7.4 Surface water and groundwater

This chapter provides an assessment of surface water and groundwater, which were nominated in the DGRs as a key environmental issue for the project. It represents a summary of the relevant parts of the *Aquatic Ecology and Water Quality Management Technical Paper* (Cardno Ecology Lab Pty Ltd, 2012) and the *Surface water, Groundwater and Flooding Technical Paper* (AECOM, 2012), which were prepared for the project with consideration of the DGRs.

The technical papers are provided at **Appendix G** and **Appendix H**. The relevant extract from the DGRs is presented below.

Director-General's requirements	Where addressed
Surface water and groundwater *- including but not limited to:*	
Water quality taking into account impacts from both accidents and runoff and considering relevant environmental water quality criteria specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000. The assessment must describe measures to control erosion and sedimentation during construction activities and measures to capture and treat runoff from the site during the operational phase.	Section 7.4.3 and Section 7.4.4. Appendix G – Technical paper: Surface water, groundwater and flooding
Identify potential risks of the project on groundwater resources including: characterising existing local and regional hydrology; potential risks of drawdown; impacts to groundwater quality; discharge requirements; and implications for groundwater-dependent surface flows (including springs and drinking water catchments), groundwater-dependent ecological communities and groundwater users.	Section 7.3.3, Section 7.4.2 and Section 7.4.3. Appendix F — Technical paper: Aquatic ecology and water quality. Appendix G – Technical paper: Surface water, groundwater and flooding.
Waterways to be modified as a result of the project, including ecological, hydrological and geomorphic impacts (as relevant) and measures to rehabilitate the waterways to pre-construction conditions or better.	Section 7.3.3, Section 7.3.4, Section 7.4.3 and Section 7.5.4. Appendix F — Technical paper: Aquatic ecology and water quality. Appendix G – Technical paper: Surface water, groundwater and flooding.

7.4.1 Methodology

Surface water

The general approach and methodology adopted for the assessment for surface water includes:

- Compilation and review of available information, such as previous reports, topographical maps, aerial photography, acid sulfate soils (ASS) maps, RMS standards and guidelines, other national and state guidelines or standards for construction and operational water quality. Review of the water quality analyses conducted by Cardno Ecology Lab in 2007, 2009 and 2011 (as reported in the *Aquatic Ecology and Water Quality Management Technical Paper* at **Appendix G**) against trigger values set in *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Environment Conservation Council (ANZECC), 2000).
- Review of previous geotechnical investigations undertaken between 2007 and 2011 to identify potential geotechnical, soil and fill issues for the project and to assist in identifying mitigation and management measures. Previous geotechnical investigations included (but were not limited to) core drilling, piezometers, electric cone (piezocone), test pits, laboratory testing of soil and rock samples.
- Assessment of soil and erosion risks during construction and identification of appropriate mitigation measures, with consideration of *Managing Urban Stormwater- Soils and Construction, Volume 1* (Landcom, 2004) and *Volume 2D Main Road Construction NSW* (Department of Environment, Climate Change and Water (DECCW), 2008) (known as the Blue Book), and other RMS procedures and guidelines.
- Use of the Australian Water Balance Model (AWBM) for the existing and proposed catchment areas within the project area following the diversion of Town Creek to assess the potential impacts on flow regimes of the impacted watercourses. This model was calibrated using daily stream flow data from the flow gauging station at Broughton Mill Creek, combined with daily rainfall data from Berry Masonic Village and monthly EvapoTranspiration data from Port Kembla.
- Development of performance targets for operational water quality basins based on *Managing Urban Stormwater: Council Handbook* (EPA, 1998).
- Use of the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) (Version 4) water quality modeling package to develop an operational water quality strategy. Using rainfall data collected at the Nowra Royal Australian Navy Air station (number 068072), the following three scenarios were modeled to predict pollutant loadings (kilograms per year) within an one hectare catchment for Total Suspended Solids , Total Phosphorus and Total Nitrogen:
  - Pre-existing (representing rural land uses only).
  - Existing (being the current highway).
  - The project.

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) form part of the National Water Quality Management Strategy and lists a range of environmental values for water bodies. The guidelines are ambient water quality guidelines and have been used in the assessment of existing water quality of creeks in proximity of the project. The guidelines would also be used in future monitoring of ambient conditions (base flow) of the downstream waterways to monitor the impacts of the project on these ecosystems.

Guidelines for the management of stormwater runoff include *Managing Urban Stormwater: Council Handbook* (EPA, 1998). These guidelines have been developed for urban catchments and are not strictly applicable to the rural environment. Instead, the recommended treatment objectives have been used as a basis for developing appropriate design criteria for the project, which are based on the required detention capacity per hectare of road surface. This is discussed further in **Section 7.4.3**.

Section 120 of the Protection of the Environment Operations Act (POEO) Act) prohibits the pollution of any waters. Standard conditions of the EPL would require compliance with the POEO Act and this has been taken into consideration in the design of the project. Mitigation measures would be implemented to prevent pollution of waters as discussed in **Section 7.4.4**.

Groundwater

The general approach and methodology adopted for the assessment for groundwater includes:

- Consideration of guidelines and policies relevant to the protection of groundwater and groundwater dependent ecosystems (GDEs) in NSW. This included the State Groundwater Policy Framework Document (Department of Land and Water Conservation (DLWC), 1997), the NSW State Groundwater Quality Protection Policy (DLWC, 1998), (Draft) NSW State Groundwater Quantity Management Policy (DLWC, no date), NSW State Groundwater Dependent Ecosystems Policy (DLWC, 2002), the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 (NSW Office of Water (NOW), 2011) and National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) & ANZECC, 1995).
- Compilation and review of available information, such as the searches of registered groundwater bores in the vicinity of the project and the review of groundwater quality data obtained from databases maintained by the NOW.
- Consideration of the relevant findings of the *Aquatic Ecology and Water Quality Management Technical Paper* at **Appendix G** with respect to GDEs.
- Consideration of the relevant findings of the assessment undertaken for surface water impacts of the project.
- Review of previous geotechnical investigations undertaken between 2007 and 2011 to identify potential groundwater issues for the project. This included site specific groundwater information derived from a geotechnical investigation (Coffey, 2010) that involved 20 monitoring wells.
- Identification of mitigation and management strategies, which consider the abovementioned groundwater guidelines of the NOW and the former DLWC.

7.4.2 Existing environment

Surface water

Waterways in study area

The main waterways that interact with the project are Broughton Creek, Broughton Mill Creek, Bundewallah Creek, Connollys Creek and Town Creek and their associated catchments (refer to **Figure 7-10**).

A small section of the project area is located within the upper Crooked River catchment, near Toolijooa Ridge. The creeks and streams that form part of the Crooked River catchment start at Currys Mountain and flow in a south-easterly direction into a coastal floodplain before discharging into the ocean via the estuarine Crooked River Lagoon. No significant or ephemeral waterways within the Crooked River catchment are located within the project footprint.

Broughton Creek is the main watercourse in the project area and starts just below the Illawarra plateau at around 500 metres AHD (Australian height datum).The Broughton Creek catchment lies next to and south of the Crooked River catchment, and is separated by the ridge that extends from Currys Mountain to Toolijooa Hill, Moeyan Hill and eventually Coolangatta Mountain. After crossing the existing Princes Highway corridor, Broughton Creek flows in a south west direction. At Berry, Broughton Creek is joined by Broughton Mill Creek at the entrance of a coastal floodplain and eventually discharges into the lower Shoalhaven River. The Broughton Creek catchment upstream of Berry is around 30 square kilometres in area.

To the north and north-west of Berry are the Broughton Mill Creek and Bundewallah Creek catchments, respectively. Broughton Mill Creek originates underneath the Illawarra plateau as a number of secondary streams. It flows south through Broughton Vale and crosses the existing Princes Highway near the Woodhill Mountain Road intersection on the eastern edge of Berry, around two kilometres upstream of its confluence with Broughton Creek.

