Northern Link

8. Air Quality and Greenhouse Gases

Northern Link

Phase 2 – Detailed Feasibility Study

CHAPTER 8

AIR QUALITY AND GREENHOUSE GASES

- September 2008

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8. Air Quality and Greenhouse Gases

This chapter addresses Part B Section 5.3 of the Terms of Reference (ToR). The chapter discusses regional air quality conditions and the local ambient air quality at each of the worksites, at possible vent site locations and at sensitive places potentially affected by the project. Prevailing meteorology and wind directions are discussed, along with existing emission sources influencing air quality in the area. The chapter deals with construction and operational air quality effects of the project.

Two Technical Reports provide the basis for much of the air quality assessment within this chapter. Technical Report No. 7 – Air Quality by Holmes Air Sciences deals with the impacts of the operation of the project on ambient air quality. Technical Report No. 7A – Construction Air Quality by SKM Connell Wagner Joint Venture deals with the potential impacts on air quality during construction..

The potential impacts on ambient air quality are assessed against criteria set by the Queensland Government and the National Environment Protection Council. Processes for managing construction impacts and mitigation measures for the operation of the tunnel are outlined.

The impacts of the proposal on air quality are assessed using:

- *for construction – an assessment of dust emissions on sensitive receivers near work compounds and construction sites; and*
- *for operation – computer dispersion modelling of emissions from ventilation outlets and from roads subject to significant changes in traffic volumes. Changes in emissions are also assessed in the context of the Brisbane airshed.*

Methods for controlling dust levels during construction activities are identified. Mitigation measures for tunnel operation are also described. Amongst the considered mitigation measures for tunnel operation are the suitability and availability of air filtration technologies. Trends in filtration technology are also reviewed.

In-tunnel air quality conditions are described and their compliance with PIARC standards and comparable standards for in-tunnel air quality from other countries are described.

Technical Report No. 7B – Greenhouse Gas Emissions Impact Assessment by SKM Connell Wagner Joint Venture provides an assessment of impacts of the project on greenhouse gas emission levels. The energy consumption during construction and operation of the tunnel is summarised in this chapter, and the implications of this for greenhouse gas emissions assessed.

8.1 Description of the Existing Environment

8.1.1 Background on Dispersion Meteorology and Modelling

The air quality assessment for the operation of the Project is based on the use of computer-based dispersion modelling to predict air pollutant concentrations in the study area. The assessment considers air pollutants arising from motor vehicles using the tunnel and regional surface roads and predicts concentrations at key locations by modelling the means by which those pollutants are dispersed. Wind patterns are important for the transportation and dispersion of air pollutants. As well as information on prevailing wind patterns, historical data on temperature, humidity and rainfall are presented in this section to give a more complete picture of the local climate. The study area for this assessment extends over about 200km^2, centred on the study corridor.

To undertake the dispersion modelling, knowledge of the meteorology in the study area is required. The meteorology in the study corridor would be influenced by several factors including the local terrain and land-use. On a smaller scale, winds would be largely affected by the local topography. Regionally, winds are affected by synoptic scale winds, which are modified by sea breezes in the daytime in summer (also to a certain extent in the winter) and also by a complex pattern of regional drainage flows that develop overnight.

Given the relatively diverse terrain and land use in the study corridor, differences in wind patterns at different locations in the study corridor would be expected. These varying wind patterns would arise as a result of the interaction of the air flow with the surrounding topography and the differential heating of the land and water.

In the air quality assessment that has been undertaken for this Project the complex mechanisms that affect air movements in the study corridor are to be assessed to ensure that these patterns are incorporated into the dispersion modelling studies that are done. One of the objectives for reviewing local meteorological data is to determine the most suitable sites and years available for the modelling. Typically, one year of hourly records would be sufficient to cover most variations in meteorology that would be experienced at a site. It is important, however, that the selected year is generally typical of the prevailing meteorology.

Wind data from four Queensland Environmental Protection Agency (EPA) monitoring sites (Brisbane CBD, Rocklea, South Brisbane and Woolloongabba) and two project monitoring sites (Bowen Hills and Kedron) have been reviewed. The meteorological data collected from all meteorological monitoring sites included hourly records of temperature, wind speed and wind direction and 2005 has been selected for development of the meteorological wind field for the air quality assessment, based on the number of nearby sites available for the modelling and on the completeness of the data records. Also, from comparison of the wind patterns at each monitoring site, 2005 can be considered a representative year.

The following sections describe each of the meteorological data sets in detail, with a focus on the 2005 calendar year.

Brisbane CBD

On an annual basis the winds are predominantly from the north or east-southeast. Very few to no winds are derived from the western sectors and it was noted by EPA that nearby tall buildings shelter the sensors from these winds and also lead to turbulence at this site. The annual average wind speed at the Brisbane CBD site in 2005 was 0.7m/s. This site recorded a very high percentage of calms, where winds are less than or equal to 0.5m/s, at 50% which would be largely due to the sheltering effect of buildings located around the wind sensors.

Rocklea

EPA’s Rocklea monitoring station is located in an open area amongst light industrial and residential land use. Annually, winds in Rocklea are predominantly from the south to south-west, with some winds also from the north-northeast and east-southeast quadrants. The south-westerly winds tend to be much lighter than the north-easterly winds, which would represent the direction of the sea-breeze. The lighter south-westerly winds occur in the cooler months of autumn and winter, while the north-easterly winds occur in the warmer months of summer and spring. Winds in the Rocklea area tend to be stronger than at the other sites examined, as the annual average wind speed for 2005 was 2.4m/s. This is consistent with the more exposed nature of the site. The percentage of calm days in 2005 was 7%.

South Brisbane

The South Brisbane site is located adjacent to the Southeast Freeway and provides information on air quality typically experienced at the boundary of major traffic corridors in southeast Queensland. Annually, winds at this site are predominantly from the north-east quadrant. This pattern of winds is present in the warmer months of summer and spring. Winds from the south and east-southeast prevail in autumn while in winter, light west-southwest winds dominate. Very few winds from the northwest are measured at this site. The annual average wind speed from South Brisbane in 2005 was 1.7m/s and the percentage of calms was 13.4%.

Woolloongabba

The EPA's Woolloongabba station is situated close to a busy road (Ipswich Road) which makes it ideal for monitoring air pollution from traffic sources. There are tall buildings nearby which shelter the site from some wind directions. Winds are variable at this site, but generally comprise light winds from the south-west or stronger winds from the north-east or east-southeast. Very few winds from the north-west are measured at this site. In 2005, the annual average wind speed at this site was 2.1m/s and the percentage of calms was 6.9%.

Bowen Hills

Ambient air quality and meteorological monitoring for the Clem Jones Tunnel (CLEM7)[1] commenced at Bowen Hills in June 2004. This site is at the north-eastern end of the Northern Link study corridor. Monitoring stopped in December 2005. Wind data collected in 2005 from this site show that, like many of the EPA monitoring locations, light winds from the south-west prevail, most commonly in the cooler seasons of the year. The sea-breeze is present as stronger winds from the north-east in the warmer seasons. This site experienced a relatively high proportion of calm conditions (15.3% or the time) and the annual average wind speed in 2005 was 1.8m/s.

Kedron

Meteorological and ambient air quality monitoring data from Kedron were collected for the Airport Link (AL) Project between January 2006 and January 2007. In 2006 winds were predominantly from the south-southwest or north-northeast. Summer winds were generally from the north-northeast to east-southeast, representing the direction of the sea-breeze. The winter months generally bring much lighter winds originating from the south-west quadrant. Spring and autumn winds show similarities between both summer and winter. The annual average wind speed at the Kedron site in 2006 was 1.6m/s and the percentage of calms was 13.9%. The data from Kedron in 2006 are similar to the data collected at Bowen Hills in 2005.

For the purposes of the air quality assessment, data collected in 2005 from the Rocklea, South Brisbane, Woolloongabba and Bowen Hills meteorological monitoring sites were considered to be the most suitable datasets for the meteorological model. The proximity of these sites to the area of interest ensures that they would contain data that are representative of the dispersion conditions in the study corridor. The meteorology at the Brisbane CBD site is affected by the turbulence induced by nearby buildings and the wind data would not be representative of the broader scale wind patterns.

8.1.2 Sensitive Places

Sensitive places identified in the general area of the Project include the residential dwellings in the Northern Link study corridor as well as 20 sensitive places in the aged care, child care, place of worship, educational, heritage and commercial categories as listed in **Table 8-1**. These sensitive places have been identified from a variety of sources including the social infrastructure study plans, general project information, site visits and a review of the latest UBD. These sensitive places are within the scope of the dispersion modelling undertaken

[1] Formerly known as the North-South Bypass Tunnel (NSBT).

for the Project and their air quality impacts are treated in the same manner as the surrounding residential properties.

- **Table 8-1** Sensitive Places

Type	Facility	Location
Aged Care	The Rosalie Nursing Care Centre	The Rosalie Nursing Care Centre
	Hilltop Gardens Aged Care	23 Rochester terrace, Normanby
Child care	C&K Rosalie Kindergarten and Preschool	cnr Nash & Elizabeth Street, Rosalie
Place of Worship	Toowong Baptist Church	5 Jephson Street, Toowong
	Brisbane New Church	21 Agars Street, Rosalie
	St Brigid's Roman Catholic Church	78 Musgrave Road, Red Hill
	Toowong State School	St Osyth Street, Toowong
	Bible College of Queensland	1 Cross Street, Toowong
Education	Milton State School	Bayswater Road, Milton
	Marist College Rosalie	58 Fernberg Road, Paddington
	Petrie Terrace State School	Moreton Street, Paddington
	Queensland University of Technology	Kelvin Grove Campus
	Brisbane Grammar School	Gregory Terrace, Spring Hill
	Brisbane Girls Grammar School	Gregory Terrace, Spring Hill
	St Joseph's College	285 Gregory Terrace, Spring Hill
Heritage	Toowong Cemetery	Mt Coot-tha Road, Toowong
	Brisbane Botanic Gardens	Mt Coot-tha Road, Toowong
Commercial	Red Cross	Kelvin Grove Urban Village
	LaBoite Theatre	Kelvin Grove Urban Village

8.1.3 Air Monitoring Results

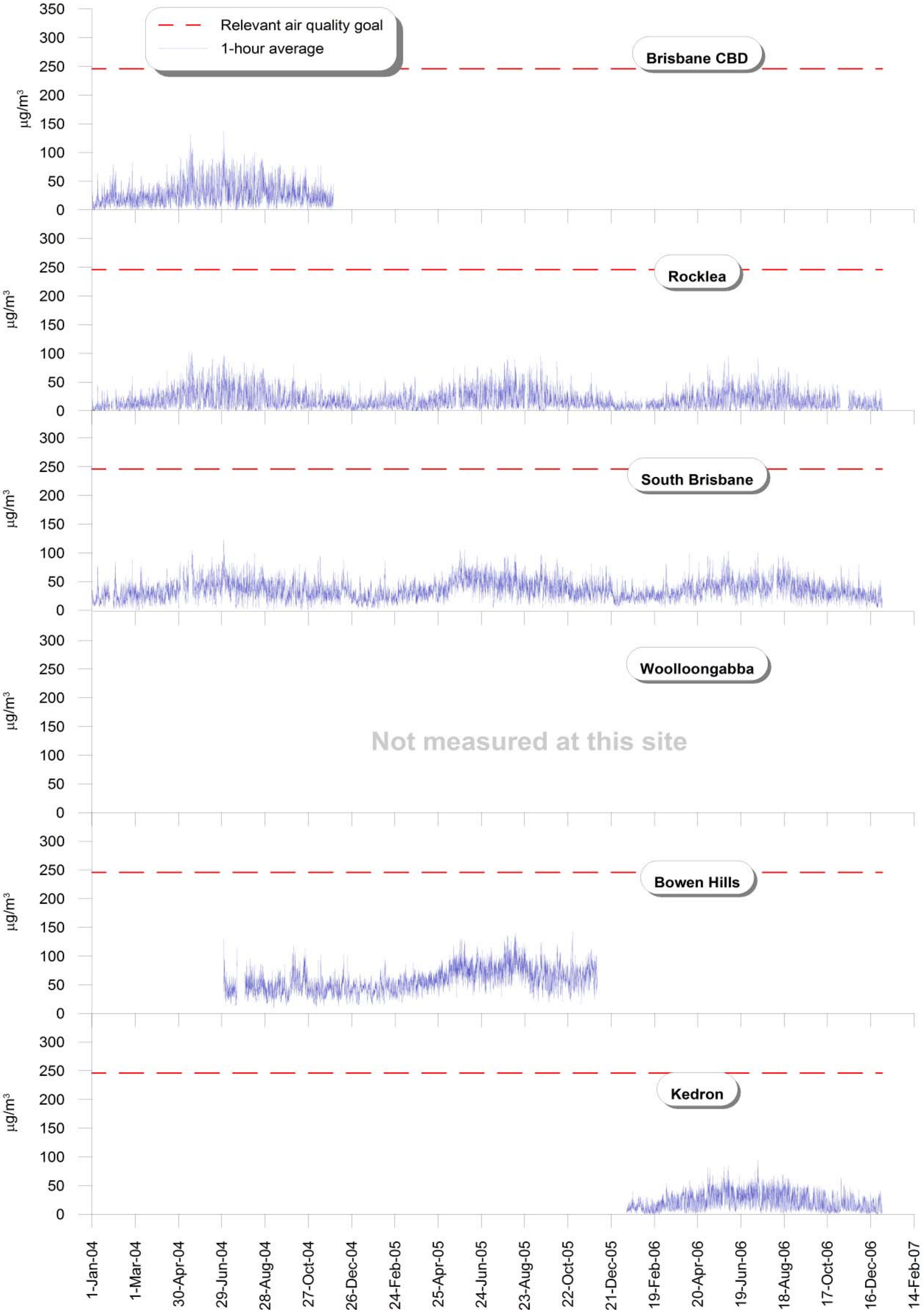
This section presents a review of air quality monitoring data that have been collected in and around the study corridor. The data are used as indicators of the existing air quality in various parts of the study area and can be compared with relevant standards and goals identified for construction and operation of the Project.

Data from four EPA air quality monitoring sites (Brisbane CBD, Rocklea, South Brisbane and Woolloongabba) and two road tunnel project monitoring sites (Bowen Hills and Kedron) have been assessed for the purposes of this study. The measurements are summarised below.

- Brisbane CBD included measurements of SO_2, NO_2, PM_{10}, O_3 and CO.
- Rocklea included measurements of O_3, NO_2, PM_{10} and $PM_{2.5}$.
- South Brisbane included measurements of CO, NO_2 and PM_{10}.
- Woolloongabba included measurements of CO and PM_{10}.
- Bowen Hills included measurements of CO, NO_2, PM_{10} and $PM_{2.5}$.
- Kedron included measurements of CO, NO_2, PM_{10} and $PM_{2.5}$.

In addition, two monitoring sites have been established for the Northern Link project, one at Toowong and another at Kelvin Grove. Monitoring at Toowong commenced in November 2007 and covers the southern end of the Project. The Kelvin Grove site covers the northern end of the Project and was established in July 2008.

