Appendix N

Greenhouse gas assessment and addendum

Environmental impact statement

watersecurity
MAJOR PROJECTS

Murrumbidgee to Googong Water Transfer

Greenhouse Gas Assessment

June 2009

ACTEW
CORPORATION

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Abbreviations

Table 1 Abbreviations

Abbreviation	Definition
a	Annum
ACT	Australian Capital Territory
CH_4	Methane
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent emissions (emissions of other greenhouse gases are multiplied by their GWP so that their effects can be compared to emissions of carbon dioxide)
DCC	Department of Climate Change
EF	Emission Factor
EIA	Environmental Impact Assessment
EPA	Environment Protection Authority
FullCAM	The Australian Government Full Carbon Accounting Model
GHG	Greenhouse Gas
GWh	Gigawatt hour
i.d.	Inside diameter
ISO	International Standards Organisation
kg	kilogram
km	kilometre
kV	kilovolt
kWh	kilowatt hour
L	litre
LCA	Life Cycle Assessment
m	metre
M2G	Murrumbidgee to Googong
ML	megalitre
mm	millimetre
NGA	National Greenhouse Accounts
NSW	New South Wales
Proponent	ACTEW

Abbreviation	Definition
PVC	Poly vinylchloride
t	Tonnes
TJ	terajoules
US	United States of America

Summary

The project involves construction and operation of infrastructure required to transfer approximately 100 ML/day of water a distance of approximately 13 km from the Murrumbidgee River to Burra Creek.

The infrastructure required to transfer the water includes an intake/low lift pump station; a high lift pump station; an underground pipeline; a discharge structure and a power supply.

Methodology

A greenhouse gas assessment of the proposed infrastructure was conducted in accordance with the general principles of:

- The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard developed by the World Business Council for Sustainable Development;
- Life Cycle Assessment principles (ISO 14040 series); and
- The Commonwealth Department of Climate Change (DCC) National Greenhouse Accounts (NGA) Factors, October 2008).

The assessment included Scope 1, 2 and 3 emissions from all stages of construction and operation, including:

- Emissions and energy use associated with the extraction and processing of construction raw materials, such as gravel, concrete, steel and sand;
- Emissions from the transportation of construction materials from their extraction and processing locations to the development site;
- Fuel use by bulldozers, excavators, trucks and other equipment during the construction phase;
- Emissions associated with the removal of vegetation;
- Transportation and landfill disposal of construction waste;
- Electricity imported from the grid during the operation of the pump stations; and
- Electricity recovered from the operation of a mini-hydro system.

Results

The total construction emissions were estimated to be 37,500 tonnes of CO_2-e over the construction period and average annual emissions of 8,000 tonnes of CO_2-e per annum. The total emissions for the first thirty years of operations without Tantangara (including construction emissions) are estimated to be 238,000 t CO_2-e.

The major sources of emissions during construction were identified as diesel for construction vehicles, steel pipes and vegetation clearance. Emissions associated with the consumption of electricity were estimated to contribute 100% of the total emissions during operation of the proposed infrastructure.

Greenhouse gas emission reduction

ACTEW (the 'Proponent') have committed to offsetting all greenhouse gas emissions associated with the construction of the infrastructure. Additionally, the Proponent has committed to offsetting any increase in emissions associated with Canberra's water supply operations following the completion of the ACT Government's Water Security Program, which the M2G is one proposed project. Therefore ACTEW is committed to offsetting all operational related emissions associated with the Water Security Program Major Projects, including the M2G project. In addition the ACTEW Board has committed to offset all construction related GHG emissions associated with the Water Securities Program Major projects.

ACTEW is following leading practise through identifying and where practicable reducing emissions. Therefore a number of potential reduction opportunities related to construction activities and optimisation of electricity consumption during operations have been identified by the Proponent and are currently being assessed.

1 Introduction

1.1 Purpose of this report

ACTEW Corporation Limited (ACTEW) proposes to undertake the Murrumbidgee to Googong Water Transfer Project (referred to in this report as 'the project'). This report has been prepared to provide an assessment of the greenhouse gas emissions of the project as an input to the environmental impact assessment. The environmental impact assessment is being prepared in accordance with the requirements of Part 3A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and the ACT *Planning and Development Act 2007.*

The report addresses the requirements of the Director-General of the NSW Department of Planning (the Director-General's Requirements) dated 7 October 2008 and the Final Scoping Document prepared by the ACT Planning & Land Authority (the Scoping Document) dated 16 December 2008.

1.2 Project overview

In recent years the Australian Capital Territory (ACT) region has been experiencing severe drought conditions coupled with increased demand for water. Canberra and Queanbeyan have been subject to level three water restrictions since 2006. The current drought, together with predicted climate change and population growth, is driving the search for a more reliable water supply for the ACT. In response to this need, the ACT Government developed the Water Security Program, which identified a range of new water supply projects.

The project is one of the preferred options for delivering improved security to the ACT's water supply. It involves pumping water from the Murrumbidgee River (within the ACT) and transferring it via a pipeline to the Googong Reservoir via Burra Creek (in NSW). The Googong Reservoir supplies water treated to drinking quality standards to the ACT.

The project involves construction and operation of infrastructure required to transfer approximately 100 ML/day of water a distance of approximately 13 km from the Murrumbidgee River to Burra Creek.

The infrastructure required to transfer the water includes an intake/low lift pump station; a high lift pump station; an underground pipeline; a discharge structure and a power supply.

1.3 The location of the project

The intake/low lift pump station would be located on the east bank of the Murrumbidgee River, in the ACT, approximately 34 km south of Canberra. It would be located in an area known as Angle Crossing, approximately 4 km west of Williamsdale on the Monaro Highway.

The high lift pump station would be located within the ACT, approximately 290 m to the east of the intake/low lift pump station.

The pipeline would cross rural land in an east/north-east direction for approximately 13 km. It is located in the vicinity of Williamsdale and Burra Roads, within the districts of Williamsdale and Burra. The majority (approximately 10.2 km) of the pipeline would be located in NSW, with approximately 2.8 km located in the ACT.

The pipeline would discharge to the discharge structure, located on the banks of Burra Creek, just downstream of an existing flow measuring station approximately 10 km south of Googong Reservoir. The discharge structure is located within land know as the Googong Foreshores, which is Commonwealth land within NSW.

2 Greenhouse Gas Assessment Scope

As the ACT Planning Authority does not have specific guidelines for conducting greenhouse gas assessments and no development specific requirements were stated, the Proponent proposed, on GHD's recommendation, that the NSW Department of Planning's Draft *Guidelines: Energy and Greenhouse in EIA,* August 2002 (the 'Guidelines') be used for the assessment. The Guidelines set out a systematic approach to the assessment of the energy and greenhouse impacts associated with a proposal.

The purpose of the greenhouse gas assessment is to calculate the emissions of greenhouse gases associated with the proposed development. In order to obtain a comprehensive estimate, emissions from all stages of construction and operation were considered, including:

- Emissions and energy use associated with the extraction and processing of construction raw materials, such as gravel, concrete, steel and sand;
- Emissions from the transportation of construction materials from their extraction and processing locations to the development site;
- Fuel use by bulldozers, excavators, trucks and other equipment during the construction phase;
- Emissions associated with the removal of vegetation;
- Transportation and landfill disposal of construction waste;
- Electricity imported from the grid during the operation of the pump stations; and
- Electricity recovered from the operation of a mini-hydro system.

2.1 Greenhouse gas assessment methodology

The greenhouse gas assessment was prepared in accordance with the general principles of:

- *The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard* developed by the World Business Council for Sustainable Development (GHG Protocol). This is a recognised international standard;
- Life Cycle Assessment principles (ISO 14040 series); and
- The Australian Government Department of Climate Change (DCC) *National Greenhouse Accounts (NGA) Factors,* 2008.

The above are considered to represent best practice in Australian greenhouse gas accounting.

2.2 Emission scopes

Scope 1, 2 and 3 emissions are defined in the *"Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard"* developed by the World Business Council for Sustainable Development and the World Resources Institute. This document is considered the global standard for emissions accounting and reporting, and as a result, the concept of scope 1, 2 and 3 emissions has been carried over into Australian publications, such as those produced by the Department of Climate Change and the draft guidelines that are applicable to this greenhouse gas assessment. These guidelines specifically require emissions to be expressed in terms of Scope 1, 2 and 3. For this greenhouse gas assessment, the scopes are defined as follows:

- Scope 1: Emissions created directly by a person or business from sources that are owned or controlled by that person or business.
- Scope 2: Emissions created as a result of the generation of electricity, heating, cooling or steam that is purchased and consumed by a person or business. These are indirect emissions as they arise from sources that are not owned or controlled by the person or business that consumes the electricity.

- Scope 3: Emissions that are generated in the wider economy as a consequence of a person or business's activities. These are indirect emissions as they arise from sources that are not owned or controlled by that person or business but they exclude Scope 2.

Scope 1 emissions are produced by the combustion of fuels such as diesel at the development site, and by vehicles and plant equipment which the Proponent owns and has operational control. Note that only the direct combustion of the fuels is considered as Scope 1. Scope 2 emissions arise from the consumption of electricity at the development site, in plant equipment that is owned and operated by the Proponent. Emissions arising from the extraction, processing and transportation and distribution of fuels and electricity are classified as Scope 3, since these activities are not within the operational control of the end user.

All other emissions associated with the project are defined as Scope 3, since they are produced outside the development site, and the Proponent does not have operational control of the facilities from which they originate. The Proponent does not own or operate any of the vehicles that transport raw materials to the site. As such, the emissions resulting from the combustion of fuels for this transportation are classified as Scope 3.

3 Greenhouse Gas Assessment

3.1 Level of assessment required

In the absence of specific ACT Planning Authority specific guidelines for conducting greenhouse gas assessments, the NSW Department of Planning's *Guidelines Energy and Greenhouse in EIA,* have been used and indicate two possible levels of assessment:

- Level 1 Assessment – A simplified assessment based on a limited number of energy sources and methane generation potential; and
- Level 2 Assessment – A more detailed assessment including all Scope 1 and 2 emissions and 'upstream' and 'downstream' emissions.

