Additional Waitemata Harbour Crossing

Air Quality Assessment

Contents

Appendices

1. Introduction

The Additional Waitemata Harbour Crossing (AWHC) Project (the Project) progresses the outcomes of previous studies undertaken which have examined the nature and form of an additional transport crossing of Auckland's Waitemata Harbour. These studies have been undertaken in recognition of the contribution of an additional crossing to improving the accessibility and resilience of Auckland's transport network in a manner that will facilitate the predicted future growth of the Auckland Region.

In order to develop a business case for an AWHC, the Project has been split into three separate, concurrent workstreams. PricewaterhouseCoopers (PwC) and the New Zealand Institute of Economic Research (NZIER) are contracted to deliver economic advisory services, develop funding options and develop the overall Business Case; Sinclair Knight Merz (SKM) and Flow Transportation Specialists (Flow) are undertaking transport and toll modelling; and Beca and AECOM are providing engineering and planning services.

The Engineering and Planning Services workstream involves a number of phases including:

Phase 1: Confirming objectives, principles, constraints and requirements.

Phase 2: Rapid narrowing of a long list of options to a short list of a bridge and tunnel options, defined for further detailed assessment.

Phase 3: Targeted design and assessment of up to three options to consider the relative merits of each option in terms of consentability or consenting risk, constructability and operational functionality.

Phase 4: Design and assessment of up to three options to understand the cost, effects, risks and benefits of each option as an input to the Business Case to recommend a preferred option.

This report has been prepared at the end of Phase 3 of the Engineering and Planning Services workstream. It provides an assessment of the relative merits of each short list option in terms of air quality effects and identifies areas of consenting risk. Ultimately, the work undertaken in this project will determine whether an additional harbour crossing should be "under the water" (tunnel), "over the water" (bridge) or a combination of both. Therefore, this report focuses on those aspects of the Project that differ between the two options, rather than presenting an overall assessment of air quality effects for the Project.

There are two possible approaches to the option comparison for air quality effects. A basic approach (Tier 1 in the Ministry for the Environment Good Practice Guide for Assessing Discharges to Air from Land Transport, hereinafter referred to as the MfE Transport GPG (MfE, 2008)) effectively applies a simple comparison based solely on traffic volumes and proximity to the nearest sensitive receptor for each road link. This approach does not provide suitable tools for comparing tunnels against surface roads. An alternate approach suggested in the MfE Transport GPG is to undertake a simple, limited assessment of the health impacts associated with the project options. Methodologies for this are presented in Appendix 4 to the MfE Transport GPG This estimates the likely health effects as a result of change in exposure at properties for each option, taking account of all changes in exposure, whether on existing or new routes. It is this latter approach that has been adopted for this assessment.

2. Previous Studies

The AWHC is only one of a number of road tunnel projects currently under construction or proposed in New Zealand and Australia. Others under construction or recently opened include the Victoria Park Tunnel in Auckland; Johnstones Hill tunnels north of Auckland; the M5 East, Cross City and Lane Cove tunnels in Sydney; the North-South Bypass; and the Eastlink tunnel in Melbourne. In addition, NoRs have recently been lodged for the Waterview Connection Project in Auckland, which includes twin 2.6km long three-lane motorway tunnels. Of the various reports prepared for those projects, only those for the Waterview Connection Project and the Victoria Park Tunnel have been considered in this assessment, being the most recent assessment completed for a comparable project, using the same vehicle fleet and assumption regarding fuel types that would apply to the AWHC project. The existing studies that have informed this report are discussed below.

2.1 2010 Additional Waitemata Harbour Crossing

An additional crossing of the Waitemata Harbour has been under consideration for a number of years and numerous studies have been reported. However, for this assessment of impacts on air quality, it is only the most recent study that has been considered, since this closely reflects one of the two options currently under consideration.

In 2010 NZTA and KiwiRail submitted a number of Notices of Requirement (NoR) to seek designations within both Auckland City and North Shore City District Plans for the protection of land to allow the construction of both a driven twin tunnel road crossing and a driven twin tunnel rail crossing. The documentation included an Assessment of Environmental Effects and a number of Specialist Technical Reports, including an assessment of effects of air quality prepared by Endpoint Ltd (Fisher, 2010).

