Greenhouse Gas Assessment Workbook for Road Projects

February 2013

Transport Authorities Greenhouse Group

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Glossary

Activity	An action that gives rise to an emission source and the release of greenhouse gases.
Assessment boundary	In the context of estimating GHG emissions for a road project, the assessment boundary is considered to be: all of the GHG emissions from operations/activities over which the designers, constructors and operators have control.
Boundary	The boundary is an imaginary line around the emission sources and activities that are included in the GHG assessment. Emission sources and activities outside the boundary are excluded.
Carbon dioxide equivalent (CO_2-e)	The mass of a greenhouse gas that is emitted is multiplied by its global warming potential to convert greenhouse gas emissions to an equivalent quantity of CO_2 emissions, referred to as carbon dioxide equivalent. For simplicity of reporting, the mass of each greenhouse gas emitted is commonly translated into a carbon dioxide equivalent (CO_2-e) amount so that the total impact from all sources can be summed to one figure
CFL	Compact Fluorescent Lamp/Light
CH_4	Methane, a greenhouse gas.
CO_2	Carbon dioxide, a greenhouse gas.
Construction	Construction is considered to be the time between obtaining development approvals and funding and handing over the asset to the relevant authority at the end of the defect liability period.
Conversion Factor	A numerical value to enable conversion from one unit of measure to another (e.g. a density conversion factor is used to convert a volume of a material to a mass of a material or vice versa)
Default quantity factor (DQF)	Default quantity factors convert an indicator of activity into estimated activity data quantities, which can be used in greenhouse gas emission calculations.
Design	Design is considered to be the time between conceiving the road project and obtaining development approvals and funding
Emission	Refers to greenhouse gas emissions
Emission factor	Emission factors convert an indicator of activity into estimated greenhouse gas emissions.
Emission source	A source from which greenhouse gases are released
Facility	A facility refers to the road project site
GHG	Greenhouse gas
GHG Protocol	The World Resource Institute and the World Business Council for Sustainable Development's Greenhouse Gas Protocol: a corporate accounting and reporting standard
GJ	Standard abbreviation for Giga-Joule. A unit of energy, equal to 1,000 MJ.
Global Warming Potential (GWP)	GWP is a measure of how much a given mass of a greenhouse gas is estimated to contribute to global warming. It is a relative scale that compares a gas with the same mass of carbon dioxide and is calculated over a specific time interval.
Greenfield Project	A project that lacks any constraints imposed by prior work
Greenhouse gas assessment boundary	The GHG assessment boundary defines which emission sources and activities are included in the assessment and which are excluded.
Greenhouse gases	Greenhouse gases are those gases which reduce the loss of heat from the earth's atmosphere by absorbing infrared radiation. Six greenhouse gases are regulated by the Kyoto Protocol: Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6). The emissions of greenhouse gases are reported in carbon dioxide equivalents (see above).
GVM	Gross Vehicle Mass
HFCs	Hydrofluorocarbons, a group of greenhouse gases.
HPS	High Pressure Sodium (lamps)

km	Standard abbreviation for kilometre. A unit of distance.
kW	Standard abbreviation for kilowatt(s). A unit of power, equal to energy use at the rate of one kJ per second.
kWh	Standard abbreviation for kilowatt hour. A unit of (normally electrical) energy, equal to power of 1 kW for 1 hour.
LED	Light emitting diode (lamps)
m	Standard abbreviation for metre. A unit of distance.
m^2	Standard abbreviation for square metre. A unit of area.
m^3	Standard abbreviation for cubic metre. A unit of volume.
Maintenance	Maintenance is considered to be post construction and includes activities that are intermittently required to keep the road assets at the required standard. Maintenance can be major (i.e. rehabilitation), planned/routine or reactive.
Major activity	Defined as design, construction, operation and maintenance
Materiality	Materiality is a measure of the estimated effect that the presence or absence of an emission source or activity may have on the accuracy or validity of a greenhouse gas assessment.
MH	Metal halide (lamps)
MJ	Standard abbreviation for Mega-Joule(s).
N_2O	Nitrous oxide, a greenhouse gas.
No.	Abbreviation for number
NZ	New Zealand
Operation	Operation is considered to be post construction and includes activities that are required on a continuous basis for the functioning of the road. This Workbook does not include road usage by vehicles in this definition.
Pavement	The road surface and road base.
PFCs	Perfluorocarbons, a group of greenhouse gases.
Post construction	The period after road construction is completed.
Project scoping	Development of the concept design and detailed business case. Tender documents would be issued at the completion of this phase if the project is to be delivered via a design and construct (D&C) contract.
Project development	Development of preliminary and detailed design. Submission of tenders would occur at the completion of this phase if the project is to be delivered via a D&C contract.
Project delivery	Project is awarded at the start of this phase if the project is to be delivered via a D&C contract. It includes construction of the road and project handover to the asset operator.
Proponent	The entity that is proposing the road project. Usually the constructor or the operator of the road.
QH	Quartz halogen (lamps)
Road furniture	Road Furniture is a generic term for various road related assets that are intended to inform and protect the motorist, They include signs and markings, delineation devices, sign supports, signal poles and equipment, lighting poles, parking meters, various types of fencing and walls of different types and functions, all of which need to be safely accommodated within the roadside.
Road project life cycle	The life cycle considered in the Workbook is limited to the major activities of: design, construction, operation and maintenance
Road structures	Includes structures that may be included in a road project (e.g. bridge, tunnel, reinforced soil walls etc.)
Scope 1 emissions	Emissions released into the atmosphere as a direct result of an activity, or series of activities (including ancillary activities) that constitutes the facility.
Scope 2 emissions	Emissions released as a result of one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but that do no form part of the facility.

Scope 3 emissions	Emissions that occur outside the site boundary of a facility as a result of activities at a facility that are not Scope 2 emissions.
SF_6	Sulfur hexafluoride, a greenhouse gas
Supporting Document	The document that provides additional information considered in the development of the Greenhouse Gas Assessment Workbook for Road Projects
Surface roads	Roads that only require pavement
t CO_2-e	Standard measurement unit for greenhouse gas emissions. Tonnes of carbon dioxide equivalents
TAGG	Transport Authorities Greenhouse Group
UNFCCC	United Nations Framework Convention on Climate Change
UOM	Unit of measurement
W	Standard abbreviation for Watt(s). A unit of power, equal to energy use at the rate of one J per second.
Workbook	This document, the Greenhouse Gas Assessment Workbook for Road Projects

Below is a list of TAGG members who were involved in the development of this Workbook. Should you have any queries regarding the methodology presented in the Workbook or to provide your comments on the Workbook and/or Supporting Document they provide a point of contact.

This workbook is intended to be updated periodically as improved information becomes available. Section 7 of the Supporting Document for further details on what will drive the update and be taken into account in the updating of this workbook.

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1. Introduction

Road traffic and transport authorities in Australian and New Zealand are committed to minimising greenhouse gas (GHG) emissions. To support this commitment, Australian state road authorities and NZ Transport Agency have formed a Transport Authorities Greenhouse Group (TAGG) to share information regarding estimating, reporting and minimising GHG emissions. The TAGG recognises that there needs to be a common approach to estimating the GHG emissions from road projects and as a result, it has developed this Workbook to provide road designers, builders, managers and operators a means of consistently estimating GHG emissions at the key stages of construction, operation and maintenance.

In developing the Workbook a ‘whole of life’ approach was taken and all major activities in the life cycle, from design through to operation and maintenance, were considered. Decommissioning of roads was excluded from the Workbook as this rarely occurs.

The Workbook outlines a process for estimating the GHG emissions for all of the major activities that were found to contribute significantly to the overall emissions arising from a road project. The operation of road infrastructure includes operation of lights, signals and ventilation systems. The maintenance of the infrastructure comprises activities which are categorised as reactive, planned/routine and/or major maintenance.

In addition to providing the means to estimate GHG emissions the Workbook will provide a better understanding of how GHG emissions can be reduced. The Workbook will also enable benchmarking and comparisons of projects (or options) on a consistent basis. Carbon Gauge is a tool referenced within this methodology,which has been developed to enable a comparison based on estimation with default quantity factors.

In considering the various purposes a Workbook such as this could be used for, the TAGG decided it would not include a process for estimating GHG emissions associated with road usage as each transport authority has its own preferred processes and traffic modelling techniques to estimate these emissions.

The TAGG methodology has been reviewed a number of times since its initial release and the road industry feedback has been positive. Some constructive recommendations for improvement have been provided and where possible these have been included in the current methodology. The Australian Road Research Board (ARRB) has also recommended in their 2012 Field Validation of Warm Mix Pavements report that the TAGG methodology be adopted as the national standard for greenhouse estimation in road construction.

Note: This Workbook is designed to enable a consistent methodology for the assessment of significant emission sources and estimation of greenhouse gas emissions. As such it deliberately does not cover activities and emission sources assessed as insignificant, and it is not designed for compliance reporting.

1.1 Overview of workbook

The Workbook includes the following sections:

- **Chapter 1:** Introduces the Workbook and the reasons for its development
- **Chapter 2:** Provides background information on GHG assessments, including the types of GHG emissions considered in this Workbook, the GHG assessment boundary and an explanation of GHG emission "scopes"
- **Chapter 3:** Outlines the process for estimating the GHG emissions for a road project
- **Chapters 4-7:** Provides the methodology and information required to estimate the GHG emissions associated with each life cycle major activity. The chapters are arranged in modules as follows:
  - **Chapter 4:** Module 1 – Design
  - **Chapter 5:** Module 2 – Construction
  - **Chapter 6:** Module 3 – Operation (not including traffic usage)
  - **Chapter 7:** Module 4 – Maintenance

  Each Module includes a description of the significant emission sources in the relevant GHG assessment boundary, the activity data required for an assessment and default quantity factors.
- **Appendices:** Provide emission factors, conversion factors, checklists and supporting information

The Workbook is complimented by the Supporting Document for Greenhouse Gas Assessment Workbook for Road Projects (the Supporting Document). The Supporting Document provides information that relates to the development of the Workbook.

2. Greenhouse gas assessments – background information

2.1 Greenhouse gases

Greenhouse gas emissions refer to the release of greenhouse gases (GHG) into the atmosphere. The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) has limited the number of GHGs that are reportable. These are:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Sulfur hexafluoride (SF_6)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs).

Whilst the Workbook methodology does include all of the Kyoto GHG, road projects will typically only result in emissions of carbon dioxide. Depending on the activities undertaken, there may also be emissions of methane, nitrous oxide and hydrofluorocarbons.

2.2 Carbon dioxide equivalence and global warming potential

Emissions estimated using this Workbook are in carbon dioxide equivalents.

Carbon dioxide equivalence, or CO_2-e, is estimated by multiplying the amount of a GHG by its global warming potential (GWP). The GWP is a measure of how much a given mass of a GHG is estimated to contribute to global warming. It is a relative scale that compares the warming potential of a gas with the same mass of carbon dioxide.

Emission factors for all GHG emissions deemed typical for road projects have been provided in carbon dioxide equivalents. Any changes to the current estimate of the GWP of a particular GHG will be taken into account when updating this Workbook and the emission factors provided within. Emission factors used to estimate GHG emissions from road projects are provided in Appendix D.

2.3 Greenhouse gas assessment boundary

Prior to undertaking a GHG assessment the 'boundary' of the assessment must be defined. The boundary defines which emission sources and activities are included in the assessment and which are excluded.

An activity is any action that gives rise to a source of GHG emissions (e.g. construction of road pavement). An emission source is a cause of GHG emissions (e.g. combustion of fuel in a vehicle). It is possible that one activity can result in several emission sources.

In the context of estimating GHG emissions for a road project, the assessment boundary is considered to include all of the emission sources that can be impacted by decisions made by designers, constructors, managers and/or operators of the road. That is, where a decision can be made that impacts the GHG emissions of a road project, then that emission source is considered to be within the GHG assessment boundary.

For example, a proponent (constructor or operator) can select either virgin materials or material with recycled content, and there will be a different GHG emissions profile depending on which material is chosen. Material selection is therefore considered under the influence of the proponent and the usage of materials is therefore included within the GHG assessment boundary.

Sections 5.1, 6.1 and 7.1 summarise the construction, operation and maintenance GHG assessment boundaries, including all the significant activities and emission sources. A comprehensive discussion of the construction, operation and maintenance GHG assessment boundaries for road projects is presented in Section 3.3 of the Supporting Document.

2.3.1 Emission scopes

To ensure consistency across multiple assessments, GHG emissions sources are usually categorised into various ‘scopes’. The most common definition of these scopes are presented below.

2.3.1.1 Scope 1 emissions

Direct GHG emissions are those that are produced by activities that are controlled by the proponent.

Road project examples include:

- The combustion of diesel fuel in an item of plant used in the construction or maintenance of a road
- The combustion of diesel fuel in a generator to produce electricity for use on site
- The combustion of petrol (gasoline) in site vehicles
- Clearing of vegetation (lost carbon sink)
- A diesel powered concrete batching plant.

2.3.1.2 Scope 2 emissions

Indirect GHG emissions are a result of activities associated with the road project, across its ‘whole of life’, that are not controlled by the proponent. Scope 2 emissions are indirect GHG emissions from the consumption of electricity, heating, cooling or steam that is produced offsite.

Road project examples include:

- The consumption of electricity by street lights and traffic lights during the operation of the road
- The consumption of electricity by site offices

2.3.1.3 Scope 3 emissions

Indirect GHG emissions are a result of activities associated with the project, across its 'whole of life', that are not controlled by the proponent. Scope 3 emissions are all indirect GHG emissions that are not Scope 2 emissions.

Embodied emissions are all the emissions created over the entire lifecycle of a material from creation to disposal, but not including direct emissions from usage. Embodied emissions are therefore Scope 3 emissions.

Road project examples include:

- The offsite mining and production of quarry products used in the construction or maintenance of a road
- The offsite mining and production of materials (e.g. concrete, asphalt, steel) used in the construction or maintenance of a road
- Emissions from the extraction, production and transport of fuel burned at electricity generators and the emissions attributable to the electricity lost in delivery in the transmission and distribution network
- The breakdown of waste disposed of to a landfill
- Emissions from the combustion of fuel when transporting materials
- The embodied emissions of materials used to manufacture equipment utilised in the construction or maintenance of a road (e.g. tunnel boring machines).

Note: Whilst the transport of materials to site and unloading materials will result in a proportion of these emissions occurring onsite (i.e. a direct or Scope 1 emission) the majority of the emissions relating to the transport of materials occur offsite. To minimise the risk of double counting and simplify data collection the emissions associated with the transport of materials are classified as 100% Scope 3 emissions.

Emissions from traffic using a road post construction are Scope 3 emissions. However, these emissions are not included in the scope of this Workbook. In order to gain a complete view of the GHG emissions associated with a road project, appropriate data and calculation models should be used to estimate the road usage GHG emissions, which should be added to the total GHG emissions estimated using the Workbook. This will provide the total GHG emissions associated with a road's construction, operation, maintenance and the vehicles that will use the road..

All Scope 1 and Scope 2 emissions are included within the GHG assessment boundary. The following Scope 3 emissions have also been included.

- Extraction, production and transport of purchased fuels used by a road project

- Mining, production and transport of purchased materials or goods used by a road project
- Disposal of waste generated in the production of purchased fuels, materials and goods associated with a road project
- Transport of project employees (including flights)
- Disposal of waste generated by the project.

Inclusion of each Scope 3 emission source is based on a materiality assessment, which is discussed in Section 2.3.2 of this Workbook, as well as an emission sources contribution to the project's GHG risk exposure, its ability to be reduced and its importance to key stakeholders.

2.3.2 Materiality and revising the activities to be assessed

The GHG assessment boundary defines the emission sources which will be considered when undertaking a GHG assessment of a road project. However, some emission sources will contribute a very small amount to a project's GHG emissions whilst others will contribute a large proportion of the total. Collecting data for emission sources can be time consuming and as the purpose of the Workbook is only to estimate GHG emissions for road projects it is therefore reasonable to omit insignificant emission sources from a GHG assessment. Emission sources are omitted based on their 'materiality'. Materiality refers to the importance/significance of an emission and provides a threshold or cut-off point which emission source must reach if it is to have an impact on the overall GHG assessment.

If a particular emission source contributes less than **5%** of the total GHG emissions of a major activity (i.e. construction, operation, maintenance), it has been considered to be not significant and subsequently has been excluded from the assessment boundary for that major activity. Similarly, design has been excluded from the assessment as it only generates a small quantity of the GHG emissions associated with the road projects life cycle (refer to Section 4).

In some instances an emission source may be significant on one project but not another – depending on the type of road project and its location. A materiality checklist is provided in Appendix A to assist in determining whether an emission source should be included within the assessment boundary.

NOTE: The assessment of materiality used to develop this Workbook has been based on 'typical' road projects using typical construction, operation and maintenance processes. If a project uses a process or material that is not considered 'typical' then certain activities or emission sources or materials that have been excluded from an assessment should be included.

For example: if a new, 'non-typical' material was used in the construction of a road (e.g. plastic pipe was used rather than concrete pipe) then the emissions associated with the production of the plastic pipe should be included in the assessment (GHG emissions to be estimated in the same way as for other materials) even though the use of plastic is not considered significant for a 'typical' road project.

3. Estimating the 'whole of life' greenhouse gas emissions for a road project

3.1 When can I do an assessment?

Although this Workbook focuses on the GHG emissions from the construction, operation and maintenance of a road, the estimation of these emissions can be conducted at any time. Obviously as the project moves from concept through detailed design to construction more accurate information will become available for items such as material type and quantity and hence the accuracy of GHG emissions estimates will improve.

Decisions made in the early scoping or concept design stages of a project can greatly impact on the GHG emissions from the construction, operation and maintenance of a road. It is strongly recommended that an assessment is made during the design stage in order to understand the greenhouse implications of different options or materials to minimise emissions, and to aid in decision making.

3.2 How do I undertake a GHG assessment?

Figure 3.1 below shows the major steps in the GHG assessment process for road projects. These steps should be applied to the construction, operation and maintenance major activities. The estimated GHG emissions for each major activity are then added together, to obtain the total GHG emissions associated with the road project.

These steps have been automated in an Excel based tool called Carbon Gauge, which is available from the Australian Road Agencies. Carbon Gauge is described in Section 8.

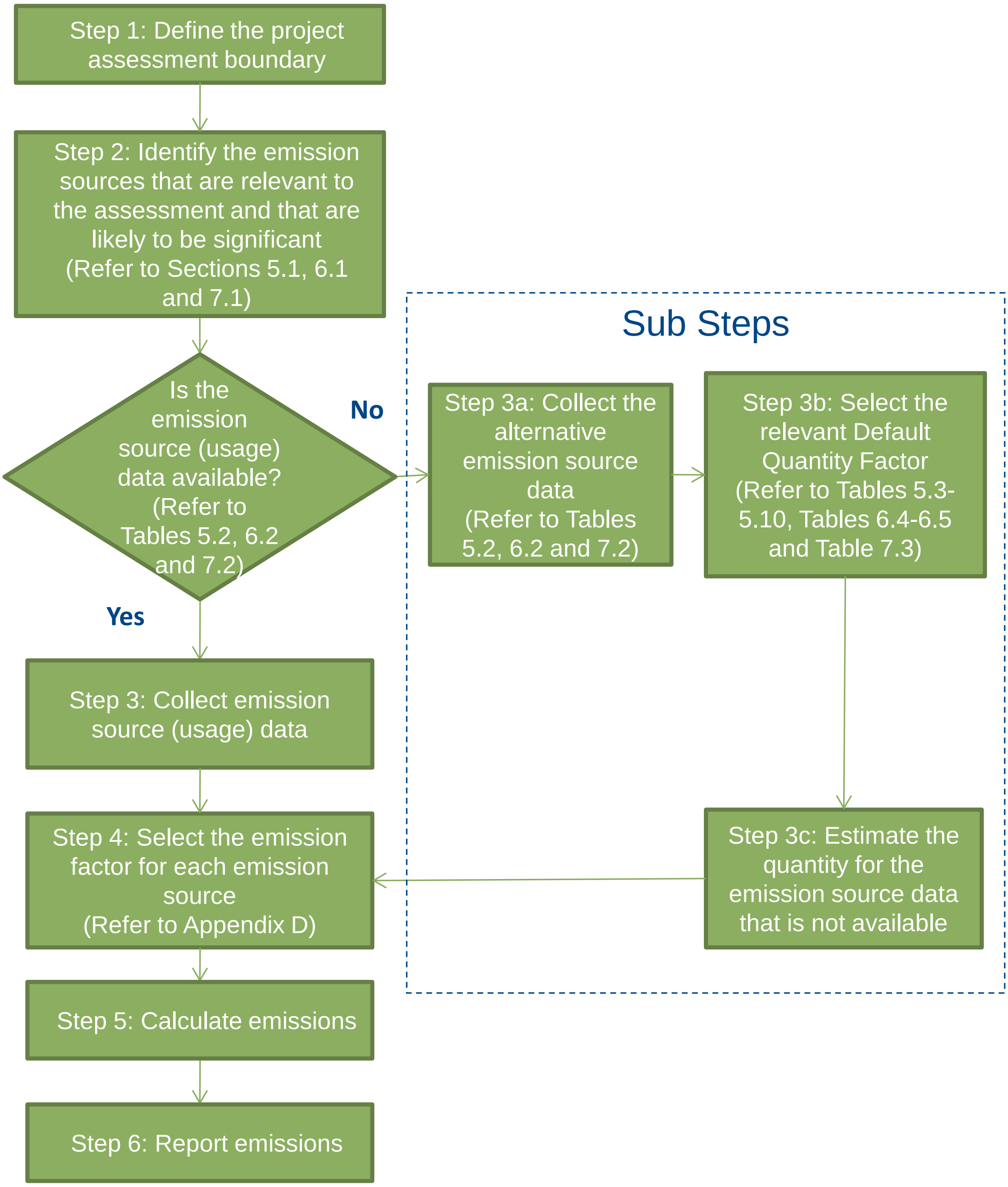


Figure 3.1 **GHG Assessment process**

A brief description of each step shown in Figure 3.1 is provided.

STEP 1:
Identify the project assessment boundary referring to the physical boundary of the project and Figures 5.1, 6.1 and 7.1 from the Workbook.

Identify the activities shown within the construction, operation and maintenance GHG assessment boundaries that will be occurring over the life cycle of the road project. Activities that are not undertaken can be excluded from your assessment.

STEP 2
Identify the emission sources associated with each activity undertaken within the project boundary.

