed design stage when the proposed construction methodologies are finalised. This modelling will assist in defining the impacts of the various activities that may result in groundwater drawdown. This assessment would include the potential extraction of groundwater for use in construction if required.

Road drainage structures across the floodplain may also impact groundwater, however the groundwater level would be expected to recover in the vicinity of the drain (Kahklen and Moll 1999).

In areas located away from the floodplains, there is potential for impacts associated with the excavation of the cuttings. Groundwater in these locations is generally associated with a bedrock aquifer. Works most likely to result in drawdown of the bedrock aquifer include:

- Cuttings through areas of higher elevation.
- The possible extraction of groundwater for use during construction.
- Dewatering for the construction of piers and footings.

A review of cuttings across the corridor has been undertaken to identify the associated impacts from the development of these works and this is summarised in **Table 14-4**. The assessed category is taken from **Table 14-3**.

Table 14-4 Potential groundwater impacts at cuttings

Cut no.	Assessed category	Comment
1	B	It is not anticipated that groundwater would be impacted by the Proposal at this cutting. Existing groundwater bores to the south and the north of the cut do not intersect groundwater within 3 m of the ground surface.
2	B	It is not anticipated that groundwater would be impacted by the Proposal. Existing boreholes in the area were not found to intersect the groundwater within 4 m of the ground surface.
3	B	It is not anticipated that groundwater would be impacted by the Proposal. Existing bores in the area were not found to intercept groundwater within 8 m of the ground surface.
4	C	The cutting is not anticipated to impact on groundwater. The cutting extends through an area of elevation from the Hastings River floodplain up into the Cairncross State Forest.
5	C	The cutting is not anticipated to impact on groundwater. Bore holes in the surrounding area do not intersect groundwater within 15 m of the ground surface.
6	C	The cutting is not anticipated to impact on groundwater as it extends along the ridgeline of the Cairncross State Forest.
7	C	The cutting is not anticipated to impact on groundwater as it extends along the ridgeline of the Cairncross State Forest.
8	C	It is not anticipated that groundwater would be impacted by the Proposal. Bores in the area were not found to intersect the groundwater within 10 m of the ground surface.
9	B	It is not anticipated that groundwater would be impacted by the Proposal. Existing bores in the area were not found to intersect the groundwater within 15 m of the ground surface.
10	B	It is not anticipated that groundwater would be impacted by the Proposal. Existing bores in the area were not found to intersect the groundwater within 14 m of the ground surface.
11	B	It is not anticipated that groundwater would be impacted by the Proposal. Existing bores in the area were not found to intersect the groundwater within 12 m of the ground surface.

Cut no.	Assessed category	Comment
12	A	It is not anticipated that groundwater users would be impacted as a result of this cutting. A minor drop in groundwater level in the order of 1 metre within the weathered sandstone/mudstone aquifer above the base of the cutting is expected. This portion of the bedrock aquifer is not considered to provide substantial recharge to alluvial aquifers. Existing bores in the area were not found to intersect the groundwater within 12 metres of the ground surface.
13	A	This cutting would impact on the groundwater at Cooperabung Hill in Ballengarra State Forest. At this location the groundwater table is relatively elevated. The cutting may result in a drop in groundwater level within the sandstone/mudstone aquifer of up to 5 metres in the vicinity of station 21000. A negligible drop is likely to occur in some areas of the cutting at lower elevations. However the depth of this cutting is unlikely to have significant impacts on the groundwater as it is associated with an existing cutting.
14	C	It is not anticipated that groundwater would be impacted by the Proposal. Existing bores in the area were not found intersect the groundwater within 10 m of the ground surface.
15	B	It is not anticipated that groundwater would be impacted by the Proposal. Existing bores in the area were not found intersect the groundwater within 11 m of the ground surface.
16	B	It is not anticipated that groundwater would be impacted by the Proposal. Existing bores in the area were not found to be intersecting the groundwater within 12 m of the ground surface.
17	B	The cutting would not intersect groundwater
18	B	The cutting would not intersect groundwater
19	B	The cutting would not intersect groundwater
20	A	This cutting would impact on the groundwater in a gully to the south of the Maria River. The proposed cutting is within a coarser grained weathered sandstone aquifer and drops in groundwater level of up to about 5 m could be expected.
21	A	This cutting would impact on the groundwater of the Maria River alluvium. The proposed cutting would likely result in a minor drop in groundwater level (in the order of 1-2 m) within the rock aquifer and this is likely to have some effect on groundwater levels within the Maria River alluvium. The impact would be localised and is therefore unlikely to impact identified groundwater users.