2.2 2010 Western Ring Route: Waterview Connection

In August 2010, the NZTA submitted a NoR to seek designation within the Auckland City District Plan for the construction of twin motorway tunnels between Avondale and Waterview, to complete the SH20/SH16 Western Ring Route (the Waterview Connection Project). Because of the similarities between the Waterview tunnels and the AWHC tunnel option (in terms of configuration if not in traffic volumes or location), it is reasonable to use data from the air quality assessment undertaken for the Waterview Connection Project to inform this assessment. Further comparison between the two projects and a consideration of some of the outcomes of the air quality assessment for the Waterview Connection Project are given in section 6.4 of this report.

2.3 2006 Victoria Park Tunnel

In 2006, the NZTA lodged an NoR for the Victoria Park Tunnel, a three-lane cut and cover motorway tunnel under Victoria Park designed to increase capacity and relieve congestion on SH1 between the Central Motorway Junction (CMJ) and the AHB. Ambient air quality monitoring undertaken to inform the NoR for the Victoria Park Tunnel has been used to provide an indication of background air quality in the AWHC project area.

3. Short List Options Description

3.1 Project Overview

The study area for the project extends from the State Highway (SH) 1 Esmonde Road interchange on the North Shore to the locality of the Cook St/ Wellington St interchanges on SH 1 and the SH 16 links in Auckland City (i.e. the Central Motorway Junction (CMJ)). The indicative extent of this study area is shown in Figure 3.1.

For the purpose of this Project the study area is divided into a Northern Sector, Central Sector and Southern Sector as follows:

Northern Sector: located on the North Shore, extending from the SH1 / Esmonde Road interchange in the north to Stokes Point / Northcote Point in the south;

Central Sector: encompasses the Waitemata Harbour, extending from the end of Northcote Point, on the North Shore to the coastal edge of Auckland City between Point Erin and Wynyard Quarter; and

Southern Sector: encompasses the areas above Mean High Water Springs (MHWS) extending from Westhaven Drive and Wynyard Quarter in the north to the locality of the CMJ in Auckland City.

