11 Groundwater

This chapter addresses the impacts of the proposed upgrade on groundwater flows and quality. A more detailed assessment is contained in *Working Paper 3 – Groundwater Assessment*

Environmental assessment requirement	Where addressed
Groundwater impacts, considering local impacts at each deep cutting and cumulative impacts on regional hydrology. The assessment must consider: > extent of drawdown > impacts to groundwater quality > discharge requirements; and > implications for groundwater-dependent surface flows (including springs and drinking water catchments) > groundwater-dependent ecological communities > groundwater users including the *Alstonville Basalt Groundwater Source Water Sharing Plan;*	Section 11.3

11.1 Approach

A phased approach was adopted for the groundwater evaluation of the proposed upgrade. The approach involved the following elements:

> Completion of initial ground investigations to characterise the geological and hydrogeological conditions along the proposed upgrade.

> Completion of detailed ground investigations, modelling and analysis at representative locations along the proposed upgrade.

> Extrapolation of the results of the detailed investigations to the remainder of the proposed upgrade.

The initial phases of the hydrogeological investigations were undertaken in conjunction with the geological and geotechnical investigations. The purpose of these investigations was to characterise the geological and hydrogeological conditions along the preferred route. In consideration of the relative complexity of the engineering issues associated with the tunnel beneath St Helena ridgeline, intensive investigations were completed in this area.

The initial investigations identified complex groundwater conditions within the basalt of the Alstonville Plateau. More detailed investigations were then undertaken to assist with the assessment of the impact that the proposed road cuttings would have on the hydrogeological conditions along the route. These additional investigations were completed at two cuttings that were considered to be representative of others along the route. The cuttings investigated comprised:

> Cutting 19 (Type A) at chainage 148000 to 148400. As this cutting penetrates below the underlying groundwater table, the impact would be related to both diversion of rainfall recharge and capture of groundwater flow.

> Cutting 6 (Type B) at chainage 140200 to 140600. As this cutting has limited penetration into the underlying groundwater table, the impact would be related to the diversion of rainfall recharge.

A third type of cutting (Type C) was also identified but not assessed as these cuttings are regarded as having little potential to impact on groundwater flows.

The locations of the different types of cuttings are shown on **Figures 11.1a, b and c.**

Table 11.1 shows details of each cutting. Following analysis and modelling of the results of the detailed investigation, the results were extrapolated along the proposed upgrade on the basis of similarity of geological and hydrogeological conditions

Table 11.1- Cutting details

Cut No	Cut Depth (m)	Approx. Area Covered (m2)	Approx Penetration into groundwater table (m, max)	Type
0	8	23,010	1 - 2	B
1	12	42,000	2 - 3	B
2	1	16,740	-	C
3	13	19,200	-	C
4a+b	9	32,200	3	A
5	13	19,800	4 - 5	A
6	17	36,000	<1	B
7	14	14,410	-	C
8	9	25,740	<2	B
9	5	24,500	9 - 12	B
10	2	5,320	-	C
11	13	27,950	<3	B
12	7	16,830	-	C
14	10	17,480	-	C
15	28	57,550	<3	B
16	1	15,738	-	C
18a	13	14,900	-	C
18b	4	23,838	-	C

Table 11.1(cont)

Cut No	Cut Depth (m)	Approx. Area Covered (m2)	Approx Penetration into groundwater table (m, max)	Type
19	19	54,890	9	A
20	13	14,000	4	B
St Helena Hill Tunnel Area				
21		1,100	-	C
22	7	11,250	<3	B
23	11	5,795	Yes (portal)	B
Tunnel	N/A	7,500	12 - 19 (tanked)	C
24	15	7,500	Yes (portal)	B
25	13	13,800	-	C
26	4	16,000	-	C

Notes: Cut depth refers to the maximum excavation of the road cut below natural ground surface at the deepest point of penetration;
Area refers to the total area of the cut excavation;
Penetration into the groundwater table refers to the deepest vertical depth the cut excavation penetrates into the prevailing groundwater system/s present at the location in 2007;
A dash ("-") means not present or not affected; and
"tanked refers to the fact that the tunnel will have a sealed concrete liner (impermeable liner will not permit measurable groundwater flows into the tunnel void).