Use the materiality checklist in Appendix A and tables 5.1, 6.1 and 7.1 to determine which emission sources should be included in the assessment and which emissions sources can be eliminate from the GHG assessment boundary.

Emission sources that are not significant on your project can be excluded from your assessment

STEP 3
Collect the usage data for each emission source. Refer to Tables 5.2, 6.2 and 7.2.

Record the usage data and the location of the data in the Emission Sources and Data checklist in Appendix A.

It may not be possible to obtain all of the required emission source data to complete the GHG calculations. If this is the case the alternative emission source data and default quantity factors should be used to estimate the activity data.

STEP 3a:
Collect the alternative emission source data where usage data is not available. Refer to Tables 5.2, 6.2 and 7.2.

Record the alternative emission source data and the location of the data in the Emission Sources and Data checklist in Appendix A

STEP 3b:
Select the appropriate default quantity factor for each emission source where alternative emission source data is being used. Refer to Tables 5.3-5.10, 6.4-6.5 and 7.3.

Record the default quantity factors in the Emission Sources and Data checklist in Appendix A

STEP 3c:
Calculate the quantity (the emission source data) using the following formula:

$$Quantity_i = Alternative\ Emission\ Source\ Data_i \times Default\ Quantity\ Factor_i$$

STEP 4:
Select the appropriate emission factors for each emission source from Appendix D.

STEP 5:
Calculate the GHG emissions for each emission source using the following formula

$$\textbf{\textit{GHG emissions}}_i = \textbf{\textit{Quantity}}_i \times \textbf{\textit{EF}}_i$$

Where:

- ***GHG emissions$_i$*** is the GHG emissions released from the emission source (i), measured in t CO_2-e
  - e.g. GHG emissions released from the combustion of liquid diesel fuel
- ***Quantity$_i$*** is the quantity of the emission source data, measured in the units of measure (UOM) outlined in the 'Emission Source Data Required' column of Table 5.2, 6.2 or 7.2 or as estimated using a default quantity factor (Refer to Step 3a-3c above)
  - e.g. quantity of liquid diesel fuel combusted, measured in kL
- ***EF$_i$*** is the emission factor for each fuel/material used or waste generated, measured in t CO_2-e/UOM
  - Where an emission factor has more than one scope of emissions (e.g. combustion of fuel is a Scope 1 and a Scope 3 emission source) then all scopes of emissions should be included in the assessment.

Total (sum) the emissions for each emission source to determine the total GHG emissions associated with the road project.

If required for reporting purposes, estimate the uncertainty of the emissions calculated using the following as a guide:

- GHG emissions calculated using actual emission source data: ± 5% of estimated emissions
- GHG emissions calculated using estimated emission source data: ± 10 % of estimated emissions
- GHG emissions calculated using alternative emission source data and default quantity factors: ± 30 % of estimated emissions

Refer to Section 2.2.1 of the Supporting Document for a discussion on the accuracy of the emission estimates.

STEP 6:

Report the GHG assessment as required by the local road authority.

A GHG assessment report should include:

- **A description of the project and the project assessment boundary**
- **The activities and emission sources included in the GHG assessment and any exclusions and the reason for the exclusion**
- **Total GHG emissions for each major activity (construction, operation, maintenance)**
- **GHG emissions for each emission source**
- **A breakdown of the GHG emissions by Scope 1, 2 and 3 emissions**
- **The uncertainty of the GHG emissions estimate and information on the quality of the data and any assumptions**
- **The report may also include an outline of any GHG reduction programs, a comparison of performance (e.g. performance against internal or external benchmarks) and a contact person.**

Refer to Appendix B for a Project GHG Emissions Report Template

3.3 Benchmarking

The ability to benchmark projects is a key objective of this Workbook. Which projects are benchmarked is to be determined by each road authority.

NOTE: Generally, the most relevant activity measure for a road project is m^2 of pavement. Using this parameter consistently enables projects to be compared in terms of t CO_2-e/m^2.

In order to enable meaningful benchmarking of road projects the following information should be recorded for each project (refer to Appendix B for a Project GHG Emissions Report Template):

- Description of the project
  - Project title
  - Project location and whether project is in an urban or rural area
  - Description of works (e.g. greenfield/brownfield, new road/road widening/duplication, road upgrade, intersection upgrade etc.)

- Value of road project ($m) and duration of the project (years)
- Pavement type and road length (km) and width (m)
- Vegetation removed (ha)
- Quantity of earthworks (e.g. volume of cut or fill [m^3])
- Whether ground stabilisation is required
- Number and type of structures (e.g. bridges, interchanges)
- Number and length of tunnels.

4. Module 1 – Design

Design is considered to be the time between conceiving the road project and obtaining development approvals and funding or the issuing of construction drawings.

Decisions made in the early scoping or concept design stages of a project can greatly impact on the GHG emissions from the construction, operation and maintenance of a road. It is strongly recommended that an assessment(s) is made during the design stage(s) in order to understand how GHG emissions may be minimised and to aid in decision making.

Whilst the design of a road can greatly impact on its emissions the actual GHG emissions associated with design activities are likely to be very small and are therefore generally considered not significant. GHG emissions associated with design activities can generally be excluded from a GHG assessment of a road project

4.1 Exception – air travel

If an unusually large amount of air travel (e.g. > 100 overseas trips or > 1,500,000 km of flight), is undertaken during the design stage of a road project due to the proponent's staff going on study tours or the designer flying in expertise from overseas or interstate, then these emissions should be included in the assessment.

In this instance the distance travelled in km and the relevant emission factor for airline travel taken from Appendix D, Table D.8 should be used.

5. Module 2 – Construction

Construction is considered to be the time between obtaining development approvals and funding and handing over the asset to the relevant authority at the end of the defect liability period.

5.1 Construction GHG assessment boundary

Table 5-1 shows the activities and Scope 1, 2 and 3 emission sources found to be significant for construction of a road (refer to Section 4.1 of the Supporting Document for further details of the materiality assessment for construction). All of the activities and emission sources considered within the construction GHG assessment boundary are shown in Figure 3.1 of the Supporting Document.

NOTE 5.1: Items in Table 5-1 in black are considered significant in 'typical' road projects and should be included in a GHG assessment.

Those in orange might be significant – Refer to the Materiality Checklist in Appendix A for guidance on when these emission sources should be included in your GHG assessment.

Activities/emission sources shown on Figure 5.1 with a dashed outline are those that may be significant for some road projects but insignificant for others.

NOTE 5.2: Whilst the clearing of vegetation (which is a carbon sink) is not a true GHG emission the net impact is that less carbon dioxide is being removed from the atmosphere and the net effect is that an equivalent amount of carbon dioxide will remain as a result. Hence, clearing of vegetation is considered as a Scope 1 emission source in this Workbook. However, any offsets from revegetation are not currently considered viable due to the implementation costs. This will continue to be reviewed as requirements evolve.

The disposal of vegetation will result in GHG emissions, in addition to those related to the loss of a carbon sink. Where vegetation is reused or left to decompose naturally on site, the rate at which GHGs are emitted is very slow and considered negligible. However, if vegetation is disposed of to landfill or combusted the rate is much higher and these emissions should be included in your assessment.

NOTE 5.3: Where the GHG emissions relating to concrete are calculated based on the usage of individual concrete ingredients (cement, sand, water etc.) rather than on the usage of concrete, the GHG emissions relating to the usage of sand and water should be included in the GHG assessment. Sand and water can otherwise be excluded from a GHG assessment, as factors for concrete are inclusive of the constituents.

Table 5-1 Emission sources to be included in GHG assessment of construction

Scope 1	Scope 2	Scope 3
Site vehicles and plant		
Combustion of fuels in site vehicles		Production and distribution of fuels used in site vehicles
Combustion of fuels in general site plant and equipment (e.g. diesel water pumps)		Production and distribution of fuels used in general site plant and equipment (e.g. diesel water pumps)
Site Offices		
Combustion of fuels in diesel generators		Production and distribution of fuels used in diesel generators
Demolition and Earthworks		
Combustion of fuels in plant and equipment		Production and distribution of fuels used in plant and equipment
Vegetation removed (lost carbon sink) (see Note 5.2 above)		Offsite decomposition of cleared vegetation in landfill (see Note 5.2 above) Transport of cleared vegetation from site to end use/landfill
	Electricity consumption by plant and equipment	Generation and distribution of electricity consumed by plant and equipment
Pavement, Structures, Drainage and Road Furniture		
Combustion of fuels in plant and equipment including on-site batch plants		Production and distribution of fuels used in plant and equipment
		Production of materials: ▪ Concrete ▪ Asphalt ▪ Cement ▪ Aggregate ▪ Steel ▪ Hot mix asphalt processing energy ▪ Bitumen ▪ Sand (see Note 5.3 above) ▪ Water (see Note 5.3 above) ▪ Lime ▪ Imported fill
		Transport of materials from production gate to site

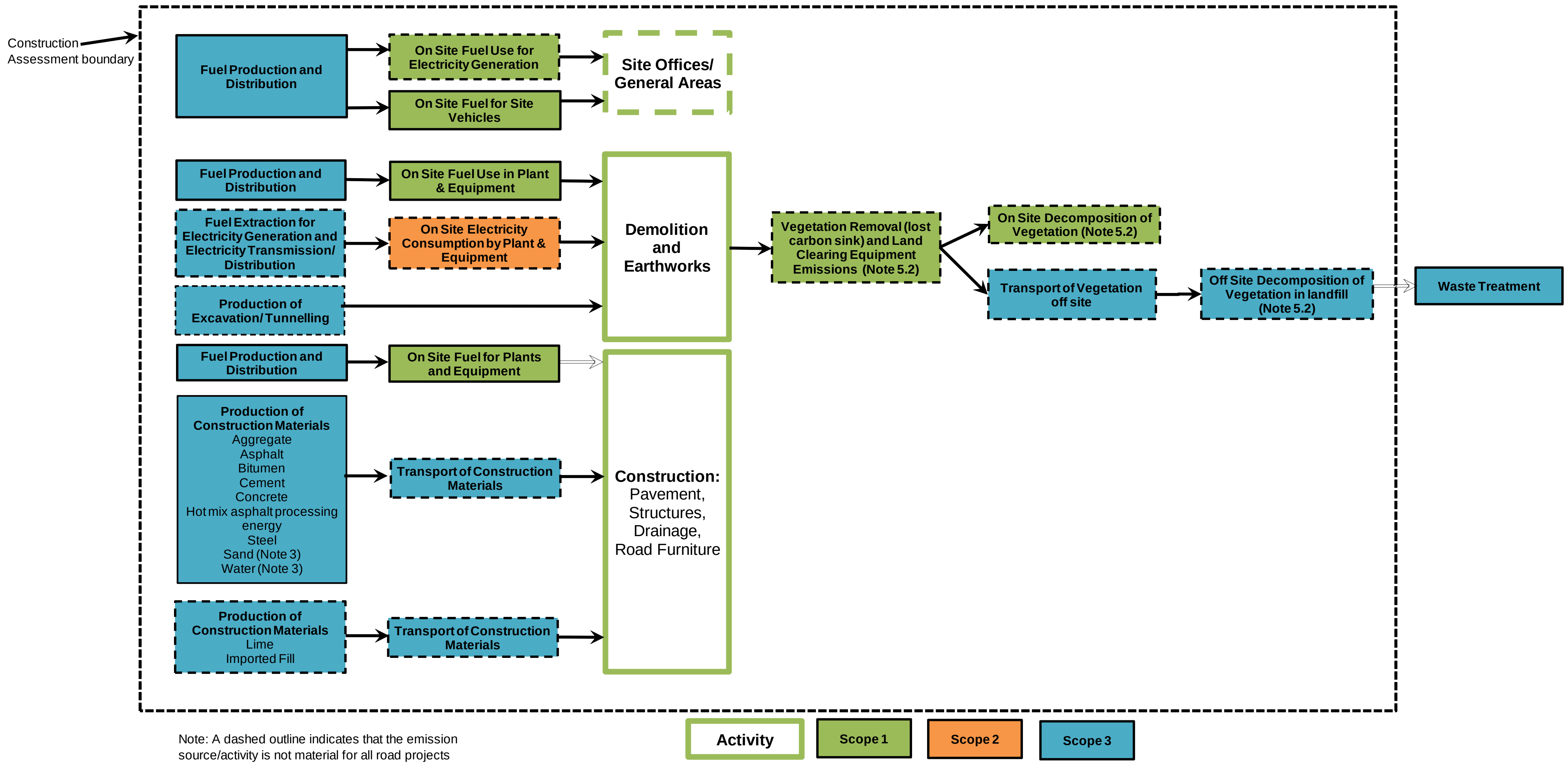


Figure 5.1 Construction GHG assessment boundary

5.1.1 Alternative processes or materials

The assessment of materiality undertaken in the development of this Workbook has been based on deemed typical road projects using deemed typical construction, operation and maintenance processes and materials. If a project uses an alternative process or material that is not 'typical' then the impact of that change should be captured in the GHG assessment by including the alternative emission source in the GHG assessment, using the process for similar emission sources. This is of particular importance if the project is looking to use 'low emission' materials in place of traditional materials.

For example, plastic is not typically used in the construction of roads in quantities sufficient to be considered significant and is therefore excluded from the list of materials to be included in a GHG assessment. However, if plastic pipe is used instead of concrete pipe for drainage then the emissions generated in making the plastic pipe should be included in the GHG assessment.

Should a road project result in a 'non-typical' GHG emission then guidance on accounting for these emissions should initially be sought by referring to:

- In Australia, the National Greenhouse Accounts (NGA) Factors Workbook (http://www.climatechange.gov.au/publications/greenhouse-acctg/national-greenhouse-factors.aspx)
- In New Zealand, the Guidance for Voluntary, Corporate Greenhouse Gas Reporting should be used. (http://www.mfe.govt.nz/publications/climate/guidance-greenhouse-gas-reporting-sept09/index.html)

Other sources of information, particularly those related to embodied emissions of materials not covered in this workbook (Scope 3 emissions) may be used but must be referenced when reporting. It is preferable that independent and/or third party verified sources are referenced.

5.2 Construction emission sources and required data

Table 5-2 presents all of the activities and emission sources within the construction GHG assessment boundary that are considered significant based on the materiality assessment (discussed in Section 4.2 of the Supporting Document). The data required for each emission source is also listed in Table 5-2.

Where the emission source (usage) data is not available (e.g. in the project scoping phase) the alternative emission source data and the associated default quantity factor(s) (refer to Section 5.3 below) may be used to estimate the emission source (usage) data.

NOTE: Items in Table 5-2 in black are considered significant in all 'typical' road projects and should be included in a GHG assessment whilst those in orange might be significant – Refer to the Materiality Checklist in Appendix A for guidance on when these emission sources should be included in a GHG assessment.

Table 5-2 Data required to estimate GHG emissions from road construction

Activity	Emission source	Emission Source Data Required	Alternative Emission Source Data Required
Site offices			**Refer to Table 5.3**
Site offices	Liquid fuel combustion – electricity generation (e.g. diesel generator)	Fuel type **AND** kL of fuel, for each fuel type	Fuel type **AND** construction period in months
Site vehicles and plant			**Refer to Tables 5.3, 5.4 and 5.5**
Site vehicles	Liquid fuel combustion – site and staff vehicles	Fuel type **AND** kL of fuel, for each fuel type	Fuel type **AND** Size of project in dollar value **AND** construction period in months **OR** Fuel type **AND** vehicle type **AND** distance travelled in km
Site plant and equipment	Liquid fuel combustion – site plant and equipment	Fuel type **AND** kL of fuel, for each fuel type	Fuel type **AND** type and size of plant **AND** construction period in months
Demolition and earthworks (including vegetation removal)			**Refer to Tables 5.6 and 5.7**
Demolition	Liquid fuel combustion – demolition equipment	Fuel type **AND** kL of fuel, for each fuel type	Number and type of buildings to be removed **OR** Equipment type(s) **AND** number of months operated **AND** load on equipment
Vegetation removal	Liquid fuel combustion – vegetation removal equipment e.g. graders, front end loaders	Fuel type **AND** kL of fuel, for each fuel type	Biomass class of vegetation removed (Refer to Table 5-6, Australian methodology) **AND** Area of vegetation removed in hectares **OR** Type of vegetation removed (Refer to Table 5-6, New Zealand methodology) **AND** Area of vegetation removed in hectares **OR** Equipment type(s) **AND** number of months operated **AND** load on equipment
	Lost carbon sink from the removal of vegetation (Australian methodology)	Biomass class AND vegetation classes AND area in hectares of vegetation removed, for each vegetation class	Location **AND** Area of vegetation removed in hectares for each vegetation class (refer to Section 5.3.3.1)
	Lost carbon sink from the removal of vegetation (New Zealand methodology)	Vegetation type AND area of vegetation removed AND mm of rainfall	Location **AND** Annual rainfall in mm **AND** Area of vegetation removed in hectares (refer to Section 5.3.3.1)

Activity	Emission source	Emission Source Data Required	Alternative Emission Source Data Required
	Downstream emissions from the transport of vegetation offsite	Quantity of vegetation per truckload **AND** return transport distance, in km	Distance from road project to likely disposal site in km
	Decomposition of vegetation in an offsite landfill	Type of vegetation removed **AND** t of vegetation disposed in an offsite landfill	Type of vegetation removed (Refer to Table 5-6) AND Area of vegetation removed in hectares **AND** % of vegetation disposed of to landfill
Earthmoving equipment	Liquid fuel combustion – earthmoving equipment	Fuel type **AND** kL of fuel, for each type	Volume of topsoil stripped **AND** Volume cut to spoil **AND** Volume cut to fill **AND** Volume of imported and placed filling **OR** Equipment type(s) **AND** number of months operated **AND** load on equipment
Earthworks - Tunnels	Electricity consumption - on-site excavation equipment (e.g. tunnel boring machines and ventilation)	State/Region **AND** kWh of electricity consumed	Refer to Section 5.4
Construction – Pavements			**Refer to Table 5.8**

Activity	Emission source	Emission Source Data Required	Alternative Emission Source Data Required
Road Pavements	Liquid fuel combustion – pavement construction equipment	Fuel type **AND** kL of fuel, for each fuel type **AND**	Equipment type(s) **AND** number of months operated **AND** load on equipment **OR** Pavement type (Refer to Table 5-8) **AND** pavement area in m^2
	Upstream emissions from the production of road construction materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Asphalt type(s) **AND** t asphalt used **OR** bitumen type(s) **AND** t bitumen used, t aggregate used and asphalt processing energy used in making asphalt **AND** Additional Bitumen type(s) **AND** t bitumen used **AND** Additional Aggregate type(s) **AND** t aggregate used **AND** Lime type(s) **AND** t lime used **AND**	Pavement type (Refer to Table 5-8) **AND** pavement area in m^2
	Upstream emissions from the transport of road construction materials	Quantity of material per truckload **AND** return transport distance, in km	**AND** distance from road project to likely source of material in km
Sealing	Liquid fuel combustion – pavement sealing equipment	Fuel type **AND** kL of fuel, for each type **AND**	Equipment type(s) **AND** number of months operated **AND** load on equipment **OR** Sealing type **AND** sealing area in m^2
	Upstream emissions from the production of road sealing materials	Asphalt type(s) **AND** t asphalt used **OR** bitumen type(s) **AND** t bitumen used, t aggregate used and asphalt processing energy used in making asphalt **AND**	Sealing type **AND** sealing area in m^2
	Upstream emissions from the transport of road sealing materials	Quantity of material per truckload **AND** return transport distance, in km	**AND** distance from road project to likely source of material in km

Activity	Emission source	Emission Source Data Required	Alternative Emission Source Data Required
Other pavements (e.g. median and traffic islands, footpaths etc.)	Liquid fuel combustion – other pavement construction equipment	Fuel type **AND** kL of fuel, for each type **AND**	Equipment type(s) **AND** number of months operated **AND** load on equipment **OR** Other pavement type (Refer to Table 5-8) **AND** pavement area in m^2
	Upstream emissions from the production of other pavement construction materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Asphalt type(s) **AND** t asphalt used **OR** bitumen type(s) **AND** t bitumen used, t aggregate used and asphalt processing energy used in making asphalt **AND**	Other pavement type (Refer to Table 5-8)**AND** pavement area in m^2
	Upstream emissions from the transport of other pavement materials	Quantity of material per truckload **AND** return transport distance, in km	**AND** distance from road project to likely source of material in km
Stationary Plant and equipment	Liquid fuel combustion – stationary engines (e.g. batching plants, dewatering pumps)	Fuel type **AND** kL of fuel, for each fuel type	Fuel type **AND** Construction period in months (Refer to Table 5.5)
Construction – Structures			Refer to Table 5.9
Bridges (including interchanges and overpasses)	Liquid fuel combustion – bridge construction	Fuel type **AND** kL of fuel, for each type **AND**	Equipment type(s) **AND** number of months operated **AND** load on equipment **OR** Type of bridge **AND** bridge area in m^2
	Upstream emissions from the production of bridge construction materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Steel type(s) **AND** t steel used	Type of bridge **AND** bridge area in m^2
	Upstream emissions from the transport of bridge construction materials	Quantity of material per truckload **AND** return transport distance, in km	**AND** distance from road project to likely source of material in km

Activity	Emission source	Emission Source Data Required	Alternative Emission Source Data Required
Reinforced soil walls	Liquid fuel combustion – reinforced soil wall construction	Fuel type **AND** kL of fuel, for each type **AND**	Equipment type(s) **AND** number of months operated **AND** load on equipment **OR** Reinforced soil wall area, in m^2
	Upstream emissions from the production of reinforced soil wall construction materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Steel type(s) **AND** t steel used	Reinforced soil wall area, in m^2
	Upstream emissions from the transport of reinforced soil wall materials	Quantity of material per truckload **AND** return transport distance, in km	**AND** distance from road project to likely source of material in km
Retaining walls	Liquid fuel combustion – retaining wall construction	Fuel type **AND** kL of fuel, for each type **AND**	Equipment type(s) **AND** number of months operated **AND** load on equipment **OR** Retaining wall distance, in m
	Upstream emissions from the production of retaining wall construction materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **OR** Timber type(s) AND t timber used **OR** Rock types AND t rock used **AND** Steel type(s) **AND** t steel used	Retaining wall length, in m
	Upstream emissions from the transport of retaining wall construction materials	Quantity of material per truckload **AND** return transport distance, in km	**AND** distance from road project to likely source of material in km