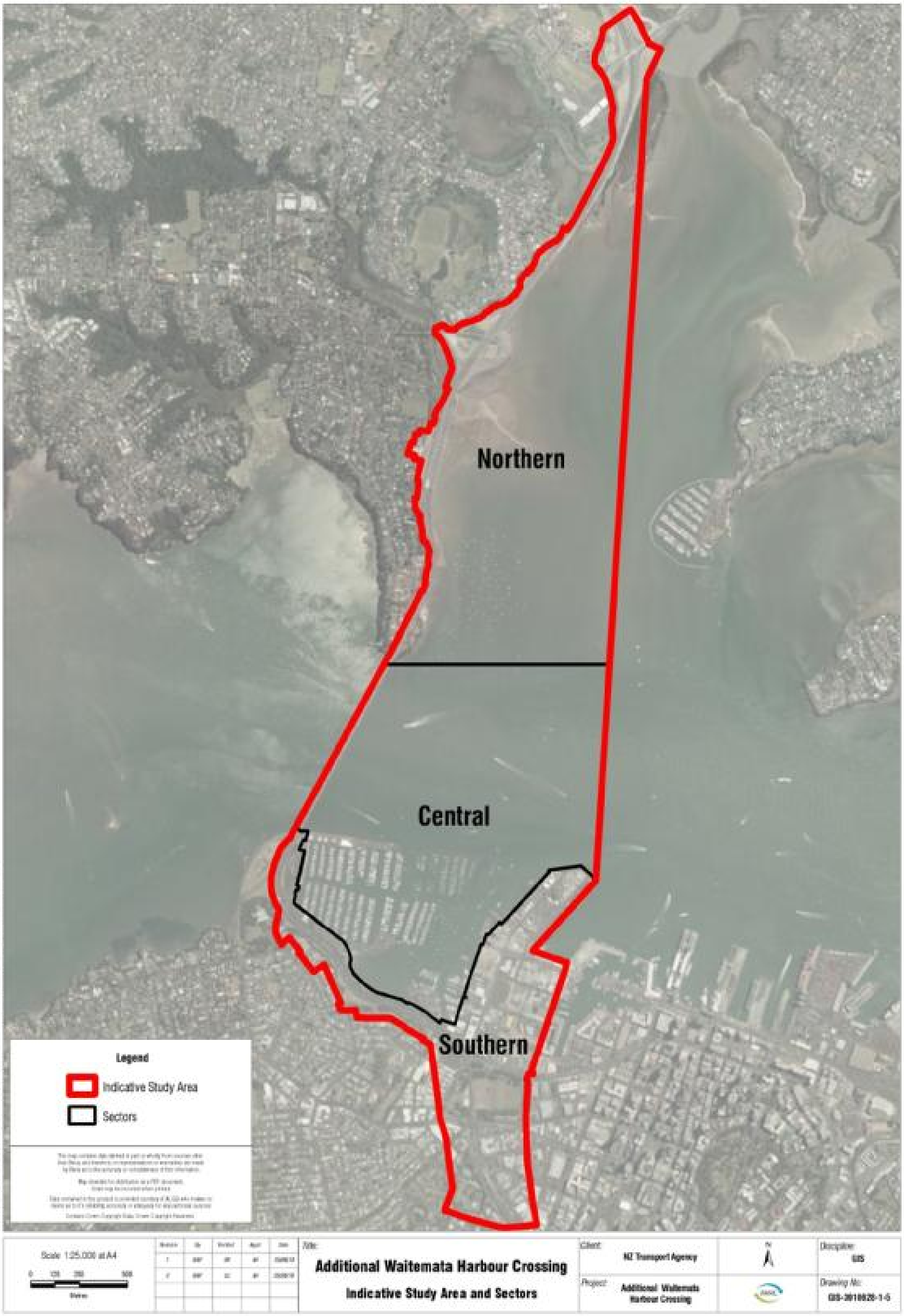

Figure 3.1: Indicative Extent of Study Area

3.2 Tunnel Option

The shortlisted tunnel option is an all tunnel option for road and rail. The alignment generally accords with the 2010 NoR Concept Design. The road tunnels connect to the existing motorway network in the vicinity of Onewa Road interchange in the north and the CMJ in the south. The rail tunnels connect to Akoranga Busway Station in the north and Gaunt Street (underground station) in the south.

To meet requirements for road tunnel health and safety (i.e. in-tunnel air quality, visibility and the removal of smoke), the road tunnels will be provided with a mechanical ventilation system to:

- Maintain in-tunnel air quality (including visibility) by providing sufficient fresh air intake for the control of vehicle pollutant concentration to acceptable levels;
- Provide portal emissions control and adequate atmospheric emissions dispersion;
- Control the spread of fire smoke, enabling safe occupant egress under fire conditions and to facilitate an effective emergency response.

The ventilation system would comprise a longitudinal in-tunnel ventilation system, an exhaust ventilation system and smoke extraction system; however, details of the design of the ventilation system are beyond the scope of this report.

As part of the ventilation system, ventilation stations would be constructed at each end of the combined tunnel alignment. The ventilation stations will house the fans and control systems which operate the ventilation system. Prior to reaching the exit portal, the air from inside the tunnels is discharged through a ventilation stack at the respective ventilation station.

A more detailed summary of the ventilation requirements for the proposed tunnels is contained in the report by Stacey Agnew Pty Ltd (Stacey Agnew, 2010).

3.2.1 Northern Sector

The tunnel option requires reclamation through Shoal Bay to accommodate road and rail. The road mainline is at grade through the northern sector, descending into a trench and cut and cover tunnel before entering a bored tunnel in the vicinity of Northcote Point. Rail will be elevated on a bridge structure from Esmonde Road to the vicinity of the City of Cork beach, where it descends into a trench and cut and cover tunnel sections before entering a bored tunnel in the vicinity of Onewa Road interchange.

The road mainline accesses the North Shore via interchanges at Onewa and Esmonde.

A ventilation station will be located close to the northern road tunnel portal. Ventilation air drawn from the northbound tunnel will be discharged via a stack located above the ventilation station. It is anticipated that the vent stack will be in the order of 25-30m high, so as to provide adequate dispersion of emissions given the surrounding topography (Northcote Point rises to approximately 20-25m above sea level within about 100m of the proposed stack location.