Figure 11.1a - Cutting locations

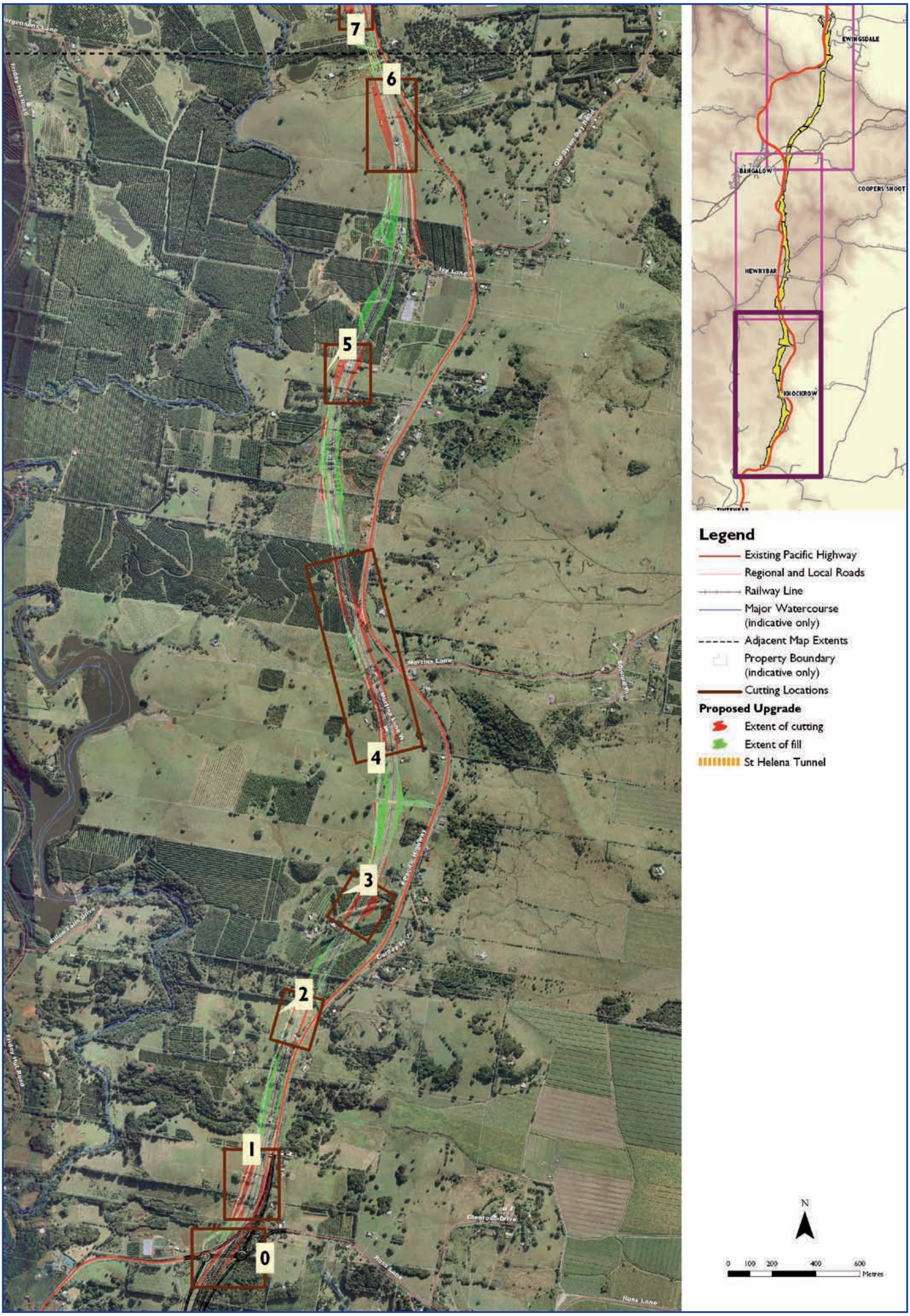


Figure 11.1b - Cutting locations