Activity	Emission source	Emission Source Data Required	Alternative Emission Source Data Required
Tunnels	Liquid fuel combustion – tunnel construction	Fuel type **AND** kL of fuel, for each type **AND**	Refer to Section 5.4
	Upstream emissions from the production of tunnel construction materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Steel type(s) **AND** t steel used **AND** Explosives type(s) **AND** t used	
	Upstream emissions from the generation and distribution of electricity	State/region **AND** kWh of electricity consumed	
	Upstream emissions from the transport of tunnel construction materials	Quantity of material per truckload **AND** return transport distance, in km	
Construction – Drainage			**Refer to Table 5.10**
Kerbing	Liquid fuel combustion –construction of kerbing	Fuel type **AND** kL of fuel, for each type **AND**	Equipment type(s) **AND** number of months operated **AND** load on equipment **OR** Kerbing type **AND** length, in m
	Upstream emissions from the production of kerbing materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Steel type(s) **AND** t steel used **AND** Additional Aggregate type(s) **AND** t aggregate used	Kerbing type **AND** length, in m
	Upstream emissions from the transport of kerbing materials	Quantity of material per truckload **AND** return transport distance, in km	**AND** distance from road project to likely material source in km

Activity	Emission source	Emission Source Data Required	Alternative Emission Source Data Required
Culverts (pipes or box culverts for water drainage)	Liquid fuel combustion – laying of culverts	Fuel type **AND** kL of fuel, for each type **AND**	Equipment type(s) **AND** number of months operated **AND** load on equipment **OR** Culvert type **AND** length, in m
	Upstream emissions from the production of culvert materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Additional Aggregate type(s) **AND** t aggregate used Steel type(s) **AND** t steel used Plastic type(s) **AND** t plastic used	Culvert type **AND** length, in m
	Upstream emissions from the transport of culvert materials	Quantity of material per truckload **AND** return transport distance, in km	**AND** distance from road project to likely material source in km
Open, unlined drains	Liquid fuel combustion – open unlined drain formation	Fuel type **AND** kL of fuel, for each type	Equipment type(s) **AND** number of months operated **AND** load on equipment **OR** Length of open, unlined drains in m
Construction – Road Furniture			Refer to Table 5.11
Road Safety Barriers	Liquid fuel combustion – road safety barrier installation	Fuel type **AND** kL of fuel, for each type **AND**	Equipment type(s) **AND** number of months operated **AND** load on equipment **OR** Barrier type **AND** length, in m
	Upstream emissions from the production of road safety barriers	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Steel type(s) **AND** t steel used	Barrier type **AND** length, in m
	Upstream emissions from the transport of road safety barrier materials	Quantity of material per truckload **AND** return transport distance, in km	**AND** distance from road project to likely material source in km

Activity	Emission source	Emission Source Data Required	Alternative Emission Source Data Required
Noise Walls	Liquid fuel combustion – noise wall construction	Fuel type **AND** kL of fuel, for each type **AND**	Equipment type(s) **AND** number of months operated **AND** load on equipment **OR** Noise wall type **AND** length, in m
	Upstream emissions from the production of noise wall materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **OR** t Hebel used **AND** Steel type(s) **AND** t steel used	Noise wall type **AND** length, in m
	Upstream emissions from the transport of noise wall materials	Quantity of material per truckload **AND** return transport distance, in km	**AND** distance from road project to likely material source in km

5.3 Default quantity factors – road construction

The Workbook provides an alternative method for determining activity data quantities. The alternative method uses an indicator of activity level and default quantity factors to estimate the activity data quantities. Default quantity factors (DQFs) can be used to estimate the usage of various components for various emission sources, should actual activity data not be available or readily accessible.

The default quantity factors have been developed using cost estimating first principles in most cases and are based on 'typical' construction, operation and maintenance processes and materials. If a project uses an alternative process or material then the default quantity factors should not be used. Refer to Section 5 of the Supporting Document for further details of the tools and methods used to determine the default quantity factors.

NOTE: The DQFs in the following tables should be used to estimate the quantities of fuel and materials used only when the actual usage data is not available.

The following section provides a list of the data sources and major assumptions used to develop the default quantity factors included in the Workbook. A brief introduction to the data sources is provided in Section 5.3 and 5.4 of the Supporting Document.

5.3.1 Site offices and plant

Table 5-3 provides default quantity factors for emission sources associated with site offices and vehicles whilst Table 5-4 provides default quantity factors for fuel usage for common site vehicles.

Table 5-3 Default quantity factors – Site offices and vehicles

Emission Source	Unit of Measure (UOM)	Diesel (kL/UOM)	Petrol (kL/UOM)	Comments
Site Offices				
Liquid fuel combustion – electricity generation (e.g. diesel generator)	Construction months	3.1	N/A	Assumes 500 m^2 of office space, equivalent of 2 star NABERS rating, operating 12 hours a day, Monday to Friday
Site vehicles				

Emission Source	Unit of Measure (UOM)	Diesel (kL/UOM)	Petrol (kL/UOM)	Comments
Small project (<$2m)	Construction months	0.65	1.02	2 Hilux utes, assumes all vehicles are diesel or all vehicles are petrol
Medium project ($2-10m)	Construction months	1.31	2.05	4 Hilux utes, assumes all vehicles are diesel or all vehicles are petrol
Large project ($10-100m)	Construction months	3.40	5.32	10 Hilux utes, assumes all vehicles are diesel or all vehicles are petrol

Source Data – Diesel Generators: McFarlane Generators

Source Data – Site Vehicles: Cost estimator & Green Vehicle Guide, Department of Infrastructure and Transport (Commonwealth of Australia)

If the likely project mileage is known for various vehicle types Table 5-4 maybe used in place of the default quantity factors in Table 5-3 above.

It is recognised that there may be a mix of site vehicles running on both diesel and petrol, therefore Carbon Gauge allows as input the percentage of each type of vehicle.

Table 5-4 Default quantity factors - Vehicles

Vehicle Type	Unit of Measure (UOM)	Diesel (kL/ UOM)	Petrol (kL/ UOM)	LPG (kL/ UOM)	Ethanol (10%) (kL/ UOM)	Comments
Hybrid	km	-	5.95×10^{-5}	-	-	Hybrid fuel consumption ranged from 4.4L/100km (Toyota Prius) to 9.3L/100km (Lexus LS600hL).
Car	km	0.114×10^{-3}	0.111×10^{-3}	0.136×10^{-3}	0.124×10^{-3}	Needs to be calculated separately for each fuel type.
Light Commercial ≤ 3.5 t gross vehicle mass [GVM])	km	0.122×10^{-3}	0.136×10^{-3}	0.151×10^{-3}	0.145×10^{-3}	Needs to be calculated separately for each fuel type.

Vehicle Type	Unit of Measure (UOM)	Diesel (kL/ UOM)	Petrol (kL/ UOM)	LPG (kL/ UOM)	Ethanol (10%) (kL/ UOM)	Comments
Medium Truck 3.5t≤GVM≤12t	km	0.280×10^{-3}	0.213×10^{-3}	0.288×10^{-3}	0.261×10^{-3}	Needs to be calculated separately for each fuel type.
Heavy Truck 12t≤GVM≤25t	km	0.560×10^{-3}	0.476×10^{-3}	0.792×10^{-3}	0.402×10^{-3}	Needs to be calculated separately for each fuel type.

Source Data – Hybrid vehicles: Hybrid vehicle data based on the average fuel consumption for hybrid vehicles listed in the GreenVehicle Guide as at 12 December 2012.

Source Data – Other vehicles: Vehicle data based on the average fuel consumption for vehicle type as listed in the ABS Survey of Motor Vehicle Use Cat 9208.0, 31 October 2010.

Source Data – Ethanol: AGO Factors and Methods Workbook 2006, Table 4.

Notes: Medium trucks are assumed to be rigid trucks. Heavy trucks are assumed to be articulated trucks.

5.3.2 Plant and Equipment

Should the road project involve fuel burning activities that are not covered in the default quantity factor tables in Sections 5.3.3 – 5.3.7 then Table 5-5 can be used to estimate the emissions from typical road construction plant and equipment.

Table 5-5 Default quantity factors – Plant and Equipment

Emission Source	Unit of Measure (UOM)	Diesel (kL/UOM)	Comments
Stationary Plant			
Batching plant	Months	9.0	60 m3/hour, 0.5 L diesel/m^3 of concrete, 300 hours/month
Diesel pump	Months	2.3	30kW motor, 300 hours/month
Mobile Plant			
Backhoe loader (backhoe)	Months	3.0	4WD Class 2 to Class 5, Medium application, 300 hours/month

Emission Source	Unit of Measure (UOM)	Diesel (kL/UOM)	Comments
Crane (Hydraulic)	Months	7.9	50 t, Medium application, 300 hours/month
Dozer	Months	5.7	Cat, Class D6, Medium application 300 hours/month
Excavator (digger, trackhoe)	Months	5.1	Crawler Class 100, Medium application, 300 hours/month
Grader (road grader, blade, maintainer, motor grader)	Months	5.1	Class 110, Medium application, 300 hours/month
Haul Truck 25 t	Month	7.9	Cat. 25 Tonne Articulated, medium application, 300 hours/month.
Haul Truck 40 t	Month	12.5	Cat. 40 Tonne Articulated, medium application, 300 hours/month.
Loader – skid steer (track type)	Months	1.6	Medium application, 300 hours/month
Loader – wheeled	Months	4.5	Class 50WL, Medium application, 300 hours/month
Material handlers (excavator with grapple)	Months	3.0	Medium application, 300 hours/month
Material Transfer Vehicle	Months	11.9	MTV Shuttle Buggy SB2500, 300 hours per month @ 67% loading
Paver	Months	7.14	Roatec RP170 300 hours per month @ 70% loading
Roller, Steel	Months	4.8	Medium Application, 300 hours/month
Portable Screening & Crushing Plant	Months	11.35	Medium Application, 300 hours/month
Vibrating Roller (asphalt, soil)	Months	4.8	Class VR35, Medium application, 300 hours/month

Emission Source	Unit of Measure (UOM)	Diesel (kL/UOM)	Comments
Scraper	Months	14.5	Caterpillar TS220, 300 kW, Medium application, 300 hours/month
Stabiliser soil	Months	17.1	450kW power, 2,440mm working width & 500mm working depth, Medium application, 300 hours/month
Tractor dozer	Months	12.9	Class 300C (D9 size), Medium application, 300 hours/month
Water Pump	Months	1.2	6" pump running continuously for dewatering

Source Data Stationary Plant: NPI EET Manual – Combustion Engines (2008), VicRoads and Pneucon Process Technology's website (www.pneucon.net)

Source Data for Crane, Dozer, Haul Trucks, Portable Screening and Crushing Plant, derived from information contained in NCHRP Report 744 Fuel Usage Factors in Highway and Bridge Construction, TRRB.

Source Data Mobile Plant: RTA Construction GHG Emissions Inventory Tool, v. 1.5

- Low application – multiply medium application factor by 0.66
  - Light road maintenance. Finish grading. Plant and road mix work. Machine movement is mainly consisting of idle running or travelling unloaded.
- Medium application
  - Average earth moving, scraper hauling or easy pushing operations. Road mix work or scarifying.
- High application – multiply medium application factor by 1.4
  - Ripping, heavy pushing and operations continued without rest at full power. Heavy maintenance of hard packed roads with embedded rock.

5.3.3 Demolition and earthworks

Table 5-6 provides default quantity factors for emission sources associated with demolition and earthwork activities (including vegetation removal).

Table 5-6 Default quantity factors – demolition and earthworks

Emission Source	Unit of Measure (UOM)	Diesel (kL/UOM)	Vegetation Mass (t/UOM)	Comments
Demolition				
Liquid fuel combustion - Demolition of existing structures				Assumes demolition will be conducted using conventional plant (i.e. graders and dozers) Based on historical data
▪ Houses	No.	720×10^{-3}	-	150 m^2 average
▪ Small commercial	No.	$1{,}920 \times 10^{-3}$	-	Up to 400m^2, prorated from houses
▪ Medium commercial	No.	$6{,}000 \times 10^{-3}$	-	Up to 1,250m^2, prorated from houses
▪ Large commercial	No.	$16{,}800 \times 10^{-3}$	-	Up to 3,500m^2, prorated from houses
Vegetation removal				
Liquid fuel combustion - Clearing and grubbing of vegetated areas (Australian methodology)				Assumes vegetation removal will be conducted using conventional plant (i.e. graders and dozers) For the GHG emissions relating to the loss of a carbon sink as a result of vegetation removal refer to Section 5.3.3.1
▪ Class 1	ha	0.4	-	Assumed to be equivalent to 0 - 50 (t dry matter/ha)
▪ Class 2	ha	1	-	Assumed to be equivalent to 50 - 100 (t dry matter/ha)
▪ Class 3	ha	1.6	-	Assumed to be equivalent to 100 - 150 (t dry matter/ha)

Emission Source	Unit of Measure (UOM)	Diesel (kL/UOM)	Vegetation Mass (t/UOM)	Comments
▪ Class 4	ha	2.2	-	Assumed to be equivalent to 150 - 250 (t dry matter/ha)
▪ Class 5	ha	2.8	-	Assumed to be equivalent to 250 - 350 (t dry matter/ha)
▪ Class 6	ha	3.4	-	Assumed to be equivalent to 350 - 450 (t dry matter/ha)
▪ Class 7	ha	4	-	Assumed to be equivalent to > 450 (t dry matter/ha)
Liquid fuel combustion - Clearing and grubbing of vegetated areas (New Zealand methodology)				Assumes vegetation removal will be conducted using conventional plant (i.e. graders and dozers)
▪ Grasslands	ha	0.4	10	Average from all IPCC Climate Zones For the GHG emissions relating to the loss of a carbon sink as a result of vegetation removal refer to Section 5.3.3.1
▪ Low shrubs	ha	1	30	Assumed to be equivalent to low shrublands For the GHG emissions relating to the loss of a carbon sink as a result of vegetation removal refer to Section 5.3.3.1

Emission Source	Unit of Measure (UOM)	Diesel (kL/UOM)	Vegetation Mass (t/UOM)	Comments
▪ High shrubs and medium dense trees < 10m	ha	2.8	210	Assumed to be equivalent to Woodland For the GHG emissions relating to the loss of a carbon sink as a result of vegetation removal refer to Section 5.3.3.1
▪ Dense, mature forest	ha	4	400	Highly dependent upon size of trees, whether they can be burnt, pushed up or logged, accuracy on this item plus/minus 50% Assumed to be equivalent to Open Forest For the GHG emissions relating to the loss of a carbon sink as a result of vegetation removal refer to Section 5.3.3.1
Transport of cleared vegetation offsite				Refer to Table 5.4
Earthworks				
Liquid fuel combustion – earthmoving equipment ▪ Strip and respread topsoil	m^3	1.2×10^{-3}		Assumes earthworks will be conducted using conventional plant (i.e. graders and dozers) Includes scraper operation
▪ Cut to spoil	m^3	4.0×10^{-3}		Includes box out for pavements

Emission Source	Unit of Measure (UOM)	Diesel (kL/UOM)	Vegetation Mass (t/UOM)	Comments
▪ Cut to fill	m^3	1.0×10^{-3}		Includes scraper, excavator/truck operation within 1 km. Includes fuel used for compaction.
▪ Import and place filling	m^3	3.5×10^{-3}		Assumes bulk operation in metro location. Does not include fuel used to 'extract' import fill (i.e. offsite emissions).

Source Data – Demolition: DTEI Greenhouse Gas Assessment Tool v4_0

Source Data – Vegetation Removal - Diesel: DTEI Greenhouse Gas Assessment Tool v4_0

Source Data -–Vegetation Removal – Vegetation Mass (Australian methodology): Vegetation emissions methodology for road construction workbook: workbook methodology, June 2012

Source Data – Vegetation Removal – Vegetation Mass (New Zealand methodology):Adapted from NCAS Technical Report No. 17, Tables 2.3, 2.5 and Table 3.8

Source Data – Vegetation Mass Grasslands (New Zealand Methodology): IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 6 Grasslands, Table 6.4

Source Data – Earthworks: Cost estimator

The New Zealand methodology is currently being reviewed and will be updated in a future release. For further information contact NZTA.

5.3.3.1 Vegetation removal - lost carbon sink

Australia

This methodology for estimating the greenhouse gas impacts associated with clearance takes into account the carbon that exists in the vegetation at the time of clearing and carbon that could have been sequestered in the future if the vegetation was not cleared. The methodology is considered a conservative estimation approach and **assumed** that:

- All carbon pools (i.e. woody, non-woody, debris and soil) are removed.
- All carbon removed is converted to carbon dioxide and released to the atmosphere.
- Sequestration from revegetation of the project site is not included.

It is acknowledged that this is a conservative approach to estimating greenhouse gas emissions from vegetation removal.

The current methodology used for determining the loss of sequestration is contained in Appendix E Vegetation Emissions Methodology.

New Zealand

The New Zealand methodology is currently being reviewed and will be updated in a future release. For further information contact NZTA. The following methodology will be used in the interim.

Table 5-7 provides default quantity factors for emission sources associated with demolition and earthwork activities (including vegetation removal).

Table 5-7Default Quantity Factors - New Zealand Vegetation Carbon Dioxide Sequestration

Vegetation Type	Carbon Dioxide Sequestration ($t\ CO_2/ha$)
Grassland	
Native Grassland	584
Weedy Grassland	409
Shrubland	**347**
Forests – pre 1990	
Pinus Radiata	1,245
Douglas Fir	957
Exotic Softwoods	642
Exotic Hardwoods	626
Indigenous Forest	N/A
Forests – post 1990	
Pinus Radiata	1,245
Douglas Fir	957
Exotic Softwoods	641

Vegetation Type	Carbon Dioxide Sequestration ($t\ CO_2/ha$)
Exotic Hardwoods	618
Indigenous Forest	323

5.3.4 Pavements

Table 5-8 provides default factors for emission sources associated with the construction of pavements.

Table 5-8 Default quantity factors – pavements

Emission Source	Unit of Measure	Diesel (kL/UOM)	30 MPa Concrete (m^3/UOM)	Steel (t/UOM)	Bitumen (t/UOM)	Aggregate (t/UOM)	Fly Ash (t/UOM)	Sand (t/UOM)	Cement (t/UOM)	Comments
Pavements – Flexible										Grader based gang using average production rates , urban project
Full Depth Asphalt	m^2	1.69 x10^{-3}	-	-	32.2 x10^{-3}	1.26	-	-	5.58 x10^{-3}	280mm of Asphalt, 150mm of 2% cement treated aggregate, 150mm of aggregate basecourse. 5% bitumen content in Asphalt
Deep Strength Asphalt	m^2	2.15 x10^{-3}	-	-	20.1 x10^{-3}	1.47	-	-	20.5 x10^{-3}	175mm of Asphalt, 200mm of 4% cement treated aggregate, 150mm of 2% cement treated aggregate, 150mm of aggregate basecourse. 5% bitumen content
Warm Mix Asphalt	m^2	1.58 x10^{-3}	-	-	22.4 x10^{-3}	1.13	-	-	9.77 x10^{-3}	195mm of Asphalt, 175mm of 4% cement treated aggregate and150mm of aggregate basecourse
Granular + spray and seal (Equivalent to Chip Seal)	m^2	1.82 x10^{-3}	-	-	2.0 x10^{-3}	1.15	-	-	-	500mm of aggregate, two coat sprayseal
Pavements - Rigid										
Plain Concrete (PC)	m^2	1.44 x10^{-3}	-	-	-	0.53	14.0 x10^{-3}	0.23	50.7 x10^{-3}	270mm of base concrete (40MPa), 150mm of subbase concrete (LMC), 150mm 2% stablised SMZ, 150mm SMZ Lean mix concrete cement content is 220 kg/m^3 25MPa concrete cement content is 300 kg/m^3

Emission Source	Unit of Measure	Diesel (kL/UOM)	30 MPa Concrete (m^3/UOM)	Steel (t/UOM)	Bitumen (t/UOM)	Aggregate (t/UOM)	Fly Ash (t/UOM)	Sand (t/UOM)	Cement (t/UOM)	Comments
Reinforced Concrete	m^2	1.44×10^{-3}	-	6.53×10^{-3}	-	0.53	14.0×10^{-3}	0.23	45.0×10^{-3}	270mm of base concrete (40MPa), 150mm of subbase concrete (LMC), 150mm 2% stablised SMZ, 150mm SMZ Lean mix concrete cement content is 220 kg/m^3 25MPa concrete cement content is 300 kg/m^3 Steel is 1.5% of total weight
Sealing										
Prime, AMC 00	m^2	0.12×10^{-3}	-	-	1.2×10^{-3}	-	-	-	-	Based on 1.2 litres/m^2. Includes diesel rural multiplication factor of 6
Waterproofing layer	m^2	0.23×10^{-3}	-	-	1.0×10^{-3}	0.012	-	-	-	Based on 0.9 L/m^2 bitumen and 170m^2/m^3 for 7mm Includes diesel rural multiplication factor of 7
2 coat, spray seal	m^2	0.49×10^{-3}	-	-	2.0×10^{-3}	0.031	-	-	-	Based on 0.9 l/m^2 x 2 layers, aggregate @ 105 m^2/m^3 for 16mm and 170m^2/m^3 for 7mm . Includes diesel rural multiplication factor of 7
Other pavements										
Median and traffic island infill	m^2	3.8×10^{-4}	0.34	6.90×10^{-3}		0.112	-	-	-	175mm thick with 150mm cap of concrete, Reinforcement assumed 2% of concrete weight
Concrete footpaths	m^2	1.0×10^{-4}	0.075	3.45×10^{-3}	-	0.112	-	-	-	Assumed 30MPa concrete. 75mm thick, not less than 50mm aggregate base, Reinforcement assumed 2% of concrete weight
Block paved footpaths	m^2	2.0×10^{-3}	8.0×10^{-5}	-	-	0.336	-	-	-	80mm ICPU, not less than 150mm aggregate base
Bike path - asphalt	m^2	7.3×10^{-4}	-	-	4.0×10^{-3}	0.412	-	-	-	Pavement – 35mm HMA on prime on 150mm of crushed rock, minor earthworks to 0.5m, no steel edge strips, no kerbing, no lighting

Emission Source	Unit of Measure	Diesel (kL/UOM)	30 MPa Concrete (m^3/UOM)	Steel (t/UOM)	Bitumen (t/UOM)	Aggregate (t/UOM)	Fly Ash (t/UOM)	Sand (t/UOM)	Cement (t/UOM)	Comments
Bike path - concrete	m^2	5.2×10^{-4}	0.125	5.7×10^{-3}	-	0.224	-	-		125mm thick, , not less than 100mm aggregate base, Reinforcement assumed 2% of concrete weight

Source Data – Pavements Flexible: RTA Pavements types document (refer Section 5.2 of Supporting Document), DTEI Greenhouse Gas Assessment Tool v4_0

Source Data – Pavements Rigid: RTA Pavements types document(refer Section 5.2 of Supporting Document), SA Water TS 1a PB

Source Data – Sealing: DTEI Greenhouse Gas Assessment Tool v4_0

Source Data – Other Pavements: DTEI Greenhouse Gas Assessment Tool v4_0, VicRoads Drawings

5.3.5 Road structures

Table 5-9 provides default factors for emission sources associated with the construction of road structures.