3.2.2 Central Sector

The tunnel option consists of two bored tunnels for road (three lanes in each tunnel) and two bored tunnels for rail (one track in each tunnel) through the central sector. The outside diameter (OD) of the road tunnels is 15.5 metres and rail tunnels have an OD of 6.9 metres. Road and rail tunnels will be some 50 metres below sea level across the harbour.

The existing Auckland Harbour Bridge (AHB) will be retained and used for general traffic, pedestrians, cyclists and bus public transport.

3.2.3 Southern Sector

The bored road tunnels emerge in Victoria Park and continue south in cut and cover tunnel and trench to the CMJ. Rail tunnels continue as a bored tunnel through Wynyard Quarter and are 30 metres below ground level at Gaunt Street station.

The south connections are to SH16/ Ports and the motorway south of Cook Street. Cook Street off ramp from AHB is a three lane cut and cover tunnel over the top of the road mainline bored tunnels. Cook Street on ramp to AHB is a two lane cut and cover tunnel beneath the road mainline trenches and joins Victoria Park Tunnel (VPT).

A ventilation station will be required to extract and discharge air from the southbound tunnels. At present, two alternate locations are being considered for this ventilation station, one being adjacent to the Fanshawe Street / Beaumont Street intersection and the other at the mid-point of where the tunnels will pass under Victoria Park. It is anticipated that the vent stack will be in the order of 32m high, so as to provide adequate dispersal of emissions given the surrounding topography and the number of relatively tall buildings in the area.

3.3 Bridge Option

The shortlisted bridge option is a road bridge west of the NoR alignment and rail tunnels generally on the NoR alignment. The road bridge is three lanes each way and connects to the existing motorway network in the vicinity of Onewa Road Interchange in the north and the CMJ in the south. Two rail tunnels are bored (one track in each tunnel) and connect to Akoranga Busway Station in the north and Gaunt Street (underground station) in the south.

3.3.1 Northern Sector

The bridge option requires reclamation through Shoal Bay to accommodate road and rail. The road mainline is at grade through the northern sector. Rail will be elevated on bridge structure from Esmonde Road to the vicinity of the City of Cork beach, where it descends into a trench and cut and cover tunnel sections before entering a bored tunnel in the vicinity of Onewa Road interchange.

The road mainline accesses the North Shore via interchanges at Onewa and Esmonde.

3.3.2 Central Sector

The bridge spans 2.8 kilometres in length with a maximum vertical gradient of 5%. 41 metres of clearance will be maintained over the navigation channel within the harbour and a clearance of 30 metres will be provided over the Westhaven Marina entrance. The rail tunnels have an OD of 6.9 metres and will be some 50 metres below sea level across the harbour.

The existing AHB will be retained and used for general traffic, pedestrians, cyclists and bus public transport.

3.3.3 Southern Sector

The bridge southern approach is located in the vicinity of Z-Pier. The south bound connection to CMJ will be a new cut and cover tunnel east of Victoria Park Tunnel. Rail tunnels continue as a bored tunnel through Wynyard Quarter and are 30 metres below ground level at Gaunt Street station.

The south connections are to SH16/ Ports and the motorway south of Cook Street. Fanshawe Street off and on ramps will pass under the bridge at grade. Cook Street off ramp from AHB is at grade under the bridge and enters a cut and cover tunnel to Cook Street. Cook Street on ramp to AHB is a cut and cover tunnel. Wellington Street is a north bound on ramp to the mainline tunnel.

It is anticipated that the cut and cover tunnels will rely on ventilation via the tunnel portals only, rather than via stacks.

4. Assessment Matters

Several pieces of legislation guide land transport planning. The statutory framework for land use planning is largely contained within the RMA. The purpose of the RMA is to promote the sustainable management of natural and physical resources. The Land Transport Management Act 2003 (LTMA) sets out requirements for the operation, development and funding of the land transport system.

The NZTA uses designations for its State Highway network. In applying for a designation, the requiring authority (in this case the NZTA) submits a notice of requirement to the relevant territorial local authority (in this case, the Auckland Council). The notice of requirement is accompanied by an assessment of environmental effects (AEE) including an assessment of potential effects on air quality.

4.1 Resource Management Act 1991

The purpose and principles of the RMA are set out in Sections 5 to 8 of that Act. Of particular relevance to the assessment of effects of discharges into air from land transport activities are Sections 5(1) and 5(2)(c), which state:

"(1) The purpose of this Act is to promote the sustainable management of natural and physical resources

(2) In this Act, sustainable management means managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural wellbeing and for their health and safety while – …

(c) Avoiding, remedying or mitigating any adverse effects of activities on the environment."