The main cuttings that may result in groundwater drawdown from the bedrock aquifer are located north of Haydons Wharf Road (cut 12), at Cooperabung Hill (cut 13) and the Maria River State Forest (cuts 20 and 21). There are no existing bores in the vicinity of these cuttings and therefore impacts to existing groundwater users would be minimal. Impacts from cuts 12, 20 and 21 are likely to be relatively localised as the depth of penetration through the water table is relatively small. These cuts may impact on some groundwater movement across the alignment although this is likely to be localised in nature and extent.

The impacts on groundwater from cut 13 would have localised impacts including a slight lowering of the groundwater table at that location and potential reduction in groundwater recharge. It should be noted that cut 13 is a widening of an existing cutting for the Pacific Highway so the impacts are unlikely to be significant on any ground water movement which is already obstructed by the existing cutting. There are no existing groundwater wells in the vicinity of this cutting.

14.3.3 Impediments or changes to flow patterns

Fill embankments

The placement of fill materials on the floodplains and in areas of soft soils would involve the introduction of a weight on the land surface and compaction of the underlying soil. This has the potential to change groundwater flow patterns in the vicinity of the embankments, particularly if the weight is orientated perpendicular to flow directions.

For the Hastings and Wilson river floodplains, where embankments are proposed to be constructed, groundwater is recharged from surface rainfall on floodplain areas, and discharges at the waterways. The Proposal would involve placing embankments perpendicular to the waterways, and therefore parallel to groundwater flow within the alluvial aquifers. Whilst the weight of the embankments would reduce the connectivity of substrate material, no significant cross highway movements of groundwater are expected to be impeded.

Cuttings

As shown in **Table 14-3**, four of the proposed cuttings would be expected to intercept groundwater and may therefore have an impact on groundwater flows.

Cut 12 would be located approximately 100 to 200 metres south of Cooperabung Creek. The proposed cutting would result in a minor drop in groundwater level (in the order of 1 metre) within the weathered sandstone/mudstone aquifer above the base of the cutting. This portion of the rock aquifer is not considered to provide a substantial amount of recharge to the Cooperabung Creek alluvium. Therefore the proposed cutting would have a minimal impact on this alluvium and the users of the alluvial groundwater.

Cut 13 would be located approximately 1 kilometre from Cooperabung Creek. There is a cutting through Cooperabung Hill for the existing highway alignment in this area. The proposed cutting may result in a drop in groundwater level within the sandstone/mudstone aquifer of up to 5 metres in the vicinity of station 21000. A negligible drop is expected to occur in some areas of the cutting at lower elevations. There is potential that this drop in groundwater level may have a limited impact on the recharge of alluvial groundwater adjoining Cooperabung Creek, however it is unlikely to be substantial due to the distance of the cutting from the Creek and the relatively low drop in groundwater level.

Cutting 20 would be located approximately 1.5 kilometres from the Maria River. The proposed cutting would be within a coarser grained weathered sandstone aquifer and drops in groundwater level of up to about 5 m could be expected. This rock aquifer would provide some recharge to the Maria River alluvium, however the expected change to the groundwater table at Cutting 20 is unlikely to have a substantial affect on the alluvium due to the distance of the cutting from the Creek.

Cutting 21 would be located north of Maria River, south of Stumpy Creek adjacent to the Maria River alluvium. The sandstone aquifer at this location is likely to provide recharge to the alluvium. The proposed cutting would result in a minor drop in groundwater level (in the order of 1-2 metres) within the rock aquifer. This would have a localised effect on groundwater levels within the Maria River alluvium, and is unlikely to impact identified groundwater users.

14.3.4 Groundwater quality impacts

Groundwater can be contaminated in a number of ways. If surface water that recharges the aquifer is contaminated, the groundwater will also become contaminated. This can, in turn, affect the quality of surface water at discharge areas. Groundwater can also be contaminated by liquid hazardous substances (or solids that can dissolve in water) that filter through the soil into groundwater, by salt water moving in from the ocean, or by minerals that are naturally present in the area.

The groundwater quality across the Proposal area is variable, ranging in quality with the general average salinity in the Hastings River alluvium of 1000 milligrams per litre which limits the general use of the groundwater.

Groundwater quality impacts may be associated with the alluvial aquifers across the Hastings and Wilson river floodplains during construction. Potential impacts may result from:

- Disturbance and/or exposure of acid sulfate soil or acidic water.
- Intrusion of saline water from the Hastings and Wilson rivers during de-watering.
- Intrusion of saline water from the Hastings and Wilson rivers from bored or driven piles during the construction of bridges.
- Chemical spills during construction.

