Northern Link

18. Health and Safety

Northern Link

Phase 2 – Detailed Feasibility Study

CHAPTER 18

HEALTH AND SAFETY

- September 2008

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18. Health Risk and Safety

This chapter addresses Part B Section 5.13 of the Terms of Reference detailing the impacts of the project on public health. Potential air quality, noise and vibration impacts on human health are based on the data and modelling results reported in Chapter 8, Air Quality and Greenhouse Gases and Chapter 9, Noise and Vibration. Other measures or precautions developed as part of the reference project, aimed at the protection of human health, are outlined.

18.1 Potential Public Health Impacts of Northern Link

The principal potential public health risks of the Project are associated with the project's effect on:

- regional ambient air quality during construction and operation;
- air quality impacts of the ventilation outlets;
- air quality along roads associated with the project;
- increased noise levels during construction;
- vibration effects during construction; and
- increased noise levels during operation.

18.2 Health Assessment of Air Quality Changes

Estimating the health impacts of the forecast changes in ambient air pollutants was based on an assessment of established peer reviewed publications dealing with the relationships between community health outcomes and changes in air pollutants in Brisbane. Where sufficient information was not available for Brisbane, peer reviewed publications from other Australian or overseas cities were used.

18.2.1 Health Risks from Regional Air Quality Changes due to the Project

Based on forecast increases in pollutants for three specific ground level receptors at Bowen Hills, Toowong and Brisbane Grammar School (Table 21 and Table 25 in *Technical Report No. 8 - Air Quality Health in Volume 3* of the EIS), CALPUFF modeling has simulated the air quality impacts of the project over an area 20km by 20km. The proposed Northern Link was located approximately in the centre of the modeled area. Bowen Hills and Toowong were selected so that a comparison could be made between model predictions and monitoring data. Brisbane Grammar School was selected as a sensitive place in an area where the regional changes were predicted to be amongst the highest, although still very low. It should be noted that other locations, such as sites close to roadways, are predicted to experience greater changes in air quality than the regional sites. The health effects at these near road locations have also been considered.

The net increase or decrease enables an assessment of the health effects on the community as a result of the changes in pollutants associated with Northern Link.

In all cases where a net increase is forecast and added to the existing background level of pollutants, the resultant concentration is well below the goal in the Ambient Air Quality NEPM (AAQNEPM) which are designed to protect the community. The AAQNEPM was introduced in 1998 by the National Environment Protection Council (NEPC) and provides the criteria for the national ambient air quality standards for air pollutants to which most Australians are exposed. The AAQNEPM standards were set after consideration of the health effects of these pollutants based on reports prepared by health experts, , the Technical Review Panel of the NEPC and the National Health and Medical Research Council.

There is, however, no lower limit below which an adverse health impact would not occur. As such, an incremental increase in a pollutant can have an impact on health, even though it is below the AAQNEPM. For all the pollutants, the worst case maximum forecast increases, as a result of Northern Link, are well below the maximum levels currently recorded in Brisbane.

To estimate the size of the health effects from the forecast changes in air pollution, known peer reviewed and published relationship between air pollution and health outcomes were used. The studies and estimates used are provided in *Technical Report No. 8 – Air Quality Health in Volume* 3 of the EIS. Where more than one health effect estimate was available, the most conservative estimate, that is, the one that gave the largest adverse health impact, was used.

The health effects resulting from predicted worst case increases in ambient air pollutants were examined. The pollutants considered were 1, 3 butadiene, benzene, CO, formaldehyde, NO_2, PM_{10}, $PM_{2.5}$, polycyclic aromatic hydrocarbons (PAHs), toluene and xylene. These pollutants are produced as a result of motor vehicle exhaust and considered to be the major air pollutant of concern for human health. The health effects were modelled for the worst affected sites.

Both acute and long term health effects were examined. The acute health effects examined were:

- mortality and hospital admission; and
- lung function, symptoms and GP visits.

The long term effects considered were:

- mortality;
- cancer incidence; and
- lung function growth in children.