Air is one such natural resource. Section 7 of the RMA requires consent authorities to give particular regard to those matters listed in the section. In the case of discharges into air from this particular Project, the following matters are considered relevant: maintenance and enhancement of amenity values (Section 7(c)) and maintenance and enhancement of the quality of the environment (Section 7(f)). In the context of this assessment, the quality of the environment is described in the context of effects on human health.

Discharges of contaminants into air are specifically addressed in section 15 of the RMA. Sections 15(2) and (2A) state:

(2) No person may discharge a contaminant into the air, or into or onto land, from a place or any other source, whether moveable or not, in a manner that contravenes a national environmental standard unless the discharge—

(a) is expressly allowed by other regulations; or

(b) is expressly allowed by a resource consent; or

(c) is an activity allowed by section 20A.

(2A) No person may discharge a contaminant into the air, or into or onto land, from a place or any other source, whether moveable or not, in a manner that contravenes a regional rule unless the discharge—

(a) is expressly allowed by a national environmental standard or other regulations; or

(b) is expressly allowed by a resource consent; or

(c) is an activity allowed by section 20A.

The relevant regional plan requirements as they relate to air discharges are described in more detail below.

4.2 Proposed Auckland Regional Plan: Air, Land and Water

The PARP: ALW was first notified in October 2001. Following consideration of submissions, Decision Notices were issued on 8 October 2004 and the PARP: ALW was updated to include the decisions on submissions. The text of the 2004 Decision Notices version has been revised several times since then to incorporate the ongoing settlement of relevant appeals, most recently in November 2009. It is the text of the November 2009 version that is referenced in this document.

The PARP: ALW contains objectives, policies and rules relating to air quality impacts from mobile sources.

Regional Objectives and Policies

Objective 4.3.6 is:

"To minimise the discharge of contaminants into air from mobile sources while enabling sustainable development and protecting the health and social well being of the people of the Auckland region"

Policy 4.4.15 states:

"Any land use proposals with transportation effects, and any new transport projects or proposals for redeveloping transport infrastructure which have the potential to adversely affect air quality, should be assessed at a level considered appropriate for the size and scale of the project or proposal, and shall consider the following:

(a) Effects on human health;

(b) Effects on regional and local air quality; and

(c) Any alternatives or methods to mitigate effects on air quality or minimise the discharge of contaminants into air."

The management approach to protect human health in the Auckland region from ambient air pollution has been to select key pollutants as indicators, by utilising the AQNES and setting additional complementary ARAQT. The primary methods for implementing these policies will be through land use planning procedures and transport strategies.

Regional Rules

Rule 4.5.1, the general permitted activity rule, states:

"Unless provided for otherwise in this plan, activities that discharge contaminants into air are Permitted Activities, subject to the following conditions:

(a) That beyond the boundary of the premises where the activity is being undertaken there shall be no noxious, dangerous, offensive or objectionable odour, dust, particulate, smoke or ash; and

(b) That there shall be no noxious, dangerous, offensive or objectionable visible emissions; and

(c) That beyond the boundary of the premises where the activity is being undertaken there shall be no discharge into air of hazardous air pollutants that does, or is likely to, cause adverse effects on human health, ecosystems or property; and . . ."

'Premises' is defined in the PARP: ALW as including land, buildings, mobile sources and any other location where an activity that discharges contaminants into air takes place.

Vehicle exhaust emissions, whether directly from vehicles on surface roads or discharged via tunnel ventilation stacks or portals, are specifically provided for in Rule 4.5.3, which states:

> *"The discharge of contaminants into air from motor vehicle, aircraft, train, vessel and lawnmower engines including those located on industrial or trade premises is a Permitted Activity."*

Therefore, resource consent is not required for the discharge of contaminants into air from proposed tunnel portals, ventilation stacks or new surface sections of road.

