

8.5 Greenhouse gas and climate change

Increasing public concern and debate regarding the likelihood and magnitude of climate change impacts in Australia has resulted in a number of national and state policy commitments addressing both climate change mitigation and adaptation. Most recently the Federal Government has enacted the '*Clean Energy Future Legislation Package 2011*' which introduces a Carbon Price from July 2012. The NSW and Federal Governments have also provided guidance regarding the assessment of climate change risks in the *NSW Climate Impact Profile, Illawarra Region* (Department of Environment, Climate Change and Water (DECCW), 2010) and *Climate Change Impacts and Risk Management: A Guide for Business and Government* (Department of Environment and Heritage Australian Greenhouse Office, 2006). These legislative, policy and guidance documents highlight the importance of assessing and mitigating such impacts for key infrastructure projects.

This section outlines the legislative and policy framework for the control of GHG emissions and climate change. It provides an assessment of the impacts of the project upon climate change, due to the release of greenhouse gas (GHG) emissions during construction and operation phases and to provide recommended mitigation measures. This section also provides an assessment of the potential impacts of climate change upon the project and recommended mitigation or adaptation measures.

8.5.1 Legislative and policy framework

GHG emission requirements and considerations are included in a growing number of legislative and policy mechanisms in Australia (State and Federal) and internationally.

The 'Kyoto Protocol to the United Nation Framework Convention on Climate Change' (UNFCCC) was signed in 1997 and Australia ratified the protocol in December 2007. The Kyoto Protocol's objective is to reduce GHG emissions through setting reduction targets for GHG emissions produced by ratifying countries. These targets are set using the countries' 1990 baseline emissions. Australia is committed to a target of 108 per cent of 1990 emission levels by the end of 2012. A key issue of ongoing international negotiations is how and if these targets will develop post 2012.

The Australian Government's climate change policies and regulations are managed by the Department of Climate Change and Energy Efficiency (DCCEE). The following are key federal climate change policies:

- The *Energy Efficiency Opportunities Act 2006* (EEO Act).
- The *National Greenhouse and Energy Reporting Act 2007* (NGER Act).
- The 'Clean Energy Future Legislative Package 2011' (including the Carbon Price).

'Securing a clean energy future. The Australian Government's Climate Change Plan' (DCCEE, 2011) details policies to reduce GHG emissions and transition to a clean energy future for Australia. The Federal Government has committed to a target of reducing carbon pollution by five per cent below 2000 emission levels by 2020 irrespective of what other countries do and by up to 15 or 25 per cent depending on the scale of global action. The long term carbon pollution reduction target is 80 per cent below 2000 emission levels by 2050.

One of the objectives of the NSW *Environment Planning and Assessment Act 1979* (EP&A Act) is to encourage ecologically sustainable development (ESD). GHG emissions associated with the project would contribute to global GHG emissions, which are relevant to the principles of ESD. **Chapter 11** provides further discussion of the how the principles of ESD have been applied to the project.

In November 2005 the NSW State Government released the NSW Greenhouse Plan (The NSW Greenhouse Office, 2005), which provides a strategic management approach to addressing climate change. In addition, the NSW 2021 State Plan, includes a target to minimise the impacts of climate change in local community as outlined in Goal 23: *to increase opportunities for people to look after their own neighbourhoods and environments*.

8.5.2 Methodology

GHG assessment methodology

The purpose of the assessment of the estimated GHG emissions generated through the construction and operation of the project is to:

- Identify the sources of GHG emissions associated with the project (construction, operation, maintenance and utilisation by traffic).
- Quantify the GHG emissions associated with each GHG source.
- Present the GHG emissions associated with the project.
- Identify opportunities (mitigation measures) which may be implemented to reduce the GHG emissions associated with the project.

GHG emissions are reported in this assessment as tonnes of carbon dioxide equivalent (tCO₂-e).

GHG accounting and reporting principles

The GHG assessment uses the methodologies detailed in:

- The Greenhouse Gas Protocol: Corporate Standard (World Council for Sustainable Business Development and World Resources Institute, 2005).
- National Greenhouse Accounts (NGA) Factors (DCCEE, 2011).
- Greenhouse Gas Assessment Workbook for Road projects (the Workbook) (Transport Authorities Greenhouse Group (TAGG), 2011).

The assessment was also conducted according to the following GHG accounting and reporting principles:

- **Relevance** – Select and use GHG sources, sinks, data and methodologies appropriate for the project/organisation and intended use of GHG inventory results.
- **Completeness** – Include all relevant GHG emissions and information which support methodology and criteria used.
- **Consistency** – Use consistent data, calculation/modelling methods, criteria and assumptions to enable valid comparisons.
- **Transparency** – Include clear, sufficient and appropriate information to enable others to understand the basis for results and make decisions regarding use of GHG inventory results with reasonable confidence.
- **Accuracy** – Reduce bias and uncertainties, as much as practical.

In addition to the accounting and reporting principles presented above, the issue of materiality is also assessed in a GHG assessment. This is a core accounting and auditing principle which ensures that sources, assumptions, values and procedures included in the GHG assessment are material to the project. As materiality is valued within the context of the project being assessed, this can vary significantly. In this assessment, emissions are assumed immaterial if they are less than five per cent of the overall GHG inventory, as per the Workbook.

GHG calculation methodology

The Workbook provides a consistent methodology for estimating the GHG emissions for all of the major activities that are considered to contribute significantly to the overall emissions associated with a road project. The steps involved in undertaking a GHG assessment in accordance with the Workbook were adopted for this assessment and are illustrated in **Figure 8-6**. The calculation methods used to estimate the GHG emissions from liquid fuel combustion, electricity use, vegetation clearing, materials use and traffic use of the road post construction, are presented in **Appendix O**.