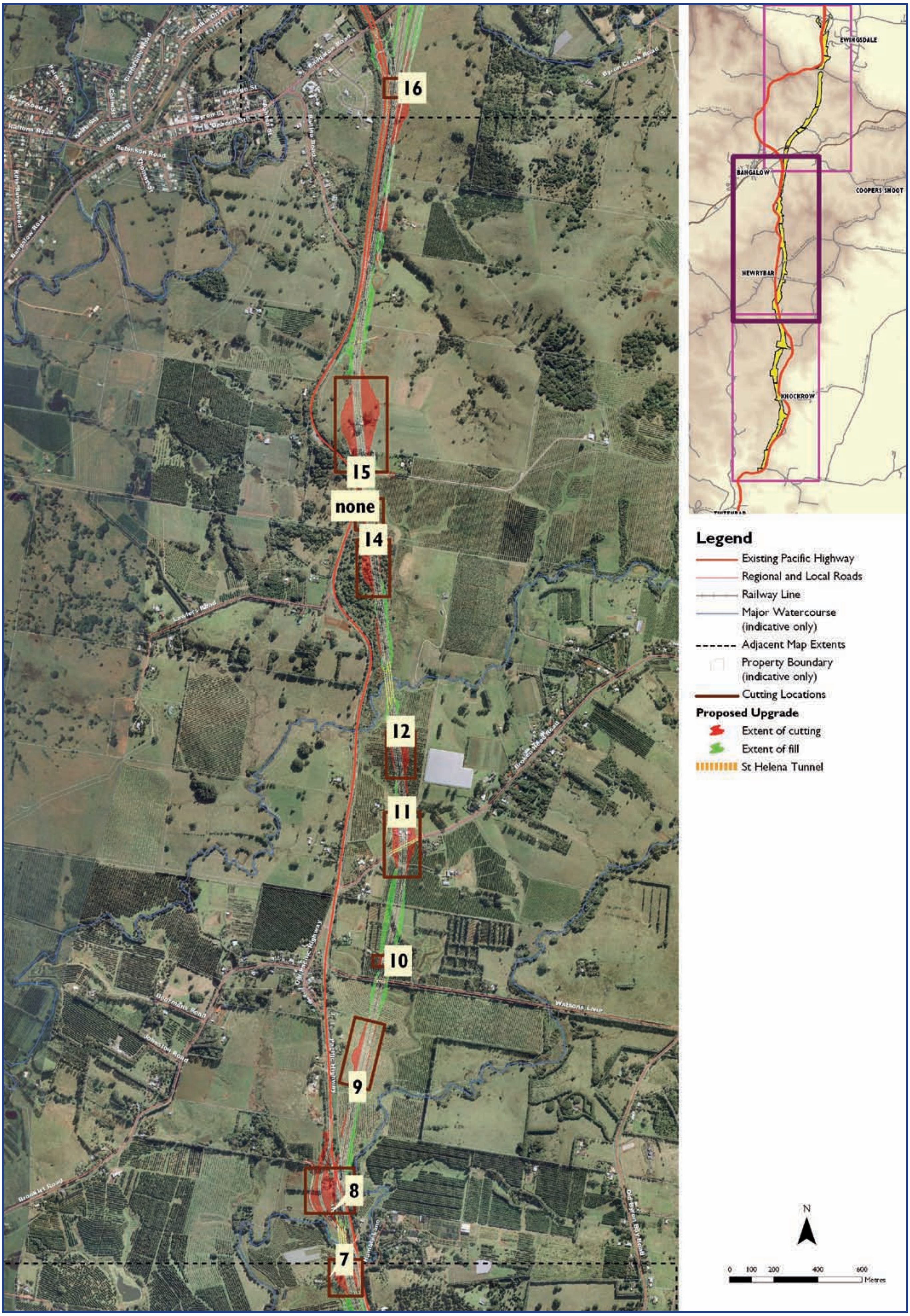
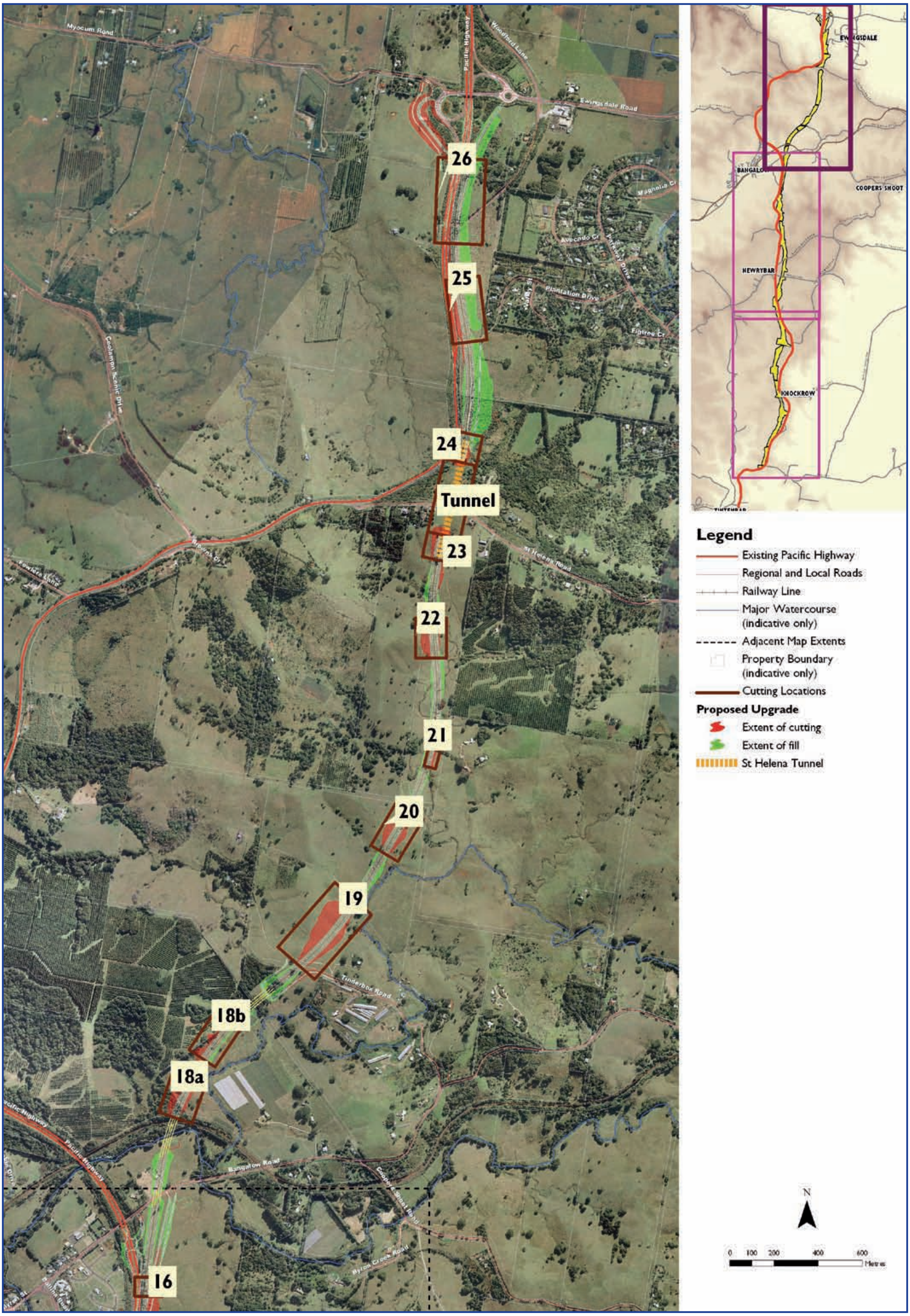