4.3 Land Transport Management Act

The Land Transport Management Act 2003 (LTMA) sets out requirements for the operation, development and funding of the land transport system. Section 94 of the LTMA states that the objective of the NZTA is to "*undertake its functions in a way that contributes to an affordable, integrated, safe, responsive, and sustainable land transport system.*" The functions of the NZTA in the context of this proposal are set out in Section 95(1) of the LTMA, while Section 96 sets out the operating principles of the NZTA. The specific principle that applies to this assessment is set out in Section 96(1)(a)(i), as follows:

> *"(1) In meeting its objective and undertaking its functions, the* [NZTA] *must—*
>
> *(a) exhibit a sense of social and environmental responsibility, which includes—*
>
> *(i) avoiding, to the extent reasonable in the circumstances, adverse effects on the environment; and ..."*

4.4 New Zealand Transport Strategy 2008 (NZTS)

The NZTS has established targets that support the delivery of the government's transport objectives and provide a focus for many of the government's actions over the life of the Strategy. The NZTS guides New Zealand transport policy at all levels to create a sustainable, affordable, integrated, safe and responsive transport system. The vision of the NZTS is that by "*2010 New Zealand will have an affordable, integrated, safe, responsive and sustainable transport system*".

The NZTS includes a target to *'reduce the number of people exposed to health-endangering concentrations of air pollution in locations where the impact of transport emissions is significant'*.

4.5 Auckland Regional Land Transport Strategy (RLTS)

The 2010 Auckland Regional Land Transport Strategy (the RLTS) is a statutory document prepared under the LTMA. The RLTS sets the direction for the region's transport system for the next 30 years. One of the seven objectives of the RLTS that relates to air quality is: *Objective 4: Protecting and Promoting Public Health.*

The Auckland region as a whole experiences a significant impact from transport emissions as identified in the ARC's Emissions Inventory (2004) which concludes that "*the largest single contributors to annual emissions of PM_{10} are motor vehicles (41%) and domestic heating (38%). For NO_x emissions, the principal source is motor vehicles (71%). Consequently, emissions management strategies that target these sources will have the greatest impact on improving air quality in Auckland*."

Objective 4 looks to improve community health by promoting active modes of transport, and to protect public health by reducing exposure to health-impacting pollutants from the transport system. Reducing the levels of congestion, the amount of travel by motor vehicles and improving fuel quality can improve public health by reducing air pollution, water pollution and noise.

4.6 Air Quality Assessment Criteria

Air quality standards and guidelines are used to assess the potential for air pollutants to give rise to adverse health or nuisance effects. The MfE Transport GPG recommends the following order of precedence when selecting suitable assessment criteria:

- New Zealand National Environmental Standards (AQNES)
- New Zealand Ambient Air Quality Guidelines (NZAAQG)
- Regional Air Quality Targets.

The recent (1 October 2009) amendments to the Resource Management Act 1991 strengthened the standing of the national environmental standards. In the Auckland region, the Auckland regional air quality targets (ARAQT) are the same as the ambient air quality guidelines with the exception that the ARAQT includes a target for $PM_{2.5}$ whereas the NZAAQG includes $PM_{2.5}$ as a monitoring threshold only, not a guideline. For the contaminants that should be considered for an assessment of effects of discharges of vehicle exhaust emissions, there are relevant New Zealand National Environmental Standards, Ambient Air Quality Guidelines and Regional Air Quality Targets. Relevant assessment criteria are summarised in Table 4.1.

Table 4.1: Relevant Assessment Criteria

Parameter	Threshold concentration	Averaging period	Rationale
Fine particles (as PM_{10})	50 µg/m^3 20 µg/m^3	24-hour Annual	AQNES ARAQT, NZAAQG
Fine particles (as $PM_{2.5}$)	25 µg/m^3 10 µg/m^3	24-hour Annual	ARAQT, NZAAQG WHO
Carbon monoxide	30 mg/m^3 10 mg/m^3	1-hour Rolling 8-hour	ARAQT, NZAAQG AQNES
Nitrogen dioxide	200 µg/m^3 100 µg/m^3 40 µg/m^3	1-hour 24-hour Annual	AQNES ARAQT, NZAAQG WHO
Benzene	3.6 µg/m^3	Annual	ARAQT, NZAAQG

5. Existing environment

5.1 Background Air Quality

The northern and southern sectors of the Project are both located within the Auckland Urban airshed, which has been gazetted[1] under the Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004 (AQNES).