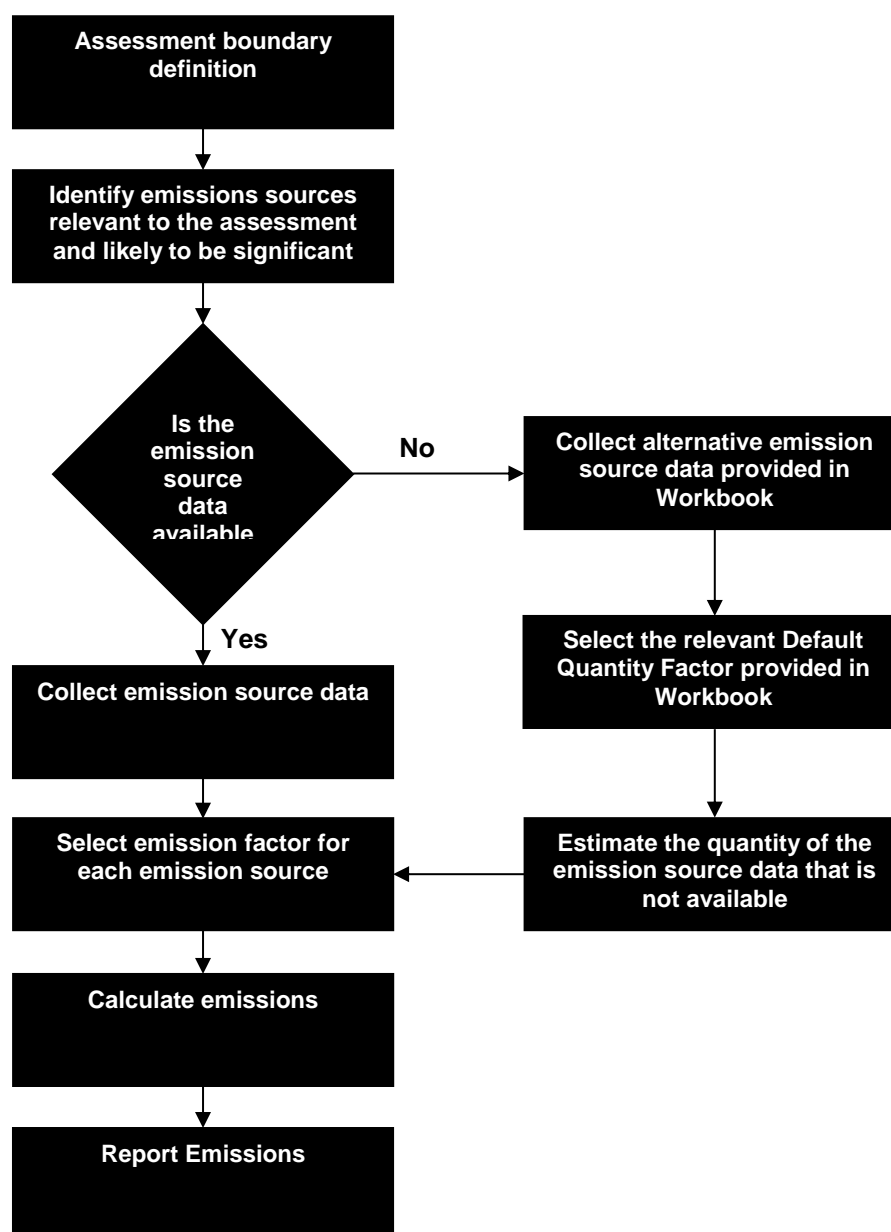


Figure 8-6 GHG emission quantification steps.

GHG inventory scope and boundary

The Workbook considers the GHG assessment boundary of a road project to include all emissions sources that can be impacted by decisions made by designers, constructors, managers and/or operators of the road. Following definition of the GHG assessment boundary, emissions sources are categorised into three different scopes, to identify and classify emissions sources according to the extent to which the project has operational control over the emissions. The three scopes are:

- **Scope 1** – Direct emissions: GHG emissions generated by sources owned or controlled by the project, e.g. emissions generated by the use of diesel fuel by project-owned construction plant, equipment or vehicles.
- **Scope 2** – Indirect emissions: GHG emissions from the generation of purchased electricity in project-owned or controlled equipment or operations. These GHG emissions are generated outside of the project's boundaries, e.g. the use of purchased electricity from the grid.
- **Scope 3** – Indirect upstream emissions: GHG emissions generated in the wider economy due to third party supply chains as a consequence of activity within the boundary of the project, e.g. GHG emissions associated with the offsite mining, production and transport of materials used in the construction or maintenance of the road.

Some emission sources may be categorised into two scopes (ie Scope 1 and Scope 3 or Scope 2 and Scope 3), to account for GHG emissions generated by sources owned or controlled by the project (Scope 1) and associated indirect upstream GHG emissions, generated outside of the project boundary due to third party supply chains in direct relation to the project. For example, the use of fuel by project operated construction equipment would incur Scope 1 GHG emissions from the combustion of fuel in construction equipment on site and Scope 3 GHG emissions associated with the extraction, production and transport of the purchased fuel.

Table 8-9 and **Table 8-10** list the emissions sources and activities considered within the project construction GHG assessment boundary and project operation and maintenance GHG assessment boundary, according to scope.

Table 8-9 Construction GHG emission sources

Emission source category	Emission source	Emission scope		
		Scope 1	Scope 2	Scope3
Fuel	Mobile equipment	✓		✓
	Site vehicles	✓		✓
	Earthworks	✓		✓
	Material delivery			✓
	Equipment delivery			✓
	Waste removal			✓
	Spoil removal			✓
	Vegetation removal			✓
Materials	Construction materials			✓

Table 8-10 Operation and maintenance GHG emission sources

Emission source category	Emission source	Emission scope		
		Scope 1	Scope 2	Scope3
Fuel	Mobile equipment	✓		✓
	Material delivery			✓
Electricity	Street lighting		✓	✓
	Variable message sign		✓	✓
Materials	Maintenance materials			✓

The Workbook provides guidance on which emission sources are generally always significant, which emission sources may be significant on a project specific basis and those emission sources that generally would be insignificant and excluded from the GHG assessment boundary. Based on this guidance, the disposal of waste from demolition (including the disposal of excess spoil for reuse purposes) is considered insignificant to the assessment and is excluded from the GHG assessment boundary.

Based on a materiality criteria of five per cent, (as outlined in the section above) the removal of vegetation and the use of electricity in site offices during construction have been removed from the GHG assessment boundary, as the GHG emissions from these sources accounted for less than one per cent of total GHG emissions from construction.

Climate change risk/impact assessment methodology

Climate change poses an increasing and serious challenge to economic development, including new and existing infrastructure such as roads and highways. In order to assess the likely impacts, climate change risks need to be identified and prioritised in relation to the project. To prioritise the climate change risks identified, each risk has been rated based on the consequences and the likelihood of those consequences occurring. Climate change would affect the project and its associated infrastructure during the course of its design life (circa 100 years).

The climate change risk assessment is based on the latest available climate science and risk assessment research and publications, including the following:

- Fourth Assessment Report, Working Group I: Climate Change 2007 – The Physical Science Basis (Intergovernmental Panel on Climate Change (IPCC), 2007).
- Climate Change in Australia: Technical Report (CSIRO, 2007).
- NSW Climate Change Action Plan – Summary of Climate Change Impacts Illawarra Region (DECC, 2008).
- Climate Change and the NSW State Road Network, Climate Change Risk Assessment (AECOM, 2008).
- NSW Government 'Sea Level Rise Policy Statement' (DECCW, 2009)
- NSW Climate Impact Profile, Illawarra Region (DECCW, 2010)
<http://www.environment.nsw.gov.au/climateChange/20100171ClmtChngNSW.htm>¹.