Figure 11.1c - Cutting locations



11.2 Existing groundwater characteristics

11.2.1 Geology

The Alstonville Plateau is made up largely of Lismore Basalt and all of the proposed works would occur in this geological unit.

The Lismore Basalt typically consists of a series of individual lava flows. These lava flows were extruded over a long period of time forming successive layers. Each flow is typically less than 25 m thick. In the periods between lava flows, weathering and deposition took place which allowed thin soil layers to be formed. These layers are now represented within the basalt as poorly lithified sedimentary rocks and as fossil soil horizons.

The hydrological characteristics of each individual basalt lava flow can be quite varied and can change both vertically and horizontally.

Recent exposure and weathering of the Lismore Basalt has resulted in further weathering of the rock.

While the stratigraphy of the plateau is quite complex, it typically comprises:

> Residual soils (derived from the weathering of the Basalt). These can be up to 5 m thick.

> Extremely weathered basalt rock, with essentially soil like properties. These can be up to 15 m thick.

> Discrete layers of basalt rock, generally less weathered but of very variable strength.

11.2.2 Groundwater model

Based upon the results of investigations, a groundwater model was developed to assist with the assessment of impacts. The model comprises an upper groundwater flow system and a deep groundwater flow system.

The upper groundwater flow system is contained within the residual soil and extremely weathered basalt layers. This system is complex, highly variable and likely to comprise numerous localised perched sub-systems. Flow in the system is largely horizontal and is likely to cascade down from one perched sub-system to another, until it reaches the deep groundwater system. For modelling purposes this system is considered to be unconfined.

The deep groundwater flow system is contained largely within the discrete layers of less weathered basaltic rock. Groundwater flow is likely controlled largely by the natural horizontal and vertical fractures within the rock and to a lesser extent by the fossil soil layers between individual flows. For modelling purposes this system is considered to be confined or semi-confined.

Groundwater features pertinent to this study are as follows:

> The local residual weathering profiles and regional layered geological sequences within the Lismore Basalt govern the nature of the 'upper and 'deep' (respectively) groundwater regimes in the area.

