NSW Roads and Maritime Services

WOOLGOOLGA TO BALLINA | PACIFIC HIGHWAY UPGRADE

ENVIRONMENTAL IMPACT STATEMENT

MAIN VOLUME 1A

Chapter 9 – Soils, sediments and water

Chapter summary

This chapter presents a discussion on soils, contamination, water quality and groundwater.

Water quality

The project would cross and drain to a large number of waterways, including the major Clarence and Richmond river systems and other sensitive receiving environments including the Solitary Islands Marine Park, Coldstream River wetlands, Broadwater National Park and threatened fish habitat.

The project would also cross groundwater resources including the Woodburn Sands aquifer bore field located about two kilometres south-east of Woodburn, run by Rous Water. The bore field provides a reserve water supply during drought and an auxiliary supply for the region.

To safeguard these important water resources, the project includes a number of design features and management measures to minimise the likelihood of impacts as a result of the project.

During construction, these measures would involve the installation of sedimentation basins to intercept sediment-laden runoff. During operation, these measures would include permanent water quality management measures to protect adjacent waterways from pollutants, including water quality ponds, grassed swales and gross pollutant traps.

A water quality monitoring program would be implemented prior to and during construction, and during operation of the project to assess the effectiveness of the water quality management measures, and assess the need for additional measures to meet water quality guidelines.

Together, these measures would minimise any impact to the quality of water resources and sensitive receiving environments.

Soils

During construction, there would be an increased risk of soil erosion from exposed soil and stockpile sites, in particular areas of clearing and earthworks. There is a moderate to high risk of soil erosion in most of the project area. Also, acid sulfate soils may be exposed as a result of drainage, excavation, dewatering and clearing activities. Disturbance of acid sulfate soils would be managed and mitigated through the implementation of standard management measures. There are a number of areas of contamination which could be impacted during construction, resulting in potential risks to the environment.

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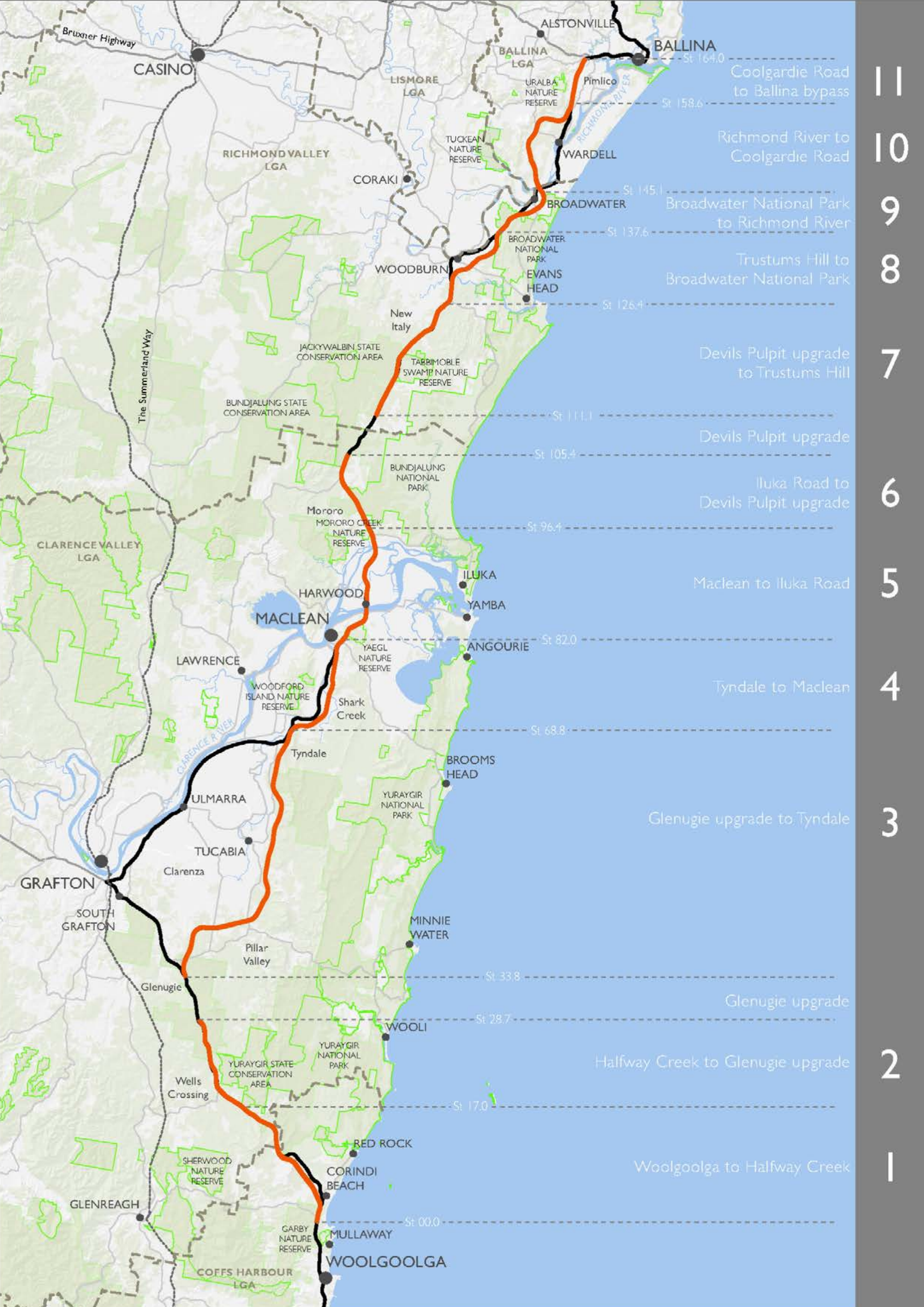

Bruxner Highway
CASINO
ALSTONVILLE
BALLINA
BALLINA LGA
LISMORE LGA
URALBA NATURE RESERVE
Pimlico
RICHMOND RIVER
St 164.0
Coolgardie Road to Ballina bypass
11
St 158.6
TUCKEAN NATURE RESERVE
WARDELL
RICHMOND VALLEY LGA
CORAKI
Richmond River to Coolgardie Road
10
St 145.1
BROADWATER
Broadwater National Park to Richmond River
9
St 137.6
BROADWATER NATIONAL PARK
WOODBURN
EVANS HEAD
Trustums Hill to Broadwater National Park
8
St 126.4
New Italy
JACKYWALBIN STATE CONSERVATION AREA
TABBIMOBLE SWAMP NATURE RESERVE
The Summerland Way
Devils Pulpit upgrade to Trustums Hill
7
BUNDJALUNG STATE CONSERVATION AREA
St 111.1
Devils Pulpit upgrade
St 105.4
BUNDJALUNG NATIONAL PARK
Iluka Road to Devils Pulpit upgrade
6
Mororo
MORORO CREEK NATURE RESERVE
St 96.4
CLARENCE VALLEY LGA
ILUKA
HARWOOD
YAMBA
MACLEAN
Maclean to Iluka Road
5
St 82.0
ANGOURIE
YAEGL NATURE RESERVE
LAWRENCE
WOODFORD ISLAND NATURE RESERVE
Shark Creek
CLARENCE RIVER
Tyndale to Maclean
4
St 68.8
Tyndale
BROOMS HEAD
ULMARRA
YURAYGIR NATIONAL PARK
TUCABIA
Glenugie upgrade to Tyndale
3
Clarenza
GRAFTON
SOUTH GRAFTON
MINNIE WATER
Pillar Valley
St 33.8
Glenugie
Glenugie upgrade
St 28.7
WOOLI
YURAYGIR STATE CONSERVATION AREA
YURAYGIR NATIONAL PARK
Wells Crossing
Halfway Creek to Glenugie upgrade
2
St 17.0
RED ROCK
SHERWOOD NATURE RESERVE
CORINDI BEACH
Woolgoolga to Halfway Creek
1
GLENREAGH
St 00.0
GARBY NATURE RESERVE
MULLAWAY
WOOLGOOLGA
COFFS HARBOUR LGA

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9 Soils, sediments and water

This chapter presents a discussion on soils, contamination, water quality and groundwater. Specialist studies undertaken included a water quality impact assessment and groundwater impact assessment (refer to the Working paper – Groundwater (SKM, 2012a), and Working paper – Water quality (SKM, 2012b)).

This chapter also addresses the Director General's requirements and the supplementary requirements from the Commonwealth Minister for Sustainability, Environment, Water, Population and Community (DSEWPaC).

Director General's requirements	Where addressed
The EIS must address **Soils, Sediments and Water** – including but not limited to:	
• impacts on surface water flows, quality and quantity, with particular reference to any likely impacts on surrounding water bodies, wetlands and their habitats, including potential indirect impacts on the Solitary Island Marine Park by works in the Arrawarra Creek and Corindi River Catchments;	Section 8.4.2 Section 9.2.2 Section 9.3
• groundwater impacts, taking into consideration local impacts at deep cuttings and fill locations, and cumulative impacts on regional hydrology. The assessment shall consider: the extent of drawdown, impacts to groundwater characteristics, quality, quantity, and connectivity, discharge and recharge rates, and implications for surface flows, groundwater users, groundwater dependent ecosystems and wetlands;	Section 9.2.3 Section 9.3
• impacts to the Rous Water Regional Water Supply (Woodburn) bore fields drinking water source, taking into account discharge/ recharge rates and groundwater yield, and consideration of the relevant public health and environmental water quality criteria specified in the *Australian and New Zealand Guidelines for Fresh and Marine Water quality 2000* ((Australian and New Zealand Environment and Conservation Council) and the *Australian Drinking Water Guidelines 2004* (National Health and Medical Research Council and the Natural Resource Management Ministerial Council);	Section 9.2.2 Section 9.2.3 Section 9.3
• identification and assessment of soil characteristics and properties that may impact or be impacted by the proposal; and	Section 9.2.1 Section 9.3.
• identification and assessment of soft soils, soil contamination, acid sulfate soils, and details of erosion and sedimentation control measures.	Section 9.2.1 Section 9.3 Section 9.4.
Supplementary Director- General's requirements	**Where addressed**
A description of the existing environment including: • Details of relevant baseline conditions to be used to assess the impacts of the action and the performance and effectiveness of proposed mitigation measures, including water quality, road kill data and habitat parameters for relevant areas that support migratory species, listed threatened species and ecological communities	Section 9.2.2 Section 10.4

9.1 Assessment methodology

9.1.1 Soils

The general information on soils and geology presented in this chapter was sourced from the results of geotechnical investigations carried out for the purposes of project planning during 2007–10. The geotechnical investigations included a review of existing data, field work (involving test pitting, borehole drilling, cone penetration testing and seismic refraction traverses) and laboratory testing. Soil landscape information was obtained from Soil Landscapes NSW (Milford 1999, Morand 1994 and Morand 2011), however, some areas have not been mapped, in which case data from the Atlas of Australia Soils (Northcote et al 1960-1968) was used. Information on acid sulfate soil issues was obtained from existing acid sulfate soil risk maps. Information on soft soils was obtained from the Woolgoolga to Ballina Soft Soil Issues – Pacific Highway Upgrade Front End Study: Early Works Ground Treatment Assessment (Coffey Geotechnics, 2010).

Information on contamination was obtained from preliminary site contamination studies carried out for previous project development phases and a follow-up assessment of contamination carried out in 2012. The previous studies were carried out between 2005 and 2010 and involved identifying potential contamination based on past and present land uses, using a combination of aerial photographs, historical records and visual site inspections. Limited sampling and laboratory testing of surface soils was carried out at a selection of locations where contamination was considered to have the potential to occur.

The follow-up assessment of contamination carried out in 2012 involved a review of the results of previous studies and existing contamination databases, and a site inspection of accessible areas of interest to verify locations of potential contamination. An assessment of contamination risks was carried out, taking into consideration the proximity of potentially contaminated areas to the project boundary, the likelihood of exposure of contamination during project construction, and the potential consequences of disturbance and exposure of contaminants. Sources of information on areas of potential contamination included:

- RMS and local councils
- Registers of potential and confirmed contaminated sites maintained by the NSW Environment Protection Authority, including the List of NSW Contaminated Sites notified to EPA and the Contaminated Land: Record of Notices
- Registers maintained by the NSW Environment Protection Authority under the *Protection of the Environment Operations Act 1997*
- The register of cattle dip sites maintained by the NSW Department of Primary Industries.

9.1.2 Water quality

The assessment of water quality was based on existing available data and involved:

- Identifying water catchments and waterways along the project boundary
- Reviewing conditions using GIS functions to identify the locations of sensitive receiving environments such as waterways, national parks, nature reserves, State conservation areas, SEPP No. 14 wetlands, and key fish habitat areas
- Identifying any sensitive receiving environments that have the potential to be impacted by construction and operation
- Reviewing existing water quality conditions in the relevant receiving waterways based on available water quality data and relevant water quality guidelines (refer to Section 9.1.1 and further details below)
- Undertaking a geographic assessment to determine existing catchments along the project boundary and proposed catchments based on the project alignment
- Assessing the potential impacts of project construction and operation on water quality

- Identifying impact mitigation measures for construction and operation of the project based on the principles and guidelines set out in DECC (2008a), Landcom (2004) and RMS and Austroads guidelines (2003)
- Locating and sizing sedimentation basins and water quality basins for the construction and operational phases using 12D software and the Model for Urban Stormwater Improvement Conceptualisation (MUSIC).

The assessment was based on comparing existing water quality data with the guideline values for protection of aquatic ecosystems set out in the Australian and New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) Australian and New Zealand Guidelines for Fresh and Marine Water quality (ANZECC and ARMCANZ, 2000). These guidelines are referred to throughout this report as the ANZECC and ARMCANZ guidelines. The specific ANZECC and ARMCANZ guidelines used were the default trigger values for chemical and physical stressors for the protection of aquatic ecosystems in slightly disturbed estuarine and lowland river systems of south-eastern Australia.

9.1.3 Groundwater

The information presented in this chapter is based on existing data obtained from groundwater bores and previous modelling studies. Information from registered groundwater extraction bores located within 10 kilometres of the project was used in conjunction with topographical information (via a digital elevation model) to estimate the height of the water table and gradients of groundwater flow along the project boundary.

In many areas along the project boundary there is insufficient groundwater information to provide a reliable estimate of water table depth. In these areas, the height of the water table surface has been estimated using one of the following two approaches:

- Assume the water table is independent of geology and landform and use statistical extrapolation techniques to generate a water table surface from the most relevant available groundwater bore data
- Assume the water table follows the general form of the land surface and use available point data from groundwater bores to estimate the depth along the project.

These data extrapolations must be interpreted with caution as they do not take into account the different characteristics of groundwater flow through different media or the presence of impediments to flow, such as faults and dykes.

The potential groundwater issues that have been addressed in this impact assessment are:

- Potential impacts on the quantity and quality of groundwater supply, including impacts on the bore field at Woodburn
- Potential impacts on the quality of groundwater supply
- Potential impacts on groundwater-dependent ecosystems and estuary health.

The investigation considered the Australian Drinking Water Guidelines (NHMRC and NRMMC, 2011). The principles behind this framework have been applied in this EIS, including the identification and likelihood of hazards resulting in the contamination of a groundwater source and potential consequences. Prescriptive activities have not been followed as there is currently insufficient groundwater data. Full development of this framework would be incorporated into a groundwater management plan for the area within the project boundary. It is expected that contamination of groundwater supplies can be prevented by a combination of simple measures.

9.2 Existing environment

9.2.1 Soils

Topography

The topography throughout the project boundary is variable but can be broadly categorised as either ‘lowland’ or ‘elevated’. Lowland areas are predominately associated with the Clarence and Richmond river floodplains and occur within sections 4 to 5 and 8 to 11 where elevations are less than about 15 metres Australian Height Datum. Elevated areas are mainly confined to the southern and central parts of the project boundary, occurring in sections 1 to 3 and 6 to 7, and rise to a maximum elevation of about 135 metres Australian Height Datum on the Coast Range and footslopes of the Pillar and Richmond ranges. Topographic conditions within each section of the project are summarised in Table 9-1.

Table 9-1: Summary of topographic conditions within the project boundary

Project section	Dominant landform	Proportion of section (%)	Typical elevation (m AHD[1])	Description
1	Elevated	70	30–135	Footslopes, low hills, undulating rises and summit surfaces of the Coast Range around Dirty Creek. Lowland coastal plains of elevation 2–15 m in the south.
2	Elevated	100	55–95	Rolling low hills and undulating terrain between Halfway Creek and Glenugie.
3	Elevated	80	15–45	Low rounded hills and narrow drainage plains of the Pillar Valley in the south and footslopes and gullies of the Pillar Range in the north. Lowland alluvial valleys and narrow floodplains of elevation 1–15 m in the central area.
4	Lowland	95	1–10	Low, predominately level terrain of the Clarence River (South Arm) floodplain between Tyndale and Maclean. Isolated areas of low hills and undulating rises of elevation 15–40 m in the central and northern area.
5	Lowland	100	1–5	Low, predominately level terrain of Clarence River floodplain (North and South Arm) and Clarence River delta (Harwood and Chatsworth islands) between Maclean and Mororo.
6	Elevated	80	15–30	Gently undulating terrain comprising the eastern footslopes of the Richmond Range between Mororo and Tabbimoble. Lowland terrain of elevation 5–15 m in the south.
7	Elevated	65	15–45	Gently undulating terrain comprising the eastern footslopes of the Richmond Range between Tabbimoble and Trustums Hill. Lowland terrain of elevation 1–12 m in the north.
8	Lowland	85	1–15	Low, predominately level terrain from Trustums Hill to Kilgin. Gently undulating terrain of elevation 15–20 m in the south.
9	Lowland	100	1–10	Low, predominately level terrain of the Richmond River floodplain between Kilgin and Broadwater.
10	Lowland	100	1–5	Low, predominately level terrain of the Richmond River floodplain between Broadwater and Coolgardie bounded by the Blackwall Range to the west. Some isolated low rises of maximum elevation 20 m at southern end of route. Route crosses Richmond River.

Project section	Dominant landform	Proportion of section (%)	Typical elevation (m AHD[1])	Description
11	Lowland	100	1–5	Low, predominately level terrain of the Richmond River floodplain between Coolgardie and Emigrant Creek bounded by the Blackwall Range to the west.

1. AHD = Australian Height Datum

Geology

The project would generally traverse the geological sequence of the Clarence-Moreton Basin, an extensive Mesozoic age sedimentary basin extending from southern Queensland to the NSW North Coast and comprising sedimentary rocks about 2.5 to four kilometres thick. Both the northern and southern extents of the project extend beyond the sedimentary basin, with the underlying Palaeozoic basement rocks of the New England Fold Belt outcropping at Woolgoolga and Ballina.

The Jurassic age Walloon Coal Measures outcrop generally parallel to the coastline in elevated and steeper terrain areas of north-eastern NSW and are known to result in slope instability in some areas. Sections 1, 4, 6 and 7 of the project would traverse Walloon Coal Measures and may therefore have elevated levels of slope instability. Further geological mapping and hazard assessment needs to be carried out in these areas during detailed design to determine the extent of slope instability and the management and risk mitigation requirements. The remaining sections of the project (section 2, 3, 5, 8, 9, 10 and 11) would traverse relatively flat, low-lying areas and rolling hills. Slope stability issues are not considered likely in these areas.

Soil landscapes

The mapped soil landscapes underlying the project area are described in Table 9-2 and shown in Figure 9-1 to Figure 9-11, with further details on their distribution and erosion potential provided in Table 9-3. The most common soil landscapes within the project boundary are the erosional, transferral and alluvial types. Soils within these landscapes are generally highly erodible and have low bearing strength. Soft soils occur between the Dirty Creek Range and Halfway Creek and in low-lying areas, including the Clarence River floodplain between Grafton and Tyndale.

Table 9-2: Description of mapped soil landscape types within the project boundary

Soil landscape type	Component soil landscape units	Characteristics	Project section
Erosional	New Italy, Gulmarrad and Olive Gap	Generally associated with gently undulating to undulating rises and low hills. Slopes are in the order of 2–35% and soils are typically of a low foundation hazard and highly erodible when cleared.	4, 6, 7 and 8
Transferral	Moonee, Pretty Plain and Billinudgel	Generally associated with undulating rises, low hills, footslopes, drainage plains and fans. Slopes are in the order of 0–10% and soils are typically highly acidic, highly sodic, highly erodible and of low bearing strength due to seasonal waterlogging.	1, 6, 7 and 10
Alluvial	Corindi, Brushgrove, Cowper, Dungarubba and Empire Valley	Generally associated with level to very gently undulating alluvial plains, floodplains and river back plains. Slopes are in the order of 0–6% and soils are typically highly acidic, highly erodible, of low bearing strength and subject to flood hazards.	1, 4, 8 to 11
Stagnant alluvial	Tabbimoble	Associated with stagnant alluvial plains and drainage depressions derived from mixed alluvium within the Tabbimoble lowlands. Slopes are generally around 0–1% and soils are moderately erodible and of low bearing strength due to seasonal waterlogging.	6 and 7

Soil landscape type	Component soil landscape units	Characteristics	Project section
Estuarine	Palmers Island and Burns Point	Generally associated with deltaic plains and extra tidal flats of the Clarence and Richmond rivers. Slopes are in the order of 0–3% and soils are typically saline, subject to regular flooding and of low bearing strength. Soil types are also prone to water erosion.	5 and 11
Aeolian	Iluka, Bundjalung and Wardell	Generally associated with extremely low level to gently undulating sand sheets, beach ridges and dune fields. Slopes are in the order of 0–5% and soils are non-cohesive, highly erodible and highly permeable.	8, 9 and 11
Swamp	Newports Creek and Everlasting	Generally associated with low, level to gently undulating coastal back barrier floodplains and estuarine backswamps of the Clarence and Richmond rivers. Slopes are in the order of 0–2% and soils are highly acidic, sodic and saline, and of a low bearing strength. Soil types are also prone to water erosion.	1 and 4
Disturbed	Disturbed terrain	Varies from level plains to undulating terrain and comprises land that has been disturbed by human activity, including the use of fill. Landfill includes soil, rock, building refuse and waste material. Potential issues include subsidence, poor drainage, low fertility and the presence of toxic materials.	3, 5, 9 and 10

Table 9-3: Soil landscape distribution by project section

Project section	Description
1	Section 1 is underlain by swamp and alluvial landscapes at lower elevations (ie < 10 m), and transferral landscapes at higher elevations near Dirty Creek. No published soil landscape map is available for the northern portion of the project section. Soils in the section are highly erodible and prone to water erosion in lower elevations. Reported presence of erodible siltstone seams around Dirty Creek Range.
2	No published soil landscape map is available for Section 2, but soils are assumed to be highly erodible. Reported presence of soft soils.
3	No published soil landscape map is available for Section 3, but soils are assumed to be highly erodible. Reported presence of soft soils.
4	No published soil landscape map is available for the southern portion of Section 4. The northern portion of this section is underlain by swamp and alluvial landscapes at lower elevations (ie < 5 m) and erosional landscapes at higher elevations near Maclean; all are highly erodible. Presence of soft soils throughout the Clarence River floodplain.
5	Section 5 is mainly underlain by estuarine landscapes of the Clarence River delta and associated floodplains, which are prone to water erosion. An area of disturbed landscape is located on the southern bank of the Clarence River at the southern extremity of the section.
6	Section 6 is mainly underlain by erosional landscapes, with transferral landscapes located in the central portion, both of which are highly erodible. Stagnant alluvial landscapes located in the northern extremity near Tabbimoble, are moderately erodible.
7	Section 7 is mainly underlain by erosional landscapes (highly erodible). Isolated areas of stagnant alluvial landscapes are located in the southern (highly erodible) and central portions and isolated areas of transferral landscapes located in the northern portion near New Italy and Trustums Hill (moderately erodible).
8	Section 8 is generally underlain by erosional landscapes in the south, alluvial landscapes in the central portion and Aeolian landscapes in the north. All of these landscapes are highly erodible. The far northern end of the section, north-east of Woodburn, traverses an isolated area of erosional landscapes.

Project section	Description
9	Section 9 is mainly underlain by Aeolian landscapes. An isolated area of disturbed landscape is located in the southern portion. These landscapes are highly erodible. Swamp landscapes located at the far northern end of the section adjoining the Richmond River are prone to water erosion, including areas of soft soils.
10	Section 10 is mainly underlain by transferral landscapes. An isolated area of disturbed landscape is located in the southern portion. Alluvial landscapes are located at the far southern end of the section adjoining the northern bank of the Richmond River. All these landscapes are highly erodible.
11	Section 11 is mainly underlain by alluvial landscapes, which are highly erodible. Estuarine landscapes located at the northern end of the section, typically west of Emigrant Creek, are prone to water erosion.

Photo 1: Shark Creek (in Section 4)

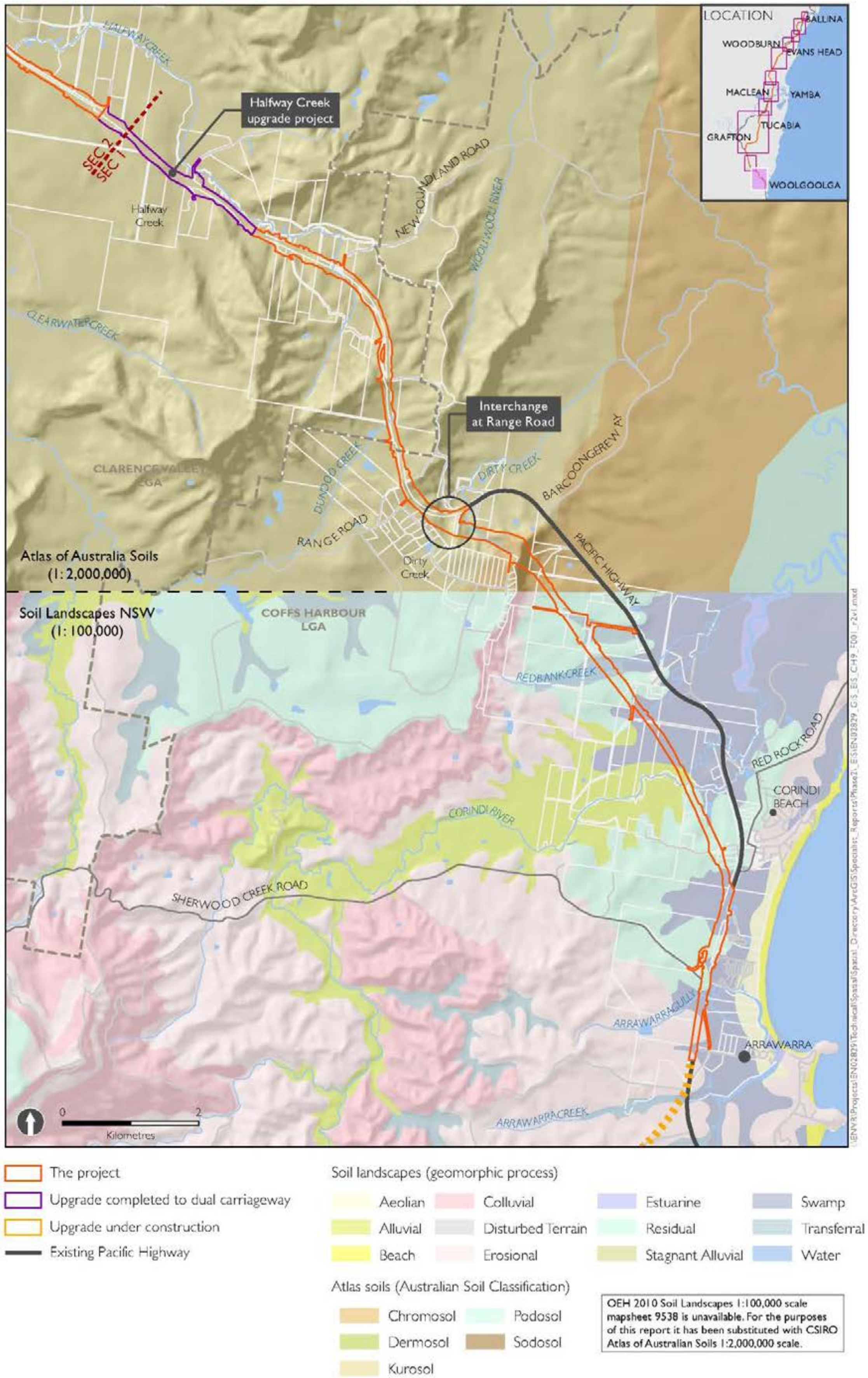
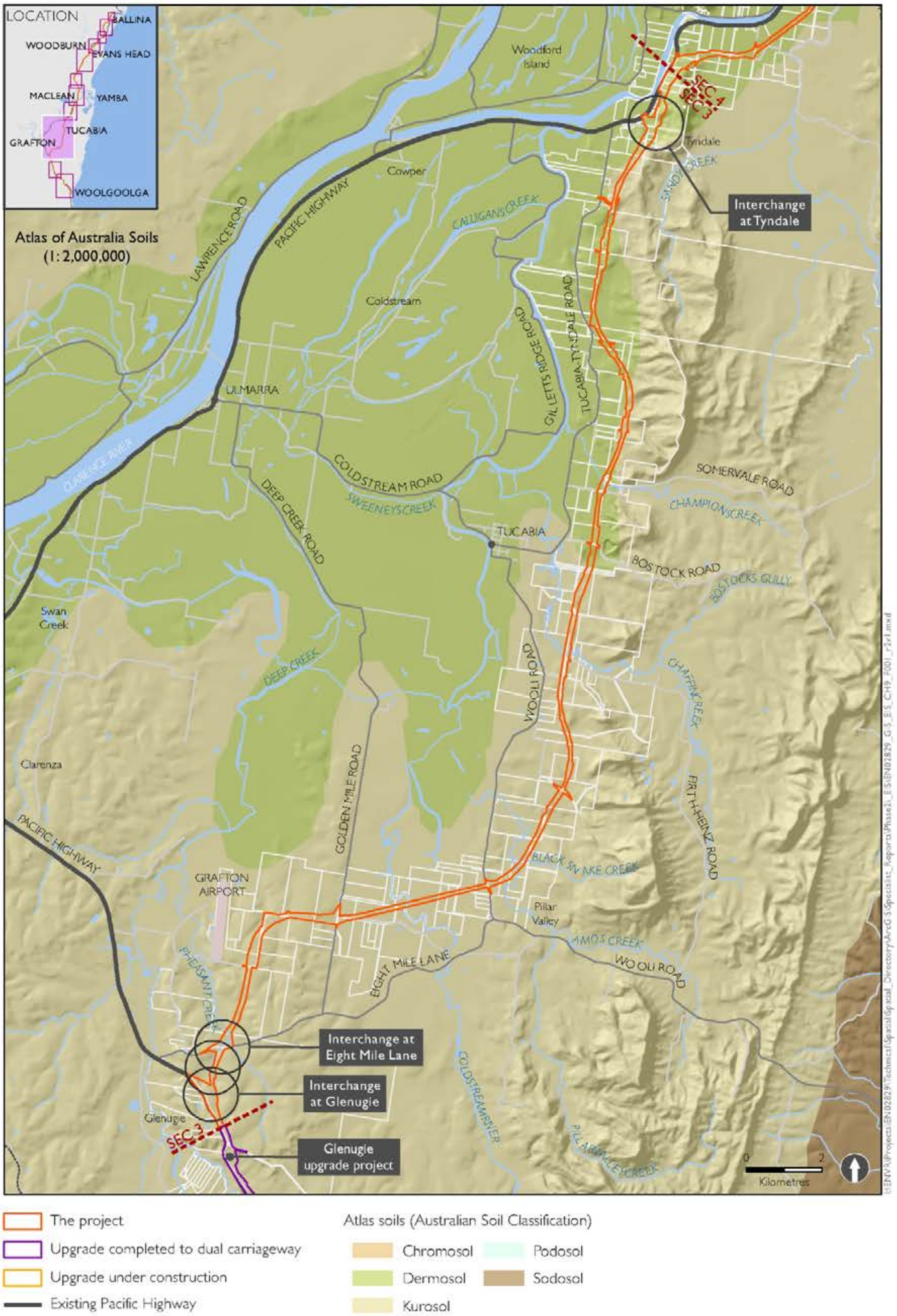


Figure 9-1: Soil landscape types: Section 1

OEH 2010 Soil Landscapes 1:100,000 scale mapsheet 9538 is unavailable. For the purposes of this report it has been substituted with CSIRO Atlas of Australian Soils 1:2,000,000 scale.