Table 5-9 Default quantity factors – road structures

Emission Source	Unit of Measure	Diesel (kL/UOM)	40MPa Concrete (m^3/UOM)	Steel (t/UOM)	Timber (m^3/UOM)	Comments
Bridges						
Bridge constructed using precast reinforced concrete beams	m^2	0.038	1.52	0.25	-	Based on 4 span, 4 lane,1,500mm deep reinforced concrete super T structure with piles. Suitable for spans up to 35m.
Bridge constructed using steel beams	m^2	0.038	1.2	0.44	-	Based on 4 span 2 lane welded beam structure without piles
Reinforced Soil walls						
Reinforced Soil Walls	m^2	0.048	0.2	0.02	-	Includes reinforced earth block
Retaining walls						
Concrete retaining walls	m^2	0.3×10^{-3}	0.57	0.058	-	Assumes 180mm thick reinforced concrete wall, 1.5-1.8m high
Timber retaining walls	m^2	0.9×10^{-3}	0.17	0.028	0.02	Assumes 1.5-1.8m high
Rock retaining walls	m^2	4.0×10^{-3}	-	-	-	Assumes gabion style, 1.5-1.8m high Assumed that the rock is taken from nature (i.e. not processed) and therefore has no associated quantity for aggregate.

Source Data – Bridges: DTEI Greenhouse Gas Assessment Tool v4_0

Source Data – Reinforced Soil Walls: DTEI Greenhouse Gas Assessment Tool v4_0

Source Data – Retaining Walls: Cost estimator

5.3.6 Drainage

Table 5-10 provides default factors for emission sources associated with drainage.

Table 5-10 Default quantity factors – drainage

Emission Source	Unit of Measure	Diesel (kL/UOM)	30 MPa Concrete (m^3/UOM)	Steel (t/UOM)	Aggregate (t/UOM)	Comments
Kerbing						**All based on conventional construction methods using plant typical for this type of work**
Mountable Kerb	m	0.2×10^{-3}	0.04	-	-	Unreinforced , mountable kerb
Semi-mountable Kerb	m	0.3×10^{-3}	0.06	-	-	Unreinforced , semi-mountable kerb
Upright kerb and Gutter (Channel)	m	0.4×10^{-3}	0.08	-	-	Unreinforced , barrier kerb and gutter
Invert drain	m	1.1×10^{-3}	0.22	0.003	-	
Culverts – pipes or box culverts for water drainage						Based on standard class 2 pipes with imported backfilling
Small <450 RCP	m	35.0×10^{-3}	0.07	2.9×10^{-3}	3.07	RCP=Reinforced Concrete Pipe, Assumes trench width is approximately 600mm wider than pipe diameter, cover = 1.0m and includes all imported bedding, surround and backfill materials. Steel is 1.8% of total weight
Medium 450 – 750 RCP	m	45.0×10^{-3}	0.11	4.55×10^{-3}	4.39	Assumes trench width is approximately 600mm wider than pipe diameter, cover = 1.0m and includes all imported bedding, surround and backfill materials. Steel is 1.8% of total weight
Large 750 – 1200 RCP	m	95.0×10^{-3}	0.15	6.21×10^{-3}	5.91	Assumes trench width is approximately 600mm wider than pipe diameter, cover = 1.0m and includes all imported bedding, surround and backfill materials. Steel is 1.8% of total weight
375 x 600 RCBC	m	67.0×10^{-3}	0.19	0.018	4.26	RCBC = reinforced concrete box culvert Assumes trench width is approximately 600mm wider than culvert width, cover = 1.0m and includes all imported bedding, surround and backfill materials. Steel is 1.8% of total weight

Emission Source	Unit of Measure	Diesel (kL/UOM)	30 MPa Concrete (m^3/UOM)	Steel (t/UOM)	Aggregate (t/UOM)	Comments
600 x 1200 RCBC	m	100.5 x10^{-3}	0.40	0.039	6.83	Assumes trench width is approximately 600mm wider than culvert width, cover = 1.0m and includes all imported bedding, surround and backfill materials. Steel is 1.8% of total weight
Open, unlined drains						
Form open, unlined drains	m	0.5 x10^{-3}	-	-	-	Assumes V drains cut with a grader

Source Data – Kerbing: DTEI Greenhouse Gas Assessment Tool v4_0

Source Data – Culverts: Cost estimator

Source Data – Open, Unlined Drains: DTEI Greenhouse Gas Assessment Tool v4_0

5.3.7 Road furniture

Table 5.11 provides default factors for emission sources associated with the manufacture and installation of road furniture.

Table 5-11 Default quantity factors – road furniture

Emission Source	Unit of Measure	Diesel (kL/UOM)	30 MPa Concrete (m^3/UOM)	Steel (t/UOM)	Timber (t/UOM)	Comments
Road safety barriers						
Wire rope barrier	m	0.6 x10^{-3}	67.9 x10^{-3}	10.6 x10^{-3}		Assumed to be 4 rope barrier, 1.2kg/m wire, steel posts (1,230mmx100mmx25mm) at 2.5m spacing with a concrete footing 300mm diameter by 600mm deep
W-beam barrier	m	0.6 x10^{-3}	-	23.3 x10^{-3}		Assumed to be 5m panels of 2.7mm base metal thickness, steel posts 150mmx110mmx4.3mm at 2m spacing
F-type (New Jersey) barrier	m	0.97 x10^{-3}	0.687	12.6 x10^{-3}		Assumes 1.8% steel and 4m barrier weighs 2.8t
Noise walls						
Reinforced concrete noise wall	m	0.04	0.477	0.031		Assumed to be 3m high, 4.2m long steel posts HW 350, concrete footing 450mm in diameter by 1,500mm deep, precast concrete panels 150mm thick, 4m between posts

Emission Source	Unit of Measure	Diesel (kL/UOM)	30 MPa Concrete (m^3/UOM)	Steel (t/UOM)	Timber (t/UOM)	Comments
Hebel noise wall	m	0.04	0.286	0.031		Assumed to use 40% less concrete than reinforced concrete noise wall
Timber noise wall	m	0.04	0.045	0.05	0.059	Assumed to be 3m high wall, 4.2m long steel posts HW 350, concrete footing 450mm in diameter by 1,500mm deep, plywood acoustic panels -. assumed 28mm thick, 2.4m between posts
Steel plate noise wall	m	0.04	0.036	0.74		Assumed to be 3m high wall, 4.2m long steel posts HW 350, concrete footing 450mm in diameter by 1,500mm deep, 3mm thick steel plate. 3m between posts

Source Data – Road Safety Barriers: Ingal Civil Products

Source Data – Noise Walls: Cost estimator & VicRoads As-Built drawing and schedules

5.4 Road projects that include tunnels

The construction methods and GHG emissions for tunnels are project specific. It is therefore not possible to develop meaningful default quantity factors for the construction of tunnels.

The commonly used tunnelling methods are:

- Cut and cover
- Driven
- Tunnel boring machine
  - Sacrificed
  - Retrieved
- Road header

In order to estimate the GHG emissions from constructing a tunnel the information shown in Table 5. -12 will need to be known, as a minimum.

Table 5. -12 Information required to estimate the GHG emissions from construction of tunnels

Information Required	Activity measure
Length and cross section of the tunnel	Indicates the quantity of spoil that will need to be removed
Geotechnical conditions	Indicates the productivity of tunnelling and therefore the tunnelling duration
Volume of lining	Usage of materials
Type of tunnelling equipment	Electricity and fuel consumption
Lighting and ventilation requirements during construction	Electricity consumption
General road items required: ▪ Pavement ▪ Culverts ▪ Road safety barriers ▪ Signage etc.	Usage of materials

Information Required	Activity measure
Mechanical and Electrical equipment ▪ Fans (supply and extraction) ▪ Pumps ▪ Fire life safety systems ▪ Lights	Electricity consumption during operation Planned Maintenance requirements

6. Module 3 – Operation

Operation is considered to be post construction and includes activities that are required on a continual basis for the functioning of the road.

This Workbook does not include road usage by vehicles in this definition.

6.1 Operation GHG assessment boundary

Table 6-1 shows the Scope 1, 2 and 3 emission sources included within the operation GHG assessment boundary.

NOTE: Items in Table 6-1 in orange might be significant – Refer to the Materiality Checklist in Appendix A for guidance on when these emission sources should be included in a GHG assessment.

As some roads, particularly rural roads, have no street lighting, traffic signals or intelligent transport systems (ITS) none of the operational emission sources are considered material for all road projects. Hence, all fields in Table 6-1 are orange.

Table 6-1 Emission sources to be included in GHG assessment of road operation

Scope 1	Scope 2	Scope 3
Street Lighting		
	Electricity consumption by street lights	Generation and distribution of electricity consumed by plant and equipment
Traffic Signals		
	Electricity consumption by traffic signals	Generation and distribution of electricity consumed by plant and equipment
Intelligent Transport Systems		
	Electricity consumption by signs, travel time boards and ramp metering	Generation and distribution of electricity consumed by plant and equipment

NOTE: The revegetation of road verges will result in carbon dioxide being sequestered during operation of the road. However, the quantity of carbon sequestered is not well correlated with climate conditions (e.g. annual rainfall) and hence revegetation has not been included in the Workbook or the GHG assessment boundary.

Figure 6.1 below shows the operation GHG assessment boundary and the activities and emission sources found to be significant (refer to Section 3.7 of the Supporting Document for further details of the materiality assessment for operation). All of the activities and emission sources considered within the operation GHG assessment boundary are shown in Figure 3.2 of the Supporting Document.

NOTE: Activities/emission sources with a dashed outline are those that may be significant for some road projects but insignificant for others.

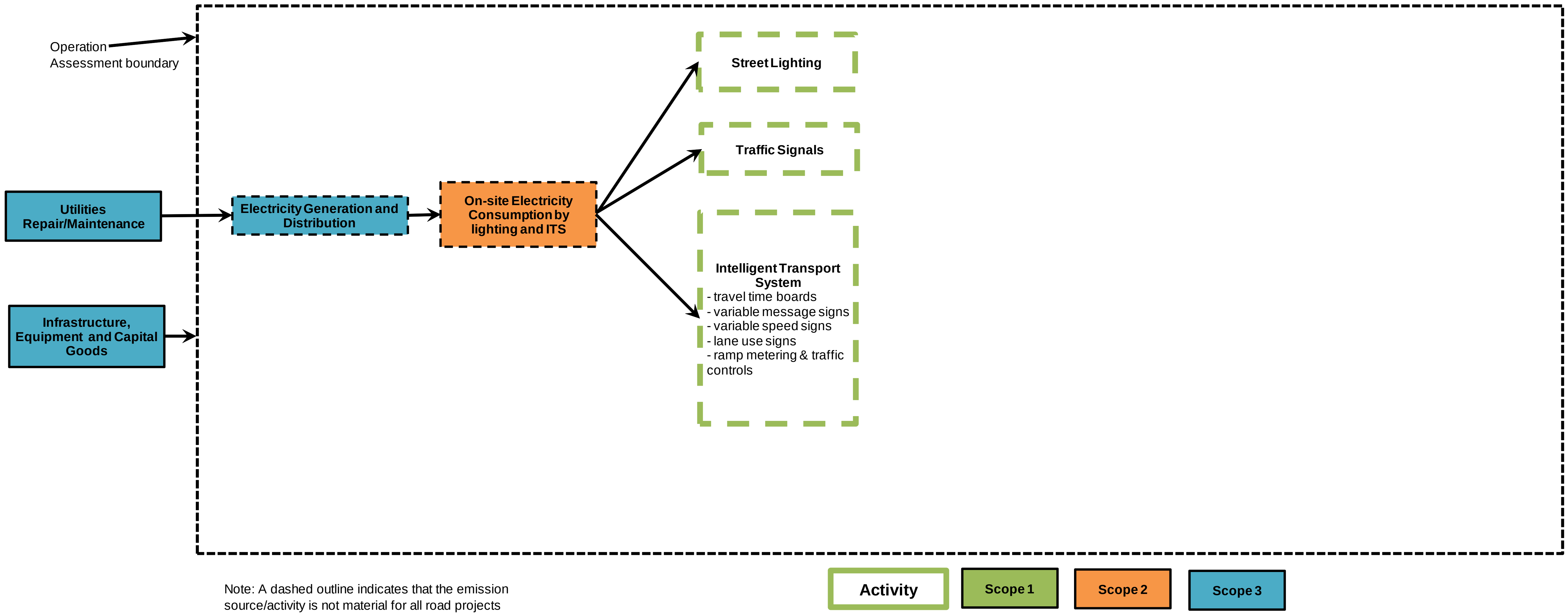


Figure 6.1 Operation GHG assessment boundary

6.2 Operation emission sources and required data

Table 6-2 presents all of the activities and emission sources within the operation GHG assessment boundary that are considered significant. The data required for each emission source is also listed in Table 6-2.

Where the emission source (usage) data is not available (e.g. in the project scoping phase) the alternative emission source data and the associated default quantity factor(s) (refer to Section 6.3 below) may be used to estimate the emission source (usage) data.

NOTE: Items in Table 6-2 in orange might be significant – Refer to the Materiality Checklist in Appendix A for guidance on when these emission sources should be included in a GHG assessment.

Table 6-2 Data required to estimate the GHG emissions associated with the operation of a road

Activity	Emission Source	Emission Source Data Required	Alternative Emission Source Data Required
Street lighting	Generation and distribution of electricity consumed by street lighting	Number, type and wattage of lamps **AND** Operating hours	Road type/application (see Table 6-4 below) **AND** length of road/application
Traffic signals	Generation and distribution of electricity consumed by traffic signals	Number and type of signal pedestals **AND** Type and wattage of lamps (assumed operating 24 hours a day)	Type of intersection (see Table 6-5below)
Intelligent transport systems	Generation and distribution of electricity consumed by intelligent transport systems	Number, type and wattage of travel time boards **AND** operating hours Number, type and wattage of variable message signs **AND** operating hours Number, type and wattage of variable speed signs **AND** operating hours Number, type and wattage of lane use signs **AND** operating hours Number, type and wattage of ramp metering and controls **AND** operating hours Number, type and wattage of control systems **AND** operating hours	Refer to Section 6.5

6.3 Electricity ratings for typical road lighting and signals

Table 6-3 provides electricity ratings for typical street lights and traffic signals.

Table 6-3 Electricity ratings for typical road lighting and signals

Application	Lamp/ Signal Type	Initial Lumens	Wattage	Comments
Street Lights				
Underpasses	HPS or MH	HPS ~ 16,000 MH ~ 14,000	150	
Freeway ramps and arterial roads	HPS or MH	HPS ~29,000 MH ~ 21,000	250	
Freeway through carriageways	HPS or MH	HPS ~ 47,500 MH ~ 36,000	400	
Pedestrian lighting	CFL	~3,000	42	Replaces 80W Mercury Vapour or 50W HPS
Pedestrian lighting	LED	4,800	60	Replaces 220W HPS or MH
Pedestrian lighting	LED	6,400	80	Replaces 350W HPS or MH
Pedestrian lighting	LED	8,000	100	Replaces 400W HPS or MH
Pedestrian lighting	LED	9,600	120	Replaces 500W HPS or MH
Traffic Signals				
Traffic signals – Controller Small			50	
Traffic signals – Controller Large			100	
Traffic signals – 200mm	Incandes-cent		67	
Traffic signals – 300mm	Incandes-cent		150	
Traffic signals – 200mm	QH		30	
Traffic signals – 300mm	QH		50	
Traffic signals – 200mm	LED		11	Red 6W, Yellow11W, Green 6W
Traffic signals – 300mm	LED		29	Red 11W, Yellow 29W, Green 11W
Traffic signal turning arrows – 200mm	LED		6	
Traffic signal turning arrows – 300mm	LED		14	Red 11W, Yellow 13W, Green 14W
Pedestrian Walk Sign	LED		6	
Intelligent Transport System components				
Variable Speed Limit sign	LED		320	

Application	Lamp/ Signal Type	Initial Lumens	Wattage	Comments
Variable Message Sign	LED		1,200	
Camera			120	
Ramp control lights			72	
FRS Cabinets			150	
Roadside Cabinets			200	
Wireless distribution system			50	

Source: LED Street Lights- http://www.ledlightingaustralia.net.au/LED-Street-Lighting-C16/
Source: Incandescent, QH & LED Traffic Lights - Aldridge Traffic Systems
http://www.aldridgetraffic.com.au/traffic_signal_lanterns.html
Source: Intelligent Transport System – VicRoads M1 information

6.4 Default quantity factors – operation

The Workbook provides an alternative method for determining emission source data quantities. The alternative method uses an indicator of activity level and default quantity factors to estimate the emission source data quantities. Default quantity factors can be used to estimate the usage of various components for various emission sources, should actual emission source data not be available or readily accessible.

The default quantity factors for operation have been developed using Australian and New Zealand road lighting standards and are based on 'typical' operational aspects. If a project uses an alternative equipment item or standard then the default quantity factors should not be used.

NOTE: The default quantity factors in the following tables should be used to estimate the quantities of electricity used, only when the actual usage data is not available.

Table 6-4 provides default factors for emission sources associated with the operation of street lights. Electricity usage is calculated for a 50 year period.

NOTE: The replacement of light globes is considered a minor maintenance activity and hence, the fuel usage associated with replacing light globes in not included in the default quantity factors above.

Table 6-4 Default quantity factors – street lights

Application	Lamp Type	50 year electricity consumption (kWh/m of lights)	Comments
Freeway through carriageways	400W HPS or MH	990	Assume 12 hours of operation per day, Category V3 road as per AS1158, spacing 89m, single outreach, lighting **ONE** side of road **ONLY**

Application	Lamp Type	50 year electricity consumption (kWh/m of lights)	Comments
Freeway ramps and arterial roads	250W HPS or MH	640	Assume 12 hours of operation per day, Category V3 road as per AS1158, spacing 86m, single outreach, lighting **ONE** side of road **ONLY**
Underpasses - where lighting is required and soffit levels (clearances) are 10m or less - also used to light slip lanes and municipal roads or where the use of 250W HPS is inefficient	150W HPS or MH	600	Assume 12 hours of operation per day, Category V3 road as per AS1158, spacing 55m, single outreach, lighting **ONE** side of road **ONLY**

Source Data – AS 1158 & VicRoads Guidelines for Road Lighting Design

NOTE: The lighting design for tunnels is project specific. It depends on the entrance size, tunnel length and vision on approach. Dimming is also applied so that the light levels in the tunnel match those outside the tunnel. It is therefore not possible to develop meaningful default quantity factors for the lighting of tunnels

Table 6-5 provides default quantity factors for various types of intersections that utilise traffic signals. Electricity usage is for a 50 year period.

Table 6-5 Default quantity factors – Traffic signals for typical interchanges (LED)

Emission Source	No. Pede-stals	No. Turning Arrows	No. Pedestrian walk signals	50 year electricity consumption (kWh/ intersection)	Comments
Incandescent Traffic Signals					
Major urban intersection - Divided Road	16	4	12	**1,711,123**	300mm vehicle lantern, 300mm turning lanterns, 200mm pedestrian lantern
Major intersection - Undivided Road	12	4	10	**1,389,411**	300mm vehicle lantern, 200mm pedestrian lantern
Freeway with divided road (full diamond interchange)	26	4	16	**2,486,038**	300mm vehicle lantern, 200mm pedestrian lantern
Quartz Halogen Traffic Signals					
Major urban intersection - Divided Road	16	4	12	**639,918**	300mm vehicle lantern, 300mm turning lanterns, 200mm pedestrian lantern

Emission Source	No. Pede-stals	No. Turning Arrows	No. Pedestrian walk signals	50 year electricity consumption (kWh/ intersection)	Comments
Major intersection - Undivided Road	12	4	10	**525,960**	300mm vehicle lantern, 200mm pedestrian lantern
Freeway with divided road (full diamond interchange)	26	4	16	**911,664**	300mm vehicle lantern, 200mm pedestrian lantern
LED Traffic Signals					
Major urban intersection - Divided Road	16	4	12	**303,304**	300mm vehicle lantern, 200mm pedestrian lantern
Major intersection - Undivided Road	12	4	10	**247,201**	300mm vehicle lantern, 200mm pedestrian lantern
Freeway with divided road (full diamond interchange)	26	4	16	**440,930**	300mm vehicle lantern, 200mm pedestrian lantern

Source Data – Aldridge Traffic Systems,
http://www.aldridgetraffic.com.au/traffic_signal_lanterns.html

6.5 Intelligent transport systems

The GHG emissions through operation for intelligent transport systems (ITS) are project specific. It is therefore not possible to develop meaningful default quantity factors for the operation of ITS.

In order to estimate the GHG emissions from as ITS the power rating (Watts) of each equipment item/light and the estimated hours of operation per day will need to be determined. To calculate the kWh of electricity consumed over a 50 year period: multiply the wattage by the daily hours of operation then by 365.25 then by 50 and divide by 1,000.

$$\text{Electricity consumption (kWh)} = \frac{\text{Wattage x Hours of Operation/day x Days/ Year (365.25) x Years (50)}}{1000}$$

7. Module 4 – Maintenance

Maintenance is considered to be post construction and includes activities that are intermittently required to keep the road assets at the required standard. Maintenance can be major (e.g. rehabilitation), planned/routine or reactive.

7.1 Maintenance GHG assessment boundary

Table 7-1 shows the Scope 1, 2 and 3 emission sources included within the maintenance GHG assessment boundary.

NOTE: Items in Table 7-1 in black are considered significant in 'typical' road projects and should be included in a GHG emissions assessment whilst those in orange might be significant – Refer to the Materiality Checklist in Appendix A for guidance on when these emission sources should be included in a GHG assessment.

Refer to the Supporting Document for a discussion on the materiality of road maintenance activities and the basis for excluding minor maintenance activities (i.e. planned/routine and reactive maintenance activities).