A Level 2 Assessment is required for proposals with projected emissions above a threshold of 20,000 t CO_2-e per annum or energy consumption in excess of 200 TJ. Although the anticipated quantity of energy consumed during operations indicated a Level 1 assessment under the Guidelines, a Level 2 assessment has been undertaken to assist in the identification of potential emissions reduction opportunities from all life cycle stages of the development.

3.2 Boundary of the assessment

3.2.1 System boundary

The system boundary is the inputs and outputs of each of the identified life cycle stages, including transportation and support services. This includes the manufacture of products and raw materials, the use of energy and utilities and the treatment of solid, liquid and gaseous wastes generated.

The system boundary is depicted in Figure 2 within Appendix A. Exclusions from the system boundary are discussed in Section 3.4.

3.2.2 Aspects of energy use considered

The following aspects of energy use have been considered for the development:

- Energy required to produce and prepare raw materials for building and pipeline infrastructure;
- Energy required to transport materials to the development site;
- Energy required for operations of the pump stations;
- Energy recovered from a mini-hydro system; and
- Energy used to dispose or recycle waste products from each life cycle stage.

3.2.3 Greenhouse gases considered

The greenhouse gases considered in this assessment are:

- Carbon dioxide;
- Nitrous oxides; and
- Methane.

The development is unlikely to store or generate any perfluorocarbons, and uses only negligible quantities of hydrofluorocarbons for refrigeration during construction and sulfur hexafluoride in switchgear during operations. These gases have therefore been excluded.

3.3 Data collection and calculation procedures

Emission factors that are used in the calculations are outlined in Appendix B. Where possible, factors have been sourced from the *National Greenhouse Accounts (NGA) Factors,* October 2008. If factors have been sourced elsewhere then source references have been provided in Table 5 within Appendix B.

Wherever possible, estimates with high confidence were used to calculate greenhouse gas emissions. When data was unavailable, assumptions and approximations were made in order to obtain a reasonable estimate. Recognised standards, such as the World Business Council Greenhouse Gas Protocol, were used to assist in these estimations whenever appropriate.

All energy consumption and emissions data has been converted into quantities of carbon dioxide equivalent for each life cycle stage of the project, as shown in Appendix B. The emission values for each life cycle stage have been summed to reach an estimate of the total greenhouse gas emissions over the entire life cycle.

3.4 Exclusions and assumptions

3.4.1 Exclusions

Exclusions from the greenhouse gas assessment are:

- Emissions associated with the manufacturing of construction vehicles and equipment and their transportation to site. The construction period was considered minimal when compared to the life of the capital equipment required for construction activities such as excavators, dozers, trucks and cranes. Therefore, construction equipment is not manufactured primarily for this project and hence the emissions associated with manufacturing are not included. The emissions from use of the construction equipment were included.
- Emissions associated with on-site refuelling infrastructure. It is understood that the re-fuelling infrastructure comprises a mobile plant. The emissions associated with the transportation and construction of the refuelling infrastructure and the fugitive emissions from fuel storage and refuelling activities were excluded.
- Emissions associated with infrastructure for electricity distribution onsite (lines, substations etc). These items were considered negligible compared to the overall construction activity emissions.
- Emissions associated with minor construction items and materials such as cabling and associated electrical equipment within the pump station structures, rubber rings or flanges (if used) for pipe connections, and minor pipe work within pump station structures. These items were considered negligible compared to the overall construction activity emissions.
- Emissions associated with the use of explosives for rock removal. This item was considered negligible compared to the overall construction activity emissions.
- Emissions associated with the consumption, treatment and disposal of water and wastewater during construction, with the exception of potable water at site compounds. These items were considered negligible compared to the overall construction activity emissions.
- Emissions associated with the maintenance of construction vehicles and the use of oils, grease, lubricants and replacement parts. These items were considered negligible compared to the overall construction activity emissions.
- Emissions associated with establishing and maintaining vegetation planted after construction. Vegetation maintenance such as seedling growth, transportation to site, fertilisation and water use, weather protection measures and mulching were considered negligible compared to the overall construction activity emissions.
- Emissions associated with the general maintenance of the pipeline and pump stations during operation. The emissions associated with general maintenance were considered low compared with anticipated electricity consumption and were therefore excluded.
- Abatement due to re-vegetation of cleared land. This abatement was considered negligible compared to the emissions associated with the electricity consumption during operations.
- Emissions associated with decommissioning. Details of decommissioning procedures were not available at the time of the assessment. It was assumed that the infrastructure would be made safe and remain in place should operations cease in 100 years. The emissions associated with the decommissioning of minor

items, such as pumps and valves are unlikely to be significant when annualised over the operating life of the pump stations and pipeline and were therefore excluded.

The discrepancies in the total emissions inventory due to the exclusions and limitations of the assessment are anticipated to be minor.

3.4.2 Assumptions

Assumptions used in estimating the activity levels and associated greenhouse gas emissions for the development are listed in Table 2 below.

Table 2 Greenhouse gas assessment assumptions for Murrumbidgee to Googong Pipeline

Parameter measured	Assumptions
Raw materials	
Pipes	Quantity estimated as 13,100 m of Mild Steel Cement Lined pipe, steel i.d. 1,016 mm, steel wall thickness 8 mm, 10 mm layer cement. The density of cement lining was assumed to be 3,150 kg/m^3. This is based on Portland cement and considered a conservative estimate. The emissions factors (EFs) for the pipe raw materials were used as an approximation for the manufactured pipe. Steel EF sourced from SimaPro based on Australian data for steel with a 10% recycled content. Cement EF sourced from SimaPro based on Australian data for Portland Cement.
Concrete	Quantity estimated as 4,000 t. EF sourced from SimaPro based on Australian data for ready mix concrete.
Sand	Quantity estimated as 16,000 m^3 compacted. The bulk volume delivered to site was assumed to be 20% greater than the compacted volume with a bulk density of 1,442 kg/m^3, sourced from http://www.simetric.co.uk/si_materials.htm. EF sourced from SimaPro based on Australian data for sand from river.
Cables	Quantity estimated as 4,500 m of 25 mm^2 1.9/3.3 kV copper/PVC cable, with total cable mass of 690 kg/km. Copper mass, based on density of 8,960 kg/m^3, calculated to be 224 kg/km and mass of PVC was determined by difference. The EFs for the cable raw materials were used as an approximation for the manufactured cable. Copper EF sourced from SimaPro based on Australian data for copper. PVC EF sourced from SimaPro based on Australian data for PVC.
Pumps	Quantity estimated as 15 t. It was assumed that the pumps were 80% iron and 20% steel. The EFs for the pump raw materials were used as an approximation for the manufactured pumps. Iron EF sourced from SimaPro based on Australian data for iron. Steel EF sourced from SimaPro based on Australian data for steel with a 10% recycled content.
Reinforcing steel	Quantity estimated as 300 t. EF sourced from SimaPro based on Australian data for steel with 10% recycled content.
Gravel	Gravel to be used as a road base for temporary construction roads. Quantity estimated based on 74,000 m^2 of roads, and assumed depth of 300 mm and gravel density of 2.3 t/m^3. EF sourced from SimaPro based on Australian data for gravel.

Parameter measured	Assumptions
Potable water	Quantity estimated as 780 kL, based on consumption of 10,000 L per week and a construction period of 18 months. EF sourced from ActewAGL's 2006-2007 Greenhouse Challenge Plus report.
Transport to Site	
Pipes	It is assumed that pipes will be sourced from suppliers in Somerton, VIC and transported by rigid truck. Road distances have been estimated by using the website http://maps.google.com.au. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.
Concrete	It is assumed that ready mix concrete will be sourced locally, within 40 km of site and transported by rigid truck. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.
Sand	It is assumed that sand will be sourced from Bungendore, NSW and transported by rigid truck. Road distances have been estimated by using the website http://maps.google.com.au. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.
Cables	It is assumed that the cables will be sourced from Liverpool, NSW and transported by rigid truck. Road distances have been estimated by using the website http://maps.google.com.au. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.
Pumps	It is assumed that the pumps will be sourced from Germany, travel to Melbourne by ship and then to site by rigid truck. Ship distances have been estimated by using the website http://www.handytankers.com/handy/toolbox/distance/distance.asp. Road distances have been estimated by using the website http://maps.google.com.au. Ship EF sourced from SimaPro based on Australian data for international shipping freight. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.
Reinforcing steel	It is assumed that reinforcing will be sourced from suppliers in Sydney and transported by rigid truck. Road distances have been estimated by using the website http://maps.google.com.au. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.
Reinforcing steel	It is assumed that reinforcing will be sourced from suppliers in Sydney and transported by rigid truck.