Bundewallah Creek starts to the north west of Berry and flows eastwards under a bridge at Woodhill Mountain Road to join Broughton Mill Creek. Connollys Creek enters Bundewallah Creek about 600 metres upstream of the point Bundewallah Creek joins Broughton Mill Creek. Bundewallah Creek and Connollys Creek have catchment areas of around 1500 hectares and 630 hectares respectively (RTA, 2008). Broughton Mill Creek has a catchment area of around 2000 hectares immediately upstream of the confluence with Bundewallah Creek (RTA, 2008).

Town Creek is a small ephemeral watercourse that passes directly through the Berry township. It has a catchment area of 70 hectares upstream of Berry. Town Creek crosses the undeveloped section of North Street, on the north west edge of Berry, before crossing the town between Princess Street and Queen Street and exiting via Prince Alfred Street. Town Creek flows south east before joining Broughton Mill Creek near its confluence with Broughton Creek. The reach of Town Creek through Berry is in poor condition.

Hitchcocks Lane Creek, its tributary and an unnamed tributary of Broughton Creek flow across the existing highway, south of Berry. These watercourses join southwest of the existing highway and eventually discharge into the estuarine reach of Broughton Creek. Hitchcocks Lane Creek and its tributary have a catchment area of 68 hectares and 75 hectares respectively. The unnamed tributary of Broughton Creek has a catchment area of 6.2 hectares.

Water quality in waterways

The long term agricultural land use in the region has resulted in significant pollution that is greater than the water quality levels that are considered to be sustainable for maintaining ecosystem integrity. The values of total phosphorus within the Crooked River and Broughton Creek catchments are regularly above the ANZECC guidelines. The application of fertilisers and manure from stock are the likely sources of the high nutrient levels (The Ecology Lab, 1999, 2007).

Broughton Creek, Broughton Mill Creek, Connollys Creek and Bundewallah Creek are considered to be sensitive receiving environments owing to the ecological values of these waterways (refer to **Section 7.3**).

Previous studies within the Crooked River and Broughton Creek catchments have also found that water quality was generally within the ANZECC threshold limits for pH and conductivity, and to a lesser extent, turbidity (The Ecology Lab, 1999; 2007). Sampling carried out in 2007 during a period of low rainfall found that sites within Crooked River and Broughton Creek catchments were frequently below ANZECC lower limits for dissolved oxygen (The Ecology Lab, 2007). Low dissolved oxygen values can be caused by low flow conditions and/or high in-stream organic loads.

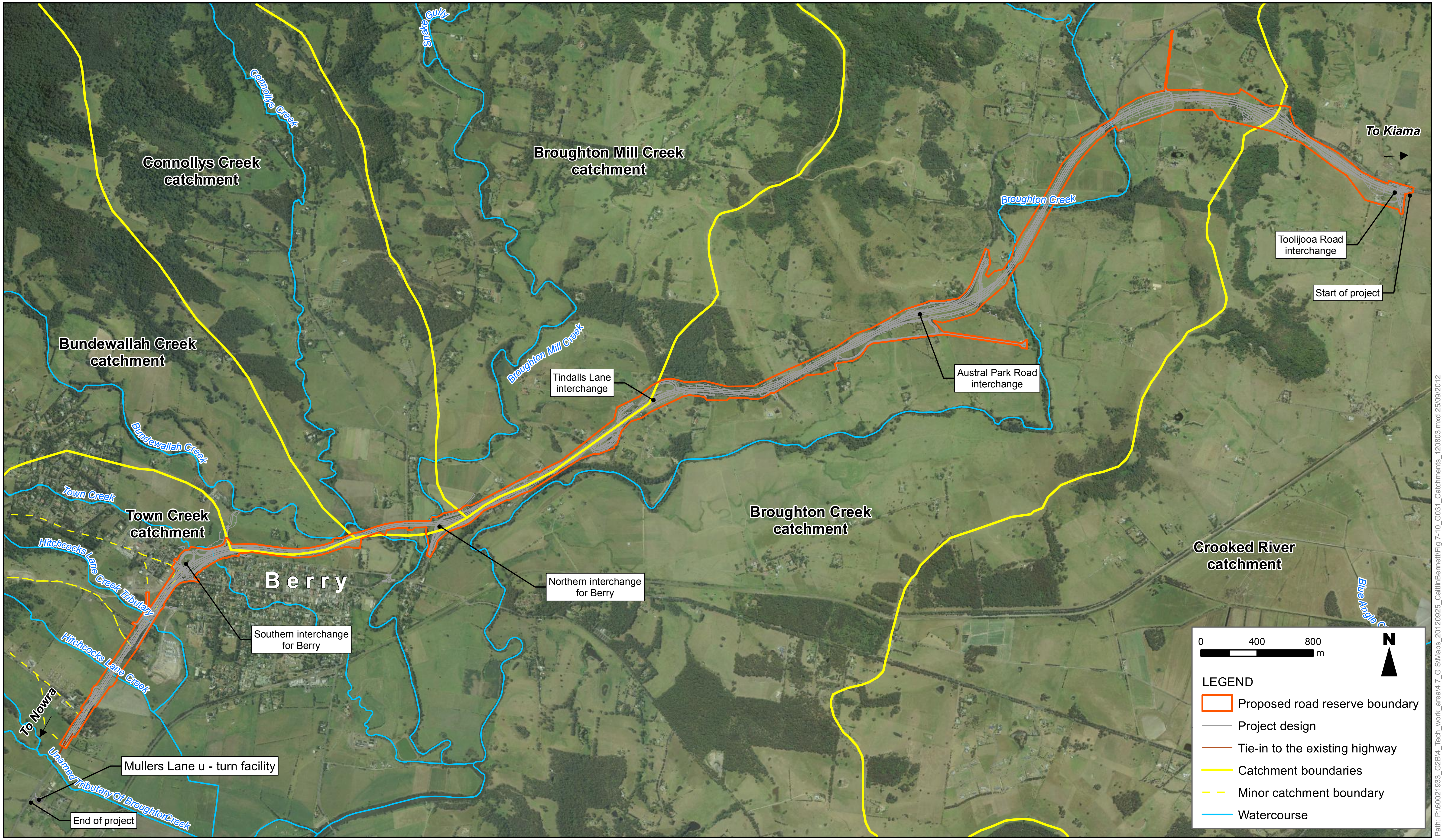

Figure 7-10 Location of catchments within the project area

Source: AECOM (2012), LPMA (2011)

NOTE: No significant or ephemeral waterways within the Crooked River catchment are located within the project footprint

Crooked River, Broughton Creek and Broughton Mill Creek have previously been found to be within ANZECC aquatic ecosystem threshold limits for a range of organochlorine pesticides, oxides of nitrogen and trace elements, although all were above the ANZECC guidelines for chloride. Crooked River was also above the ANZECC guidelines for copper and recorded concentrations of oil and grease, and suspended solids, that were much higher than samples taken from sites within the Broughton Creek catchment (The Ecology Lab, 2007).

The existing highway, which has no water quality controls, is also likely to be contributing pollutant loads to nearby waterbodies particularly at or near creek crossings. This would include oil, grease and other hydrocarbon products, generated by general vehicular use of the highway.

The water quality within Town Creek is expected to be characteristic of a watercourse with a developed residential and agricultural catchment. The long-term urban and agricultural land use in the area has likely lead to elevated nutrient levels (for example from fertilisers and livestock manure), low dissolved oxygen and raised suspended solids resulting from the erosion of soils.

Aquatic biodiversity

The biodiversity values of waterways within the project area are discussed in detail in **Section 7.3**.

Drainage catchments

The drainage catchments of 29 farm dams are located within the project footprint. The locations of these dams are shown in **Figure 7-11**.

Groundwater

Aquifer systems

The two main aquifer systems present in the project area are the unconsolidated and unconfined alluvial/colluvial aquifers, and the Shoalhaven Group sediments.

The alluvial/colluvial aquifer occurs as sand, silt clay and gravels adjacent to the creek systems and as more widespread floodplain deposits. Within the floodplain sediments, localised perched groundwater is expected above interbedded clay horizons. Groundwater movement within the alluvial aquifer and floodplain sediments would flow towards low lying topographical features, discharging into local creek systems or as springs. Groundwater available for extraction within the aquifer would be limited, and would be of low salinity given low residence times and recharge via infiltration of rain and local runoff.