Figure 9-2: Soil landscape types: Section 2



OEH 2010 Soil Landscapes 1:100,000 scale mapsheet 9538 is unavailable. For the purposes of this report it has been substituted with CSIRO Atlas of Australian Soils 1:2,000,000 scale.

Figure 9-3: Soil landscape types: Section 3

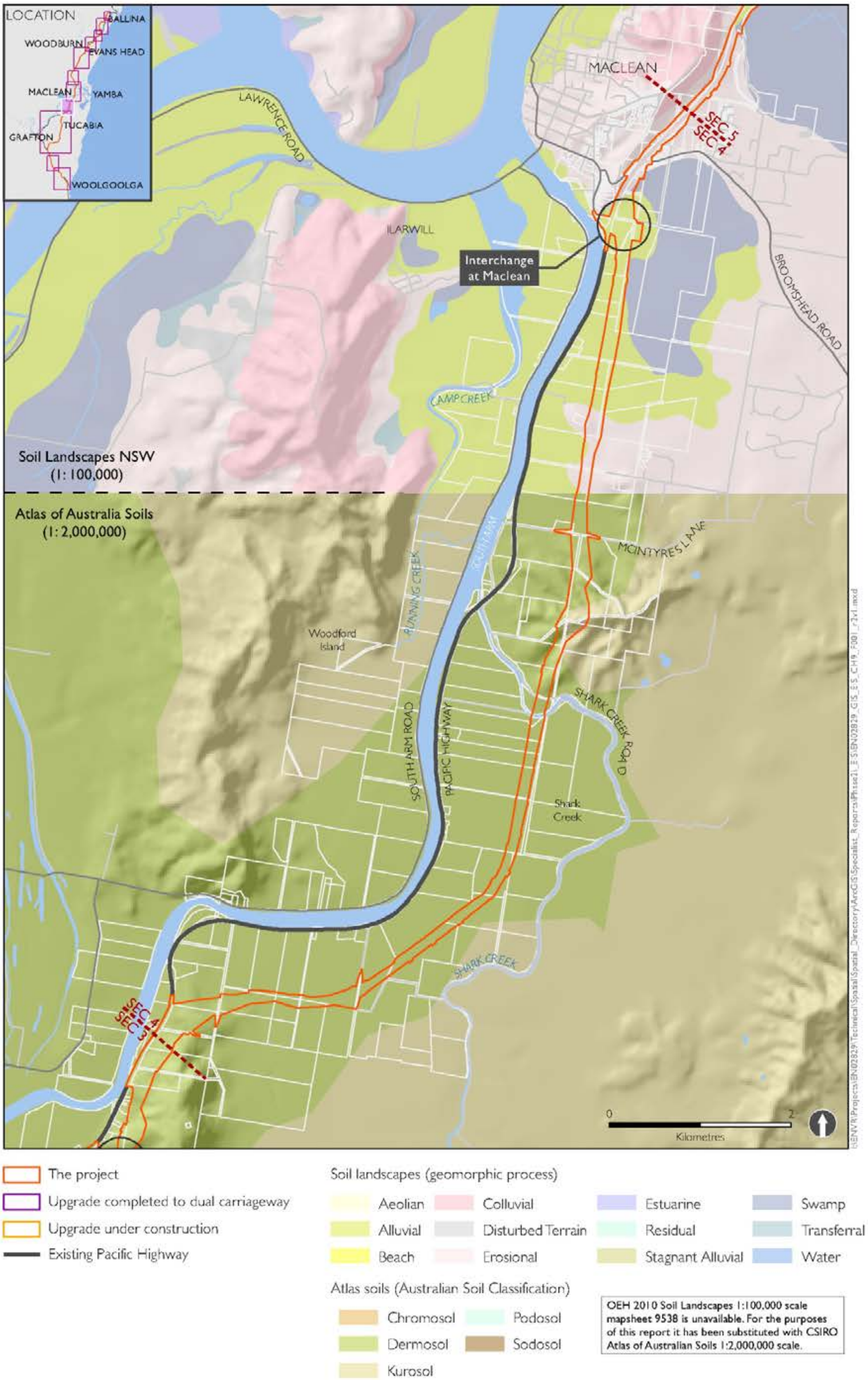


Figure 9-4: Soil landscape types: Section 4

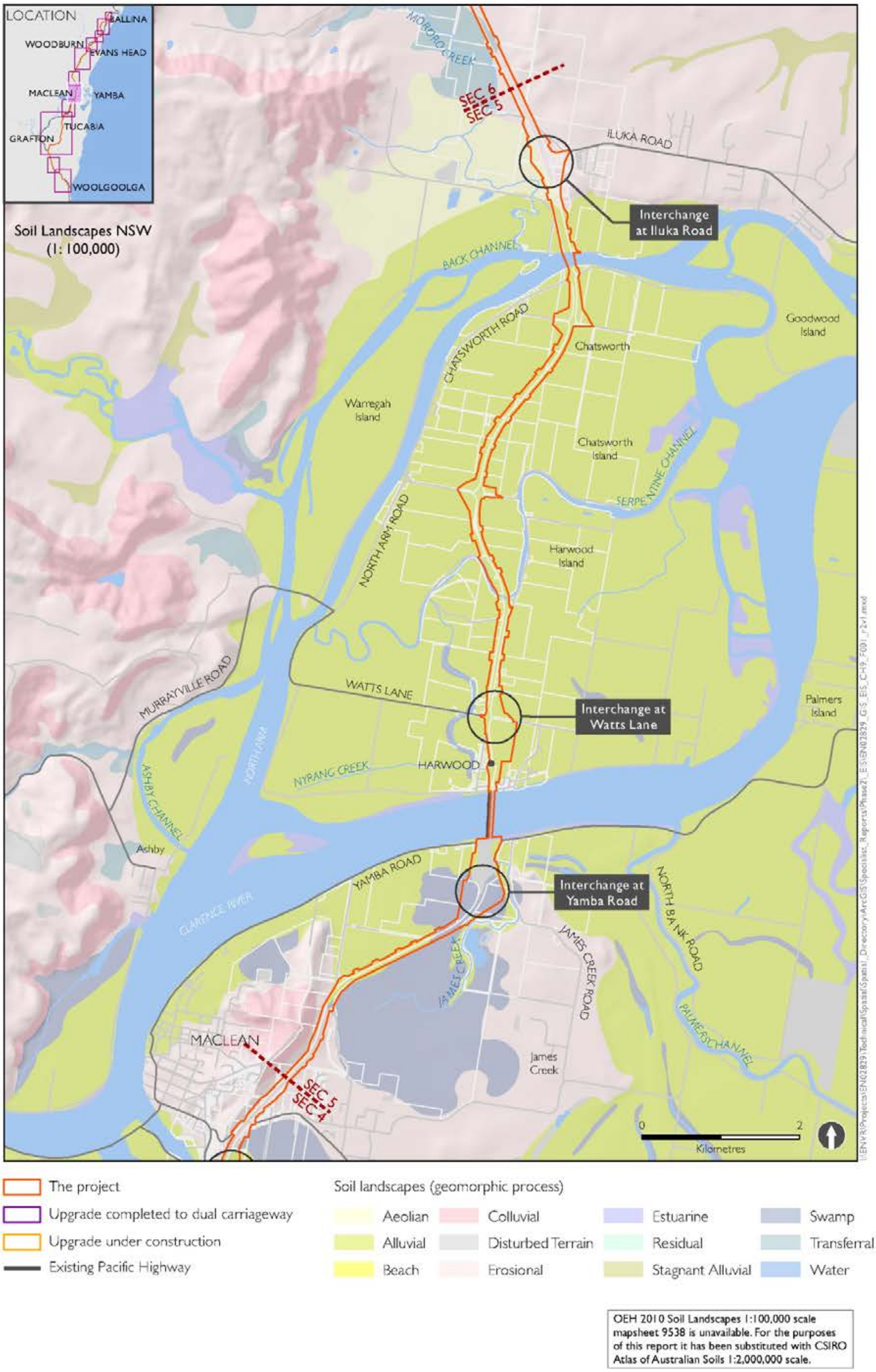


Figure 9-5: Soil landscape types: Section 5

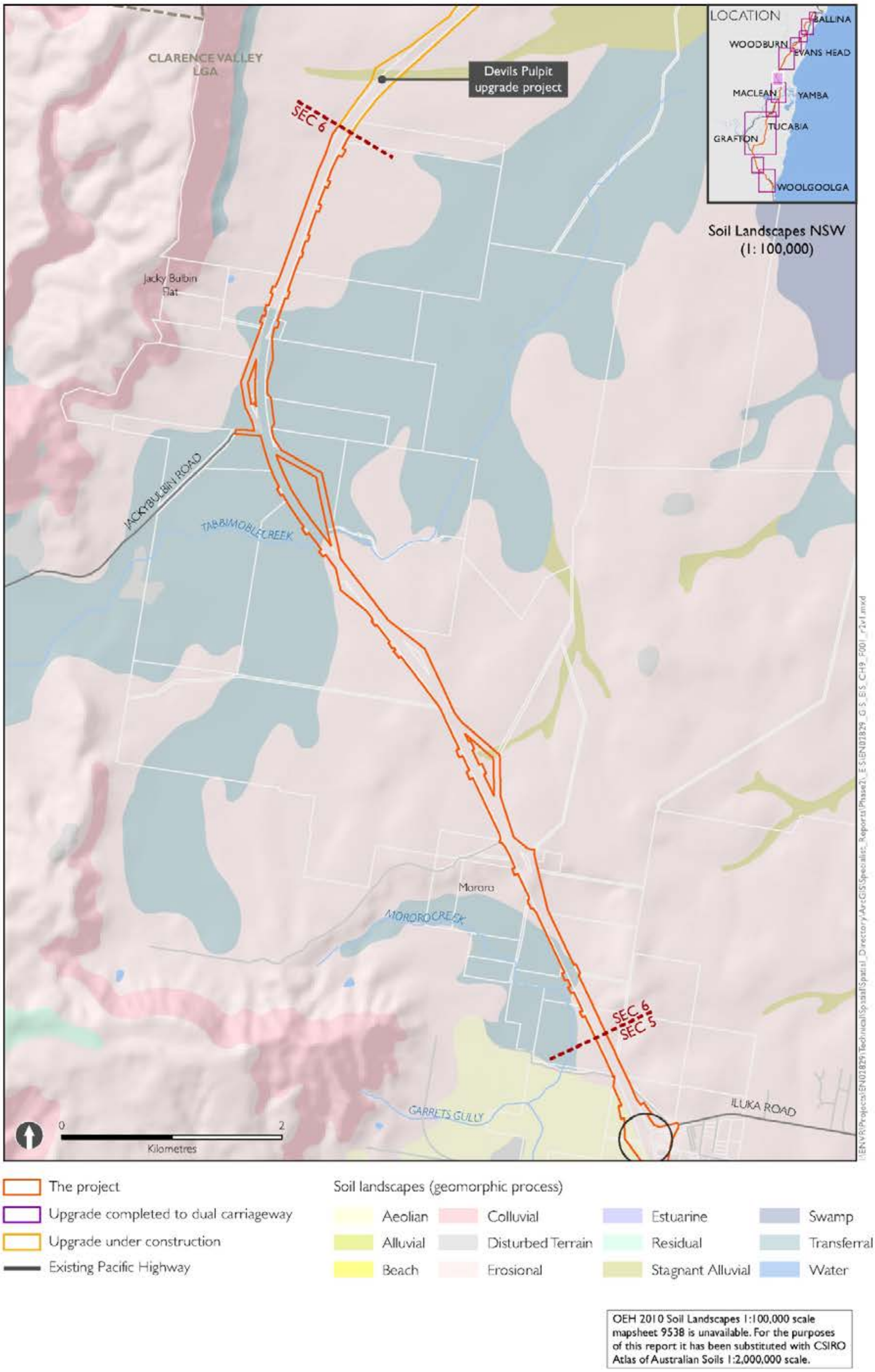
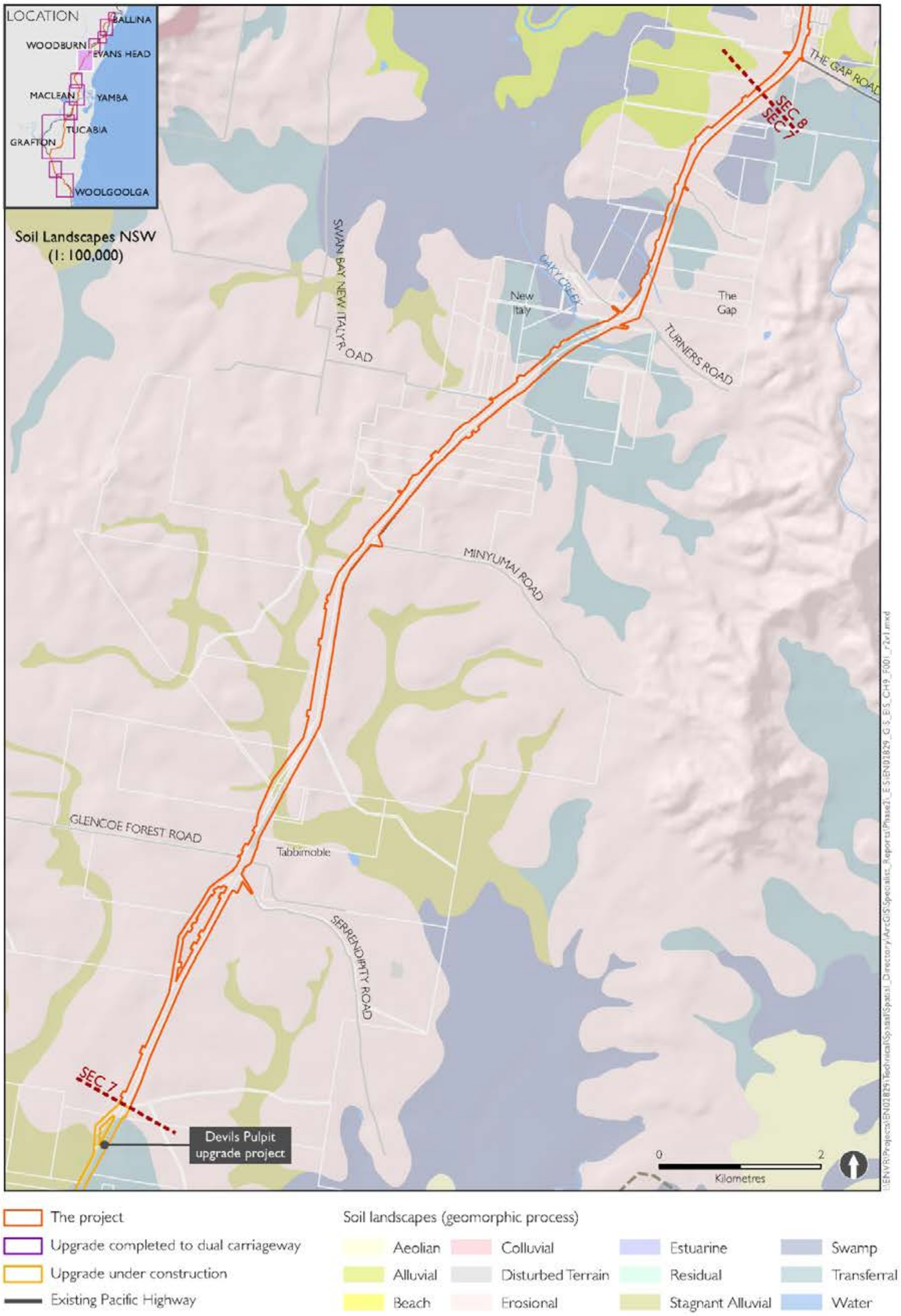


Figure 9-6: Soil landscape types: Section 6



OEH 2010 Soil Landscapes 1:100,000 scale mapsheet 9538 is unavailable. For the purposes of this report it has been substituted with CSIRO Atlas of Australian Soils 1:2,000,000 scale.

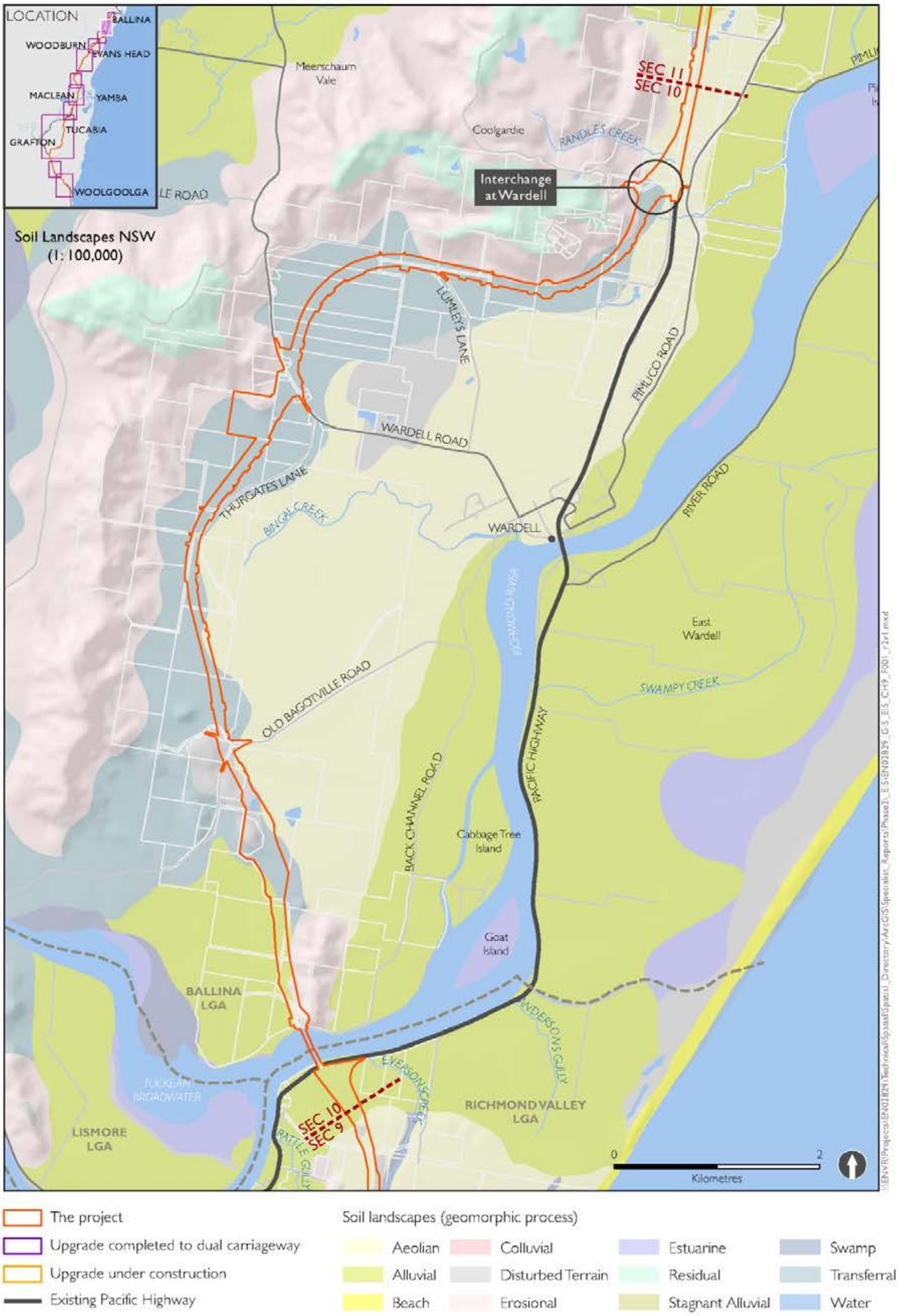
Figure 9-7: Soil landscape types: Section 7

OEH 2010 Soil Landscapes 1:100,000 scale mapsheet 9538 is unavailable. For the purposes of this report it has been substituted with CSIRO Atlas of Australian Soils 1:2,000,000 scale.

Figure 9-8: Soil landscape types: Section 8

OEH 2010 Soil Landscapes 1:100,000 scale mapsheet 9538 is unavailable. For the purposes of this report it has been substituted with CSIRO Atlas of Australian Soils 1:2,000,000 scale.

Figure 9-9: Soil landscape types: Section 9



OEH 2010 Soil Landscapes 1:100,000 scale mapsheet 9538 is unavailable. For the purposes of this report it has been substituted with CSIRO Atlas of Australian Soils 1:2,000,000 scale.

Figure 9-10: Soil landscape types: Section 10

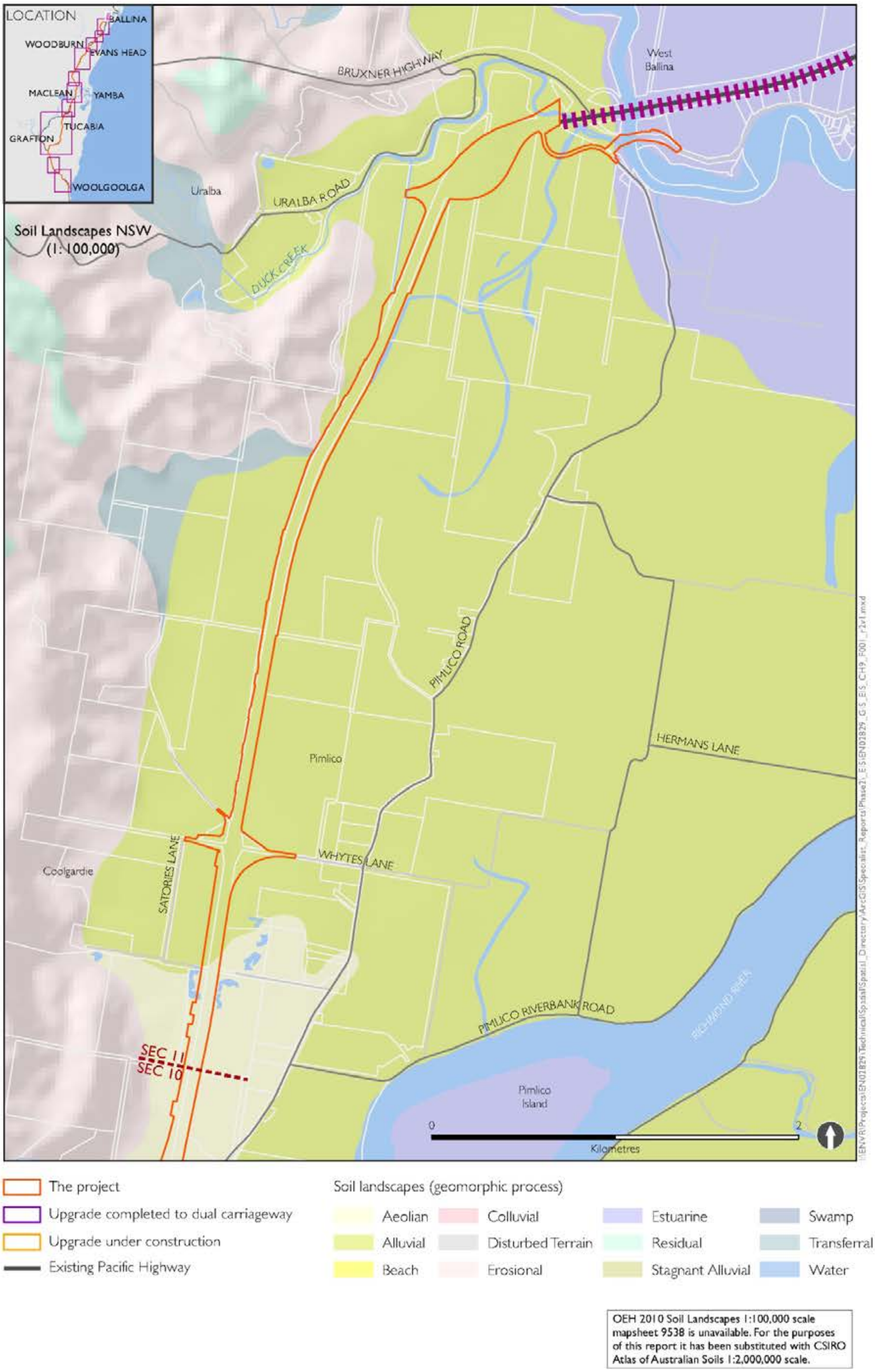


Figure 9-11: Soil landscape types: Section 11

Acid sulfate soils

Acid sulfate soils are soils and sediments containing iron sulfides. When exposed to oxygen, these soils generate sulfuric acid, resulting in potential adverse effects on both the natural and built environment and human health. The generation of sulphuric acid may also result in the release of toxic quantities of aluminium and heavy metals from soils and bedrock, with consequent effects on ecosystems and human health. Exposure of acid sulfate soils to oxygen can occur through excavation or through activities that result in lowering of the groundwater table and subsequent aeration of previously waterlogged soils.

KEY TERM – Acid Sulfate Soils (ASS)

Naturally acid clays, mud and other sediments usually found in swamps and estuaries. They may become extremely acidic when drained and exposed to oxygen and may produce acidic leachate run-off that can pollute waters and liberate toxins.

The majority of acid sulfate soils are formed by natural processes under specific environmental conditions. They are commonly associated with low-lying estuarine areas at elevations of less than five metres above sea level, and are particularly common near major rivers, drainage depressions and creeks. Acid sulfate soils occur extensively across the floodplains of the Clarence and Richmond Rivers, both as actual and potential acid sulfate soils.

There is a high probability of acid sulfate soils occurring within sections 4, 5, 8, 9 and 11, with the highest probability of occurrence being across the floodplains of the Clarence and Richmond rivers. These regions generally correspond to areas where the groundwater table is within three metres of the surface. Table 9-4 provides a summary of identified acid sulfate soil risks by project section based on published acid sulfate soil risk maps. Acid sulfate soil maps are provided in Figure 9-12 and Figure 9-22.

Table 9-4: Summary of acid sulfate soil risks by project section

Project section	Predominant ASS risk level	Portion of section with predominant risk level (%)	Details
1	No known occurrence	65	A large part of this section has no known occurrence of acid sulfate soils. Areas of low and high probability of occurrence are found on the lowland coastal plains near Arrawarra and Corindi Beach.
2	No known occurrence	100	The entire section is mapped as having no known occurrence of ASS. It is located on elevated terrain where acid sulfate soils are not expected.
3	No known occurrence	80	Most of this section is mapped as having no known occurrence of acid sulfate soils. The southern and central parts of the section traverse several isolated areas of low and high probability of occurrence.
4	High probability	65	A large part of this section is mapped as having a high probability of occurrence of acid sulfate soils. Isolated areas of no known occurrence are found near Maclean.
5	High probability	100	The entire section is mapped as having a high probability of occurrence of acid sulfate soils.

Project section	Predominant ASS risk level	Portion of section with predominant risk level (%)	Details
6	No known occurrence	100	The entire section is mapped as having no known occurrence of acid sulfate soils. This section is located on elevated terrain where acid sulfate soils are not expected. An area of low probability of occurrence is located immediately west of the southern portion of this section.
7	No known occurrence	95	Most of this section is mapped as having no known occurrence of acid sulfate soils. Isolated areas of low and high probability of occurrence are located in the northern part of the section.
8	High probability	80	Most of this section is mapped as having a high probability of occurrence of acid sulfate soils and is also close to the boundary of additional low and high probability areas to the north of Woodburn. The southern extremity of the section is mapped as having no known occurrence of acid sulfate soils.
9	High probability	60	Most of this section is mapped as having a high probability of occurrence of acid sulfate soils. The southern portion of this section is mapped as having a low probability of occurrence. Cane cultivation around the Richmond River has exposed acid sulfate soils.
10	Low probability	55	Most of the section is mapped as having a low probability of occurrence of acid sulfate soils. The northern portion of this section is mapped as having no known occurrence.
11	High probability	85	Most of this section is mapped as having a high probability of occurrence of acid sulfate soils. The southern extremity of the section is mapped as having a low probability of occurrence.

Soft soils

The soft soils within the project boundary are associated with alluvial soil landscapes (refer to Table 9-2 and Table 9-12 to Figure 9-22). Extensive deposits of soft soils occur within sections 3 to 6 of the project, with the greatest extent occurring in section 4 in and around the Shark Creek area. The thickness of soft soil deposits in sections 3 to 6 ranges from less than one metre to a maximum of about 22 metres. Extensive soft soil deposits with a thickness of up to 20 metres also occur in sections 8 and 11, particularly around Tuckombil Canal bridge, Woodburn Drain bridge, Richmond River bridge, Duck Creek and Emigrant Creek. Soft soils have also been found in Section 1 as limited deposits near the surface, and isolated pockets in the vicinity of Corindi Creek.

Photo 2: Bridge over Tuckombil Canal

Contamination

There are 84 areas that could contain areas of contamination (identified as ‘potential areas of environmental concern’), including areas within and near the project boundary (refer to Figure 9-12 to Figure 9-22). These areas are listed in Table 9-5 and are largely associated with past land uses, including sawmills, farms, plantations, cattle dip sites, service stations, landfills or areas of agricultural or forestry uses (identified as either ‘agricultural property’ or ‘general observation’). Potential contaminants include:

- Heavy metals (eg arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc)
- Hydrocarbons (eg benzene, toluene, ethylbenzene and xylene)
- Polycyclic aromatic hydrocarbons
- Pesticides, including organochlorine pesticides (eg endosulfan, aldrin, BHC, chlordane, dieldrin, DCB and heptachlor) and organophosphorous pesticides
- Polychlorinated biphenyls (PCBs)
- Asbestos
- Potential contaminants associated with unexploded ordnance
- Nutrients (ammonia, nitrogen, nitrate, nitrite)
- Microbiological (e.coli, faecal coliforms)
- Acid sulfate soils.