Parameter measured	Assumptions
	Road distances have been estimated by using the website http://maps.google.com.au. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.
Reinforcing steel	It is assumed that reinforcing will be sourced from suppliers in Sydney and transported by rigid truck. Road distances have been estimated by using the website http://maps.google.com.au. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.
Potable water	It was assumed that potable water would be sourced from the Canberra main within 40 km of the site compounds and transported by rigid truck. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.
Construction	
Diesel consumption - construction vehicles	The quantity of diesel consumed by construction equipment was estimated as 7,500 kL using Brake Specific Fuel Consumption data reported in US EPA's report *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition, Report No. NR-009c (2004)*. The hours of use for each construction vehicle/equipment was estimated based on 9 h per day, 21 days per month and an utilisation factor that varied depending on the vehicle. The number of months for each vehicle/equipment was estimated and varied between 9 to 18 months. The horsepower for each vehicle/equipment was obtained from manufacturer vehicle specifications, where the model to be used was known, or estimated based on similar vehicles (using Caterpillar, John Deere specifications). EF from Tables 4 and 38 of the DCC NGA Factors (October 2008) for diesel (Scopes 1 and 3).
Diesel consumption - generators	The quantity of diesel consumed by generators used outside the site compounds was estimated using Brake Specific Fuel Consumption data reported in US EPA's report *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition, Report No. NR-009c (2004)*. The hours of use were estimated based on operation of 4 generators for 9 hours per day, 21 days per month for 8-12 months and a power rating of 3.3 kVA. The quantity of diesel consumed by generators inside the site compounds was estimated as 400 L/day for the main compound, 300 L/day for the low lift and high lift site compounds and an 18 month construction period was assumed. Total quantity of diesel consumed by generators estimated as 500 kL. EF from Tables 3 and 38 of the DCC NGA Factors (October 2008) for diesel (Scopes 1 and 3).
Vegetation clearance	The quantity of vegetation to be cleared was estimated as being equivalent to: • Mature trees covering 5 ha; • Young tress (10 years) covering 2.1 ha; and • Saplings (3 years) covering 3 ha. These areas were based on the removal of: • 215 mature trees;

Parameter measured	Assumptions
	• 265 young trees (between 2-6 m in height); and • 525 saplings (less than 2 m in height). The total carbon content of vegetation removed was estimated as 258 t C using FullCAM, based on *Eucalyptus sp.* CO_2-e emissions were calculated assuming carbon in vegetation formed carbon dioxide.
Disposal of spoil	Quantity estimated as 115,000 t, based on the quantity of material not returned to the trenches after placement of the pipes. All spoil was assumed to be stockpiled for re-use. Only emissions associated with transportation of spoil were considered in the disposal. It was assumed the spoil would be re-used within 50 km of site and transported by rigid ruck. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.
Petrol consumption by workers travelling to site	Quantity estimated as 260 kL based on workers travelling separately in passenger vehicles, with fuel consumption of 0.113 L/km, sourced from Table 4, AGO Factors and Methods Workbook, December 2006. The number of workers and duration assumed is outlined below. The total number of days was based on 300 working days per year. • Intake/low lift pump station – 11 workers, 9 month duration; • High lift pump station – 22 workers, 12 month duration; • Outlet – 11 workers, 6 month duration; • Pipeline – 42 workers, 12 month duration; and • General – 12 workers, 18 month duration. It was assumed all workers would be situated in the Canberra region for the duration of the project an 80 km round trip would be taken each day. EF from Tables 4 and 38 of the DCC NGA Factors (October 2008) for diesel (Scopes 1 and 3).
Operations	
Electricity	Quantity of water transferred from Murrumbidgee to Googong estimated as 8,877 ML/year (average for first 30 years of transfer) based on ActewAGL modelling. The electricity associated with pumping estimated as 1,138 kWh/ML based on the pipeline design. The electricity recovery percentage from the inclusion of a mini-hydro system is estimated as 26% (27% with Tantangara flows). Imported electricity sourced from grid. EF from Table 5 of the DCC NGA Factors (October 2008) for NSW and ACT (Scopes 2 and 3). Note, if water released from Tantangara Dam is included in the Murrumbidgee to Googong transfer, the volume of water transferred may be 14,000 ML/year. There would be no change in the electricity associated with pumping.

4 Energy and Greenhouse Analysis

4.1 Greenhouse emissions results

Emissions were calculated based on Scope 1, 2 and 3 emissions. These emissions were categorised as either occurring during the construction period or as an operational emission (annual basis).

4.1.1 Greenhouse inventory

The greenhouse assessment indicates total construction emissions of approximately 37,500 tonnes of CO_2-e over the construction period and average annual emissions of 8,000 tonnes of CO_2-e per annum. Scope 1, 2 and 3 emissions are summarised in Table 3 below.

Table 3 Summary of Scope 1, 2 and 3 emissions for Murrumbidgee to Googong Pipeline

Scope	Quantity (t CO_2-e)[1]
Construction	
1	23,000
2	0
3	14,500
Total emissions for construction	37,500
Annual operating emissions without Tantangara flows[3]	
1	0
2	7,000
3	1,000
Total annual operating emissions	8,000
Total annual operating emissions as percentage of NSW & ACT total emissions[2]	0.005%
Annual operating emissions with Tantangara flows[3]	
1	0
2	10,000
3	2,000
Total annual operating emissions	12,000
Total annual operating emissions as percentage of NSW & ACT total emissions[2]	0.007%

1. Emissions have been rounded.

2. Total emissions for NSW and ACT based on DCC 'State and Territory Greenhouse Gas Inventories 2006'. Emissions for 2006 were 161,100,000 t CO_2-e.

3. Includes energy recovery from mini-hydro.

Emissions for construction were also categorised as raw materials (i.e. emissions associated with the extraction and processing of raw materials), transportation of raw materials to site, and construction activities. Construction activities are estimated to contribute 70% of all emissions associated with the M2G, raw materials 25% and transportation 5%. The major sources of emissions during construction and operations are summarised in Section 4.1.2, and the total emissions inventory for construction is given in Appendix B.

Electricity consumption was assumed to contribute 100% of the emissions during operations. Emissions and abatements associated with minor activities during operations were considered negligible and were excluded as detailed in Section 3.4.1.

4.1.2 Major emission sources for construction

The emissions contributing to 90% of the total emissions for construction are listed in Table 4.

Table 4 Emissions contributing 90% of total emissions for Murrumbidgee to Googong Pipeline construction

Ranking	Source	Emissions (t CO_2-e)	Fraction of emissions
1	Diesel consumption in construction vehicles	22,000	58%
2	Steel content of pipes	5,500	15%
3	Diesel consumption in generators	1,500	4%
4	Transportation of spoil for re-use	1,500	4%
5	Cement content of pipes	1,000	3%
6	Vegetation removal	1,000	3%
7	Gravel for temporary roads	1,000	2%
8	Petrol consumption by workers travelling to site	1,000	2%
		33,500	**90%**

4.1.3 Breakdown between NSW and ACT

Approximately 2.3 km (or 22%) of the pipeline is located in the ACT. This includes the low lift and high lift pump stations, and as such, all electricity for operation of the pipeline will be consumed in the ACT. On this basis, approximately 8,000 t CO_2-e of construction emissions will be associated with the ACT section of the pipeline. Approximately 29,500 t CO_2-e of construction emissions will be associated with the NSW section of the pipeline.

4.1.4 Emissions over the life of the development

The total emissions (without Tantangara flows) for the first thirty years of operations are estimated to be 238,000 t CO_2-e. With Tantangara flows the total emissions for the first thirty years of operation would are estimated to be 370,000 t CO_2-e (Figure 1). Projections past thirty years may provide inaccurate estimates due to likely changes in emission factors associated with electricity production. The construction emissions contribute approximately 14% of the total emissions for the first thirty years without Tantangara flows and approximately 9% with Tantangara flows. This percentage will decrease as the operation of the pipeline extends past thirty years.

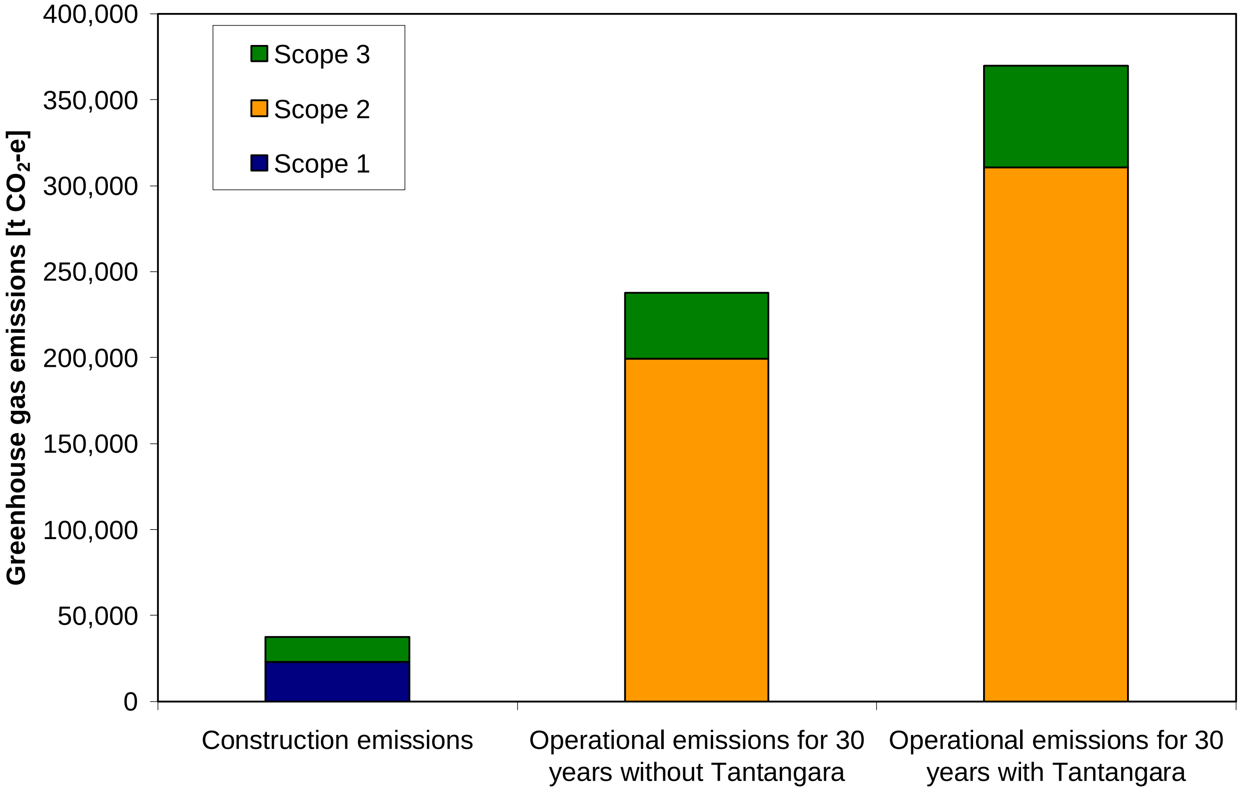

Figure 1 Emissions associated with construction and operation of the proposed infrastructure. Scope 1, 2 and 3 emissions are defined in Section 2.2 and the total emissions inventory is given in Appendix B

5 Greenhouse Gas Emission Reduction

The Proponent has committed to offsetting all greenhouse gas emissions associated with the construction of the infrastructure. Additionally, the Proponent has committed to offsetting any increase in emissions associated with Canberra's water supply following the completion of the ACT Government's Water Security Program, of which the M2G is one proposed project. The Proponent is interested in reducing construction and operational greenhouse gas emissions as much as practicable. Construction emissions that cannot be practicably reduced will be offset. The Proponent is currently investigating offsetting options, with the view of developing a portfolio of offsets.