For the health effect modelling, the worst case forecast increases in emissions across the three sites are listed below. The timeframes over which these pollutants were modelled represents the timeframes associated with adverse health events and also the AAQNEPM goals.

- Annual average 1,3 butadiene: 0.0008µg/m^3
- Annual average benzene: 0.008µg/m^3
- Eight hour carbon monoxide (CO): NIL
- Annual average formaldehyde: 0.003µg/m^3
- One hour maximum nitrogen dioxide (NO_2): 2.7 µg/m^3 in 2014 at one site only (decreases elsewhere)
- 24 hour PM_{10} µg/m^3: 0.1µg/m^3
- Annual average PM_{10}: 0.1µg/m^3
- 24 hour $PM_{2.5}$ µg/m^3: 0.1µg/m^3
- Annual average $PM_{2.5}$: 0.1µg/m^3
- Annual average PAHs: 0.00000005µg/m^3
- 24 hour toluene: 0.03µg/m^3
- Annual average toluene: 0.013µg/m^3

- 24 hour xylene: 0.02µg/m^3
- Annual average xylene: 0.0009µg/m^3.

In all cases the forecast increases in ambient air pollutants were small (0.001% to 0.17%), relative to the current air quality goals as shown in Chapter 8, Air Quality and Greenhouse Gases). The results are summarised below.

1, 3 Butadiene

Based on the worst case scenario, the highest forecast increase in annual average ambient 1, 3 butadiene was 8 x 10^{-7} mg/m^3 or 0.0008µg/m^3. There is currently no AAQNEPM for 1, 3 butadiene.

This forecast worst case increase of 0.0008µg/m^3 in annual average 1,3-butadiene concentration, if maintained for a 70 year period, would result in an increase in cancer of 0.024 persons per one million people exposed to the forecast most conservative increase in 1,3-butadiene, which is an increase in risk of 0.0000024%. By comparison, in Queensland in 2002 the cumulative rate for all types of cancer by age 70 was 15%. In 2002 the total number of people with cancer aged 70 years and older in Queensland was 46,462 persons and the incidence was 4,778 new cases for 2001-2002.

Benzene

The forecast worst case increase in ambient benzene is 0.008µg/m^3. If sustained over a 70 year period this would be expected to result in approximately 0.064 additional leukaemia cases per one million people exposed over a 70 year period[103]. Therefore the additional risk of developing leukaemia as a result of 70 years of exposure to the 0.008µg/m^3 increase in benzene is 0.0000064%. This is a negligible increase in leukaemia risk. By comparison in Queensland in 2002 the cumulative rate for all types of leukemia by age 70 was 0.35%[119]. In 2002 the total number of people with leukaemia aged 70 years and older in Queensland was 1,086 persons and the incidence was 173 new cases for 2001-2002[119].

CO

For all sites no increases in eight-hour ambient CO in 2014, 2016, 2021 and 2026 are predicted, therefore no adverse health events are expected at these sites due to changes in ambient CO as a result of Northern Link.

Formaldehyde

The modeled maximum annual average formaldehyde concentrations of 0.003µg/m^3 , is equivalent to 0.3% of the unit risk factor and therefore would be predicted to result in 0.039 additional cancer cases per one million people exposed to this increase over a 70 year period, which is an increase of 0.0000039% . By comparison, in Queensland in 2002 the cumulative rate for all types of cancer by age 70 was 15%. In 2002 the total number of people with cancer aged 70 years and older in Queensland was 46,462 persons and the incidence was 4,778 new cases for 2001-2002.

NO_2

The worst case maximum increase in regional 1-hour NO_2 as a result of Northern Link project is forecast to be 2.7µg/m^3. The incremental increase in hospital admissions for cardiovascular diseases, respiratory admissions and asthma are forecast to be 0.007 (=1 in 15,000,000), 0.020 and 0.006 persons per 100,000 population exposed to the maximum increase per day on the days when the maximum increases in NO_2 occurs. The incremental increase in mortality is forecast to be 0.003 persons per 100,000, or approximately one in 29.2 million people exposed to the most conservative increase in NO_2.