Table 9-5: Areas of potential environmental concern within or near the project boundary

Project section	No. of areas	Potentially contaminating activities	Potential contaminants
1	9	Former sawmill, possible banana plantation, Blueberry Exchange, quarry, stockpile, cattle dip site, former orchards and water storage tank.	Heavy metals, pesticides, hydrocarbons, arsenic, PCBs, asbestos.
2	12	Three service stations, two flower farms/ orchards and shop, manufacturing site, mechanical workshop, two cattle dip sites, stockpile site, diesel tank.	Hydrocarbons, heavy metals, pesticides, arsenic, PCBs, solvents, asbestos, volatile organic compounds.
3	8	Abandoned sawmill, two landfills, service station and four areas of rural and agricultural use.	Hydrocarbons, heavy metals, pesticides, solvents, PCBs, asbestos, volatile organic compounds, ammonia, microbiological.
4	14	Three cattle dip sites, service station, four stockpile sites, fuel depot, four areas of agricultural use and sewage treatment plant.	Pesticides, heavy metals, hydrocarbons, asbestos, nutrients, microbiological.
5	7	Service station, truck depot, two bridge sites, cattle dip site, manufacturing site and stockpile site.	Hydrocarbons, heavy metals, pesticides, solvents, asbestos, volatile organic compounds.
6	2	Two cattle dip sites.	Hydrocarbons, pesticides, heavy metals, asbestos.
7	11	Three cattle dip sites, six stockpile sites, old storage tanks and an agricultural property.	Hydrocarbons, heavy metals, pesticides, asbestos, volatile organise compounds.
8	8	Two cattle dip sites, substation, car yard and other land uses, depot, two areas of agricultural use and storage tanks.	Hydrocarbons, heavy metals, pesticides, asbestos, PCBs
9	9	Agricultural land uses, landfill site, sugar mill and conveyor, two quarries, two areas used as air weapons range.	Hydrocarbons, heavy metals, pesticides, solvents, asbestos, microbiological, nutrients, potential contaminants associated with unexploded ordnance.
10	3	Quarries, sewerage treatment works and area of agricultural/ forestry use.	Hydrocarbons, heavy metals, pesticides, solvents, asbestos, microbiological, nutrients.
11	1	Agricultural property.	Hydrocarbons, pesticides, asbestos.

Salinity

The presence of shallow groundwater tables (less than two metres below ground surface) has been used in NSW as an indicator of areas potentially affected by dryland salinity. Although around 250 hectares of land in the Richmond and Clarence catchments has been estimated to have shallow groundwater tables, the high rainfall within these catchments would result in frequent flushing of the soil profile and prevent accumulation of salts. Salinity is unlikely to be a significant issue for any of the catchments crossed by the project.

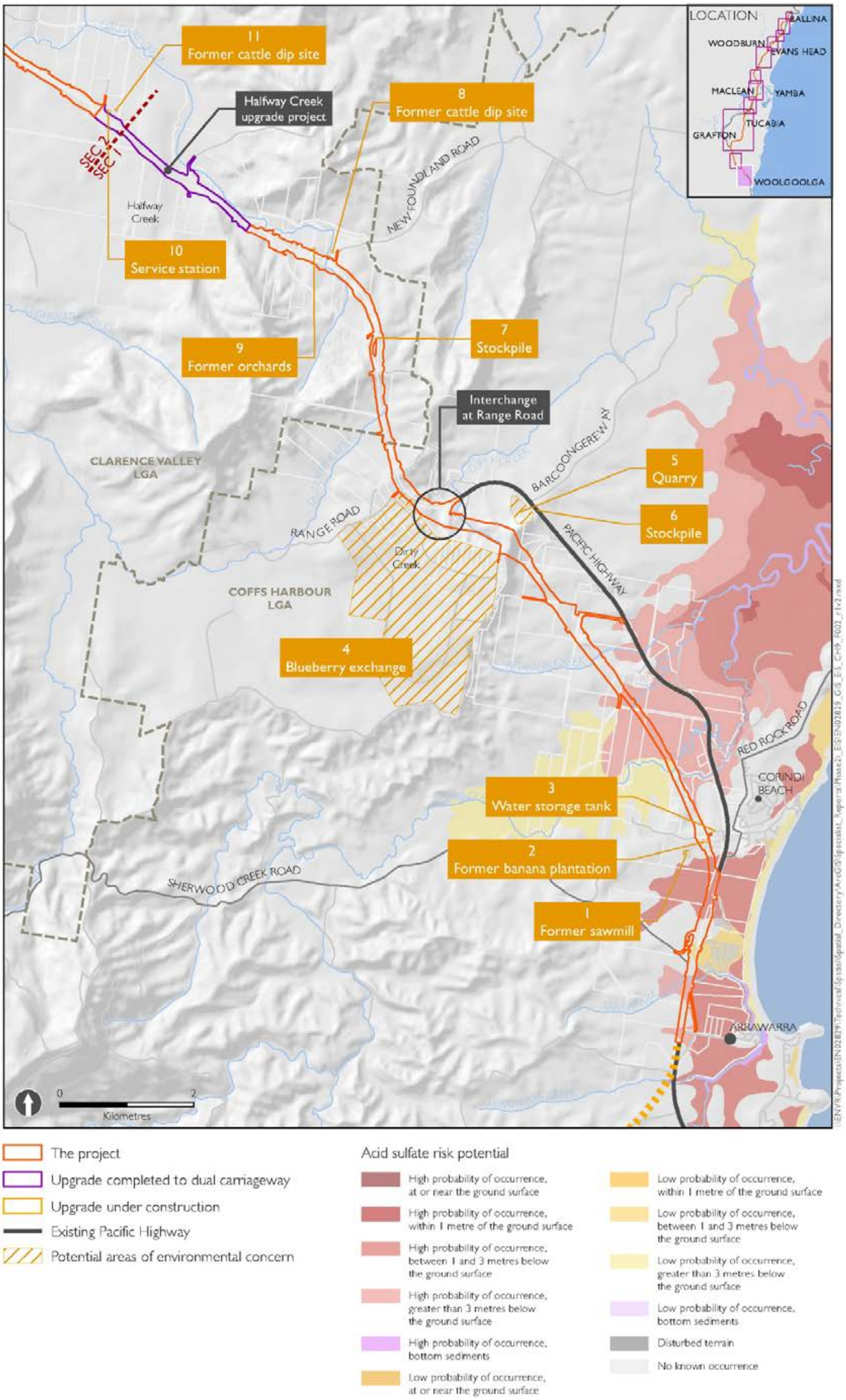


Figure 9-12: Acid sulfate soils and potential areas of environmental concern - Section 1

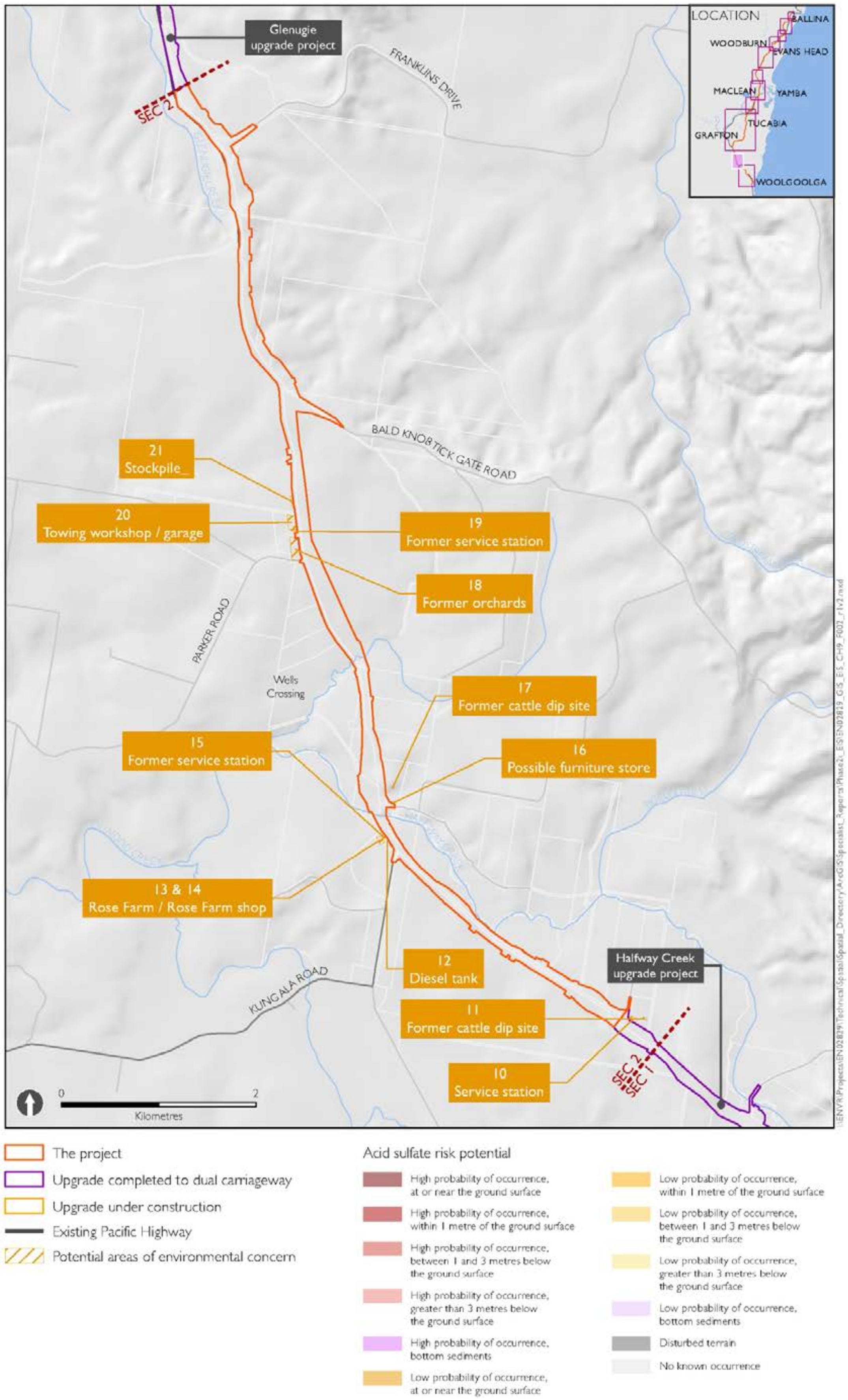


Figure 9-13: Acid sulfate soils and potential areas of environmental concern - Section 2

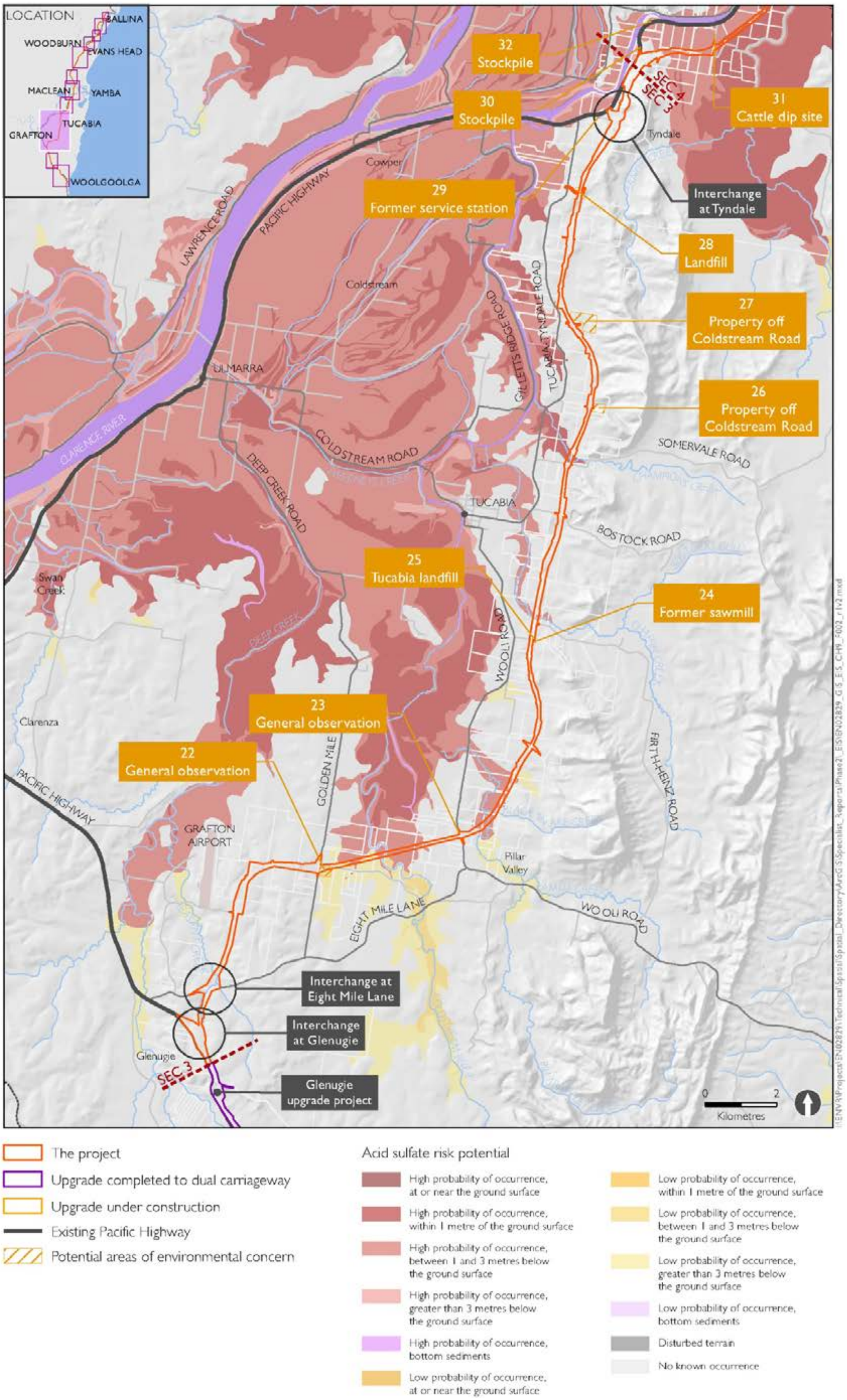


Figure 9-14: Acid sulfate soils and potential areas of environmental concern - Section 3

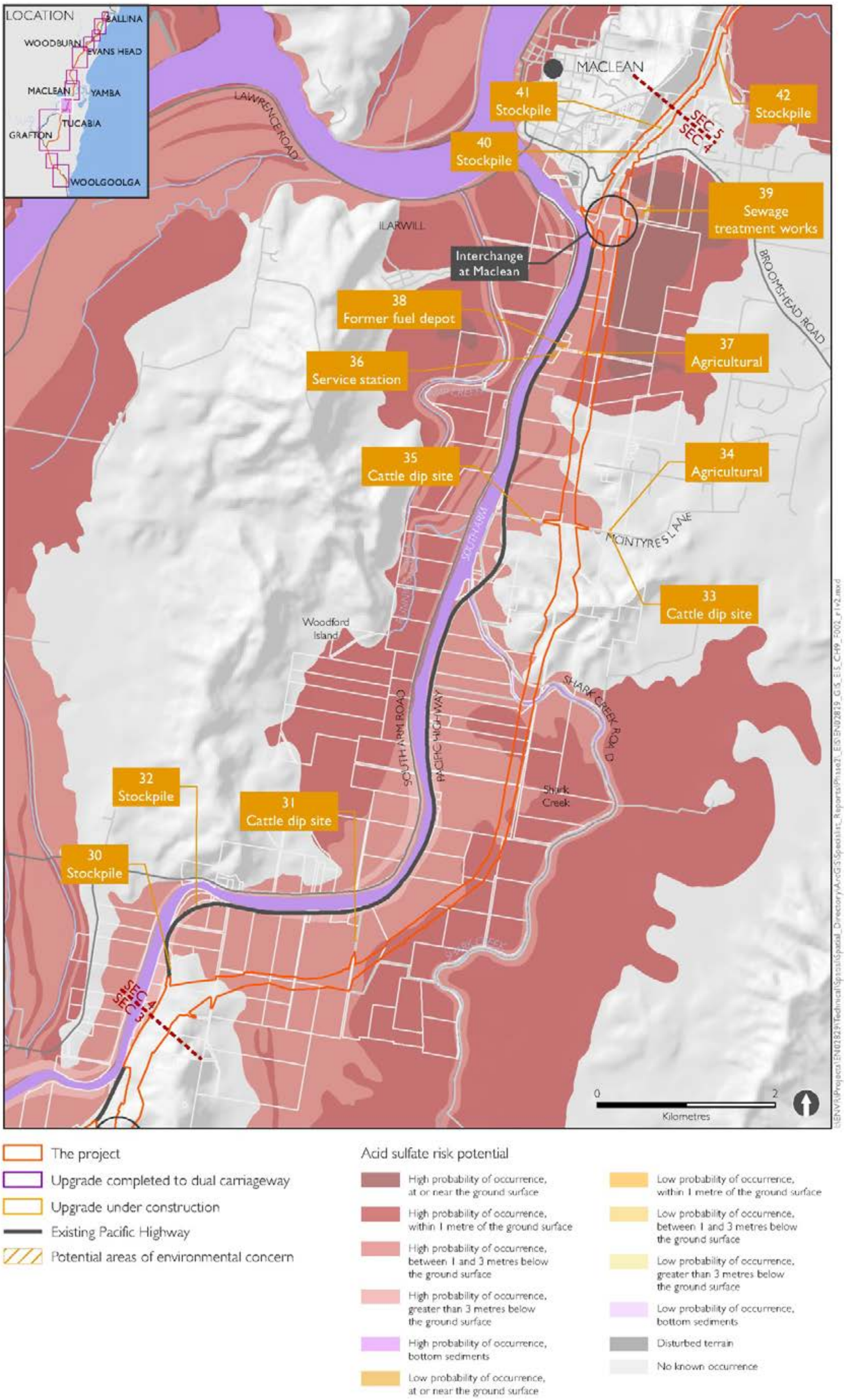


Figure 9-15: Acid sulfate soils and potential areas of environmental concern - Section 4

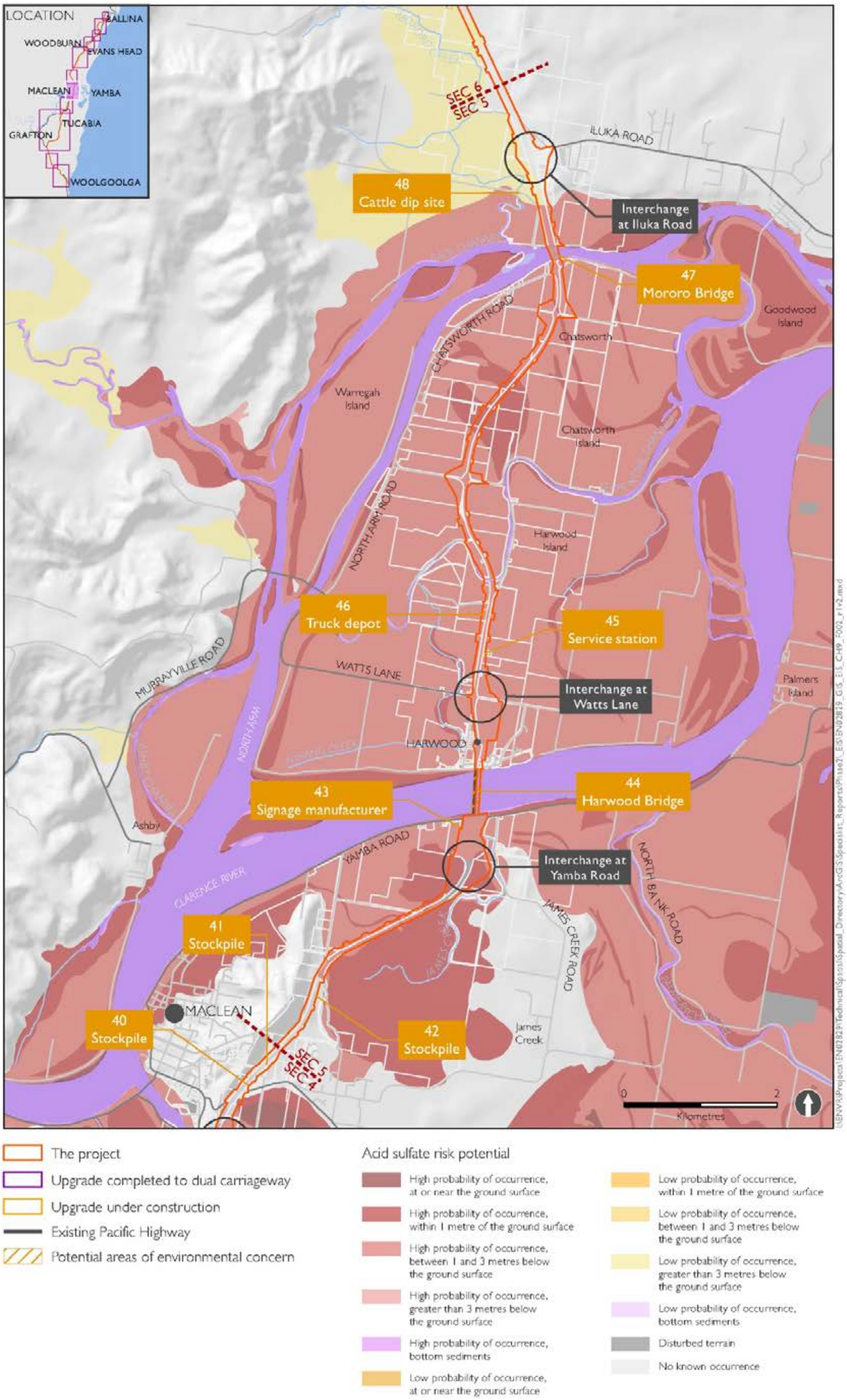


Figure 9-16: Acid sulfate soils and potential areas of environmental concern - Section 5

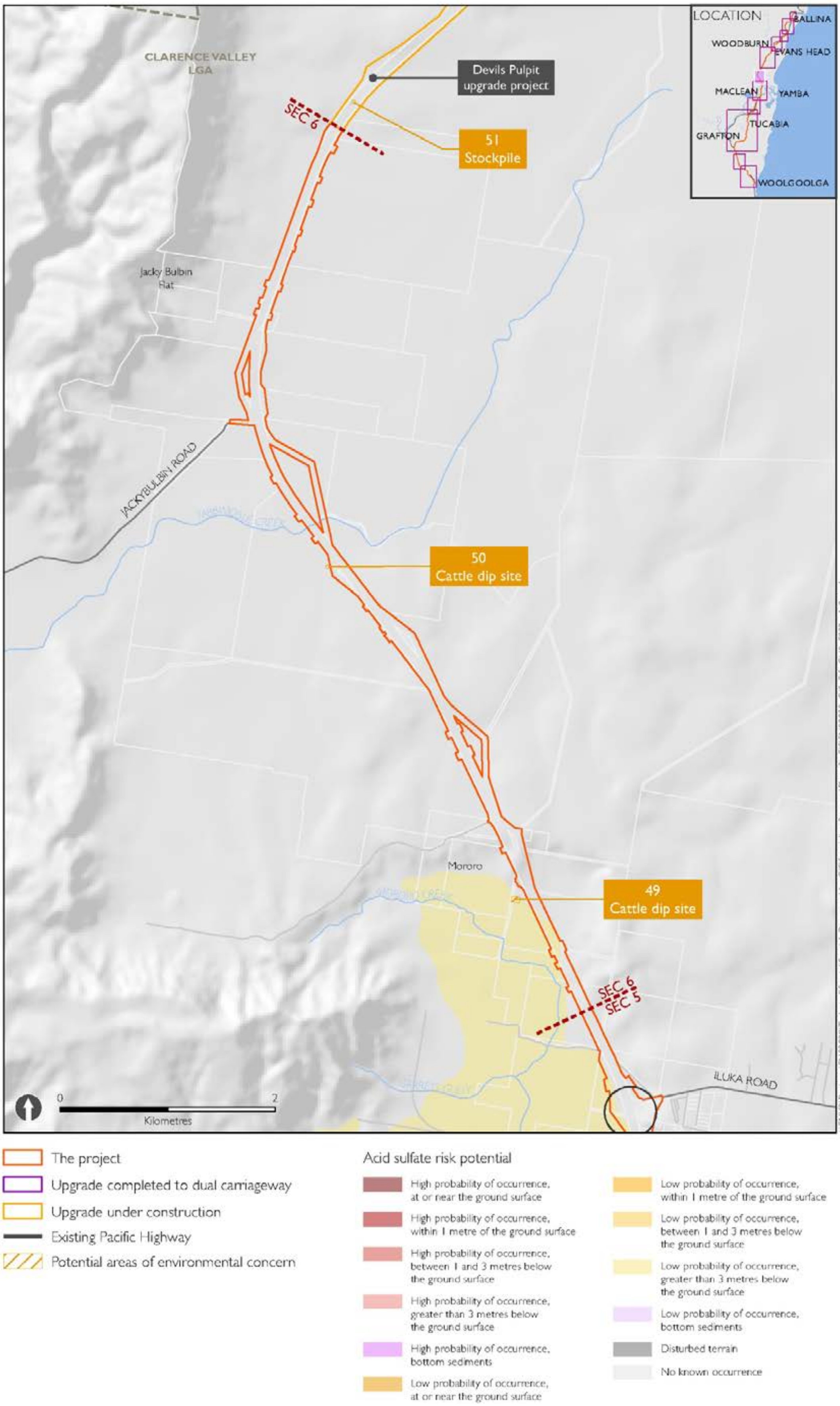


Figure 9-17: Acid sulfate soils and potential areas of environmental concern - Section 6

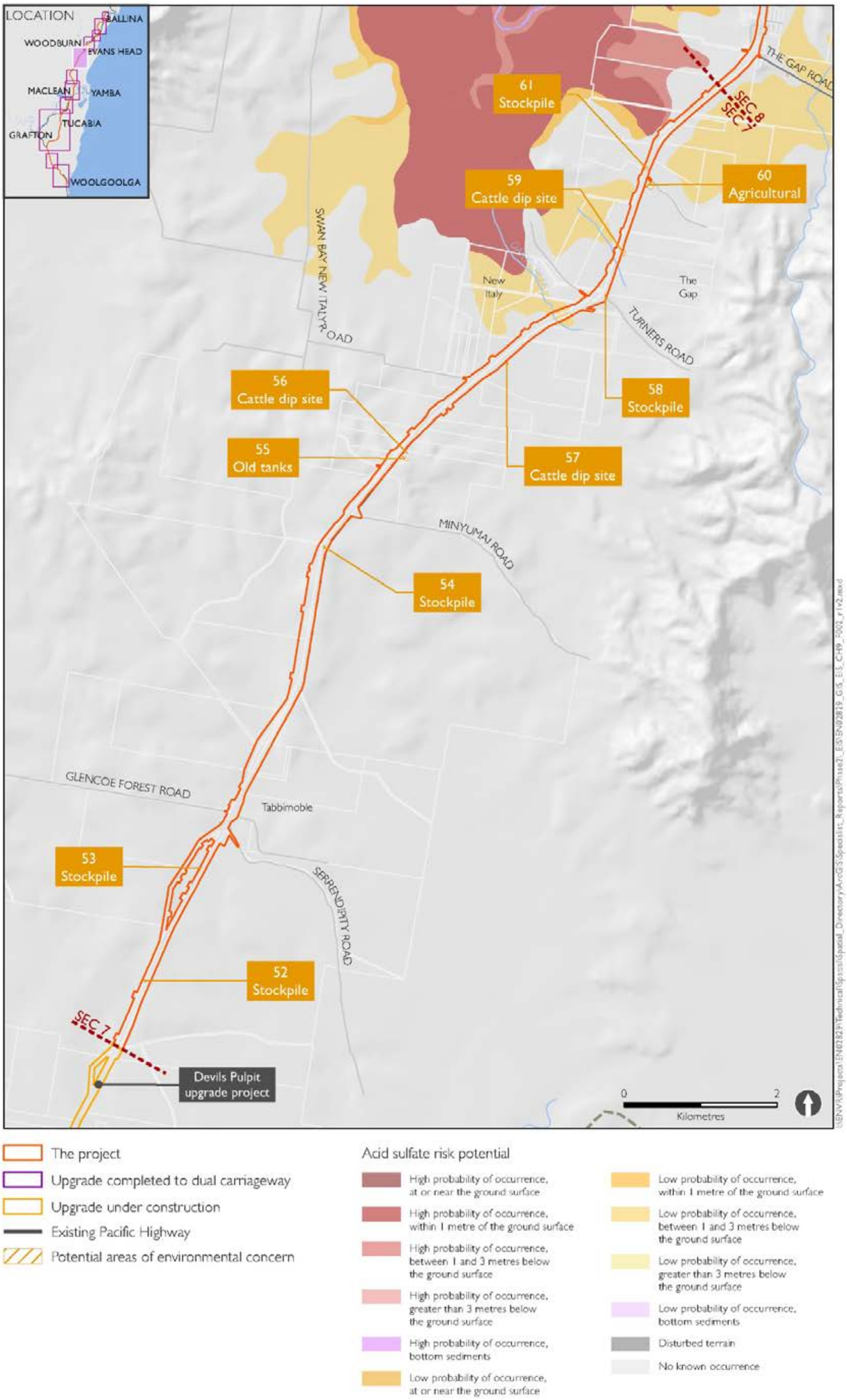


Figure 9-18: Acid sulfate soils and potential areas of environmental concern - Section 7

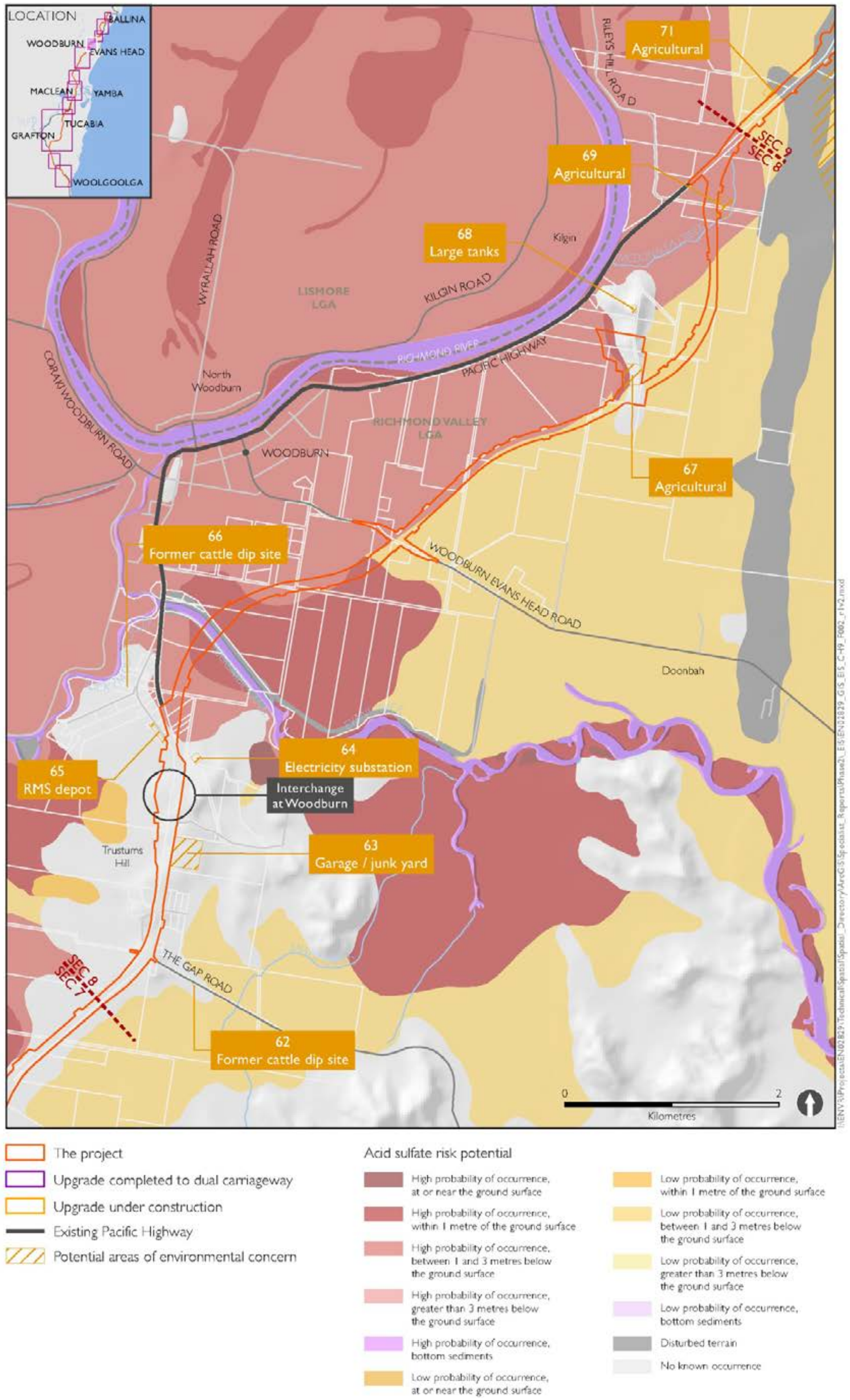


Figure 9-19: Acid sulfate soils and potential areas of environmental concern - Section 8