Based on the estimation of greenhouse gas emissions, a number of potential reduction opportunities relating to the construction and operation of the pump stations and pipeline were identified and are outlined below.

5.1 Direct greenhouse gas minimisation

5.1.1 Biodiesel during construction

As shown in Table 5 emissions due to diesel consumption during construction is estimated to be approximately 23,500 t CO_2-e. The use of biodiesel (blended with regular diesel) in construction vehicles has the potential to reduce greenhouse gas emissions during construction. The reduction in emissions is dependent on the type of feedstock and its processing location. The Proponent is currently investigating the feasibility of reducing emissions by using biodiesel. The feasibility assessment includes consideration of the biodiesel feedstock and associated GHG emission reduction, environmental impacts of biodiesel feedstocks, fuel characteristics in relation to climatic conditions at the site (e.g. requirement for winter blends) and the suitability of using biodiesel blends in construction equipment.

5.1.2 Renewable Energy

The Proponent has undertaken a technical feasibility study to assess the suitability of installing a mini-hydro system. The facility would be located near the outlet structure and would comprise of a turbine and generator, and would be located below ground, with some minor above ground auxiliary components.

The hydropower station is estimated to be able to recover approximately 26% of the M2G pumping energy without Tantangara flows and 27% of the M2G pumping energy with Tantangara flows. The energy recovery from a mini-hydro system has been included in the calculations presented in Section 4.

The GHG emissions associated with the construction of a mini-hydro system are likely to be minimal compared with the overall construction GHG emissions.

The Proponent is currently undertaking a financial feasibility assessment of a mini-hydro system.

5.2 Indirect greenhouse gas minimisation

Indirect greenhouse gas emissions (i.e. those generated off site such as electricity use) can be minimised by purchase of renewable energy (GreenPower). As shown in Table 3, consumption of electricity generated offsite is projected to contribute 8,000 t CO_2-e per annum (without Tantangara flows). Purchasing 100% accredited renewable energy, such as GreenPower would remove these emissions from the inventory. GreenPower is, however, considerably more expensive than standard grid electricity.

GreenPower costs approximately an additional 5 cents per kWh (retail rate), which equates to an emissions reduction cost of $47/ t CO_2-e for NSW electricity. The Proponent may be able to access renewable energy at a price lower than the retail rate. Switching to 100% GreenPower could cost an additional estimated $376,000 annually – this has not been included in the budget for this project.

Appendix A System Boundary

Raw Materials		Transport of Raw Materials to Site		Construction Activities		Operation
Emissions associated with the transportation of raw materials from their point of production to the site. • Steel (pipes, pumps, reinforcement, valves, miscellaneous items) • Concrete • Cement (pipes, miscellaneous works) • Sand • Gravel • Diesel • Cables (major) • Potable water • Construction vehicle maintenance materials (oil/lubricants) • Materials for electricity distribution infrastructure • Materials for minor construction items (cables and associated electrical equipment, flanges etc) • Construction water from river/ retention dams	→	*Emissions associated with the construction activities.* • Diesel (construction vehicle and generators) • Transportation of spoil for re-use • Vegetation clearance • Petrol consumption by workers travelling to site • Wastewater treatment • Re-vegetation activities • Manufacture and transportation of construction vehicles and equipment to site. • Onsite refuelling infrastructure and fugitive emissions.	→	*Emissions associated with the construction activities.* • Diesel (construction vehicle and generators) • Transportation of spoil for re-use • Vegetation clearance • Petrol consumption by workers travelling to site • Wastewater treatment • Re-vegetation activities • Manufacture and transportation of construction vehicles and equipment to site. • Onsite refuelling infrastructure and fugitive emissions.	→	*Emissions associated with the operation of the pipeline.* • Electricity • Electricity generation from mini-hydro • Abatement due to re-vegetation of cleared land • Maintenance items and activities ↓ • **Decommissioning** *Emissions associated with decommissioning.*

Items in blue have been excluded from the assessment.

Figure 2 System Boundary for the Murrumbidgee to Googong Pipeline

Appendix B Construction Greenhouse Gas Inventory

Table 5 Greenhouse Gas Inventory for Construction of the Murrumbidgee to Googong Pipeline

Component	Value (Q)	Units	Scope 1 Emission Factor (EF)	Scope 2 Emission Factor (EF)	Scope 3 Emission Factor (EF)	Total Emission Factor (EF)	Units	Source	Method	Scope 1 Emissions ($t\ CO_2$-e)	Scope 2 Emissions ($t\ CO_2$-e)	Scope 3 Emissions ($t\ CO_2$-e)	Total Emissions ($t\ CO_2$-e)	Proportion of Total Inventory %
Raw Materials														
Cement (in pipes)	1,300	t			0.804	0.804	kg CO_2-e/kg	SimaPro Australian Database	Q x EF	0	0	1,045	1,045	2.8%
Steel (in pipes)	2,700	t			2.070	2.070	kg CO_2-e/kg	SimaPro Australian Database	Q x EF	0	0	5,589	5,589	14.9%
Concrete (pump station structures, thrust blocks, outlet structure)	4,000	t			0.141	0.141	kg CO_2-e/kg	SimaPro Australian Database	Q x EF	0	0	564	564	1.5%
Sand	28,000	t			0.017	0.017	kg CO_2-e/kg	SimaPro Australian Database	Q x EF	0	0	473	473	1.3%
Copper in cables	1	t			5.520	5.520	kg CO_2-e/kg	SimaPro Australian Database	Q x EF	0	0	6	6	0.0%
PVC in cables	2	t			2.410	2.410	kg CO_2-e/kg	SimaPro Australian Database	Q x EF	0	0	5	5	0.0%
Pumps (iron component)	12	t			1.180	1.180	kg CO_2-e/kg	SimaPro Australian Database	Q x EF	0	0	14	14	0.0%
Pumps (steel component)	3	t			2.070	2.070	kg CO_2-e/kg	SimaPro Australian Database	Q x EF	0	0	6	6	0.0%
Reinforcing steel	300	t			2.070	2.070	kg CO_2-e/kg	SimaPro Australian Database	Q x EF	0	0	621	621	1.7%
Gravel for temporary roads	51,000	t			0.017	0.017	kg CO_2-e/kg	SimaPro Australian Database	Q x EF	0	0	862	862	2.3%
Potable water for site compounds	780	kL			0.299	0.299	t CO_2-e/ML	ActewAGL 2006-2007 Greenhouse Challenge Plus report	Q x EF / 1000	0	0	0	0	0.0%
Total Raw Materials										**0**	**0**	**9,185**	**9,185**	**24.5%**
Transportation of Materials to Site														
Pipes	4,000	t			161.0	161.0	kg CO_2-e/kg	Materials Delivery worksheet	Q x EF / 1000	0	0	644	644	1.7%
Concrete (pump station structures, thrust blocks, outlet structure)	4,000	t			10.0	10.0	kg CO_2-e/kg	Materials Delivery worksheet	Q x EF / 1000	0	0	40	40	0.1%
Sand	28,000	t			14.7	14.7	kg CO_2-e/kg	Materials Delivery worksheet	Q x EF / 1000	0	0	412	412	1.1%
Cables	3	t			67.9	67.9	kg CO_2-e/kg	Materials Delivery worksheet	Q x EF / 1000	0	0	0	0	0.0%
Pumps	15	t			278.4	278.4	kg CO_2-e/kg	Materials Delivery worksheet	Q x EF / 1000	0	0	4	4	0.0%
Reinforcing steel	300	t			76.4	76.4	kg CO_2-e/kg	Materials Delivery worksheet	Q x EF / 1000	0	0	23	23	0.1%
Gravel for temporary roads	51,000	t			7.4	7.4	kg CO_2-e/kg	Materials Delivery worksheet	Q x EF / 1000	0	0	375	375	1.0%
Diesel	6,800	t			76.7	76.7	kg CO_2-e/kg	Materials Delivery worksheet	Q x EF / 1000	0	0	521	521	1.4%
Potable water for site compounds	780	t			9.8	9.8	kg CO_2-e/kg	Materials Delivery worksheet	Q x EF / 1000	0	0	8	8	0.0%
Total Materials Transportation										**0**	**0**	**2,027**	**2,027**	**5.4%**
Construction														
Diesel use in construction vehicles	7,500	kL	2.7		0.2	2.9	t CO_2-e/kL	NGA Factors October 2008	Q x EF	20,236	0	1,534	21,770	58.1%
Diesel in generators	500	kL	2.7		0.2	2.9	t CO_2-e/kL	NGA Factors October 2008	Q x EF	1,341	0	102	1,444	3.9%
Vegetation clearance								Refer to Table 2		945	0	0	945	2.5%
Transportation of spoil for re-use	115,000	t			12.3	12.3	t CO_2-e/ha	Materials Delivery worksheet	Q x EF / 1000	0	0	1,409	1,409	3.8%

Component	Value (Q)	Units	Scope 1 Emission Factor (EF)	Scope 2 Emission Factor (EF)	Scope 3 Emission Factor (EF)	Total Emission Factor (EF)	Units	Source	Method	Scope 1 Emissions (t CO_2-e)	Scope 2 Emissions (t CO_2-e)	Scope 3 Emissions (t CO_2-e)	Total Emissions (t CO_2-e)	Proportion of Total Inventory %
Petrol consumption (Workers travel to site)	260	kL	2.4		0.2	2.6	t CO_2-e/ha	NGA Factors October 2008	Q x EF	619	0	47	666	1.8%
Total Construction										**23,141**	**0**	**3,093**	**26,234**	**70.1%**
Total emissions for construction period										**23,141**	**0**	**14,305**	**37,446**	

watersecurity
MAJOR PROJECTS

Greenhouse Gas Assessment
Addendum

December 2009

ACTEW
CORPORATION

Contents

1 Introduction

1.1 Background

ACTEW Corporation Limited (ACTEW) proposes to transfer water from the Murrumbidgee River through an underground pipeline to Burra Creek in NSW which flows into Googong Reservoir. This proposed project is known as the Murrumbidgee to Googong Water Transfer.