> Intermittent and perennial perched groundwater tables can be present within the shallow soil and weathered rock forming a complex, largely layered, cascading groundwater flow system.
> A deeper groundwater systems exist within the more permeable fractured or weathered layers of basalt that can be confined or semi-confined between the relatively massive and less permeable, basalt layers.
> Each of the identified systems has its own unique influence on the way recharge water (rainfall) runs off or infiltrates into the subsurface, thus creating two connected groundwater systems. There is likely to be a zone where the two systems overlap and where groundwater flow will be affected in part by each system. This zone produces a complex groundwater flow pattern, and one which is extremely difficult to interpret, predict and model.
> Regional groundwater flow in the Lismore Basalt generally follows the regional dip of the lava flows, that is, to the north-west. Local flow directions will be largely governed by the local topography, geology, and weathering profile.
> Each groundwater flow regime has the potential to give rise to springs at the surface, typically where zones or layers of lower permeability soil or rock outcrop at the ground surface.

Spring locations identified by the Bureau of Rural Sciences (BRS, Brodie and Green, 2002) are shown on **Figure 11.2.**

11.3 Potential groundwater impacts

The results of the various investigations and groundwater modelling were used to assess the likely impacts on the groundwater systems. The results from the investigation and analysis of two representative cutting types were used to extrapolate along the entire highway upgrade, based on cut area, depth of cut, extent of penetration into the groundwater table and slope shape. Based upon these criteria three types of cutting were identified: Type A, Type B and Type C out of 27 total cuts (not including the proposed tunnel).

Cutting type A is representative of three of the proposed 27 cuts. These cuttings are characterised by a significant depth of excavation, a large length and area and deep penetration into the groundwater table.

Cutting type B is representative of eleven of the 27 proposed cuts. These cuttings are characterised by moderate depth of excavation, small to moderate length and area and limited – less than 4 m – penetration into the groundwater table.

Cutting type C is representative of thirteen of the 27 proposed cuts. These cuttings are characterised by shallow depth of cuts and little or no penetration into the groundwater table. These are considered to have negligible impact on groundwater.

Details of the analysis and modelling carried out are given in *Working Paper 3 - Groundwater Assessment* and the location of these various cutting type are shown in **Figure 11.1.**

11.3.1 Extent of drawdown

Drawdown of the groundwater at Type A cuttings is likely to extend to the same depth as the base of the cutting. This could potentially cause a reduction in recharge to the local groundwater systems of up to 25 percent of their normal recharge. This drawdown is likely to have impacts to a distance of about 200 m from the cutting.

11.3.2 Impacts on groundwater quality

Surface water running off the road surface would generally be intercepted by catch-drains before seeping into cuttings. Some runoff may infiltrate before reaching sediment basins. The small quantity of untreated runoff entering the groundwater system suggests a low likelihood of impact to groundwater quality beyond the immediate road corridor.

11.3.3 Discharge requirements

Measures proposed to mitigate the impacts estimated include options to re-introduce water capture by the road cuttings in the local ground water systems. These measures will require the water quality be polished to ensure it meets background water quality in the local aquifer system.

11.3.4 Impacts on groundwater dependant surface flows, springs, drinking water catchments and groundwater dependent ecosystems

The potential impacts on groundwater dependent surface flows, springs and water catchments and groundwater dependent ecosystems at each cut are summarised in **Table 11.2.** Potential requirements for monitoring and mitigation are also identified. The implementation of the management measures described in **Section 11.4** would be expected to reduce the impacts described in **Table 11.2** to minimal levels. Definitions of groundwater dependent ecosystems are provided in **Section 12.3.9**.