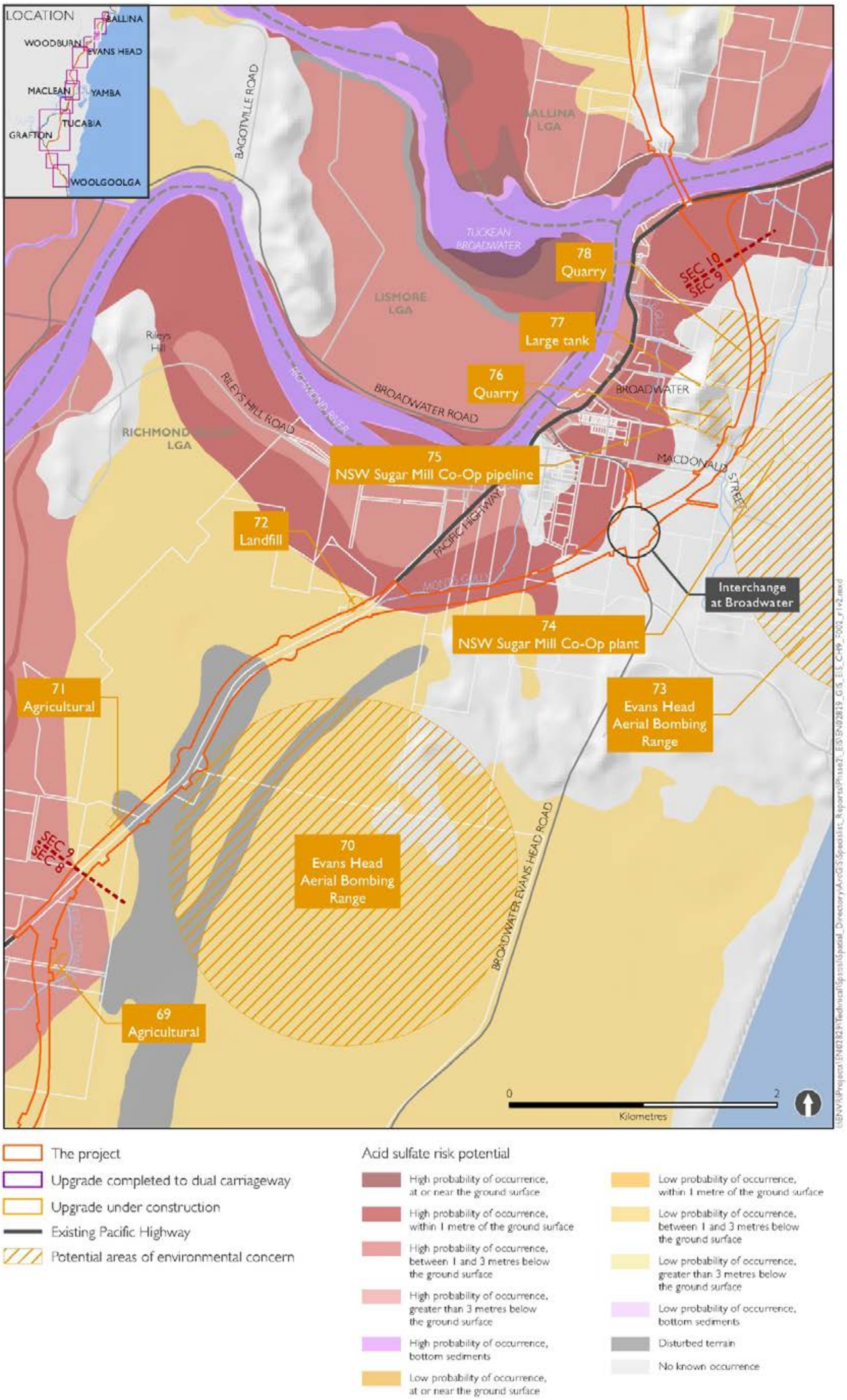


Figure 9-20: Acid sulfate soils and potential areas of environmental concern - Section 9

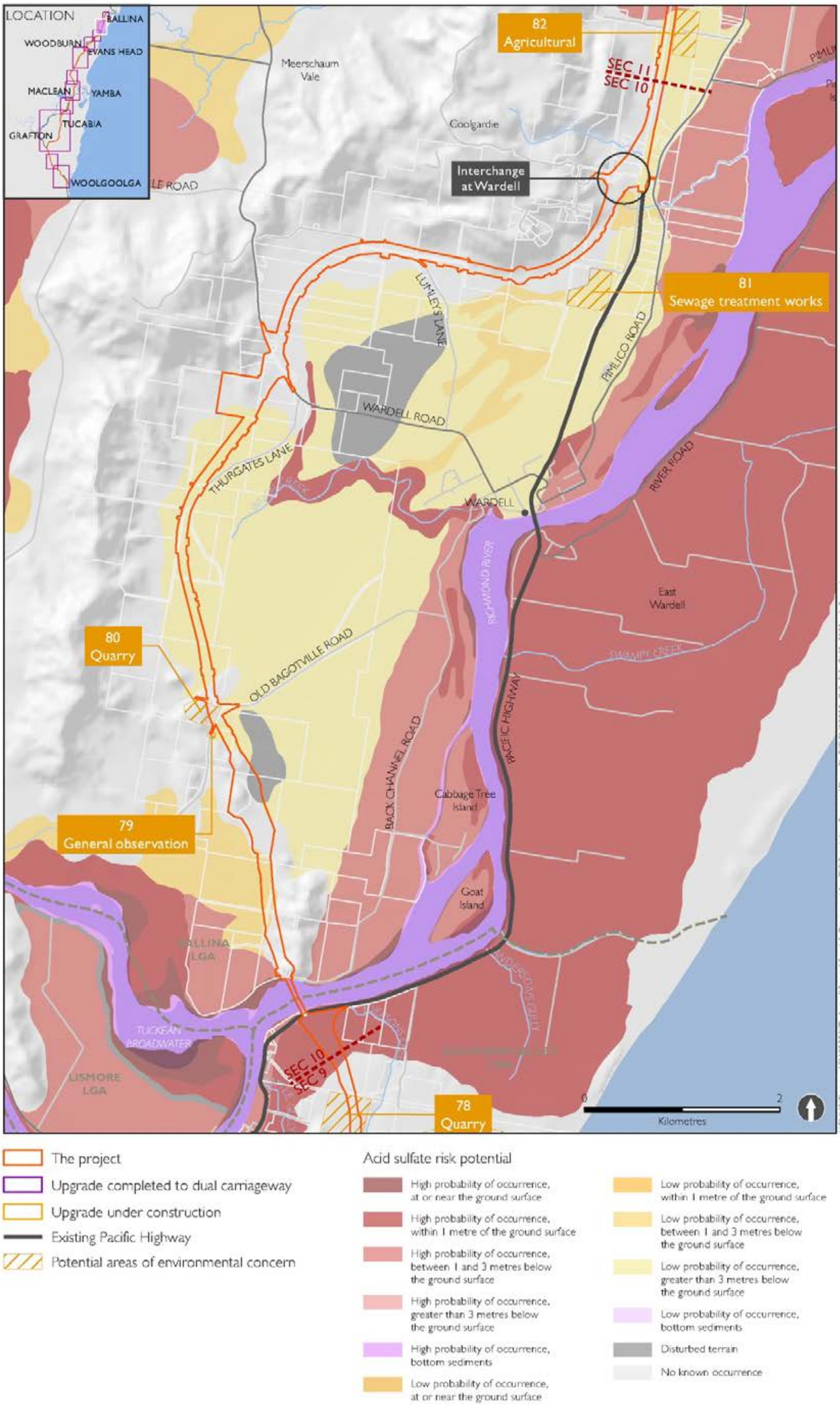


Figure 9-21: Acid sulfate soils and potential areas of environmental concern - Section 10

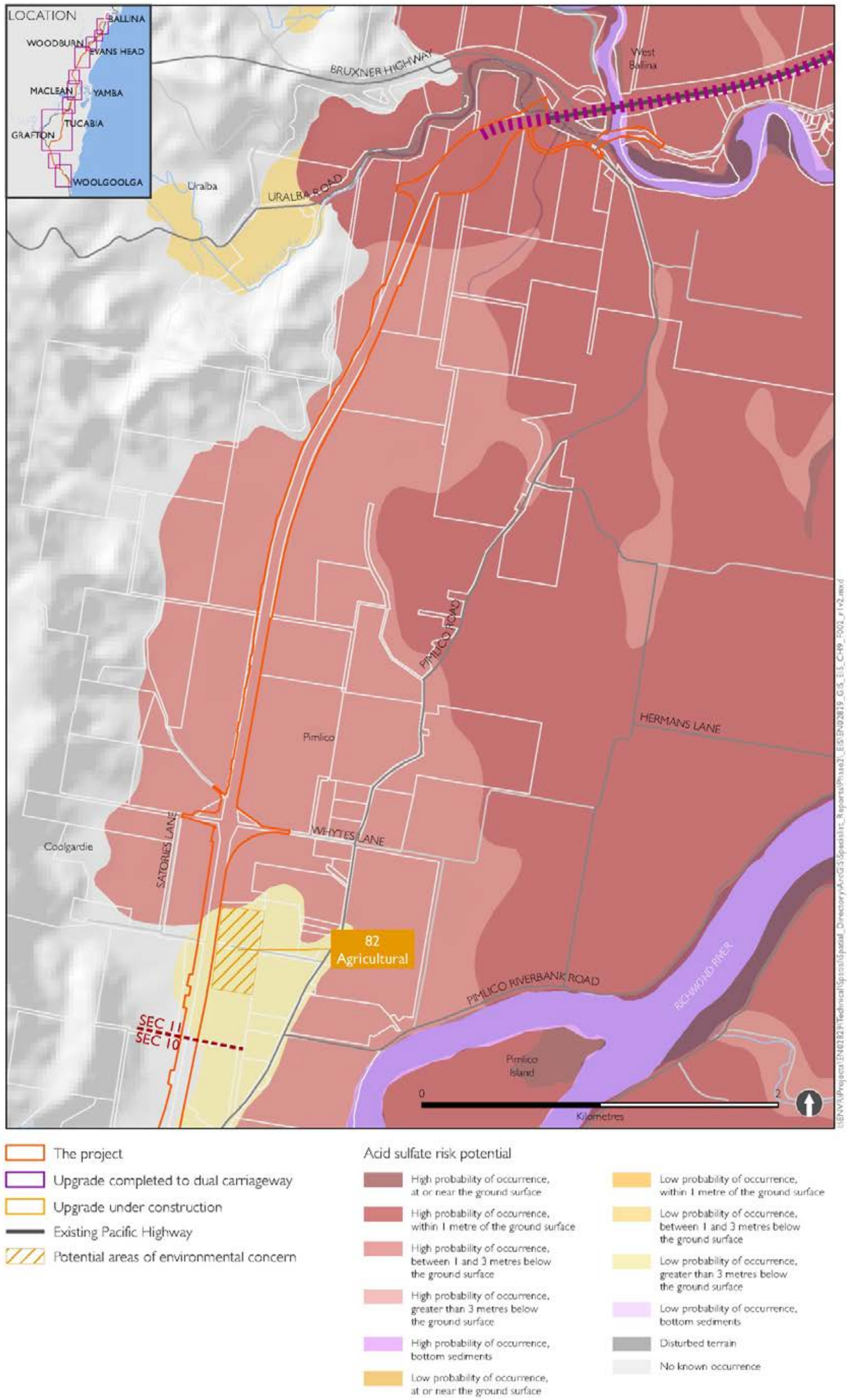


Figure 9-22: Acid sulfate soils and potential areas of environmental concern - Section 11

9.2.2 Water quality

Receiving waters and sensitive receiving environments

The project would cross and drain to a large number of waterways, including the major Clarence and Richmond river systems. These waterways comprise the receiving waters for the project, or the waters that have the potential to be impacted by the construction and operation of the project. A detailed description of major catchments crossed by the project is provided in Chapter 8 (Hydrology and flooding).

Many of the receiving waters for the project drain to or support sensitive aquatic and riparian environments, including aquatic ecosystems and fish habitat. These sensitive aquatic and riparian environments are referred to throughout this chapter as sensitive receiving environments.

A sensitive receiving environment is defined as one that has a high conservation or community value or supports ecosystems or human uses of water that are particularly sensitive to pollution or degradation of water quality. Sensitive receiving environments are considered to include:

- Nationally Important Wetlands and State Environmental Planning Policy No 14 (SEPP) wetlands (actual or potential groundwater dependent ecosystems)
- National parks, marine parks, nature reserves and State conservation areas
- Threatened ecological communities associated with aquatic ecosystems
- Known and potential habitats for threatened fish
- Key fish habitats as identified by the NSW Department of Primary Industry (DPI)
- Recreational swimming areas
- Areas that contribute to drinking water catchments, such as the Rous Water supply catchment
- Areas that are available or used for aquaculture and commercial fishing.

Sensitive receiving environments that would be crossed by the project are identified in Table 9-6 and shown in Figure 9-23 to Figure 9-33. Note the figures exclude locations of threatened ecological communities as these areas are too extensive to map.

Where a number of sensitive receiving environments are located in a single region, or where there would be severe implications of changes in surface water quality to the receiving environment, the region has been defined as a high risk area. The regions include:

- The Solitary Islands Marine Park (Section 1)
- Upper Coldstream wetlands (Section 3)
- Tabbimoble Swamp Nature Reserve (Section 7)
- The Rous Water Woodburn Sands aquifer catchment (Section 8)
- Broadwater National Park and associated wetlands (Section 9)
- Wardell Heath (Section 10)
- Various areas where surface water from the project would discharge to or within 50 metres of known or potential habitat of threatened aquatic species.