PM_{10}

The highest forecast increase in regional 24 hour PM_{10}, of 0.1µg/m^3 is predicted to result in very small increases in hospital admissions for all respiratory diseases (0.03%), cardiovascular diseases (0.02%) and a 0.02% increase in total mortality on the days when this maximum increase actually occurs. The background daily rate of these health events is small. Therefore small increases in these events are forecast one in 103 million-281 million people.

At present the daily rate of GP attendances for asthma is around 47 per 100,000 people. Therefore the increased risk for GP attendance for asthma as a result of the most conservative increase in regional 24 hour PM_{10} from Northern Link is 0.041 visits per 100,000 people exposed on each day when the maximum level of PM_{10} occurred.

The forecast increase in regional PM_{10} from Northern Link is expected to result in a 0.04% increase in coughs for adults and 0.01% increase in lower respiratory symptoms in children with chronic respiratory conditions exposed to the most conservative increase in PM_{10} are forecast .

$PM_{2.5}$

The highest forecast increase in regional 24 hour $PM_{2.5}$ resulting from Northern Link is 0.1µg/m^3 which represents 0.4% of the $PM_{2.5}$ NEPM of 25µg/m^3.

The maximum forecast increase in regional $PM_{2.5}$ from Northern Link is predicted to result in a 0.05% increase in hospital admissions for cardiovascular diseases, a 0.09% increase in asthma admissions and 0.02% increase in all respiratory admissions and a 0.009% increase in total mortality. The background daily rate of cardiovascular admissions in Brisbane is 2.19 persons per 100,000, therefore it is forecast that there would be an additional 0.001 persons per day admitted to hospital for cardiovascular diseases per 100,000 people exposed to the most conservative increase in $PM_{2.5}$ on the days when this most conservative increase occurs. This worst case community health outcome is equivalent to an increased risk of one in 91.6 million.

Polycyclic Aromatic Hydrocarbons PAHs (benzo(a)pyrene)

The highest forecast increase in regional annual average PAHs was 0.00000005µg/m^3 which is 0.17% of the NEPM. Based on this most conservative increase in annual PAHs the increased risk of respiratory cancer is one per 30 million people exposed to the highest forecast increase in PAHs over a 70 year period.

Toluene

The highest forecast regional maximum 24-hour and annual average toluene concentrations were 0.03µg/m^3 and 0.01µg/m^3 ,respectively, which represent 0.001% and 0.003%, respectively, of the AAQNEPM. The NEPC 'no observable effect' level is 250,000 times higher than the maximum forecast increase from Northern Link, suggesting that toluene emissions from Northern Link are unlikely to have a known impact on health.

Xylene

The highest maximum increase in ambient annual and 24-hour average xylene concentrations are 0.0009µg/m^3 (0.0002% of the NEPM) and 0.02µg/m^3, respectively. The NEPC 'no adverse effect' level is ~43,500 times higher than the most conservative forecast increase from Northern Link, suggesting that increases in regional xylene concentration from Northern Link are unlikely to have a known impact on health.

18.3 Health Risk from Ventilation Outlet Emissions

Assessments of the health effects as a result of the eastern (N4) and western (W1) ventilation outlets were based on the modelled changes in pollutants at specific ground level receptors (**Table 18-1**).

- **Table 18-1 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	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[a]
Maximum 1-hour average NO_2 ($\mu g/m^3$)	3.1	7.0	3.3	8.3	2.7	7.3	2.5	6.8	94.3	246[b]
Annual average NO_2 ($\mu g/m^3$)	0.3	0.9	0.3	0.9	0.3	0.7	0.3	0.7	18.5	62[b]
Maximum 24-hour average PM_{10} ($\mu g/m^3$)	0.3	0.4	0.3	0.4	0.2	0.3	0.2	0.3	52.6	50[b]
Annual average PM_{10} ($\mu g/m^3$)	0.02	0.07	0.02	0.07	0.02	0.05	0.02	0.05	16.7	25[c]

a =QLD EPA, the AAQNEPM is $11mg/m_3$
b – AAQNEPM
c-World Health Organisation, there is no AAQNEPM for annual average PM_{10}