Table 11.2 - Groundwater impact summary

Cut No.	Type	Potential Impact before Mitigation
0	B	Minor reduction of groundwater to creek and potential spring and local water resource within approximately 100 m of cutting. Water course related Groundwater dependent ecosystems present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
1	B	Minor reduction of groundwater to creek and potential springs, and local water resource within approximately 100 m of cutting. Potential impact to water course related groundwater dependent ecosystems present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
2	C	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
3	C	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
4a+b	A	Reduction of groundwater to local creeks and streams, and local water resource in the southern portion of the cut, i.e. within approximately 100 m of cutting. Potential impact to water course related groundwater dependent ecosystems present in the vicinity of cut (no springs or groundwater-reliant rainforest or wetlands are present in the area of potential impact, i.e. within 200 m of cutting).
5	A	Reduction of groundwater to local creeks and streams, and local water resource in the southern portion of the cut, i.e. within approximately 100 m of cutting. Potential impact to water course related groundwater dependent ecosystems present in the vicinity of cut (no springs or groundwater-reliant rainforest or wetlands are present in the area of potential impact, i.e. within 200 m of cutting).
6	B	Minor reduction of groundwater to creek and 4 potential springs, and local water resources within approximately 100 m of cutting. Potential impact to water course related groundwater dependent ecosystems and groundwater-reliant rainforest (north of cutting) present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).
7	C	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
8	B	Minor reduction of groundwater to creek and potential spring and water resource within approximately 100 m of cutting. Potential impact to water course related Groundwater dependent ecosystems present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
9	B	Minor reduction of groundwater to creek and potential spring and water resource within approximately 100 m of cutting. Potential impact to water course related groundwater dependent ecosystems present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).

Table 11.2 (cont)

Cut No.	Type	Potential Impact before Mitigation
10	C	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
11	B	Minor reduction of groundwater to creek and water resource within approximately 100 m of cutting. Potential impact to water course related groundwater dependent ecosystems present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
12	C	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
14	C	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
15	B	Minor reduction of groundwater to creek and potentially to springs, and local water resources within approximately 100 m of cutting. Potential impact to water course related Groundwater dependent ecosystems present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
16	C	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
18a	C	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
18b	C	No measurable impact on local or regional groundwater systems or resources anticipated, there is a groundwater-reliant rainforest cluster (south) nearby but it is unlikely to be impacted. No wetlands are present in the vicinity of the cut.
19	A	Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100 m of cutting. Likely impact to water course related groundwater dependent ecosystems present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
20	B	Minor reduction of groundwater to creek and potential spring and local water resources within approximately 100 m of road cutting. Potential impact to water course related groundwater dependent ecosystems present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).
St Helena Hill Tunnel Area		
21	C	No measurable impact on local or regional groundwater systems or resources anticipated. A cluster of groundwater-reliant rainforest may exist of the west and east of the Cut 21 but these are not likely to be impacted. No springs or groundwater-reliant wetlands are present in the vicinity of the cut.
22	B	Minor reduction of groundwater to creek and potential spring and local water resource within approximately 100 m of cutting. Potential impact to water course related Groundwater dependent ecosystems present in the vicinity of cut (no groundwater-reliant rainforest or wetlands are present in the area of potential impact).

Table 11.2 (cont)