In order to obtain community feedback and satisfy statutory approval requirements a series of community meetings and a period of public exhibition of the Environmental Assessment (NSW) and Draft Environmental Impact Statement (ACT) (referred to as the EA/Draft EIS) were undertaken. In response to community feedback received before and during the public exhibition period ACTEW has modified the location at which the pipeline would discharge into Burra Creek.

This report addresses the impacts associated with the proposed upstream outlet location into Burra Creek.

1.2 Upstream outlet overview

The project involves construction and operation of infrastructure required to transfer approximately 100 ML/day of water a distance of approximately 12 km from the Murrumbidgee River to Burra Creek which flows into Googong Reservoir. The infrastructure required to transfer the water includes an intake/low lift pump station; a high lift pump station; an underground pipeline; an outlet structure and a power supply.

The original outlet location outlined in the EA/Draft EIS proposed that the pipeline would discharge just downstream of an existing flow measuring station near Burra Road, approximately 10 km south of Googong Reservoir. The original outlet structure was located east of Burra Road within land known as the Googong Foreshores, which is Commonwealth owned land within NSW.

The modified outlet location is 3.2 km upstream from that previously proposed in the EA/Draft EIS. The new outlet location is located in the vicinity of the low level crossing on Williamsdale Road near the junction of Burra and Williamsdale Roads.

The transferred water would discharge through a concrete structure located on the banks of Burra Creek. The outlet structure has been modified to suit this alternative Burra Creek location where the channel is only approximately 1 m deep. It would be a concrete topped structure stretching approximately 12 m along the creek bank with a 250 mm grated opening.

A mini-hydro power generation facility would be located close to the Burra Creek discharge location, but above flood level. The mini-hydro power generation facility would largely be housed underground and would recover almost 20% of the total electricity used for the pumping of the water.

The upstream outlet proposed by the community submissions would reduce a number of adverse environmental and social impacts of the original project including:

- Project footprint reduced as follows:
  - Pipe length reduced by one km;
  - One less pipeline creek crossing;
  - Five landholders no longer affected by easement requirements;
  - An estimated 10 landholders no longer indirectly impacted by construction works;
  - An estimated five air valves, four scour valves and associated potential impacts reduced;
  - Four less road crossings;
  - Less disruption to flora and fauna (habitats within this area are mostly highly disturbed but includes a small area of box-gum grassy woodland close to the original proposed outlet site);

– Outlet location not on Commonwealth land;

– Greenhouse gas emissions would be reduced by at least 3% during construction.

Additional targeted consultations are also underway with major stakeholders and those landholders located near the new outlet location or abutting the additional length of creek that would be affected by increased flows.

1.3 Purpose and scope of the report

The purpose of this study is to discuss:

- The greenhouse gas emissions associated with construction and the operation of the pipeline and associated infrastructure with consideration of the new outlet location; and
- Changes to the greenhouse gas estimate based on updated construction data.

1.4 Structure of the report

This report will address:

- Changes to the data collection and the calculation methodology based on Target Outturn Cost data;
- Changes to the system boundary for the greenhouse gas assessment;
- The exclusions and assumption from the greenhouse gas assessment based on the updated data and the new outlet location; and
- Changes to the estimate of greenhouse gas emissions associated with construction and the operation of the pipeline and associated infrastructure.

This report should be read in conjunction with Murrumbidgee to Googong Water Transfer Greenhouse Gas Assessment, June 2009.

2 Greenhouse Gas Assessment

2.1 Data collection and calculation procedures

Data on the quantity of construction materials was primarily obtained from the Target Outturn Cost (TOC) estimate (as of 30 April 2009). Where data was not detailed in the TOC estimate, appropriate assumptions were made, based on discussions with the M2G project team.

Emission factors that are used in the calculations are outlined in Appendix B. Where possible, factors have been sourced from the *National Greenhouse Accounts (NGA) Factors,* June 2009. If factors have been sourced elsewhere then source references have been provided in Table 4 within Appendix B.

Wherever possible, estimates with high confidence were used to calculate greenhouse gas emissions. When data was unavailable, assumptions and approximations were made in order to obtain a reasonable estimate. It is particularly difficult to accurately estimate the greenhouse gas emissions of electrical items and equipment – this is due to the complexity of the numerous materials that comprise electrical equipment, and the substantial embodied energy/greenhouse involved in the assembly of electrical equipment. Therefore, a cost-based methodology was employed for the electrical components based around an economic input-output life-cycle assessment (EIO-LCA) methodology described in Section 2.1.1. Recognised standards, such as the World Business Council Greenhouse Gas Protocol, were used to assist in estimations whenever appropriate.

All energy consumption and emissions data has been converted into quantities of carbon dioxide equivalent for each life cycle stage of the project, as shown in Appendix B. The emission values for each life cycle stage have been summed to reach an estimate of the total greenhouse gas emissions over the entire life cycle.

2.1.1 Economic Input-Output Life Cycle Assessment Calculation Procedure

Green Design Institute's (Carnegie Mellon University) EIO-LCA method[1] estimates greenhouse gas emissions for a product, process or service based on its economic cost. An Australian database is not available, however it was assumed that a price conversion to fit the US 1997 Industry Benchmark Purchaser Price Model can be made to give a sufficient level of accuracy – avoiding the need to exclude items that are considered too difficult to calculate using standard process based methodologies. The conversion of current (4^{th} quartile 2008/09) Australian dollars to 1997 US dollars is a two step process:

1. Convert 2009 $AU to 2009 $US:

   1 $AU (2009) = 1.25 $US (2009)[2]

2. Convert 2009 $US to 1997 $US

   1 $ US (2009) × (CPI 1997 ÷ CPI 2009) = 1 × (160.5 / 212.63) = 0.755 $ US (1997) [3]

Overall 1 $AU (2009) is assumed equivalent to 0.604 $US (1997).

2.2 Exclusions and assumptions

2.2.1 Exclusions

Exclusions from the greenhouse gas assessment are:

- Emissions associated with the manufacturing of construction vehicles and equipment and their transportation to site. The construction period was considered minimal when compared to the life of the capital equipment required for construction activities such as excavators, dozers, trucks and cranes. Therefore, construction equipment is not manufactured primarily for this project and hence the emissions

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1 Carnegie Mellon University Green Design Institute. (2009) Economic Input-Output Life Cycle Assessment (EIO-LCA), Available from: <http://www.eiolca.net/> [Accessed 28 Jul, 2009]

2 Source: www.xe.net – considered an average exchange rate over Apr-09 to Jun-09

3 Source: U.S. Department Of Labor, Bureau of Labor Statistics, Washington, D.C. 20212, Consumer Price Index, All Urban Consumers - (CPI-U), U.S. city average associated with manufacturing are not included. The emissions from use of the construction equipment were included.

- Emissions associated with on-site refuelling infrastructure. It is understood that the re-fuelling infrastructure comprises a mobile plant. The emissions associated with the transportation and construction of the refuelling infrastructure and the fugitive emissions from fuel storage and refuelling activities were excluded.
- Emissions associated with infrastructure for electricity distribution onsite (lines, substations etc). These items were considered negligible compared to the overall construction activity emissions.
- Emissions associated with minor construction items and materials such as cabling and associated electrical equipment within the pump station structures, rubber rings or flanges (if used) for pipe connections, and minor pipe work within pump station structures. These items were considered negligible compared to the overall construction activity emissions.
- Emissions associated with the use of explosives for rock removal. This item was considered negligible compared to the overall construction activity emissions.
- Emissions associated with the consumption, treatment and disposal of water and wastewater during construction, with the exception of potable water at site compounds. These items were considered negligible compared to the overall construction activity emissions.
- Emissions associated with the maintenance of construction vehicles and the use of oils, grease, lubricants and replacement parts. These items were considered negligible compared to the overall construction activity emissions.
- Emissions associated with establishing and maintaining vegetation planted after construction. Vegetation maintenance such as seedling growth, transportation to site, fertilisation and water use, weather protection measures and mulching were considered negligible compared to the overall construction activity emissions.
- Emissions associated with the general maintenance of the pipeline and pump stations during operation. The emissions associated with general maintenance were considered low compared with anticipated electricity consumption and were therefore excluded.
- Abatement due to re-vegetation of cleared land. This abatement was considered negligible compared to the emissions associated with the electricity consumption during operations.
- Emissions associated with decommissioning. Details of decommissioning procedures were not available at the time of the assessment. It was assumed that the infrastructure would be made safe and remain in place should operations cease in 100 years. The emissions associated with the decommissioning of minor items, such as pumps and valves are unlikely to be significant when annualised over the operating life of the pump stations and pipeline and were therefore excluded.

The discrepancies in the total emissions inventory due to the exclusions and limitations of the assessment are anticipated to be minor.

2.2.2 Assumptions

Assumptions used in estimating the activity levels and associated greenhouse gas emissions for the development are listed in Table 1 below.