Ambient air quality has been monitored at two locations in the vicinity of the AWHC:

- Victory Christian Church (2006) and Westhaven Drive (August-November 2009); sites operated on behalf of the NZTA in connection with the Victoria Park Tunnel project.
- Westlake Girls High School, Wairau Road, Takapuna (1995 on); site operated on behalf of the ARC as part of the ARC's regional ambient air quality monitoring network.

The Auckland Regional Council (ARC) has undertaken continuous monitoring of concentrations of PM_{10}, NO_x and CO at a site adjacent to Wairau Road, Takapuna for a number of years. This monitoring site is located approximately 70m east of SH1 and approximately 5km north or the study area.

5.1.1 Victoria Park

An air quality monitoring site was operated in the car park of the Victory Christian Church, Beaumont St between January 2006 and January 2007, to monitor ambient concentrations of oxides of nitrogen and carbon monoxide. The results of this monitoring were used in support of the Notice of Requirement for the Victoria Park Tunnel on SH1. The results of this monitoring are summarised in Table 5.1.

[1] Gazetted airsheds include areas where the PM_{10} standard is regularly breached each year, and a smaller number that have the potential to breach the standard unless carefully managed.

Table 5.1: Summary of Ambient Air Quality Monitoring at Victory Christian Church, 2006

Parameter	Contaminant and Averaging Period			
	NO_2 1-hour average	NO_2 24-hour average	CO 1-hour average	CO 8-hour average
Maximum	92.0 µg/m³	50.5 µg/m³	7.7 mg/m³	3.6 mg/m³
99.9th percentile	73.9 µg/m³	N/A	3.4 mg/m³	2.9 mg/m³
Annual Average	22.5 µg/m³	22.8 µg/m³	0.5 mg/m³	0.5 mg/m³
Exceedances of ARAQT	N/A	Nil	Nil	N/A
Exceedances of AQNES	Nil	N/A	N/A	Nil

Notes: AQNES for NO_2 is 200 µg/m³ as an 1-hour average, while ARAQT and NZAAQG are 100 µg/m³ as 24-hour averages.
AQNES for CO is 10 mg/m³ as an 8-hour average, while ARAQT and NZAAQG are 30 mg/m³ as 1-hour averages.

Pre-construction monitoring for the Victoria Park Tunnel was undertaken at a site on Westhaven Drive for a period of three months during 2009. The results of this monitoring are summarised in Table .

Table 5.2: Summary of Ambient Air Quality Monitoring at Westhaven Drive, August – November 2009

Parameter	PM_{10} 24-hour average
Maximum 24-hour average (µg/m³)	140.8 µg/m³
2nd highest 24-hour average (µg/m³)	36.3 µg/m³
Annual Average (µg/m³)	19.6 µg/m³
Exceedances of AQNES	1

Note: AQNES for PM_{10} is 50 µg/m³ as a 24-hour average.

The one exceedance of the AQNES for PM_{10} was recorded on 24 September 2009. Similar exceedances of the AQNES were also recorded at other monitoring sites located in the Auckland region. Based on the timing of the highest concentrations (overnight 24 - 25 September 2009) and the wide geographical distribution of exceedances, it is likely that the high PM_{10} levels were caused by fine dust carried across the Tasman Sea from Australia. New South Wales and Queensland were affected by intense dust storms between 22 and 24 September 2009.

5.1.2 Takapuna

The ARC undertakes ambient air quality monitoring at a number of sites across the Auckland region. Monitoring of ambient concentrations of oxides of nitrogen and carbon monoxide commenced at Westlake Girls High School, Wairau Road, Takapuna (Takapuna monitoring site) in 1995. Continuous monitoring of ambient concentrations of PM_{10} at the same location commenced in February 2004. The results of this monitoring for the years 2004 to 2009 are summarised in Table 5.3 to Table 5.6.

Aside from an exceedance recorded on 24 September 2009 (refer to section 5.1.1), there have been no exceedances of the AQNES for PM_{10} recorded at the Takapuna monitoring site since June 2005.