Figure 7.1 below shows the maintenance GHG assessment boundary and the activities and emission sources found to be significant (refer to Section 3.8 of the Supporting Document for further details of the materiality assessment for maintenance). All of the activities and emission sources considered within the maintenance GHG assessment boundary are shown in Figure 3.3 of the Supporting Document.

NOTE: Activities/emission sources with a dashed outline are those that may be significant for some road projects but insignificant for others.

Table 7-1 Emission sources to be included in GHG assessment of maintenance

Scope 1	Scope 2	Scope 3
Major Maintenance		
Combustion of fuels in rehabilitation plant and equipment		Production and distribution of fuels used in rehabilitation plant and equipment
		Production of materials used in major maintenance activities
		Transport of materials used in major maintenance activities

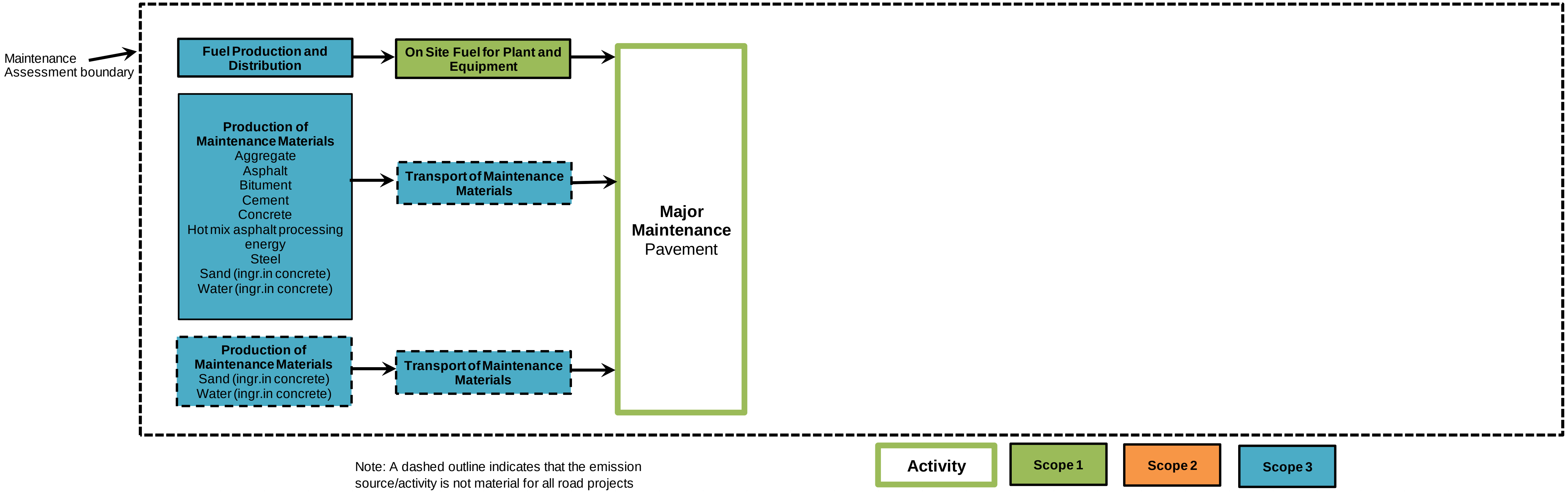


Figure 7.1 Maintenance GHG assessment boundary

7.2 Maintenance emission sources and required data

Table 7-2 presents all of the activities and emission sources within the maintenance GHG assessment boundary that are considered significant. The data required for each emission source is also listed in Table 7-2.

Where the emission source (usage) data is not available (e.g. in the project scoping phase) the alternative emission source data and the associated default quantity factor(s) (refer to Section 7.3 below) may be used to estimate the emission source (usage) data.

NOTE: Items in Table 7-2 in black are considered significant in all ‘typical’ road projects and should be included in a GHG assessment whilst those in orange might be significant – Refer to the Materiality Checklist in Appendix A for guidance on when these emission sources should be included in a GHG assessment.

Table 7-2 Data required to estimate the road maintenance related GHG emissions

Activity	Emission Source	Emission Source Data Required	Alternative Emission Source Data Required
Rehabilitating Road Pavements	Liquid fuel combustion – pavement rehabilitation equipment	Fuel type **AND** kL of fuel, for each fuel type **AND**	Equipment type(s) **AND** number of months operated **AND** load on equipment **OR** Pavement type (Refer to Table 7-3) **AND** pavement area in m^2
	Upstream emissions from the production of road rehabilitation materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Asphalt type(s) **AND** t asphalt used **OR** bitumen type(s) **AND** t bitumen used, t aggregate used and asphalt processing energy used in making asphalt **AND** Additional Bitumen type(s) **AND** t bitumen used **AND** Additional Aggregate type(s) **AND** t aggregate used	Pavement type (Refer to Table 7-3) **AND** pavement area in m^2
	Upstream emissions from the transport of road rehabilitation materials	Quantity of material per truckload **AND** return transport distance, in km	**AND** distance from road project to likely source of material in km

7.3 Default quantity factors – maintenance

The Workbook provides an alternative method for determining emission source data quantities. The alternative method uses an indicator of activity level and default quantity factors to estimate the emission source data quantities. Default quantity factors (DQFs) can be used to estimate the usage of various components for various emission sources, should actual usage data not be available or readily accessible.

The default quantity factors have been developed using cost estimating first principles in most cases and are based on 'typical' maintenance activities. If a project uses an alternative process or material then the default quantity factors should not be used.

NOTE:
The default quantity factors in the following tables should be used to estimate the quantities of energy, fuel and materials used only when the actual usage data is not available.

Table 7-3 provides default factors for activities associated with maintenance of a road.

Table 7-3 Default quantity factors – Maintenance activities

Activity	Unit of Measure	Diesel (kL/UOM)	Steel (t/UOM)	Bitumen (t/UOM)	Aggregate (t/UOM)	Cement (t/UOM)	Comments
Pavements – Flexible							
Full Depth Asphalt	m^2	4.3×10^{-4}	-	18.9×10^{-3}	0.38	0.28×10^{-3}	One major rehabilitation with top 150mm replaced - once every 50 years and 5% of road replaced to full depth every 50 years for patching/repair
Deep Strength Asphalt	m^2	4.5×10^{-4}	-	18.3×10^{-3}	0.39	1.02×10^{-3}	One major rehabilitation with top 150mm replaced - once every 50 years and 5% of road replaced to full depth every 50 years for patching/repair
Pavement Stabilisation	m^2	6.0×10^{-3}	-	-	-	0.3×10^{-3}	150mm deep stabilisation. No seal.
Pavement stabilisation + sprayseal	m^2	6.5×10^{-3}	-	2×10^{-3}	31×10^{-3}	0.3×10^{-3}	150mm deep stabilisation. Assumed existing sprayseal is embedded in stabilisation layer. 2 coat sprayseal.
Granular + spray and seal	m^2	7.4×10^{-4}	-	6.0×10^{-3}	0.42	-	Assumes two respray and one major rehabilitation within 50 years. 150mm of aggregate replaced.
Pavements - Rigid							
Plain Concrete (PC)	m^2	10.7×10^{-3}	-	-	14.3×10^{-3}	2.7×10^{-3}	5% of road replaced over 50 year period Assumes only the top concrete layer replaced and that the lean mix and sub-grade layers are not replaced.
Reinforced Concrete	m^2	10.7×10^{-3}	0.4×10^{-3}	-	13.1×10^{-3}	2.5×10^{-3}	5% of road replaced over 50 year period Assumes only the top concrete layer is replaced and that the lean mix and sub-grade layers are not replaced. Steel is 1.5% of total weight

8. Carbon Gauge

Carbon Gauge is a software implementation of the GHG calculation methods described in this workbook.

Carbon Gauge provide a means of estimating the materially significant whole of life GHG emissions during the major road activities of construction, operation, and maintenance calculated over a 50 year life. The calculator does not estimates design phase GHG emissions for a road project. These emissions are not materially significant in the whole of life emissions for the road project, unless significant amounts of air travel are undertaken. However, it is recognised that the design phase of a road project is still important as the decisions made during this phase can have a large impact on emissions relative to construction, operation and maintenance.

Carbon Gauge provides a means of estimating the GHG emissions associated with road projects and enables a better understand how GHG emissions can be reduced.

The initial release of Carbon Gauge is Microsoft Excel® macro-enabled spreadsheet based tool. The development of a web based tool is under consideration.

8.1 Overview of Carbon Gauge

The GHG Assessment Calculator for Road Projects comprises four steps to estimate your road projects GHG emissions. The first step is to select the major activities associated with the road project for which you wish to calculate the GHG emissions. The second step involves selecting the activities associated with the road project likely to be significant. This is done by selecting specific activities from the Materiality Checklist. The third step involves entering the specific road project inputs so that the calculator can estimate the associated emissions. This is done by filling out the appropriate user defined areas on the Input worksheet, coloured yellow. The final step provides a method to review the GHG Assessment results as generated by the calculator including the ability to print a copy of the results as a report. These steps are outlined in Figure 8.1-The four steps required to estimate the GHG emissions for a road project.

Figure 8.1-The four steps required to estimate the GHG emissions for a road project.

8.2 The Carbon Gauge Menu

At the top of the Calculator Menu is a selection of options that allow you to either access help, view the About screen, exit or reset the form. This is shown in Figure 8.2 – Carbon Gauge Menu, along with descriptions of the button functions

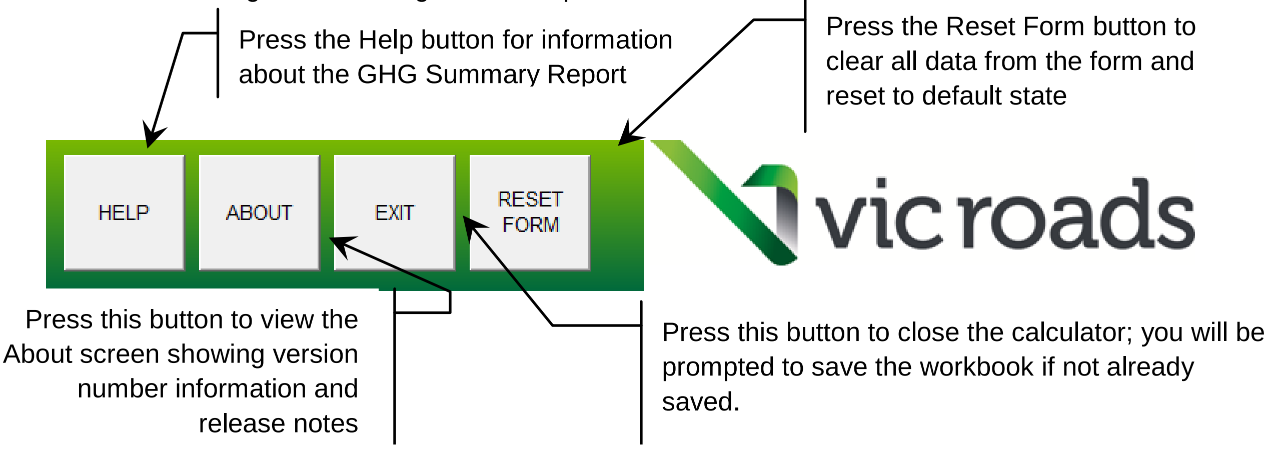


Figure 8.2 – Carbon Gauge Menu

8.3 Entering information into Carbon Gauge

The user can enter information in cells coloured Yellow. Data cannot be entered into any other cells in the calculator. Grey cells indicate information that is calculated by the GHG Assessment Calculator while Dark Grey cells indicated a cell is not available for input This is usually because the option for this component to be assessed has not been selected from the Materiality Checklist.

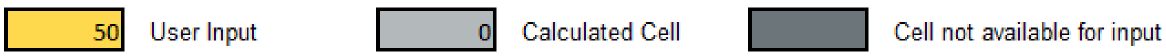


Figure 8.3 - Key for entering data input the calculator.

8.4 Overview of GHG Emissions

Table 8-1-The scope of GHG emissions estimated by the calculator. provides a summary explanation of the GHG emissions associated with a road project and estimated by the calculator. For a more detailed explanation of the GHG emissions associated with road projects see Section 2.3.1.

Scope 1 emissions	Emissions released into the atmosphere as a direct result of an activity, or series of activities (including ancillary activities) that constitutes the facility.
Scope 2 emissions	Emissions released as a result of one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but that do no form part of the facility.
Scope 3 emissions	Emissions that occur outside the site boundary of a facility as a result of activities at a facility that are not Scope 2 emissions.

Table 8-1-The scope of GHG emissions estimated by the calculator.

Appendix A Checklists

GHG assessment checklist

Check off each task as you complete it to ensure that your GHG emissions assessment is as comprehensive as possible.

TASK		YES/NO/NA
1.	Set the project assessment boundary	
2.	Identify the activities and emission sources applicable to the road project	
3.	Use the Materiality Checklist from Appendix A to determine which emission sources are significant and should be included in the GHG assessment for this road project	
4.	Collect activity (usage) data for each of the emission sources identified in Step 2.	
5.	Check that the data is in the correct Units Of Measurement (UOM)	
6.	If the data is not in the correct UOM, apply appropriate conversion factors.	
7.	If there is data missing for any of the emission sources listed, collect the alternative activity data listed in Table 5.2, 6.2 and 7.2 .	
8.	Choose the appropriate default quantity factors from Table 5.3-5.11, 6.4-6.5 and 7.3 for each emission source where the activity data is not available	
9.	Estimate quantities using the alternative activity data and the default quantity factors to fill the gaps in your activity data.	
10.	Select the emission factor for each emission source from Appendix D	
11.	Calculate the GHG emissions for each emission source using the formula in Section 3.2.	
12.	For loss of sequestration, utilise the process outlined in Appendix E	
13.	Sum all emissions together to obtain an estimate of the total GHG impact of your road project.	
14.	Record your assessment results, along with the date of the assessment and project details using the Example Reporting Template in Appendix B.	

Materiality checklist

Define your road project and review against the materiality checklist below to determine whether certain emission sources are likely to be significant.

Activity/Emission Source	Yes	No	Emission source to be included in GHG Assessment
Construction			
Will a diesel generator be used to provide power to the project site office for more than 12 months?			If yes, include fuel combusted in powering site offices
Will more than 120 buildings be required to be demolished per 1km of road?			If yes, include fuel combusted in demolishing buildings
Will more than 0.5 hectares of vegetation (5000 m^2) be removed?			If yes, include vegetation removal
Will the project involve tunnelling?			If yes, include electricity consumption and explosives used
Is the project located more than 50 km from the nearest material suppliers/quarry/city?			If yes, include the emissions associated with the transport of materials to site
Will the project utilise on-site batching plants or other continuously operating stationary plant and equipment for more than 6 months?			If yes, include fuel combusted in stationary engines
Will the project include road safety barriers along > 50% of the road length if barriers are used on both sides of a dual carriageway (i.e. 4 sets) or 100% of the road length if used on both side of a single carriageway (i.e. two sets)?			If yes, include the emissions from the construction and installation of road safety barriers
Will the project include noise walls along more than 50% of the road length (both sides)?			If yes, include the emissions from the construction and installation of noise walls
Operation			
Will the project include lighting continuously along greater than: 15% of the road length (VIC) 20% of the road length (ACT, NSW, QLD,WA,NT) 25% of the road length (SA) 70% of the road length (TAS) 100% of the road length (NZ)?			If yes, include the emissions from the operation of street lighting
Will the project include traffic signals and/or interchanges using incandescent lights that are less than: 14.9 km apart (VIC) 11.5 km apart (ACT, NSW, QLD, NT) 8.0 km apart (SA, WA) 3.1 km apart (TAS) 1.7 km apart (NZ)?			If yes, include the emissions from the operation of incandescent traffic signals
Will the project include traffic signals and/or interchanges using quartz halogen lights that are less than: 5.6 km apart (VIC) 4.5 km apart (ACT, NSW, QLD, NT) 3.5 km apart (SA, WA) 1.3 km apart (TAS) 0.6 km apart (NZ)?			If yes, include the emissions from the operation of quartz halogen traffic signals
Will the project include traffic signals and/or interchanges using LED lights that are less than: 2.7 km apart (VIC)			If yes, include the emissions from the operation of LED traffic signals

2.0 km apart (ACT, NSW, QLD) 1.8 km apart (SA, WA, NT) 0.6 km apart (TAS) 0.3 km apart (NZ)?			
Will the project include emissions from vehicles using the road during its 50 year life?			If yes, include the emissions from vehicles using the road over the 50 year life of the road project.

NOTE: The above materiality checklist was developed based on a 'typical' GHG emission profile of 0.25 t CO_2-e/m^2 of pavement. Where items run the length of a road, a pavement width of 20m was assumed to establish the t CO_2-e/m^2 of pavement for an item. Where items are independent of road length a road length of 1km and pavement width of 20m was used to establish the t CO_2-e/m^2 of pavement for an item. This is being progressively examined in light of results determined to date, which look to be lower than this 0.25 t CO_2-e/m^2 figure. Exceptions are noted for vegetation, transportation and lighting as shown in Section 3.6 and 3.7 of the supporting document..

Emission sources and data checklist - Construction

Use this checklist to record whether you have collected the required data or alternative data; and the corresponding data sources.

- Is the required data available?
  - **YES** Record the activity data, units of measurement and the source of the data
  - **NO** Identify appropriate alternative activity data and default quantity factors, estimate the quantity and record your data source
  - **N/A** Activity or emission source is not applicable to the road project or not significant

Activity	Emission Source	Emission Source Data Required	Fuel/ Material Type	Emission Source Data	Unit of Measure	Data source/location
Site offices – Refer to Table 5.3						
Site offices	Liquid fuel combustion – electricity generation	Fuel type **AND** kL of fuel, for each fuel type				
Site vehicles and plant – Refer to Tables 5.3, 5.4 and 5.5						
Site vehicles	Liquid fuel combustion – site and staff vehicles	Fuel type **AND** kL of fuel, for each fuel type				
Site plant & equipment	Liquid fuel combustion – site plant and equipment	Fuel type **AND** kL of fuel, for each fuel type				
Demolition and earthworks – Refer to Tables 5.6, 5.7 and Appendix E						
Demolition	Liquid fuel combustion – demolition equipment	Fuel type **AND** kL of fuel, for each fuel type				
Vegetation removal	Liquid fuel combustion – vegetation removal equipment e.g. graders, front end loaders	Fuel type **AND** kL of fuel, for each fuel type				
	Lost carbon sink from the removal of vegetation	**AUS:** Biomass Category from map **AND** Area of vegetation removed in hectares by vegetation category **NZ:** Vegetation type **AND** Area of vegetation removed in hectares				
	Downstream emissions from the transport of vegetation offsite	Quantity of vegetation per truckload **AND** return transport distance, in km				
	Decomposition of vegetation in an offsite landfill	Type of vegetation removed **AND** t of vegetation disposed in an offsite landfill				
Earthmoving equipment	Liquid fuel combustion – earthmoving equipment	Fuel type **AND** kL of fuel, for each type				
Earthworks - Tunnels	Electricity consumption - on-site excavation equipment (e.g. tunnel boring machines and ventilation)	State/Region **AND** kWh of electricity consumed				

Activity	Emission Source	Emission Source Data Required	Fuel/ Material Type	Emission Source Data	Unit of Measure	Data source/location
Pavements – Refer to Table 5.8						
Road Pavements	Liquid fuel combustion – pavement construction equipment	Fuel type **AND** kL of fuel, for each fuel type **AND**				
	Upstream emissions from the production of road construction materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Asphalt type(s) **AND** t asphalt used **OR** bitumen type(s) **AND** t bitumen used, t aggregate used and asphalt processing energy used in making asphalt **AND** Additional Bitumen type(s) **AND** t bitumen used **AND** Additional Aggregate type(s) **AND** t aggregate used **AND** Lime type(s) **AND** t lime used **AND**				
	Upstream emissions from the transport of road construction materials	Quantity of material per truckload **AND** return transport distance, in km				
Sealing	Liquid fuel combustion – pavement sealing equipment	Fuel type **AND** kL of fuel, for each fuel type **AND**				
	Upstream emissions from the production of road sealing materials	Asphalt type(s) **AND** t asphalt used **OR** bitumen type(s) **AND** t bitumen used, t aggregate used and asphalt processing energy used in making asphalt **AND**				
	Upstream emissions from the transport of road sealing materials	Quantity of material per truckload **AND** return transport distance, in km				
Other pavements (e.g. median and traffic islands, footpaths etc.)	Liquid fuel combustion – other pavement construction equipment	Fuel type **AND** kL of fuel, for each fuel type **AND**				
	Upstream emissions from the production of other pavement construction materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Asphalt type(s) **AND** t asphalt used **OR** bitumen type(s) **AND** t bitumen used, t aggregate used and asphalt processing energy used in making asphalt **AND**				
	Upstream emissions from the transport of other pavement materials	Quantity of material per truckload **AND** return transport distance, in km				
Stationary Plant and equipment	Liquid fuel combustion – stationary engines (e.g. batching plants)	Fuel type **AND** kL of fuel, for each fuel type				

Activity	Emission Source	Emission Source Data Required	Fuel/ Material Type	Emission Source Data	Unit of Measure	Data source/location
Structures						
Bridges (including inter-changes and overpasses)	Liquid fuel combustion – bridge construction	Fuel type **AND** kL of fuel, for each fuel type **AND**				
	Upstream emissions from the production of bridge construction materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used and t water used in making concrete **AND** Additional Aggregate type(s) **AND** t aggregate used **AND** Additional steel type(s) **AND** t steel used				
	Upstream emissions from the transport of bridge construction materials	Quantity of material per truckload **AND** return transport distance, in km				
Reinforced Soil walls	Liquid fuel combustion – reinforced soil wall construction	Fuel type **AND** kL of fuel, for each fuel type **AND**				
	Upstream emissions from the production of reinforced soil wall construction materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Steel type(s) **AND** t steel used				
	Upstream emissions from the transport of reinforced soil wall materials	Quantity of material per truckload **AND** return transport distance, in km				
Retaining walls	Liquid fuel combustion – retaining wall construction	Fuel type **AND** kL of fuel, for each type **AND**				
	Upstream emissions from the production of retaining wall construction materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **OR** Timber type(s) AND t timber used **OR** Rock types AND t rock used **AND** Steel type(s) **AND** t steel used				
	Upstream emissions from the transport of retaining wall construction materials	Quantity of material per truckload **AND** return transport distance, in km				

Activity	Emission Source	Emission Source Data Required	Fuel/ Material Type	Emission Source Data	Unit of Measure	Data source/location
Tunnels	Liquid fuel combustion – tunnel construction	Fuel type **AND** kL of fuel, for each fuel type **AND**				
	Upstream emissions from the production of tunnel construction materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Steel type(s) **AND** t steel used **AND** Explosives type(s) **AND** t used				
	Upstream emissions from the generation and distribution of electricity	State/region **AND** kWh of electricity consumed				
	Upstream emissions from the transport of tunnel construction materials	Quantity of material per truckload **AND** return transport distance, in km				
Drainage						
Kerbing	Liquid fuel combustion – construction of kerbing	Fuel type **AND** kL of fuel, for each fuel type **AND**				
	Upstream emissions from the production of kerbing materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Additional Aggregate type(s) **AND** t aggregate used **AND** Steel type(s) **AND** t steel used				
	Upstream emissions from the transport of kerbing materials	Quantity of material per truckload **AND** return transport distance, in km				
Culverts (pipes or box culverts for water drainage)	Liquid fuel combustion – laying of culverts	Fuel type **AND** kL of fuel, for each fuel type **AND**				
	Upstream emissions from the production of culvert materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Additional Aggregate type(s) **AND** t aggregate used **AND** Steel type(s) **AND** t steel used Plastic type(s) **AND** t plastic used				
	Upstream emissions from the transport of culvert materials	Quantity of material per truckload **AND** return transport distance, in km				
Open, unlined drains	Liquid fuel combustion – open unlined drain formation	Fuel type **AND** kL of fuel, for each type				

Activity	Emission Source	Emission Source Data Required	Fuel/ Material Type	Emission Source Data	Unit of Measure	Data source/location
Road Furniture						
Road safety barriers	Liquid fuel combustion – road safety barrier installation	Fuel type **AND** kL of fuel, for each fuel type **AND**				
	Upstream emissions from the production of road safety barriers	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **AND** Additional Steel type(s) **AND** t steel used				
	Upstream emissions from the transport of road safety barrier materials	Quantity of material per truckload **AND** return transport distance, in km				
Noise Walls	Liquid fuel combustion – noise wall construction	Fuel type **AND** kL of fuel, for each type **AND**				
	Upstream emissions from the production of noise wall materials	Concrete type(s) **AND** t concrete used **OR** cement type(s) **AND** t cement used, Steel type(s) **AND** t steel used, t aggregate used, t sand used, t fly ash used and t water used in making concrete **OR** **t** Hebel used **AND** Additional steel type(s) **AND** t steel used				
	Upstream emissions from the transport of noise wall materials	Quantity of material per truckload **AND** return transport distance, in km				

Appendix B GHG emissions reporting templates

Reporting Template

Use this template to record the results of the GHG assessment.