Table 1 Greenhouse gas assessment assumptions for Murrumbidgee to Googong Water Transfer Pipeline

Parameter measured	Assumptions
Raw materials	
Asphalt - gravel	Quantity estimated as 440 t based on:

Parameter measured	Assumptions
	• 1,800 m^2 asphalt pavement 2 coats (assumed 130 mm thick for 2 coats) • 1,100 m^2 asphalt pavement AC14 (assumed 50 mm thick) Bitumen quantities within the asphalt are assumed to have been calculated separately (see below). The density of gravel was assumed to be 1,522 kg/m^3. Gravel Emission Factor (EF) sourced from SimaPro based on Australian data for gravel.
Bitumen	Quantity estimated by as 3 t based on: • 3,271 m^2 bitumen 2 coats (assumed AMC2 – 0.5 L/m^2 per coat) The density of bitumen was assumed to be 1,016 kg/m^3. Bitumen EF sourced from SimaPro based on Australian data for bitumen.
Cement	Quantity estimated as 40 t based on: • 1,330 m^3 of 2% stabilised sand (assumed 2% by volume). The density of Portland cement was assumed to be 1,506 kg/m^3. Emission Factor (EF) sourced from SimaPro based on Australian data for Portland Cement.
Cement mortar	Quantity estimated as 1 t based on: • 28 No. 20 kg bags Emission Factor (EF) sourced from SimaPro based on European Ecoinvent data for “light mortar”.
Pipes	Quantity estimated as 1,617 t cement and 2,864 t steel based on: • 11,730 m of DN1000 Mild Steel Cement Lined pipe (assumed steel wall thickness 10 mm, 19 mm layer cement) The following equations were used to determine steel and cement mass per m length: • Steel mass (kg/m) = 0.02466.(D-t) .t • Cement mass (kg/m) = 0.00755.T.(D-2t-T) where ‘t’ is the steel wall thickness, ‘T’ is the cement lining thickness, and ‘D’ is the outside diameter of the pipe. The EFs for the pipe raw materials were used as an approximation for the manufactured pipe. Steel EF sourced from SimaPro based on Australian data for steel with a 10% recycled content. Cement EF sourced from SimaPro based on Australian data for Portland Cement.

Parameter measured	Assumptions
Concrete (precast and readymix)	Quantity estimated as 6,023 t, based on: • 714 m^2 of precast panels (assumed 200 mm thick) • 2,214 m^3 of concrete of various strengths ranging from 15 MPa to 40 MPa • 274 m of chainwire fence (calculated 21.2 kg/m of concrete footings based on AS 1725 – chain link fences) • 150 m^3 of concrete for discharge structure The density of concrete was assumed to be 2,400[4] kg/m^3. EF sourced from SimaPro based on Australian data for ready mix concrete.
Gravel	Quantity estimated as 8,900 for road base and sub-base. EF sourced from SimaPro based on Australian data for gravel.
Gypsum	Quantity estimated as 72 t, based on: • 36 ha of soil gypsum treatment (assumed 2 t/ha) EF sourced from SimaPro based on Australian data for gypsum.
Hay bales	Quantity estimated as 440 t, based on: • 8,000 No. Hay bales (assumed ‘regular’ size bales – 55 kg / bale[5]) EF sourced from SimaPro based on European Ecoinvent data for “hay, intensive IP, at farm”.
HDPE pipes	Quantity estimated as 7 t, based on: • 588 m HDPE PE DN200 pipe (calculated 12.7 kg/m) EF sourced from SimaPro based on Industry Data 2.0 data for HDPE pipes.
PET geofabric	Quantity estimated as 71 t, based on: • 213,700 m^2 geofabric (assumed Bidim A34 – 0.28 kg/m^2) • 41,900 m 0.91m high silt fence (assumed Bidim A34 – 0.28 kg/m^2) EF sourced from SimaPro based on Australian data for PET.

[4] *Source: http://www.simetric.co.uk/si_materials.htm*

[5] *Source: http://www.gilmac.com.au/packaging.php*

Parameter measured	Assumptions
Pipes – Reinforced concrete	Quantity estimated as 164 t concrete and 5 t steel, based on: • 186 m PN16 375 dia. RC pipe (PN20 used for calculations), • 320 m PN35 375 dia. RC pipe • 13 m 300 dia. RC pipe • 44 m 600 dia. RC pipe • 94 m 750 dia. RC pipe • 71 m 900 dia. RC pipe For all pipes, the steel and concrete proportions were obtained from Reinforced Concrete Pty Ltd. The density of steel was assumed to be 7,850 kg/m^3. The density of concrete was assumed to be 2,400 kg/m^3. The EFs for the pipe raw materials were used as an approximation for the manufactured pipe. Steel EF sourced from SimaPro based on Australian data for steel with a 10% recycled content. Concrete EF sourced from SimaPro based on Australian data for Readymix Concrete.
Pumps	Quantity estimated as 15 t. It was assumed that the pumps were 100% steel. The EF for the pump raw materials were used as an approximation for the manufactured pumps. EF sourced from SimaPro based on Australian data for steel with a 10% recycled content.
PVC pipes	Quantity estimated as 41 t, based on: • 6,348 m DN125 electrical conduit (calculated 4.04 kg/m) • 6,000 m DN100-150 pipe (assumed 50% DN100 and 50% DN150; calculated 1.67, 3.33 kg/m respectively) [6] The density of PVC pipes was assumed to be 1,530 kg/m^3. EF sourced from SimaPro based on Industry Data 2.0 data for PVC pipes.
Quicklime	Quantity estimated as 3 t of quicklime. EF sourced from SimaPro based on Australian data for quicklime.
Sand	Quantity estimated as 41,700 t, based on: • 39,631 t bedding and fill sand • 1,330 m^3 2% stabilised sand The density of sand was assumed to be 1,602 kg/m^3. EF sourced from SimaPro based on Australian data for sand (from river).
Soil (fill)	Quantity estimated as 18,886 t of fill EF assumed to be similar to gravel and sand.

[6] *Source: Iplex http://www.vinidex.com.au/vinidex/live/RESOURCES/DOCUMENTS/DWVRRJ.pdf*

Parameter measured	Assumptions
Steel - reinforcement	Quantity estimated as 258 t, based on: • 213 t reinforcing bars and sundries • 40 t reinforcement for discharge structure • 1,260 m^2 F82 mesh[7] The density of steel was assumed to be 7,850 kg/m^3. EF sourced from SimaPro based on Australian data for steel with a 10% recycled content.
Steel - miscellaneous	Quantity estimated as 253 t, based on: • 72 m^2 floor grating (assumed WK3422[8]) • 106 t structural steel • 20,950 No. silt fence posts (assumed 3 kg per post)[9] • 1,079 m^2 reno steel mattress (assumed 50 pitch, 3.15 core galvanised steel) • 100 m stock fence (assumed 1m high) • 774 m chainwire fence (calculations based on AS 1725) The density of steel was assumed to be 7,850 kg/m^3. EF sourced from SimaPro based on Australian data for steel with a 10% recycled content.
Stone / rock	Quantity estimated as 2,500 t, based on: • 2,389 t rock • 240 m^2 of rip rap (assumed 300 mm thick) The density of rip rap was assumed to be 1,602 kg/m^3. EF assumed to be similar to sand / gravel.
Valves	Quantity estimated as 26 t, based on: • 8 No. 2.5 m width x 1.2 m height Penstock (assumed 1.7 m x 1.7 for calculations)[10] It was assumed that the valves were 100% steel. The EFs for the valves raw materials were used as an approximation for the manufactured valves. EF sourced from SimaPro based on Australian data for steel with a 10% recycled content.
Raw Materials – EIO-LCA Method[11][12]	
Flow meters	Quantity estimated as 7 No. Magnetic flow meters. EF sourced from EIO-LCA US 1997 Purchaser Price database for 'Totalizing fluid meters and counting devices'.

[7] *Source: http://www.arcreo.com.au/content/news/docs/ARC_Reo_Handbook_08ed.pdf*

[8] *Source: http://www.locker.com.au/pdf/catalogues/tdm/LOCKER%20TDM%206-12.pdf*

[9] *Source ftp://ftp-fc.sc.egov.usda.gov/WSI/UrbanBMPs/water/construction/siltfence.pdf*

[10] *Source: http://www.trisuria.com/brochure_pdf/kt_penstock.pdf*

[11] *Source: Carnegie Mellon University Green Design Institute. (2009) Economic Input-Output Life Cycle Assessment (EIO-LCA) US Dept of Commerce 1997 Purchaser Price model [Internet], Available from: <http://www.eiolca.net/> [Accessed 13 Jul, 2009]*

[12] *Cost of items from TOC estimate. Values not provided as cost estimates are Commercial In Confidence.*

Parameter measured	Assumptions
Measuring instruments	Quantity estimated as 1 No. temperature transmitter. EF sourced from EIO-LCA US 1997 Purchaser Price database for 'Industrial process variable instruments'.
Control instrumentation	Quantity estimated as 1 No. PLC hardware. EF sourced from EIO-LCA US 1997 Purchaser Price database for 'Relay and industrial control manufacturing'.
Switchboard	Quantity estimated as: • 1 No. High Voltage Switchboard including spares • 1 No. Low Voltage Switchboard including spares EF sourced from EIO-LCA US 1997 Purchaser Price database for 'Switchgear and switchboard apparatus manufacturing'.
Electrical Installation	Quantity estimated as 1 No. electrical installation. EF sourced from EIO-LCA US 1997 Purchaser Price database for 'Wiring device manufacturing'.
Uninterruptible Power Supply	Quantity estimated as 1 No. 10 kVA UPS. EF sourced from EIO-LCA US 1997 Purchaser Price database for 'Electric power and specialty transformer manufacturing'.
Transport to/from Site[13]	
Cement, Cement mortar, precast Concrete, HDPE pipework, PET Polyester Geofabric, Steel (reinforcement, structural, miscellaneous), Bitumen and Diesel	It is assumed that these items will be sourced from Sydney, NSW and transported by rigid truck/tanker.
Concrete (ReadyMix)	It is assumed that these items will be sourced from Fyshwick, ACT and transported by rigid truck.
Construction equipment - cranes	It is assumed that cranes will be sourced from Newcastle, NSW and transported by rigid truck.
Construction equipment - vehicles	It is assumed that construction vehicles will be sourced locally from within 100 km and transported by rigid truck.
Gravel (including for asphalt)	It is assumed that these items will be sourced from Queanbeyan, ACT and transported by rigid truck.
Gypsum	It is assumed that gypsum will be sourced from Cassilis, NSW and transported by rigid truck.
Hay bales	It is assumed that these hay bales will be sourced from within 50 km and transported by rigid truck.
Pipes - PVC	It is assumed that PVC pipes will be sourced from Chipping Norton, NSW and transported by rigid truck.