Groundwater within the Shoalhaven Group sediments is present within the volcanoclastic Broughton Formation, as well as within latite and underlying Berry Siltstone. Groundwater within the Shoalhaven Group sediments occurs in perched horizons within the sandstone, latite and siltstone, and within the deeper regional aquifer. Bores constructed in the Shoalhaven Group sediments in the area have variable yields. The deep aquifers are accessed by the majority of licensed bores in the area, extracting groundwater from depths typically between 30 metres and 50 metres below ground level. Based on limited data, groundwater from the Broughton Sandstone is expected to be of better quality than that derived from the Berry Siltstone. This is due to the poor quality groundwater within the shale lenses leaking into the Berry Siltstone aquifer.

The depth of groundwater along the project alignment is influenced by positioning in the landscape and proximity to discharge features. Typically, the watertable is a subdued reflection of the topography, with it being deepest beneath hills and shallowest adjacent to creeks and wetlands. This was confirmed by groundwater monitoring conducted between November 2009 and January 2010 by Coffey (2010).

Groundwater along the route is shallow and typically less than ten metres below ground level for all lithologies. The elevation of groundwater is variable, ranging from six metres AHD in low lying silts and gravels, up to 100 metres AHD within latite in topographically elevated areas. The watertable naturally fluctuates in response to climatic variation. Groundwater levels increase following significant rainfall and decline following periods of low rainfall. The degree of the groundwater response is variable and dependent upon landscape position and aquifer type. Low to moderate groundwater fluctuations of less than one metre were recorded in the siltstone and sandstone aquifers, whereas larger fluctuations (between three and four metres) were typically measured in the sandstone and latite aquifers.

Groundwater bores

There are 16 registered bores located within 500 metres of the project. Groundwater along the alignment is a valuable resource for stock, domestic and agricultural purposes to supplement surface water supplies collected in dams and pumped from creeks. Groundwater is extracted from a variety of aquifers, including latite, gravels, sandstone, shale and fractured rock. The groundwater yield is variable, but is typically less than two litres per second.

Drinking water catchments

There are no drinking water catchments in the project area. Groundwater has low use within the region because the area receives a relatively high rainfall and Shoalhaven Water provides a reticulated water supply to Berry. North of Berry water users are more reliant on tank water and groundwater.

Groundwater dependent ecosystems

GDEs are flora and fauna communities that depend on groundwater for survival. A GDE may either be entirely dependent on groundwater for survival or it may use groundwater opportunistically or for a supplementary water source (Hatton and Evans, 1998). GDEs are most likely to occur in low lying areas with shallow groundwater close to the surface.

Groundwater from the alluvial aquifer systems associated with the Broughton Creek floodplain discharges into Broughton Creek. Riparian vegetation associated with Broughton Creek is likely to be dependent upon groundwater in some capacity. Groundwater discharge via springs, seeps or spring fed dams may also sustain local small communities.

Foys Swamp and Coomonderry Swamp located east of Broughton Creek are listed under *State Environmental Planning Policy No 14 – Coastal Wetlands* (SEPP 14). Coomonderry Swamp is also identified as a high priority GDE in the Sydney Basin Southern management zone of the Greater Metropolitan Regional Water Sharing Plan. Floodplain swamp forest is a low, dense forest tolerant of brackish groundwater occurring along Toolijooa Road and the railway line between Gerringong and Berry. This community may grade into estuarine fringe forest with increasing groundwater salinity. Refer to **Section 7.3** for further information on GDEs.

7.4.3 Assessment of potential impacts

Surface water

Construction

Clearing, cut and fill operations along the project alignment, including the construction of permanent and temporary creek crossings, represent the primary risk to surface water quality during and following construction. These activities have an increased potential for sediment release and transportation due to runoff from disturbed areas or from roads where sediment has been tracked onto roads by construction vehicles. If uncontrolled, increased sedimentation of watercourses could smother and kill aquatic habitats and organisms. It could also increase the concentration of nutrients, metals and other potential toxicants that attach to sediment particles in surrounding waterways.

Previous water quality studies indicate several waterways in the study area have turbidity levels (a measure of the amount of sediment in water) that are narrowly outside the ANZECC lower thresholds. As a result, an increase in sedimentation could place additional physical stress on aquatic habitats and organisms.

The risk of these impacts, and the severity of the impact should it occur, would be dependent on the effectiveness of the erosion and sediment controls implemented during construction.

Other potential risks to surface water as a result of construction or due to activities at the proposed ancillary construction sites include:

- Sediment release from stockpiles that have not been suitably stabilised and earthmoving activities.
- Dust generation during excavation that could settle in waterbodies.
- Chemical or fuel spills that could pollute receiving waterbodies. This includes fuel or oil leakage from construction equipment, accidental spills or the release of chemicals due to damage to chemical storage areas.
- Exposure of ASS, resulting in acidic runoff that could have major environmental impacts and constrain construction (refer to **Section 8.1** for further detail).
- Construction materials or general waste generation from construction that could enter waterbodies.
- An increase in surface runoff due to an increase in cleared and impervious surfaces.
- Damage to ancillary facilities (including flood damage) that could result in an export of pollutants to receiving waters.
- Tannins leachate from vegetation stockpiles.
- Riparian vegetation removal that could result in sediment release to adjoining watercourses. This could impact on water quality and result in decreased health of aquatic ecosystems.
- The construction of Town Creek diversion could result in reduced water quality, primarily due to erosion. This could lead to excess sediment loads into Bundewallah Creek, leading to impacts on aquatic species and habitats.

Construction water, which would be used for dust suppression, earthwork compaction and planted vegetation maintenance, would be sourced as follows in order of priority, where practicable, and based on the intended use:

- Recycled effluent from the tertiary treatment plant at Gerringong Gerroa and/or Berry.
- Surface water, sourced from on-site detention basins.
- Surface water, sourced from watercourses.
- Potable water.
- Groundwater.

The volume of water required would depend on a number of factors including rainfall, wind direction and intensity, soil type and area of ground disturbance at any one time.

Effluent at the Gerringong Gerroa sewerage scheme undergoes tertiary treatment and 80 per cent of the recycled effluent is re-used for agricultural irrigation. The remainder is currently irrigated on sand dunes, or discharged to an on-site natural wetland that is ultimately released into Crooked Creek. Discharge concentration criteria contained in the Environment Protection Licence (EPL) for the plant is provided in **Table 7-51**. Recycled effluent may also be sourced from the Berry sewerage treatment plant which is owned and operated by Shoalhaven Water. Recycled effluent from this plant is discharged to land and Broughton Mill Creek. Discharge concentration criteria contained in the EPL for the plant are provided in **Table 7-52**. It has higher concentration limits for total suspended solids and biochemical oxygen demand.

Table 7-51 Concentration limits for the Gerringong-Gerroa sewage treatment system as contained in the EPL

Pollutant	Unit of measure	50 percentile concentration limit	100 percentile concentration limit
Oil and grease	milligrams per litre	-	10 (with visible oil and grease)
pH	-	-	6.5-9
Nitrogen (total)	milligrams per litre	3	
Phosphorous (total)	milligrams per litre	0.1	
Total suspended solids	milligrams per litre	3	
Biochemical oxygen demand	milligrams per litre	5	
Faecal coli forms	Colony forming units per 100 millilitres	2	

Source: Environment Protection Licence 11317 (dated 2 July 2009), accessed on 21 September 2011 on www.environment.nsw.gov.au.

Table 7-52 Concentration limits for the Berry sewage treatment system as contained in the EPL

Pollutant	Unit of Measure	50 percentile concentration limit	100 percentile concentration limit
Oil and grease	milligrams per litre	-	10 (with visible oil and grease)
Total suspended solids	milligrams per litre	15	30
Biochemical oxygen demand	milligrams per litre	10	20

Source: Environment Protection Licence 1736 (dated 1 June no year), accessed on 11 November 2011 on www.environment.nsw.gov.au.