All air quality monitoring is benchmarked against a series of standards or goals established by the Queensland EPA or by the National Environmental Protection Council as listed in **Table 8-10**. Ambient air quality data collected in the Brisbane area is presented in *Technical Report No 7 Air Quality in Volume 3* of the EIS. **Figure 8-1** shows the measured NO2 levels in the Brisbane region and **Figure 8-2** shows the measured levels of PM10 in the Brisbane region.

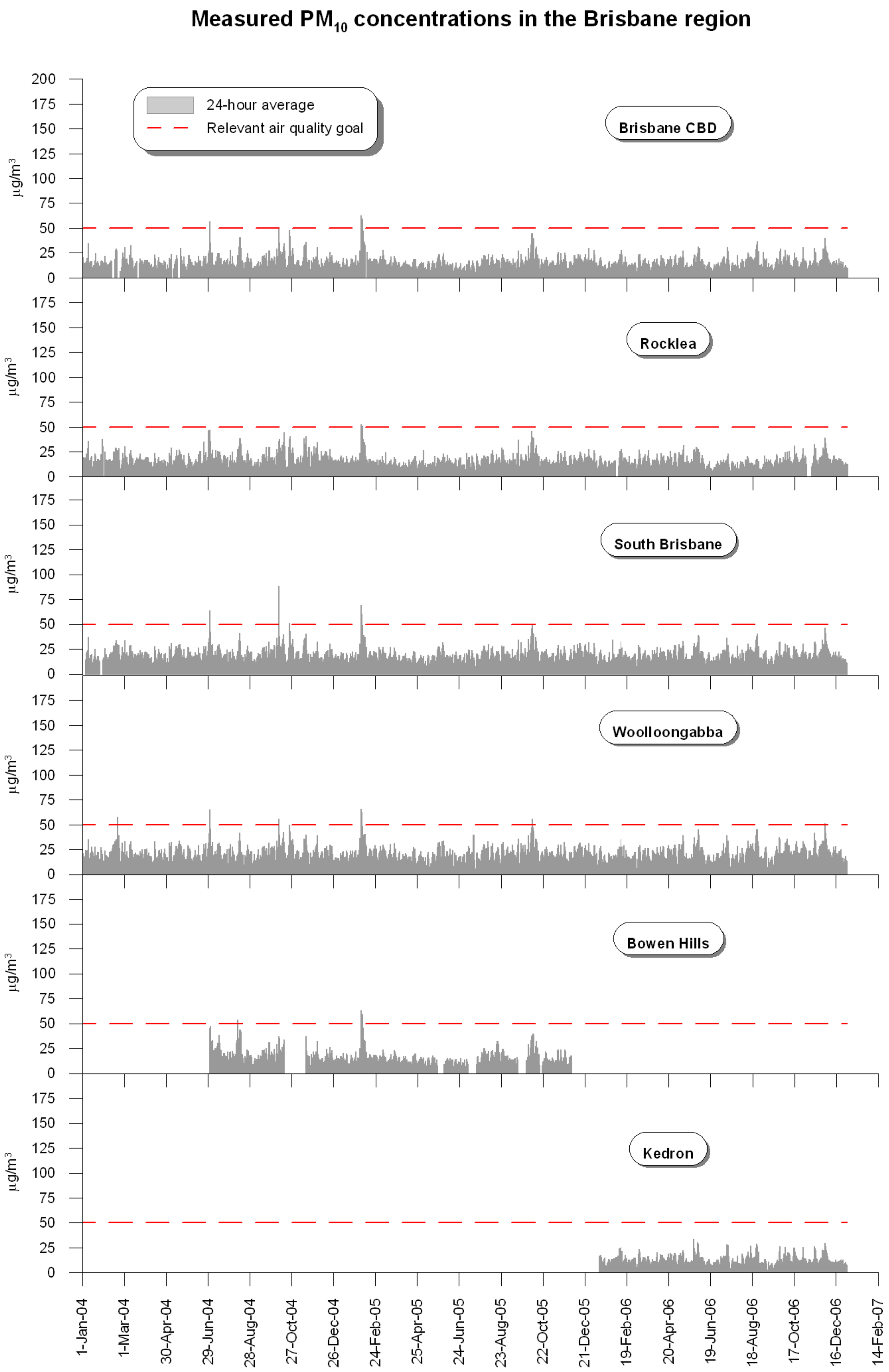


LEGEND

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 8-1

Measured NO_2 concentrations in the Brisbane region



NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 8-2

Measured PM_{10} concentrations in the Brisbane region

Northern Link
SKM Connell Wagner
JOINT VENTURE

The monitored data of pertinent pollutants in the Brisbane region show the following

- CO concentrations have been, and are likely to continue to be, below the EPA air quality goal. Compliance with the EPA goal has been exhibited near busy roads as well as in residential areas and parklands.
- Maximum NO_2 concentrations have been, and are likely to continue to be, below the EPA's short-term air quality goal. One instance where an exceedance of the annual average NO_2 goal has been recorded at a location near a train yard with movements of diesel engines. Annual average NO_2 concentrations at the remaining monitoring sites, covering busy road as well as residential locations, have been below the EPA's goal.
- Lighter winds and less rain in the cooler months of the year generally lead to higher concentrations of the primary pollutants, CO and NO_2 in particular, at most monitoring locations.
- Ozone and SO_2 concentrations are below the EPA's air quality goals at all monitoring locations.
- Short-term (that is, daily) PM_{10} concentrations have exceeded the NEPM standard (of 50ug/m^3) at all monitoring locations on at least one occasion in recent years. These events generally coincide with widespread dust storms or bushfires which can influence large areas. Widespread dust storms or bushfires generally trigger elevated levels at all monitoring locations. There have been no exceedances of the EPA goal (of 150ug/m^3), which is less stringent than the NEPM standard.
- Annual average PM_{10} concentrations are below the EPA's air quality goals at all monitoring locations.
- Short-term (daily) and annual average $PM_{2.5}$ concentrations have been above the NEPM 'Advisory Reporting Standards' on occasions at two of the three monitoring locations. As for PM_{10}, the highest $PM_{2.5}$ concentrations are usually influenced by widespread events.

Mt Coot-tha quarry dust monitoring

Because there are existing community concerns relating to potential dust nuisance emanating from the operation of Mt Coot-tha quarry operations this study has accessed dust monitoring data independently acquired for the quarry over a representative 12 month period in 2004-2005.

The air quality goals of Schedule 1 of the *Environmental Protection Policy (Air)* relevant to dust nuisance and applicable to this Project, are as follows:

- PM_{10} maximum 24-hourly average – 150 µg/m^3;
- PM_{10} annual average - 50 µg/m^3;
- TSP annual average - 90 µg/m^3.

The relevant standard for PM_{10} in the National Environment Protection Measure (NEPM) for Air Quality (NEPC, 2003) is:

- PM_{10} maximum 24-hourly average, 50 µg/m^3 (with 5 allowable exceedences per year).

The application of the NEPM is intended to provide a representative measure of regional air quality, rather than a project specific target. Although the NEPM is not considered strictly applicable to construction projects it is recognised that projects should work towards achieving the NEPM goals.

Based on these standards the air quality goals adopted for Northern link for the assessment of construction impacts are presented in **Table 8-2**.

Table 8-2 Construction Air Quality Goals for the Project

Pollutant	Construction Air Quality Goals	
	Aim to achieve	Not to be exceeded
Particles as PM_{10}	50 µg/m^3 (24 hr average)	150 µg/m^3 (24 hr average)
	-	50 µg/m^3 (annual average)
Total Solid Particulates	-	90 µg/m^3 (annual average)
Dust deposition	120 mg/m^2/day	-

Holmes Air Sciences (2008) have provided a comprehensive picture of ambient air quality in the Brisbane area, from which has been extracted the dust-relevant data in **Table 8-3**.

Table 8-3 Particulate Matter Monitoring Results (µg/m^3), Brisbane (2004 – 2006)

Parameter	Brisbane CBD	Rocklea	South Brisbane	Woolloongabba
PM_{10}, 24-hour* maximum	62.4	52.6	88.3	66
PM_{10}, Annual Average	16.6	17.4	20	21.8

* 24-hour clock average

Maximum 24-hour PM_{10} concentrations exceed the NEPM goal of 50 µg/m^3 at all four monitoring locations. These relatively high concentrations of PM_{10} are usually attributed to widespread events such as dust storms or bushfires. Average PM_{10} concentrations do not exceed the relevant goal of 50 µg/m^3.

In addition, air quality investigations have been included for the area surrounding Mt Coot-tha Quarry. This information has been sourced from an investigation undertaken by Air Noise and Environment (2005) between April 2004 and March 2005. Two methods were used to assess particulate impacts from the quarry – dust deposition (total fall out) and directional dust monitoring. The directional dust method assesses the relative contribution of emissions from four wind directions (each with an angle of 90°) to particulate loadings at the receptor position. In both cases, monitoring was completed for a 30 day period (+/- 2 days) each month.

Monitoring results are summarised in **Table 8-4**. The dust deposition criterion of 120 mg/m^2/day was met at all residential sites and all quarry sites except during January 2005 at Site7 adjacent to the quarry .

As a group, March 2005 results show the highest average monthly levels recorded, and it is considered possible that the blasting at the quarry and resurfacing works to the north of Stuartholme College influenced this peak. The March results are similar, however, to those for February, and the most likely cause of the higher dust fallout rates was thought to be the meteorological conditions.

Table 8-4 Total Insoluble Matter (mg/m²/day) (Air Noise and Environment, 2005)

Site	2004								2005			Average
	Apr	May	June	July/ Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	
Community												
1[1] 333 Birdwood Tce	33.3	13.3	26.6	23.3	26.6	59.9	-[4]	16.7	30.0	59.9	30.0	28.2
2 15 Walter St	59.9	36.6	30.0	28.3	26.6	53.3	-[4]	-[4]	-[4]	23.3	50.0	28.0
5 Stuartholme College	63.3	16.7[3]	43.3	-[4]	33.3	76.6	73.3	50.0	76.6	40.0	46.6	43.6
Quarry												
3 Dingo Hill" above primary crusher	50.0	16.7	53.3	35.0	36.6	73.3	33.3	26.6	33.3	83.3	93.2	46.5
4 Botanical Garden / Quarry back entrance	53.3	10.0	40.0	31.6	30.0	83.3	40.0	3.3	36.6	63.3	96.6	42.4
6 Truck entry, Mt Coot-tha Rd	-[2]	50.0	40.0	-[4]	30.0	59.9	36.6	56.6	53.3	76.6	79.9	40.8
7 Bot. Grdn/ Quarry boundary	46.6	33.3	23.3	23.3	36.6	59.9	10.0	33.3	146.5	30.0	86.6	44.3

The directional dust gauge monitoring (Air, Noise & Environment, 2005) shows that for the sites located at the quarry (Sites 4 and 7) the direction quadrants with a full or partial angle of view to the quarry workings have the highest mass loadings. This is the northern quadrant for site 4 and the northern and western quadrants for site 7. These results indicate that for these locations the quarry is a significant influence on dust impacts.

This is not necessarily the case for the monitoring stations in residential areas. At Site 1, it was expected that the southern and western quadrants would display the highest dust loadings. This was not the case, however, with annual mass loadings highest for the south and north quadrants. This suggests that whilst the quarry (and perhaps other sources to the south such as the Western Freeway) may contribute to the dust there, other sources of particulates are located to the north.

At Site 5 the most significant influence is from the north of the monitoring location with mass levels more than double that of the southern quadrant. The eastern quadrant has the second highest mass loading, again indicating other local particulate sources are affecting the measurement position.

The data collected by Air Noise and Environment (2005) suggests that the quarry clearly influences dust deposition rates at the sampling sites close or adjacent to the quarry. While monitoring located further from the quarry indicates that a number of factors contribute to dust accumulation and the quarry is not necessarily the most significant contributor.

8.2 Potential Construction Impacts and Mitigation Measures

8.2.1 Construction Impacts Methodology and Criteria

The main construction activities associated with the Project would include:

- surface works, mainly road construction on the existing surface and in troughs constructed to accommodate roads ;
- underground works (ie: tunnel boring machine (TBM) and road headers to construct the main tunnels); and
- spoil removal by conveyor to the Mt Coot-tha quarry.

Road and tunnel projects potentially generate dust from excavation and material handling, odour from excavated material, and exhaust emissions from diesel powered equipment.

This section provides a qualitative assessment of impacts associated with the key construction activities including surface road works, worksite activities, Mt Coot-tha Quarry, diesel powered plant and equipment and cumulative impacts (ie: the combined impacts from the identified impacts).

Construction of the project is expected to occur for 3.5 years, commencing in 2009/2010. The following construction hours are expected.

- Surface works –6:30am – 6:30pm Monday – Saturday, and at no time during Sundays or Public holidays except in exceptional circumstances.
- Underground works may occur 24-hours a day, seven days per week.

Exceptional circumstances include works on arterial roads (to avoid disruption to peak traffic flows), works in railway corridors, or works involving transport of large prefabricated components such as bridge elements or tunnel boring machines.

Anticipated surface works may include demolition activities of existing buildings, demolition of existing road pavements and sidewalks, worksite preparation, earthmoving and excavation works, some drilling and blasting, stockpiling, handling and transport of excavated material (including loading of spoil into trucks), surface road and bridge construction works, dust from vehicles moving around unpaved areas or dirty paved areas, vehicle exhaust and operation of diesel powered equipment.

At this stage of project development surface works are anticipated to occur in relation to worksite compounds and to have the potential for impacts in areas adjacent to the following locations.

- Western Freeway south of Mt Coot-tha Botanical Gardens.
- Valentine Street, Toowong.
- The western end of Milton Road between Frederick Street and Markwell Street, Toowong.
- Morley Street, Toowong.
- Croydon Street, Toowong.
- The northern block of Jephson Street, Toowong.
- Sylvan Road between St Osyth Street and Earle Lane, Toowong.
- Lower Clifton Terrace, Kelvin Grove.
- Kelvin Grove Road between Dalley Street and the Inner City Bypass.
- On the corner of Rusden Street and Victoria Street, Kelvin Grove.
- Along the southern section of Victoria Park Road, Kelvin Grove.
- Along the eastern end of the Inner City Bypass.

8.2.2 Construction Air Quality Impacts

The major project activity with the potential to cause air quality impacts is the construction of the tunnels and handling of the spoil so generated. These activities may potentially generate dust that must be contained and prevented from escaping to the atmosphere. The quantities of spoil produced and the methods of handling the spoil generated from different construction methodologies are described in Chapter 4 of the EIS.

Western Freeway Worksite (WS1)

The primary function of Worksite 1 would be to service tunnelling activities and surface works on the Western Freeway. The main sources of potential air quality impacts at WS1 include:

- land clearing for site preparation;
- earthmoving and excavation works;
- tunnelling (driven and cut-and-cover) and emissions of tunnel ventilation air;
- stockpiling, handling and transport of excavated material (including loading of spoil into trucks);
- wheel generated dust
- from vehicles moving around unpaved or dirty areas;
- vehicle exhaust emissions; and
- operation of diesel powered equipment.

To control dust emissions from the tunnelling and spoil movement, a Tunnel Portal Cover Shed (TPCS) would be constructed on site as part of the initial site establishment works. The area would also be surrounded by a 2m fence covered with a cloth screen to help reduce dust emissions from the site.