[13] *Unless otherwise stated, road distance has been estimated by using the website http://maps.google.com.au. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.*

Parameter measured	Assumptions
Pipes – Reinforced Concrete and MSCL	It is assumed that these items will be sourced from Somerton, VIC and transported by rigid truck.
Quicklime	It is assumed that quicklime will be sourced from Marulan, NSW and transported by rigid truck.
Sand	It is assumed that sand will be sourced from Bungendore, NSW and transported by rigid truck.
Soil (fill)	It is assumed that fill will be sourced from within 50 km and transported by rigid truck.
Stone / rocks	It is assumed that stone / rocks will be sourced from within 100 km and transported by rigid truck.
Valves, Pumps	It is assumed that these items will be sourced from Germany, transported to Melbourne by sea and then to site by rigid truck. Ship distances have been estimated by using the website http://www.portworld.com/map/. Road distances have been estimated by using the website http://maps.google.com.au. Ship EF sourced from SimaPro based on Australian data for international shipping freight. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.
Waste	It is assumed that waste will be disposed of at Mugga Lane landfill, ACT and transported by rigid truck.
Construction	
Diesel consumption - construction vehicles	The quantity of diesel consumed by construction equipment was estimated as 4,600 kL using Brake Specific Fuel Consumption data reported in US EPA's report *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition, Report No. NR-009c (2004)*. The hours of use for each construction vehicle/equipment was estimated based on 8 h per day, 21 days per month and an utilisation factor that varied depending on the vehicle. The number of months for each vehicle/equipment was estimated and varied between 9 to 18 months. The horsepower for each vehicle/equipment was obtained from manufacturer vehicle specifications, where the model to be used was known, or estimated based on similar vehicles (using Caterpillar, John Deere specifications). EF from Tables 4 and 38 of the DCC NGA Factors (June 2009) for diesel (Scopes 1 and 3).

Parameter measured	Assumptions
Diesel consumption - generators	The quantity of diesel consumed by generators used outside the site compounds was estimated using Brake Specific Fuel Consumption data reported in US EPA's report *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition, Report No. NR-009c (2004)*. The hours of use were estimated based on operation of 4 generators for 8 hours per day, 21 days per month for 8-12 months and a power rating of 3.3 kVA. The quantity of diesel consumed by generators inside the site compounds was estimated as 400 L/day for the main compound, 300 L/day for the low lift and high lift site compounds and an 18 month construction period was assumed. Note electricity for site sheds is from generators. Total quantity of diesel consumed by generators estimated as 450 kL. EF from Tables 3 and 38 of the DCC NGA Factors (June 2009) for diesel (Scopes 1 and 3).
Disposal of spoil	Quantity estimated as 37,364 t, based on the quantity of material not returned to the trenches after placement of the pipes. All spoil was assumed to be stockpiled for re-use. Only emissions associated with transportation of spoil were considered in the disposal. It was assumed the spoil would be re-used within 50 km of site and transported by rigid truck. Rigid truck EF sourced from SimaPro and is based on Australian data for rigid trucks.
Waste	Quantity estimated as 2,729 t. EF sourced from Tables 42 of the DCC NGA Factors (June 2009) for construction and demolition waste (Scope 3).
Vegetation clearance	The quantity of vegetation to be cleared was estimated as being equivalent to: • Mature trees covering 5 ha; • Young tress (10 years) covering 2.1 ha; and • Saplings (3 years) covering 3 ha. These areas were based on the removal of: • 215 mature trees; • 265 young trees (between 2-6 m in height); and • 525 saplings (less than 2 m in height). The total carbon content of vegetation removed was estimated as 258 t C using FullCAM, based on *Eucalyptus sp*. 945 t CO_2-e emissions were calculated assuming carbon in vegetation formed carbon dioxide.

Parameter measured	Assumptions
Petrol consumption by workers travelling to site	Quantity estimated as 260 kL based on workers travelling separately in passenger vehicles, with fuel consumption of 0.113 L/km, sourced from Table 4, AGO Factors and Methods Workbook, December 2006. The number of workers and duration assumed is outlined below. The total number of days was based on 300 working days per year. • Intake/low lift pump station – 11 workers, 9 month duration; • High lift pump station – 22 workers, 12 month duration; • Outlet – 11 workers, 6 month duration; • Pipeline – 42 workers, 12 month duration; and • General – 12 workers, 18 month duration. It was assumed all workers would be situated in the Canberra region for the duration of the project and an 80 km round trip would be taken each day. EF from Tables 4 and 38 of the DCC NGA Factors (June 2009) for petrol (Scopes 1 and 3).
Operations	
Electricity	Quantity of water transferred from Murrumbidgee to Googong estimated as 8,877 ML/year (average for first 30 years of transfer) based on ActewAGL modelling. The electricity associated with pumping estimated as 1,138 kWh/ML based on the pipeline design. The electricity recovery percentage from the inclusion of a mini-hydro system is estimated as 18% (20% with Tantangara flows). Imported electricity sourced from grid. EF from Table 39 of the DCC NGA Factors (June 2009) for NSW and ACT (Scopes 2 and 3). Note, if water released from Tantangara Dam is included in the Murrumbidgee to Googong transfer, the volume of water transferred may be 14,000 ML/year. There would be no change in the electricity associated with pumping.

3 Energy and Greenhouse Analysis

3.1 Greenhouse emissions results

Emissions were calculated based on Scope 1, 2 and 3 emissions. These emissions were categorised as either occurring during the construction period or as an operational emission (annual basis).

3.1.1 Greenhouse inventory

The greenhouse assessment indicates total construction emissions of approximately 31,700 tonnes of CO_2-e over the construction period and average annual emissions of 8,800 tonnes of CO_2-e per annum. Scope 1, 2 and 3 emissions are summarised in Table 2 below.

Table 2 Summary of Scope 1, 2 and 3 emissions for Murrumbidgee to Googong Pipeline

Scope	Quantity (t CO_2-e)[1]
Construction	
1	15,200
2	0
3	16,500
Total emissions for construction	31,700
Annual operating emissions without Tantangara flows[2]	
1	0
2	7,400
3	1,400
Total annual operating emissions	8,800
Total annual operating emissions as percentage of NSW & ACT total emissions[3]	0.005%
Annual operating emissions with Tantangara flows[2]	
1	0
2	11,300
3	2,200
Total annual operating emissions	13,500
Total annual operating emissions as percentage of NSW & ACT total emissions[3]	0.007%

1. Emissions have been rounded.

2. Includes energy recovery from mini-hydro.

3. Total emissions for NSW and ACT based on DCC 'State and Territory Greenhouse Gas Inventories 2007'. Emissions for 2007 were 163 Mt CO_2-e

Emissions for construction were also categorised as raw materials (i.e. emissions associated with the extraction and processing of raw materials), transportation of raw materials to site, and construction activities. Construction activities are estimated to contribute 55% of all construction emissions associated with the M2G, raw materials 37% and transportation 7%. The major sources of emissions during construction and operations are summarised in Section 3.1.2, and the total emissions inventory for construction is given in Appendix B.

Electricity consumption was assumed to contribute 100% of the emissions during operations. Emissions and abatements associated with minor activities during operations were considered negligible and were excluded as detailed in Section 2.2.1.

3.1.2 Major emission sources for construction

The emissions contributing to 90% of the total emissions for construction are listed in Table 3.

Table 3 Emissions contributing 90% of total emissions for Murrumbidgee to Googong Water Transfer Project construction

Ranking	Source	Emissions ($t\ CO_2$-e)	Percentage of total emissions
1	Diesel consumption in construction vehicles	13,400	42%
2	Steel content of MSCL pipes	5,900	19%
3	Cement content of MSCL pipes	1,300	4%
4	Diesel consumption in generators	1,300	4%
5	Vegetation removal	900	3%
6	Waste disposal in landfill	800	3%
7	Ready mix concrete	800	3%
8	Transportation of MSCL pipe to site	700	2%
9	Sand	700	2%
10	Petrol consumption by workers travelling to site	700	2%
11	Transportation of sand to site	600	2%
12	Electrical installation items	600	2%
13	Reinforcement and anchor bars	**500**	**2%**
		28,200	**90%**

3.1.3 Breakdown between NSW and ACT

Approximately 2.3 km (or 20%) of the pipeline is located in the ACT. This includes the low lift and high lift pump stations, and as such, all electricity for operation of the pipeline will be consumed in the ACT. On this basis, approximately 6,300 t CO_2-e of construction emissions will be associated with the ACT section of the pipeline. Approximately 25,400 t CO_2-e of construction emissions will be associated with the NSW section of the pipeline.

3.1.4 Emissions over the life of the development

The total construction and operational emissions (without Tantangara flows) for the first thirty years of operations are estimated to be 295,700 t CO_2-e. With Tantangara flows the total construction and operational emissions for the first thirty years of operation would are estimated to be 436,700 t CO_2-e. Projections past thirty years may provide inaccurate estimates due to likely changes in emission factors associated with electricity production. The construction emissions contribute approximately 11% of the total emissions for the first thirty years without Tantangara flows and approximately 7% with Tantangara flows. This percentage will decrease as the operation of the pipeline extends past thirty years.

Appendix A System Boundary

Construction materials

Emissions associated with the extraction and processing of construction materials.