Construction - Pavements	Scope 1	Scope 2	Scope 3	**Total**
Fuel combustion - pavement constuction plant & equipment				
Material usage - aggregate				
Material usage - concrete				
Material usage - cement				
Material usage - sand/gravel				
Material usage - steel				
Material usage - hot mix asphalt				
Material usage - bitumen				
Material usage - hot mix asphalt processing energy				
Material usage - lime				
Transport of materials to site				
Electricity consumption (tunnels only)				
Other				
Other				
Total				

Construction - Structures (e.g. bridges, interchanges etc)	Scope 1	Scope 2	Scope 3	**Total**
Fuel combustion - structures constuction plant & equipment				
Material usage - aggregate				
Material usage - concrete				
Material usage - cement				
Material usage - sand/gravel				
Material usage - steel				
Material usage - hot mix asphalt				
Material usage - bitumen				
Material usage - hot mix asphalt processing energy				
Material usage - lime				
Transport of materials to site				
Other				
Other				
Total				

Construction - Drainage	Scope 1	Scope 2	Scope 3	**Total**
Fuel combustion - drainage constuction plant & equipment				
Material usage - aggregate				
Material usage - concrete				
Material usage - cement				
Material usage - sand/gravel				
Material usage - steel				
Material usage - lime				
Transport of materials to site				
Other				
Other				
Total				

Construction - Road Furniture	Scope 1	Scope 2	Scope 3	**Total**
Fuel combustion - road furniture constuction plant & equipment				
Material usage - aggregate				
Material usage - concrete				
Material usage - cement				
Material usage - sand/gravel				
Material usage - steel				
Material usage - timber				
Material usage - lime				
Transport of materials to site				
Other				
Other				
Total				

GHGe Summary by activity- Operation	Scope 1	Scope 2	Scope 3	**Total**
Street Lighting				
Traffic Signals				
Intelligent Transport System (ITS)				
Total				

GHGe Summary by emission source - Operation	Scope 1	Scope 2	Scope 3	**Total**
Electricity consumption - street lighting				
Electricity consumption - traffic signals				
Electricity consumption - ITS				
Other				
Other				
Total				

GHGe Summary by activity- Maintenance	Scope 1	Scope 2	Scope 3	**Total**
Major Maintenance				
Other				
Total				

GHGe Summary by emission source - Maintenance	Scope 1	Scope 2	Scope 3	**Total**
Fuel combustion - plant & equipment				
Material usage - aggregate				
Material usage - concrete				
Material usage - cement				
Material usage - sand/gravel				
Material usage - steel				
Material usage - hot mix asphalt				
Material usage - bitumen				
Material usage - hot mix asphalt processing energy				
Other				
Other				
Other				
Other				
Total				

Appendix C Conversion factors

Conversion factors

Measurement Conversion factors	
1 Watt	= 1 Joule/Sec
3600 Watt-seconds	= 1 Watt-hour (3600 seconds in one hour)
1 Watt-hour	= 3600 Joules
1000 Watt-hours	= 1Kilowatt hour (kWh)
1 kWh	= 3.6 x 10^6 Joules = 3.6 MJ
1 kWh	= 3.6 x 10^{-3} GJ
1 GJ	= 278 kWh
1 PJ	= 278 x 10^6 kWh = 278 GWh
1 ha	= 10,000 m^2
1 m^2	= 0.0001

(A) For conversion from first unit to second unit:	(B) Multiply quantity in first unit by conversion factor:	(C) To calculate quantity in second unit:
kWh to J	kWh x 3.6 x 10^6	Joules
J to kWh	J x 1/3.6 x 10^{-6}	kWh
kWh to MJ	kWh x 3.6	MJ
MJ to kWh	MJ x 0.278	kWh
kWh to GJ	kWh x 3.6 x 10^{-3}	GJ
GJ to kWh	GJ x 278	kWh
kWh to PJ	kWh x 3.6 x 10^{-9}	PJ
PJ to kWh	PJ x 278 x 10^6	kWh

Density Conversion factors	Density (kg/m^3)
Aggregate - Quarried	2,240
Aggregate - Recycled	1,920
Aluminium - General	2,700
Asphalt	2,300
Bitumen	1,000
Bricks	1,920
Cement - Portland	1,860
Cement General – 25% fly ash	1,860
Cement General – 50% fly ash	1,860
Cement General – 25% blast furnace slag	1,860
Cement General – 50% blast furnace slag	1,860
Clay tiles	1,900
Concrete - reinforced	2,300

Density Conversion factors	Density (kg/m^3)
Copper	8,600
Diesel	836
Fuel Oil	848
Glass	2,500
Kerosene	837
LPG	520
Petrol (gasoline)	669
Plastic - General	960
Plastic - Polyethylene	900
Plastic - PVC	1,380
Sand	2,240
Soil - common	1,460
Steel – general, section, sheet , wire, stainless	7,800
Steel – bar and rod	7,900
Timber - Softwood (e.g. pine)	510
Timber- Hardwood	800
Timber - Plywood	700

Source: UK, Bath Inventory, version 2.0 (2011)

Appendix D Emission factors

Emission factors

Introduction

Emission factors have been provided for each emission source relevant to road projects. The boundary column summarises the specific activities that are accounted for in the emission factor. The boundary classifications are:

- Direct (Scope 1): Emission factor boundary is limited to the project site
  - (e.g. GHG emissions from combustion of a fuel onsite or lost carbon sink from the removal of vegetation);
- Indirect (Scopes 2 & 3): Emission factor boundary includes all offsite activities required to extract raw materials, transport raw materials, produce the fuel/material and transport the fuel/material to site to be used by the road project
  - (i.e. GHG emissions from the extraction, production and transport of a fuel combusted onsite);
- Mine to End of Production: Emission factor boundary includes all offsite activities required to extract raw materials, transport raw materials and produce the fuel/material
- Disposal Site: Emission factor boundary includes decomposition of waste in a materials final offsite disposal location.

NOTE: ‘Cradle to Production Gate’ and ‘Disposal site to Grave’ emissions do not include the transport of product/waste materials.

The **main difference** between the **‘Indirect’ and ‘Cradle to Production Gate’ emission factor boundaries** is that the **indirect boundary includes** the **transport of the final product** whereas this is **excluded** from **Cradle to Production Gate emission factor boundary**.

In order to assess the total emissions of the road project, **ALL SCOPES SHOULD BE INCLUDED IN THE ASSESSMENT WHERE AN EMISSION FACTOR HAS MULTIPLE SCOPES**.

If reporting requirements do not require Scope 1, 2 and 3 emissions to be reported separately the emission factors for each emission source may be added together. For example, the total emission factor for diesel use in Australia would be 2.68 (Scope 1) + 0.205 (Scope 3) = 2.885 t CO_2-e/kL.

Fuels

The Australian and New Zealand governments have published emission factors for fuel combustion for a number of years. These emission factors have been

Table D.1 Liquid fuel usage emission factors

Fuel	Boundary	Unit	Scope 1 EF (Direct)		Scope 3 EF (Indirect)		Full Fuel Cycle Emission Factor (EF)	
			Australia	New Zealand	Australia	New Zealand	Australia	New Zealand
Biodiesel*	Direct only	t CO_2-e/kL	0.009	0.009	N/A	N/A	0.009	0.009
Biodiesel (B10)	Direct and indirect - Direct only for Biodiesel component	t CO_2-e/kL	2.42	2.43	0.184	0.184	2.599	2.642
Biodiesel (B20)	Direct and indirect - Direct only for Biodiesel component	t CO_2-e/kL	2.15	2.16	0.164	0.164	2.312	2.350
Diesel	Direct and indirect	t CO_2-e/kL	2.68	2.70	0.205	0.205	2.887	2.935
Fuel Oil	Direct and indirect	t CO_2-e/kL	2.90	3.01	0.210	0.210	3.114	3.215
Kerosene	Direct and indirect	t CO_2-e/kL	2.57	2.57	0.199	0.199	2.764	2.775
LPG	Direct and indirect	t CO_2-e/kL	1.56	1.58	0.129	0.129	1.691	1.701
Unleaded Petrol	Direct and indirect	t CO_2-e/kL	2.38	2.34	0.181	0.181	2.562	2.521

Source Data – Australia: AUS DCCEE National Greenhouse Accounts Factors, July 2012

Source Data – New Zealand: NZ Guidance for voluntary, corporate greenhouse gas reporting: Data and Methods for the 2008 Calendar Year (Scope 1) and Australian DCCEE National Greenhouse Accounts Factors workbook, July 2010 (Scope 3)

** Scope 3 factors for biofuels, such as biodiesel and ethanol, are highly dependent on individual plant and project characteristics, and therefore have not been provided. It should be noted that scope 3 emissions from biofuels can be significant, especially when produced from tallow and canola.*

*

Table D.2 Gaseous fuel usage emission factors

Fuel	Boundary	Unit	Emission Factor (EF)								
			ACT	NSW	VIC	SA	WA	NT	QLD	TAS	New Zealand
Metro											
Natural gas – Scope 1	Direct	t CO_2-e/GJ	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	53.4 $\times10^{-3}$
Natural gas – Scope 3	Indirect	t CO_2-e/GJ	14.2 $\times10^{-3}$	14.2 $\times10^{-3}$	4 $\times10^{-3}$	10.4 $\times10^{-3}$	4 $\times10^{-3}$	N/A	8.6 $\times10^{-3}$	N/A	5.342 $\times10^{-3}$
Natural Gas - metro – Full Fuel Cycle	Direct and Indirect	t CO_2-e/GJ	65.5 $\times10^{-3}$	65.5 $\times10^{-3}$	55.3 $\times10^{-3}$	61.7 $\times10^{-3}$	55.3 $\times10^{-3}$	N/A	59.9 $\times10^{-3}$	N/A	58.74 $\times10^{-3}$
Non-Metro											
Natural gas – Scope 1	Direct	t CO_2-e/GJ	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	51.3 $\times10^{-3}$	53.4 $\times10^{-3}$
Natural gas– Scope 3	Indirect	t CO_2-e/GJ	15 $\times10^{-3}$	15 $\times10^{-3}$	4 $\times10^{-3}$	10.2 $\times10^{-3}$	3.9 $\times10^{-3}$	N/A	7.8 $\times10^{-3}$	N/A	5.342 $\times10^{-3}$
Natural Gas – non-metro – Full Fuel Cycle	Direct and Indirect	t CO_2-e/GJ	66.3 $\times10^{-3}$	66.3 $\times10^{-3}$	55.3 $\times10^{-3}$	61.5 $\times10^{-3}$	55.2 $\times10^{-3}$	N/A	59.1 $\times10^{-3}$	N/A	58.74 $\times10^{-3}$

Source Data – Australia: AUS DCCEE National Greenhouse Accounts Factors, July 2012

Source Data – New Zealand: NZ Guidance for voluntary, corporate greenhouse gas reporting: Data and Methods for the 2008 Calendar Year

Electricity

Emission factors for electricity consumption are published by both the Australian and New Zealand governments. These emission factors have been used where available.

Table D.3 Electricity Scope 2 and 3 emission factors

Electricity	Boundary	Unit	Emission Factor (EF)								
			ACT	NSW	VIC	SA	WA	NT	QLD	TAS	New Zealand
Electricity – Scope 2	Indirect	t CO_2-e/kWh	0.88 $\times10^{-3}$	0.88 $\times10^{-3}$	1.19 $\times10^{-3}$	0.65 $\times10^{-3}$	0.82 $\times10^{-3}$	0.71 $\times10^{-3}$	0.86 $\times10^{-3}$	0.26 $\times10^{-3}$	0.137 $\times10^{-3}$
Electricity – Scope 3	Indirect	t CO_2-e/kWh	0.18 $\times10^{-3}$	0.18 $\times10^{-3}$	0.14 $\times10^{-3}$	0.14 $\times10^{-3}$	0.10 $\times10^{-3}$	0.12 $\times10^{-3}$	0.14 $\times10^{-3}$	0.02 $\times10^{-3}$	0.01 $\times10^{-3}$
Electricity – Full fuel cycle	Indirect	t CO_2-e/kWh	1.06 $\times10^{-3}$	1.06 $\times10^{-3}$	1.34 $\times10^{-3}$	0.79 $\times10^{-3}$	0.92 $\times10^{-3}$	0.98 $\times10^{-3}$	0.98 $\times10^{-3}$	0.28 $\times10^{-3}$	0.15 $\times10^{-3}$

Source Data – Australia: AUS DCCEE National Greenhouse Accounts Factors, July 2012

Source Data – New Zealand: NZ Guidance for voluntary, corporate greenhouse gas reporting: Data and Methods for the 2008 Calendar Year

Construction Materials

Table D.4 Construction Material emission factors

Material	Boundary	Unit	Scope 3 Emission Factor (EF)	
			Australia	New Zealand
Aggregate[†]				
Aggregate (e.g. crushed rock)	Mine to End of Production	**t CO_2-e/t**	0.005	0.002
Sand	Mine to End of Production	**t CO_2-e/t**	0.003	0.007
Crushed Brick/Glass/Concrete	Mine to End of Production	**t CO_2-e/t**	0.004	0.002
Recycled Asphalt Pavement (RAP)	Mine to End of Production	**t CO_2-e/t**	0.009	0.009
Aluminium				
Primary Aluminium	Mine to End of Production	**t CO_2-e/t**	20.68	8.0
100% Recycled Aluminium	Mine to End of Production	**t CO_2-e/t**	1.66	0.62
Asphalt & Bitumen				
Hot Mix Asphalt (400 MJ/t)	Mine to End of Production	**t CO_2-e/t**	0.058	0.015
Hot Mix Asphalt (400 MJ/t) 10% RAP	Mine to End of Production	**t CO_2-e/t**	0.057	N/A
Hot Mix Asphalt (400 MJ/t) 20% RAP	Mine to End of Production	**t CO_2-e/t**	0.056	N/A
Hot Mix Asphalt (400 MJ/t) 30% RAP	Mine to End of Production	**t CO_2-e/t**	0.055	N/A
Hot Mix Asphalt (400 MJ/t) 40% RAP	Mine to End of Production	**t CO_2-e/t**	0.054	N/A
Hot Mix Asphalt (400 MJ/t) 50% RAP	Mine to End of Production	**t CO_2-e/t**	0.053	N/A
Warm Mix Asphalt (372 MJ/t)	Mine to End of Production	**t CO_2-e/t**	0.054	0.01395
Warm Mix Asphalt (372 MJ/t) 10% RAP	Mine to End of Production	**t CO_2-e/t**	0.053	N/A
Warm Mix Asphalt (372 MJ/t) 20% RAP	Mine to End of Production	**t CO_2-e/t**	0.052	N/A
Warm Mix Asphalt (372 MJ/t) 30% RAP	Mine to End of Production	**t CO_2-e/t**	0.051	N/A

[†] *Emissions can be dominated by transport emissions - location and sourcing are key factors*

Material	Boundary	Unit	Scope 3 Emission Factor (EF)	
			Australia	New Zealand
Warm Mix Asphalt (372 MJ/t) 40% RAP	Mine to End of Production	**t CO_2-e/t**	0.050	N/A
Warm Mix Asphalt (372 MJ/t) 50% RAP	Mine to End of Production	**t CO_2-e/t**	0.049	N/A
Bitumen	Mine to End of Production	**t CO_2-e/t**	0.630	0.171
Bricks/Clay				
Bricks[‡]	Mine to End of Production	**t CO_2-e/t**	0.39	0.14
Clay	Mine to End of Production	**t CO_2-e/t**	0.003	0.005
Cement and Concrete				
Concrete 40MPa (1:1.5:3)	Mine to End of Production	**t CO_2-e/t**	0.155	0.20
Concrete 40MPa 10% Fly Ash	Mine to End of Production	t CO_2-e/t	0.143	N/A
Concrete 40MPa 20% Fly Ash	Mine to End of Production	t CO_2-e/t	0.131	N/A
Concrete 40MPa 30% Fly Ash	Mine to End of Production	t CO_2-e/t	0.119	N/A
Concrete 30MPa (1:2:4)	Mine to End of Production	**t CO_2-e/t**	0.127	0.16
Concrete 30MPa 10% Fly Ash	Mine to End of Production	**t CO_2-e/t**	0.118	N/A
Concrete 30MPa 20% Fly Ash	Mine to End of Production	**t CO_2-e/t**	0.108	N/A
Concrete 30MPa 30% Fly Ash	Mine to End of Production	**t CO_2-e/t**	0.098	N/A
Concrete 20 MPa (1:3:6)	Mine to End of Production	**t CO_2-e/t**	0.096	0.120
Concrete 20MPa 10% Fly Ash	Mine to End of Production	**t CO_2-e/t**	0.089	N/A
Concrete 20MPa 20% Fly Ash	Mine to End of Production	**t CO_2-e/t**	0.082	N/A
Concrete 20MPa 30% Fly Ash	Mine to End of Production	**t CO_2-e/t**	0.075	N/A
Portland Cement	Mine to End of Production	**t CO_2-e/t**	0.82	0.99
Fly Ash	Mine to End of Production	**t CO_2-e/t**	0.161	0.14
Lime (calcined)	Mine to End of Production	**t CO_2-e/t**	1.09	0.73

[‡] *Emission factor is for common bricks and not engineering bricks, which are fired at higher temperatures.*

Material	Boundary	Unit	Scope 3 Emission Factor (EF)	
			Australia	New Zealand
Lime (re-carbonated)	Mine to End of Production	**t CO_2-e/t**	0.42	0.056
Copper				
Copper	Mine to End of Production	**t CO_2-e/t**	5.15	7.74
Recycled Copper	Mine to End of Production	**t CO_2-e/t**	0.112	0.11
Explosives				
ANFO	Mine to End of Production	**t CO_2-e/t**	0.17	0.17
Heavy ANFO	Mine to End of Production	**t CO_2-e/t**	0.18	0.18
Emulsion	Mine to End of Production	**t CO_2-e/t**	0.17	0.17
Plastic (Polymer)				
Polyvinyl Chloride (PVC)	Mine to End of Production	**t CO_2-e/t**	2.41	4.35
Low Density Polyethylene (LDPE)	Mine to End of Production	**t CO_2-e/t**	1.92	3.54
High Density Polyethylene (HDPE)	Mine to End of Production	**t CO_2-e/t**	4.70	3.45
Polyethylene Terephthalate (PET)	Mine to End of Production	**t CO_2-e/t**	2.50	2.33
Rubber				
Natural Rubber	Mine to End of Production	**t CO_2-e/t**	1.95	0.58
Synthetic Rubber	Mine to End of Production	**t CO_2-e/t**	2.60	2.28
Steel				
Virgin Steel	Mine to End of Production	**t CO_2-e/t**	2.19	1.24
Recycled Steel	Mine to End of Production	**t CO_2-e/t**	1.06	0.35
Structural Steel	Mine to End of Production	**t CO_2-e/t**	1.05	1.24
Steel Sheet	Mine to End of Production	**t CO_2-e/t**	2.19	1.71
Steel Furnace Slag	Mine to End of Production	**t CO_2-e/t**	0.13	0.031
Timber				
Sawn Hardwood	Mine to End of Production	**t CO_2-e/t**	0.29	0.14

Material	Boundary	Unit	Scope 3 Emission Factor (EF)	
			Australia	New Zealand
Structural Pine	Mine to End of Production	**t CO_2-e/t**	-0.81	-1.66
Plywood (Structural)	Mine to End of Production	**t CO_2-e/t**	1.15	1.15
Plywood (Exterior, e.g. noise wall)	Mine to End of Production	**t CO_2-e/t**	1.08	1.08

Source Data – Australia (excluding recycled copper and explosives): SimaPro and the Australian LCA Dataset, 2010

Data Source – Australia Aggregate. RMCG. Sustainable Aggregates – CO_2 Emission Factor Study

Source Data – Australia Recycled copper: “Embodied Energy and CO_2 Coefficients for New Zealand Building Materials”, Alcorn, 2003

Source Data – Australia Explosives: AUS DCCEE National Greenhouse Accounts Factors workbook, July 2010

Source Data – New Zealand (excluding Rubber, Timber, Steel sheet and Steel furnace slag): “Embodied Energy and CO_2 Coefficients for New Zealand Building Materials”, Alcorn, 2003

Source Data – New Zealand Rubber, Timber, Steel sheet and Steel furnace slag: Ecoinvent NZ, v 2.2

Source Data – Warm Mix Asphalt: Rippol, JO & Farre, CM 2008, 'Evaluation of greenhouse gas emissions from the production of hot asphalt mixtures', Eurasphalt and Eurobitume Congress, 4th 2008, Copenhagen, Denmark, Eurasphalt & Eurobitume Congress Secretatiat, Brussels, Belgium

Waste to landfill

The amount of GHG emissions released from the decomposition of waste in landfill is dependent on the amount of organic material within the waste and how readily this organic material breaks down.