It is anticipated that spoil generated during construction of the transition structures and cut and cover tunnels at the Western Freeway connection would be trucked to the Swanbank spoil placement site. Spoil removed by the TBMs would travel by conveyor from the tunnel mouths to a transfer station from which a single conveyor would emerge and continue to the Mt Coot-tha Quarry. All stockpiling, truck and conveyor loading activities would be undertaken entirely within the worksite sheds or within the tunnel excavation area. The conveyor would be fully enclosed along its length between the work shed and the quarry.

To maintain adequate air quality within the underground working environment, ventilation fans would need to be located within the tunnels. At each of the tunnel portal worksites, ventilation air from the tunnelling works would leave the work shed after passing through dust extraction equipment to remove particles from the ventilation air. Details on the dust extraction equipment would be provided during the detailed design stage of the project construction works, when tunnel ventilation and air extraction rates are determined. The performance of the extraction equipment would be detailed during the detailed design stage of the works but would be designed to satisfy the Environmental Protection (Air) Policy 1997 requirements and be sufficient to minimise nuisance dust impacts on adjacent sensitive places.

A summary of excavation at Worksite 1 is provided in **Table 8-5**.

Table 8-5 Excavation Works Summary – Worksite 1

Parameter	Value
Total spoil (m^3)	1,105,000
- quantity sent to Mt Coot-tha Quarry (m^3)	840,000
- quantity sent to Swanbank (m^3)	265,000
Duration (months)	14
Average number of trucks per day	58

Toowong Worksite (WS2)

WS2 would primarily service activities associated with surface works on Milton Road and Valentine Street, the proposed overpass from Milton Road into the tunnels and roadheader works to construct the on and off ramps and the Y-Junctions on the mainline tunnels.

Activities likely to be undertaken at WS2 include:

- site preparation on the corner of Frederick Street and Milton Road including demolition of existing buildings and pavements;
- cut and cover activities east of Frederick Street;
- road header excavated driven tunnels east of Frederick Street;
- spoil movement and stockpiling at WS2;
- loading of spoil to trucks and transport off site;
- wind erosion from exposed surfaces;
- wheel generated dust from vehicles travelling along unpaved or dirty paved surfaces;
- surface road and bridge construction works; and
- potential drilling and blasting in areas with hard rock, or where particularly difficult conditions exist.

Spoil generated due to road works on Milton Road would not be stockpiled. This spoil would be immediately trucked from the site to Swanbank or transferred to the Western Freeway worksite to be carried by conveyor to the Mt Coot-tha Quarry.

A fence with cloth screening would be erected around the worksite to help reduce nuisance dust impacts.

Table 8-6 provides a summary of excavation work expected at Worksite 2.

Table 8-6 Worksite 2 Excavation Works Summary – Worksite 2

Parameter	Value
Total spoil (m^3)	260,000
- quantity sent to Mt Coot-tha Quarry (m^3)	240,000
- quantity sent to Swanbank (m^3)	20,000
Duration (months)	19
Average number of trucks per day	43

Kelvin Grove Worksite (WS 3)

WS3 would primarily service nearby surface works, road header works to construct the on and off ramps and the Y-Junctions along the mainline tunnels. A list of activities to be undertaken at Worksite 3 is identical with the list provided above for Worksite 2.

Spoil would be removed from road works as it is produced and trucked to the Port of Brisbane, with the intention of having as few permanent stockpiles as possible. A summary of excavation activities at Worksite 3 is provided in **Table 8-7**.

- **Table 8-7 Worksite 3 Excavation Works Summary**

Parameter	Value
Total spoil to Port of Brisbane (m^3)	300,000
Duration (months)	18
Average number of trucks per day	49

ICB work area

The ICB connection would require a number of relocations of traffic lanes as outlined in the Reference Project drawings, to enable construction of the transition structures and cut and cover tunnel sections. For this operation the works area would shift several times to areas between or beside operational traffic lanes. It would not be established as a permanent worksite. Towards the end of the construction works the TBMs would be taken out of the ground near the Victoria Park Road intersection at the end of their drives or in the troughs constructed for the cut and cover sections.

Activities likely to be undertaken at the ICB connection include:

- lane realignments along the Inner City Bypass;
- surface works along the Inner City Bypass;
- spoil removal from transition structures and cut and cover tunnel construction;
- loading of spoil to trucks and transport off site; and
- potential drilling and blasting in areas with hard rock, or where particularly difficult conditions exist.

A summary of activities at Worksite 4 is provided in **Table 8-8**.

- **Table 8-8 Worksite 4 Excavation Works Summary**

Parameter	Value
Total spoil (m^3)	25,000
Total spoil (tonnes)	63,750
Duration (months)	23
Average number of trucks per day	3
Average number of trucks per hour	N/A

Mt Coot-tha Quarry

Mt Coot-tha Quarry currently extracts materials for asphalt and concrete aggregate. Current operations at the Quarry include:

- excavation activities and occasional blasting;

- crushing and screening;
- product stockpiling and transfers; and
- product loading to trucks and transport off site via Mt Coot-tha Road.

The quarry operates under a licence issued under the provisions of the Environmental Protection Act 1994. This licence has certain air quality provisions that are not expected to be exceeded by the placement and processing of tunnel construction spoil at the quarry.

The preferred option handling spoil generated from tunnel construction is via an enclosed conveyor to the quarry. Spoil would then be stockpiled, processed and distributed to appropriate uses. Changes to activities at Mt Coot-tha Quarry are likely to include reduced blasting and increased stockpiling but numbers of truck movements are not expected to change.

Diesel Powered Vehicles and Plant

The potential for air quality impacts from construction vehicle fleet exhaust emissions would depend on the size and type of vehicle fleet, the hours of operation and the type of controls adopted by the Construction Contractor. The main sources of exhaust emissions from diesel powered equipment are likely to include:

- vehicles working at the surface construction site, such as excavators, front-end loaders, scrapers, rollers, backhoes, concrete trucks, delivery trucks, truck-mounted cranes, rock hammers, etc;
- trucks queuing adjacent to sensitive receivers located near the surface worksites;
- fully-laden trucks exiting the main tunnel excavation worksites and commencing their journey to spoil placement areas;
- stationary plant emissions (mobile generators, dewatering pumps, concrete pumps, etc); and
- vehicles and equipment operating within the underground excavation area or within the enclosed workshed, including front end loaders, trucks, and mobile diesel generators.

The main potential for impacts from diesel emissions is likely to result from trucks queuing adjacent to residents located near to the surface worksites and operation of diesel equipment within the underground excavation area. The exhaust emissions would contribute to volumes of particulates, carbon monoxide, carbon dioxide, hydrocarbons and nitrogen oxides in the atmosphere. The level of air quality impact on surface receivers adjacent to the construction site would be subject to the location of the tunnel ventilation exit point, the loading of these pollutants within the tunnel air, the local dispersion meteorology and the controls (including particulate removal) incorporated as part of the tunnel construction ventilation systems.

Cumulative Impacts

In terms of dust impacts the most significant area where cumulative impacts may occur would be in the area surrounding Mt Coot-tha Quarry. The quarry influences dust impacts in the areas immediately adjacent to the site, while in areas further from the quarry (eg: on Walter Street approximately 280m from the Quarry) dust monitoring indicates a number of factors contribute to dust impacts, and the quarry is not necessarily the most significant contributor. As such, it is likely that the highest risk area in terms of cumulative impacts is likely to be the Brisbane Botanic Gardens, Mt Coot-tha and Brisbane Forest Park.

8.2.3 Mitigation Measures for Construction Impacts

The following sections outline construction mitigation measures which may be implemented to minimise the potential for nuisance dust impacts during Project construction works.

The most effective way of avoiding nuisance from construction activities is to have in place a system that addresses the following:

- effective management of dust generation:
- effective monitoring of impacts;
- effective communications with the local community on issues associated with the construction activities;
- a clearly identified point of contact should the community have comments or complaints;
- a well defined process to ensure that any issues are dealt with promptly and to a satisfactory level; and
- a well defined system of recording any incidents or complaints.

The Contractor responsible for construction would implement a system which incorporates those elements for the duration of the tunnels and surface construction works. Further detail on the requirements for a comprehensive dust and odour management and communications system would be included as part of a Construction Dust Environmental Management Sub Plan for the Northern Link Project. The requirements for monitoring of particulate levels within areas adjacent to the main worksites would also be included as part of this plan.

Management Measures for Nuisance Dust Mitigation

The following components of the dust and odour management and mitigation strategy are to be considered during the construction works.

- Demolition activities (buildings on acquired land, kerbs and road pavements etc) would be performed using appropriate dust controls such as consideration of meteorological conditions, use of water sprays, erecting a fence around the site, and covering loads of material transported from the sites. If the site needs to be cleared in advance of work commencing, the site should be stabilised with appropriate dust suppressant.
- Excavation at the tunnel portals would be performed within enclosed work sheds. The sheds would be constructed prior to the commencement of underground works and would cover the excavated areas and tunnel portals.
- Worksheds would need to be large enough to allow stockpiling of the excavated tunnel material, access and egress of trucks and truck and conveyor loading operations.
- Conveyor system from WS 1 would be covered to ensure minimal dust emissions.
- Truck and wheel wash stations would be located at the worksites and locations where trucks would be moving from unsealed areas of pavement to sealed roads.
- The tunnel would be ventilated during excavation works. Ventilation air would be treated, by passing through a particulate filter, prior to exit from the work sheds. The particle filter would be regularly maintained and the performance of the particulate removal technology would meet required standards. Dust collected from the filtration system would be disposed of appropriately.
- All trucks transporting spoil should be covered to ensure dust is not blown from the trucks during transportation.
- Regular monitoring of Total Suspended Particulate Matter (TSP), PM_{10} and dust deposition levels at nearest sensitive places adjacent to the worksites, and locations representative of the work space, would provide a basis for compliance with appropriate criteria.
- Water sprays would be used on newly established stockpiles at the placement sites and within the existing Mt Coot-tha Quarry in accordance with their existing environmental authority. Water sprays on newly

established stockpiles could be activated when wind speed is above a certain threshold, say 5-8m/s, and would be switched on more regularly during drier periods and times of higher winds.

- Un-sealed construction access roads and construction traffic areas would be kept damp as necessary to minimise dust emissions from surface disturbance.
- Sealed construction access roads and construction traffic areas would be cleaned as necessary to minimise the release of dust and particulate matter to the atmosphere.

There are two methods for monitoring nuisance dust and particulate matter - real time PM_{10} monitoring and dust deposition monitoring. Real time PM_{10} and $PM_{2.5}$ monitoring has been established for the Project at two locations, one at Toowong and another at Kelvin Grove. Monitoring at Toowong commenced in November 2007 and covers the southern end of the Project. The Kelvin Grove site covers the northern end of the Project and was established in July 2008. Data monitored prior to construction commencing can be used as a baseline to compare construction impacts.

Dust deposition monitoring should also be undertaken to determine the level of nuisance dust at residential locations.

A number of potential monitoring sites have been identified to undertake dust deposition monitoring (**Table 8-9**). These sites have been chosen as they represent the highest risk in terms of nuisance dust impacts due to their close proximity to surface works and worksite locations. In addition a site on Walter Street has been chosen as dust deposition is monitored there, and these sites provide baseline monitoring to which any changes in dust deposition due to construction impacts can be compared.

- **Table 8-9 Potential Dust Deposition Monitoring Locations**

Suggested monitoring location	Potential influence
15 Walter Street	Mt Coot-tha Quarry (monitoring currently undertaken)
Mt Coot-tha Botanical Gardens	Surface works on Western Arterial Road, WS1
Toowong Cemetery	Surface works on Western Arterial Road, WS1, WS2
Residence on Wool Street	Surface works on Western Arterial Road, WS1
Residence on Valentine Street	Surface works on Valentine Street and surrounds, WS2
QUT on Kelvin Grove Road	Surface works on Kelvin Grove Road, WS3
Residence on Lower Clifton Terrace	Surface works on Kelvin Grove Road, WS3
Brisbane Girls Grammar School	Surface works on Inner City Bypass

Management Measures for Diesel Exhaust Emissions

The effects of diesel exhaust emissions would be minimised by the following measures.

- Avoiding queuing of the construction traffic vehicle fleet in the streets adjacent to the sites which would in turn minimise the amount of exhaust emissions generated during the construction works.
- Where possible, exhaust emissions from mobile and stationary plant would be directed away from the ground and sensitive receivers.

Vehicles and machinery would be fitted with appropriate emission control equipment and be maintained sufficiently to enable design specifications to be met and compliance with ADR28/01[2] to be achieved.

8.3 Potential Operational Impacts and Mitigation Measures

8.3.1 Ambient Air Quality Criteria

In assessing any project with significant air emissions, it is necessary to compare the impacts of the project with relevant air quality goals. Air quality standards or goals are used to assess the potential for ambient air quality to give rise to adverse health or nuisance effects.

The Queensland Government Environment Protection Agency (EPA) has set air quality goals as part of its *Environmental Protection (Air) Policy 1997*. The policy was developed to meet air quality objectives for Queensland's air environment as outlined in the *Environmental Protection Act 1994*.

In addition, the National Environment Protection Council of Australia (NEPC) has determined a set of air quality goals for adoption at a national level, which are part of the National Environment Protection Measures (NEPM). In line with the NSBT and Airport Link projects, NEPM air quality standards and goals are proposed, either where there are no set EPA criteria or where the NEPM criteria are more stringent than the set EPA criteria.

It is important to note that the standards established as part of the NEPM are designed to be measured to give an 'average' representation of general air quality. That is, the NEPM monitoring protocol was not designed to apply to monitoring peak concentrations from major emission sources.

Table 8-10 lists the air quality goals for criteria pollutants noted by the EPA and NEPM that are relevant for this study. The primary air quality objective of most projects is to ensure that the air quality goals listed in **Table 8-10** are not exceeded at any location where there is the possibility of human exposure for the time period relevant to the goal.

- **Table 8-10 Air quality goals for operational aspects of the project**

Pollutant	Goal	Averaging Period	Agency
Carbon monoxide (CO)	8 ppm or 10 mg/m^3 9 ppm or 11 mg/m^3	8-hour maximum 8-hour maximum	EPA NEPM[1]
Nitrogen dioxide (NO_2)	0.16 or 320µg/m^3 0.12 ppm or 246µg/m^3 0.03 ppm or 62µg/m^3	1-hour maximum 1-hour maximum[1] Annual mean	EPA NEPM NEPM
Particulate matter less than 10µm (PM_{10})	150µg/m^3 50µg/m^3 50µg/m^3 (30µg/m^3) (25µg/m^3)	24-hour maximum 24-hour maximum Annual mean (Annual mean) (Annual mean)	EPA NEPM[2] EPA (NSW DECC) WHO
Particulate matter less than 2.5µm ($PM_{2.5}$)	25µg/m^3 8µg/m^3	24-hour maximum Annual average	NEPM NEPM

[2] Australian Design Rules are developed by the National Road Transport Commission with 28/01 referring to diesel exhaust performance requirements.