- Bitumen
- Cement (pipes, miscellaneous works)
- Cement mortar
- Concrete (pipes, miscellaneous works)
- Electrical equipment (flow meters, measuring instruments, control instruments (PLC), switchboard, UPS, electrical wiring)
- Gypsum
- Hay bales
- HDPE pipes
- PVC pipes
- PET geofabric
- Sand
- Gravel
- Quicklime
- Soil (fill)
- Steel (pipes, pumps, reinforcement, valves, miscellaneous items)
- Stone / rocks
- *Construction vehicle maintenance materials (oil/lubricants)*
- *Manufacture of construction vehicles and equipment*
- *Materials for electricity distribution infrastructure*
- *Materials for minor construction items (cables and associated electrical equipment, flanges etc)*
- *Water*
- *Explosives*

→

Transport of Materials

Emissions associated with the transportation of construction materials from their point of production to the site and waste material from site

- Bitumen
- Cement (pipes, miscellaneous works)
- Cement mortar
- Concrete (pipes, miscellaneous works)
- Construction equipment and vehicles
- Diesel
- Electrical equipment (flow meters, measuring instruments, control instruments (PLC), switchboard, UPS, electrical wiring)
- Gypsum
- Hay bales
- HDPE pipes
- PVC pipes
- PET geofabric
- Sand
- Gravel
- Quicklime
- Soil (fill)
- Steel (pipes, pumps, reinforcement, valves, miscellaneous items)
- Stone / rocks
- Waste to landfill
- *Construction vehicle maintenance materials (oil/lubricants)*
- *Materials for electricity distribution infrastructure*
- *Materials for minor construction items (cables and associated electrical equipment, flanges etc)*
- *Water*
- *Explosives*

→

Construction Activities

Emissions associated with the construction activities

- Diesel consumption in construction vehicles and generators
- Transportation of spoil for re-use
- Vegetation removal
- Waste disposal in landfill
- Workers travelling to site
- *Wastewater treatment*
- *Re-vegetation activities*
- *Onsite refuelling infrastructure and fugitive emissions*
- *Use of explosives*

→

Operation

Emissions associated with the operation and maintenance of the pipeline

- Electricity
- *General maintenance and operations*
- *Abatement due to re-vegetation of cleared land*

↓

Decommissioning

Emissions associated with decommissioning of the infrastructure

Items in blue have been excluded from the assessment.

Figure 1 System Boundary for the Murrumbidgee to Googong Pipeline

Appendix B Construction Greenhouse Gas Inventory

Table 4 Greenhouse Gas Inventory for Construction of the Murrumbidgee to Googong Pipeline

Component	Value (Q)	Units	Scope 1 Emission Factor (EF)	Scope 2 Emission Factor (EF)	Scope 3 Emission Factor (EF)	Total Emission Factor (EF)	Units	Source	Method	Scope 1 Emissions (t CO_2-e)	Scope 2 Emissions (t CO_2-e)	Scope 3 Emissions (t CO_2-e)	Total Emissions (t CO_2-e)	Proportion of Total Inventory %
Raw Materials														
Asphalt - gravel	440	t			0.017	0.017	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	7	7	0.0%
Bitumen	3	t			0.427	0.427	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	1	1	0.0%
Cement	40	t			0.804	0.804	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	32	32	0.1%
Cement - mortar	1	t			0.466	0.466	t CO_2-e/t	SimaPro EcoInvent Database	Q x EF	0	0	0	0	0.0%
Pipe – cement component of MSCL pipes	1,617	t			0.804	0.804	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	1,300	1,300	4.1%
Concrete - precast	343	t			0.141	0.141	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	48	48	0.2%
Concrete - Readymix	5,680	t			0.141	0.141	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	801	801	2.5%
Gravel	8,900	t			0.017	0.0169	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	150	150	0.5%
Gypsum	72	t			0.182	0.182	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	13	13	0.0%
Hay bale	440	t			0.213	0.213	t CO_2-e/t	SimaPro EcoInvent Database	Q x EF	0	0	94	94	0.3%
HDPE pipes	7	t			2.400	2.4	t CO_2-e/t	SimaPro Industry Data 2.0 database	Q x EF	0	0	18	18	0.1%
PET geofabric	71	t			2.250	2.25	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	159	159	0.5%
Pipes – concrete component of RC pipes	164	t			0.141	0.141	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	23	23	0.1%
Pipes - steel component of RC pipes	5	t			2.07	2.070	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	11	11	0.0%
Pumps - steel	15	t			2.070	2.07	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	31	31	0.1%
PVC - pipes	41	t			3.140	3.14	t CO_2-e/t	SimaPro Industry Data 2.0 database	Q x EF	0	0	128	128	0.4%
Quick Lime	3	t			1.130	1.130	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	3	3	0.0%
Sand	41,700	t			0.017	0.0169	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	705	705	2.2%
Soil	18,886	t			0.017	0.017	t CO_2-e/t	Assumed similar to Sand / gravel	Q x EF	0	0	319	319	1.0%
Steel - reinforcement and anchor bars	258	t			2.070	2.07	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	534	534	1.7%
Steel - pipe	2,864	t			2.070	2.07	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	5,928	5,928	18.7%
Steel - structural, miscellaneous	253	t			2.070	2.07	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	523	523	1.7%
Stone	2,500	t			0.017	0.017	t CO_2-e/t	Assumed similar to Sand / gravel	Q x EF	0	0	42	42	0.1%
Valves - steel	26	t			2.070	2.07	t CO_2-e/t	SimaPro Australian Database	Q x EF	0	0	55	55	0.2%
Total Raw Materials										**0**	**0**	**10,925**	**10,925**	**34.5%**
Raw Materials – IO Method[14]														
Flow meters	1	item			24	24	t CO_2-e/item	Carnegie Mellon University Green Design Institute	Q x EF	0	0	24	24	0.1%
Measuring instruments	1	item			1	1	t CO_2-e/item	Carnegie Mellon University Green Design Institute	Q x EF	0	0	1	1	0.0%

[14] *Carnegie Me lon University Green Design Institute (2009) Economic Input Output Life Cycle Assessment (EIO LCA) US Dept of Commerce 1997 Purchaser Price model [Internet], Available from <http //www eiolca net/> [Accessed 13 Jul, 2009]*

Component	Value (Q)	Units	Scope 1 Emission Factor (EF)	Scope 2 Emission Factor (EF)	Scope 3 Emission Factor (EF)	Total Emission Factor (EF)	Units	Source	Method	Scope 1 Emissions (t CO_2-e)	Scope 2 Emissions (t CO_2-e)	Scope 3 Emissions (t CO_2-e)	Total Emissions (t CO_2-e)	Proportion of Total Inventory %
Control instrumentation	1	item			77	77	t CO_2-e/item	Carnegie Mellon University Green Design Institute	Q x EF	0	0	77	77	0.2%
Switchboard	1	item			183	183	t CO_2-e/item	Carnegie Mellon University Green Design Institute	Q x EF	0	0	183	183	0.6%
Electrical Installation	1	item			577	577	t CO_2-e/item	Carnegie Mellon University Green Design Institute	Q x EF	0	0	577	577	1.8%
Uninterruptible Power Supply	1	item			19	19	t CO_2-e/item	Carnegie Mellon University Green Design Institute	Q x EF	0	0	19	19	0.1%
Total Raw Materials (IO Method)										**0**	**0**	**881**	**881**	**2.8%**
Transportation of Materials to Site														
Asphalt - gravel	440	t			7	7	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	3	3	0.0%
Bitumen	3	t			80	80	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	0	0	0.0%
Cement	40	t			80	80	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	3	3	0.0%
Cement - mortar	1	t			80	80	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	0	0	0.0%
Concrete - precast	343	t			80	80	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	27	27	0.1%
Concrete - Readymix	5,680	t			10	10	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	57	57	0.2%
Construction equipment - construction vehicles	1,116	t			25	25	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	27	27	0.1%
Construction equipment - cranes	289	t			113	113	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	33	33	0.1%
Diesel	4,293	t			80	80	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	342	342	1.1%
Gravel	8,900	t			7	7	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	65	65	0.2%
Gypsum	72	t			153	153	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	11	11	0.0%
Hay bale	440	t			12	12	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	5	5	0.0%
HDPE pipes	7	t			80	80	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	1	1	0.0%
PET geofabric	71	t			80	80	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	6	6	0.0%
Pipes - MSCL	4,481	t			161	161	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	721	721	2.3%
Pipes - reinforced concrete	170	t			161	161	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	27	27	0.1%
Pumps - steel	15	t			278	278	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	4	4	0.0%
PVC - pipes	41	t			63	63	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	3	3	0.0%
Quick Lime	3	t			39	39	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	0	0	0.0%
Sand	41,700	t			15	15	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	613	613	1.9%
Soil	18,886	t			12	12	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	231	231	0.7%
Steel - reinforcement and anchor bars	258	t			80	80	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	21	21	0.1%
Steel - structural, miscellaneous	253	t			80	80	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	20	20	0.1%
Stone	2,504	t			25	25	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	61	61	0.2%
Valves - steel	26	t			278	278	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	7	7	0.0%

Component	Value (Q)	Units	Scope 1 Emission Factor (EF)	Scope 2 Emission Factor (EF)	Scope 3 Emission Factor (EF)	Total Emission Factor (EF)	Units	Source	Method	Scope 1 Emissions (t CO_2-e)	Scope 2 Emissions (t CO_2-e)	Scope 3 Emissions (t CO_2-e)	Total Emissions (t CO_2-e)	Proportion of Total Inventory %
Waste	2,729	t			7	7	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	20	20	0.1%
Total Materials Transportation										**0**	**0**	**2,310**	**2,310**	**7.3%**
Construction														
Diesel in generators	450	kL	2.7		0.2	2.9	t CO_2-e/kL	NGA Factors June 2009	Q x EF	1,207	0	92	1,299	4.1%
Diesel use in construction vehicles	4,600	kL	2.7		0.2	2.9	t CO_2-e/kL	NGA Factors June 2009	Q x EF	12,411	0	941	13,353	42.2%
Petrol consumption (Workers travel to site)	260	kL	2.4		0.2	2.6	t CO_2-e/kL	NGA Factors June 2009	Q x EF	619	0	47	666	2.1%
Transportation of spoil for re-use	37,364	t			12	12	kg CO_2-e/t	Materials Delivery worksheet	Q x EF / 1000	0	0	458	458	1.4%
Vegetation clearance	Refer to Table 1									945	0	0	945	3.0%
Waste	2,729	t			0.3	0.3	t CO_2-e/t waste	NGA Factors June 2009	Q x EF	0	0	819	819	2.6%
Total Construction										**15,183**	**0**	**2,357**	**17,540**	**55.4%**
Total emissions for construction period										***15,183***	***0***	***16,474***	***31,657***	