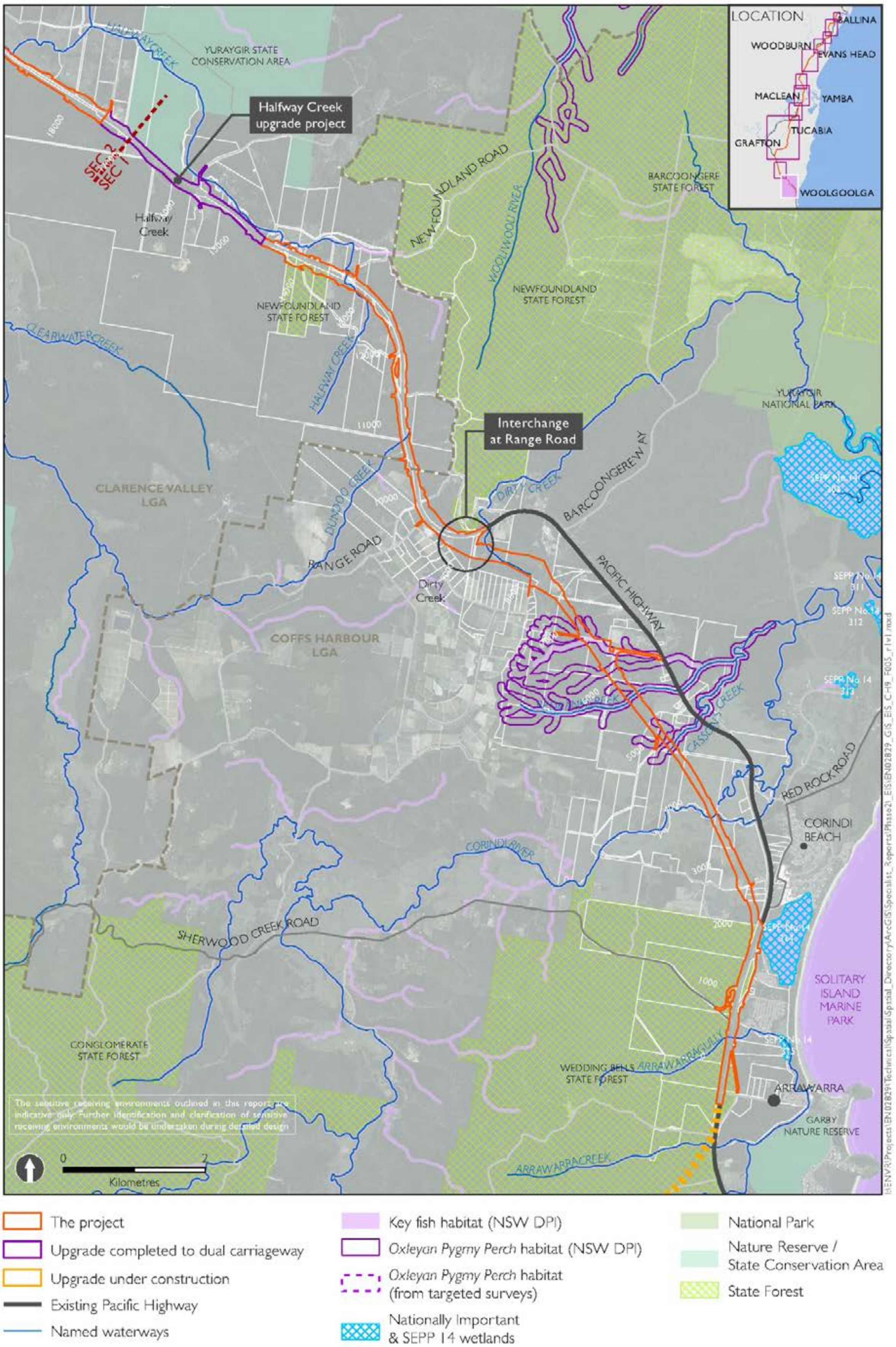


Figure 9-23: Sensitive receiving environments in Section 1

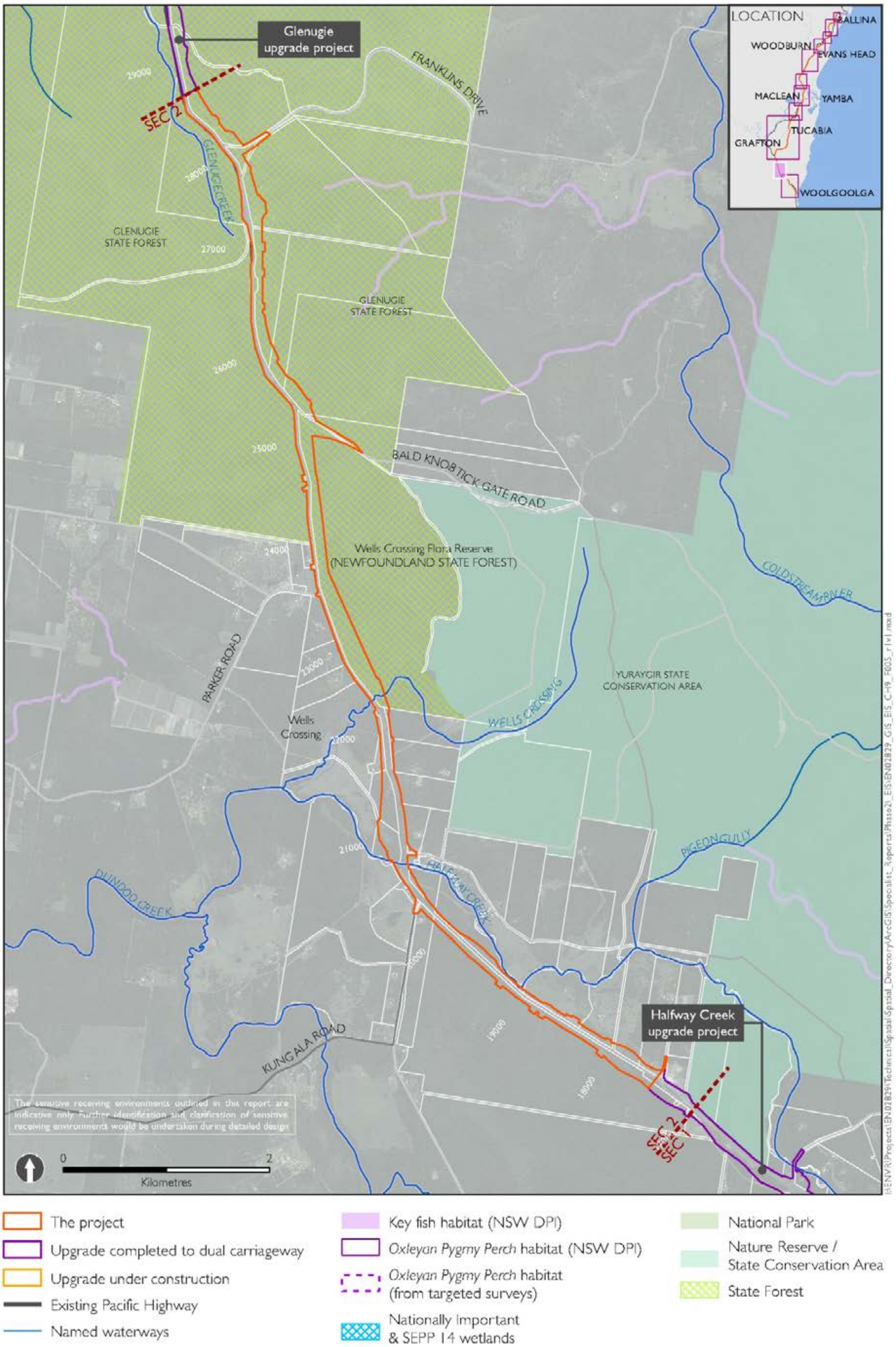


Figure 9-24: Sensitive receiving environments in Section 2

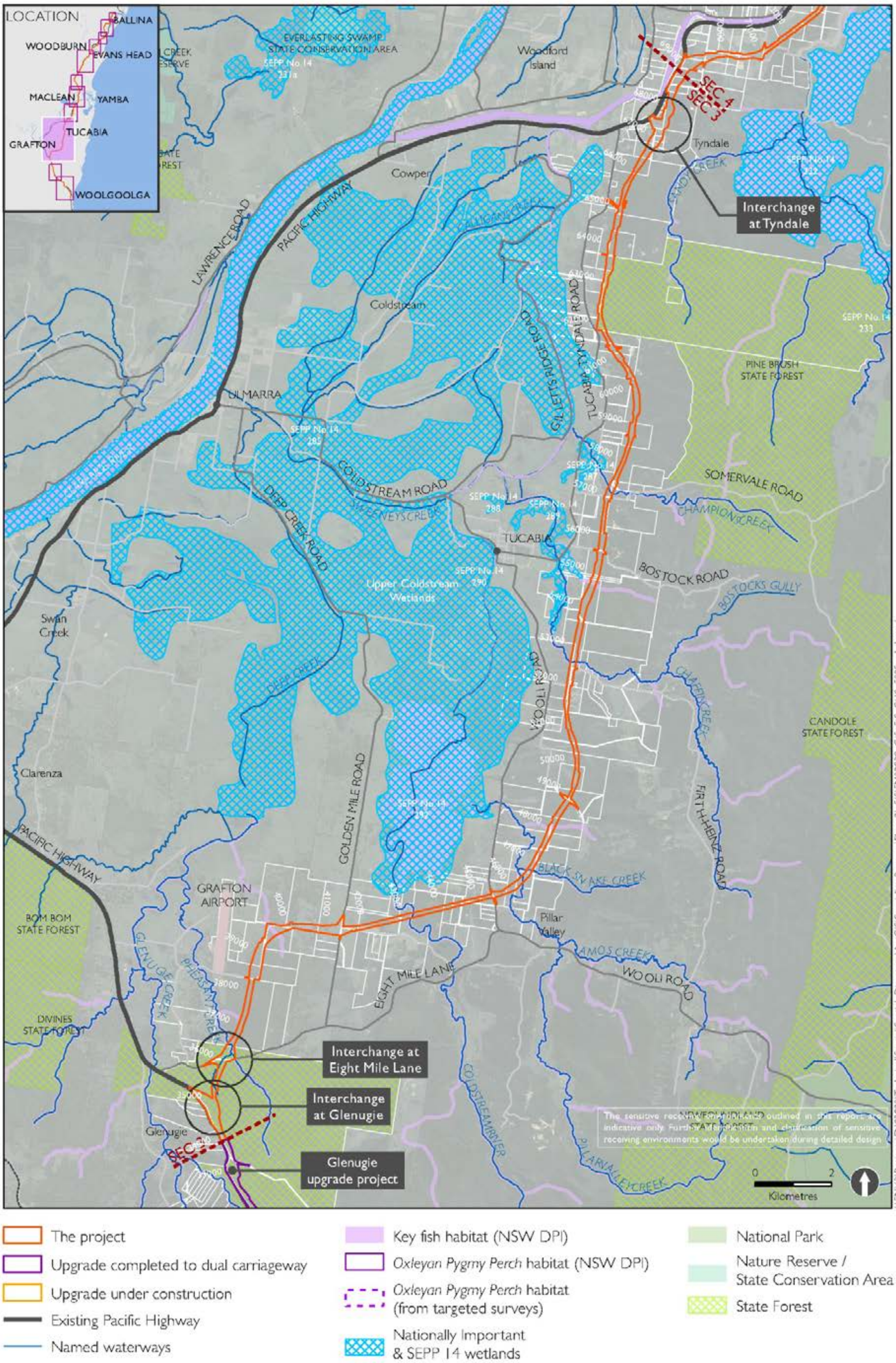


Figure 9-25: Sensitive receiving environments in Section 3

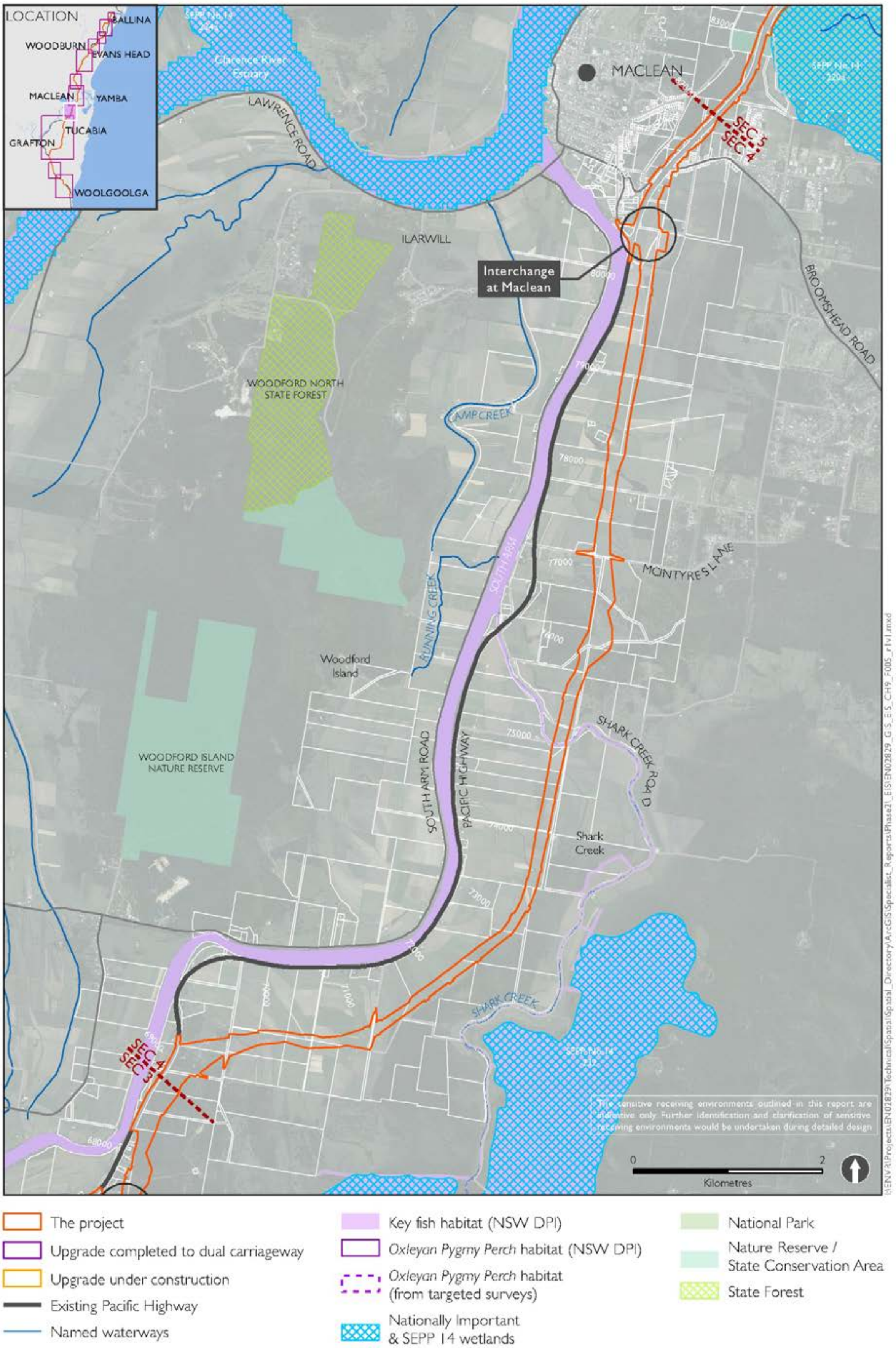


Figure 9-26: Sensitive receiving environments in Section 4

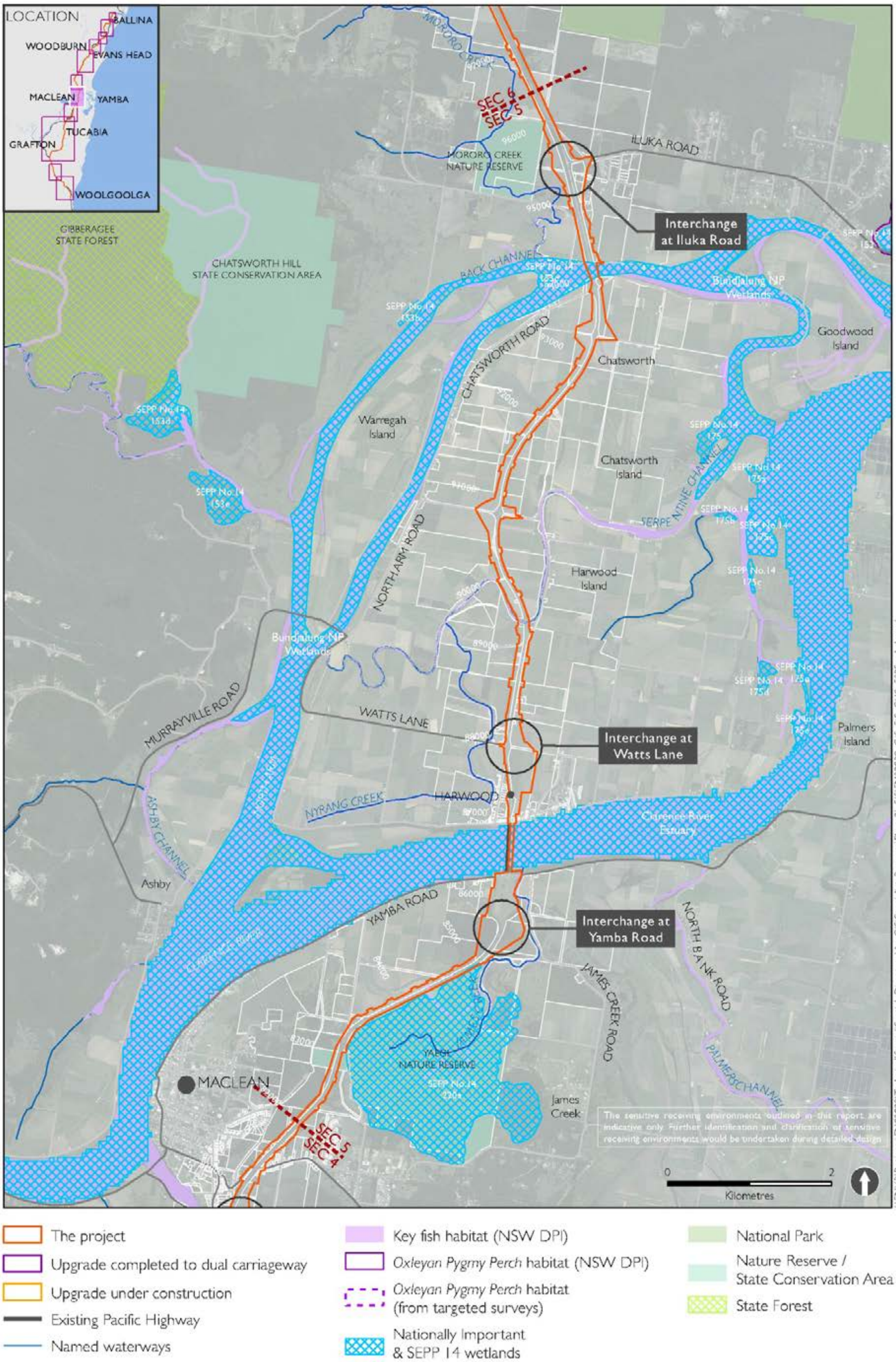


Figure 9-27: Sensitive receiving environments in Section 5

Figure 9-28: Sensitive receiving environments in Section 6

Figure 9-29: Sensitive receiving environments in Section 7

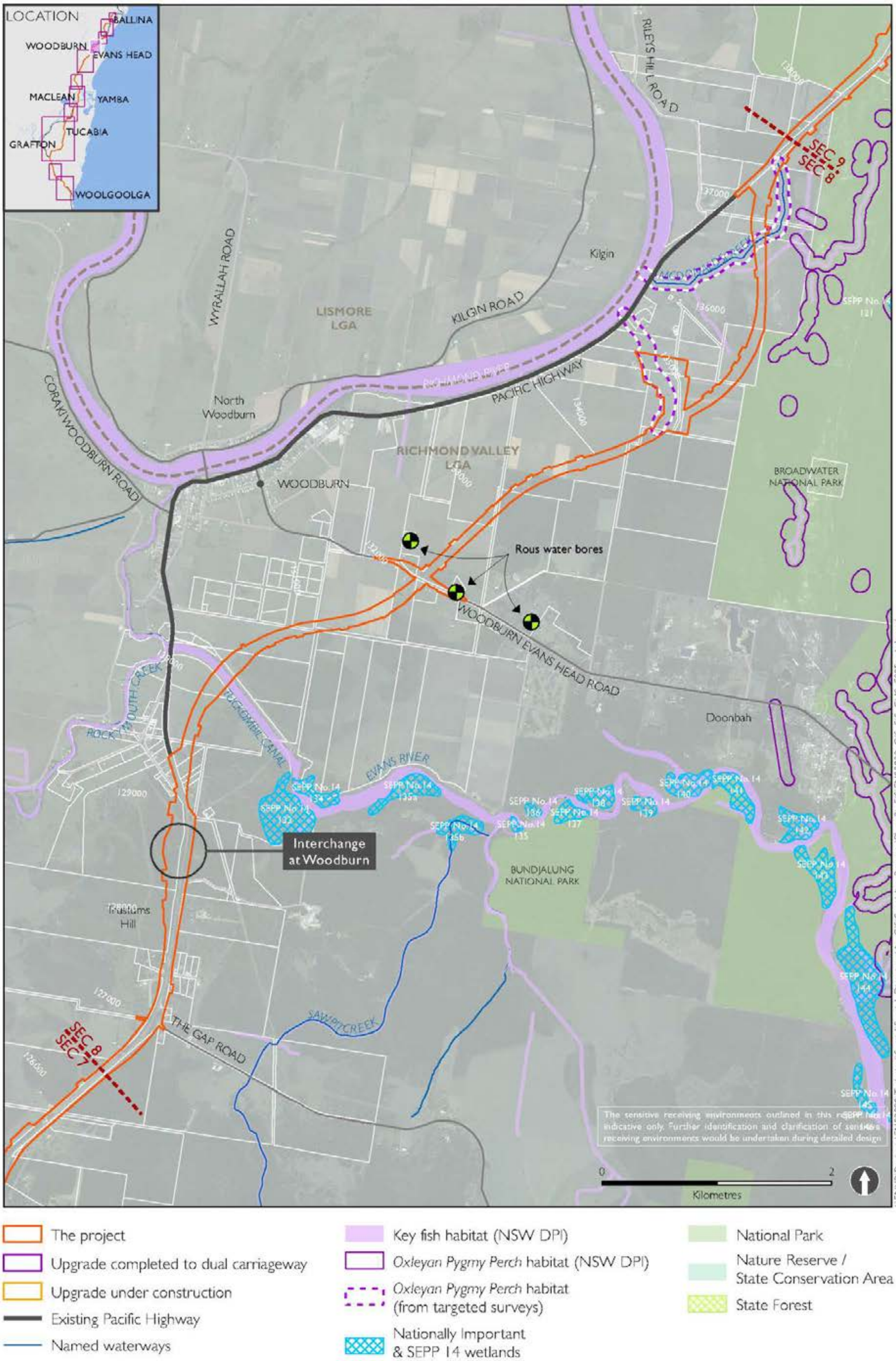


Figure 9-30: Sensitive receiving environments in Section 8

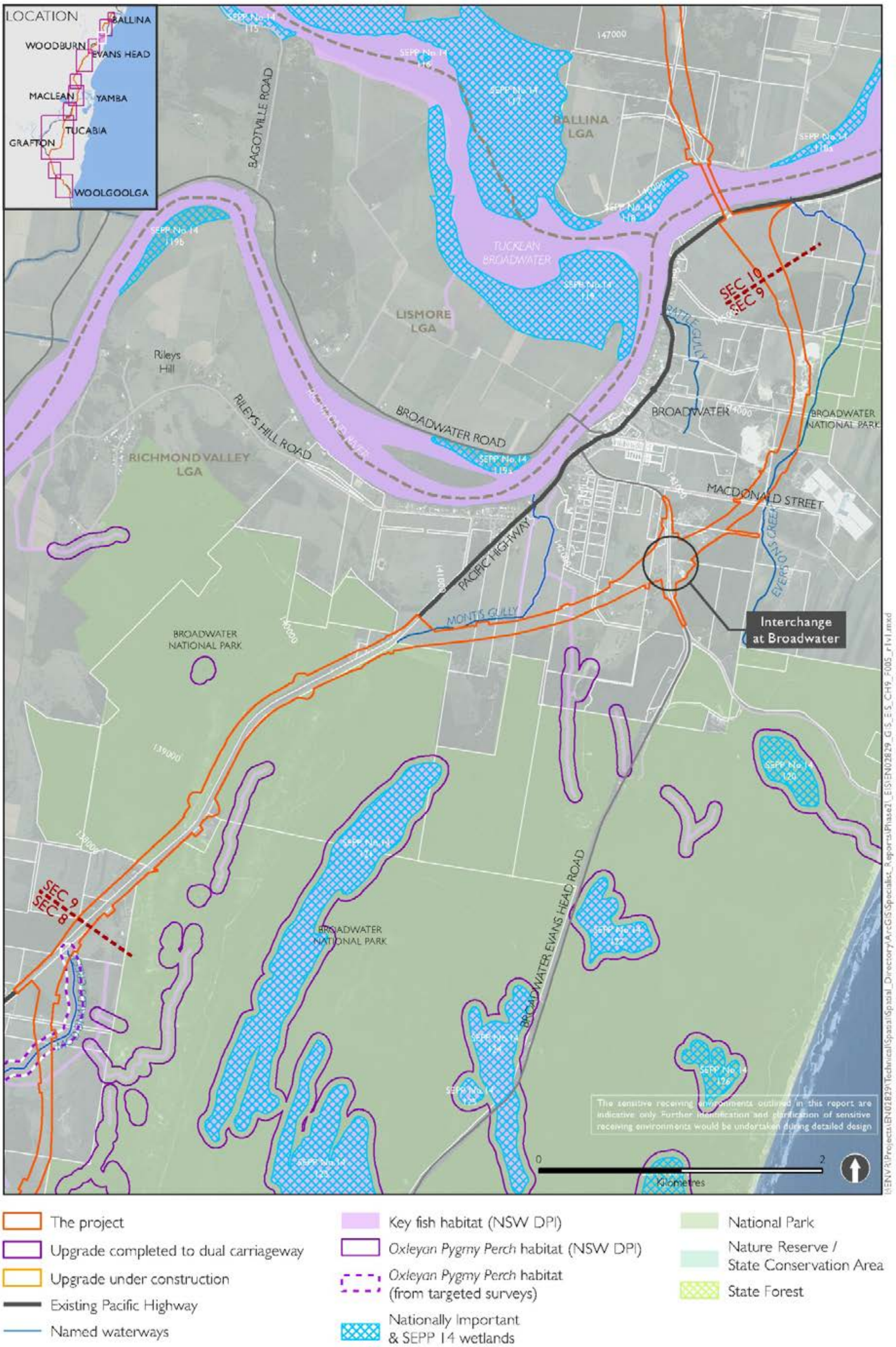


Figure 9-31: Sensitive receiving environments in Section 9

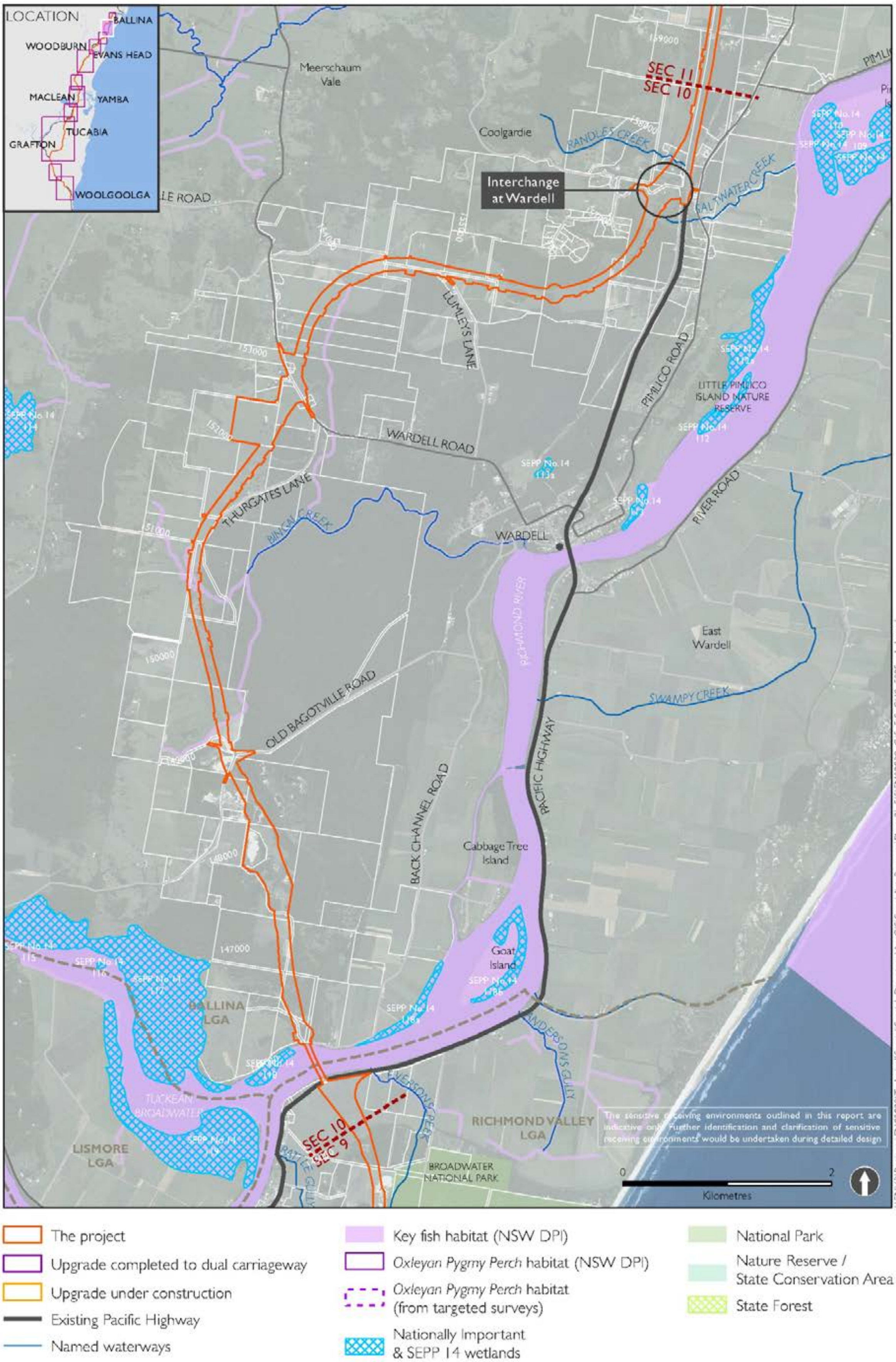


Figure 9-32: Sensitive receiving environments in Section 10

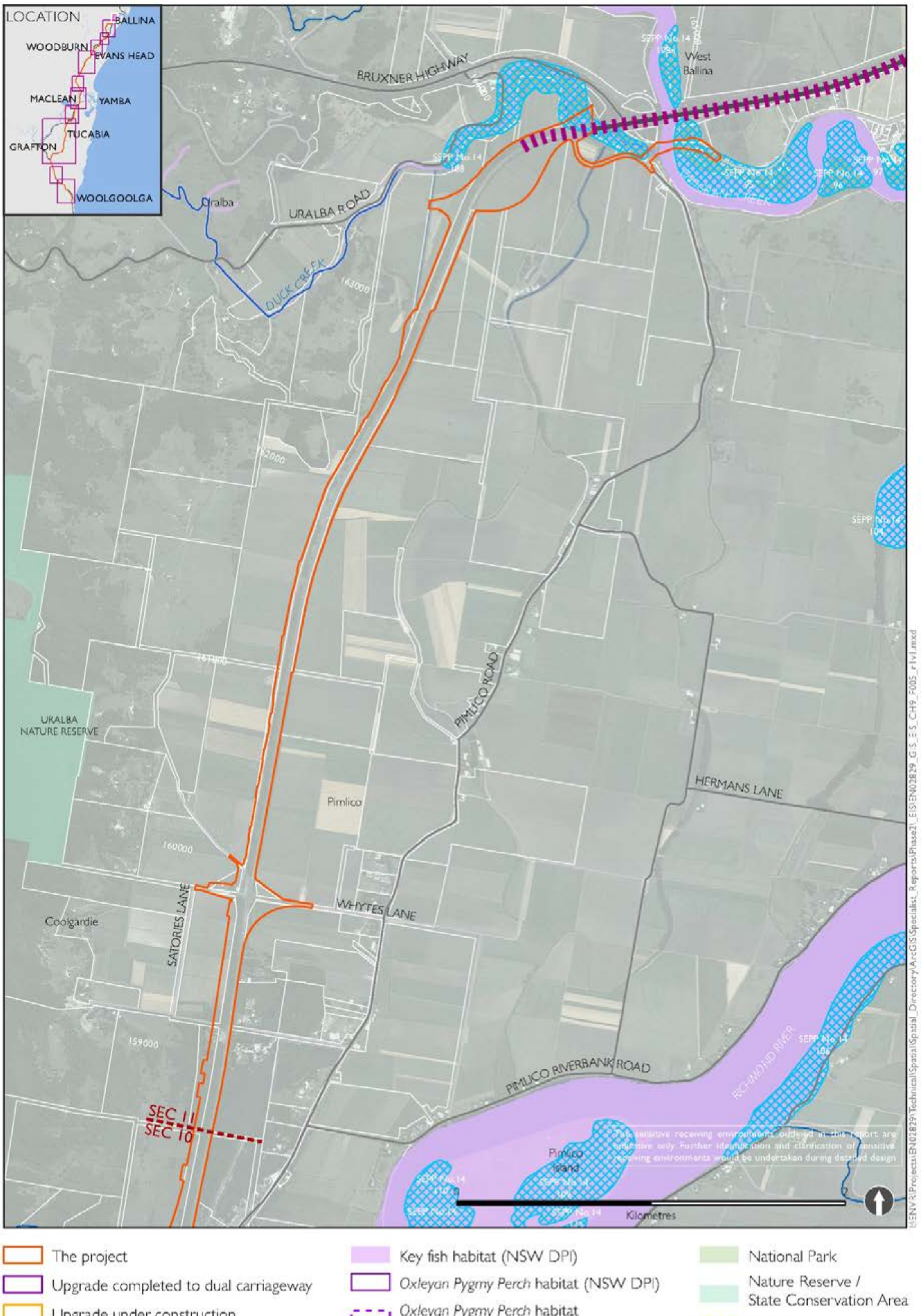


Figure 9-33: Sensitive receiving environments in Section 11

Table 9-6: Receiving waterways and sensitive receiving environments by project section

Project section	Named receiving waterways	Description	Sensitive aquatic receiving environments
1	Arrawarra Gully Corindi River Cassons Creek Blackadder Gully Redbank Creek Dirty Creek Dundoo Creek Halfway Creek	Waterways are primarily lowland freshwater systems. Corindi River, Cassons Creek and Blackadder Creek form part of the Corindi River floodplain. Arrawarra Gully, Corindi River, Blackadder Gully, Cassons Creek, Redbank Creek and Dirty Creek form part of the Arrawarra Creek and Corindi River catchments and flow to the Solitary Islands Marine Park.	SEPP 14 Coastal Wetland No. 314 is located 60 m east of the project near Corindi Beach. Key fish habitats are all named waterways plus an unnamed tributary of Redbank Creek at station 6.7. Threatened aquatic species habitat are in Arrawarra Gully, Corindi River, Cassons Creek, Redbank Creek, Halfway Creek, and an unnamed tributary of Redbank Creek at station 6.7. Solitary Islands Marine Park located downstream of the project at Arrawarra Gully and Corindi River. Habitat protection zones are located along one arm of the Corindi River and in Arrawarra Gully, and a sanctuary zone is also located downstream in the tidal reaches of Corindi Creek.
2	Halfway Creek Wells Crossing Creek Glenugie Creek	Waterways are primarily lowland freshwater systems.	Newfoundland and Glenugie State forests are located adjacent to the project. All named and unnamed waterways are considered to be key fish habitats with potential threatened aquatic habitat present.
3	Pheasant Creek Coldstream River Black Snake Creek Pillar Valley Creek Chaffin Creek Champions Creek	Waterways are primarily lowland freshwater systems. Coldstream Creek, Chaffin Creek and Champions Creek have estuarine properties downstream and lowland river characteristics upstream.	Crows Nest Swamp is located adjacent to the project. SEPP 14 Coastal Wetland No. 287 is located 600 m downstream of proposed crossing of Champions Creek. SEPP 14 Coastal Wetland No. 289 is associated with Chaffin Creek and located 450 m to the west of the project. SEPP 14 Wetland No. 292 is part of the Upper Coldstream wetlands, associated with Coldstream River and Pillar Valley Creek, located downstream and to the west of the alignment. Key fish habitats are in all named waterways, plus an unnamed tributary of Glenugie Creek at station 39.7, an unnamed tributary of Pillar Valley Creek at station 48.0, and an unnamed tributary of Chaffin Creek at station 54.6. Known and potential threatened aquatic species habitat is present in Coldstream River, Black Snake Creek, Pillar Valley Creek, and Chaffin Creek.
4	South Arm (Clarence River) Edwards Creek Shark Creek	These are tidally influenced estuarine systems dominated by saline conditions, although the upstream reaches of Shark Creek are considered to be a lowland freshwater ecosystem.	The alignment near Shark Creek is close to SEPP 14 Wetland No. 232, which is located on the eastern side of the upstream reaches of Shark Creek, upstream of the project. There are key fish habitats in South Arm (Clarence River), and Shark Creek.

Project section	Named receiving waterways	Description	Sensitive aquatic receiving environments
5	James Creek Nyrang Creek Clarence River Serpentine Channel North Arm (Clarence River) Mororo Creek	The Clarence River is the largest river on the NSW coast. Waterways in Section 5 are mainly tidally influenced estuarine systems dominated by saline conditions with estuarine water quality characteristics.	SEPP 14 Coastal Wetland No. 220a is located to the south-east of the project and extends into Yaegl Nature Reserve. James Creek flows through the wetland into the nature reserve. SEPP 14 Coastal Wetland No.153c is located about 400 m west of the crossing of North Arm. There are key fish habitats in all named waterways plus all unnamed waterbodies, including the unnamed tributary of James Creek at station 84.4. Threatened aquatic species habitat is present in Clarence River.
6	Mororo Creek Tabbimoble Creek	Tabbimoble Creek is estuarine downstream of the weir and freshwater upstream.	SEPP 14 Coastal Wetland No. 153a is located on Tabbimoble Creek about 1 km to the east of the project. SEPP 14 Coastal Wetland No. 153 is located 4.5 km to the east of the project, mostly within Bundjalung National Park and Devils Pulpit State Forest, and extends between North Arm in the south and the Evans River in the north. All named waterways and unnamed waterbodies are key fish habitats with the potential for threatened aquatic species habitat.
7	Tabbimoble Floodway No. 1 Nortons Gully Oaky Creek.	Waterways are typically freshwater. Many are ephemeral, flowing only after heavy or prolonged rainfall.	SEPP 14 Coastal Wetland No. 161 is located about 260 m to the east of the project. There are key fish habitats and known and potential habitat for threatened aquatic species in all named waterways and unnamed water bodies including waterways at station 114.0, 121.7 to 122.4 and 124.5
8	Tuckombil Canal (becomes Evans River) Rocky Mouth Creek MacDonalds Creek	Waterways are typically freshwater. Many are ephemeral and flow only after heavy or prolonged rainfall. Tuckombil Canal is a flood control structure (directing waters from the Richmond floodplain to the Evans River) and is subject to tidal influences.	The project would be adjacent to Broadwater National Park, which contains a number of SEPP 14 wetlands. Tuckombil Canal, Rocky Mouth Creek, Macdonalds Creek, the unnamed waterways at station 134.7 and 136.5 are key fish habitats. The Rous Water bore fields are located in this section to the east of Woodburn.
9	Montis Gully Eversons Creek	Waterways are typically small freshwater streams, with the exception of Richmond River (which is a large tidal river).	The project would run through Broadwater National Park, which contains a number of SEPP 14 wetlands including SEPP 14 No. 121. There are key fish habitats and known and potential threatened aquatic species habitat present in all named and unnamed waterbodies, including the unnamed tributary of Montis Gully at station 141.9.

Project section	Named receiving waterways	Description	Sensitive aquatic receiving environments
10	Tuckean Swamp and Tuckean Broadwater (upstream of Richmond River) Richmond River Saltwater Creek Randals Creek.	Section 10 would cross the Richmond River floodplain. Tuckean Swamp and Randals Creek are located on the floodplain.	SEPP 14 Wetland No. 119 mangroves are located at Tuckean Broadwater (700 m upstream from the proposed crossing at Richmond River). SEPP 14 Wetland No. 118 and No. 118a are located on the northern banks of the Richmond River, either side of the project boundary. There are key fish habitats in Tuckean Swamp and Tuckean Broadwater (upstream of Richmond River), Richmond River, and unnamed tributaries of Bingal Creek at stations 149.3, 150.6 and 153.9. Threatened aquatic species habitat is present in Tuckean Swamp, Tuckean Broadwater and Richmond River.
11	Duck Creek Emigrant Creek	The creeks are located on the Richmond River floodplain. The upstream sections of the creeks are freshwater, while the downstream reaches adjacent to the project are estuarine.	SEPP 14 Coastal Wetland No. 108 and No. 95 are located around Duck Creek and Emigrant Creek, respectively. Both waterways are key fish habitats, with potential for threatened aquatic species habitat.

Surface water quality

The water quality in receiving waters for the project is summarised in Table 9-7. The existing data indicate that the majority of the waterways potentially impacted by the project have a history of water quality problems, with conditions commonly found to be below the standards required for protection of aquatic ecosystems. The occurrence of poor water quality can be attributed to a number of factors, including modification of channel structure, macrophyte and weed growth, soil erosion, acid sulfate soils and nutrient enrichment as a result of runoff from agricultural land.

Table 9-7: Summary of water quality by project section

Project section	Water quality
1	Samples taken in 2007 from Arrawarra Creek, Corindi River, Blackadder Gully, Cassons Creek and Redbank Creek indicated that, with the exception of Corindi River, water quality does not meet the relevant ANZECC/ ARMCANZ guidelines (RTA, 2008b). Issues include low pH, possibly caused by acid sulfate soils and low dissolved oxygen. Redbank Creek and Blackadder Gully were found to have high turbidity, which can be attributed to the presence of stock in the water at the time of sampling. Previous studies of the Corindi River have found that some areas have low dissolved oxygen levels and are impacted by agricultural land uses and bank erosion (HRC, 2003). Other studies of the estuarine section of Corindi River have found that water quality meets the relevant ANZECC/ ARMCANZ guidelines (Department of Commerce, 2004).
2	Samples from Glenugie Creek in 2007 indicated that dry weather water quality failed to meet the ANZECC/ ARMCANZ guidelines (RTA, 2008a). At the time of sampling, the waterway was affected by low flows and excessive macrophyte growth, which would have contributed to low dissolved oxygen levels. Water quality was substantially higher during wet weather, complying with ANZECC/ ARMCANZ guidelines for all water quality indicators measured. HRC (2003) found that water quality in Halfway Creek was relatively good but was affected by soil and stream bank erosion, at least partially attributable to the poor design of existing creek crossings (RTA, 2005b).
3	Sampling of Pheasant Creek, Coldstream River, Pillar Valley Creek, Chaffin Creek and Champions Creek between 2005 and 2007 indicated that water quality was generally poor, with little difference between wet and dry weather conditions (RTA, 2009). These creeks generally have low flow and often have no flow in their upstream reaches during dry weather. This results in low dissolved oxygen, low pH and high turbidity, with conditions failing to meet the ANZECC/ ARMCANZ guidelines. The low dissolved oxygen and pH levels may also be related to the presence of acid sulfate soils. Black water events are known to have occurred in the Coldstream River, resulting in fish kills. Black water events can occur naturally due to the breakdown of large quantities of organic material and can result in low dissolved oxygen levels.
4	Wet and dry weather samples were taken from South Arm, Edwards Creek and Shark Creek during 2007 (RTA, 2009). Water quality was found to be generally poor and failed to meet the ANZECC/ ARMCANZ guidelines. Possible reasons for poor water quality included low flow, channel modification, bank erosion, weed growth, and drainage from acid sulfate soils.
5	Samples taken from waterways in this section between 2005 and 2007 indicated that water quality was generally good (RTA, 2009). The main exception was the water quality in Serpentine Channel, which failed to meet ANZECC/ ARMCANZ guidelines for turbidity, pH and diNorth Arm was generally good, although turbidity was high during wet weather. Agricultural use of floodgates and cane drains could also contribute to poor water quality.
6	Wet and dry weather samples taken from Nyrang Creek during 2007 failed to meet the ANZECC/ ARMCANZ ecosystem protection guidelines for turbidity, dissolved oxygen and electrical conductivity (RTA, 2009). Samples taken from Tabbimoble Creek in 2009 also failed to meet these guidelines for electrical conductivity and dissolved oxygen (RTA, 2010). Tabbimoble Creek was found to have high concentrations of aluminium, which could be a result of leaching of aluminium from soils due to the effects of acid sulfate soils.
7	Water quality sampling undertaken for the previous development project , found that most creeks did not comply with the relevant ANZECC/ ARMCANZ (2000) water quality guideline trigger values for pH, dissolved oxygen and total nitrogen; this could have been due to the low flows observed (RTA, 2006). Monitoring also showed low levels of total suspended solids (TSS), indicating that catchment activities and processes are not contributing substantial quantities of particulate material to the creeks under the low flow. Field observations noted visible oils and greases in the creek.

Project section	Water quality
8	Water quality sampling undertaken by other organisations (mostly Richmond River Council) indicates that both Rocky Mouth Creek (upstream of Tuckombil Canal) and Tuckombil Canal have highly variable water quality and are subject to acidic influxes from acid sulfate soils. Both watercourses have a history of fish kills (RTA, 2008a). Previous studies indicate that water quality does not comply with the relevant ANZECC/ ARMCANZ guidelines for pH, dissolved oxygen or total nitrogen. Tuckombil Canal has been found to have high salinity levels (due to tidal influences downstream of the weir) and extremely low dissolved oxygen (Hyder, 2005). Water quality monitoring of Tuckombil Canal in 2005 showed elevated electrical conductivity and high phosphorus levels. More recent monitoring (2010) identified slightly elevated turbidity and low dissolved oxygen.
9	Sampling of Tuckean Broadwater for previous development projects identified very low pH levels, extremely dissolved oxygen levels and high turbidity, with levels of these water quality indicators failing to meet the ANZECC/ ARMCANZ guidelines (Hyder, 2005). Additional monitoring in Tuckean Broadwater and Tuckean Swamp show low salinity, dissolved oxygen and pH levels.
10	Samples taken from the Richmond River identified low pH and dissolved oxygen levels (Hyder, 2005). Cane cultivation on the Richmond River floodplain has involved construction of a network of channels with tidal gates that prevent backflow from the river up the channels. This has resulted in the lowering of the water table and oxidation of acid sulfate soils, leading to generation of sulphuric acid inflows to the Richmond River.
11	Water quality sampling in Section 11 has been undertaken as part of the Lower Richmond Water quality Monitoring Program, Manly Hydraulics Lab monitoring program and long-term monitoring by Richmond Valley Council. These programs have concluded that the waterways in this section are degraded and have poor water quality, with low pH, low dissolved oxygen and elevated turbidity.

KEY TERM – Dissolved Oxygen (DO)

Amount of oxygen dissolved in a body of water as an indication of the degree of health of the water and its ability to support a balanced aquatic ecosystem.

9.2.3 Groundwater

Hydrogeology

Alluvial deposits occur throughout the area within the project boundary, laid down by the numerous rivers emanating from the Great Dividing Range. The most significant of these are the Clarence River and Richmond River alluvial floodplain sequences, which underlie the northern half of the project boundary. These are connected along the project by unconsolidated coastal sediments and deposits, the most important being the Woodburn Sands, which provide potable groundwater (though with locally high iron and aluminium content) for the Lismore region. These sediments are generally poorly consolidated, although hardpans have developed locally and the floodplains are commonly capped with clay-rich deposits of variable thickness, which form an impermeable seal to the underlying sands, gravels and other sediments.