Total Suspended Particulate Matter (TSP)	90µg/m^3	Annual average	EPA
Sulfur Dioxide (SO_2)	0.25 ppm or 700µg/m^3 0.20 ppm or 570µg/m^3 0.08 ppm or 225µg/m^3 0.02 ppm or 60µg/m^3	10-minute maximum 1-hour maximum 24-hour maximum Annual average	EPA NEPM[1], EPA NEPM[1] NEPM, EPA
Ozone (O_3)	0.10 ppm or 210µg/m^3 0.08 ppm or 170µg/m^3	1-hour maximum 4-hour maximum	NEPM[1], EPA NEPM[1], EPA
Lead (Pb)	1.5µg/m^3 0.5µg/m^3	90-day average Annual average	EPA NEPM

Table Notes:

[1] One day per year maximum allowable exceedances

[2] Five days per year maximum allowable exceedances

Queensland does not have a long-term goal for PM_{10} that is consistent with the 24-hour NEPM goal. The NSW Department of Environment and Climate Change (DECC) and the World Health Organisation (WHO) long-term goals have been included to provide a benchmark for comparison with the 24-hour NEPM goal.

On a local scale, the Brisbane City Council developed the Brisbane Air Quality Strategy (BAQS) (Brisbane City Council 2004) which is intended to provide the framework for air quality management in Brisbane. The BAQS identifies photochemical smog, urban haze and particle pollution and air toxics as high priorities. Some of key air quality approaches in the BAQS include:

- reducing emissions from the main source groups;
- improving the understanding of air pollution processes; and
- addressing air quality priorities such as local air pollution through better planning.

In addition, the BAQS recognises the ambient air quality guidelines from Commonwealth, State and Local Governments but proposes that an Environmental Policy specific to South East Queensland be developed to place greater priority on local environmental factors.

8.3.2 Air Quality Issues Associated with Roadway Projects

One objective for roadway projects is to improve air quality or to minimise air quality impacts and it is important to review the change in air quality that is likely to occur with the project. Assessing the change in air quality should take into account any reduction or increase in emissions in the study area due to the project. Decreases or increases in emissions would arise as a result of a change in the traffic along a particular corridor.

Emissions from vehicles vary depending on a number of factors. A major factor in emissions from vehicles is the increasing standard being applied to engine emissions and improvements to the fuels allowed to be sold in Australia, which results in decreasing emissions from newer vehicles as the transport fleet on Australian roads is replaced over time. In general, a congested road with numerous intersections would generate higher emissions than a free flowing road with no intersections. Steeper road gradients generate higher emissions due to the higher engine loads, and roads with a higher percentage of heavy vehicles typically generate higher emissions.

In terms of emissions from vehicles and resultant pollutant concentrations the difference between surface roads and tunnels lies at the point of emission. Emissions from surface roads are released at ground-level where a greater proportion of the population reside. The surface road relies solely on atmospheric dispersion to reduce the pollutant concentrations between the roadway and the sensitive receptor. In contrast, tunnel emissions are generally vented via a ventilation outlet(s) assuming that the ventilation system is operated to avoid portal emissions. The point of emission from the tunnel is therefore above ground-level (at the outlet height) and the reduction of the pollutant concentrations from the outlet to the sensitive receptor combines the initial distance of the release point with the dispersive capacity of the atmosphere. An elevated point source is therefore more effective than a line source with the same emission.

8.3.3 Accounting for Background

One of the most difficult aspects in air quality assessments is accounting for the existing levels of pollutants from sources that are not included in the dispersion model. At any location within the airshed the concentration of the pollutant is determined by the contributions from all sources that have at some stage or another been upwind of the location. In the case of PM_{10} for example, the background concentration may contain emissions from the combustion of wood from domestic heating, from bushfires, from industry, other roads, wind blown dust from nearby and remote areas, fragments of pollens, moulds, sea-salts and so on. In an area such as the Brisbane airshed the background level of pollutants could also include recirculated pollutants which have moved through complicated pathways in sea breeze/land breeze cycles. In general, the further away a particular source is from the area of interest, the smaller would be its contribution to air pollution at the area of interest. The larger the area considered, however, the greater would be the number of sources contributing to the background. The task of accounting for background is further discussed in *Technical Report No 7 Air Quality in Volume 3* of the EIS.

For the Project it is necessary to consider emissions from local surface roads, from the tunnel ventilation, from more distant roads and from all other non-transport related emissions of each pollutant. The changes resulting from the Project include emissions from the local surface roads which would experience changed traffic flows as the traffic is redistributed between the tunnel and the local surface roads and as new traffic is brought into the area by the increased capacity of the network provided by the tunnel.

8.3.4 Approach to Assessment

As noted in Section 8.1 dispersion models are used as the primary tool to assess air quality impacts arising from the project. The approach is to show not only the pollutant concentrations resulting from individual road sections and tunnel ventilation outlets, but also the net effect of the project within the study area. The aim is to assess any change to air quality that may arise with the project. The most significant emissions produced from motor vehicles are CO, NO_x, hydrocarbons and PM_{10}. Estimated emissions of these pollutants are required as input to computer-based dispersion models in order to predict pollutant concentrations in the area of interest and to compare these concentrations with associated air quality goals. The primary factors which influence emissions from vehicles include the mode of travel, the grade of the road and the mix or type of vehicles on the road. Sources of emission factors which have been referenced for the purposes of this project include:

- the World Road Association, referred to as PIARC (formerly the Permanent International Association of Road Congresses); and
- the South-East Queensland Region Air Emissions Inventory.

The traffic data used for the purposes of the air quality study and discussed in more detail in Chapter 5, included the following:

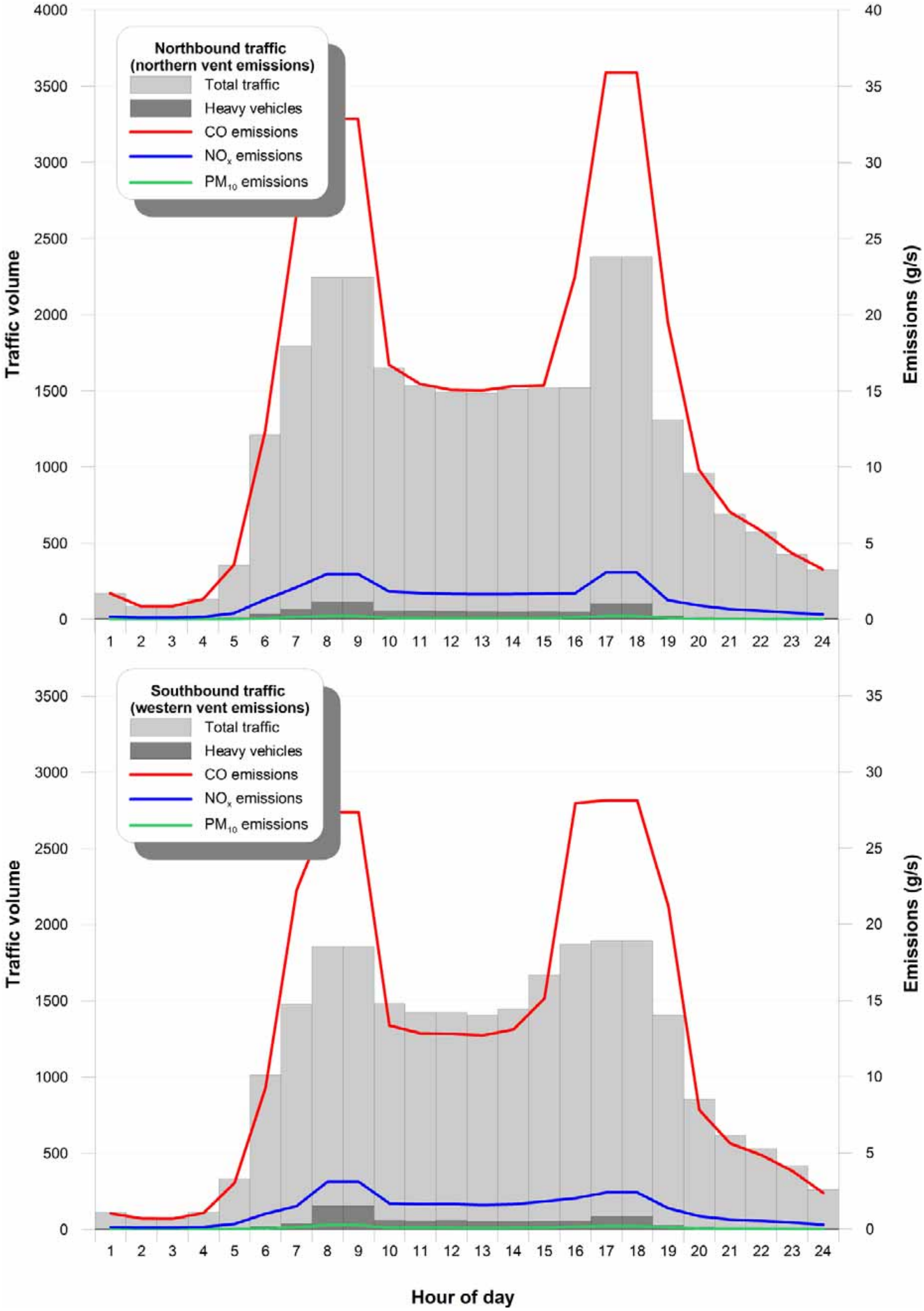
- Annualised Average Daily Traffic (AADT) for years 2007 (existing), 2014, 2016, 2021 and 2026;

- scenarios 'with' and 'without' Northern Link;
- modelled 2007 (existing), 2014, 2016, 2021 and 2026 AADT for selected surface roads and in tunnel sections; and
- indicative flow profiles for light and heavy vehicles by hour of day for each section of tunnel and for surface roads.

Information on registered vehicle types and year of the manufacture data for Queensland were obtained from the Australian Bureau of Statistics (ABS, 2003). Pollutant emissions have been estimated for each tunnel ventilation outlet and for all relevant surface roads. No potential future improvements in vehicle technology or fuel standards have been included in the PIARC emission estimates. This would result in some overestimation of emission rates for future years and tend to exaggerate the absolute difference between the 'with' and 'without' Northern Link case. Assumed reduction in the proportion of older vehicles in the fleet has simulated some improvement to vehicle emissions in future years.

To determine emissions from a ventilation outlet, the source of air which leads into the outlet has been considered. The air in the outlet comes from sections of tunnel which have a traffic volume, traffic mix, traffic speed and road grade. These data are included in the process to generate pollutant emissions for each hour of the day for each outlet. Traffic speed within the tunnel was set to 80km/h outside peak-hour periods. During peak-hour periods a speed of 20km/h has been used. For this study peak-hour periods in the tunnel have been defined as hours ending 7, 8, 9, 16, 17, 18 and 19 for both directions in the tunnel. A speed of 80km/h has been assumed for vehicles on the motorways while 50km/h has been assumed for all other surface roads. **Figure 8-3** shows the estimated traffic and pollutant emissions (CO, NO_x and PM_{10}) for each hour of the day for the Northern Link in 2014. Estimated traffic and pollutant emissions have been modelled for the operating period up to 2026 and the results of this modelling are presented in *Technical Report No 7 Air Quality in Volume 3* of the EIS. The profile of emission rates closely follows the traffic profile, although the emission rates are also influenced by other factors such as the grade in the tunnel, speed of traffic and the proportion of heavy vehicles in the traffic mix.

Figure 8-3 Hourly traffic and ventilation outlet emissions for the Northern Link tunnel in 2014



8.3.5 Assessment of Operational Air Quality

This section provides an assessment of the air quality impacts associated with the project. Many figures accompany *Technical Report No 7 Air Quality in Volume 3* of the EIS, present the results of the dispersion modelling. The number of figures has arisen from the requirement to address several different pollutants, future years and build or no-build cases and to ensure that any possible adverse air quality impacts are not overlooked. It is possible, however, to observe the overall air quality impacts of the Project by reviewing predictions for one pollutant only as similar trends for different pollutants have been noted. Contour plots showing the dispersion model predictions for 2007, 2014 and 2026 are presented in *Technical Report No 7 Air Quality in Volume 3* of the EIS (to reduce the number of figures), while results for all years are tabulated in *Technical Report No 7 Air Quality in Volume 3* of the EIS. In the assessment following the notation 2014+ indicates for 2014 and all subsequent years up to and including 2026.

Regional Effects

Carbon Monoxide

The simulations of carbon monoxide (CO) concentrations in the study area include surface road sources and tunnel ventilation outlets where appropriate. Background CO concentrations are also included in these predictions.

The following observations were made from the review of the CO model predictions.

- Predictions for the existing case (2007) show that maximum 8-hour average CO concentrations are below the 8-hour maximum air quality goal of 10mg/m^3 **Figure 8-4**). The air quality monitoring data also shows that existing maximum 8-hour average CO concentrations are below 10mg/m^3.
- CO concentrations in future years (2014+) are predicted to be very similar to existing (2007) concentrations (**Figure 8-5**). The likely improvements to vehicle emissions (not factored into the modelling) might offset projected increases in traffic in the study area based on a broad assessment of the historical rate of improvement. The emission estimates have not considered any further tightening of emission standards so the future projections are considered to be conservative.
- As expected, higher CO concentrations are predicted near roads carrying more traffic.
- Predictions for the future (2014+) build (with Northern Link) and no build (without Northern Link) cases are very similar.
- The contribution to ground-level concentrations due to tunnel ventilation outlets (with Northern Link case) appear to be overwhelmed by contributions from the major surface roads.

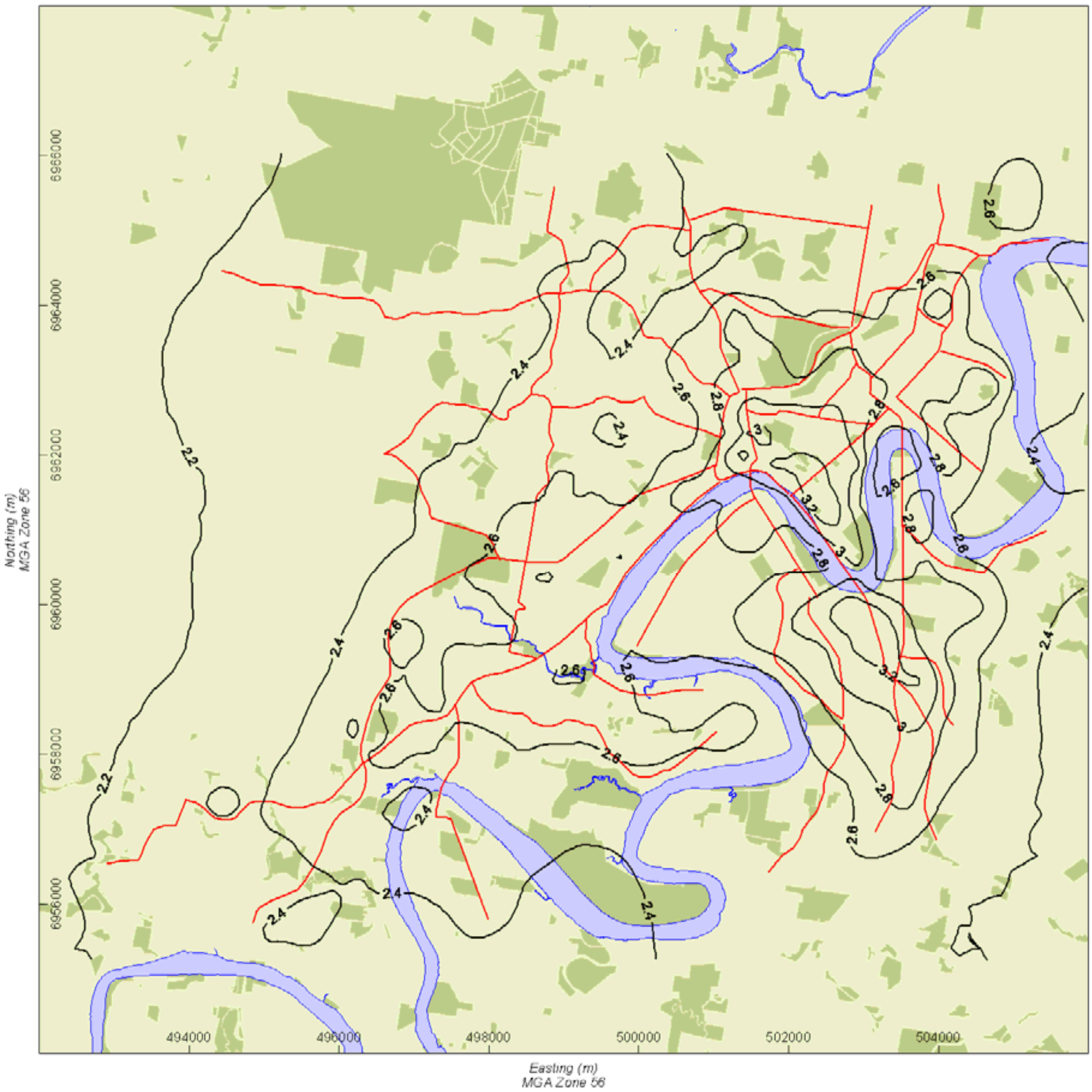
Nitrogen Dioxide

Predictions of NO_2 concentrations in the study area for existing and future years present a similar story to the CO predictions. These results also include background NO_2 concentrations. The following observations were made from the review of the NO_2 model predictions.