Acid sulfate soils or acidic water

The groundwater along the floodplains is relatively elevated with water levels at between 0.8 to 2.6 metres below the surface on the Hastings River floodplain and 0.8 to 2.4 metres below the surface on the Wilson River floodplain. The potential impacts may be exacerbated by groundwater drawdown and the exposure of potential acid sulfate soils. A high risk of acid sulfate soils occurring has been identified on both of the Hastings River and Wilson River floodplains by DECCW mapping for these areas. Potential impacts from acid sulfate soils would need to be further investigated during the detailed design and this is discussed further in **Section 20.3**.

Some localised drawdown may occur along the floodplains as a result of soft soil treatments and dewatering. Combined with the construction of temporary and permanent drainage across the floodplains there is the potential to expose acid sulfate soils and impact groundwater quality.

There is also a risk of exposing acidic water from drainage excavations across the floodplains. Previous studies have identified agricultural drains on the Maria River as being a significant source of acid release. The drain excavations lower the groundwater table and provide a means for direct oxidation and release of acidic water into the environment (Thor Aasø 2000).

Salinity

The alluvial aquifer of the Hastings River floodplain from upstream of the Proposal to the mouth of the River is generally saline groundwater with the alluvium dominated by estuarine silts which contain saline water. The development of the Proposal may impact groundwater quality with the potential for recharge from runoff on the base of the batters along the Proposal. Reflecting the salinity of the groundwater, there are few groundwater bores near the Proposal on the southern and northern banks of the Hastings River. The Proposal would not add to the salinity of the groundwater in this area, and would not diminish groundwater quality. Existing groundwater users in this area would not be impacted.

Chemical spills during construction

Potential impacts to groundwater quality may result from chemical contamination during construction activities such as fuel spills or accidents involving construction equipment. Appropriate management measures would be implemented to minimise the risk of this occurring.

14.3.5 Discharge of excess groundwater to the environment

Groundwater could be extracted to assist with construction activities, such as for use in concrete batching plants. This groundwater, along with collected surface water runoff, could be an important source of water for construction activities such as dust suppression and vegetation watering. The use of water during construction is discussed in **Section 7.5.2**.

The volume of groundwater to be used for construction purposes would be determined at the detailed design stage and the commencement of construction after a full water use study is complete. The results of the water use study and the quality of the groundwater would determine the requirements for discharging excess groundwater to the environment. The aim of the overall water balance for the construction of the Proposal would be to minimise the need for discharges. If discharges are required they would be undertaken in accordance with DECCW requirements.

14.3.6 Groundwater dependent ecological communities

The potential impacts on groundwater may have impacts on groundwater dependent ecosystems. Potential implications for groundwater dependent ecological communities are discussed below, and impacts on specific groundwater dependent ecological communities are assessed in **Chapter 15 Flora and fauna**.

Groundwater dependent ecological communities are ecosystems which have their species composition and their natural ecological processes determined by groundwater. Ecosystems vary greatly in the degree of their dependency on groundwater, from having no apparent dependence through to being entirely dependent on it (Department of Land and Water Conservation 2002).

Impacts on groundwater dependent ecological communities as a result of construction are most likely to arise from groundwater drawdown.

Table 14-5 assesses the potential impacts from the construction and operation of the Proposal on groundwater dependent ecological communities.

Table 14-5 Potential general impacts on groundwater dependent ecological communities

Potential Impact	General description	Implications for the Proposal	Potential implications for groundwater dependent ecological communities
Impediment to groundwater flow by fill embankments	The placement of fill materials on soft floodplain soils leads to compaction of the underlying soil. The compacted soil is less permeable and can impede groundwater flows.	Embankments on the Hastings and Wilson river floodplains would be expected to be generally perpendicular to the rivers and, therefore, parallel to groundwater flows. Impacts on groundwater flows would thus be minimal.	It is expected that construction of the embankments would have negligible impact on any groundwater dependent ecological communities in the vicinity of the Proposal.