18.3.1 Eastern Ventilation Outlet

CO

The incremental increases in hospital admissions for all respiratory diseases, asthma and cardiovascular diseases as a result of the maximum increase in CO from the eastern ventilation outlet are one in 39.3 million, one in 25.7 million and one in 19.5 million people, respectively, exposed on each day when the maximum CO level occurs. This is a negligible increase in health risk

NO_2

The predicted maximum increase of $3.3\mu g/m^3$ for 1-hour maximum NO_2 in 2016 is equivalent to 3.4% of the highest one hour maximum recorded at the Environmental Protection Agency's (EPA) Brisbane CBD monitoring station in 2005.

The incremental increase in hospital admissions for cardiovascular diseases, respiratory admissions and asthma are forecast to be 0.009, 0.025 and 0.007 persons per 100,000 population exposed to the maximum increase per day on the days when the maximum increases occur. The incremental increase in mortality is forecast to be one in 24 million people exposed to the maximum predicted increase.

PM_{10}

The highest forecast increase in ambient 24 hour PM_{10} concentrations resulting from the eastern ventilation outlet is expected to be $0.3\mu g/m^3$. The highest forecast increase in annual average PM_{10} is forecast to be $0.02\mu g/m^3$.

The maximum forecast increase in 24 hour PM_{10} is predicted to result in very small increases in hospital admissions for all respiratory and cardiovascular diseases of one in 34 million-94 million people on the days when this maximum increase actually occurs.

$PM_{2.5}$

Assuming 100% of the PM_{10} was $PM_{2.5}$, the highest forecast increase in $PM_{2.5}$ is 0.3μg/m^3 from the eastern ventilation outlet.

The maximum forecast increase in $PM_{2.5}$ from the eastern ventilation outlet is predicted to result in a 0.15% increase in hospital admissions for cardiovascular diseases, a 0.26% increase in asthma admissions and 0.05% increase in all respiratory admissions. The background daily rate of cardiovascular admissions in Brisbane is 2.19 persons/100,000, therefore it is forecast that there would be an additional 0.003 persons per day admitted to hospital for cardiovascular diseases per 100,000 people exposed to the maximum forecast increase in $PM_{2.5}$. This worst case community health outcome is equivalent to an increased risk of one in 30.5 million.

18.3.2 Western Ventilation Outlet

CO

The World Health Organisation (WHO) eight hour guideline of 10ppm (11.6mg/m^3) is well above the forecast 0.1mg/m^3 predicted increase in CO, therefore acute clinical effects of CO exposure from regional increases in CO associated with the Western outlet of Northern Link are not expected.

The incremental increase in hospital admissions for all respiratory diseases, asthma and cardiovascular diseases as a result of the maximum increase in CO associated with the western ventilation outlet is in the order of one in 20 million to one in 40 million. This is a negligible increase in health risk

NO_2

The predicted maximum increase of 8.3μg/m^3 for 1-hour maximum NO_2 in 2016 is equivalent to 8.7% of the highest one hour maximum recorded at the EPA's Brisbane CBD monitoring station in 2005.

The incremental increase in hospital admissions for cardiovascular diseases, respiratory admissions and asthma are forecast to be 0.022, 0.062 and 0.019 persons per 100,000 population, respectively, exposed to the worst case increase per day on the days when the maximum increase in NO_2 occurs. The incremental increase in mortality is forecast to be approximately one in 9.5 million people exposed to the most conservative increase in NO_2.

PM_{10}

The highest forecast increase in ambient 24 hour PM_{10} concentrations resulting from western ventilation outlet is expected to be 0.4μg/m^3.

The maximum forecast increase in 24 hour PM_{10} is predicted to result in very small increases in hospital admissions for all respiratory (0.12%) and cardiovascular diseases (0.09%) on the days when this maximum increase actually occurs. The background daily rate of these health events is small; therefore small increases in these events are forecast in the order of one in 26 million – one in 70 million people.