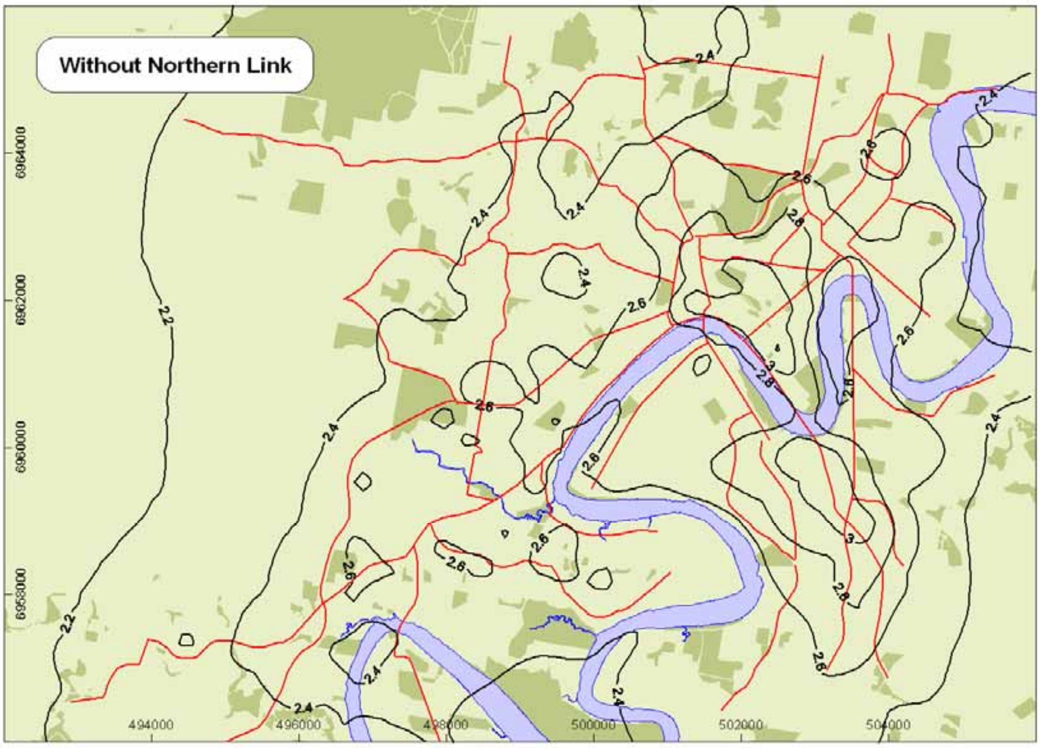
- Predictions for the existing case (2007) show that maximum 1-hour average NO_2 concentrations are up to around 160µg/m^3 near the busy roads in the CBD (**Figure 8-6**). These levels are below the 246µg/m^3 air quality goal. Monitoring data from the sites examined for this study show that existing maximum one hour average NO_2 concentrations are below the goal.
- Predictions for the existing case (2007) show that annual average NO_2 concentrations are below the annual air quality goal of 62µg/m^3. The air quality monitoring data also shows that existing annual average NO_2 concentrations are below 62µg/m^3.

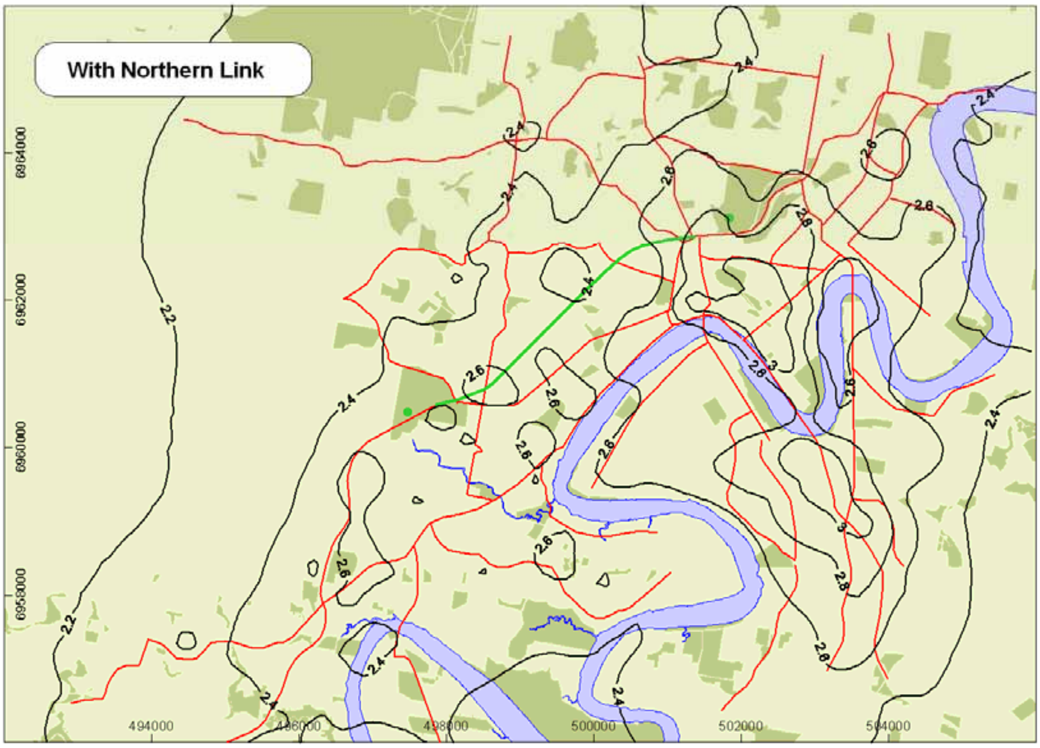
- NO_2 concentrations in future years (2014+) are predicted to be very similar to existing (2007) concentrations (**Figure 8-7**). The likely improvements to vehicle emissions appear to offset projected increases in traffic in the study area. The emission estimates have not considered any further tightening of emission standards so the future projections are considered to be conservative.
- As expected, higher NO_2 concentrations are predicted near roads carrying more traffic.
- Predictions for the future (2014+) build and no-build cases are very similar.
- The contribution to ground-level concentrations due to tunnel ventilation outlets (with Northern Link case) appear to be overwhelmed by contributions from the major surface roads.

Figure 8-4 Predicted maximum one-hour average CO concentrations in 2007 (mg/m^3)

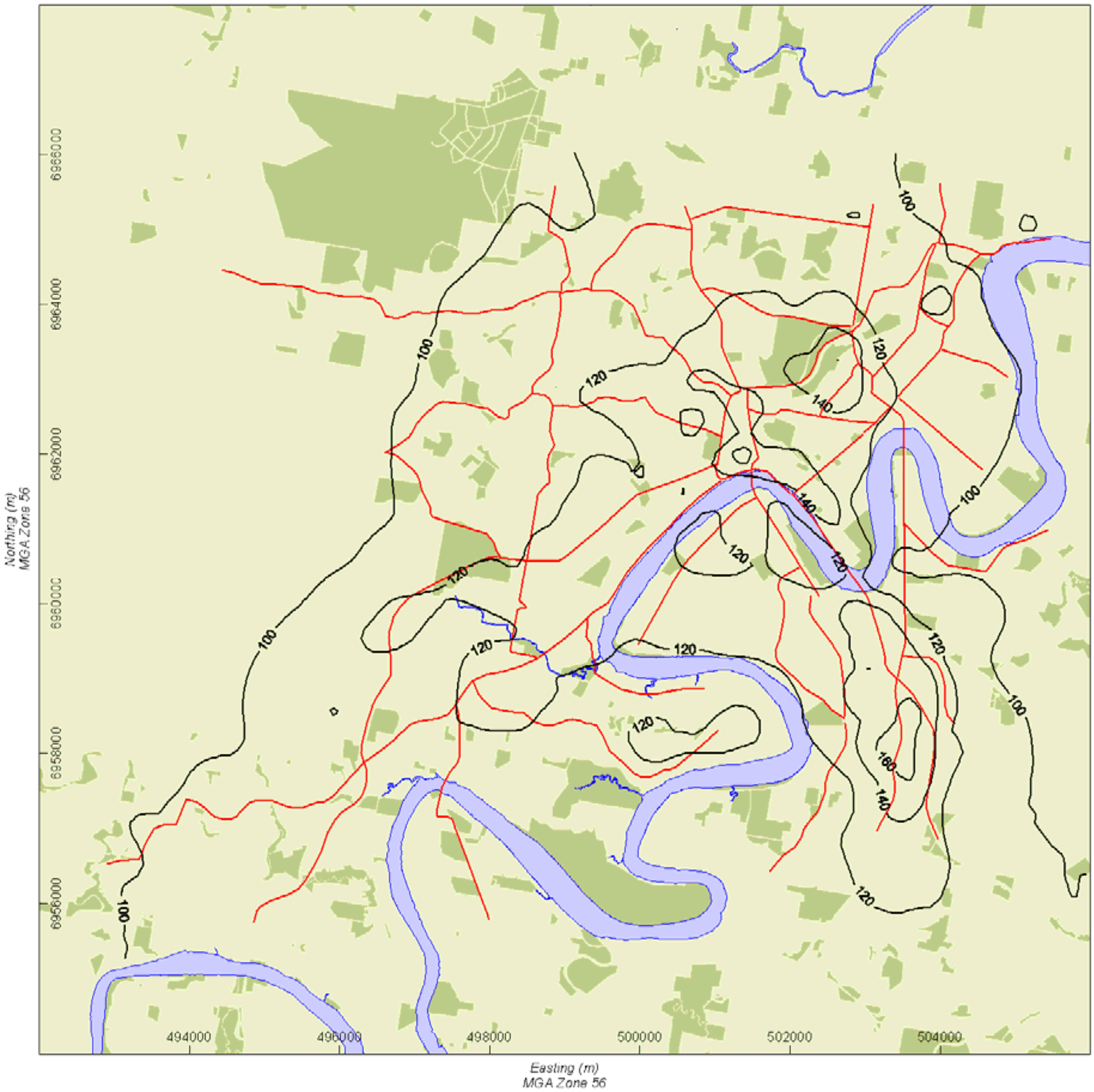


- **Figure 8-5 Predicted maximum eight-hour average CO concentrations in 2014 (mg/m^3)**

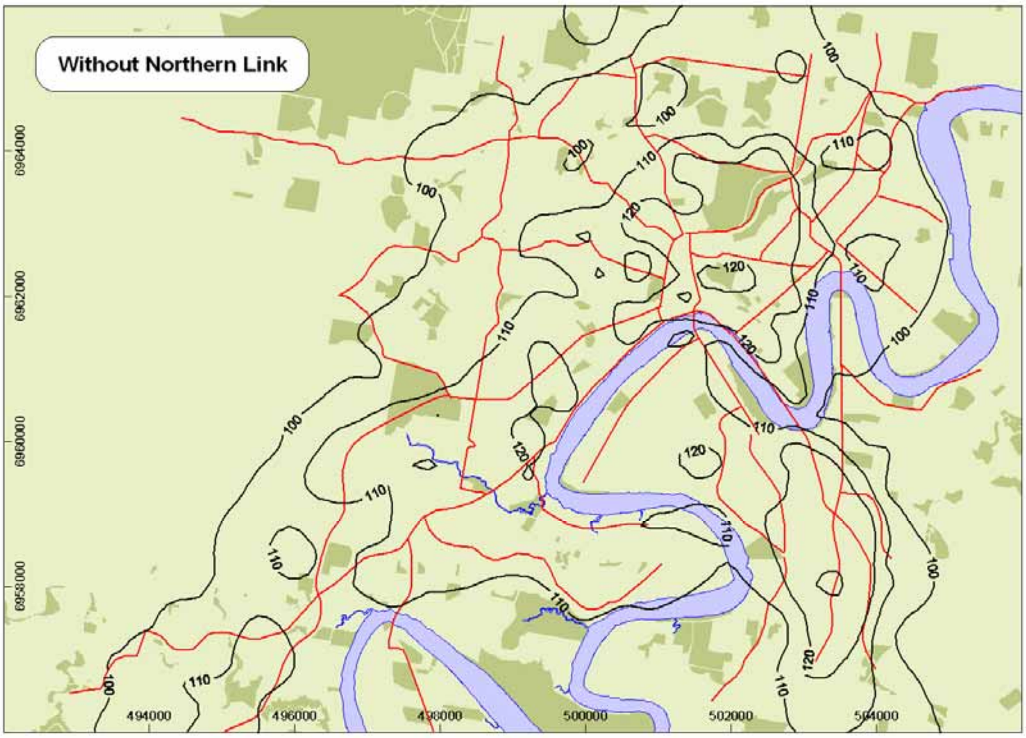


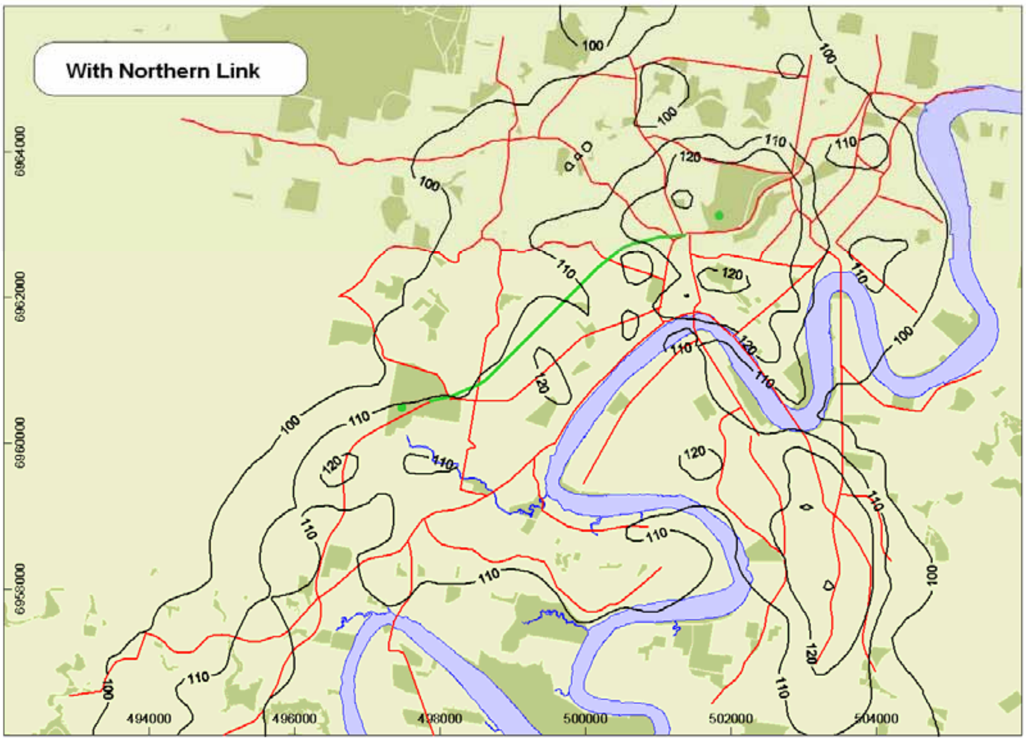


- **Figure 8-6 Predicted maximum one-hour average NO_2 concentrations in 2007 ($\mu g/m^3$)**



- **Figure 8-7 Predicted maximum one-hour average NO_2 concentrations in 2014 ($\mu g/m^3$)**





Particulates

The regional dispersion modelling results for PM_{10} showed that existing maximum 24-hour background PM_{10} levels can be above the goal of 50µg/m^3 (up to 88µg/m^3) and the major sources contributing to these levels are most likely bushfires and dust storms. For this reason the concentrations include only the modelled surface roads and ventilation outlet sources.