Potential Impact	General description	Implications for the Proposal	Potential implications for groundwater dependent ecological communities
Impediment to groundwater flow by cuttings	Cuttings have the potential to impede groundwater flow by intersecting the aquifer and severing the link between opposite sides of the road. As cuttings are required where there are hills, the main impact is likely to be on confined bedrock aquifers in, for example, sedimentary rock strata.	The groundwater in the Proposal area is largely alluvial (plus sand bed groundwater also occurring to the east). Cuttings are unlikely to interfere with alluvial (or sand bed) groundwater due to the locations of cuttings in hillier areas rather than on the alluvial plains.	As groundwater dependent ecological communities in the study area are associated with alluvial rather than bedrock aquifers, no impacts on groundwater dependent ecological communities are anticipated.
Groundwater drawdown	Groundwater drawdown may result from use of wick drains to accelerate consolidation of soft soils, de-watering during bridge and culvert construction, and any groundwater extraction for use during construction.	Activities that could result in groundwater drawdown are most likely to occur in alluvial areas. However, potential drawdown is expected to be of limited duration and of limited spatial extent, although this is not defined at this stage.	As the identified groundwater dependent ecological communities mostly occur on the alluvial floodplains, they could be vulnerable to groundwater drawdown. The potential impacts would be dependent on the proximity of the groundwater dependent ecological communities to the construction works, the natural variability of the groundwater, the duration of the drawdown and the spatial extent of the drawdown.
Discharge of excess water to the environment	Discharge of collected stormwater or excess extracted groundwater to the environment could result in a localised mounding of the watertable in the vicinity of the discharge point.	The volume, duration and location of any discharge are critical to any potential impacts. While such discharges are expected to be minor, consideration of location of discharge points could mitigate potential impacts.	Prolonged discharge could result in localised dieback, whereas intermittent or short-term discharge would be likely to result in no evident changes.
Groundwater quality impacts	Both water level and chemistry changes can potentially affect groundwater dependent ecological communities. Water chemistry changes that can have the most significant effects are changes to salinity, pH and macronutrients, as these are major drivers of ecosystem variability. However, relatively small quantities of some chemicals, such as petrochemicals, may also have toxic effects on groundwater dependent ecological communities.	Potential construction impacts on groundwater quality are disturbance of acid sulfate soils, chemical spills, and saline intrusion during dewatering near the rivers. The first two can be managed as part of standard operational procedures and would not result in changes in groundwater chemistry if correctly managed. The extent of saline water intrusion would be dependent on river conditions at the time of the works, and on the duration of the dewatering.	None of the identified freshwater groundwater dependent ecological communities in the vicinity of the corridor occur close to either the Hastings or the Wilson Rivers, and dewatering for bridge construction in these areas is unlikely to result in saline groundwater intrusion impacts. The other potential impacts should be effectively managed at source and not impact groundwater dependent ecological communities.

14.3.7 Groundwater dependent surface flows

Groundwater dependent surface flows are waterways such as streams or rivers that derive the majority of source water from groundwater discharge. Surface flows in the Proposal area are primarily fed by rainfall and surface runoff. The contribution to surface flows from groundwater in the Proposal area is very minor. Any impacts on any groundwater fed surface flows would primarily result from cuttings in the bedrock aquifers in the Cooperabung Hill and Maria River State Forest areas However this impact is expected to be very minor.

14.3.8 Staging implications

In preparing this Environmental Assessment, the groundwater impacts of the possible staging option described in **Section 7.3.2** in comparison to the construction of the entire Proposal to a full motorway standard have been considered as outlined below.

In the possible staging option, major cuts through Cooperabung Hill could be constructed to the full motorway width, to provide enough fill material for construction activities where necessary. Alternatively, these cuts could be constructed to a lesser width to suit the arterial standard requirements only if there is adequate material available for fills. Generally, other cuts and fills in the northern sections of the project would be built to arterial standard only and would require further widening at a later stage to cater for the ultimate motorway standard upgrade.

It is considered that the groundwater impacts would most likely be similar to those of the motorway standard upgrade for any of these situations. However, further groundwater assessment would be undertaken during the detailed design phase to determine if there is any likelihood of additional groundwater impacts based on the staging option adopted.

Should the Proposal be delivered in stages, the staging report described in **Section 7.3.3** would detail the groundwater impacts of the staging option. If any additional or altered impacts are identified, the staging report would further assess these impacts and identify appropriate management measures.

14.4 Potential groundwater impacts during operation

Impacts to groundwater levels and flow regimes from the operation of the Proposal are likely to be more pronounced along the alluvial floodplains than in the bedrock aquifer. This would primarily be a result of changes to recharge and discharge characteristics for the alluvial aquifers.