The management and use of treated effluent would be undertaken in accordance with RMS' Environmental Direction No: 19 - Use of Reclaimed Water (RTA 2006) and RMS' Tip Sheet – Use of Reclaimed Water (RTA 2006). The recycled effluent, which is fit for discharge for irrigation purposes and eventual discharge into waterways, would be dispersed within the project area at low loadings over a large area, and for a short duration in response to demand. As such, it is expected that no significant water quality impacts would eventuate. Nonetheless, a number of mitigation and management measures are proposed to minimise potential risks to the environment and human health. These are discussed further in **Section 7.4.3**.

To supplement this water source, water may be extracted from the construction and operational sedimentation basins that would collect runoff from the site during construction. While the remaining sources for water supply (being potable water, or extraction from surface water and groundwater sources), are possible options, these are not preferred.

Should surface water extraction from creeks be required, it would be extracted pursuant to clause 18 of the Water Management General Regulation 2011, under which Roads authorities are exempt from Access Licence requirements in relation to water required for road construction and road maintenance.

Operation

Surface water runoff would increase during operation due to an increase in impervious surfaces and concentration of road runoff through drainage infrastructure. This in turn would increase the frequency, volume and velocity of flows in receiving waterways, potentially leading to or exacerbating erosion.

Associated with this risk is the increased potential for the following pollutants to enter nearby watercourses via road runoff:

- Sediments from paved surfaces.
- Nutrients (phosphorus and nitrogen) deposited onto paved surfaces due to atmospheric deposition.
- Heavy metals attached to particles washed off paved surfaces.
- Oil, grease and other hydrocarbon products, generated by general vehicular use of the highway.
- Gross pollutants (roadside litter).
- Fuels and chemicals from spills caused by traffic accidents.
- Contaminants from the erosion of the roadway or road shoulders.

The diversion of Town Creek would lead to flow regime and water quality impacts within Town Creek, and Bundewallah Creek. This is discussed later within this section. The construction of piers within Bundewallah Creek would change the average velocities of water near the piers with reductions to average velocities immediately upstream and increases close to the piers. However, the change would not typically extend across the entire width of the creek.

Studies undertaken in the Broughton Creek catchment generally show that turbidity levels are narrowly outside the ANZECC lower thresholds and values of total phosphorus generally exceeded the ANZECC guidelines. Without appropriate management controls the potential operational impacts may place further stress on waterways as a result of the project.

Heavy metals, hydrocarbon products and nutrients are primarily transported off site by road runoff as particle-bound contaminants. As such, the protection of aquatic ecosystems and the treatment of road runoff are directed at the removal of suspended solids, and the associated contaminants.

Total nitrogen is a more difficult pollutant to remove, when compared to total suspended solids and phosphorus. Total suspended solids and a large fraction of total phosphorus are associated with particulates, which are readily trapped by basins or swales. As only a small fraction of total nitrogen is particulate, the remaining dissolved forms of nitrogen can only be removed by biological processes such as bio-retention systems.

The results of the model for urban stormwater improvement conceptualisation (MUSIC) determined that the existing and proposed highway generate significant increases in pollutant loadings for total suspended solids, total phosphorus and total nitrogen when compared to a pre-developed rural catchment (refer to **Table 7-53**). The model also illustrated that the project, in the absence of any treatment measures, would likely increase the impact on receiving waterways when compared to the existing highway. This is due to the increase of impervious areas and primarily pavement widths.

Table 7-53 MUSIC model pollutant loadings (without water quality treatment).

Scenario*	Total suspended solids (kg/year)	Total phosphorous (kg/year)	Total nitrogen (kg/year)
Pre-developed	235	0.62	6.36
Existing	1260	2.31	10.8
Proposed	1980	3.64	16.6

** Refer to the Surface water, Groundwater and Flooding Technical Paper at **Appendix H**.*

Worst case scenario

The worst case scenario for operational water quality treatment would occur if all treatment structures fail or were not installed.

To assess the worst case stormwater runoff scenario, consideration has been given to the lack of installation, or the failure of, all stormwater management measures (as discussed in **Section 7.4.5**). It would be highly unlikely that all these measures could fail, and as such, there is a very low risk of the worst case impacts occurring. If all measures were to fail, there would be an increased volume of water, flowing at a much higher rate due to increased impervious areas. This would result in:

- Pavement drainage systems collecting road runoff, concentrating the flow (together with sediment, oil, grease and atmospheric nitrogen dissolved in rainwater) to a single untreated discharge location.
- Immediate impacts such as erosion, nutrient loading and concentration of sediment and litter.
- The receiving waterways potentially eroding over around one or two decades (depending on rainfall) to result in a new form, which would be wider and deeper than the existing stream. This could impact the geomorphic and sediment diversity of the affected stream.
- Reductions in the biodiversity within receiving waterways.

Untreated stormwater runoff can also lead to the accumulation of pollutants in waterways over time. This would create pressures on the ecology of these waterways and impacts on biodiversity. These impacts would be similar to that generated in other urban or developed areas, where stormwater is discharged untreated into receiving waters.

Further downstream from the pavement drainage discharge location, the relative magnitude of the water quality impacts would be reduced by dilution. The existing highway has no water quality controls and as such, worst case loading of vehicle-generated pollutants from the proposed design would be equivalent to the present day situation, plus an allowance for increased traffic over the design life of the project.

The worst case consequences for vehicle spills would be similar under both existing and proposed situations. The proposed alignment would however improve accident rates and therefore reduce the likelihood of spills occurring.

Impacts resulting from the Town Creek diversion

The diversion of Town Creek would alter the flow regimes in parts of Bundewallah Creek, Connollys Creek, Broughton Mill Creek and Town Creek. The diversion would result in runoff from around 70 hectares of the Town Creek catchment being diverted into Bundewallah Creek. This would result in:

- A maximum increase of five per cent to the catchment area for Bundewallah Creek, Connollys Creek and Broughton Mill Creek.
- A loss of 47 per cent of the Town Creek catchment downstream of Berry.

Based on the results of the Australian Water Balance Model (AWBM) model, the minimal change in catchment area would have negligible impact on flow volumes of Bundewallah Creek, Connolly's Creek and Broughton Mill Creek. For Town Creek, the results of the AWBM model show that:

- There would be no flow at the upstream end of reach of Town Creek immediately south of the southern interchange.
- The flow volume of Town Creek just before it joins Broughton Mill Creek would be reduced to around one third of the existing flow volumes at this location.

As described in Section 7.4.2, the long-term urban and agricultural land use in the area has likely lead to elevated nutrient levels (for example from fertilisers and livestock manure), low dissolved oxygen and raised suspended solids resulting from the erosion of soils. As an ephemeral stream, Town Creek has intermittent flows during rain events only and has few standing pools located south of Berry.

The reduction in flow volumes in Town Creek would lead to reduced flushing efficiency. This could lead to a decline in water quality due to sediment accumulation, increases in nutrient levels, and decreases in dissolved oxygen. Aquatic habitats nearest the diversion point would be reduced to isolated pools with associated declines in water quality. Given the existing degraded condition of Town Creek through Berry and its ephemeral nature, the reduction in flow volumes should not have any significant adverse impacts on water quality. There is also no aquatic ecological benefit to overbank flooding in large events within Berry. Any further degradation of Town Creek is considered to be acceptable given the positive flood mitigation provided by the diversion of flood flows.

There is the potential for a decrease in water quality where the diversion would connect to Bundewallah Creek due to eddying. The design and revegetation of the diversion channel would ensure that there is no detrimental impact on water quality in the diversion channel and Bundewallah Creek.

The revegetation of the diversion channel would also stabilise the new banks and reduce the risk of erosion. This would enhance the structural integrity of the diversion channel and would provide the following benefits:

- Increased protection to the adjacent landowners land.
- Increased channel roughness, which would reduce flow velocities and erosive flows.
- Increased channel shear strength and soil binding.
- Provision of habitat, habitat corridors, nutrient assimilation and increased biodiversity.
- Minimised risk of water quality impacts in Bundewallah Creek.

The potential impacts on aquatic habitat and riparian vegetation at Town Creek and Bundewallah Creek as a result of the diversion is discussed further in **Section 7.3**.

Farm dams

The project may also cause permanent changes to drainage catchments for existing farm dams. Surface water runoff that currently flows downhill to farm dams may be diverted around road cuttings via catch drains and other drainage infrastructure to a natural waterway. Such a reduction in runoff areas could prevent the natural flow of water into farm dams and potentially reduce their yield.