As for CO and NO_2, there are some common patterns of high and low concentrations predicted in the study area resulting from the modelled sources. The dispersion model predictions for PM_{10} are summarised below.

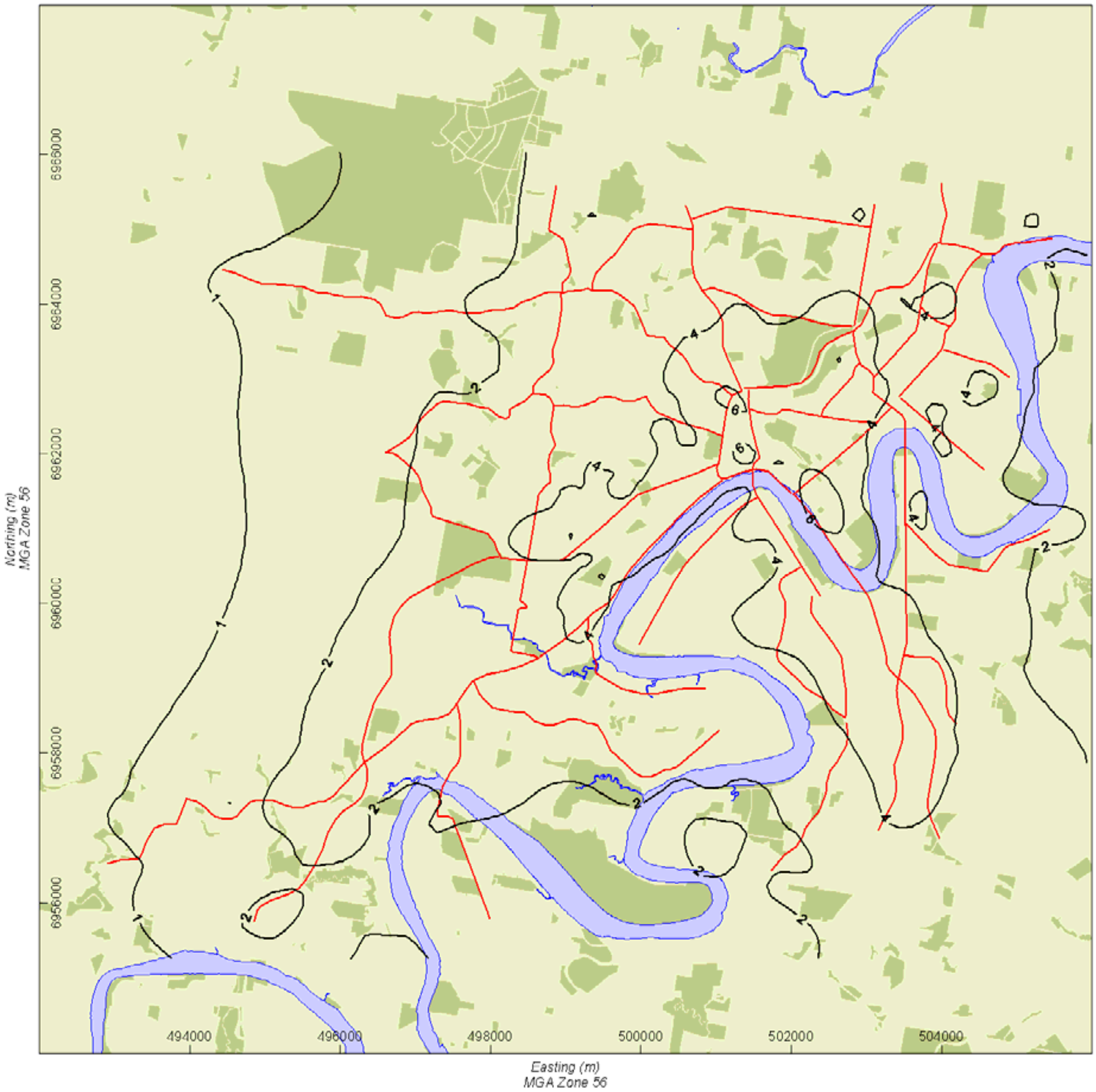
- Predictions for the existing case (2007) show that PM_{10} concentrations are below the maximum 24-hour (**Figure 8-8**) and annual average air quality goals (50 and 25µg/m^3). These predictions are due only to the modelled sources and not from other particulate matter sources.
- PM_{10} concentrations in future years (2014+) are predicted to be very similar to existing (2007) concentrations (**Figure 8-9**). The likely improvements to vehicle emissions appear to offset projected increases in traffic in the study area. Again, the emission estimates have not considered any further tightening of emission standards so the future projections are considered to be conservative.
- Higher PM_{10} concentrations are predicted near roads carrying more traffic.
- Predictions for the future (2014+) build and no-build cases are very similar.
- The contribution to ground-level concentrations due to tunnel ventilation outlets (with Northern Link case) appear to be overwhelmed by contributions from the major surface roads.

There is a generally held view that most of the PM_{10} in urban areas is $PM_{2.5}$ derived from motor vehicles. The proportion of $PM_{2.5}$ at the monitoring site at Bowen Hills comprised 50%, whereas monitoring in tunnel outlets in Sydney and Melbourne show results varying between 35 and 70%. Air quality standards or goals are used to assess the potential for ambient air quality to give rise to adverse health or nuisance effects and it is now generally considered that finer particles (those less than 2.5µm in equivalent aerodynamic diameter or $<PM_{2.5}$) are more likely to have health consequences than larger particles. An air quality goal has been provided for $PM_{2.5}$ (**Table 8-10**), although it should be noted that this is an advisory rather than a project specific goal.

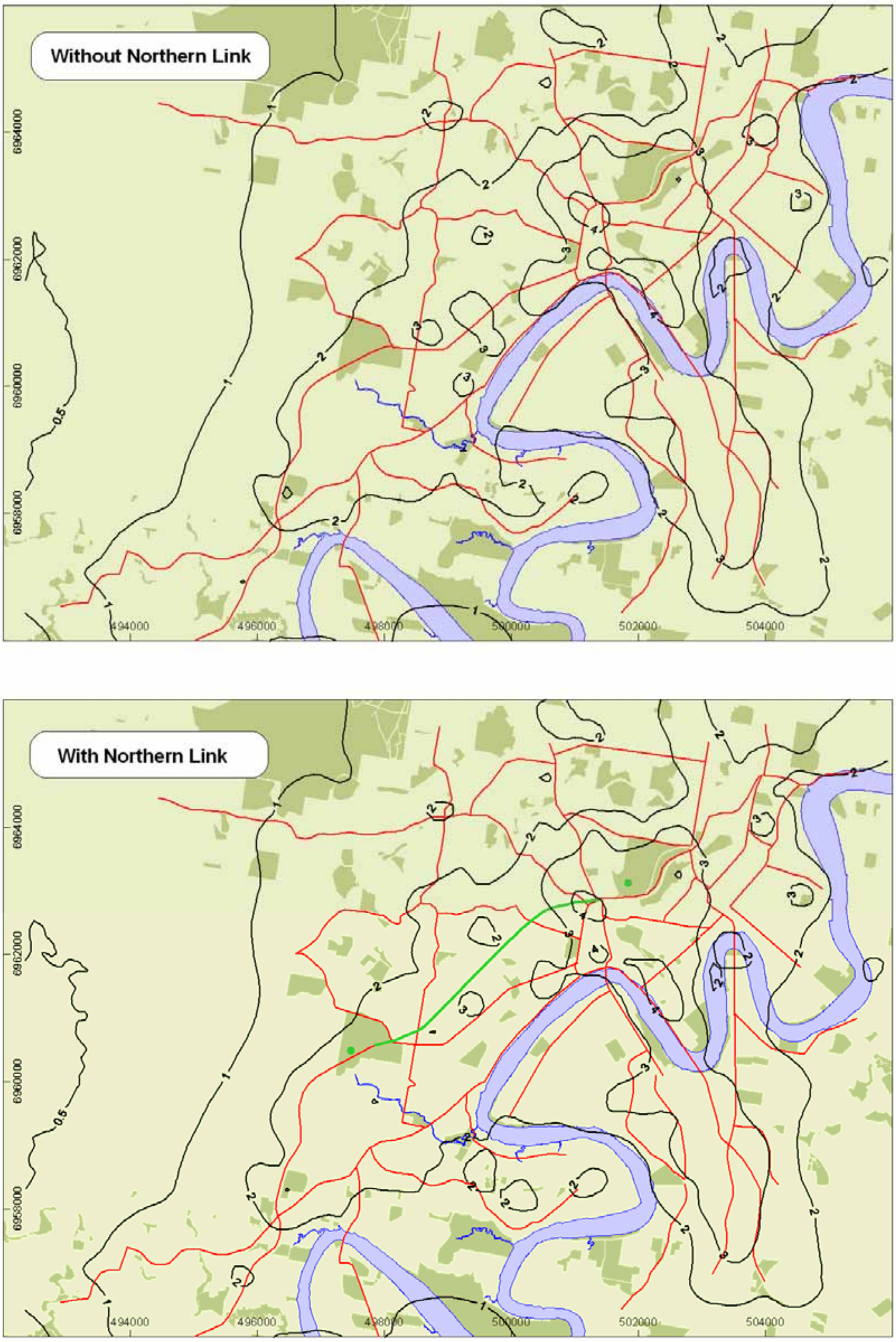
To assess the implications of $PM_{2.5}$ concentrations in the regional context, the data has been remodelled (*Technical Report No. 7 – Air Quality in Volume 3 of the EIS*) assuming that most (96%) of the particulate matter was $PM_{2.5}$. This is based on measurements made in diesel exhaust, although not all emissions on roadways are from diesel exhaust and in practice the percentage would be less than 96%. The data show that the changes in $PM_{2.5}$ between 'with' and 'without' Northern Link are relatively minor. As with PM_{10}, the existing background levels already exceeded the NEPM goal on occasions.

Ultrafine particles are defined as those smaller than 0.1µm in diameter. While ultrafine particles make a small contribution to total particle mass, they make a very large contribution to particle number. Particles in this size range are generally formed from combustion, gas to particle conversion, nucleation and photochemical processes. Some are emitted as primary particles and others are secondary in nature formed from precursor molecules.

- **Figure 8-8 Predicted maximum 24-hour average PM_{10} concentrations in 2007 ($\mu g/m^3$)**



- **Figure 8-9 Predicted maximum 24-hour average PM_{10} concentrations in 2014 ($\mu g/m^3$)**



While an association between health effects and concentrations of fine particles (those less than 2.5μm in equivalent aerodynamic diameter) is well established, the role played by the ultrafine particles is less clear. There are plausible mechanisms to suggest that ultrafine particles may indeed be a dominant factor in the health effects of particulate matter. At this stage, however, the evidence is too limited to develop exposure standards. In addition, methodologies for measuring ultrafine particles are still being developed and there is no widely agreed technique for measuring both ultrafine particle mass and number.

This study has considered the issue of ultrafine particles by modelling the change in particulate numbers resulting from the Project. This assessment needs to be qualified in that there is very limited data available on ultrafine emission rates from vehicles. Morawska *et al.* (2003) has derived sub-micrometre particle emission factors for motor vehicles in the Brisbane area. The emission factors provided by Morawska *et al.* (2003) have been used to scale dispersion model predictions of PM_{10} ($\mu g/m^3$) to particle numbers (with units of particles/cm^3). In terms of emissions factors from the fleet using surface roads, 1$\mu g/m^3$ of PM_{10} is determined to be equivalent to 1,036 sub-micrometre particles/cm^3. Annual average PM_{10} concentrations, as measured at Woolloongabba in 2006, are of the order of 22$\mu g/m^3$ which would be equivalent to 22,792 sub-micrometre particles/cm^3, assuming a similar proportion of ultrafine particles. This is of course an oversimplification as the total PM_{10} measured at a particular monitoring site would generally be from a number of sources, not just motor vehicle emissions. Nevertheless, this value is in the range referenced by Morawska *et al.* (2003) for 'Urban concentrations in six Australian cities', that is, 10,000 to 50,000 particles/cm^3.

The predicted maximum 24-hour particle numbers, scaled from PM_{10} predictions, was determined. These predictions included emissions from the modelled surface roads as well as ventilation outlets, where appropriate. The trends with the particle number predictions (that is, comparisons between scenarios) are the same as those observed for the PM_{10} predictions suggesting very little difference between the build and no build scenarios.

Comparison of Modelled Results with Monitored Results

The dispersion model results were compared specifically for the city-based air quality monitoring locations for each of the criteria pollutants. From these results it is possible to assess the performance of the model, that is, by comparing the 2007 predictions with the 2007 monitoring data. Spatial variation (between the different sites) can also be assessed as well as differences between build and no-build cases and existing and future cases.

For the Bowen Hills and Toowong monitoring sites, the dispersion modelling indicated that pollutant concentrations in future years (2014+) would be very similar to existing (2007) concentrations. This is true for all selected locations in both the 'with' or 'without' Northern Link cases. At all selected locations, there are no pollutants where future concentrations are substantially different from existing concentrations.

Spatially, the 2007 model predictions show that CO concentrations at the two monitoring sites are similar. The Toowong and Brisbane Grammar School sites are predicted to experience slightly higher maximum NO_2 concentrations than the Bowen Hills site, most likely because of the closer proximity of these sites to the modelled emission sources such as major roadways.