Recharge to the coastal sediments is generally considered to be via direct infiltration of rainfall and floodwaters, though the impermeable nature of the surface clays in many areas means that localised recharge is probably the dominant recharge mechanism.

Existing water table levels

Over one-third of the project overlies lowland and floodplain areas where groundwater is close to the surface. These areas include the floodplains of the Clarence and Richmond rivers.

Groundwater levels within the lowland areas of the project boundary are typically within three metres of the surface. On the floodplains of the Clarence and Richmond rivers, groundwater levels can be two metres from the surface. Following periods of heavy rainfall, the groundwater levels in lowland and floodplain areas are often at the existing ground surface. The water-bearing units in these areas are generally associated with alluvial aquifers on low-lying, alluvial deposits.

In elevated areas underlain by bedrock, groundwater levels are typically more than eight metres below the surface and locally over 45 metres below the surface on the summit of the Coast Range. The water-bearing units in these areas are generally deep within the rock formations (that is, greater than 10 to 15 metres below the surface).

Groundwater flow characteristics

In the southern portion of the project groundwater systems are dominated by groundwater flow system characteristics of local alluvial systems overlying fractured rocks and porous rock aquifers. These systems are variably connected and responses tend to be rapid and seasonally driven. These systems are easily disturbed, but respond rapidly to mitigation and management.

In the northern part of the project, floodplains on the coastal sand aquifers dominate. These broad, low-gradient systems provide a large buffer to any disturbance although they can take a long period to recover if impacted. The low gradients and large groundwater stores mitigate against local impacts to the system and may require on-going intervention if water tables are required to be lowered as part of a management strategy.

Salinisation

Salinisation due to discharging groundwaters is not known to occur along the project boundary. In inland NSW, salinisation is a common condition where roads with inadequate drainage cut across shallow groundwater flow lines. In the high rainfall areas of the project, however, any accumulation of surficial salts from the evaporation of discharging groundwaters is periodically and effectively flushed away and there are no known occurrences of natural soil salinisation within or near the project boundary.

However, the northern sections of the project are within the seaward floodplains of the Richmond River. Groundwater interference may cause seawater ingress into the coastal aquifers, such as the Woodburn Sands aquifer. This is not known to be a risk to the aquifer.

Groundwater use

During average climatic/ weather conditions, groundwater is generally not a major source of water throughout the project area. Of nearly 10,000 bores investigated as part of this EIS:

- Less than three per cent of bores have an allocation for irrigation and an additional one per cent are licensed to extract groundwater for commercial ventures. Combined, this accounts for an entitlement of 30 gigalitres per year, though only an estimated 8.5 gigalitres was used in 2010–11
- Eighty-five percent of registered bores are licensed for stock and domestic use, with an annual entitlement of generally one to three megalitres per year each (but up to 14 megalitres per year in one case)
- Ten per cent of bores are rated as ‘lapsed’ or ‘cancelled’ and the remainder are monitoring or test bores with no water use requirements.

Under normal climatic conditions, groundwater is a minor water source, with surface water supplies sufficient for most operations. However, during periods of drought, as occurred between 2000 and 2007, groundwater becomes an increasingly important water source.

Rous Water Woodburn Sands bore field

The project would cross a bore field that is used as a potable water source for the local area. This bore field is operated by Rous Water and is located about two kilometres south-east of the Woodburn township, and coincides with the Woodburn Sands aquifer.

The bore field contains three operational bores (as shown in Figure 9-30) that provide a reserve water supply during drought and an auxiliary supply for the region. Groundwater quality is rated as good, but may contain elevated levels of iron and aluminium. Groundwater is treated by aeration and filtration. Following treatment, sodium hypochlorite is added to provide disinfection residual.

An important groundwater source is located near Woodburn, where, up to 242 megalitres per year can be taken by three bores in the north of the project as part of the Rous Water town water supply entitlement.

Overlying the Woodburn Sands aquifer is a clay layer that acts as an intermittently impermeable barrier. The clay appears to be between 0.6 and 2.2 metres thick in the immediate area of the project. Recharge to the Woodburn Sands aquifer is via direct (diffuse) recharge from local rainfall infiltrating through the soil profile, with additional lateral recharge from local elevated areas. The presence of clay in the vicinity of the Rous Water bore field suggests that recharge in this area may be from further afield, such as from Trustums Hill and other local high ground.

Groundwater-dependent ecosystems

The known groundwater-dependent ecosystems in the study area are limited to wetlands, several of which are listed under State Environmental Planning Policy No. 14 Coastal Wetlands or are identified as Nationally Important (refer to Section 9.2.2 and Figure 9-23 to Figure 9-33). While the degree of groundwater dependency varies between these wetlands, groundwater typically plays a critical role in wetlands found on alluvial floodplains.

Many coastal wetlands are predominantly supported by shallow, perched groundwater systems (perched on a clay layer, for example) that effectively arrest the infiltration of surface waters. These systems are also reliant on surface water, with the shallow groundwater acting as a local storage that reduces effective evaporation and sustains wetland species. Elsewhere, groundwater is sourced from further afield and is brought to the surface due to an impediment to flow or via a topographic low. These groundwater-dependent systems typically occur in valleys and in coastal sand environments.

KEY TERM – Groundwater dependent ecosystems

Ecosystems that depend to some extent on groundwater supply for the maintenance of their existing species composition and ecological processes. Groundwater-dependent ecosystems can include cave systems, springs and wetlands.

9.3 Assessment of impacts

9.3.1 Construction impacts

Soils

During construction, impacts on soils would be associated with:

- Soil erosion
- Acid sulfate soils
- Contamination
- Settlement of soft soils.

These impacts are discussed below.

Soil erosion

During construction, there would be an increased risk of soil erosion from areas of exposed soil and stockpiles, in particular areas of clearing and earthworks.

The project would require removal of vegetation and extensive earthworks, including excavation, translocation of soils and fill, and the construction of subgrade, embankments, culverts and bridges. These activities would result in exposure of soils and subsoils, creating an elevated risk of soil erosion. Eroded soils and sediments have the potential to be transported by water runoff and wind to nearby waterways and sensitive receiving environments. This would result in degradation of receiving water quality and settlement of eroded sediments on the beds of streams, floodplains and wetlands, with associated adverse impacts on aquatic flora and fauna, and human water uses.

The potential for soil erosion and consequent impacts on water quality would vary along the project boundary depending on the following key risk factors:

- Soil erodibility
- Scale of earthworks
- Proportion of road batter area relative to the road catchment size
- Road gradient.

These soil erosion risk factors have been estimated for each project section and are summarised in Table 9-8; the table indicates that there are moderate to high levels of soil erosion risk within the majority of the project boundary, with lower levels of risk in project Section 6.

Table 9-8: Indicative risk factors for soil erosion and associated impacts on water quality

Project section	Risk factors			
	Soil erodibility	Scale of earthworks	Proportion of batter area to catchment area	Road gradient
1	Moderate	Moderate	Low	Moderate
2	High*	Low	Low	Low
3	High*	High	Low	Low
4	Moderate	High	Low	Low
5	Moderate	Low	High	Low
6	Low	Low	Low	Low
7	High	Low	Low	Low
8	Low	Moderate	Moderate	Low
9	Moderate	Moderate	Moderate	Low
10	Moderate	Moderate	Moderate	Low

Project section	Risk factors			
	Soil erodibility	Scale of earthworks	Proportion of batter area to catchment area	Road gradient
11	Moderate	Low	Low	Low

* No data available. Assumed to be highly erodible.

Acid sulfate soils

There is a high probability of acid sulfate soils occurring and being impacted within several sections of the project boundary, as indicated in Table 9-4 and Figure 9-12 to Figure 9-22.

The construction activities with the greatest risk of disturbing acid sulfate soils are drainage, excavation, dewatering and clearing. These activities pose a significant environmental risk when carried out in areas identified as having acid sulfate soils. The activities could disturb and expose acid sulfate soils to oxygen, which could generate sulphuric acid and toxic quantities of aluminium and other heavy metals. These could be readily released into the surrounding environment, polluting surface water and groundwater.

The impacts of acid sulfate soils entering water bodies include changes to pH levels and the potential for habitat degradation, fish disease or kills, loss of food resources, lowered potential for fish migration and recruitment, disturbance to water plant communities, and secondary effects on water quality (Stone et al, 1998).

The Rous Water Regional Water Supply catchment is located in a high-risk area for the presence of acid sulfate soils. Infiltration of acid water into the ground water system would create an elevated risk of dissolved metal contaminants in the Woodburn Sand aquifer system and therefore the Woodburn water supply bores.

The risks associated with disturbance of acid sulfate soils and potential acid sulfate soils can be adequately managed and mitigated through the implementation of the relevant measures and procedures set out in the Acid Sulfate Soil Manual (Stone et al., 1998) and Acid Sulfate Soils Assessment Guidelines (Ahern et al., 1998). The potential engineering consequences of building new road infrastructure on acid sulfate soils have been taken into account during the design of the project and would be further considered during detailed design. Impact mitigation measures are discussed further in Section 9.4.

Contamination

Any existing contamination present within the soils or groundwater underlying the project area and associated ancillary facilities has the potential to be exposed or disturbed by construction activities. The highest risk activities would be excavation, earthworks and demolition.

The risk of disturbing any contamination would be highest at proposed road cuttings. At road embankment sites, by contrast, the project is unlikely to increase the risks associated with any site contamination and the placement of fill would also act as a barrier to future exposure and disturbance of contamination. Similarly, ancillary facilities would generally be established by placing a layer of aggregate or similar material over the ground surface. This overlying aggregate layer would reduce any risks of exposure to, and disturbance of, contamination.

Investigations have identified areas of potential contamination within or immediately adjacent to (less than 10 metres from) the project boundary, including the boundary of nominated ancillary facilities.

Table 9-9 provides details of those areas of environmental concern which are believed to represent the highest risk with respect to potential impacts to receptors through release of contamination during construction activities.

Table 9-9: Areas of potential contamination that may be disturbed by project construction

Site ref number	Site name or description	Project section	Location
2	Former banana plantation	1	Within project boundary
4	Blueberry Exchange	1	Within project boundary and two nominated ancillary facilities (sites 4a and 4b)
5	Quarry	1	Adjacent to the project boundary
7	RMS stockpile, north of Dundoo Creek	1	Within project boundary
9	Former orchards	1	Within and adjacent project boundary
10	Service station	2	Adjacent to project boundary
11	Former cattle dip site	2	Immediately adjacent to one nominated ancillary facility (site 1b)
12 and 15	Diesel tank (above ground) and former service station, Kungala Road, Pacific Highway	2	Immediately adjacent to project boundary and one nominated ancillary facility (site 3)
13 and 14	Rose farm and shop	2	Within and adjacent to project boundary
16	Possible furniture shop	2	Adjacent to project boundary
17	Former cattle dip site	2	Adjacent to project boundary
18	Former orchards	2	Within ancillary facility (site 5a)
19	Former service station	2	Within project boundary
20	Towing company with workshop	2	Within project boundary
21	Stockpile	2	Within project boundary
24	Former sawmill	3	Within project boundary
25	Tucabia landfill, south of Firth Heinz Road	3	Within project boundary
27	Property off Upper Coldstream Road, Tucabia	3	Adjacent to project boundary
28	Old Maclean Shire Council landfill – Coldstream Road, within 10 m of project boundary	3	Within and immediately adjacent to project boundary
30	RMS stockpile	4	Within project boundary
31	Former cattle dip site	4	Adjacent to project boundary
33	Cattle dip site	4	Adjacent to project boundary
34	Agricultural	4	Adjacent to project boundary
35	Cattle dip site	4	Adjacent to project boundary
36	Service station	4	Adjacent to project boundary
37	Agricultural	4	Adjacent to project boundary
38	Former fuel depot	4	Adjacent to project boundary
39	Townsend sewage treatment plant	4	Adjacent to project boundary
43	Harwood Bridge – signage manufacturer	5	Adjacent to one nominated ancillary facility (site 2a)
44	Harwood Bridge	5	Within project boundary
45	United service station, eastern side of existing highway	5	Within project boundary
46	Mills truck depot, western side of existing highway	5	Within project boundary

Site ref number	Site name or description	Project section	Location
47	Mororo Bridge	5	Within project boundary
49	Cattle dip site	6	Adjacent to project boundary
50	Cattle dip site	6	Adjacent to project boundary
51	RMS stockpiles	6	Within project boundary
52	RMS Stockpile	7	Within project boundary
53	RMS Stockpile	7	Within project boundary
54	RMS Stockpile	7	Within project boundary
55	Old tanks	7	Adjacent to project boundary
56	Cattle dip site	7	Adjacent to project boundary
57	Cattle dip site	7	Adjacent to project boundary
58	RMS Stockpile	7	Within project boundary
59	Stockpile – south of Serendipity Road	7	Adjacent to project boundary
60	Small scale agriculture	7	Adjacent to project boundary
61	Stockpile – North of New Italy rest stop	7	Within project boundary
63	Garage / Junk Yard	8	Adjacent to project boundary
64	Electrical substation	8	Adjacent to project boundary
65	RMS Woodburn Depot	8	Adjacent to project boundary
67	Unknown material/structure	8	Adjacent to project boundary
69	Agriculture	8	Within and adjacent to project boundary
70	Evans Head Air Weapons Range	9	Adjacent to project boundary
71	Agriculture	9	Adjacent to project boundary
72	Council Landfill - Broadwater	9	Within project boundary
73	Evans Head Air Weapons Range	9	Adjacent to project boundary
74 and 75	NSW Sugar Mill Co-Op – Sugar Cane stockpile area and processing plant	9	Within and adjacent to project boundary
76 and 78	Quarry, Quarry Road, Broadwater	9	Within and adjacent to project boundary
79	General observation – between existing quarries	10	Adjacent to project boundary
80	Quarries – northern section of the project, Old Bagotville Road	10	Within and adjacent to project boundary
81	Sewage Treatment Works	10	Adjacent to ancillary facility site 4
82	Agricultural	11	Adjacent to project boundary

Disturbing these contaminated sites could have the following impacts:

- Mobilisation of surface and subsurface contaminants (impacting groundwater, surface water and soils)
- Migration of contaminants into the surrounding area (impacting groundwater, surface water and soils) via leaching, overland flow and/or subsurface flow
- Mobilisation of groundwater and/or surface water contamination
- Exposure of contaminants to ecological receptors (impacting flora and fauna)
- Exposure of contaminated soils and/or groundwater to human receptors.

The impacts that could result from disturbing different types of contaminated sites are listed in Table 9-10.

Table 9-10: Impacts from disturbing contaminated sites

Site type	Contaminants	Type of impacts
Landfills	• Release of landfill gas emissions and toxic gases.	• Air quality and local environmental receptors.
Service stations	• Emissions to air of potentially contaminative vapours associated with the storage of fuels and oils on site • Exposure of contaminated soils and/or contents of underground storage tanks through excavation works.	• Air quality and local environmental receptors • Groundwater, surface water and soils.
Stockpiles	• Potential for contaminated materials contained within the stockpiles to contaminate surrounding soils.	• Soils, flora and fauna.
Cattle dip sites and agricultural land uses	• Location and disturbance of other contaminants associated with agricultural land use, eg fuel and oil storage, asbestos • Potential to disperse pesticides, fertilisers and herbicides via dust and wind, especially in areas of high vehicular activity.	• Groundwater, surface water and soils • Groundwater, surface water, soils and local air quality.
Quarries and industrial land uses	• Location and disturbance of other contaminants/activities associated with quarry land use, eg fuel and chemical storage, stockpiled material, asbestos, chemicals and activities associated with processing, and with machinery and plant • Exposure of contaminated soils and/or contents of underground storage tanks through excavation works.	• Groundwater, surface water and soils
Bridges	• Exposure of lead-contaminated soils (potentially present due to the use of lead-based paints for bridge maintenance) • Migration of potential contaminants into surrounding areas via leaching, overland flow and/or subsurface flow • Mobilisation of potential groundwater and/or surface water contamination in the vicinity of the bridges.	• Groundwater, surface water and soils
Demolition of structures/buildings	• Mobilisation of contaminants within the surface and subsurface • Exposure of contaminants associated with the structure/building fabric (eg cement sheeting, insulation materials).	• Groundwater, surface water and soils.

Current geotechnical assessments undertaken by RMS on the Tucabia landfill (25) and the old Maclean Shire Council landfill (28) have indicated that where possible, opportunities to refine the project alignment should be investigated to avoid impacting on these sites.

Settlement of soft soils

The presence of soft soils is an issue for the project as construction of the carriageways on areas underlain by soft soils could result in post-construction settlement of embankments. This in turn could result in damage to road pavement surfaces and increase the long-term maintenance requirements for the highway.

The project would involve construction of embankments up to 12 metres high over areas containing soft soils. These areas would need to be treated to achieve adequate levels of soil settlement and consolidation before construction of the road could begin.

The soft soil deposits along the project boundary have been ranked based on soft soil thickness and the height of the proposed road embankments. These ranks were used to identify priority soft soil sites, that is, those sites that would benefit from treatment of soft soils before construction. The priority soft soil sites are identified in Chapter 6 (Description of the project – construction).

A range of methods is available for treating soft soils. The preferred method would depend upon construction scheduling requirements, thickness of the soft soil layers, the soil consolidation properties, and height of the proposed road embankments. Information on the soft soil treatment methods to be applied for the project is provided in Chapter 6 (Description of the project – construction).

Water quality

Risk factors and impacts

During construction, the highest risk of impacts on water quality would be associated with:

- Exposure of soils during earthworks (including stripping of topsoil, excavation, stockpiling and materials transport), which may result in soil erosion and off-site movement of eroded sediments by wind and/or stormwater to receiving waterways, resulting in increased nutrients, metals and other pollutants
- Accidental leaks or spills of chemicals, fuels, oils and/or greases from construction plant and machinery, which may result in pollution of receiving waterways and groundwater sources
- Exposure of acid sulfate soils (as a result of earthworks or dewatering), which may result in generation of sulfuric acid and subsequent acidification of waterways and groundwater sources and mobilisation of heavy metals in the environment
- Disturbance of contaminated land causing contamination of downstream waterways, impacting on aquatic and riparian habitats
- Removal of riparian vegetation, which may result in soil and streambank erosion and increased sediment loads in nearby creeks
- Direct disturbance of waterway beds and banks during culvert and bridge construction and temporary or permanent creek diversions, which may lead to high volumes of sediment entering and polluting the waterways
- Changes to flow regimes, which can change the volumes and flow rates of water, leading to stagnation of a waterway and changes in turbidity, nitrogen and phosphorus levels. Reduction in flow regimes also has the potential to expose PASS if it results in a reduction to groundwater levels. Impacts to surface flows and quantities are identified in Chapter 8 (Hydrology and flooding) and detailed in Working paper – Hydrology and flooding
- Infiltration of surface water to groundwater sources, including sediments and particles and soluble pollutants (such as acids, salts, nitrates and soluble hydrocarbons)
- Leaching of tannins from stockpiles of cleared vegetation, which may have a number of adverse effects on receiving waters, including:
  - Increased biological oxygen demand, with consequent decreases in dissolved oxygen
  - Reduced water clarity and light penetration
  - Decreased pH.

KEY TERM – Tannins

Tannins are a natural organic material by-product of the natural process of native vegetation breakdown.

Each of the above-listed impacts would have a number of flow-on effects on water quality with the potential for adverse effects on both aquatic ecosystems and human water uses, including impacts on sensitive receiving environments.

Risk management

While construction of the project presents a high risk to water quality, the risk of adverse impacts can be reduced to minimal levels with the application of the proposed impact mitigation and management measures, including standard soil erosion and sediment controls and other construction site management procedures. With the implementation of the proposed measures during construction, adverse impacts on water quality and sensitive receiving environments would be unlikely.

It is important to note that water quality impacts during construction would vary along the project depending upon the presence of acid sulfate soils (refer to Table 9-4) and soil erosion risk factors (refer to Table 9-8). The consequences of waterway pollution would also vary depending on the proximity and nature of receiving waters and sensitive receiving environments (refer to Table 9-6).

Where construction takes place in areas that would affect sensitive receiving environments, the design criteria for sedimentation basins have been made more stringent to increase the level of treatment provided to construction runoff before its release. Indicative locations for temporary sedimentation basins are shown in Figure 6-1 to Figure 6-42. The final locations and sizes of sedimentation basins would be confirmed during detailed design.

Impacts of water quality changes on sensitive receiving environments

As noted above, construction activities could increase levels of turbidity and sediment deposition, decrease dissolved oxygen, and change pH levels in waterways downstream of the project.

These changes could have an adverse impact on the health of aquatic environments, particularly in sensitive receiving environments. Impacts would include:

- Loss of terrestrial and aquatic species
- Damage to aquatic, riparian and terrestrial environments
- Effects on the suitability of downstream waterways for recreational uses (such as swimming)
- Effects on the quality in a drinking water catchment.

Risks to water quality in high-risk locations (as identified in Section 9.2.2) during construction of the project are detailed in Table 9-11.

Photo 3: View towards Northwest Solitary Island and the Solitary Islands Marine Park

Risks to groundwater quality from surface water

In identifying hazards to the water quality of a groundwater source, as per the Australian Drinking Water Guidelines (NHMRC and NRMMC, 2011), the potential risks to groundwater quality during construction would include contamination by hydrocarbons from accidental fuel and chemical spills, refuelling or through storage facilities; and contamination by contaminants contained in turbid runoff from unpaved surfaces.

In addition, site runoff can infiltration groundwater sources. The process of infiltration is generally effective in filtering polluting particles and sediment. Hence, the risk of contamination to groundwater from any pollutants bound in particulate form in surface water, such as heavy metals, is generally low. Similarly, low-density pollutants such as insoluble hydrocarbons (oils, tars and petroleum products) would be preferentially retained in the soil profile and would not penetrate to the groundwater table. However, soluble pollutants, such as acids and alkalis, salts and nitrates, and soluble hydrocarbons, would be able to infiltrate through soils into the groundwater source and would pose a risk to that groundwater source. Under certain pH conditions, metals may also become soluble and infiltrate groundwater. In these areas, chemical treatments may be necessary. There is potential for long-term contamination risk to groundwater sources from the long-term accumulation of contaminants in the upper soil profile.

Table 9-11: Potential impacts to water quality in high-risk locations

Location	Risks to water quality
Solitary Islands Marine Park The project area that discharges into the marine park extends from the southern extent of Section 1 north to Dirty Creek incorporating the Arrawarra Creek and Corindi River catchments. The closest point between the project and the marine park is around station 1.0. To the north, the distance between the project and marine park increases, with the Dirty Creek crossing over 7 kilometres upstream of the tidal influence of the creek.	Areas of erodible soils occur around Arrawarra Gully (in the Arrawarra Creek catchment), the Corindi River and Redbank Creek (Corindi River catchment), resulting in an increased potential for sediments to travel into the marine park. Acid sulfate soils are mapped as having a high probability of occurrence, between 1 and 3 metres below the ground surface at Arrawarra Gully and between stations 1.0 and 2.0. However, construction in these areas would be in fill with removal of topsoil only and some excavation for the construction of basins. Therefore, the risk of disturbing the acid sulfate soils and impacting water quality in the marine park is low. From Corindi River to Cassons Creek there is a high probability of occurrence of acid sulfate soils in soil deeper than 3 metres. The construction of bridge piles at Corindi Creek and the Corindi River floodplain would be between 5 and 8 metres deep, exposing acid sulfate soils. There would be a large batter between station 8.5 and 8.7 near Dirty Creek, with a relatively steep road gradient between station 8.0 and 9.0. This would increase the risk of surface runoff and sediments moving into waterways. However, with mitigation and the distance between the project and the marine park, this would result in an insignificant impact. Stockpile sites are planned for this area around stations 2.5, 3.3 to 3.4 (180 metres from Corindi River), 5.2 to 5.3 (250 metres from Redbank Creek) and 7.4 to 7.7 (750 metres from a tributary of Redbank Creek). The latter two sites are proposed to also be used for material processing. There is a risk that mulch stockpiles at these sites would release sediments and tannins. Untreated construction runoff could have a major impact on the marine park. However, appropriate controls implemented during construction would reduce any impact on the marine park. In particular, sedimentation basins would be provided as part of the project to collect and treat construction runoff prior to discharge into downstream waterways.
Upper Coldstream wetlands The Upper Coldstream wetlands lie directly to the west of the project, between stations 39.0 and 66.0 in Section 3. The wetlands are a key fish habitat, they are nationally important wetlands, and areas of SEPP 14 wetlands. The wetland receives flows from the Coldstream River, Pillar Valley Creek, Black Snake Creek, Chaffin Creek, Champions Creek and a number of unnamed waterways.	The erodibility of soils in the area is not known, and further assessment would be required prior to construction to confirm the level of risk this would pose to the wetlands. There is a high probability of acid sulfate soils occurring between 1 and 3 metres deep around the crossings of Coldstream River, Pillar Valley Creek, Black Snake Creek, Chaffin Creek and Champions Creek. The construction of bridge piles, sediment basins and areas of cut may expose acid sulfate soils around these waterways. The construction of bridges (nine in this area) with in-stream works poses a risk to the water quality of the immediate waterway and the downstream Upper Coldstream wetlands. Large excavations would be undertaken between stations 54.0 and 54.3 and stations 59.5 and 59.9. While neither of these are close to named waterways, increased sediment loads in runoff would still run to the Upper Coldstream wetlands via overland flow paths. One stockpile site near waterways is proposed at station 45.6 to 46.0, (400 metres from Pillar Valley Creek). This would also contain a materials processing area, batch plant and workshop, which without appropriate mitigation would pose an increased risk of sedimentation and pollution to the wetlands. Untreated construction and operational runoff could have a major impact on the Upper Coldstream wetlands. However, appropriate controls implemented during construction would reduce any impact on the wetlands. Sedimentation basins would be provided as part of the project to collect and treat construction runoff prior to discharge into downstream waterways.

Location	Risks to water quality
Tabbimoble Swamp Nature Reserve Tabbimoble Swamp has important ecological value and is located from station 155.0 to 119.0 in Section 7. The swamp is known Oxleyan Pygmy Perch habitat and a SEPP 14 wetland.	Soils in the area are highly erodible, posing an increased risk of sedimentation to the downstream aquatic habitats. Sedimentation basins would be designed to capture and treat runoff from the area, and sized to take into account the erodibility of the soil. Untreated construction runoff could have a major impact on the Tabbimoble Swamp Nature Reserve. However, appropriate controls implemented during construction would reduce any impact on the nature reserve. Sedimentation basins would be provided as part of the project to collect and treat construction runoff.
Rous Water Woodburn Sands aquifer catchment Between stations 131.1 and 134.0 in Section 8, the project could impact on the Woodburn Sands aquifer, which is a drinking water supply source.	Acid sulfate soils have a high probability of occurring to the south of Woodburn – Evans Head Road and on the western side of the highway in this area. The construction in this area would be in fill and therefore acid sulfate soils should not be exposed. However, the construction of sedimentation basins and the Woodburn Floodway Viaduct 1 at station 131.1 would potentially expose acid sulfate soils. Any decrease in pH of the groundwater, either through dewatering leading to acid production or allowing infiltration of acid water into the groundwater system, would create an elevated risk of dissolved metal contaminants in the aquifer. This could result in the need for additional treatment of groundwater (on top of current treatments) to make the water suitable for use as a potable supply. To mitigate acid sulfate soils risks in this area, a site-specific acid sulfate soils management plan would be developed for the identified recharge area associated with the Woodburn bores. In addition, stockpile sites are planned for this area around stations 131.4 to 132.2 on the eastern side of the project and 132.0 to 132.2 on the western side of the project, and these, too, could pose a risk to water quality. The first site is proposed to be used for a site compound, with the second site proposed as a batch plant and material processing site. Due to the highly sensitive nature of the area, activities such as refuelling and washdown of vehicles and plant, storage of chemicals and concrete batch plants should not be undertaken in the catchment area. Untreated runoff could have a major impact on the Rous Water regional water supply catchment. However, appropriate controls would reduce any impact on the aquifer. All construction sedimentation basins in the bore fields would be lined with clay or a geosynthetic clay liner to prevent exfiltration or seepage through cracks in the base of the basin. Permanent channels and swales would also be lined with concrete or another type of impermeable material to prevent contamination of the underlying groundwater.
Broadwater National Park The project would pass through Broadwater National Park between stations 135.0 and 141.0 in sections 8 and 9. Waterways in the national park are known Oxleyan Pygmy Perch habitat. There are also a number of SEPP 14 wetlands. The project would cross two waterways – Macdonalds Creek and an unnamed tributary at station 136.5.	Risks to water quality in Broadwater National Park are increased by the presence of highly erodible soils along the project alignment. Around Macdonalds Creek, between stations 136.0 and 137.0, there is a high probability of acid sulfate soils occurrence between one and three metres below ground. Construction in this area would be in fill, but the basins at the southern edge of the area, to the south of the national park, would potentially expose acid sulfate soils and this effect would need to be mitigated. There is a site compound and stockpile site proposed for the area between stations 137.5 and 137.9, close to the boundary of the national park. Accidental spills as a result of the activities on the site could impact on the national park. Untreated runoff could have a major impact on the Rous Water regional water supply catchment. However, appropriate controls implemented would reduce any impact on the national park.

Location	Risks to water quality
Wardell Heath Wardell Heath is located to the east of the project between stations 146.0 and 157.0 in Section 10. The project would cross three unnamed waterways (at station 149.3, 150.6 and 153.9), all of which flow to Bingal Creek, which passes through the Heath.	There are highly erodible soils in the area. During construction, a site office and stockpile site is proposed for the area between station 152.7 and 152.8, and another site compound, batch plant, workshop, vehicle parking and stockpile site is proposed between station 156.2 and 156.6. These areas have a high potential for polluting downstream waterways and would need to be carefully mitigated through the management measures for stockpile sites In general, unmitigated construction runoff is not acceptable due to the value of the receiving environment, and therefore mitigation during construction has been included in the concept design. Mitigation would involve sedimentation basins as part of a treatment train to collect and treat construction runoff prior to discharge.
Threatened fish habitat There are areas where surface water from the project would discharge to or within 50 metres of known or potential threatened fish habitat.	There is the potential for three threatened species (Oxleyan Pygmy Perch, Purple-spotted Gudgeon, and Eastern (Freshwater) Cod to occur within the project boundary. Oxleyan Pygmy Perch and Purple-spotted Gudgeon have similar and specific habitat requirements, which include: • Physical parameters: pH 3–5 • Conductivity: Less than 350 μS/cm • Dissolved oxygen: Greater than 2 mg/L • Low turbidity (tannin stained). Both species are sensitive to any changes in these water conditions. In particular, any increase in total suspended solids, leaching of tannins into waterways, reduction in dissolved oxygen and/or change in pH beyond the tolerance limits of Oxleyan Pygmy Perch could result in stress or death. A borrow source site (Lang Hill) has been identified adjacent to Oxleyan Pygmy Perch habitat at station 134.7. There is a high risk that sediments could be transported into the waterway, affecting the water quality (such as suspended solids and pH) of the waterway, and altering the habitat so that it is no longer suitable to Oxleyan Pygmy Perch and causing stress or death of any Oxleyan Pygmy Perch present. The habitat could be severely impacted if mitigation measures are not implemented during construction.