These impacts would commence during construction. For the majority of the 29 farm dam catchments impacted by the project, the loss of catchment area would be less than 20 per cent of the original catchment (refer to **Figure 7-11** and the *Surface Water, Groundwater and Flooding Technical Paper* at **Appendix H**). Farm dams with the greatest loss of catchment area are typically smaller dams located at higher elevations and with relatively small catchments. Several of the highly impacted dams are located on properties already acquired by the RMS. The impact of these losses would be dependent on the purpose of the dam for farm operations and the availability of alternative water sources.

Groundwater

Construction

Construction activities have the potential to impact groundwater levels as a result of changes to groundwater flow patterns, recharge and discharge characteristics of the site.

Deep excavations and cuttings for the project may experience groundwater inflows as a result of intercepting groundwater. Preliminary assessments indicate that groundwater would seep into the Toolijooa Ridge cutting from the latite and Kiama Sandstone. Other cuts along the alignment are no deeper than 13 metres and may also be subject to groundwater inflows. Additional geotechnical investigations and modelling would be undertaken during the detailed design phase of the project to determine the degree of seepage that may occur at exposed cuttings, especially at Toolijooa Ridge.

Foundations for cased bored piles associated with bridges or other major structures are also expected to intercept shallow groundwater. This may require localised dewatering, which would temporarily alter groundwater flow conditions. However, the original groundwater flows would be re-established once dewatering was completed.

Temporary dewatering may also be required to artificially lower the watertable to maintain dry working conditions within excavations and at bridge footings. This would likely draw down local groundwater levels in the immediate vicinity of the excavation or footing.

Should dewatering of the alluvial aquifer be required during the construction of bridge footings, groundwater drawdown would be limited to the base of the footing, and the zone of influence or induced cone of depression, is expected to be limited due to the highly transmissive nature of an alluvial aquifer. Should dewatering be required during the construction of road cuttings, the impacts would depend on the local hydraulic conductivity of the aquifer matrix and secondary water bearing structural features.

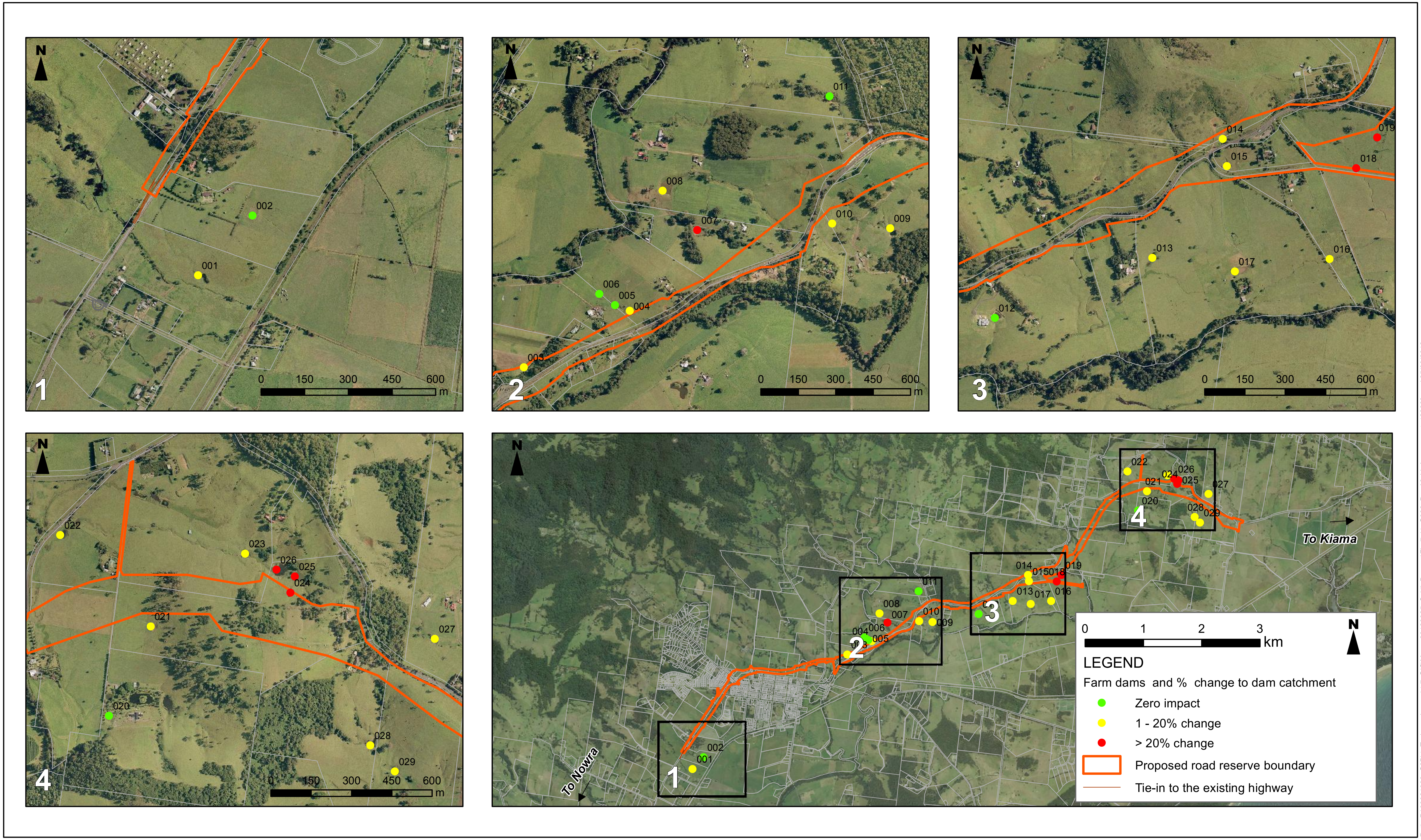

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Figure 7-11 Location and impacts on farm dams in the project area

Source: LPMA (2011)

Additional geotechnical investigations that would be undertaken during the detailed design phase of the project would determine the need for dewatering, the likely dewatering volumes, the impacts on draw down and the quality of groundwater that would be encountered during construction. The manner in which extracted groundwater would be discharged would depend on the groundwater quality and if it would require treatment prior to discharge. Options include discharge to creeks, temporary storage in detention basins to reduce turbidity prior to discharge, or re-use for dust suppression.

Excavation for cuttings beneath the watertable or intersecting perched groundwater also has the potential to reduce groundwater recharge as a result of groundwater draining into culverts, creeks or rivers. Compaction of shallow soils in areas of unconsolidated alluvial sediments, and the construction of access roads, tracks and stockpiling areas could also reduce rates of recharge.

Construction activities may also impact on the water quality of groundwater. Fuel and chemical spills including petrol, diesel, hydraulic fluids, lubricants and explosive residues could potentially contaminate groundwater and GDEs, particularly if a leak or spill occurs on highly permeable sandy soils. Spills as a result of accidents could occur during construction, refuelling operations or from storage areas.

Runoff from construction areas may be highly turbid. The movement of suspended solids to the groundwater is likely to be minimised as it filters through the unsaturated zone, reducing the significance of the impact.

There is a low risk that potential acid sulfate soils (PASS) may be present along the project (refer to **Section 8.1** for further detail and PASS occurrence). Should the watertable be lowered during excavation, if present, PASS would become exposed and oxidation of sulfide minerals could result. Sulfuric acid would then be generated and metal concentrations in solution would potentially increase, leading to groundwater degradation. Rainfall runoff could cause acidic water to migrate within the shallow groundwater system and discharge into surface water systems and groundwater receivers. This risk and any potential impacts would be mitigated and managed using an acid sulfate soil management plan (ASSMP)(refer to **Section 8.1.3**).

The potential risk to GDEs as a result of construction activity is low and is discussed in detail in **Section 7.3**.

Operation

Road runoff, major cuttings and other structures can cause permanent barriers and long term impacts to groundwater flows, recharge rates and groundwater quality.

The increase in hard road surface areas would increase runoff and decrease groundwater recharge, due to the loss of permeability. The decrease in recharge rates would be minor given the small road surface of the project compared to the remainder of the catchment.