¹ Accessed and information downloaded August, 2011.

The climate change risk assessment undertaken for the project also applied an approach to risk assessment as recommended by:

- Australian and New Zealand Standard AS/NZS 4360 Risk Management.
- Climate Change Impacts and Risk Management: A Guide for Business and Government (Department of the Environment and Heritage Australian Greenhouse Office, 2006).

The following approach was used to complete the high level desktop climate change risk assessment:

- Overview of current climate science. This includes a summary of the literature review based on the sources listed above such as the Australian climate science and studies of the regional area (Illawarra region).
- Identification and prioritisation of the main climate change risks and associated projections. This assessment considers the climate change risks and projections for climate variables: such as temperature, precipitation, sea level rise, and extreme events.
- Consideration of each relevant climate change risk as it applies to the project (such as flooding and topography of the area) and identification of priority climate change risks for further assessment.
- Assessment of potential impacts of priority climate change risks.
- Recommendation of adaptation options (project mitigation measures) for the priority climate change risks.

8.5.3 Assessment of potential impacts

The GHG emission source data used to estimate the GHG emissions associated with construction, operation and maintenance of the project is provided in **Appendix O**. Note that these results are based on design information available at the concept design stage.

GHG emissions

Construction GHG emissions

According to the GHG assessment methodology, assumptions and inputs presented in this report (see **Appendix O**), the construction of the project would generate:

- 48,959 tCO₂-e direct, Scope 1 GHG emissions.
- 0 tCO₂-e indirect, Scope 2 GHG emissions².
- 50,627 tCO₂-e indirect, Scope 3 GHG emissions.

This results in total Scope 1, 2 and 3 GHG emissions for the project of 99,586 tCO₂-e. The detailed GHG assessment results are given in **Table O-1** of **Appendix O**. The GHG emissions results from key emissions sources associated with construction are shown in **Figure 8-7**. **Figure 8-8** illustrates the GHG emissions results by scope. The major source of GHG emissions would be from the use of diesel fuel to operate construction equipment on site, accounting for 95 per cent of direct Scope 1 GHG emissions and 50 per cent of total emissions (Scope 1, Scope 2 and Scope 3). The use of materials for construction of the pavement, bridges, drainage infrastructure and road furniture would also be a major source of GHG emissions, accounting for 89 per cent of indirect Scope 3 GHG emissions and 45 per cent of total GHG emissions (Scope 1, Scope 2 and Scope 3). Pavement asphalt and cement, concrete and structural steel would contribute significantly to the emissions associated with construction materials.

² Although electricity is purchased for site offices, see Appendix O, this is not included in the emissions inventory based on materiality criteria. Table 3.3 of Supporting Document for the Workbook also recommends excluding it from the GHG assessment boundary, as it would generally be insignificant to the assessment.