The results also show that all pollutant concentrations are below air quality goals at each of the monitoring locations for all future year cases. The predictions for the 'with' (DS) and 'without' (DM) Northern Link cases are very similar and the difference in concentrations between these two cases would be considered difficult to detect by current measurement techniques.

Ventilation Outlets

This section examines pollutant concentrations due only to emissions from the tunnel ventilation outlets. **Table 8-11** shows the highest ground-level pollutant concentrations that are predicted in the study area due only to the emissions from the tunnel ventilation outlets. Note that these are the highest concentrations predicted in the study area and that in most areas the concentrations due to ventilation outlets would be much lower than these numbers.

It can be seen from **Table 8-11** that the highest ground-level concentrations due to all ventilation outlet emissions are well below the associated air quality goals. Of all the pollutants modelled, the maximum one hour average NO_2 is predicted to consume the greatest fraction of the air quality goal at less than 3%. These predictions suggest that the ventilation outlets would not be the cause of exceedances of air quality goals.

- **Table 8-11 Highest ground-level concentrations due to ventilation outlet emissions**

Pollutant and averaging time	Predicted maximum ground-level concentrations due to emissions from each ventilation outlet								Background Concentration[1]	Air quality goal
	2014		2016		2021		2026			
	N4	W1	N4	W1	N4	W1	N4	W1		
Maximum 8-hour average CO (mg/m^3)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2.5	10
Maximum 1-hour average NO_2 (µg/m^3)	3.1	7.0	3.3	8.3	2.7	7.3	2.5	6.8	94.3	246
Annual average NO_2 (µg/m^3)	0.3	0.9	0.3	0.9	0.3	0.7	0.3	0.7	18.5	62
Maximum 24-hour average PM_{10} (µg/m^3)	0.3	0.4	0.3	0.4	0.2	0.3	0.2	0.3	52.6	50
Annual average PM_{10} (µg/m^3)	0.02	0.07	0.02	0.07	0.02	0.05	0.02	0.05	16.7	25

Table Note: Background levels of pollutants in the airshed are discussed in Section 8.3.3 above where it is noted that this will vary across the modelling domain. The background values are taken from Bowen Hills (CO) and Rocklea (NO_2 and PM_{10}).

Pollutant concentrations at locations above ground level have also been assessed as part of this project. The predicted maximum eight hour average CO concentrations above ground level in 2014 due to emissions from all tunnel ventilation outlets are less than 1mg/m^3 at all locations both 30 and 50m above ground level. This level of impact demonstrates compliance with the 10mg/m^3 air quality goal at elevated locations even when considering background levels of up to 5mg/m^3.

The predicted maximum one hour and annual average NO_2 concentrations at elevated locations due to emissions from tunnel ventilation outlets are of up to 50µg/m^3 at 50m above ground-level and close to vent outlets. This level of impact demonstrates compliance with the 246µg/m^3 air quality goal at all elevated locations even when considering recent (2006) background levels of up to 103µg/m^3. Similarly, for annual average NO_2 concentrations, the highest concentrations are of the order of 5µg/m^3 – close to the ventilation outlets and at 50m above ground level. Compliance with the 62µg/m^3 should be comfortably achieved at all elevated locations even when considering annual average NO_2 concentrations (in 2006 South Brisbane reported an annual average NO_2 concentration of 34µg/m^3).

Predicted maximum 24-hour average PM_{10} concentrations at elevated locations are up to about 5µg/m^3. Again, this level is predicted at 50m above ground level and close to the vent outlets. This is well below the 50µg/m^3 goal and unlikely to be the cause of exceedances at elevated locations. Annual average PM_{10} concentrations are predicted to be less than 1µg/m^3 at 30 and 50m above ground level at all locations – well below the 25µg/m^3 goal and compliance at elevated locations would be anticipated.

Surface Roads

This section examines pollutant concentrations very close to selected surface roads. Results presented show the effect of emissions from the selected surface road only and do not include contributions from other sources. An objective of this section was to compare existing near roadside pollutant concentrations with future scenarios.

From examination of the model results, the highest pollutant concentrations for 2007 are predicted in the vicinity of Hale Street. This may be expected, given the very high traffic volumes experienced on this road (approximately 87,000 vpd). Predicted pollutant concentrations are highest at the kerb and decrease with distance from the kerb for all road sections. This shows the dispersion effect of distance from the source.

In assessing the magnitude of the predicted pollutant concentrations, an appropriate distance from the kerb should be selected based on the distance to the nearest residences. For example, the separation distance between the kerb and the nearest residences is greater for the Western Freeway than for many of the other selected roads. The most relevant distances from the Western Freeway section would be about 30m, while for most other sections, 10m from the kerb would be the appropriate distance for the nearest residences.

The following observations were made from the surface road dispersion model predictions.

- Predicted pollutant concentrations are highest at the kerb for each road section.
- Predicted pollutant concentrations for 2007 are highest near Hale Street.
- Road sections where the 'with' case is predicted to be lower than the 'without' Northern Link case include Coronation Drive and Milton Road.
- Road sections where the with tunnel case is predicted to be higher than the without tunnel case include Western Freeway and Inner City Bypass.
- Road sections where the differences between the 'with' and 'without' Northern Link cases are considered negligible include Hale Street, Waterworks Road, Boundary Street, Given Terrace, Miskin Road and Kelvin Grove Road.
- Improvements in local air quality are observed with reductions in surface traffic that occur as a result of diverting traffic to the tunnel.
- At distances appropriate for the nearest residences, the model predictions for all sections and future years are below the associated air quality goals.

A useful comparison can also be made between predicted maximum pollutant concentrations due only to ventilation outlets and maximum pollutant concentrations near surface roads. It is important not to underestimate the pollutant concentrations near surface roads as they are likely to be significantly higher than maximum levels expected as a result of emissions from tunnel ventilation outlets. Also high pollutant concentrations near surface roads are likely to occur more often than high concentrations due to ventilation outlets.

8.3.6 Conclusions and Mitigation Measures

Dispersion modelling has been used as the primary tool to quantitatively assess pollutant concentrations in the study area.

- Pollutant concentrations in the study area in future years (2014+) arising from motor vehicles would be expected to be similar to existing (2007) concentrations. This is the case both with and without the project.
- Model results for future years are considered to be conservative since no further improvements to vehicle emissions have been taken into account.
- At ground level the ‘with’ and ‘without’ Northern Link cases are predicted to be very similar, apart from in the vicinity of roads affected by the Project. That is, regional air quality with the Project may be expected to be similar to air quality without the project.
- The most significant changes in air quality are close to surface roadways affected by the Project. The Western Freeway and ICB are predicted to experience the most significant increase, although sensitive receptors are generally well removed from these roads (30m or more). Coronation Drive and Milton Road are predicted to experience the most improvement.
- At ground-level the highest concentrations due to emissions from ventilation outlets are predicted to be much less than concentrations near busy surface roads.
- Pollutant concentrations at elevated locations due to ventilation outlet emissions would be expected to be below relevant air quality goals.

The operational (ambient) air quality study shows that there would be no adverse air quality impacts as a direct result of the project. No detailed mitigation measures are proposed, although the ambient air quality would continue to be monitored at the existing monitoring sites. Consideration would be given to establishing extra monitoring locations, each at a sensitive location near a ventilation outlet, to assess whether any impacts can be demonstrated from the ventilation outlet dispersion. These sites would be established to complement the existing EPA network and be operational for at least 12 months before and at least five years after the tunnel operations commence.

In-tunnel air quality monitoring data would be updated on an hourly basis (unvalidated) and available on-line via a project website. Ambient air quality monitoring data would be reported hourly and unvalidated data would be available on-line via a project website.

Confirmation of modelling predictions is an important mitigation measure. Provision would be made for filtration in the future if a subsequent decision is made to provide for air treatment. This is discussed in Section 8.5.

8.4 Assessment of In-Tunnel Air Quality

The design of the tunnel ventilation system was described in Chapter 4, Project Description, where it was specified that in-tunnel air quality would conform with guidelines issued by PIARC.

8.4.1 In-Tunnel Guidelines

The motor vehicle generated air emissions which are considered in ventilation design for tunnels are CO (carbon monoxide), particulates and various oxides of nitrogen, termed NOx. PIARC (1995; 2000; 2003) has recommended limits on the concentrations of these emissions within a tunnel as follows.

- A peak of 70 ppm (parts per million) of CO, with a peak of up to 90 ppm during extreme congestion.
- An average (in the tunnel) of 1 ppm of NO_2.
- Visibility limit of $0.005m^{-1}$for free flowing traffic and $0.007m^{-1}$ for congested traffic.

The allowable levels of carbon monoxide and visibility specified are standard requirements in European tunnel designs and have changed little in recent years. Visibility requirements have not changed since 1991, and CO levels have decreased, mainly to allow CO to continue to be the determining pollutant for ventilation control systems and not necessarily because lower CO levels were desirable in themselves.

Oxides of nitrogen are the pollutants being given attention due to the emergence of data on potential physiological effects of NO_2. The PIARC guideline on NO_2 argues that for healthy people, an average value of the order of 1ppm that is not exceeded 98% of the time is acceptable (Mott McDonald, 2004).

The national NO_2 standards of various European countries are consistent with those specified by PIARC, with the UK and Norway requiring down to 1.5ppm, depending on length and France 0.4 – 0.8 ppm, depending on timing of opening. France is implementing its more stringent requirements in stages to align with the expected reduction in vehicle emissions resulting from better performing engines. In-tunnel guidelines for particulate matter are not offered by PIARC or most regulatory agencies, except as a visibility measure (extinction value). There are currently no plans to tighten the allowable levels of CO or visibility in tunnels in Europe. Although national standards have now considered very low levels of NO_2, no long European tunnels have been built that dilute emissions to very low levels of NO_2 and at the same time prevent emissions from the tunnel portals.

The in-tunnel requirements for air quality in Japan are outlined in RTA (2004). The specified limit for CO is 100ppm, whilst visibility limits for road tunnels in Japan are comparable to PIARC standards. There are no limits specified for NO_2.

8.4.2 In-Tunnel Concentrations

Daily traffic profiles were modelled in the development of the tunnel design to show daily profiles of the pollutant concentrations within the tunnel. The modelling showed that the peak level of CO in the tunnel would be below the PIARC criterion of 70ppm on all occasions.

The NO_2 criterion for in-tunnel concentrations is an average of 1ppm. The modelled daily profiles show that the tunnel design would allow for a peak of less than 1ppm, well within PIARC standards.

Should pollutant levels monitored in the tunnels exceed standards (for any reason including failure of the ventilation system, power loss and concurrent failure of the backup power supply) a range of responses would be developed as part of the incident response procedures. Foremost mitigation measure would be to stop traffic entering the tunnel(s) so affected with a series of possible step in the incident response procedures.

8.4.3 Mitigation Measures

Mitigation measures proposed to manage in-tunnel air quality include:

- visibility, air speed and gas monitors (for CO and NO/NO_2) would be installed in the tunnel. Automated control systems would respond to data collected by these air quality monitors, switching individual jet fans and axial fans on and off to regulate the overall air flow;
- in-tunnel air and traffic management procedures to ensure motorists within the tunnel are not subject to CO concentration levels approaching ambient guidelines defined by time exposures, (ie: 87ppm for 15 minutes); and
- in-tunnel air and traffic management procedures to ensure motorists within the tunnel are not subject to extended periods of exposure to NO_2.

8.5 Air Filtration Technologies

8.5.1 Review of Technologies

There are two established filtration technologies installed in road tunnels in Europe, Asia or Australia.

- Electrostatic precipitators (ESPs) which remove particulates (ie: suspended particles) by applying an electric charge to them as they pass through an electric field and then collecting them on a series of oppositely charged metallic plates. The plates are cleaned regularly either by a dry process (eg: shaking the plates) or by a wet process (eg: washing the plates). In both cleaning processes, the particles are collected and disposed of to an appropriate site. The wet process requires an intermediate water filtration process to form a cake, while the water is either discharged or recycled.

- Denitrification which removes nitrogen dioxide and other oxides of nitrogen by means of either chemical absorption or catalytic conversion to a more benign gas. Typically, a denitrification process requires prior particulate removal so it is often used in conjunction with a bank of ESPs.

Child and Associates (2004), RTA (2001, 2004), Arnold Dix (2004, 2006) and PIARC (2008) reviewed these technologies in terms of their state of development and actual application to road tunnels. From these reviews it is clear that:

- only two countries - Japan and Norway - have more than basic operational experience with air treatment, and this treatment is based on ESP technology - about 35 tunnels in Japan and about eight in Norway. In these countries, in-tunnel air quality issues are associated with visibility problems caused by heavy diesel truck traffic (in Japan) and tyre debris (especially Norway);
- in Norway this technology was installed in only one tunnel to maintain in-tunnel air quality (due to the tunnel length and absence of ventilation outlets and fresh air intakes). Another tunnel in Norway has ESP technology installed for treatment of air vented externally, but the filtration technology is not used;
- in at least seven tunnels in Japan ESP technology was installed prior to external discharge to address community or regulatory concerns. The major issue is to attempt to meet external air quality goals. No data are available on the performance of the technology in achieving improvements in external air quality;
- despite trials for NOx removal in Austria, Germany and Japan in the 1990s, only one tunnel has full scale NO_2 removal technology installed. This tunnel is in Norway and there has been no need for the system to be used;
- Japan is undertaking trials of NO_2 removal in ventilation outlets of the Central Circular Shinjyuka Tunnel. The tunnel is in an area where it is difficult to comply with local environmental standards for NO_2; and
- Spain has installed of full scale, fully operational ESP and NO_2 removal technology on the Madrid M30, but due to intermittent use no data are available on the performance of the installed systems. Italy is committed to full scale ESP technology in the Cessena Tunnel.

In NSW the RTA has announced its intention to proceed with the filtration trial first announced in April 2004[3]. The trial would test PM_{10} and NO_2 technology in a bypass tunnel and would be applied to the M5 East as part of a package to improve in-tunnel air quality in that tunnel. The works for the trial are under construction but the trial would not be operational until late 2009.

[3] www.rta.nsw.gov.au

Capital and operating costs for tunnel filtration of the Northern Link would be similar to previous advice provided for the Airport Link Project[4] but with an airflow through the mainline tunnel systems of approximately 1,200m3/s, or close to half the 2,350m^3/s for Airport Link. The estimated capital cost of filtration equipment incorporating both electrostatic precipitation for particle removal and scrubbing for removal of NO_2, is likely to be proportionally less than the $200million in $2006 terms identified for Airport Link, or approximately $120million subject to detailed design and construction costing. This estimate also includes an allowance of about $50 million for civil works required to support such equipment. The halving of the airflow would also reduce some of the operational costs associated with cleaning of filters, electricity costs and other consumables. Operational costs could be expected to be about $150,000 per year based on a proportional comparison with the Airport Link estimate.

In summary, only electrostatic precipitator technology can be considered as “proven” in road tunnel applications, with operational experience being limited primarily to two countries which have particular issues not associated with Northern Link. Even within these countries, verifiable operational data on actual filtration performance are not available.

8.5.2 Modelled Results from Use of Filtration

An analysis of the effect on local air quality due to the Airport Link fitted with some form of emission treatment has been carried out. Child (2004) has reviewed various emission treatment technologies and systems for road tunnels and provided information on pollutant removal efficiencies. Typical claimed performance results are as follows:

- 80% to 95% removal efficiency for total suspended particulates; and
- 60% removal efficiency for total oxides of nitrogen.