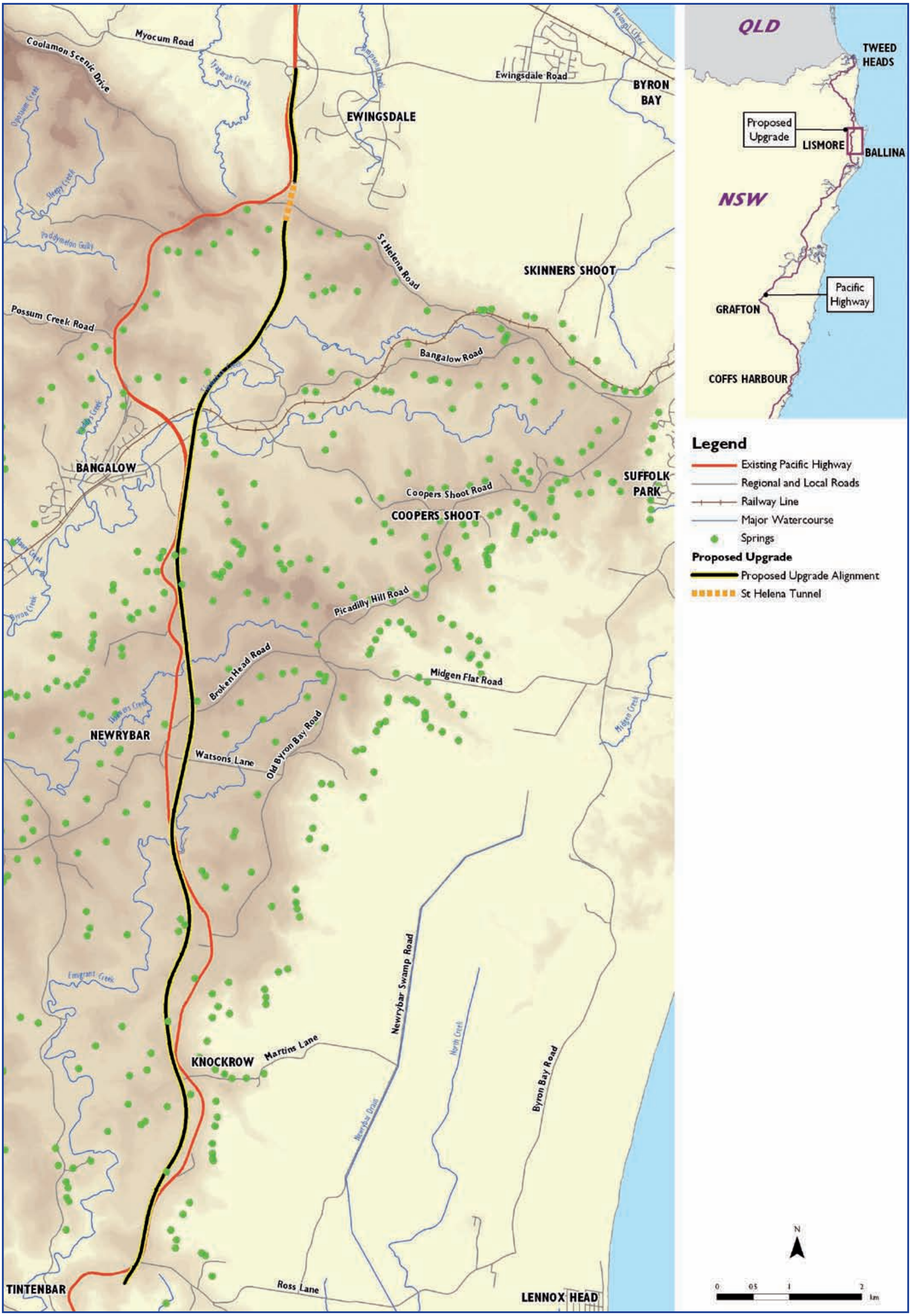
Cut No.	Type	Potential Impact before Mitigation
23	B	Minor reduction of groundwater to spring, creek and local water resource (groundwater well/s and dams) expected within approximately 100 m of portal excavation. Consequentially, minimal impact to water course related Groundwater dependent ecosystems present in the vicinity of cut (no springs, groundwater-reliant wetlands are present in the area of potential impact). Previously mapped (Brodie and Green 2002) groundwater-reliant rainforest in the vicinity of the portal cut appears to no longer exist based on vegetation survey for the environmental assessment.
Tunnel	C	The tunnel is planned to be fully tanked (negligible leakage to tunnel), and therefore no impact anticipated (leakage to tunnel essentially not measurable) within approximately 100 m of excavation. No measurable impact on local or regional groundwater systems or resources anticipated. Groundwater-reliant rainforest clusters may be present in the vicinity of the tunnel (over and east/west) but are unlikely to be impacted. No groundwater-reliant wetlands are present in the vicinity of the tunnel.
24	B	Minor reduction of groundwater to spring and associated creek leading to local water resource dam (and possible groundwater well/s) expected within approximately 100 m of excavation. Minimal local potential impact to water course related groundwater dependent ecosystems present in the vicinity of cut anticipated (no groundwater-reliant wetlands are present in the area of potential impact). Previously mapped (Brodie and Green 2002) groundwater-reliant rainforest in the vicinity of the portal cut appears to no longer exist based on vegetation survey for the environmental assessment.
25	C	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.
26	C	No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.

The results of the analysis summarised in **Table 11.2** suggest that there are potential effects from the proposed upgrade on groundwater dependent surface flows and springs. These impacts would potentially be the greatest at Type A cuts. The management regime identified in **Section 11.4** however would be expected to reduce impacts to negligible levels or in a worst-case scenario, impacts would be highly localised.

Impacts to the quantity of water entering drinking water sources would be negligible. Any impacted (redirected) groundwater flows within the Emigrant Creek or Wilsons River drinking water catchments would remain within the catchments and would ultimately flow into the surface water system.

Potential impacts to groundwater dependent ecosystems would be restricted to the instream ecology of small creeks and drainage lines in the potential area of impact of Type A and to a lesser extent Type B cuts. No groundwater dependent terrestrial communities (rainforest) would be impacted.

Figure 11.2 - Spring locations



11.3.5 Regional groundwater impacts and impacts on groundwater-dependant ecological communities

A *Water Sharing Plan for the Alstonville Plateau Groundwater Sources* (DIPNR 2004) was prepared in February 2003 in accordance with the *Water Management Act (2000)*. The purpose of the water sharing plan was to sustainably allocate groundwater from the Alstonville Plateau source to environmental flows and other uses. The Alstonville Plateau groundwater source covers an area of about 391 square kilometres (km^2), some of which is located in the study area, and comprises a Tertiary Basalt plateau overlying Clarence Moreton basin sediments.