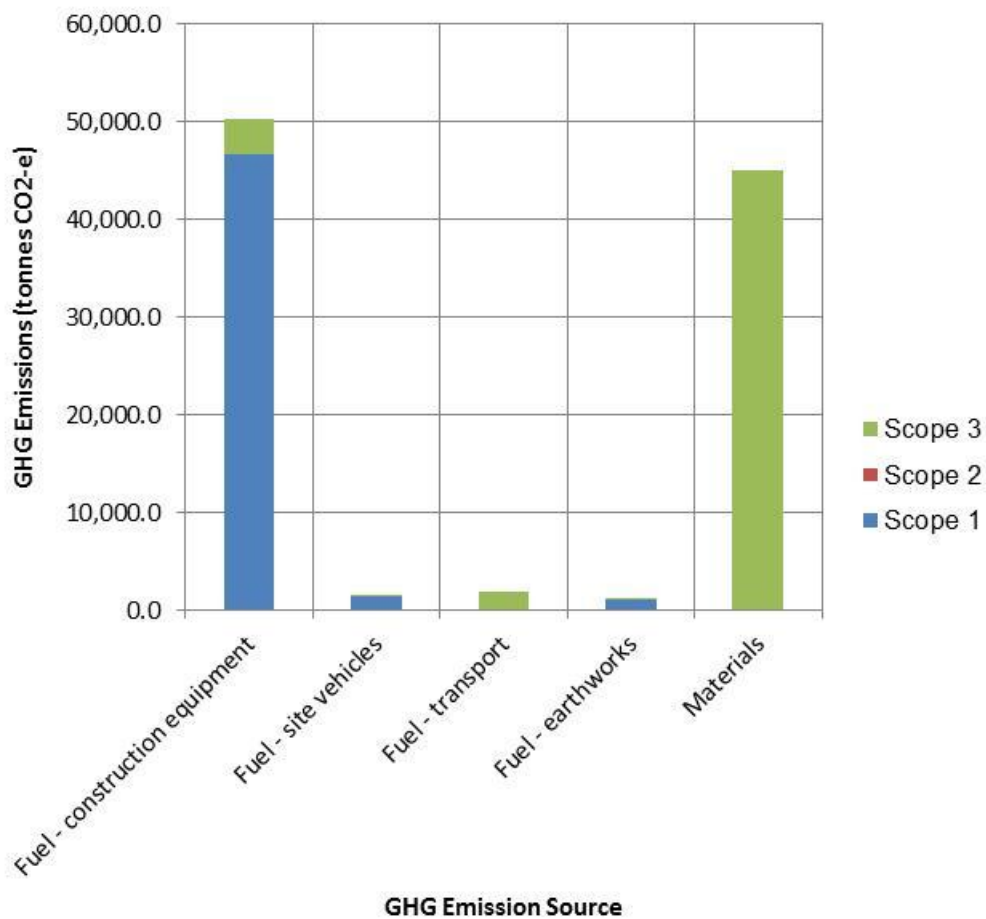


Figure 8-7 Construction GHG emissions assessment results

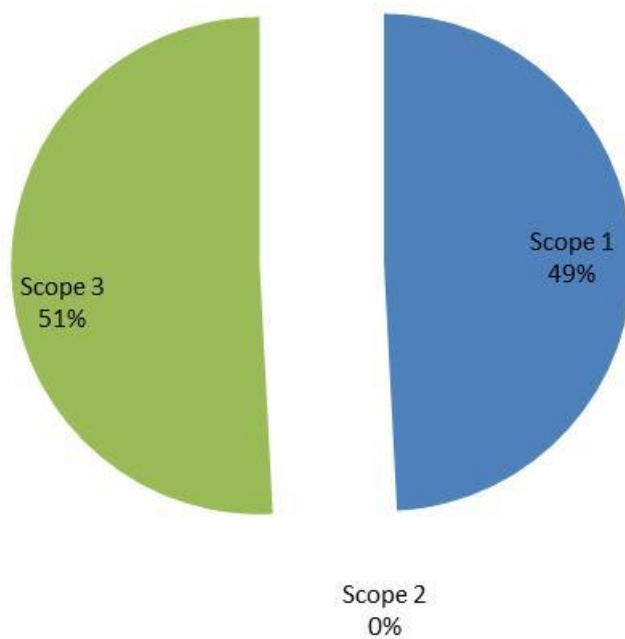


Figure 8-8 Construction GHG emissions by scope

Operation and maintenance GHG emissions

The estimated GHG emissions that would occur due to the operation and maintenance of the project are presented in **Table 8-11**. These have been calculated according to the GHG assessment methodology, assumptions and inputs presented in **Appendix O**.

Activities that would generate GHG emissions in the operation and maintenance stages of the project include:

1. Road infrastructure operation: The use of electricity for powering street lighting and a variable message sign.
2. Road infrastructure maintenance: Diesel fuel use for the operation of maintenance equipment and the delivery of maintenance materials.
3. Road infrastructure maintenance: Use of materials for maintaining the road pavement.
4. Vehicles using the road post construction: Use of the road post construction by traffic on the regional and local road network between Gerringong and Bomaderry bounded by the Princes Highway and 'Sandtrack' routes (the traffic impact footprint).

Annual use of electricity for powering street lighting and a variable message sign would incur 62 t CO₂-e indirect Scope 2 emissions and 11.9 t CO₂-e indirect Scope 3 emissions.

Emission estimates for the use of fuel, materials and the delivery of materials for the maintenance of the road pavement are based on the following maintenance activities occurring every 50 years (in accordance with 'typical' maintenance activities given in TAGG 2011):

- One major rehabilitation with the top 150 millimetres of all project pavement replaced. See **Appendix O** for areas and types of materials replaced.
- Five per cent of the full depth of all project road pavements replaced for patching/repair. See **Appendix O** for areas and types of materials replaced.

The use of fuel and materials to undertake these maintenance activities would result in 8334 t CO₂-e direct Scope 1 emissions and 7086 t CO₂-e indirect Scope 3 emissions. The total quantity of GHG emissions associated with the above road maintenance activities would be 15,420 t CO₂-e.

These GHG emissions generated during project operation and maintenance activities are relatively small in comparison with the GHG emissions savings associated with vehicle traffic use of the road.

To assess the contribution of GHG emissions from vehicles using the road post construction, total annual GHG emissions generated by vehicles using the Princes Highway and 'Sandtrack' as a consequence of 'do nothing' action (ie without the road construction) and as a consequence of operation of the project were considered (see the *Traffic and Transport Technical Paper* (AECOM 2012) for the traffic modelling methodology which was adopted to predict future traffic volumes for the project and the traffic impact footprint considered). The difference between total GHG emissions generated in the project and 'do nothing' scenarios was used to calculate the net GHG emissions attributable to operation of the project. The results, detailed in **Table 8-11** indicate that the project would generate less GHG emissions when compared to GHG emissions that would be emitted in the absence of the project, with:

- Around 13,551 t CO₂-e less net GHG emissions emitted by traffic using the project in the opening year (2017) when compared to GHG emissions emitted in the 'do nothing' scenario.
- Around 9843 t CO₂-e less net GHG emissions emitted by traffic using the project in the design year (2037) when compared to GHG emissions emitted in the 'do nothing' scenario.

Table 8-11 Operation and maintenance GHG emissions assessment results

Emission source category	Emission source	GHG emissions (t CO ₂ -e)			
		Scope 1	Scope 2	Scope 3	Total
Electricity use (per year)	Street lighting	0.0	52.6	10.1	62.7
	Variable message sign	0.0	9.4	1.8	11.2
Maintenance fuel combustion — diesel (over 50 years)	Mobile equipment	6,942.1	0.0	527.0	7,469.1
	Transport - material delivery	1,391.8	0.0	105.7	1,497.5
Maintenance Materials used (over 50 years)	Pavement - aggregate	0.0	0.0	153.5	153.5
	Pavement - cement	0.0	0.0	258.5	258.5
	Pavement - hot mix asphalt	0.0	0.0	5,554.8	5,554.8
	Pavement - Bitumen	0.0	0.0	347.4	347.4
	Pavement - lime	0.0	0.0	138.8	138.8
Total GHG emissions road use - opening year 2017 for 'do nothing' option		0.0	0.0	121,982	N/A
Total GHG emissions road use - opening year 2017 with project		0.0	0.0	108,431	N/A
Net GHG emissions road use - opening year 2017 with project compared to 'do nothing' option		0.0	0.0	-13,551.0	-13,551.0
Total GHG emissions road use - design year 2037 for 'do nothing' option		0.0	0.0	145,763.0	N/A
Total GHG emissions road use - design year 2037 with project		0.0	0.0	135,920.4	N/A
Net GHG emissions road use - design year 2037 with project compared to 'do nothing' option		0.0	0.0	-9,842.6	-9,842.6
Total GHG emissions from major maintenance		8,333.9	0.0	7,085.7	15,419.6
Total yearly operational and road use GHG emissions or savings (not including major maintenance) 2017		0.0	62.0	-13,539.1	-13,477.1
Total yearly operational and road use GHG emissions or savings (not including major maintenance) 2037		0.0	62.0	-9,830.7	-9,768.7

The project would not significantly alter the vehicle kilometres travelled (VKT) in the traffic impact footprint. VKT projections for the project and 'do nothing' scenarios at 2017 and 2037, indicate that compared to the 'do nothing' scenario, the project would reduce VKT by approximately six per cent in 2017 and two per cent in 2037 (refer to **Table O-14** in **Appendix O** for VKT data). The GHG assessment results for the project and 'do nothing' scenarios indicate that compared to the 'do nothing' scenario, the project would reduce GHG emissions by 11 per cent in 2017 and seven per cent in 2037. As such, the predicted reduction in GHG emissions is due to reduced VKT together with increased average vehicle speeds (due to road network improvements) which would have improved vehicle fuel efficiency for most road sections.