$PM_{2.5}$

Assuming 100% of the PM_{10} was $PM_{2.5}$, the highest forecast increase in $PM_{2.5}$ from the western ventilation outlet is 0.4 μg/m^3 which represents 1.6% of the NEPM.

The maximum forecast increase in $PM_{2.5}$ from the western ventilation outlet is predicted to result in a 0.20% increase in hospital admissions for cardiovascular diseases, a 0.35% increase in asthma admissions and 0.06% increase in all respiratory admissions. The background daily rate of cardiovascular admissions in Brisbane is 2.19 persons per 100,000, therefore it is forecast that there would be an additional 0.004 persons per day admitted to hospital for cardiovascular diseases per 100,000 people exposed to the worst case increase in $PM_{2.5}$ on the days when the worst case occurs. This worst case community health outcome is equivalent to an increased risk of one in 22.9 million.

18.4 Health Risk Assessment for Roadside Air Pollution

The health effects resulting from changes in roadside pollutants are likely to affect fewer people than the regional changes in pollutants. However, the changes in roadside pollutants, since they are next to major roads, are often higher than regional changes in pollutants. To estimate the likely impact the proximity of child care centres, schools, aged care facilities and hospitals form the major roads are also considered. Both acute and long term health effects are examined, using the same methodology as regional health effect modelling.

It should be noted that the roadway with the largest predicted increase in near- road concentrations, in this case the Western Freeway, has been used as a worst-case benchmark. Although other roads, for example Jephson Street and Croydon Street, are predicted to experience a greater percentage increase in traffic than the Western freeway, the increase in traffic numbers is less and so increase in near-road pollution levels would also be less.

The forecast worst case contribution of Northern Link to near road CO levels is not expected to have an impact on health. The maximum forecast increase in near road CO is $0.3mg/m^3$ at a distance of 10m from the Western Freeway and is forecast to result in extremely small increases in hospital admissions for asthma, all respiratory diseases, cardiovascular diseases and mortality. The size of the increases ranged from 0.012-0.008 persons per 100,000 people exposed to the forecast worst case increase in CO. Given the relatively localised increase in the roadside pollutants, this increase is extremely unlikely to have measurable impact on community health.

The forecast worst case contribution of Northern Link to near road one-hour maximum NO_2 levels is $11.74\mu g/m^3$ and to annual average NO_2 is $7.5\mu g/m^3$ at a distance of 10m from the Western Freeway. The forecast incremental increase in hospital admissions for cardiovascular diseases, respiratory admissions in people aged 65 and over and asthma are negligible and equal to 0.032, 0.015 and 0.027 persons per 100,000 people exposed to the maximum increase per day on the days when the maximum increases in NO_2 occurs. The incremental increase in mortality is forecast to be 0.015 person per 100,000 people exposed to the worst case increase in NO_2, which is a negligible increase in health risk.

The forecast worst case contribution of Northern Link to near road 24-hour maximum or annual average PM_{10} levels is not expected to have a significant impact on health. The predicted maximum increase in near road 24-hour PM_{10} is $2.26\mu g/m^3$ at a distance of 10m from the Western Freeway. The maximum forecast increase in 24 hour PM_{10} is predicted to result in small increases in hospital admissions for all respiratory diseases (0.68%), cardiovascular diseases (0.54%) and a 0.41% increase in total mortality on the days when this maximum increase actually occurs. Small increases in these events are forecast of the order of one in 4.5 million-12.4 million people.

The forecast worst case increase in annual average PM_{10} for 2016 10m from Western Freeway is $0.83\mu g/m^3$. Based on a number of published epidemiological studies this increase is not expected to have an effect on lung function growth in children nor to have any effect on long term mortality, lung cancer mortality or cardiopulmonary mortality even if residential areas were located 10m from the Western Freeway.