Road runoff could contain pollutants associated with vehicular movements, leaks, spills and crashes, which could lead to the contamination of groundwater. The contaminants could include hydrocarbons (petrol, diesel and oils), metals and suspended solids. Measures to minimise surface water impacts (as described in **Section 7.4.4**) would contain the risk to groundwater quality.

Toolijooa Ridge and other shallower road cuttings along the project may also be subject to groundwater inflows during the operational phase. As identified earlier in this section, investigations completed to date suggest that groundwater would seep into the Toolijooa Ridge cutting from the latite and Kiama Sandstone.

Inflow to the cuttings could potentially reduce groundwater recharge (as through flow), lower the local watertable and alter groundwater flow paths. The capacity of water extraction bores in the vicinity of the deep road cuttings may be reduced as a result. Similarly, farm dams and GDEs that are recharged by springs may also be affected by a reduced spring flow due to the altered groundwater flow conditions. The expected drawdown in the vicinity of the Toolijooa Ridge cut is not expected to impact other users, as registered groundwater bores are at a sufficient distance from the cutting not to be adversely affected. Local GDEs are within elevated parts of the catchment and would continue to be sustained.

Potential future groundwater use in this area has not been identified at this stage. The impact on bores would be confirmed as part of the additional geotechnical field investigations that would be undertaken during the detailed design phase of the project.

Worst case scenario

To assess the worst case scenario for groundwater impacts, consideration has been given to the failure of all environmental management measures (as proposed in **Section 7.4.4**) during a major spill or pollution event causing groundwater contamination. Given design standards and the implementation of environmental management measures, it would be highly unlikely that all these measures could fail. As such, there is a very low risk of the worst case impacts occurring.

If this was to happen, the severity of the impact would also be dependent on:

- The type and volume of the pollutant.
- Where in the groundwater system the contamination occurs, which would determine how slow or quickly the contaminant can move.
- The proximity to active groundwater users, including town water supply, irrigation, stock and domestic bores.

Subsequent impacts on ecosystems would also occur as result of this contamination. This includes connected GDEs, such as wetlands, and impacts on surface water systems that are fed by groundwater flows.

Reductions in groundwater flows as a result of groundwater interference may be anything from short-term, to long-term. Localised impacts from dewatering or extraction would generally disappear upon the completion of the activity. In a worst case scenario, dewatering activities may temporarily lower the watertable sufficiently to impact other users. In this case, mitigation measures can be put in place to minimise the effects.

Where a recharge zone or groundwater flow-path is significantly altered, or where a whole section of an aquifer is removed, the impacts are likely to be permanent. The likelihood of a major aquifer disruption, and the effects on users or ecosystems, is not known. The impacts would be considered once the additional geotechnical field investigations have been completed.

7.4.4 Environmental management measures

Mitigation and management measures would be implemented to minimise or manage impacts to surface and groundwater and to achieve compliance with Section 120 of the POEP Act and the EPL for the project. These mitigation and management measures are set out in **Table 7-54** (construction) and **Table 7-55** (operation) and incorporated in the draft statement of commitments in **Chapter 10**.

Table 7-54 Construction mitigation and management measures

Potential impacts	Mitigation and management measures
Construction	
General construction impacts	Prepare a Soil and Water Management Plan (SWMP) prior to construction, which would detail control measures for erosion and sedimentation for implementation before and during construction.
Reduction in surface water quality	Document the following measures in the SWMP and implement them on site: • Construct temporary drainage structures in accordance with the 'Technical Guideline – Temporary stormwater drainage for road construction' (RMS, 2011). Locate sedimentation basins during construction in areas as determined during detailed design. The proposed locations shown in **Figure 7-12** are based on the concept design and would be subject to change during detailed design of the project. These would be in addition to the permanent operational water quality basins that may be used during construction for temporary sedimentation control (refer **Figure 7.14**). • Include 'at source' management measures in areas of residual high risk erosion and sedimentation areas. These areas are where basins are not feasible due to topographical constraints or small catchment areas (as identified in **Figure 7-13)**. Measures would include small scale sedimentation capture devices, designed in consultation with a specialist soil conservationist. • Carry out construction in sequence to minimise the extent of disturbed areas and rehabilitate as soon as practicable. • Install permanent clean water diversions and top of cut drains at the start of construction to limit the volume of water on site. • Construct sediment and water quality basins prior to clearing activities in each area. • Establish water quality swales before or concurrently with clearing activities to enable their use during construction. • Stabilise fill batters progressively as they are constructed. • Manage vegetation stockpiles to minimise the impact of tannins leaching into the surrounding environment. Manage stockpiles in accordance with *Environmental Guidance – Management of Tannins from Vegetation Mulch* (RMS, 2012). • Use dust management techniques, such as water spraying, to suppress dust. • Manage and use treated effluent in accordance with RMS' Environmental Direction No: 19 - Use of Reclaimed Water (RTA 2006) and RMS' Tip Sheet – Use of Reclaimed Water (RTA 2006).

Potential impacts	Mitigation and management measures
Potential impacts to groundwater	Minimise the depth of excavations in areas of alluvium. Limit the need to dewater during construction. Implement a communications procedure to educate construction personnel on groundwater issues. Minimise disturbance and control runoff from construction areas. Provide bunding and spill kits around fuel depots and stockpile areas. Develop response plans to address fuel leaks and spills at machinery compounds or during refuelling, including a hazardous materials plan and spill emergency procedure. Establish a groundwater monitoring network along the project to monitor groundwater quality within each lithology and to establish background groundwater quality. Detail the establishment of a groundwater monitoring network along the route to adequately characterise groundwater quality and establish background water quality within the alluvial/colluvial aquifers and Shoalhaven Group Sediments, including the Broughton Sandstone and latite. Install monitoring wells adjacent to major cuts to confirm existing groundwater levels and to monitor the effect on groundwater levels by construction activity, where groundwater is encountered. Implement a groundwater monitoring plan that would assess the performance of groundwater mitigation measures during and after construction. This plan would provide an assessment of groundwater level and quality trends and identification of exceedances (if any). Utilise a soil conservation specialist during the detailed design and construction phases to assist with the management, design and mitigation of soil erosion issues.
Potential impacts of ASS	During the initial works onsite, undertake further testing for ASS across the Broughton Creek floodplains. Should the presence of ASS be confirmed, avoid or minimise disturbance, and/or activities that may lower the watertable in these areas. Prepare an ASSMP if required, to identify strategies to remove or reduce the risks associated with ASS (refer to **Section 8.1.3** for further detail).
Impacts as a result of the Town Creek diversion	Undertake staged construction of the Town Creek diversion to reduce the exposure of soils. Stabilise banks of the constructed channel prior to diversion of flows from the upper catchment of Town Creek. Maintain flushing efficiency and mitigate erosive forces at the discharge location into Bundewallah Creek through the design of the diversion. This could be achieved by increasing the channel roughness to reduce flow velocities. Revegetate the banks of the diversion channel to stabilise and reduce the risk of erosion.