Cumulative GHG emissions savings

Construction of the project would generate GHG emissions, however due to reductions in fuel use associated with the project, the GHG emissions savings relative to a 'do nothing' option (ie no road construction) would result in an overall GHG emissions reduction. **Figure 8-9** shows the cumulative GHG emissions and savings, from project construction to the design year 2037, including operational GHG emissions. It however excludes emissions from major road maintenance as these emissions are expected to occur from one major road maintenance event every 50 years, which is 30 years beyond the design year 2037 and the timeframe represented in **Figure 8-9**.

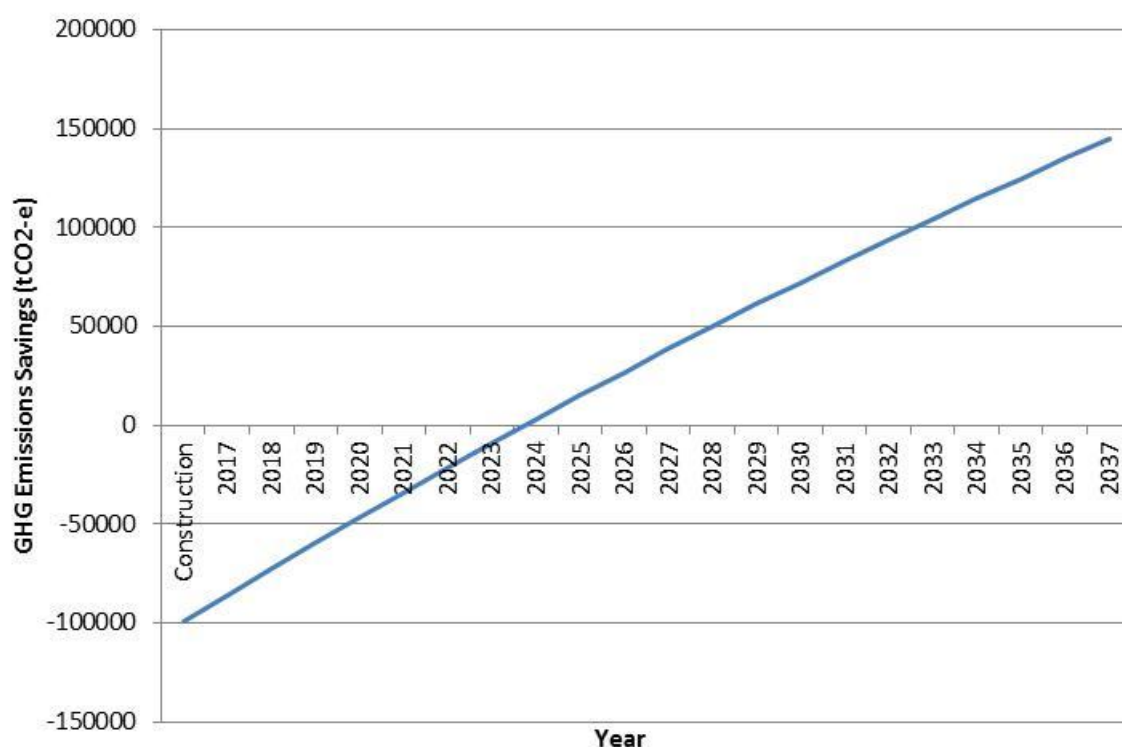


Figure 8-9 Cumulative GHG emissions savings including construction and operational emissions (not including major road maintenance)

Climate change projections and risks

In order to assess the risk to the project posed by climate change, the current climate science and model projections have been investigated.

Climate differs from region to region due to changes in the influencing factors, such as geographical location, latitude, physical characteristics, variable patterns of atmosphere and ocean circulation and in some cases, human interaction (IPCC, 2007). Consequently, climate change and the associated impacts can be expected to vary from region to region, with differences projected between climate changes on a national scale and a regional scale. As such, this literature review presents the climate change projections on an Australian national level and the regional projections for the Illawarra region on the NSW south coast, within which the project is proposed.

Australian national climate change projections have been sourced from the document *Climate change in Australia: technical report* (CSIRO, 2007), which was prepared in partnership between the CSIRO, the Bureau of Meteorology (BoM) and the Australian Greenhouse Office. The Australia and New Zealand IPCC 2007 regional projections were also referenced.

A summary of the climate change impacts for the Illawarra region have been developed for the year 2050 by NSW Government agencies and the University of New South Wales, based on information from the IPCC and CSIRO modelled data (DECC, 2008). Where data specific to the Illawarra region was unavailable, projections for the broader NSW region were used, in line with the data presented in the *NSW Climate Impact Profile - Illawarra Region* (DECCW, 2010).

Climate change risks

This assessment considers the climate change risks and projections for temperature, precipitation, sea level rise and extreme events.

Temperature

Figure 8-10 and **Figure 8-11** demonstrate the projections for mean maximum and minimum temperature changes for the Illawarra region. Both the minimum and maximum temperatures are anticipated to increase over all seasons, with changes between 1.5 degrees Celsius and three degrees Celsius projected by the year 2050 (DECC, 2008).