Bedrock aquifers

Impacts on the bedrock aquifers would be limited and localised. New cuttings would generally follow the existing cuts already in place for the existing highway. This is likely to limit further impacts away from the Proposal. The Proposal is not considered likely to result in significant drawdown of groundwater, cause groundwater impedance or result in changes to the groundwater quality such that groundwater flow in the bedrock aquifer would be significantly impacted. Where groundwater is exposed as a result of the cuttings in the Cooperabung Hill and Maria River State Forest areas, it would be managed through diversion drains so that it re-enters the environment via surface flow.

Alluvial aquifers

Changes in hydraulic conductivities due to soil consolidation may occur as a result of placing embankments on the river floodplains for the alluvial aquifers. These impacts would be mainly localised but there is potential to affect groundwater availability and groundwater quality.

As groundwater levels change, potential acid sulfate soils may become exposed. The potential for acidification would be managed during the finalisation of the design and during construction so that the Proposal does not have an ongoing impact on the alluvial aquifers crossed by the Proposal.

The different construction methods available would affect the level and significance of any impacts on the groundwater that may occur during operation. The detailed design process may involve the development of a further groundwater assessment based on the proposed construction methodology. This would be used to assist in designing measures to reduce impacts on groundwater availability and groundwater quality as a result of the operation of the Proposal.

14.5 Cumulative impacts on regional hydrology

The Proposal area predominately lies on the estuarine catchments of both the Hastings and Wilson rivers and there is potential to impact groundwater on the alluvial aquifers of these rivers. The establishment of fill embankments would produce localised drawdown of groundwater immediately down flow of the Proposal on the floodplain. The level of impact is likely to be limited to in the immediate vicinity of the Proposal and it is unlikely to significantly contribute to impacts on groundwater resulting from other developments along the Hastings and Wilson rivers.

The floodplains where the alluvial aquifers are located have been identified as having high potential to contain acid sulfate soils. The effective management of drainage and groundwater on the floodplains would be required to minimise the risk of potential oxidisation of these soils so that the Proposal does not contribute to existing acidification resulting from agricultural practices.

14.6 Groundwater management measures

A water management plan would be developed in accordance with *RTA Specification G38 Soil and Water Management (Soil and Water Management Plan)* (RTA 2004b). The water management plan would include measures to reduce impacts on groundwater during the construction and operation of the Proposal.

Measures to mitigate potential groundwater impacts during construction and operation would include:

- Limiting the risk of exposing acid sulfate soils:
    - Formulating construction methods to minimise the rate of de-watering in areas of potential acid sulfate soils. This would reduce the risk of exposure and acidification of these soils.
    - Ensuring appropriate design of water storage areas and temporary drainage systems during de-watering.
- Minimising reductions in groundwater availability:
    - Limiting direct removal of groundwater bores to the one that has been identified in the Proposed areas.
    - Limiting groundwater drawdown through cuttings where feasible.
    - Minimising the de-watering of excavations in alluvial aquifers. Where practicable, only de-water during the day while construction activities are taking place.
- Reducing impediments to groundwater flows or changes to groundwater flow patterns.
    - Ensuring appropriate design of temporary drainage systems during de-watering.

- Minimising groundwater drawdown and impacts on existing users by:
  - Monitoring groundwater levels.
  - Minimising the size and depth of excavations (phased construction).
  - Diverting runoff away from excavations.
  - Managing the groundwater pumping rate for de-watering.
  - Managing the de-watering of excavations and wells, particularly in the alluvial aquifers. Where practicable, only dewater during the day while construction activities are taking place.
  - Where practicable, locating the de-watering wells as far away from existing bores as possible.
  - Minimising the disturbance of identified acid sulfate soils.
- Protecting groundwater quality by:
  - Developing and implementing an acid sulfate soil management plan that addresses the establishment of soil remediation areas, soil liming rates and disposal.
  - Minimising the size and depth of excavations (phased construction).
  - Capturing surface runoff and spills to prevent groundwater contamination through recharge of the groundwater from contaminated surface flows.
  - Minimising the potential intersection with elevated groundwater and the potential exposure of acid sulfate soils. Drainage would be managed to prevent acidic water recharging into the groundwater or discharging into surface waters.
  - Minimising the use of water from the alluvial aquifer for construction.
  - Carrying out vehicle refuelling within bunded areas.
  - Storing chemicals within bunded areas.
  - Appropriate storage, treatment and disposal of extracted groundwater.
  - Minimising excess groundwater discharge requirements and only discharging in accordance with DECCW requirements.

Further groundwater modelling would be undertaken during the detailed design stage. Modifications or changes in construction methodology and additional mitigation and management measures may be formulated at this stage to further reduce and manage impacts on groundwater.

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