Potential impacts of ancillary facilities on water quality

The following activities and works at ancillary facilities have the potential to impact on water quality:

- Storage of chemicals and other hazardous materials
- Earthworks (including areas of potential acid sulfate soils), mulch and vegetation stockpiles
- Processing of construction materials
- Batch plants
- Vehicle washdown areas
- Vehicle refuelling areas
- High frequency of vehicle movements.

All these activities could result in sediments and particles being washed off site into drainage lines and waterways, and increasing levels of turbidity.

Mulch stockpiling causes a risk of tannins leaching into waterways, and increased loads of organics in waterways. This would result in an increase in the biological oxygen demand (BOD) of the receiving environment, which may in turn result in a decrease in available dissolved oxygen. Once discharged to the environment, tannins may also reduce visibility and light penetration and change the pH of receiving waters. The largest areas of mulch stockpiling are proposed in sections 1–3. The leaching of tannins from these stockpiles could result in impacts on aquatic ecosystems including threatened aquatic species habitat (Corindi Creek) and the Solitary Islands Marine Park (Arrawarra Gully).

There are two borrow sources proposed along the project. These include Lang Hill at station 134.7 and a site west of Wardell at station 152.2 (Lumley's Hill). Borrow sources have the potential to significantly impact surface runoff quality through contamination with dissolved and suspended materials. The most common surface-water contaminant from borrow sources is sediment produced by soil erosion from the disturbed land.

Groundwater

Potential impacts of the project on groundwater

Much of the project would be in areas with shallow groundwater levels. The main risks to groundwater during construction of the project would be from:

- Groundwater contamination, which may occur if construction activities are not adequately managed, particularly in areas of shallow groundwater
- Changes in surface flows, groundwater flow regimes and 'draw down' of the water table as a result of intersection of groundwater by cuttings and subsequent groundwater discharge (including potential oxidation of acid sulfate soils).
- Construction of large embankments would preferentially direct surface runoff and concentrate recharge to groundwaters. On soft soils, compaction could occur restricting near-surface groundwater flow resulting in discharge and waterlogging.

The project would have 157 cuttings and these were assessed to determine their likelihood of intersecting with the groundwater table. All cuttings were categorised into three classes:

- Type A (potential high impact): Where the design profile after the cutting is predicted to be below the level of the groundwater table. This could lead to localised draw down of the groundwater table around the cutting sites. Groundwater flow to local creeks, streams, springs and local water resource within around 100 metres of the cutting could result. Potential impacts could also occur to Groundwater Dependent Ecosystems. Engineered mitigation measures would need to be put in place to divert groundwater away from the site
- Type B (low to moderate impact): Where the design profile is above the groundwater table and where the groundwater table is between:

    - Two to three metres below the ground surface (resulting in a moderate impact). These cuttings may require further and possibly ongoing monitoring, but are unlikely to require engineering intervention
    - Three to five metres below the ground surface (resulting in a low impact)
- Type C (no impact): Where the groundwater table is greater than five metres below the ground surface.

During construction, 98 cuttings would potentially have high impacts, 33 would have a moderate or low impact and 26 would not have any impacts. This is shown in Figure 9-34, with further details provided in the Working paper – Groundwater. The potential for cuttings to intersect groundwater supplies is also summarised in Table 9-12.

As much of the route has existing groundwater levels that are close to the ground surface, there is a strong likelihood that groundwater exposure and discharge would be an issue for construction in areas where watertables are shallow (ie Type A cuttings). In particular, if construction proceeds during wet conditions, waterlogging through groundwater discharge is likely in all areas where watertables are naturally within two metres of the land surface.

A precautionary approach was adopted in this assessment, where, if adequate groundwater information was not available, a higher class (ie Type A) was assumed for cuttings.

Due to the very low gradients of groundwater flow along the project boundary, and the proximity of the area to the ocean, the intersection of groundwater by road cuttings along the project would not have a significant impact on regional water table levels, including water table levels within the Woodburn Sand aquifer that supplies the Rous Water bore field. Groundwater supplies for irrigation, industrial, stock and domestic and environmental use would remain unchanged. The water regime required to sustain wetlands and other groundwater-dependent ecosystems would be unchanged and adverse impacts on groundwater-dependent ecosystems are not expected. Further discussion of the potential for impacts on the Rous Water bore field is provided below.

Impacts on Groundwater Dependent Ecosystems

The project has the potential to impact Groundwater Dependent Ecosystems through locally drawing down the groundwater table. There is then the potential to impact on the rate of flow and flow duration/frequency of local springs and/or creek flow outside of the cut footprint. Spring flow rates could decline or at worst, dry up. This could reduce or remove groundwater flow to associated Groundwater Dependent Ecosystems.

Where seepage occurs at a cutting, water is captured and redirected through drains to nearby creeks and is therefore less likely to recharge the groundwater systems immediately beneath the cut footprint. Groundwater Dependent Ecosystems have the potential to be impacted if this seepage is diverted away from a downstream Groundwater Dependent Ecosystem.

Groundwater Dependent Ecosystems would also be affected where rain water that would usually recharge the groundwater system is diverted away to nearby surface water systems.

Further information on impacts to Groundwater Dependent Ecosystems is identified in Chapter 10 (Biodiversity) of this EIS.

Table 9-12: Potential for the project to intersect groundwater supplies

Section	Proposed cuttings and associated groundwater supplies
1	From Woolgoolga, the project would leave the coastal sediments of the Coffs Harbour Region to rise over the Great Dividing Range and on to the consolidated sedimentary aquifers of the Clarence-Moreton Basin. There is a general lack of groundwater information in this section, although water tables are naturally shallow from station 4.0 to station 7.0, and are deeper in the higher country. The major cutting centred at station 2.5 is likely to intersect the water table and seepage is likely. Seepage from the unconsolidated sediments may generate significant water initially, and would impose a potential impact during construction, but ingress would decrease rapidly and is unlikely to be an issue during operation. A major cutting centred at station 7.9 would be through fractured rocks (Carboniferous greywackes), so while initial seepage would be low, there is unlikely to be adequate relaxation of the water table and ingress may continue to be an issue through the operational phase. As the project progresses over the Great Dividing Range and back into an undulating landscape, groundwater tables are generally low and construction would have a low potential impact on groundwater supplies. Ten out of 19 cuttings in this section would have high potential impacts (type A). Further information on these cuttings is in section 4.5 in Working paper – Groundwater.
2	Groundwater levels appear to be deep through Section 2, except where local recharge via creeks causes elevated levels, such as at Halfway Creek. The project would cross the consolidated sediments of the Clarence-Moreton Basin and would only require minimal changes to the existing landscape through this section. The project would have minimal impact on groundwater throughout the section. The 10 cuttings in this section would have either nil or low to moderate impacts (type B or C). Further information on these cuttings is in section 4.5 in Working paper – Groundwater.
3	As the project diverges east from the existing Pacific Highway, it would cut through the headwaters of a number of Clarence River tributaries, requiring numerous cuts and fills, which may potentially impact, and be impacted by, groundwater. Data for this area is extremely poor and a precautionary approach has been adopted until further information is gathered. Cuttings have therefore been assessed as having a high potential impact during construction. While information on groundwater is limited, local knowledge and the presence of waterholes associated with depressions suggests groundwater is near ground surface. Culverts have been designed to cope with continuous discharge as the base flow in these creeks is expected to be high. Thirty one out of 35 cuts identified as type A cuts. Further information on these cuttings is in section 4.5 in Working paper – Groundwater.
4	Section 4 would run adjacent to the South Arm of Clarence River, cross Shark Creek and run near SEPP 14 Wetland No. 232. This wetland is supported by groundwater discharge to the floodplain, with most observed groundwater levels at or close to sea level. The numerous cuttings proposed through unconsolidated sediments of the Clarence River alluvium would potentially invoke ingress of groundwater during construction. Shallow groundwater is likely to vary in depth with the seasons leading to a wetting/drying regime. The route would pass through an area of high acid sulfate soil risk. Seven out of 10 cuttings in this section would have high potential impacts (type A). Further information on these cuttings is in section 4.5 in Working paper – Groundwater.
5	Section 5 would cross the main waterways of James Creek, Clarence River at Harwood Bridge, Serpentine Channel and North Arm (upstream of Clarence River). Seven out of 16 cuttings in this section would have high potential impacts (type A). Further information on these cuttings is in section 4.5 in Working paper – Groundwater.
6	Section 6 would cross Nyrang Creek and Tabbimoble Creek. Tabbimoble Creek recorded high levels of aluminium, which could be a result of acid leaching from acid sulfate soils in the area. There would be minimal or no impacts in the southern part of the section due to the elevated landforms. However, further

Section	Proposed cuttings and associated groundwater supplies
	monitoring of groundwater levels would need to be undertaken to confirm that there would be no impacts. The construction of culverts and cuttings would pose the highest potential impact on groundwater levels in this section. One out of 3 cuttings in this section would have high potential impacts (type A). Further information on these cuttings is in section 4.5 in Working paper – Groundwater.
7	In section 7, the waterways are mostly ephemeral and only flow after heavy or prolonged rainfall. The landscape is subdued and data available on groundwater tables indicate that it is generally greater than five metres below ground level implying little or no impact. There is little available groundwater data in the area, with additional measurements required to be taken before and during construction to check the depth to the watertable in the low-lying country. Twelve out of 21 cuttings in this section would have high potential impacts (type A) (due to little available data). Further information on these cuttings is in section 4.5 in Working paper – Groundwater.
8	Section 8 would cross the main waterways of Macdonalds Creek and Tuckombil Canal. Both Rocky Mouth Creek (upstream of Tuckombil Canal) and Tuckombil Canal have highly variable water quality and are subject to acidic influxes from acid sulfate soils in the catchment. Midway through this section, the project would cross the Woodburn Sands aquifer, which is an important drought relief water supply for the region, managed by Rous Water (see section below for further impact assessment on the Woodburn Sands aquifer). Most of this section has a high inherent potential impact from shallow groundwater, though most of the section would be in fill. A further complication is that the landscape and, hence, the groundwater flow gradients, is extremely low (sub-horizontal) in this section and flow may vary seasonally and with wetting/drying climate cycles. In general, as construction proceeds, potential impacts on the groundwater supply should decrease as, where the project is on fill, this would provide an additional buffer between the road and the groundwater table. Five out of 10 cuttings in this section would have high potential impacts (type A). Further information on these cuttings is in section 4.5 in Working paper – Groundwater.
9	Section 9 contains the Tuckean Broadwater, Montis Gully and Eversons Creek. These waterways would have a considerable contribution from groundwater (base flow) and it can be expected that construction would pose a potential impact on the shallow groundwater in these perennially wet areas; this potential impact on groundwater would be high as there is potential to interfere with groundwater flow. All 8 cuttings in this section would have high potential impacts (type A). Further information on these cuttings is in section 4.5 in Working paper – Groundwater.
10	Section 10 contains the Richmond River and Randals Creek. Shallow groundwater would impose a construction impact in these perennially wet areas and construction may potentially impact groundwater flow. Cuttings in this section would initially encounter groundwater, though seepage would rapidly diminish as the project forms a drain to the groundwater flow and any localised groundwater mounds would decrease to the level of the surrounding groundwater systems across the floodplain. Construction needs to be mindful of ongoing seepage. Appropriate drainage and transfer of seepage to the downstream side of the project would be required. All 12 cuttings in this section would have high potential impacts (type A). Further information on these cuttings is in section 4.5 in Working paper – Groundwater.
11	Section 11 would cross the main waterways of Randals Creek, Duck Creek, and Emigrant Creek. Groundwater conditions in this section would be similar to sections 9 and 10, with shallow groundwaters throughout. Cuttings in this section would initially encounter groundwater, but seepage would rapidly diminish as the project forms a drain to the groundwater flow and any localised groundwater mounds would decrease to the level of the surrounding groundwater systems across the floodplain. Construction needs to be mindful of ongoing seepage. Appropriate drainage and transfer of seepage to the downstream side of the project would be required. Both cuttings in this section would have high potential impacts (type A). Further information on these cuttings is in section 4.5 in Working paper – Groundwater.

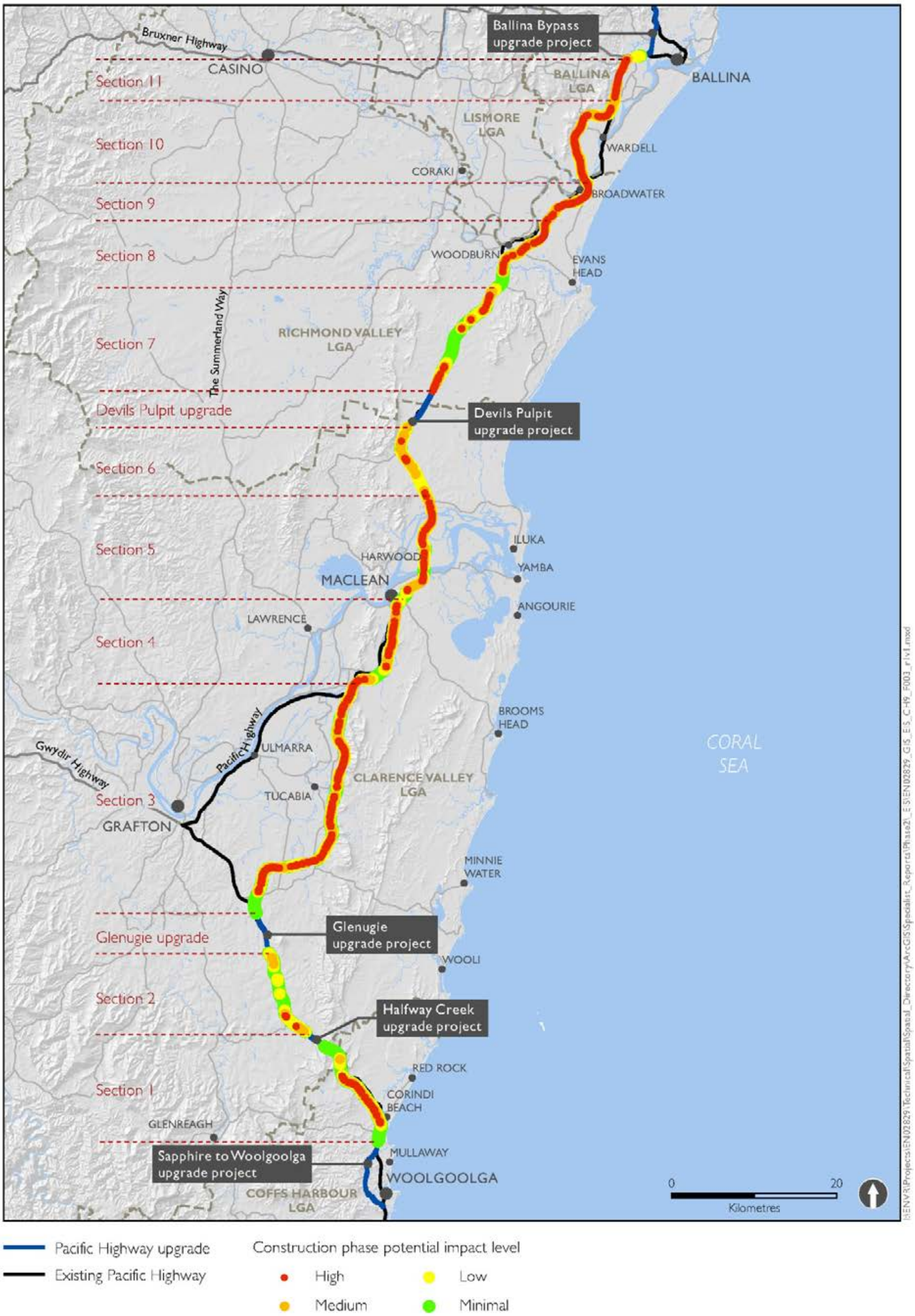


Figure 9-34: Groundwater construction impact levels

Impacts on the Rous Water bore field

The project elements that would cross the Rous Water bore field would mainly involve the placement of fill for the road embankment and would not involve any road cuttings. Therefore, construction of the project is not expected to intersect the shallow groundwater in this area and is not expected to have any effect on groundwater levels or flow rates in this area.

The Rous Water bore field area is known to contain potential acid sulfate soils in the subsurface, which would be an issue if the groundwater table were to significantly drop. The proximity of the area to the ocean, however, means that the floodplain elevation is less than three metres and the corresponding groundwater levels are at or slightly above sea-level and are unlikely to drop significantly. Hence, while there is a high probability of potential acid sulfate soils at depth, it is unlikely that these would be oxidised and develop into actual acid sulfate soils in the event of any fluctuations in groundwater levels. While water tables are within two metres of the ground surface, there is unlikely to be any acid sulfate soil impact on the bore field.

All construction runoff in the catchment of the bore field would be diverted to sedimentation basins, thus minimising risks to downstream water quality and the potential for infiltration of contaminants to groundwater. No runoff would bypass the basins untreated, regardless of the size of the footprint of the work. In addition, all basins in the bore fields would be clay lined to prevent leakage of water from the basins to groundwater. The sedimentation basins in the bore fields would be shallower than standard sedimentation basins (namely one metre in depth rather than two metres in depth) to avoid penetration of the natural clay layer, with an adequate volume achieved by adjusting the basin surface area. As the region is considered to be a sensitive receiving environment, basins that discharge to the catchment of the bore field would be designed to the 85th rainfall percentile volume. Activities associated with a high risk of chemical spills (such as fuel and chemical storage, refuelling, washdown, and installation of concrete batch plants) would also be excluded from the section of the project that crosses the Woodburn Sand aquifer and the bore field catchment to avoid risks of pollutant infiltration to groundwater in this area.

Further investigation needs to be carried out during the detailed design phase of the project to provide information on the thickness of the clay layer and the location of recharge areas so that groundwater protection strategies can be optimised.

Cumulative groundwater impacts

The assessment of the impact of the project on groundwater is discussed in detail in Working paper – Groundwater. The assessment of the impacts of the project on groundwater is considered to constitute a cumulative assessment, given the project covers a large area of the mid and far north coast region.

The project would only have localised impacts, with an overall low risk of impact to regional groundwater systems. This is due to the substantial volume and inertia of the groundwater sources along the coast that would buffer any short term impacts from construction (such as cuttings), while the low groundwater flow gradients moderate any long term impacts from operation (such as compaction).

Where groundwater is actively discharging to the surface or where groundwater is within two metres of the surface there is a higher potential for activities to impact on the groundwater. Discharging groundwater or levels within two metres of the surface occur in the low and undulating landscapes of the Clarence River floodplain and across the floodplains of the Richmond River where the river meets the coastal lowlands between Woodburn and Ballina.

Potential impacts to groundwater in both these areas would occur during construction, particularly in areas of cut, where groundwater ingress is likely. Once construction is complete, water tables would re-equilibrate. For most of the project alignment there would be little or no change. Locations where cuts would have a high potential impact and would require groundwater ingress to be controlled to maintain the local groundwater conditions are identified in Figure 9-34. Monitoring of groundwater changes would be required to determine effectiveness of management measures and the need for further controls. Impacts on stock and domestic bores within risk areas would be assessed during the detailed design phase with the aim of avoiding impacts on supply.

There are three groundwater bores operated by Rous Water Regional Water Supply located east of Woodburn in the Richmond Valley. The project would bisect the Rous Water Woodburn Sands borefield, which has groundwater levels that are close to the surface. Construction works would mainly involve placement of fill. As such, construction of the project would have little or no impact on water levels, and hence no impact on water supply in this area.

Potential risks to groundwater quality during construction include:

- Contamination by hydrocarbons from accidental fuel and chemical spills during construction activities.
- Infiltration of contaminated surface water runoff from unpaved surfaces.

The process of infiltration is generally effective in filtering polluting particles and sediment. Hence the risk of contamination of groundwater from any pollutants bound in particulate form is low. During construction, pollutants are most likely to be bound to particulate matter and would therefore be filtered during infiltration. However, some pollutants, such as certain hydrocarbons and solubles, may not be filtered through this process. Regardless, it is important to maintain barriers to potential pollution. Water quality controls including spill basins would be provided during construction and operation would provide these barriers.

Photo 4: View from Woodburn across to the Woodburn Sand borefield

9.3.2 Operational impacts

Once the highway upgrade is operating, there would be potential for impacts on soils, water quality and groundwater. However, the likelihood and severity of these potential impacts would be minimised by incorporating management and mitigation measures into the design of the highway upgrade, as described in Section 9.4. These measures would protect soils, receiving waters and groundwater.

Potential impacts are discussed below.

Impacts on soils

During operation, soil issues would be limited to the potential for:

- Oxidation of acid sulfate soils in the event that operational impacts on groundwater lead to lowering of the watertable
- Damage to new carriageways as a result of settlement of soft soils, in the event that soft soil areas are not adequately treated before construction
- Contamination from a fuel or chemical spill following vehicle accidents on the highway.

These potential impacts would be avoided through the implementation of appropriate engineering, management and mitigation measures, including water quality basins sized to accommodate fuel and chemical spills (refer Section 9.4).

Impacts on the water quality of nearby waterways

During operation, the main potential impact on water quality would be associated with runoff from stormwater and direct deposition of airborne particles, causing acute or chronic contamination of water quality in downstream waterways that receive discharged stormwater during rainfall events.

Pollutants from stormwater runoff include sediments, hydrocarbons, metals, and microbials. These deposits build up on road surfaces and pavement areas (including rest areas and truck checking stations) during dry weather and get washed off and transported to downstream waterways when it rains. Other pollutants in the atmosphere, derived from local and regional sources, would also be deposited and build up on the widened road pavement and contribute to impacts on water quality.

The publication Stormwater Flow and Quality and the Effectiveness of Non-Proprietary Stormwater Treatment Measures (Fletcher et al, 2004) derived pollutant load estimates for the range of land uses and impervious surfaces and for mean annual rainfalls of 600, 1200 and 1800 millimetres per year using MUSIC modelling. Due to the varying conditions along the project, the mean annual pollutant load would vary. At Woodburn for example, using information from Fletcher et al, provides the following approximate upper estimates of pollutant loads in stormwater runoff from one hectare of road in a single year:

- 3800 kilograms of total suspended solids
- 20 kilograms of total phosphorous
- 60 kilograms of total nitrates.

In addition, accidental spills of petroleum, chemicals and hazardous materials as a result of vehicle leaks or accidents, and waste discarded by motorists, could pollute downstream waterways and groundwater sources.

The potential impacts of reduced water quality on sensitive receiving environments have also been considered. Because the project includes design measures to minimise the likelihood of impacts on water quality, operation of the project would be unlikely to have an adverse impact on sensitive receiving environments and high risk areas.

Overall, potential impacts on water quality would be avoided through the implementation of appropriate engineering, management and mitigation measures, including water quality basins sized to accommodate fuel and chemical spills (refer Section 9.4).

Impacts on groundwater and drinking water

The project would have potential impacts on groundwater from runoff and cuttings, as discussed below.

Impacts of surface runoff on groundwater and drinking water

In identifying hazards to the water quality of a groundwater source, as per the Australian Drinking Water Guidelines (NHMRC and NRMMC, 2011), the main hazard would be pollutant runoff from the road surface infiltrating groundwater. The risks of groundwater pollution depend on the depth to groundwater and the permeability of the soils and geology that overly groundwater reservoirs. Where groundwater is shallow or not protected from direct infiltration, the risks of pollution would vary depending on the nature of the pollutants of concern. The process of infiltration is generally effective in removing insoluble substances and contaminants that are readily bound to sediment particles, including heavy metals and hydrocarbons like oils, tars and petroleum. Therefore, runoff or spills of these substances have a relatively low risk of causing groundwater contamination. In contrast, soluble pollutants, such as acids, alkalis, salts and nitrates are less readily removed by the infiltration process and have a greater chance of reaching groundwater.

The groundwater source for the Rous Water supply near Woodburn is protected from direct infiltration by a clay layer, with the result that the risks to groundwater in this area would be low. However, this clay layer is leaky and locally exhibits preferential recharge to the sands below. In addition, the clay layer may have been breached where drainage channels have been constructed in adjoining irrigated paddocks.

Potential impacts on groundwater would be avoided through the implementation of appropriate engineering, management and mitigation measures (refer to Section 9.4) and consideration of the Australian Drinking Water Guidelines and the Guidelines for Assessment and Management of Contaminated Groundwater (DEC, 2007). These measures would include the treatment of runoff prior to release to surface water systems to meet the ANZECC guidelines. In sensitive receiving environments, basins would be lined with clay or a geosynthetic clay liner to avoid exfiltration or seepage through cracks in the base of the basin prior to release of the water from the basin.

Impacts of cuttings on groundwater

In areas where cuttings penetrate water tables, ongoing seepage would occur unless measures are put in place. Cuttings in areas of naturally high groundwater (such as coastal sands and alluvial aquifers) would see a reduced risk over time as groundwater pressures relax and re-equilibrate under the elevated discharge regime. In areas cut into rocks of low permeability (such as fractured rocks and porous sediments), the risk would remain high as groundwater pressures would not relax and seepage may continue throughout the life of the road.

This change in groundwater pressures would result in only eight per cent of cuttings on the project remaining as type A cuttings over the longer term, 45 per cent would become type B, and 47 per cent would become type C cuttings. This is shown in Figure 9-35, with further details provided in the Working paper – Groundwater.

In locations where significant cuttings would intersect the existing water table, infiltration of unpolluted groundwater back into the ground would be facilitated by the collection of the groundwater in grassed swales. Groundwater that contains pollutants would be treated in water quality basins before either discharge to natural waterways, evaporation, or infiltration to downstream groundwater.

Impacts during operation in high risk areas include:

- In Section 4, areas of fill may induce variable ponding on the upstream side of the project and drying on the downstream side. Due to the very low groundwater gradients in this area, upstream and downstream may alternate with the seasons, which can further exacerbate the risk of acid release in this section
- In Section 5, major works at the sites of bridges would be impacted by shallow groundwater tables but are unlikely to impose any impact on the groundwater resource, or on groundwater supply for wetlands

- In Section 9, most of this project section would be fill, so potential impacts are expected to be low. If wetter conditions prevail, however, groundwater tables may rise and there would be some risk of pavement damage as well as potential salinisation caused by ponding associated with near-surface compaction. Seasonally varying shallow groundwater tables characterise the region and this may cause local impacts during wetter periods
- In Section 10, most of the section would be fill, so impacts are expected to be low. There is also the potential for oxidation of potential acid sulfate soils and corresponding release of acidity downslope of the project due to seasonally variable groundwater tables
- In Section 11, most of the section would be in fill, so impacts are expected to be minimal, although shallow water tables might pose a risk to pavement damage and careful monitoring for potential salinisation is advised. There is also the potential for oxidation of potential acid sulfate soils and possible release of acidity downslope of the project induced by seasonally varying groundwater tables.

With the proposed design measures, operation of the project is not expected to have a significant impact on groundwater. The effectiveness of impact mitigation measures would be assessed through a monitoring program (refer Section 9.4).

Photo 5: Location near station 134.6 – waterways such as this provide good quality aquatic habitat

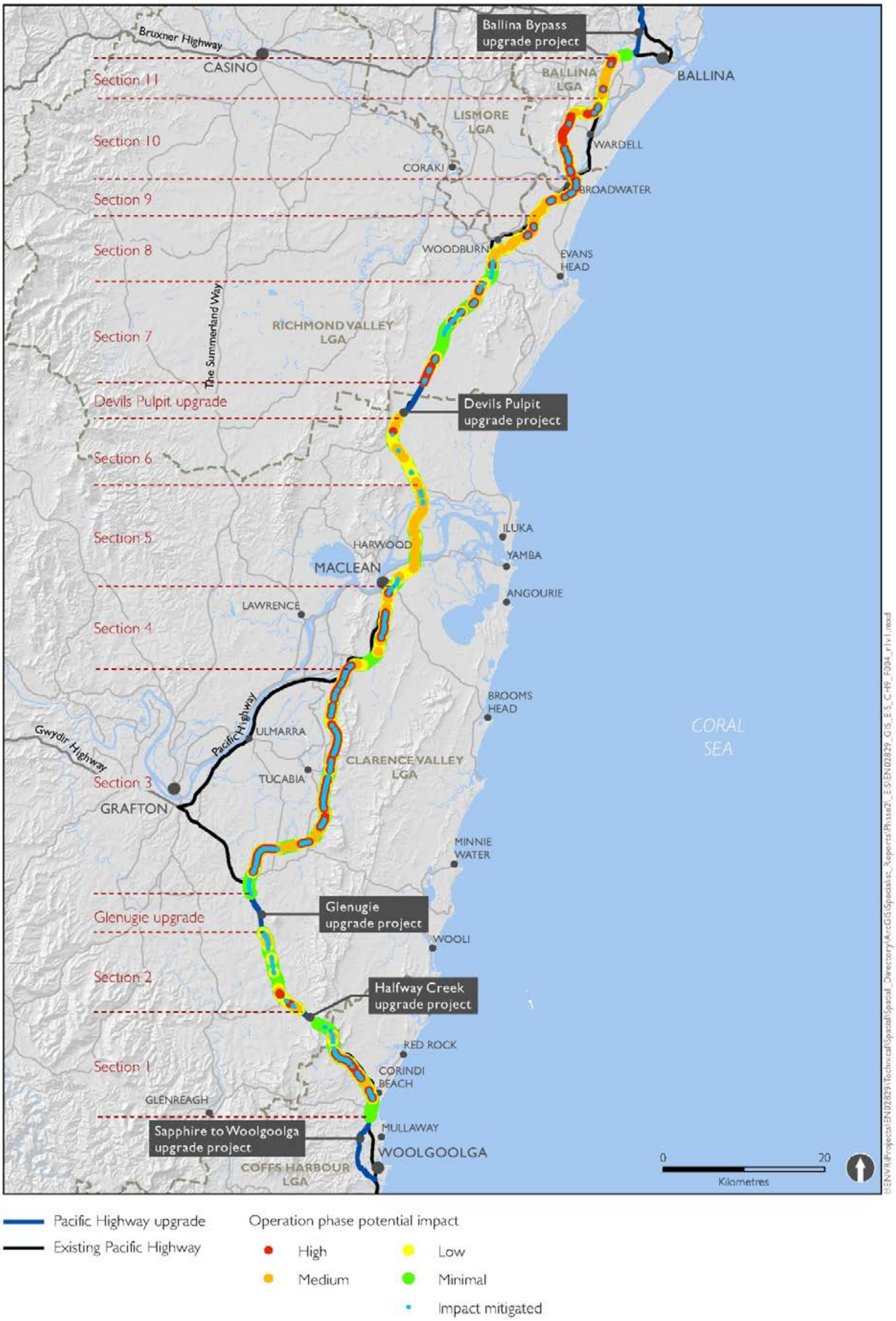


Figure 9-35: Impact of the project during operation on groundwater

9.4 Management of impacts

9.4.1 Protection of water quality during construction

During construction, temporary sedimentation basins would be installed to protect water quality. The location, design and maintenance of these sedimentation basins are outlined below.

These measures detailed in this report are consistent with industry standards such as Blue Book (Landcom, 2004 and DECC, 2008). The measures contained in the Blue Book are based on field experience and have been previously demonstrated to be effective in mitigation during construction. Strict conformance with the requirements of the Blue Book during the construction period would be required to ensure that the predicted effectiveness is achieved.