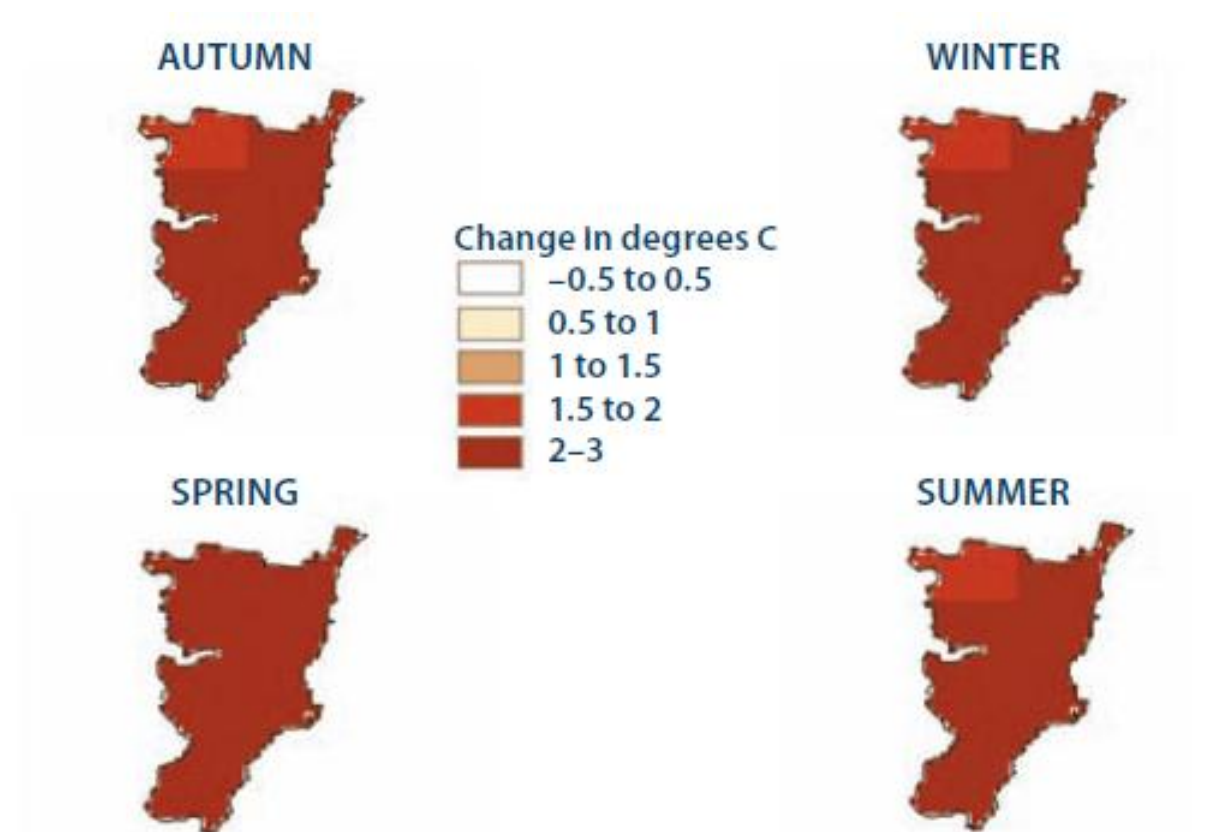


Figure 8-10 Projected change in mean maximum temperature by season, for the Illawarra Region in 2050 (DECC, 2008).

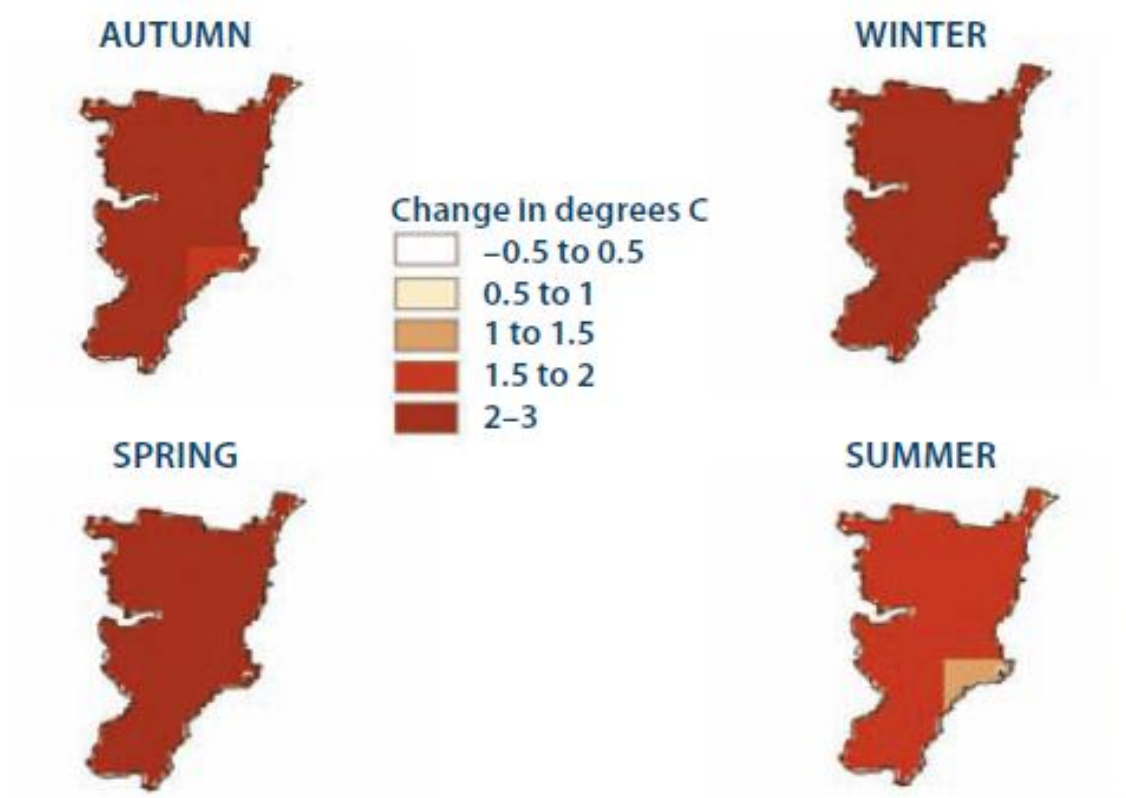


Figure 8-11 Projected change in mean minimum temperature by season, for the Illawarra Region in 2050 (DECC, 2008).

Precipitation

Precipitation across Australia has a large natural variability, and is sensitive to small differences in air and wind circulation patterns and other atmospheric processes (CSIRO, 2007).

The Illawarra region is projected to experience a substantial increase in summer rainfall and a slight to moderate increase in spring/autumn rainfall (refer to **Figure 8-12**). Rainfall along the coast in winter is likely to be similar to the existing levels.

Evaporation

Evaporation is projected to increase with temperature. Therefore, increases would be more significant in summer and spring. When considered in conjunction with projected changes in rainfall, increased evaporation could result in slightly drier conditions in winter and spring (DECC, 2008).