Emission factors for waste disposed of to landfill are published by both the Australian and New Zealand governments. These emission factors have been used where available.

The Australian 'Commercial and Industrial' waste classification has been taken to be equivalent to the New Zealand 'Office waste to landfill' classification.

Table D.5 Waste to landfill emission factors

Waste	Boundary	Unit	Emission Factor (EF)	
			Australian	New Zealand
Office Waste to Landfill (Commercial and Industrial [C&I] Waste)	Disposal site	**t CO_2-e/t**	1.10	1.55
Paper and Cardboard	Disposal site	**t CO_2-e/t**	2.50	2.52
Construction and Demolition (C&D) Waste	Disposal site	**t CO_2-e/t**	0.20	0.20
Wood Waste	Disposal site	**t CO_2-e/t**	1.20	1.89
Grassland	Disposal site	**t CO_2-e/t**	1.20	0.95
Shrubs	Disposal site	**t CO_2-e/t**	1.20	0.95

Source Data – Australia: AUS DCCEE National Greenhouse Accounts Factors, July 2012. Grassland and shrubs assumed to be equivalent to garden and green waste.
Source Data – New Zealand (excluding C&D Waste): NZ Guidance for voluntary, corporate greenhouse gas reporting: Data and Methods for the 2008 Calendar Year
Source Data – New Zealand C&D Waste: AUS DCCEE National Greenhouse Accounts Factors, July 2012

Transport

Table D.6 Transport emission factors

Vehicle	Boundary	Unit	Emission Factor (EF)	
			Australia	New Zealand
Car	Indirect	**t CO_2-e/km**	0.419x10^{-3}	0.238 x10^{-3}
Light commercial vehicles	Indirect	**t CO_2-e/km**	0.688 x10^{-3}	0.688 x10^{-3}
Medium goods vehicles	Indirect	**t CO_2-e/km**	1.16 x10^{-3}	1.16 x10^{-3}
Heavy goods vehicles	Indirect	**t CO_2-e/km**	2.14 x10^{-3}	2.14 x10^{-3}
Air Travel – Domestic	Indirect	**t CO_2-e/passenger km**	0.324 x10^{-3}	0.165 x10^{-3}
Air Travel – Short Haul International	Indirect	**t CO_2-e/passenger km**	0.180 x10^{-3}	0.111 x10^{-3}
Air Travel – Long Haul International	Indirect	**t CO_2-e/passenger km**	0.180 x10^{-3}	0.097 x10^{-3}

Source: Australia – SimaPro, 2010

Source: New Zealand – NZ Guidance for voluntary, corporate greenhouse gas reporting: Data and Methods for the 2008 Calendar Year

Appendix E Vegetation Emissions Methodology

Roads and Maritime Services and VicRoads

Report for Vegetation emissions methodology for road construction workbook

Workbook methodology

August 2012

This Vegetation emissions methodology for road construction workbook: workbook methodology(“Report”):

1. *has been prepared by GHD Pty Ltd for Roads and Maritime Services (RMS)and VicRoads on behalf of Transport Authorities Greenhouse Group (TAGG);*
2. *may only be used and relied on by RMS and VicRoads;*
3. *must not be copied to, used by, or relied on by any person other than RMS and VicRoads without the prior written consent of GHD;*
4. *may only be used for the purpose of updating the TAGG Greenhouse Gas Assessment Workbook for Road Projects (and must not be used for any other purpose).*

GHD and its servants, employees and officers otherwise expressly disclaim responsibility to any person other than RMS arising from or in connection with this Report.

To the maximum extent permitted by law, all implied warranties and conditions in relation to the services provided by GHD and the Report are excluded unless they are expressly stated to apply in this Report.

The services undertaken by GHD in connection with preparing this Report:

- *were limited to those specifically detailed in section 1 of this Report;*
- *did not include [list all scope limitations or the relevant section(s) of the Report in which scope the limitations are expressed – for example, GHD undertaking any site visits or testing, GHD undertaking testing at some parts of the site; GHD undertaking particular types of testing/analysis that could have been undertaken].*

The opinions, conclusions and any recommendations in this Report are based on assumptions made by GHD when undertaking services and preparing the Report (“Assumptions”), including (but not limited to) the assumptions outlined in GHD report Vegetation emissions methodology for road construction workbook: Supporting documentation, GHD Document number 21/21551/180969 Rev A.

GHD expressly disclaims responsibility for any error in, or omission from, this Report arising from or in connection with any of the Assumptions being incorrect.

Subject to the paragraphs in this section of the Report, the opinions, conclusions and any recommendations in this Report are based on conditions encountered and information reviewed at the time of preparation and may be relied on until 12 months, after which time, GHD expressly disclaims responsibility for any error in, or omission from, this Report arising from or in connection with those opinions, conclusions and any recommendations.

Contents

Table Index

Appendices

1. Introduction

Road traffic and transport authorities in Australian and New Zealand have formed a Transport Authorities Greenhouse Group (TAGG). A key action of the TAGG is to develop a common methodology for the estimation, reporting and minimisation of greenhouse gas emissions associated with road construction, operation and maintenance. In 2011, the TAGG released a workbook outlining a methodology for estimating greenhouse gas emissions associated with road design to road operation and maintenance.

The workbook contains a section (Section 5.3.3.1) describing the methodology for estimating the loss of carbon dioxide equivalent sequestration potential from the clearing of vegetation during road construction. The vegetation clearance methodology for Australia is currently determined by obtaining the mean average annual rainfall for the road project's location and multiplying the rainfall by a default factor to estimate the emissions associated with vegetation clearing. Following its application, this methodology was identified as limited in its ability to be applied across Australia. Consequently, it was unable to provide reasonable estimates of greenhouse gas emissions associated with vegetation removal.

GHD was engaged by the Roads and Maritime Services (RMS) and VicRoads to update the methodology for estimating the loss of carbon sequestration potential from vegetation removal. The revised methodology employs vegetation data used by the Commonwealth Department of Climate Change and Energy Efficiency (DCCEE) to estimate greenhouse gas emissions for Australia's international reporting requirements under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.

A key project objective was to provide a user friendly methodology that does not require a user to apply complex modelling techniques to model vegetation emissions and still provides a reasonable estimate of the loss of greenhouse gas sequestration potential associated with vegetation removal.

The updated vegetation clearance section for Australia is outlined in Section 2 of this report. Section 2 may be copied directly into the existing TAGG workbook. Supporting documentation for the updated methodology is provided in GHD report *Vegetation emissions methodology for road construction workbook: Supporting documentation*, GHD Document number 21/21551/180969.

2. Vegetation clearing methodology

This methodology for estimating the greenhouse gas impacts associated with clearance takes into account the carbon that exists in the vegetation at the time of clearing and carbon that could have been sequestered in the future if the vegetation was not cleared. The methodology is considered a conservative estimation approach and **assumed** that:

- All carbon pools (i.e. woody, non-woody, debris and soil) are removed.
- All carbon removed is converted to carbon dioxide and released to the atmosphere.
- Sequestration from revegetation of the project site is not included.

It is acknowledged that this is a conservative approach to estimating greenhouse gas emissions from vegetation removal.

Steps for Estimating Greenhouse Gas Emissions Associated with Vegetation Clearance in Australia.

Step 1: Look up the Project Location and Determine the 'Maxbio' class

Find the approximate location of the proposed project on the maps located in Appendix A. Each map is colour coded showing the maximum potential biomass (or maxbio) class for all areas of Australia. The maxbio class is derived from the Australian Greenhouse Office and estimates the maximum tonnes dry vegetation matter per hectare for a specific location. If it is unclear which maxbio class the project is located in, select the higher class (higher maxbio range).

Step 2: Determine Vegetation Types and Hectares to be Cleared

Using Table 1 identify the vegetation class (e.g. open forest, open woodlands) and the area in hectares for each vegetation type to be cleared. To assist in identifying the vegetation types, descriptions including photographs and distribution maps are provided by the Australian Natural Resources Atlas located at (http://www.anra.gov.au/topics/vegetation/pubs/native_vegetation/vegfsheet.html). It is acknowledged that there may be multiple vegetation groups impacted by a road infrastructure project.

Table 1 Vegetation Classes

Vegetation Class	Name	Major Vegetation Groups (Including Hyperlinks)
A	Rainforest and vine thicket	Rainforest and Vine Thickets
B	Eucalypt Tall Open Forest	Eucalypt Tall Open Forest
C	Open Forest	Eucalypt Open Forest
		Melaleuca Forest and Woodland
		Eucalypt Low Open Forest
D	Open Woodlands	Acacia Forest and Woodland
		Eucalypt Woodland

Vegetation Class	Name	Major Vegetation Groups (Including Hyperlinks)
		Eucalypt Open Woodland
		Casuarina Forest and Woodland
		Tropical Eucalypt Woodland/Grassland
		Other Forests and Woodland
E	Callitris Forest and Woodland	Callitris Forest and Woodland
F	Mallee and Acacia Woodland and Shrubland	Mallee Woodland and Shrubland
		Low Closed Forest and Closed Shrubland
		Acacia Open Woodland
G	Open Shrubland	Acacia Shrubland
		Other Shrubland
		Unclassified Native Vegetation
H	Heathlands	Heathlands
		Chenopod Shrub, Samphire Shrub and Forbland
I	Grassland	Tussock Grassland
		Hummock Grassland
		Other Grassland, Herbland, Sedgeland and Rushland

Step 3: Look Up the Vegetation Clearance Emission Factors

Use Table 2 to look up the carbon dioxide equivalent emission factor for each vegetation class within the maxbio class (Step 1). If the emission factors selected is highlighted blue, then review the vegetation class for the project as it is rare that vegetation class to exist in that specific location.

Table 2 Emission Factors (t CO_2-e/ha)

	Potential maximum biomass class						
Vegetation Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**
A			227	384	532	594	768
B			237	401	554	618	
C	77	209	307	521	718		
D	77	209	307				
E	80	217	316				
F	106	287					
G	113						
H	115	309					
I	110	110	110	110	110	110	110

Step 4: **Multiply the area of vegetation with the corresponding emission factor**

Multiply the area of vegetation with the corresponding emission factor (derived from Table 2), and sum for all vegetation classes. Two worked examples are provided below.

Example 1: In this first example, a duplication of an existing road is proposed from Forbes to Parkes, in NSW.

When looking at **Error! Reference source not found.**, within Appendix A, this location sits within Maximum Potential Biomass Class 2 (purple colour).

From a flora report it is known that there will need to be 10 hectares of vegetation class C removed, 5 hectares of vegetation class E removed and 7 hectares of vegetation class I removed.

This is calculated as follows:

10 Ha x 209 TCO_2-e/ Ha (Veg class C) = 2090 T CO_2-e

5 Ha x 217 TCO_2-e/ Ha (Veg class E) = 1085 T CO_2-e

7 Ha x 110 TCO_2-e/ Ha (Veg class I) = 770 T CO_2-e

This totals a carbon sequestration loss of 3945 T CO_2-e.

Example 2: In this second example, a duplication of an existing road is proposed from Scottsdale to Launceston, in Tasmania.

When looking at **Error! Reference source not found.**, within Appendix A, this location sits within Maximum Potential Biomass Classes 2 (purple colour), 4 (darker green) and class 5 (lighter green). For this estimation process, it would all be assumed to be in class 5.

From a flora report it is known that there will need to be 7 hectares of vegetation class B removed, 10 hectares of vegetation class C removed and 25 hectares of vegetation class I removed.

The following represents the calculation.

7 Ha x 554 TCO_2-e/ Ha (Veg class B) = 3878 T CO_2-e

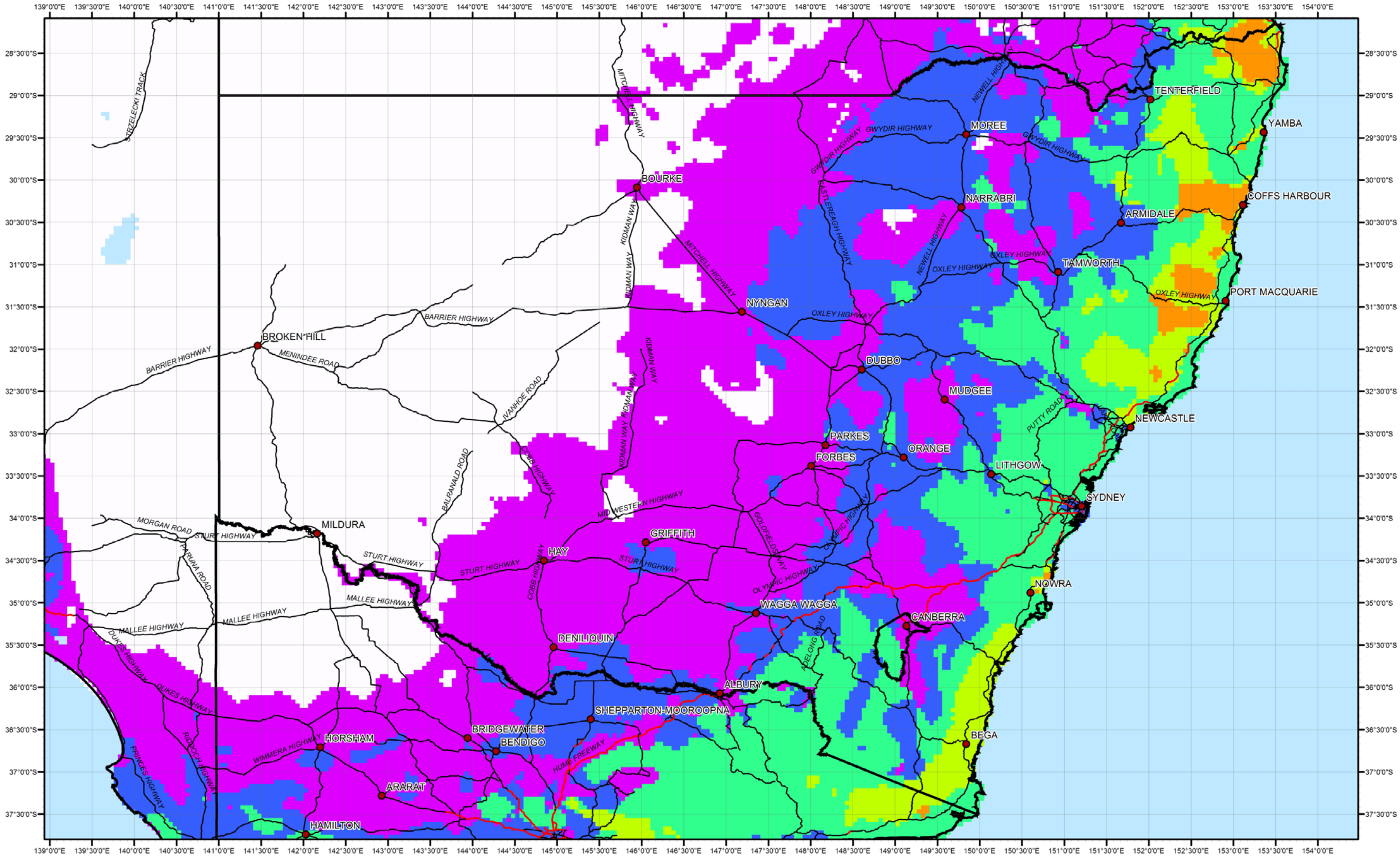
10 Ha x 718 TCO_2-e/ Ha (Veg class C) = 7180 T CO_2-e

25 Ha x 110 TCO_2-e/ Ha (Veg class I) = 2750 T CO_2-e

This totals a carbon sequestration loss of 13,808 T CO_2-e.

Appendix A

Maximum Potential Biomass Classes



1:4,500,000(at A3)

0 50 100 150 200

Kilometers

Horizontal Datum: Geocentric Datum of Australia (GDA) 1994

N

Legend

- Populated Places
- Dual Carriageway
- Principal Road

Maximum Potential Biomass Class
(tonnes dry matter per hectare)

- Class 1: 0 - 50
- Class 2: 50 - 100
- Class 3: 100 - 150
- Class 4: 150 - 250
- Class 5: 250 - 350
- Class 6: 350 - 450
- Class 7: >450

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Transport Authorities Greenhouse Group
Greenhouse Gas Assessment Workbook for Road Projects

Job Number	21-21553
Revision	A
Date	28 Aug 2012

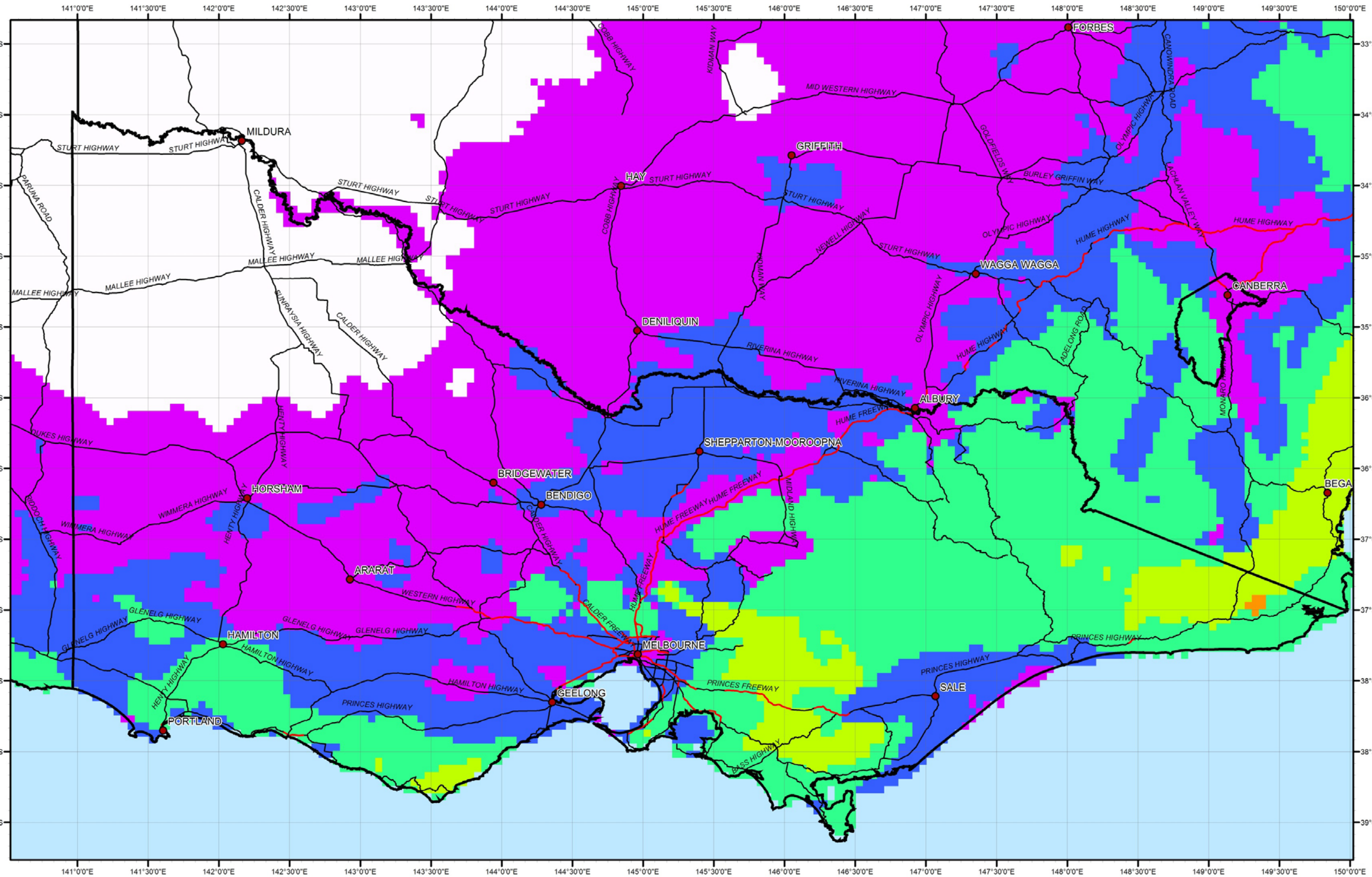
Maximum Potential Biomass Classes - NSW

Figure 1

G:\21\21553\GIS\Maps\MXD\2121553_Z014_Final_Map_NSW_RevA.mxd

Data Source: Geoscience Australia: 250k Data - Jan 2011; Department of Climate Change and Energy Efficiency: Maximum Potential Biomass, 2004. Created by: sjduce

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au



1:2,750,000(at A3)

0 12.5 25 50 75 100
Kilometers

Horizontal Datum: Geocentric Datum of Australia (GDA) 1994

N

Legend

- Populated Places
- Dual Carriageway
- Principal Road

Maximum Potential Biomass Class
(tonnes dry matter/ha)

- Class 1: 0 - 50
- Class 2: 50 - 100
- Class 3: 100 - 150
- Class 4: 150 -250
- Class 5: 250 - 350
- Class 6: 350 - 450
- Class 7: >450

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Greenhouse Gas Assessment Workbook for Road Projects