These performance results were claimed in relation to trials conducted in Germany. The quoted figures were among the highest of the total suspended particulates and oxides of nitrogen removal efficiencies presented in the review.

Dispersion modelling has assisted with the analysis of the effects on ambient air quality arising from the Northern Link both with and without some form of emission treatment. For the analysis it has been assumed that the emission treatment would remove 60% of the NO_x and 90% of the PM_{10} from ventilation outlets emissions.

Dispersion modelling results were obtained which compare ground-level pollutant concentrations for the Project without and with emission treatment. Maximum one hour and annual average NO_2 and maximum 24-hour and annual average PM_{10} concentration predictions for 2012 were generated to show the effect of vehicle emissions from surface roads and from the tunnel’s proposed ventilation outlets.

The ground-level pollutant concentrations both without and with tunnel filtration were found to be very similar as shown in Figures 62-65 in *Technical Report No. 7 – Air Quality in Volume 3 of the EIS* . Differences to ambient air quality arising solely from emission treatment for the tunnel would be difficult to detect. The model predictions suggest that pollutant concentrations in the study area are dominated by emissions from motor vehicles on the surface roads and that emissions treatment for each of the five kilometres (approximately) of

[4] Airport Link EIS Volume 1 Part B October 2006, Chapter 9 page 9-34.

tunnels associated with the project would result in very similar ambient air quality implications to the project without emissions treatment.

8.5.3 Rationale for Approach to Ventilation and Air Treatment

The system of mechanical ventilation proposed for the project would be achieved by longitudinal air flow in each tunnel tube. That is, air would be drawn in at the entry portal, carried along the tunnel in the direction of traffic, and drawn out just prior to the exit portal to the ventilation station located nearby on the surface. A series of roof mounted jet fans would draw air into and convey it along each tube. Between the draw off point and the exit portal, the jet fans would be reverse mounted so as to draw air into the tunnel to the draw-off point, thereby mitigating portal discharge at the exit. Unlike recent road tunnels in Sydney (M5 East), there would be no recirculation of air from one tube to the other.

It is proposed that this project would have two separate ventilation stations. Each ventilation station would have an elevated outlet, 20m high, at the Western site (W1) and 15m high, at the eastern site (N4), to achieve adequate dispersion of the in-tunnel air. The quality of the in-tunnel air, the appropriate terrain and the ability to disperse the air via the ventilation outlets means that filtration at the ventilation station is not required.

An alternative or supplementary approach to the control of air pollution levels in the tunnel and ultimately in the wider airshed following discharge is to place filtration systems within the tunnel itself. This could be achieved by installing bypass tunnels which draw a percentage of air from the traffic tunnel into a separate return tunnel that contains the treatment system (eg: ESPs). The treated air is then returned to the main tunnel and mixes with the untreated air to lower overall concentrations within the tunnel and ultimately at the discharge vent or portal. A similar effect can be achieved with roof mounted systems, installed in niches above the roadway. This type of facility is generally limited to very long tunnels (eg: 10km in length or more) where intermediate air intakes or off-takes are not available (eg: below mountain ranges) and in-tunnel filtration is needed to maintain in-tunnel air quality. It has never been used as a method to control the quality of air emissions being discharged into the wider airshed, although it is likely that the quality of air emitted from the vent outlet would benefit from the in-tunnel treatment. The length of the Northern Link tunnels is such that in-tunnel air quality goals can be achieved without the need for intermediate treatment.

The rationale behind this proposed ventilation arrangement is that:

- it achieves a more equitable spread of motor vehicle emissions through two separate outlets rather than concentrating all emissions at a single point and having to raise the height of that outlet significantly;
- it provides an operationally more efficient ventilation system with lower power consumption and associated greenhouse gas emissions (ie: there are fewer ‘corners' for the air to turn through);
- it provides more redundancy (ie: backup) in the event of any operational difficulties or incidents (eg: fire); and
- the placing of ventilation stations on the surface (rather than in the tunnel) provides space and flexibility to accommodate any air treatment technology that may be considered for the project in the future.

8.6 Greenhouse Gas Assessment

This section estimates fuel and energy consumption during the construction and operation of the Project. These estimates are based on preliminary design information relating to the works and on typical diesel consumption rates in the construction vehicle fleet, electricity consumption from tunnel excavation and ventilation equipment, and site services.

This assessment uses the emission factors as set out by DCC (2008) to estimate potential greenhouse gas emissions associated with the construction and operation of the Project. Emission factors relevant to the Project are detailed in **Table 8-12**.

- **Table 8-12 Relevant GHG Emission Factors (DCC, 2008)**

Activity	Emission Factor (Full Fuel Cycle)	Units
Scope 1 - direct (or point source) emissions per unit of activity at the point of emission release		
Diesel	2.9	t CO_{2-e}/ kL
Blasting	0.17	t CO_2 / t explosive
Scope 2 - covers indirect emissions from the combustion of purchased electricity, steam or heat produced by another organisation		
Purchased electricity (full fuel cycle)	1.04	kg CO_{2-e} / kWh

8.6.1 Construction Emission Estimates

Greenhouse gas emissions during construction would be associated with fuel use, electricity consumption and blasting.

Fuel consumed during the construction of the Project would be associated with:

- construction vehicles moving on and between sites; and
- haulage of construction materials to and from site (including spoil haulage).

Fuel consumption estimates during the 3.5 years of construction of the Project are presented in **Table 8-13**. Over the 3.5 years of construction it is estimated that 2,579,240 litres of diesel would be consumed, resulting in 7,480 tonnes CO_{2-e}. This equates to an average of 736,926 litres per annum ie: 2,137 tonnes CO_{2-e}.

- **Table 8-13 Estimated Construction Fuel Consumption**

Location	Total Construction (3.5 years)	Annual Average
Fuel Consumption (litres)		
Western Freeway Worksite	1,696,318	484,662
Toowong Worksite (Milton Road)	119,988	34,282
Kelvin Grove Worksite	545,098	155,742
ICB modifications	217,836	62,239
Total Fuel Consumption	**2,579,240**	**736,926**
Greenhouse Gas Emission (t CO_{2-e})	**7,480**	**2,137**

Electricity consumption would be associated with the following:

- site offices;
- tunnel boring machine;
- road headers;
- lighting;
- tunnel ventilation;
- electrical equipment; and
- mobile plant and equipment.

An estimate of electricity consumption for the three worksites is presented in **Table 8-14**. A total of 39.4 million kWh is estimated to be consumed during construction of the Project. This equates to 40,976 tonnes CO_{2-e}.

Table 8-14 Estimated Construction Electricity Consumption

Site	Total Construction (3.5 years)	Annual Average
Electricity Consumption (million kWh)		
Western Freeway (WS1)	16.8	4.8
Kelvin Grove (WS3)	13.9	4.0
Toowong (WS2)	9.3	2.7
Total	**40.0**	**11.5**
Greenhouse Gas Emission (t CO_{2-e})	**41,6**	**11,960**

Table Note: Rounding errors may occur

It is envisaged that blasting would be required during the construction process. It is estimated that 850 tonnes of ammonium nitrate/fuel oil (ANFO) would be required for the Project. This equates to 145 tonnes CO_{2-e} over the construction period, or 41 tonnes CO_{2-e} per annum.

A summary of greenhouse gas emission estimates during construction is provided in **Table 8-15**. Over the construction period of the Project greenhouse gas emissions would be in the order of 48,601 tonnes CO_{2-e}. This equates to an annual average of 14,138 tonnes CO_{2-e}.

Table 8-15 Estimated GHG Emissions Due to Project Construction

Construction Activity	Estimated CO_{2-e} Emissions (tonnes)	
	Total Construction	Annual Average
Scope 1		
Diesel	7,480	2,137
Blasting (ANFO)	145	41
Scope 2		
Electricity	41,600	11,960
Total	**49,225**	**14,138**

8.6.2 Operational Emission Estimates

Once operational, greenhouse gas emissions would be associated with the consumption of electricity and through changes to road network performance. The Northern Link assumes a concession period of 45 years. The operating period is assumed to commence after construction completion which is 3.5 years from financial close. Electricity would be required to run ventilation fans, pumps, lighting, pressurisation fans, and portal buildings and control cubicles.

Site Operations

The operations power consumption breakdown is presented in **Table 8-16**. The two dominant power consumption systems are the tunnel ventilation and lighting systems. The ventilation system consumes the majority of the power and it tends to vary with the:

- level of pollution of the motor vehicles;
- speed at which the vehicles are moving through the tunnel and hence the piston effect they create; and
- location of the extraction points.

Table 8-16 Operational Power Consumption Breakdown

Unit	Consumption (%)
Ventilation	64.6%
Pumps	1.0%
Lighting	29.6%
Pressurisation Fans	4.8%

Analysis of energy consumption during operation shows that energy demand increases in a linear fashion from the year of opening for the 41 years on analysis. This assessment considers years 2014, 2016, 2021 and 2026 to be consistent with the Vehicle Kilometres Travelled (VKT) data presented below (**Table 8-17**). Electricity consumption has been estimated for 41 years of operation. Over this time period annual average electricity consumption is 22,872,890 kWh, which equates to 23,788 tonnes CO_{2-e} (assuming today's greenhouse intensity for electricity consumption).

Table 8-17 Operational Energy Consumption and Associated Greenhouse Gas Emissions Estimate

Description	2014	2016	2021	2026
Energy Consumption (kWh)	20,685,390	21,102,057	22,143,723	23,185,390
Greenhouse Gas Emissions Estimate (tonnes (CO_{2-e})	21,513	21,946	23,029	24,113

Changes to Road Network Performance

The delivery of the Project may affect road network performance and therefore greenhouse gas emissions from Brisbane's vehicle fleet. Aside from engine fuel efficiency modifications, greenhouse gas emissions could arise by either changing VKT for the network or improving the flow of traffic, which improves the fuel efficiency of vehicles.

For the purposes of this assessment, the efficiency of the road network was assumed to be reflected in a comparison of projected VKT with and without the Project to 2026. This is considered a conservative assumption as it does not account for any improvements in traffic flow or potential future improvements in energy efficiency from alternative fuels.

The projected VKT on the Brisbane road network with and without the Project is summarised in **Table 8-18**. The delivery of the Project would result in a small increase (approximately 0.1%) in VKT compared to the 'Do Minimum' case.

Table 8-18 Total Current and Predicted Future VKT With and Without the Project

Year	Total VKT		Increase in VKT
	Do Minimum Scenario (AWDT)	Northern Link Scenario (AWDT)	
2014	62,114,786	62,182,347	(67,561 AWDT) (22,970,625 Annual)
2016	64,640,294	64,697,490	(57,196 AWDT) (19,446,606 Annual)
2021	70,965,411	71,006,133	(40,722 AWDT) (13,845,522 Annual)
2026	76,634,450	76,690,882	(56,432 AWDT) (19,186,899 Annual)

Table Notes:

AWDT = average weekday travelled

Annual = AWDT x 330

The greenhouse gas emissions associated with changes in road network performance have been determined using the following assumptions.

- The vehicle fleet is made up of 93% light passenger vehicles, 7% heavy vehicles.
- Fuel consumption rates per kilometre travelled are derived using the AGO (2006) conversion factors as set out in **Table 8-19**.
- All passenger vehicles use petrol, and all heavy vehicles use diesel.

Table 8-19 Fuel Consumption (AGO, 2006)

Fuel Type	Fuel Consumption (L/km)
Unleaded petrol passenger cars	0.113
Diesel heavy trucks	0.546

The difference in greenhouse gases emissions as a result of changed road network performance due to the implementation of the Project is presented in **Table 8-20**.

Table 8-20 Difference in GHG Emissions from Network Performance

Year	Increase in GHG Emissions (tonnes CO_{2-e})
2014	5,541
2016	4,516
2021	2,419
2026	3,255

The greenhouse inventory for the implementation of the Project indicates that there would be a small increase in greenhouse gas emissions due to an increase in VKT. However, these calculations do not take into account the difference in fuel consumption associated with traffic congestion compared to free flow. A study conducted by the Royal Automotive Club of Queensland (RACQ 2008) showed that Brisbane's morning peak hour increases vehicle fuel consumption and greenhouse emissions by around 30%. The survey also found the trip to work took almost twice as long as travelling the same routes between the morning and evening peaks.

8.6.3 Reporting Implications

The body with operational control over the tunnel would be required to report greenhouse gas emissions should these emissions exceed the relevant *National Greenhouse Emissions Reporting Act (2007)* thresholds. It is expected that the Project would be considered a "facility" under the *NGER Act*, with an ANZSIC code '529 – other transport support services'. In 2014 electricity consumption would be in the order 18,810,390 kWh, which equates to 68 tera joules, and 19,563 tonnes CO_{2-e}. This does not trigger the reporting threshold for a facility. Over time, energy consumption and associated greenhouse gas emissions for tunnel operation are expected to increase, and in 2040 greenhouse gas emissions will exceed the facility reporting level of 25,000 tonnes CO_{2-e}. When this occurs the body with operational control of the tunnel will be required to report these emissions.

Reporting may be required at an earlier stage if the body with operational control of the facility also has operational control over other facility(s) whose aggregate emissions in 2010-2011 or beyond exceed the criteria set out for corporations by the *NGER Act* of 50,000 tonnes CO_{2-e}emission or 200 tera joules energy consumption

8.6.4 Mitigation Measures

In order to minimise greenhouse gas emissions due to construction of the project a variety of mitigation and management measures are available, including:

- designing a construction works program to minimise haul distances from construction sites to spoil placement locations;
- maintaining construction equipment and haul trucks in good working order so fuel efficiency of equipment is maximised;
- using of appropriately sized equipment for construction activities;
- minimising waste from construction;
- substituting high energy intensity building materials, where possible, for materials that have a lower energy intensity; and
- using low intensity lighting throughout the length of the tunnel and more powerful lighting would be used at the portals for safety reasons.

In order to minimise greenhouse gas emissions during operation of the reference project a variety of mitigation and management measures are available, including:

- automatic control of light intensity in the portal region as varying with ambient light conditions on the surface; and
- design of ventilation system which utilises the piston effect of traffic movement through the tunnels and utilises demand management of the ventilation system based on in-tunnel concentrations of air pollutants or in the event of fire or emergency situations.

Further design refinements would consider measures to minimise energy consumption and greenhouse gas generation. Although the traffic modelling shows the implementation of the reference project would result in an overall increase in VKT on the Brisbane road network, and therefore an increase in greenhouse gas emissions compared with a lesser amount of traffic travelling at the same speed, the improvements in energy efficiency within Brisbane's vehicle fleet (from reduced congestion) is likely to result in a small reduction in greenhouse gas emissions per passenger kilometre travelled compared with the 'Do Minimum' scenario. Easing congestion on surface streets would provide opportunities to improve public transport network. Improving public transport is also likely to result in improvements to Brisbane's transport related greenhouse gas emissions.

Brisbane City Council is committed to achieving the targets for its greenhouse gas production by using renewable energy sources, reducing greenhouse gases, supporting sustainable development and being energy efficient. In parallel to this project, Brisbane City Council and the Queensland Government are managing greenhouse emissions across the community through the provision of better public transport alternatives, travel demand management measures and promoting cycling and walking as important transport modes.