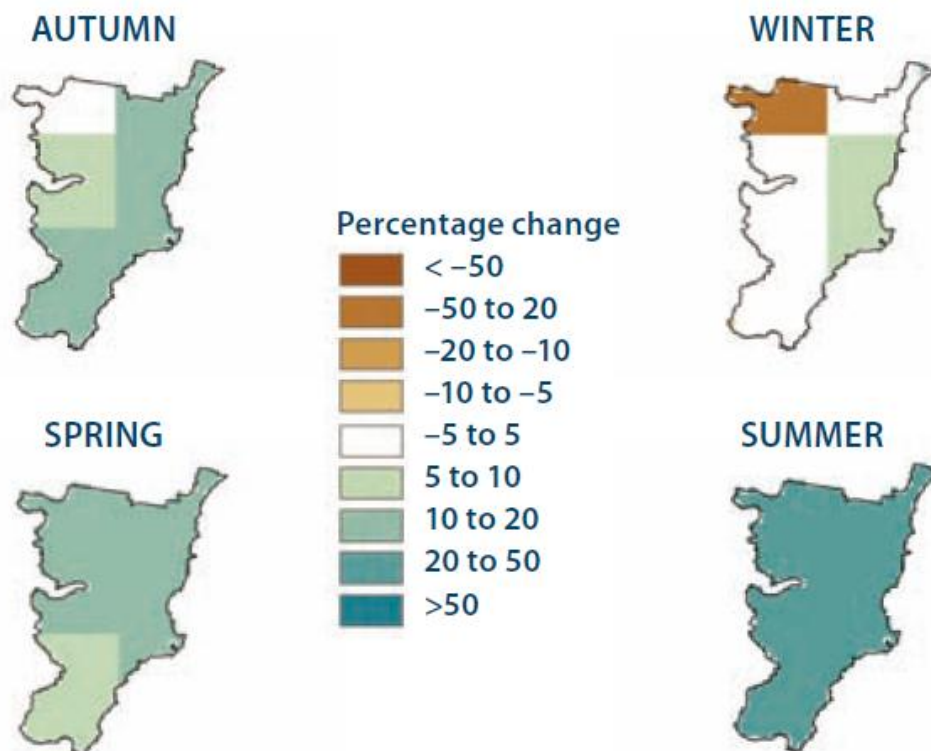


Figure 8-12 Projected change in seasonal rainfall for the Illawarra region in 2050 (DECC, 2008).

Sea level rise

Data for sea level rise is currently unavailable on a regional scale but impacts associated with sea level rise and storm events for NSW are anticipated to be significant. The NSW Government 'Sea Level Rise Policy Statement' outlines that the best national and international projections of sea level rise along the NSW coast are for a rise relative to 1990 mean sea levels of up to 40 centimetres by 2050, and 90 centimetres by 2100 (DECCW, 2009).

Sea level rise is expected to inundate and erode unconsolidated parts of the shoreline, and ultimately projected to result in a coastal recession of up to 20 - 40 metres by 2050 and 45-90 metres by 2100 (DECCW, 2010). Changes in rainfall events, storm frequency and severity, river flow and wind and wave action specific to a locality are likely to either amplify or reduce the erosion impacts of sea level rise, resulting in a varied level of impact along the NSW coastline.

Issues associated with ASS of the lower Shoalhaven floodplain are likely to continue in the short term, however, increased rainfall events and the intrusion of saline water from sea level rise are likely to decrease the occurrence and impact of such soil environments (DECC, 2008).

Sea level rise is relevant to the project area due to its proximity to the shoreline along parts of the route. As indicated above, impacts resulting from sea level rise such as coastal recession, inundation and erosion therefore have the potential to impact directly on the project area and as a result the structural integrity and design life of the asset.

Extreme events

Extreme weather events, such as storm surges, are projected to increase in severity, intensity and frequency. Tropical cyclones, however, while projected to increase in intensity, are anticipated to become less frequent rather than more frequent (IPCC, 2007).

The rise in sea level is also anticipated to increase the risk of flooding of the lower floodplain of the Illawarra region. Increases in the severity and duration of rainfall events are likely to result in flooding from urban streams and drainage systems. Although reports indicate that “major roads such as the Princes Highway are likely to be flooded from time to time at low-lying locations” (DECC, 2008), the highest risk areas are all located outside the project area (DECCW, 2010).

The risk of frequent, very high to extreme bushfires is predicted to increase across NSW. Increases in temperature, evaporation and high fire-risk days are likely to influence fire frequency and intensity across the region. The fire season is also likely to be extended as a result of warmer temperatures (DECC, 2008).

Uncertainty

Climate change model projections are tools used for understanding how the climate will respond to changes in GHG emission levels. These models are generated by a computer and include a number of variables to simulate climate. However, climate processes are complex and not all variables are known or able to be modelled. Most model projections are presented as averages for a given region or subregion, for which a level of uncertainty must be taken into account. Uncertainties to be considered include:

- Emission scenario uncertainty (uncertainty associated with the modelled data).
- Perception of uncertainty towards climate science. Uncertainty in this instance is perceived as a lack of knowledge, as opposed to prescribing a level of accuracy of the scientific results.
- Uncertainty associated with projecting climate change up to 2100. Although the project life is anticipated to be 100 years, much of the data modelled only projects impacts up to the year 2050 or 2070.

Climate change impacts to the project

This assessment is based on the following facts regarding the broader landscape of the project:

- The project area (as identified in the concept design) encompasses the foothill slopes of the escarpments around Berry and Toolijooa. The topography is primarily comprised of rocky outcrops, ridges and steep inclines, surrounded by floodplains and agricultural land use areas.
- The project involves three crossings of Broughton Creek, and a crossing at the confluence of Broughton Mill Creek, Bundewallah Creek and Connollys Creek. Embankments would be constructed along floodplains at Broughton Creek and north of Berry.
- The project is typically elevated between 40 – 100 metres above sea level and is shielded to some extent by Toolijooa Ridge to the east.
- During flood events, “major roads such as the Princes Highway are likely to be flooded from time to time at low-lying locations” (DECC, 2008).

Based on these area facts and the review of climate change variables and risks identified above, the following are considered priority climate change risks for the project:

1. Increased temperatures and evaporation.
2. Increased severity and frequency of heavy rainfall.
3. Increased severity and frequency of flood events resulting from heavy rainfall.
4. Increased intensity and frequency of fire-risk days resulting from increased temperatures and evaporation.

Table 8-12 outlines how these priority climate change risks would potentially impact the project. Further details are provided in the *Surface water, Groundwater and Flooding Technical Paper (AECOM 1012)* provided at **Appendix H**.