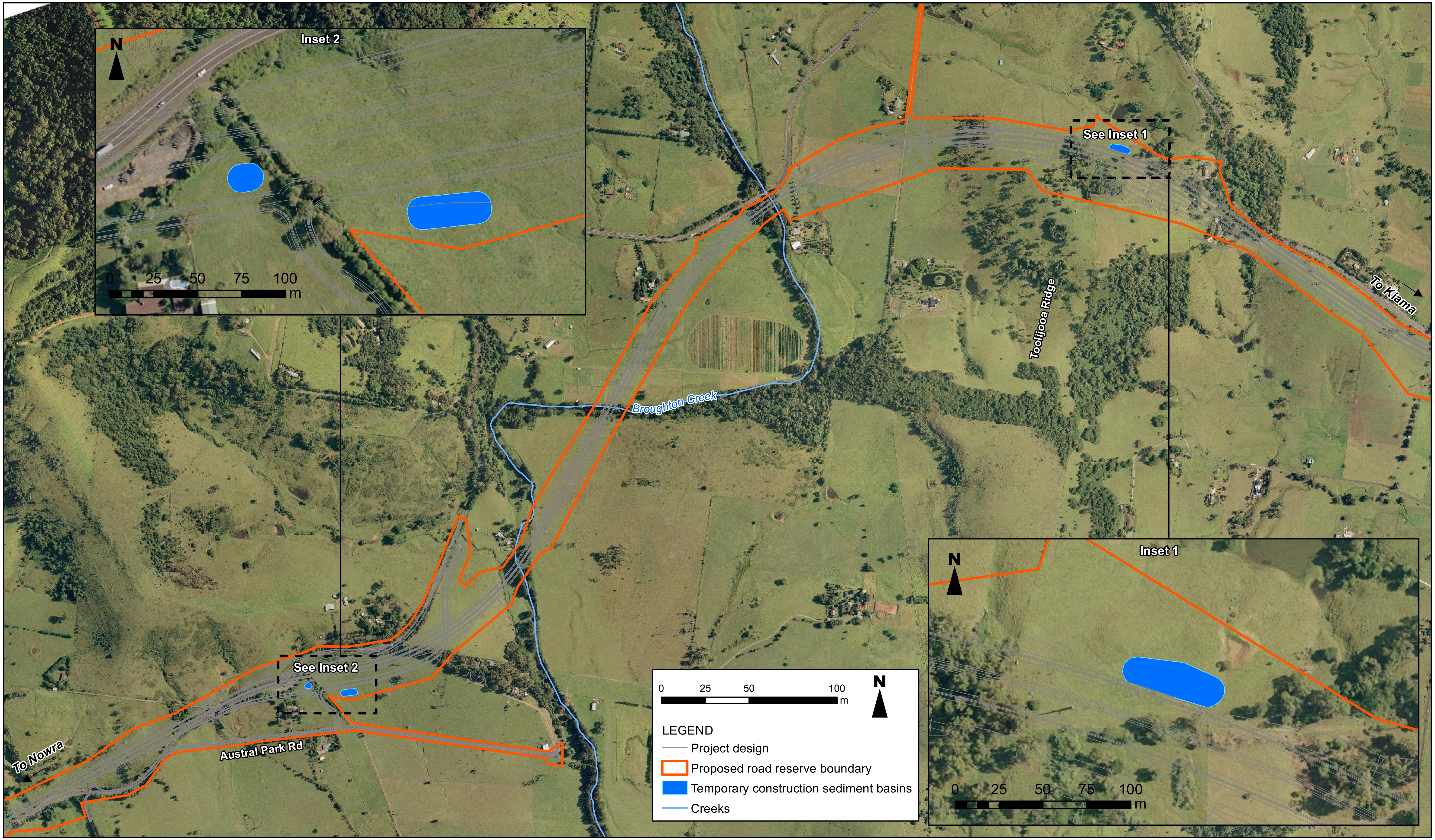

Figure 7-12 Location of construction sediment basins

Source: AECOM (2011)

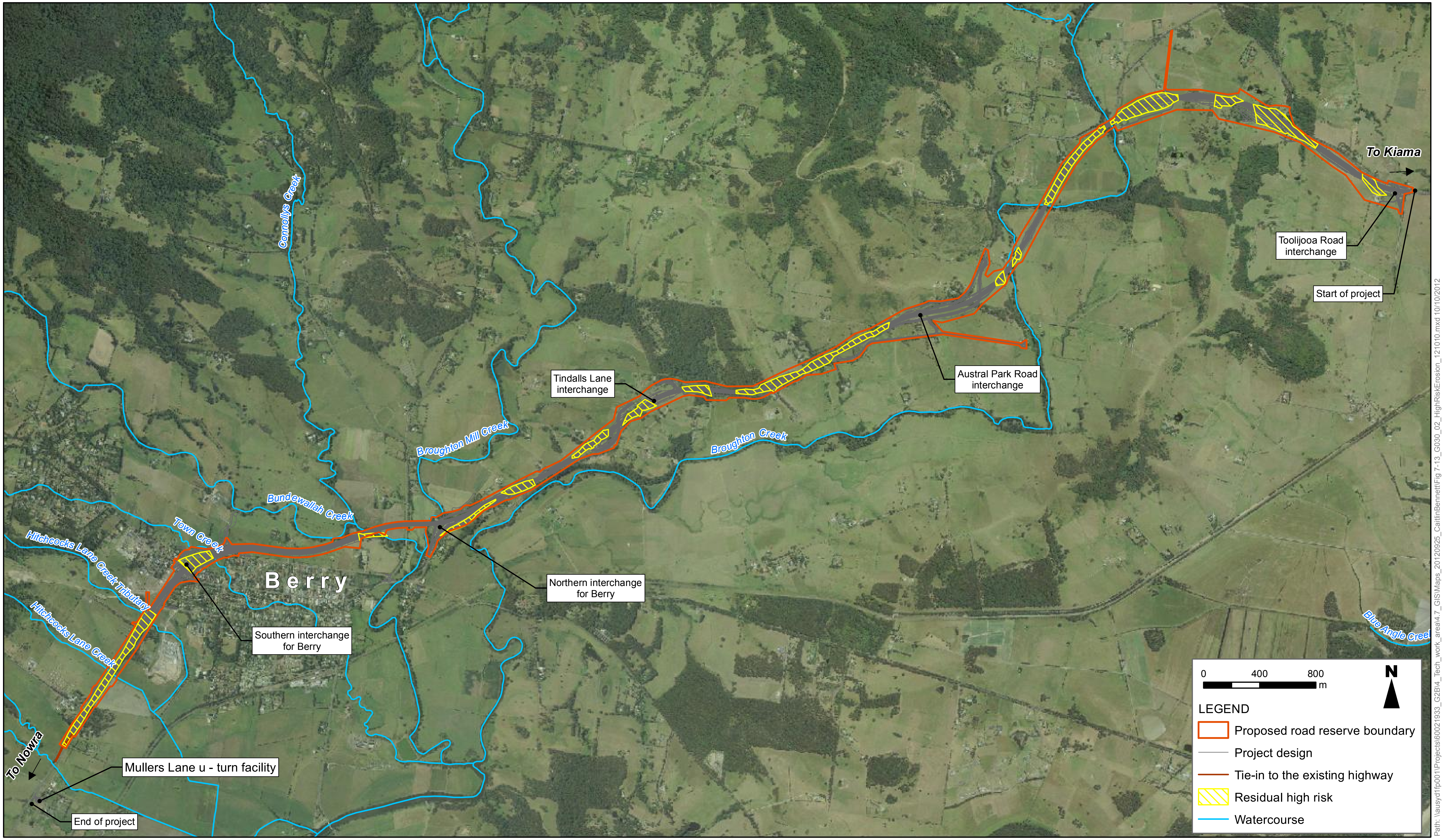

Figure 7-13 Areas of residual high risk of sedimentation and erosion

Source: AECOM (2012)

Table 7-55 Operation mitigation and management measures

Potential impacts	Management and mitigation measures
Operation	
Reduction in surface water quality	Where reasonable and feasible, water quality treatment targets for the project are: • 80 per cent reduction in total suspended solids load. • 60 per cent reduction in total phosphorus load. For the more sensitive receiving environments of Broughton Creek, Broughton Mill Creek, Connollys Creek and Bundewallah Creek, and where reasonable and feasible, the water quality treatment targets are: • 85 per cent reduction in total suspended solids load. • 60 per cent reduction in total phosphorus load. • 40 per cent reduction in total nitrogen load. Include a combination of swales and water quality basins to treat road runoff and protect downstream receiving environments to achieve the water quality treatment targets and prevent pollution of waters. Provide swales of varying lengths located both in the median and along outer road edges to convey and treat runoff. Example design options include swales that meet the total area requirements of 140 metres by two metres. Provide water quality basins at various locations to achieve the water quality treatment targets for the project. Around 18 basins have been identified, which would be confirmed during detailed design (refer to **Figure 7-14**). Refer to **Table 2-4** to **Table 2-7** in the *Surface Water, Groundwater and Flooding Technical Paper* at **Appendix H** for detailed assumptions and design methodology. Include bioretention systems at sensitive receiving environments where reasonable and feasible. Ensure biofiltration systems comprise a vegetated swale or basin, overlaying a filter media (usually soil-based) with a drainage pipe at the base (refer **Appendix H**). Where reasonable and feasible, size bioretention systems to achieve the water quality treatment targets. Suitable bioretention designs include: • 80 square metres of bioretention with a 140 metre swale. • 85 square metres of bioretention with a 30 cubic metre water quality basin. Confirm the configuration and location of the bioretention systems during the detailed design phase of the project. The total nitrogen target may be reconsidered if hydraulic capacity of the basin is compromised or risk of exposing PASS. Refer to **Table 2-8** to **Table 2-10** in the *Surface Water, Groundwater and Flooding Technical Paper* at **Appendix H** for more detailed assumptions and design methodology. Subject to detailed design, direct runoff from bridges over watercourses and floodplains to water quality basins and swales.