The forecast worst case contribution of Northern Link to near road 24-hour maximum or annual average $PM_{2.5}$ levels is not expected to have a significant impact on health. $PM_{2.5}$ is assumed conservatively that all of the near-road PM_{10} is $PM_{2.5}$, therefore the size and location of forecast increases was as per PM_{10}. The predicted increases in hospital admission for cardiovascular diseases as result of the worst case increase in $PM_{2.5,}$ is one in 4 million people who are exposed to the worst case increase in $PM_{2.5}$ on the days when the worst case occurs. The impact is forecast to be negligible.

18.5 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, places of worship, educational, heritage and commercial categories as listed in **Table 18-2**. 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 for the Project and their air quality impacts are treated in the same manner as the surrounding residential properties. Accordingly, since this health risk assessment covers the area for which the air quality assessment was undertaken it has addressed the health risk at these sensitive places. The health effects modelled above (Sections 18.2, 18.3 and 18.4) represent the worst case health effects as a result of the highest ambient and roadside changes in air pollutants that were modelled across the entire study area. The impact at each of the sensitive receptors identified in Table 18.2 has not been modelled, however it would be less than the worst case impact that was modelled and reported in Sections 18.2, 18.3 and 18.4, above.

Table 18-2 Sensitive Places

Type	Facility	Location
Aged Care	The Rosalie Nursing Care Centre	18 Howard St Rosalie (Paddington)
	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

18.5.1 Conclusions and Mitigation Measures

The health risk study undertaken in *Technical Report No. 8 - Air Quality Health in Volume 3* of the EIS shows that regional air pollution as a result of Northern Link is not expected to have an impact on community health. As noted above, the worst case changes in regional ambient benzene, carbon monoxide, formaldehyde, nitrogen dioxide, coarse and fine particulate matter, toluene and xylene, as a result of Northern Link, are forecast to be very small. These worst case increases are used to predict the acute and chronic health impacts based on a range of known published relationships between air pollutants and health. The increased risk of acute adverse health

events, such as hospital admissions or mortality are correspondingly small, in the order of one in 5 million to one in 300 million on the day and at the location where the forecast worst case occurs. The forecast impact on symptoms of asthmatic children, a sensitive subgroup within the community, is also found to be small, representing a worst case acute effect of a 0.008% increase in lower respiratory tract symptoms. Long term health effects on cancer, mortality and lung function growth in children are also forecast to be negligible.

No mitigation measures to manage regional health effects are required.

18.6 Health Risks from Construction Noise and Vibration

18.6.1 Noise

Community or environmental noise is defined by the WHO as noise emitted from all sources (except noise at the industrial workplace) including road, rail, air traffic, construction, public works and the neighbourhood. The WHO's *Guidelines for Community Noise* lists the major potential health effects as:

- noise-induced hearing impairment;
- interference with speech communication;
- disturbance of rest and sleep;
- psycho-physiological, mental-health and performance effects;
- effects on residential behaviour and annoyance; and
- interference with intended activities.

Annoyance

The most common subjective response to noise is annoyance which may include mild anger and fear stemming from belief that one is being avoidably harmed. The level of 'annoyance' may differ considerably among individuals due to factors such as personal characteristics (eg: people who are already stressed) or ability to control the living environment.

As construction works associated with the Project would occur in proximity to noise sensitive receivers it is inevitable that some people may experience annoyance as a result of the project. It is therefore imperative that construction noise be minimised through best practice measures, that the community be kept informed of construction works in advance and that any complaints are promptly addressed.

Hearing Impairment

Hearing impairment can be defined as an increase in the threshold of hearing. In terms of environmental noise, hearing impairment can result from exposure to very high levels of noise of short duration or moderately loud noise over longer durations. The obvious consequence of hearing impairment is the inability to understand speech which can have a significant effect on a person's quality of life.

The first morphological changes after noise exposure are usually found in the inner and outer hair cells of the cochlea where the stereocilia become fused and bent. After more prolonged exposure the outer and inner hair cells related to transmission of high-frequency sounds are missing.

The WHO recognises that in developing countries, not only occupational noise but also environmental noise is an increasing risk factor for hearing impairment. The WHO Guidelines for Community Noise suggest that the risk for hearing impairment from any noise source would be negligible for $L_{Aeq,24hr}$ values of 70dBA over a lifetime. $L_{Aeq,24hr}$ values of 70dBA are very unlikely to occur at any stage during construction of the Project.