Table 8-12 Climate change risks and potential impacts

Climate change risk	Possible impacts/consequences of climate change risk	Evaluation of risk level after mitigation
Increased temperatures and evaporation	Bridge structural material degradation: through thermal expansion of bridge joints and paved surfaces, damage can occur to bridge structure material.	Negligible risk- The forecast increase in mean maximum and minimum temperature arising from climate change is within the range of temperatures presently experienced by bridge infrastructure across the state. Australian design standards allow for significantly hotter (hot inland desert) and cooler (Snowy Mountains) environments than predicted under Climate Change in the project region.
	Asphalt degradation: due to heat events deterioration can lead to melting, cracking or rutting.	Negligible risk- There is sufficient knowledge and experience to demonstrate that bituminous and concrete surfaces currently perform satisfactorily in Australia's extremely hot climates such as the tropical north and the dry inland where extreme weather conditions are similar to or more severe than predicted as a result of climate change on the NSW State Road network.
Increased intensity and frequency of fire-risk days resulting from increased temperatures and evaporation.	Public safety risk due to bushfire events	Negligible risks- There is currently a range of site-specific plans that are used on a day to day basis by traffic controllers, working with the Police, Ambulance, Fire and other emergency services to respond to unplanned incidents on the road network. Should climate change result in more frequent floods or fires, these plans are available for implementation, or may be updated over time should that be necessary.
Increased severity and frequency of heavy rainfall.	Asphalt degradation: due to heavy rainfall can lead to cracking, potholes or rutting.	Negligible risk- existing road pavements already cope with a wide range of rainfall events across the State within the range of climate change related changes. Standards and specifications are constantly being reviewed to ensure pavements perform to a high standard.
	Road foundation degradation: the road foundation can also deteriorate due to increased moisture resulting in cracking.	Negligible risk- existing road foundations already cope with a wide range of rainfall events across the State and standards and specifications are constantly being reviewed to ensure foundations perform to a high standard.
Increased severity and frequency of flood events resulting from heavy rainfall.	Flood damage to roads: overtopping and inundation of roads and other road infrastructure as a result of flood events can damage road materials through erosion or other failure modes.	Medium risk: Roads are designed to cope with a certain amount of overtopping. However with climate change, there may be changes in floodwater velocity and height which can increase the risk of damage. The road level has been designed not to be overtopped (to edge of shoulder) by the one in 100 year event including a six per cent climate change allowance.

Climate change risk	Possible impacts/consequences of climate change risk	Evaluation of risk level after mitigation
	Flood damage to bridges: overtopping and inundation of bridges as a result of flood events can damage bridge structure.	High risk- Bridges are difficult to modify once constructed. Flooding loads are well understood and the bridge structural design: <ul style="list-style-type: none"> Allows for the passage of a 100 year average recurrence interval design flood with a six per cent climate change allowance in the design event); and Effectively accounts for potentially larger increases in rainfall intensity by considering loads on the structure and lateral loads from overtopping floodwater by undertaking a sensitivity analysis modelling of a 1 in 2000 year event.
	Underpass flooding: flooding of culverts or underpasses can result in structural damage and deterioration of material.	High risk- Underpasses are very difficult to modify once constructed. Climate change related rainfall increases have been included through a six per cent climate change allowance in the design event. As new information about the impact of climate change on performance of materials becomes available, should there be concern that existing design practices or policies are insufficient, the policies, specifications or practices will be reviewed.
	Overloading of drainage systems and inaccessible drainage elements: as a result of flood events roads with poor or inadequate drainage systems can become overloaded or blocked. This can lead to a loss of strength and bearing capacity in the road foundation.	Medium risk- Inaccessible drainage elements (e.g. drainage culverts and pits) are very difficult to modify once constructed and typically have a structural design life of around 100 years. Climate change related rainfall increases have been accounted for by including a six per cent climate change allowance in the design event.
Increased severity and frequency of flood events resulting from heavy rainfall. Increased intensity and frequency of fire-risk days resulting from increased temperatures and evaporation.	Changes in landscaping and road-side vegetation: due to flood or heat events which can result in a variety of impacts including direct impacts on flora and fauna, biodiversity or habitat and blocked roads or damaged vehicles due to fallen trees.	Medium risk- It is recognised that changes to the climate will have an impact on vegetation and fauna. Climate change impacts will add to the stresses that are created by the fragmentation of habitats that occurs when a road is constructed through the landscape and as urbanisation occurs.

The project has been planned with an awareness of the potential for climate change impacts on the project. Drainage structures would adequately withstand future climatic changes, such as increased rainfall intensity and more frequent flood events. Specifically:

- The project has been designed and would be constructed to provide flood immunity on the carriageway for a 100 year flood event (without accounting for climate change).
- An additional six per cent increase in rainfall intensity has been factored into design of the drainage infrastructure for the project to ensure adequate drainage to take into account the effect of climate change.

While incorporation of climate change impacts into the design of the project would reduce the severity of those impacts, additional adaptation measures would be required to minimise the potential impacts associated with the expected climate change risks as discussed below.

8.5.4 Environmental management measures

Mitigation and management measures would be implemented to avoid, minimise or manage greenhouse gas and climate change impacts. These mitigation and management measures have been identified in **Table 8-13** and incorporated in the draft statement of commitments in **Chapter 10**.

Table 8-13 Mitigation and management measures

Potential impacts	Mitigation and management measures
Construction	
GHG emissions	<p>Select the most fuel efficient plant, equipment and vehicles practicably available through consultation with subcontractors and suppliers.</p> <p>Ensure that all plant and vehicles are maintained regularly to maintain fuel efficiency</p> <p>Procure locally produced goods and services where feasible and cost effective to reduce transport fuel emissions.</p> <p>Specify construction materials with lower emissions intensity in the detailed design (eg recycled steel in place of virgin steel and asphalt in place of concrete) where engineering and other technical specifications can be met and the alternative is reasonable and feasible. This measure could also be applied to the selection of maintenance materials in the operational stage.</p> <p>Seek opportunities to reduce the quantity of construction materials used through innovative design and construction methodologies.</p> <p>Where reasonable and feasible, procure recycled content road construction and maintenance materials such as recycled aggregates in road pavement and surfacing (including crushed concrete, granulated blast furnace slag, glass, slate waste and fly ash). This measure forms part of RMS' implementation of the NSW Government's 'Waste Reduction and Purchasing Policy' (WRAPP).</p> <p>Consider the procurement of renewable energy technologies (eg solar photovoltaic, wind power) for power generation onsite during the construction stage.</p> <p>Design earthworks to, where reasonable and practicable, avoid long haulage distances and reduce excess spoil.</p>

Potential impacts	Mitigation and management measures
Climate change impacts	<p>Adopt standard climate change mitigation measures, including development of a Vegetation Management Plan, to avoid, minimise and mitigate impacts on habitats and the ecology of the project area consistent with RMS 'Draft Wildlife Connectivity Guidelines' and 'Protecting and Managing Biodiversity – Guidelines for RMS Projects' Refer to measures in Section 7.3.</p> <p>Review existing design policies, specifications or practices as new information about the impact of climate change on performance of materials (for road foundation, fill, asphalt, bitumen etc) and drainage structures becomes available with the aim of using materials less susceptible to degradation impacts of climate change.</p>
Operation	
GHG emissions	<p>Specify energy efficient street lighting appropriate for project needs.</p> <p>Encourage the use of less GHG intensive modes of transport by incorporating a shared pedestrian/cycle path at the Kangaroo Valley Road overbridge and bus pick up and drop off facilities in the design of the upgrade.</p>
Climate change	Monitor and review the performance of structures and materials in response to climate change related events.