Potential impacts	Management and mitigation measures
	In the event of a spill, initiate emergency response plans to contain and clean up a spill (refer **Section 8.4)**.
Monitoring of surface water quality, swales and water quality basins	Inspect swales, basins and bioretention systems every three months until established and, once established, after large storm events (minimum one inspection per year). Clean sediment basins every five years or as required, Implement an independent surface water quality monitoring program (refer to **Appendix G** for further details). This program would use ANZECC trigger values for the protection of aquatic ecosystems as a starting point to develop locally appropriate thresholds that would trigger operational mitigating management responses. This would include monitoring parameters such as turbidity and pH (to monitor ASS), Nutrients (TP and TN), Metals (Aluminium, Cadmium, Copper, Lead, Zinc) and Total Petroleum Hydrocarbons.
Reduced groundwater quality	Implement a groundwater monitoring program prepared in consultation with the EPA and NOW. Include an assessment of groundwater level data trends and comparison with rainfall data, and an assessment of water quality trends and exceedences, if any in the program. Large cuttings, such as that at Toolijooa Ridge, would be a focus of the groundwater monitoring program. Use the existing groundwater monitoring network, established during construction. Carry out groundwater monitoring every six months during operation with a review after two years to assess data trends and assess if further monitoring is warranted. Provide results to the EPA and NOW. Establish a framework for monitoring in the Sampling Analysis and Quality Plan.
Loss of flow into farm dams	Undertake consultation with affected landowners prior to the commencement of construction where there would be permanent losses in dam catchments.

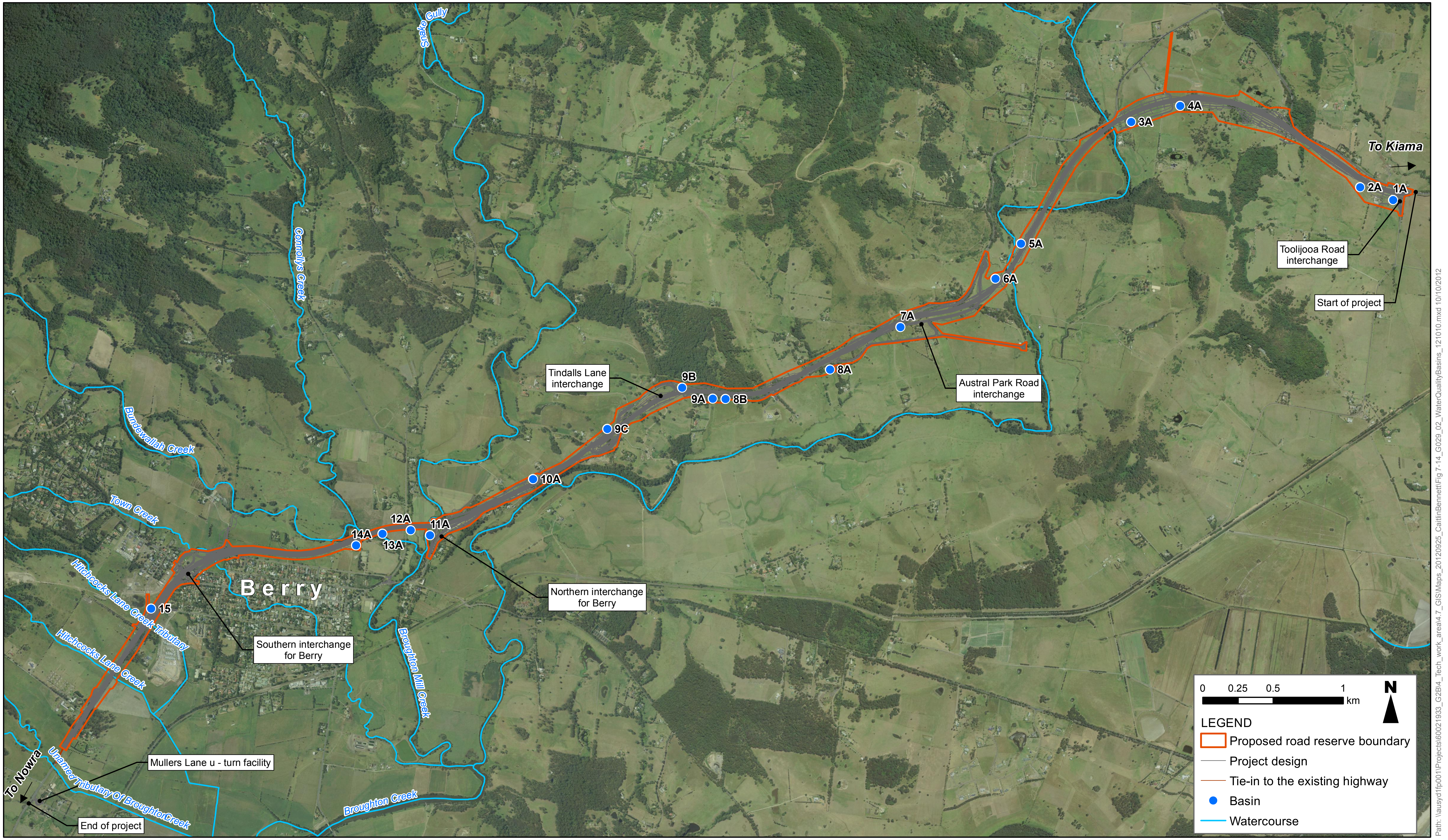

Figure 7-14 Proposed permanent operational sediment basin locations

Source: LPMA (2011)

Note: Refer to Table 2-7 in the *Surface Water, Groundwater and Flooding Technical Paper* at Appendix H for corresponding basin references.

7.4.5 Residual impacts

Following the construction of the project and implementation of mitigation strategies, there would be residual impacts on surface water and groundwater. These would be confirmed during detailed design and subject to the further investigations to inform the development of mitigation strategies (refer to **Table 7-52** (construction) and **Table 7-53** (operation). These impacts would include:

- Permanent diversion of Town Creek. The project would cause a residual loss of overall flows and flushing flows from Town Creek which would potentially increase sedimentation in both Town Creek and Bundewallah Creek. However, the diversion would also have the positive residual impact of reducing flood impacts within Berry. The design and revegetation of the diversion channel would ensure there is no detrimental impact on water quality within the channel and therefore for flows into Bundewallah Creek.
- Permanent changes to drainage catchments for existing farm dams. Such a reduction in runoff areas could prevent the natural flow of water into farm dams and potentially reduce their yield.
- Increase in surface water runoff during operation due to an increase in impervious surfaces and concentration of road runoff through drainage infrastructure. However, the water quality treatment system selected for the project aims to improve the quality of runoff compared to the existing highway and therefore have a net benefit to receiving waterways.
- Temporary alteration to groundwater flow conditions during construction due to localised dewatering, if required. However, once dewatering is completed, original groundwater flows would be re-established.
- A decrease in groundwater recharge due to the increase in impervious hard surface road area. However recharge decrease would be minor given the small road surface compared to the remainder of the catchment.
- Potential for reduced groundwater recharge, lowering of the local watertable and altered groundwater flow paths due to groundwater inflow to the cuttings along the project. The capacity of water extraction bores in the vicinity of the deep road cuttings may be reduced as a result. The impact on bores would be confirmed as part of the additional geotechnical field investigations that would be undertaken during the detailed design phase of the project.