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Date	28 Aug 2012

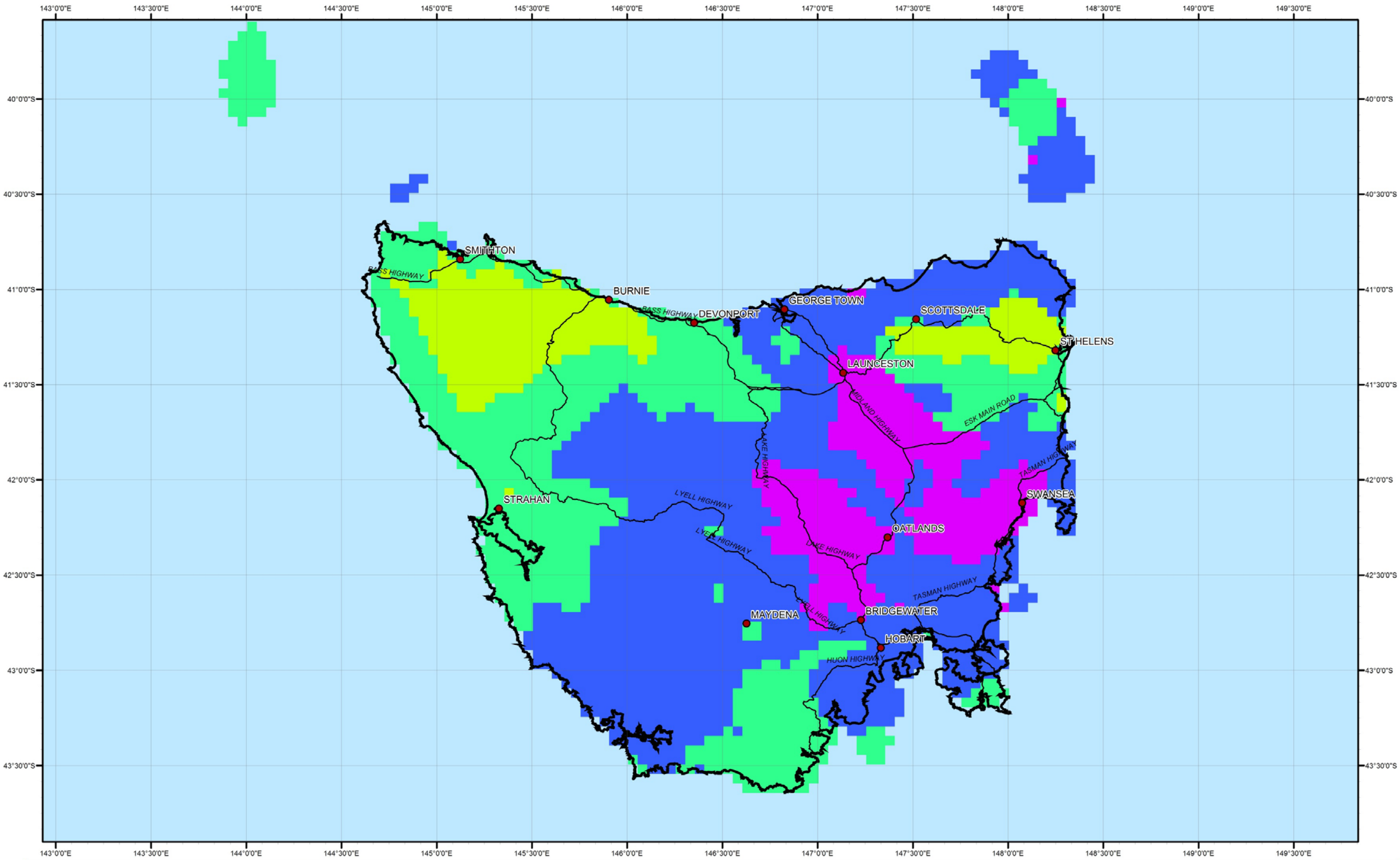
Maximum Potential Biomass Classes - Victoria and ACT

Figure 2

G:\21\21553\GIS\Maps\MXD\2121553_Z015_Final_Map_Vic_RevA.mxd

Data Source: Geoscience Australia: 250k Data - Jan 2011; Department of Climate Change and Energy Efficiency: Maximum Potential Biomass, 2004. Created by: sjduce

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au



1:2,000,000 (at A3)

0 12.5 25 50 75 100

Kilometers

Horizontal Datum: Geocentric Datum of Australia (GDA) 1994

N

Legend

- Populated Place
- Dual Carriageway
- Principal Road

Maximum Potential Biomass Class
(tonnes dry matter/ha)

- Class 1: 0 - 50
- Class 2: 50 - 100
- Class 3: 100 - 150
- Class 4: 150 -250
- Class 5: 250 - 350
- Class 6: 350 - 450
- Class 7: >450

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Maximum Potential Biomass Classes - Tasmania

Figure 3

G:\21\21553\GIS\Maps\MXD\2121553_Z016_Final_Map_Tas_RevA.mxd

Data Source: Geoscience Australia: 250k Data - Jan 2011; Department of Climate Change and Energy Efficiency: Maximum Potential Biomass, 2004. Created by: sjduce

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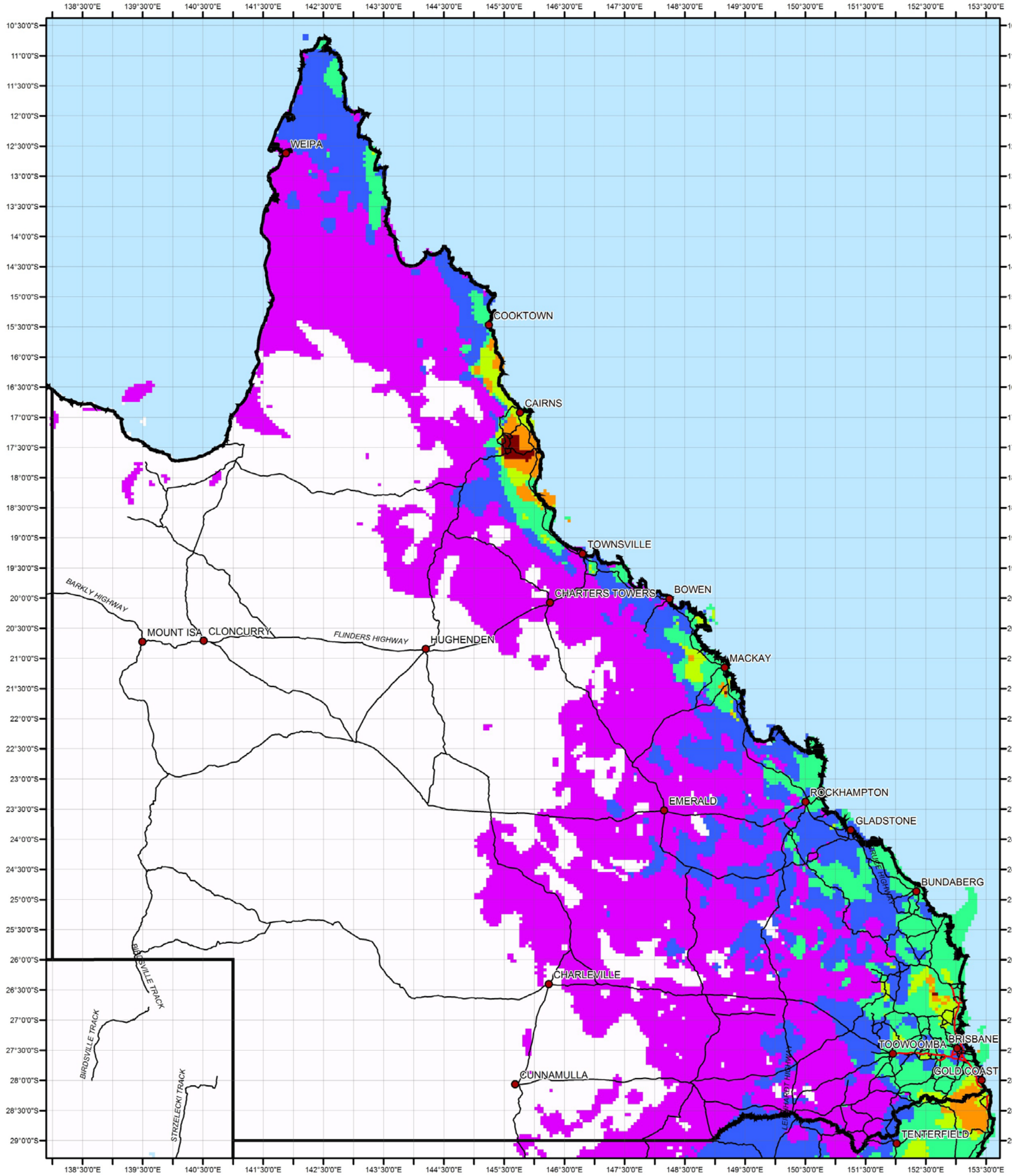

LEGEND

- Populated Places
- Dual Carriageway
- Principal Road

Maximum Potential Biomass Class (tonnes dry matter/ha)

- Class 1: 0 - 50
- Class 2: 50 - 100
- Class 3: 100 - 150
- Class 4: 150 -250
- Class 5: 250 - 350
- Class 6: 350 - 450
- Class 7: >450

1:6,500,000 (at A3)

0 50 100 200 300 Kilometers

Horizontal Datum: Geocentric Datum of Australia (GDA)

N

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Maximum Potential Biomass Classes - Queensland

Figure 4

G:\21\21553\GIS\Maps\MXD\2121553_Z017_Final_Map_QLD_RevA.mxd

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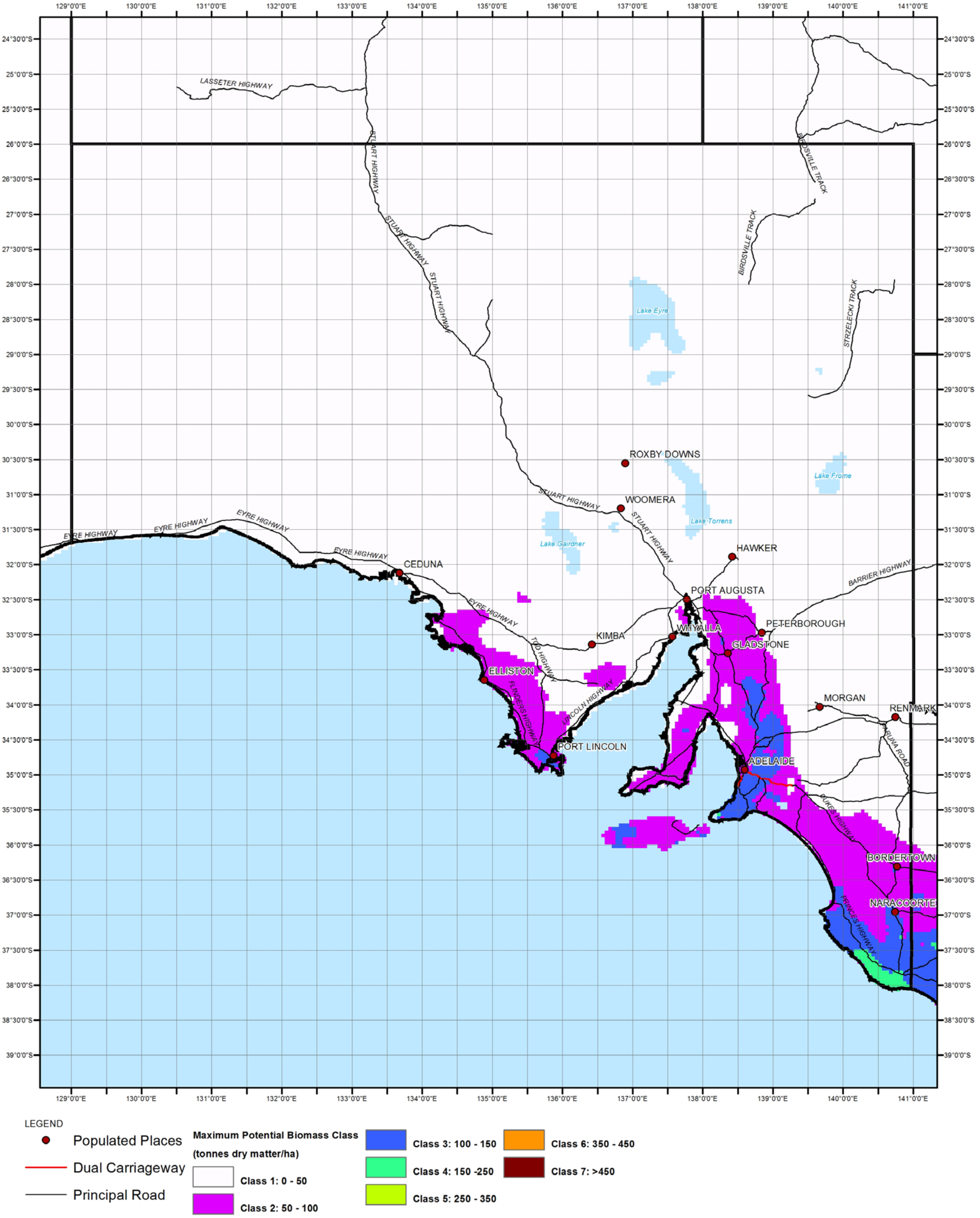
Data Source: Geoscience Australia: 250k Data - Jan 2011; Department of Climate Change and Energy Efficiency: Maximum Potential Biomass, 2004. Created by: sjduce



1:5,250,000 (at A3)

0 25 50 100 150 200 Kilometers

Horizontal Datum: Geocentric Datum of Australia (GDA)

N

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Maximum Potential
Biomass Classes - South Australia

Figure 5

G:\21\21553\GIS\Maps\MXD\2121553_Z018_Final_Map_SouthAust_RevA.mxd

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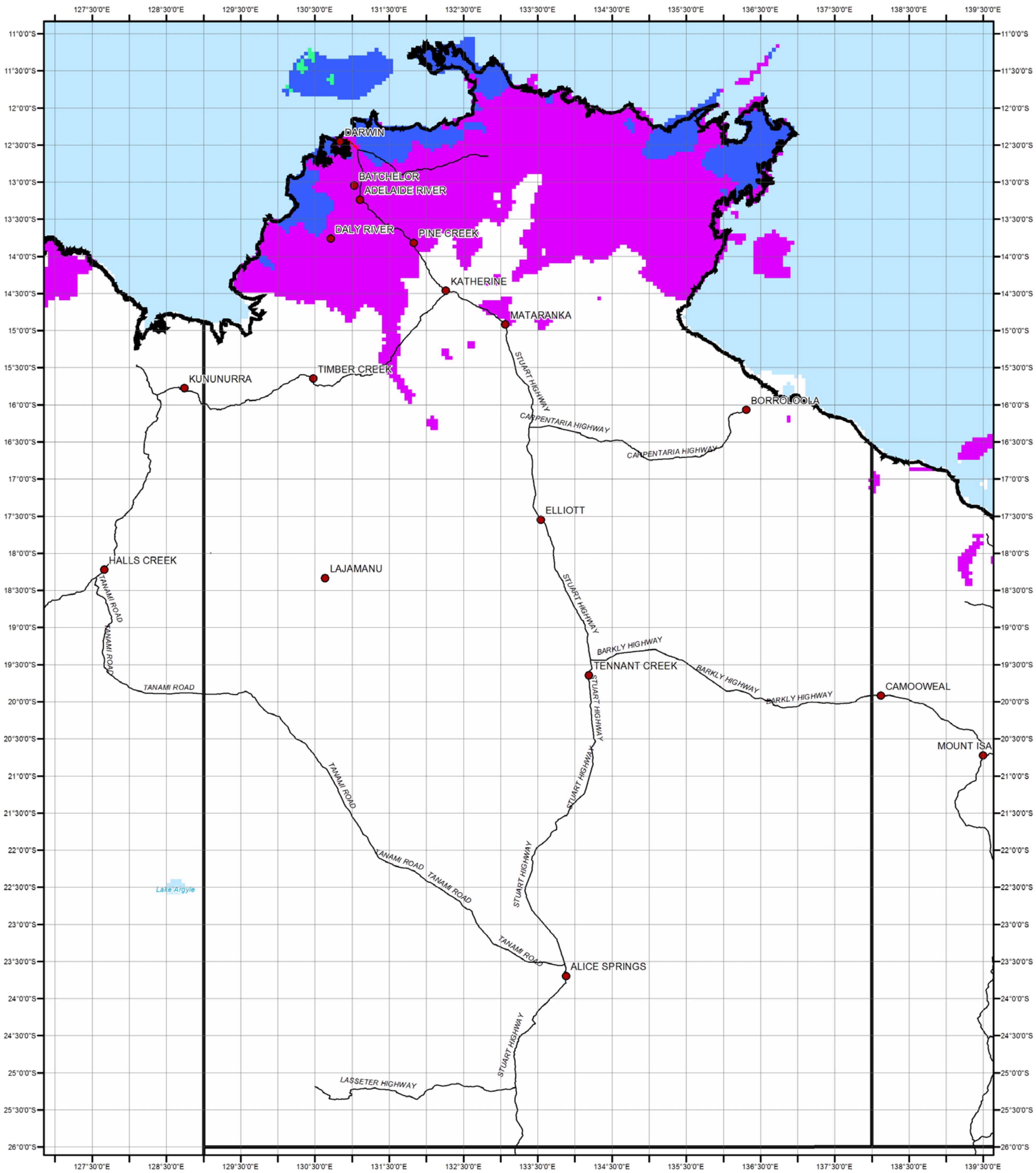
Data Source: Geoscience Australia: 250k Data - Jan 2011; Department of Climate Change and Energy Efficiency: Maximum Potential Biomass, 2004. Created by: sjduce



LEGEND

- Populated Places
- Dual Carriageway
- Principal Road

Maximum Potential Biomass Class (tonnes dry matter/ha)

- **Class 1: 0 - 50**
- **Class 2: 50 - 100**
- **Class 3: 100 - 150**
- **Class 4: 150 -250**
- **Class 5: 250 - 350**
- **Class 6: 350 - 450**
- **Class 7: >450**

1:5,250,000 (at A3)

0 25 50 100 150 200 Kilometers

Horizontal Datum: Geocentric Datum of Australia (GDA)

N

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Maximum Potential
Biomass Classes - Northern Territory

Figure 6

G:\21\21553\GIS\Maps\MXD\2121553_Z019_Final_Map_NorthernTerritory_RevA.mxd

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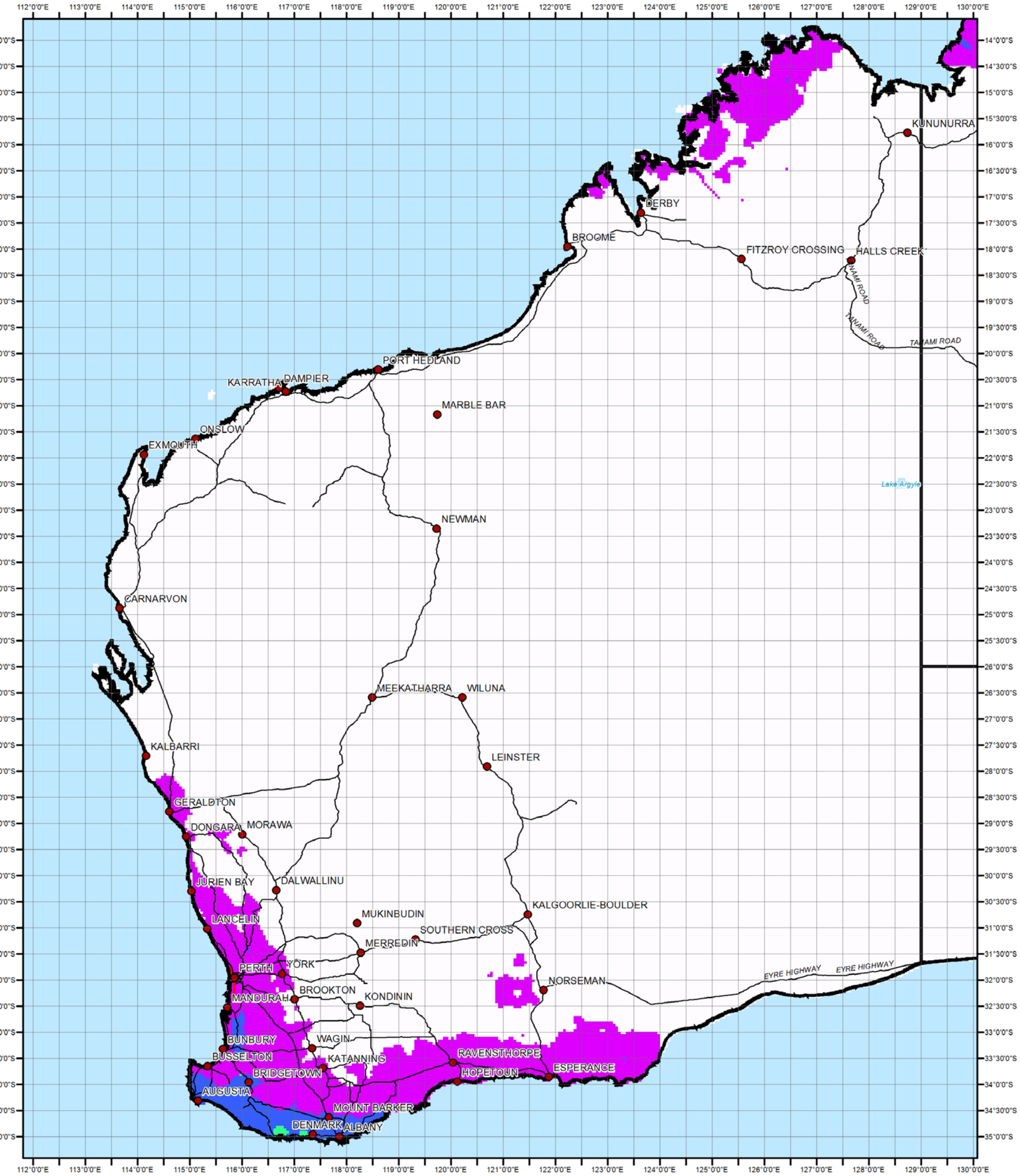
Data Source: Geoscience Australia: 250k Data - Jan 2011; Department of Climate Change and Energy Efficiency: Maximum Potential Biomass, 2004. Created by: sjduce



LEGEND

- Populated Places
- Dual Carriageway
- Principal Road

Maximum Potential Biomass Class (tonnes dry matter/ha)

- **Class 1: 0 - 50**
- **Class 2: 50 - 100**
- **Class 3: 100 - 150**
- **Class 4: 150 -250**
- **Class 5: 250 - 350**
- **Class 6: 350 - 450**
- **Class 7: >450**

1:7,500,000 (at A3)

0 25 50 100 150 200 Kilometers

Horizontal Datum: Geocentric Datum of Australia (GDA)

N

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Maximum Potential
Biomass Classes - Western Australia

Figure 7

G:\21\21553\GIS\Maps\MXD\2121553_Z020_Final_Map_WA_RevA.mxd

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Data Source: Geoscience Australia: 250k Data - Jan 2011; Department of Climate Change and Energy Efficiency: Maximum Potential Biomass, 2004. Created by: sjduce

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Document Status

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