The annual average recharge of the aquifer was reported to be 44,472 megalitres per year (ML/yr), of which 80 percent or 35,578 ML/yr is allocated to environmental flows. Water allocated to environmental flows is to support river and stream base flows as well as groundwater dependent ecosystems.

The proposed upgrade traverses Bangalow Zone 3 Groundwater Source zone, Alstonville Zone 1 Groundwater Source zone and is slightly overlying Lennox zone 6 Groundwater Source zone as defined by the DWE.

The regional impact on either environmental flows or groundwater users as a result of the proposed upgrade is expected to be minimal given the small area of the resource traversed, and the proposed management of impacts described below, which would reduce local impacts to minimal levels.

11.4 Management of impacts

11.4.1 General mitigation

To effectively manage and mitigate groundwater impacts, and potential uncertainties about the actual impacts, the following approach is proposed:

> **Type A cuts:** There is a high likelihood that Type A cuts would affect groundwater regimes. Engineering measures to be implemented where necessary as part of construction to mitigate groundwater impacts. Long-term monitoring of the groundwater regime in the vicinity of Type A cuts would be commenced well in advance of the road construction. The results of the monitoring, before and during road construction, would determine whether engineering mitigation is required at some or all of the Type A cuts. After road construction, the monitoring should continue to verify the effectiveness of the engineering mitigation, so that modifications can be made, if required.

> **Type B cuts:** It is less likely that Type B cuts would adversely impact on groundwater regimes. Engineering mitigation measures are unlikely to be required at Type B cuts. However, long-term monitoring is proposed, commencing prior to construction, and observation of groundwater behaviour and impact during construction to verify impacts. The results of the monitoring and observations, would determine if engineering mitigation is required at any of the Type B cuts.

> **Type C cuts:** These cuts are expected to have no or negligible groundwater impacts. Monitoring and engineering mitigation measures are not required.

11.4.2 Monitoring

Monitoring of both groundwater level and chemical quality is proposed as an essential measure to mitigate uncertainty in predictions of groundwater behaviour, which have been based largely on groundwater observations over a relatively short period of time. The monitoring would comprise:

> Installation and monitoring of wells.

> Groundwater sampling and analyses for suspended solids and metals.

> Visual observations of surface water flows at springs and creeks.

> An assessment of groundwater dependent ecosystem healthiness.

Long-term monitoring of the existing monitoring wells should be continued up to, during and following construction of the cuts. The monitoring would be initiated prior to construction (background data collection), during construction and during the early years of operation, at a frequency to be determined (potentially quarterly for the first 5 years of operation, with a review of data to determine whether further monitoring is required).

New monitoring wells will need to be installed at Type A and B cuts where there are currently no monitoring wells installed. Additional monitoring wells may also be required at Cuts 6 and 19 where wells were previously installed for the purpose of this study.

The objective of long-term monitoring will be to:

> Obtain baseline groundwater data over a longer period than for this groundwater study and verify the validity of groundwater levels at the two cuts investigated during the study and at the other Type A and B cuts, verify long-term and adverse trends.

> For cuts at which engineering mitigation measures are implemented, permit an early assessment of groundwater behaviour in response to engineering mitigation measures and verify the effective functioning of the mitigation measures.

> At cuts where mitigation measures are not planned (Type B) verify that there are no adverse impacts as a result of the construction.

11.4.3 Potential engineering mitigation measures

Two categories of engineering mitigation measures could be considered at Type A cuts, and at Type B cuts, if monitoring indicates that engineering mitigation is required:

> Engineering mitigation 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 ponds before being released back into the creek or natural drainage system at some point downstream.

> Engineering mitigation measures that transfer the seepage water (where present) into the groundwater ecosystem immediately down-slope of the cut. These may involve collecting the seepage water from the cut face just above the level of the road, and piping it under the cut/fill platform to the down-slope side of the highway. This collection and piping system would also likely include seepage collected from the drainage blanket under the highway pavement. The collected water could then be returned to the ground through absorption trenches or discharged directly to the surface water system.

From the perspective of risk to local groundwater flow patterns, the second option above, would provide the better solution, although a system combining both may need to be applied in some circumstances. The preferred method and exact form of the mitigation measures would be the subject of ongoing development of the concept design and environmental assessment process.