Temporary sedimentation basins

During construction, temporary sedimentation basins would be installed to intercept sediment-laden runoff and retain the sediment and attached pollutants. Temporary sedimentation basins have been designed for the project in accordance with the 'Blue Books' - Managing Urban Stormwater: Soils and Construction Vol. 1 (Landcom, 2004) and Managing Urban Stormwater: Soils and Construction Chapter 2d – Main Road Construction (DECC, 2008a).

A geographic assessment was undertaken to determine existing catchments along the project, using the 12D modelling software. A further assessment of the catchments was undertaken, based on the proposed upgraded road alignment. The locations for construction phase sedimentation basins were selected to best capture runoff from these catchments throughout the full construction process, using gravity-driven diversion drains to divert runoff to the basins. Where possible, existing natural features have been incorporated into the treatment system. Indicative locations for these sedimentation basins are shown in Figure 6-1 to Figure 6-42. The final locations and sizes of sedimentation basins would be confirmed during detailed design.

Sites for sedimentation basins

The sites for sedimentation basins have been selected to avoid impacts on properties and sensitive areas to the greatest extent practicable. Where the water table is identified as being within two metres of the base of a sedimentation basin, the basin would be lined to prevent seepage and potential impacts on groundwater. The design, location and sizing of sedimentation basin, would be fine-tuned throughout the detailed design phase.

Sections 4, 5, 8, 9 and 11 of the project would be situated on floodplains, which are relatively flat. In these sections, sedimentation basins would be located about every 400 metres so that on-site diversion drains can be constructed with sufficient grade to convey site runoff to the basins. As the catchment areas for basins located on floodplains are relatively small, the basins would provide a settling period for sediments suspended in runoff during rainfall events. Basins would then overflow as sheet flow with low velocity into the surrounding floodplain, reducing the impact on water quality to an acceptable level.

Design criteria for sedimentation basins

Where construction takes place in areas that would affect sensitive receiving environments, the design criteria for sedimentation basins have been made more stringent to increase the level of treatment provided to construction runoff before its release. Where the project has the potential to impact sensitive receiving environments, as identified in Table 9-6, basins have been sized to contain the five-day 85th percentile rainfall value. In high risk locations such as the Solitary Island Marine Park five-day 90th percentile capacity basins would be examined and considered.

In other areas, where the project is unlikely to impact a sensitive receiving environment, basins have been sized based on the 80th percentile rainfall. All basins in sections 1–3, 5–8 and 10–11; and more than 80 per cent of the basins in sections 4 and 8 have been designed to the 85th percentile rainfall value.

Timeframe for sedimentation basins

Construction phase sedimentation basins would be integrated with the strategy for permanent water quality ponds as far as practicable. Where appropriate and required, construction phase sedimentation basins would therefore be designed so that they could be retained and used as operational water quality ponds.

In locations where sedimentation basins would be used only for the construction stage, additional land outside the road corridor would be leased for the location of these basins during the construction phase of the project. These temporary basins would be mainly situated on floodplains. The flat topography of these areas means that swales would be the most appropriate form of water quality treatment during the operational stage. As such, construction phase sedimentation basins could be removed once construction is complete.

The following management and maintenance procedures would be implemented for the temporary sedimentation basins:

- Inspections would be undertaken at regular intervals and following significant rainfall events to assess available water storage capacity, water quality, structural integrity and debris levels
- Where appropriate, an approved flocculent would be applied to sedimentation basins as early as possible so that early mixing of flocculants occurs. Water quality would be tested prior to discharge in accordance with any licence requirements
- Where sediment has built up in a basin to a point where greater than 30 per cent of its total capacity has been used, sediment would be removed and appropriately disposed of
- Water from sedimentation basins would be used for construction purposes, such as dust suppression, where feasible
- When sedimentation basins require pumping out rather than discharge via a flow outlet, a float would be attached to the suction hose or the hose would be located inside a bucket to prevent the discharge of sediment from the basin floor
- Records would be kept of water quality monitoring and erosion and sediment control inspections, including details of rain events, use of flocculants, discharge, sediment removal and dewatering activities.

9.4.2 Protection of water quality during operation

Permanent water quality management and protection measures would be installed to protect adjacent waterways from pollutants generated by operation of the project. These would include:

- Water quality ponds
- Grassed swales
- Gross pollutant traps.

All management and mitigation measures would be maintained for the operational life of the project.

These measures have been modelled using the industry established MUSIC model developed by eWater Catchment Hydrology CRC. The modelling undertaken in the MUSIC model is based on algorithms that have been previously demonstrated to be effective in mitigation during highway operation. Strict conformance with the appropriate ongoing maintenance of these controls is required to ensure the predicted effectiveness is achieved.

Water quality ponds

Where sensitive areas are located downstream of the project, water would be directed to permanent water quality ponds. All water quality ponds would incorporate measures to contain accidental fuel and chemical spills resulting from vehicle accidents on the highway. Specifically, to prevent any spills from reaching downstream ecosystems and groundwater used for drinking water supply, basins would be designed to accommodate a spill volume of up to 40,000 litres.

A preliminary assessment of the size requirements for water quality ponds has been undertaken. Water quality pond locations and volumes have been calculated based on the water quality treatment targets. Pond volumes would range from 540 to 620 cubic metres per hectare, depending on the location and impervious area within the catchment. Indicative locations and size requirements for permanent water quality ponds for each project section are identified in the Working paper – Water quality.

Grassed swales

Water quality ponds are not proposed for areas of lower environmental sensitivity. In these areas, water would be directed through open swales beside the road, which would be designed to contain spills prior to discharge into local creeks. In most locations, water would drain directly off the road into these swales. For water quality treatment in floodplains and other locations with minimal changes in gradient, grassed swales would provide sufficient treatment to meet the water quality treatment targets. Where necessary, to reduce flow concentration and mitigate scour erosion, rock check dams may be constructed across the swales. The sizes and locations of rock check dams would be determined during detailed design.

Photo 6: Example of a lined / grassed swale

Monitoring program

Water quality monitoring

A water quality monitoring program would be developed prior to construction and include details of the monitoring objectives and commitments in relation to baseline data, locations of monitoring sites, the frequency and duration of monitoring, and parameters to be monitored. The monitoring program would be developed with input from relevant agencies including, but not limited to, the Environmental Protection Authority and Department of Primary Industries. The monitoring plan would comply with the requirements of Australian Standard AS/NZS 5667.1 1998 – Water quality Sampling Guidance and the ANZECC/ARMCANZ (2000) Australian Guidelines for Water quality Monitoring and Reporting.

Water quality monitoring would be undertaken during the pre-construction and construction phases of the project in accordance with RMS' Guideline for Construction Water quality Monitoring (RTA, 2003).

The objectives of pre-construction monitoring are to:

- Identify parameters for monitoring during construction
- Determine the indicative existing water quality.

The objectives of construction monitoring are to:

- Identify if any water quality changes are occurring as a result of construction activities
- Demonstrate compliance with legal and other monitoring requirements including any Environmental Protection Licence.

Pre-construction monitoring would be undertaken where the previous water quality sampling results for the intersected waterways are more than one year old.

Water quality monitoring would also be carried out during the operational phase of the project for at least two years or until results demonstrate the construction site has stabilised and sampling can be discontinued. The objectives of operational phase monitoring would be to:

- Assess the effectiveness of the site stabilisation process following construction
- Assess the effectiveness of the permanent water quality ponds and grassed swales
- Assess the need for additional impact mitigation and management measures.

The requirements for construction and operational phase water quality monitoring would be detailed in the soil and water management plan; additional specific requirements for monitoring acid sulfate soils issues would be identified in the acid sulfate soils management plan.

Water quality thresholds would be developed prior to construction, either through an Environmental Protection Licence (EPL), in consultation with Department of Primary Industries (Fisheries) and against the criteria in ANZECC/ARMCANZ (2000) guidelines for protection of aquatic ecosystems. The thresholds would be listed in the project Water quality Monitoring Plan. An outline of the monitoring program is provided in the Working paper – Water quality.

Groundwater monitoring

Groundwater level, flow and quality would be monitored during pre-construction, construction and operation to verify the predictions of groundwater behaviour. Both cuttings and major embankment areas would be subject to monitoring.

The objectives of pre-construction phase monitoring are to:

- Identify parameters for monitoring during construction
- Determine the indicative existing groundwater conditions (that is, depth below ground surface and groundwater quality).

The objectives of the construction phase monitoring are to:

- Identify if any groundwater problems are occurring as a result of construction activities
- Identify where groundwater may be intersected by the construction works and hence require additional constraints for the works

- Demonstrate compliance with legal and other monitoring requirements including the water quality criteria and/or targets for the project.

Groundwater monitoring would also be carried out during the operational phase of the project.

The objectives of operational phase monitoring would be to:

- Assess and manage impacts on the receiving waters as the site stabilises
- Assist in deciding when the site has stabilised and in setting a new baseline condition for each site.

Monitoring would be undertaken monthly until results demonstrate the site has stabilised. Subsequently, monitoring would be undertaken quarterly at designated monitoring bores. This would be for a period of at least five years, at which point a review of data would determine whether further monitoring is required.

Groundwater monitoring would be undertaken in accordance with the Australian Drinking Water Guidelines (NHMRC and NRMMC 2011) and the Guidelines for Assessment and Management of Contaminated Groundwater (DEC, 2007).

The requirements for construction and operational phase groundwater monitoring would be detailed in the soil and water management plan. An outline of the monitoring program is provided in the Working paper – Groundwater.

General mitigation measures

Measures identified for the management of soil, sediment and water quality impacts are detailed in Table 9-13. These mitigation measures are a summary of those identified in the Working paper – Water quality and Working paper – Groundwater.

Table 9-13: Soils, sediment and water quality mitigation measures

Issue	Mitigation ID no.	Mitigation measure	Timing	Relevant section
Design of cut-and-fill batters	SSW1	• Batters to be designed using appropriate slope gradients to minimise erosion of selected covering topsoil where possible, to minimise the erosion potential.	Pre-construction	All
	SSW2	• Where cuttings are to be benched, benches would be diverted onto contours and surface flow drainage paths designed to spread flow at the source in preference to concentrating the flow and treating it further downstream, with consideration of site constraints.	Pre-construction	All
Management of soils, sediment and water issues	SSW3	• As part of the Construction Environmental Management Plan, a soils and water management plan would be prepared and include (but not limited to): • Erosion and sediment control plans for all stages of construction • Consideration of soil erodibility • At-source erosion controls (eg check dams) • Sedimentation basin construction and management • Protection of waterways • Acid sulfate soil issues • Management of stockpiles • Tannin leachate management control • Batch plant/ chemical storage controls • Water quality monitoring and checklists • Detailed consideration of measures to prevent, where possible, or minimise any water quality impacts.	Pre-construction	All
	SSW4	• Erosion and sediment control plans would be developed in line with current RMS specifications and as detailed in the Working paper – Water quality.	Pre-construction	All
	SSW5	• A soil conservationist would be engaged during detailed design to develop an erosion and sedimentation management report to inform the soils and water management plan.	Pre-construction	All
	SSW6	• Sedimentation basins and water quality ponds would be sized and located in accordance with the principles identified in the Working paper – Water quality.	Pre-construction and construction	All
	SSW7	• Exposed areas would be progressively rehabilitated. Methods would include permanent revegetation, or temporary protection with spray mulching or cover crops.	Construction	All

Issue	Mitigation ID no.	Mitigation measure	Timing	Relevant section
	SSW8	• Approval would be obtained from relevant agencies for permanent and temporary waterway crossing. Each contractor would be required to comply with any conditions the approval authority imposes.	Construction	All
Stockpile management	SSW9	• Topsoil, earthworks and other excess spoil material would be stockpiled in accordance with RMS Stockpile Management Guidelines (RMS, 2011a).	Construction	All
	SSW10	• The maintenance of established stockpile sites would be in accordance with RMS' Stockpile Management Guidelines (RMS, 2011a).	Construction	All
	SSW11	• Stockpiles would be positioned in low, flat elongated embankments with a height not exceeding 2.5 metres and batter slopes not steeper than 2H:1V.	Construction	All
	SSW12	• Stockpiles would be placed within a designated ancillary site and would: • not require removal of areas of native vegetation (where reasonable and feasible) • not be located under the 'dripline' of trees • be located outside of known areas of weed infestation • be located such that waterways and drainage lines are not directly impacted.	Construction	All
	SSW13	• Where practicable, stockpiles would be located away from areas subject to concentrated overland flow. Stockpiles located on a floodplain would be finished and contoured so as to minimise loss of material in flood or rainfall events.	Construction	All
	SSW14	• Materials which require stockpiling for longer than 28 days would be stabilised by compaction, covering with anchored fabrics, or seeded with sterile grass.	Construction	All
	SSW15	• Potential runoff from stockpiles would be controlled by a suitable sediment trap such as a sediment fence or compost berm.	Construction	All
	SSW16	• Topsoil would be stockpiled separately and inspected for noxious weed seedlings at six monthly intervals and controlled with herbicide as required.	Construction	All
	SSW17	• All construction stockpiles would comply with the requirements of the *Protection of the Environment Operations Act 1997* and NSW Waste Avoidance and Resource Recovery Strategy 2007 for any waste activities that involve the generation, storage and/or disposal of waste and also consider the NSW Resource Recovery Exemptions as applying the storage of stockpiled material.	Construction	All
	SSW18	• Stockpiles containing potential acid sulfate soils would be lined, bunded and covered in accordance with relevant guidelines.	Construction	All

Issue	Mitigation ID no.	Mitigation measure	Timing	Relevant section
	SSW19	• Management of tannin leaching from vegetation mulch stockpiles into waterways would be in accordance with RMS' Environmental Direction – Management of Tannins from Vegetation Mulch (RMS, 2012). Management measures would include: • Locating vegetation stockpiles away from overland flowpaths • Diverting runoff around vegetation stockpile sites • Minimising the number and size of vegetation stockpiles • Lining the base of vegetation stockpiles if they are located over a shallow water table • Treating vegetation stockpiles by covering them with plastic sheets or collecting stockpile drainage in a stockpile-specific sedimentation basin or sump and monitoring the water quality of the basin to determine its suitability for discharge to the environment.	Construction	All
Management of contamination	SSW20	• Opportunities to refine the project alignment in vicinity of the Tucabia landfill and old Maclean Shire Council landfills would be investigated.	Pre-construction	3
	SSW21	• A Stage 1 Preliminary Site Investigation would be conducted to verify past and present potentially contaminating activities, potential contaminants of concern and the need for further investigation. This would include a review of past highway crashes and spills and the associated contamination risks.	Pre-construction	All
	SSW22	• If necessary (based on the results of the Stage 1 Preliminary Site Investigation), a Stage 2 Detailed Site Investigation would be undertaken to: • Provide information on the type, nature, extent and concentrations of contamination present, and the corresponding risks to human health and the environment • Examine pathways of contaminant dispersal and exposure, the potential for off-site impacts and the management requirements and options.	Pre-construction	All
	SSW23	• If the Stage 2 Detailed Site Investigation recommends further action, a Stage 3 Remedial Action Plan would be produced, detailing the remediation goals, environmental safeguards, and any necessary approval and licence requirements.	Pre-construction	All
	SSW24	• Where further assessment indicates that further action is not required, RMS' Contaminated Land Management Guideline (RTA, 2005a) would be applied to address any contamination issues and prevent any associated adverse impacts.	Pre-construction	All
	SSW25	• Where required, a remedial action plan or appropriate environmental management plan would be prepared to remove and/or manage the contamination risks in accordance with NSW Office of Environment and Heritage guidelines.	Pre-construction	All

Issue	Mitigation ID no.	Mitigation measure	Timing	Relevant section
	SSW26	• A hazardous materials buildings assessment would be carried out before the demolition of any structures or buildings to identify the issues of concern and the management requirements. This is required under Clause 1.6 of Australian Standard AS 2601 – 2001 The Demolition of Structures.	Construction	All
Emergency spill response	SSW27	• An emergency spill response plan would be developed and incorporated into the soils and water management plan. This plan would detail measures for the prevention, containment and clean-up of accidental spills of fuels and chemicals.	Construction	All
	SSW28	• The storage, handling and use of the chemicals and fuels would be in accordance with the Work Health and Safety Act 2000 and Workcover's Storage and Handling of Dangerous Goods Code of Practice (WorkCover, 2005).	Construction	All
Acid sulfate soils	SSW29	• Where it is identified that a temporary sedimentation basin or permanent water quality pond is located in an area of acid sulfate soil, the basin sizing would be reviewed to reduce basin depth to avoid excavation into the acid sulfate soil layer. The minimum allowable depth would be in accordance with the Blue Book, with the volume of the basin maintained. Alternatively, where not feasible, clay capping/ lining of the basin would be undertaken.	Pre-construction	All
	SSW30	• Acid-resistant construction materials would be used where possible in areas known to contain acid sulfate soils.	Construction	All
	SSW31	• Where excavation is to be carried out in areas anticipated to contain acid sulfate soils, works would proceed according to the acid sulfate soils management plan. Specific controls to be implemented would include: • Capping of exposed surfaces with clean fill to prevent oxidation. • Placing excavated acid sulfate soils separately in a lined, bunded and covered area. • Neutralising acid sulfate soils for reuse (where appropriate) by using additives such as lime. • Disposing of acid sulfate soils where necessary in accordance with the relevant guidelines set out in DECC (2008b).	Construction	All
	SSW32	• If acid sulfate soils are disturbed, any acid produced would be neutralised and acid waste leaving the site would be prevented in accordance with the applicable guidelines.	Construction	All

Issue	Mitigation ID no.	Mitigation measure	Timing	Relevant section
Soil erosion and sedimentation control	SSW33	• Appropriate erosion and sediment controls, following the guidelines of the 'Blue Books' (Landcom, 2004 and DECC, 2008a), would be established before the start of construction and maintained in effective working order for the duration of the construction period until site stabilisation. Specific controls would include: • Sediment fences and filters to intercept and filter small volumes of non-concentrated construction runoff • Rock check dams across swales and diversion channels to reduce the velocity of flow, thereby reducing erosion of the channel bed and trapping sediment • Level spreaders to convert erosive, concentrated flow into sheet flow • Diversion drains that collect construction runoff and direct it away from unstable and/or exposed soil to treatment facilities • Diversion drains to collect clean runoff from upstream of the construction area and divert it around or through the site without it mixing with construction runoff • Lining of channels and other concentrated flow paths • Sedimentation basins to capture sediment and associated pollutants in construction runoff (see further details below) • Specific measures and procedures for works within waterways, such as the use of silt barriers and temporary creek diversions, in accordance with RMS' Technical Guideline – Temporary Stormwater Drainage for Main Road Construction (RMS, 2011b).	Construction	All
	SSW34	• Sensitive receiving environments would be reconsidered during detailed design to include any threatened ecological communities and non- aquatic species and their habitats that may be affected by the project. Appropriate management measures would be implemented, if required.	Pre-construction	All
	SSW35	• When designing and implementing specific measures and procedures for works within waterways, consideration would be given to the need to maintain fish passage.	Construction	All
	SSW36	• The design and construction of works within riparian corridors and within the minimum required distance from waterways would be undertaken in accordance with NSW Office of Water guidelines for working within riparian corridors.	Pre-construction and construction	All
	SSW37	• Flow discharge points would be designed with erosion controls to slow the flow velocities.	Pre-construction	All
	SSW38	• In steep areas, the length between sediment fences and other physical controls would be decreased to reduce soil erosion.	Construction	All

Issue	Mitigation ID no.	Mitigation measure	Timing	Relevant section
	SSW39	• Construction sequencing and temporary diversions of water would be developed and designed to consider the impact of change on flow regimes and to minimise these changes throughout construction.	Pre-construction and construction	All
Design and maintenance of construction sedimentation basins	SSW40	• Where appropriate and required, construction phase sedimentations basins would be designed so they could be retained and used as permanent operational water quality ponds.	Construction	All
	SSW41	• Sediment basins would be located within the permanent boundary where possible, or on leased land, subject to approval from the landowner.	Construction	All
	SSW42	• The final locations and sizes of sedimentation basins would be confirmed during detailed design.	Construction	All
	SSW43	• Sizing of sedimentation basins that drain into the Solitary Islands Marine Park would be reviewed to consider the use of 100th percentile sedimentation basins.	Construction	Section 1
	SSW44	• In areas of highly erodible soils or in areas of large excavations or embankment construction, sedimentation basins would be designed to include sediment storage capacity sufficient for the increased sediment loading in these areas.	Pre-construction and construction	All
	SSW45	• Sedimentation basins would be inspected at regular intervals and following significant rainfall events to assess available water storage capacity, water quality, structural integrity and debris levels.	Construction	All
	SSW46	• Where appropriate, an approved flocculent would be applied to sedimentation basins as early as possible so that early mixing of flocculants occurs. Water quality would be tested prior to discharge in accordance with any licence requirements.	Construction	All
	SSW47	• Where sediment has built up in a basin to a point where the total sediment storage zone has reached capacity, sediment would be removed and appropriately disposed of.	Construction	All
	SSW48	• Water from sedimentation basins would be used for construction purposes, such as dust suppression, where feasible.	Construction	All
	SSW49	• When sedimentation basins require pumping out rather than discharge via a flow outlet, a float would be attached to the suction hose or the hose would be located inside a bucket to prevent sediment from the basin floor from being discharged.	Construction	All

Issue	Mitigation ID no.	Mitigation measure	Timing	Relevant section
	SSW50	• Records would be kept of water quality monitoring and erosion and sediment control inspections, including details of rain events, use of flocculants, discharge, sediment removal and dewatering activities.	Construction	All
Chemical use and storage	SSW51	• Physical controls to address the potential risks associated with the use and storage of chemicals on site would include: • Use of appropriately bunded storage facilities for chemicals and fuels • Use of appropriately bunded areas for refuelling and washdown • Availability of effective spill kits at all construction sites.	Construction	All
Ancillary facility management	SSW52	• Measures to be implemented to minimise impacts to surface and ground water quality include: • Bunded storage facilities for chemicals and clay lined where located on land where groundwater is within two metres of the ground surface • Bunded areas for refuelling and washdown • Locating storage areas away from areas of known near-surface groundwater supplies, in areas where the water table is more than five metres below the surface, otherwise the areas are to be lined if they are located over a shallow groundwater source less than two metres deep. Providing bunded storage facilities for chemicals; these bunded areas would be lined with clay where located on land where groundwater is within two metres of the ground surface • Providing bunded areas for refuelling and washdown • Locating storage areas away from areas of known near-surface groundwater supplies, in areas where the water table is more than five metres below the surface; otherwise, the areas would be lined if located over a shallow groundwater source less than two metres deep.	Construction	All

Issue	Mitigation ID no.	Mitigation measure	Timing	Relevant section
	SSW53	• At ancillary facilities, management of runoff and spills would include: • Restricting vehicle movements to designated pathways where feasible • Paving areas that would be exposed for extended periods, such as car parks and main access roads, where feasible • Diverting off-site runoff around sites where required • Locating chemical or other hazardous material storage areas away from areas of known near-surface groundwater supplies, in areas where the water table is more than five metres below the surface; otherwise, areas would be lined if they are to be located over a shallow groundwater source less than two metres deep • If the above local controls are not implemented, and where required, treating onsite runoff with a construction or compound-specific sedimentation basin, which would be monitored for parameters such as dissolved oxygen levels and organics to determine suitable discharge to the environment (such basins would be considered during detailed design).	Construction	All
	SSW54	• Where possible, stockpiles, vehicle washdown, batch plants, refuelling and chemical storage sites would be located in areas where the groundwater table is located greater than five metres from the surface.	Construction	All
	SSW55	• Mitigation of borrow source sites (particularly Lang Hill) would be in line with Volume 2E of the Blue Book which covers water management of mines and quarries.	Construction	8,10
	SSW56	• Management of soil and erosion issues at borrow sources would include : • Development of detailed site specific erosion sediment control plans for borrow sources covering construction and rehabilitation of the site (considering the needs for any adjacent aquatic habitats). • Diverting upstream runoff around borrow sources. • Treating runoff from borrow sources at the source as per the Blue Book (Landcom, 2004 and DECC, 2008) requirements, or otherwise treating with a site-specific sedimentation basin and monitoring the sedimentation basin for parameters such as dissolved oxygen levels, pH and organics to determine suitable discharge to the environment (such basins would be considered during detailed design).	Construction	8,10

Issue	Mitigation ID no.	Mitigation measure	Timing	Relevant section
	SSW57	• Runoff from the Lang Hill borrow source would be treated by a sedimentation basin. The required water quality parameters for the basins discharging into this area would be determined during detailed design based on pre-construction water quality monitoring. These would be included in the EPL. Discharges from the sediment basins during construction that do not meet the water quality parameters for Oxleyan Pygmy Perch habitat should not be discharged into the waterway but rather sprayed into adjacent open grass areas or used for construction purposes such as dust suppression to avoid changing water depth and physico-chemical conditions in the potential Oxleyan Pygmy Perch Habitat. If it is not feasible to irrigate to land to completely re-use sediment basin water, then as a last resort discharge water from sedimentation basins to Oxleyan Pygmy Perch waterways will be treated to ensure it has the correct pH of less than 6.5 and total suspended solids of less than 50mg/L.	Construction	8
Management of groundwater intersection	SSW58	• Further assessment involving geotechnical boreholes, monitoring boreholes and water quality testing at cutting sites would be undertaken at deep cutting sites to confirm that impacts would be limited to minor impacts on local groundwater reserves.	Pre-construction	All
	SSW59	• Where groundwater is released, recharge of the water table is the preferred option of managing groundwater. This would be facilitated by collecting groundwater in grassed swales for infiltration back to the groundwater source. Where possible, these swales would divert the groundwater around the construction area so that the groundwater does not further mix with construction runoff.	Construction	All
	SSW60	• If recharging is not possible or suitable, then discharging groundwater would be collected via the sedimentation basins before discharge into natural waterways. If discharging to downstream groundwater, then the potential effects of mounding1 would be mitigated.	Pre-construction	All
	SSW61	• Dewatering of excavations would be undertaken in line with RMS' Technical Guideline – Environmental Management of Construction Site Dewatering (RMS, 2011c), and in accordance with any licence conditions.	Construction	All

[1] An outward and upward expansion of the free water table caused by surface recharge.

Issue	Mitigation ID no.	Mitigation measure	Timing	Relevant section
Prevention of groundwater impacts at type A and type B cuttings and major embankments	SSW62	• The proposed management strategy to address potential impacts at type A cuttings includes: • Pre-works investigations – geotechnical investigations of cuts to determine groundwater condition (quality parameters: electrical conductivity, groundwater depth, geological information), presence of actual or potential acid sulfate soils, presence or potential of salinisation, establishing groundwater monitoring sites, and gathering of other pertinent information • Assessment – involving this study, the pre-works investigations carried out, groundwater modelling of cuts (and the Rous Water Woodburn borefield site), and predictions made from those results • Monitoring – to assess whether the investigation and its predictions are accurate and to instigate early intervention in the unlikely case/s that the actual outcomes deviate from predictions. Monitoring would start before construction, and continue during construction. Monitoring would also continue into the operation phase of the project until groundwater conditions have stabilised • Mitigation – implement environmental and engineering management measures where predictions and/or modelling and monitoring suggest that these are required to minimise impacts on groundwater.	Pre-construction and construction	All
	SSW63	• The monitoring of type B cuttings and major embankments would commence before construction to identify the need to implement any mitigation measure.	Pre-construction, construction and operation	All
	SSW64	• If required to manage groundwater impacts at type A and type B cuttings and major embankments, the following engineering mitigation measures would be considered: • Engineering measures that transfer the seepage water downstream. Standard practice would be to collect the seepage from the cut face in the drainage system for the highway, which would be diverted into water quality basins before being released back into the creek or natural drainage system at some point downstream. • Engineering impact mitigation measures that transfer the seepage water (where present) into the groundwater ecosystem immediately downslope of the cutting or embankments.	Pre-construction and construction	All
	SSW65	• Major embankments will be designed to enable distributed flow of surface waters.	Pre-construction and construction	All

Issue	Mitigation ID no.	Mitigation measure	Timing	Relevant section
Prevention of potential impacts on groundwater quality	SSW66	• Measures to manage high-risk groundwater impact areas would continue to be considered through the detailed design process. In identified areas, the design of water quality controls would be reviewed and the need for additional controls may be identified.	Pre-construction	All
	SSW67	• Where practical, sites used for stockpiles, washdown, batch plants, refuelling and chemical storage would be located in areas where the water table is more than five metres below the surface. If this is not possible, the sites would be lined to protect groundwater. The sites that require lining to protect groundwater would be identified during detailed design.	Construction	All
Prevention of impacts on Rous Water bore fields	SSW68	• All construction runoff in the catchment of the Rous Water bore fields would be diverted to sedimentation basins. No runoff would bypass the basins untreated, regardless of the size of the footprint of the work. In addition, all basins in the bore fields would be clay lined to prevent seepage. If required, the depth of the basins would be reduced from the standard depth of two metres to one metre in these areas to avoid penetration of the natural clay layer, with the volume of the basins maintained by increasing their footprint.	Construction	Section 8
	SSW69	• Sizing of sedimentation basins in the Rous Water bore fields would be reviewed to consider the use of 90th percentile basins.	Construction	Section 8
	SSW70	• The following construction activities would not be permitted within the Rous Water bore field catchment: • Refuelling • Washdown • Storage of chemicals or other hazardous substances • Installation of concrete batch plants.	Construction	Section 8
	SSW71	• Water quality ponds would be designed to be shallower between stations 131.1 and 134.0 (namely one metre compared to two metres) to avoid penetration of the natural clay layer, where possible. Alternatively, where not feasible, clay capping/ lining of the basin would be undertaken.	Pre-construction	Section 8
	SSW72	• Alternative operational water quality management measures such as the use of biofilters, sand filters or measures used in the Tintenbar to Ewingsdale Pacific Highway upgrade project would be considered during detailed design.	Pre-construction	Section 8
	SSW73	• Consultation will be undertaken with Rous Water to co-ordinate mitigation actions including the definition of appropriate buffer zones between the project and bores.	Pre-construction	Section 8

Issue	Mitigation ID no.	Mitigation measure	Timing	Relevant section
Protection of water quality	SSW74	• Permanent water quality management and protection measures to protect adjacent waterways from pollutants from the highway upgrade would include: • Permanent water quality basins • Grassed swales • Gross pollutant traps.	Operation	All
	SSW75	• All permanent water quality basins would incorporate measures to contain accidental fuel and chemical spills resulting from vehicle accidents on the highway. Basins would be designed to accommodate a spill volume of up to 40,000 litres.	Operation	All
	SSW76	• For water quality treatment in floodplains and other locations with minimal changes in gradient, grassed swales would provide sufficient treatment to meet the water quality treatment targets.	Operation	All
	SSW77	• In addition to water quality basins and grassed swales, rock check dams would be used to provide additional impact mitigation, including mitigation of flow concentration and scour erosion. The sizes and locations of rock check dams would be determined during detailed design.	Operation	All
Monitoring programs	SSW78	• Surface water quality monitoring would be undertaken in accordance with RMS' Guideline for Construction Water Quality Monitoring (RTA, 2003), and as per the framework outlined in the Working paper – Water quality.	Pre-construction	All
	SSW79	• Groundwater monitoring would be undertaken in accordance with the framework outlined in the Working paper – Groundwater (Section 5.2).	Construction	All
Impacts to former Evans Head aerial bombing ranges	SSW80	• Consultation will be undertaken with Department of Defence regarding the potential for unexploded ordnance to be encountered within the area of the Evans Head aerial bombing ranges.	Pre-construction	9 and 10

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