To avoid hearing impairment, impulse noise exposures should never exceed 140dB peak sound pressure in adults and 120dB peak sound pressure in children. The only activity during construction of the Project that has the potential to exceed this limit is blasting. Impacts associated with Northern Link blasting will be addressed in the Blast Management Plan and include detailed mitigation measures, for example provision of an acoustic enclosure, to prevent exceedances above the recommended limits for adults and children.

Sleep Disturbance

Out of hours Northern Link construction works have been assessed throughout this report in terms of sleep disturbance impacts.

Potential for sleep disturbance resulting from Northern Link construction works have been identified. The consequences of sleep disturbance can be awakenings and alterations of sleep stages (categorised as 1, 2, 3, 4 and REM), difficulty falling asleep, changes in respiration, cardiovascular effects and increased body movements. These changes can affect mood and performance during the following day.

As sleep is critical to restore biological processes, all practicable mitigation measures are required to minimise potential for sleep disturbance during out of hours Northern Link construction works. Mitigation measures are outlined in Chapter 9 – Noise and Vibration.

18.6.2 Vibration

The key issues having potential to affect the health and wellbeing of receivers exposed to Northern Link vibration are annoyance, sleep disturbance and whole body vibration exposure. Most research to date focuses on health effects associated with occupational vibration exposure such as back pain.

The following sections include a brief discussion of the health issues relating to vibration from construction.

Annoyance

Like noise, annoyance resulting from vibration exposure can vary from person to person and in severe cases can lead to feelings similar to that experienced by people annoyed from noise. Some particularly sensitive people may become annoyed when exposed to vibration levels slightly above the threshold of perception. Annoyance can often stem from a feeling of fear and anxiety particularly if the individual is concerned about the potential for damage to property from the vibration.

The AS 2670 human comfort criteria applied to the Project aim to avoid annoyance to receivers. However the vibration assessment in Chapter 9, Noise and Vibration, Section 9.2.5 indicates that the human comfort limits may at times be exceeded during construction. Subsequently it is important that construction vibration be minimised insofar as possible through best practice measures, the community be kept informed of construction works in advance, particularly tunnelling progress, and that any complaints are promptly addressed.

Sleep Disturbance

The recommended guide level to avoid sleep disturbance is 0.5mm/s (peak) based on experience of human perception levels and various vibration standards. Some people may be comfortable with much higher levels of night vibration than this level. In some areas above the Northern Link tunnels, the sleep disturbance guide level is predicted to be exceeded indicating possible sleep disturbance.

Whole Body Vibration

Vibration from tunnelling activities would occur at frequencies below 200Hz so potential health impacts would result from high vibration levels at relatively low frequencies, provoking an assessment of Whole Body Vibration (WBV).

Australian standard AS 2670.1-2001 '*Evaluation of human exposure to whole-body vibration*' identifies criteria to assess vibration and its effects on humans.

- Health effects - from periodic, random and transient vibration on the health of workers exposed to whole body vibration during travel, at work or during leisure activities.
- Comfort and perception - estimation of the effect of vibration on the comfort of persons who are exposed to whole-body vibration during travel, at work or during leisure activities.
- Motion sickness - the effects of oscillatory motion on the incidence of motion sickness.

The process of assessment of the potential for health impacts from vibration is outlined in Annexure B of AS 2670.1-2001 '*Guide to the effects of vibration on health*' and is outlined in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

Expected vibration levels from Northern Link tunnelling would be much lower than the calculated equivalent peak particle vibration (PPV) where health risks may become an issue; therefore the health risk associated with generated vibration levels during construction may be considered extremely low.

18.7 Health Risks in Operation

18.7.1 Noise

With the mitigation measures identified for specific locations adjacent to the reference project in place no effects on community health are expected from the operation of Northern Link.

18.7.2 Vibration

Regenerated noise and vibration from roadways in shallow tunnel areas is not considered to be an issue for this project provided road surfaces are well maintained.