Table 5.3 : Summary of Ambient PM_{10} Monitoring at ARC Takapuna Monitoring Site, 2004 -2009

	2004	2005	2006	2007	2008	2009
Maximum 24-hour average (µg/m^3)	60	52	46	39	35	126
2nd highest 24-hour average (µg/m^3)	46	49	44	38	34	88
Annual Average (µg/m^3)	20	17	18	14	17	16
Exceedances of AQNES	1	1	0	0	0	2

Notes: Data courtesy of the ARC.
AQNES for PM_{10} is 50 µg/m^3 as a 24-hour average.

Table 5.4 : Summary of Ambient $PM_{2.5}$ Monitoring at ARC Takapuna Monitoring Site, 2007 -2009

	2007	2008	2009
Maximum 24-hour average (µg/m^3)	24	29	50
2nd highest 24-hour average (µg/m^3)	23	28	40
Annual Average (µg/m^3)	7	7	7
Exceedances of ARAQT and NZAAQG	0	3	4

Notes: Data courtesy of the ARC.
ARAQT and NZAAQG for $PM_{2.5}$ is 25 µg/m^3 as a 24-hour average.

Table 5.5 : Summary of Ambient NO_2 Monitoring at ARC Takapuna Monitoring Site, 2004 -2009

	2004	2005	2006	2007	2008	2009
Maximum 24-hour average (µg/m^3)	51	57	57	44	52	52
Exceedances of ARAQT and NZAAQG	0	0	0	0	0	0
Maximum 1-hour average (µg/m^3)	124	122	132	102	110	110
99.9th percentile of 1-hour averages (µg/m^3)	89	94	114	86	86	89
Exceedances of AQNES	0	0	0	0	0	0
Annual Average	26	26	27	24	21	28

Notes: Data courtesy of the ARC .

AQNES for NO_2 is 200 µg/m^3 as an 1-hour average.

ARAQT and NZAAQG for NO_2 are 100 µg/m^3 as 24-hour averages.

Table 5.6 : Summary of Ambient CO Monitoring at ARC Takapuna Monitoring Site, 2004 -2009

	2004	2005	2006	2007	2008	2009
Maximum 8-hour average (mg/m^3)	5.9	6.3	6.3	5.7	4.7	4.2
99.9th percentile of 8-hour averages (mg/m^3)	5.1	5.3	5.3	4.6	4.6	3.4
Exceedances of AQNES	0	0	0	0	0	0
Maximum 1-hour average (mg/m^3)	7.5	8.7	8.0	6.8	6.8	5.6
Exceedances of RAQT	0	0	0	0	0	0
Annual Average	0.6	0.5	0.7	0.5	0.5	0.4

Notes: Data courtesy of the ARC .

AQNES for CO is 10 mg/m^3 as a running 8-hour average.

ARAQT and NZAAQG for CO are 30 mg/m^3 as 1-hour averages.

No exceedances of the AQNES or RAQT for NO_2 or CO have been recorded at the Takapuna monitoring site within the past six years.

5.1.3 Air Quality in the Project Area

The Takapuna monitoring site is located 50m to the east of SH1, approximately 2.5km north of Esmonde Road. Both the Victory Christian Church and Westhaven Drive sites were within 60m of SH1 at the southern end of the project area. Ambient concentrations of NO_2 and CO recorded at the Takapuna monitoring site in 2006 were slightly higher than those recorded at the Victory Christian Church site in the same period.

Given the locations of these monitoring sites in relation to the AWHC project, it is reasonable to assume that air quality in the project area will be comparable to that at the Takapuna monitoring site.

As previously noted, the entire project area is located within the Auckland Urban Airshed, in which is regarded as being in breach of the AQNES for PM_{10} (i.e. 24-hour average ambient concentrations of PM_{10} exceed 50 µg/m^3 on more than one day per year anywhere within the airshed). However, the results of ambient air quality monitoring undertaken at the ARC Takapuna, Victory Christian Church and Westhaven Drive monitoring sites indicate that air quality in the project area can be regarded as reasonably good. Aside from the exceedance on 24 September 2009 caused by dust blown across the Tasman from Australia, there has been only one exceedance of the PM_{10} AQNES recorded at these monitoring sites in the past four years (a value of 88 µg/m^3 recorded on 28 May 2009).

Based on this (limited) assessment of ambient air quality in the project area, exhaust emissions from vehicles using the AWHC would have to cause significant increases in ambient concentrations (greater than about 20% for PM_{10} and 40% for NO_2) for discharges to air associated with the AWHC project to be likely to contribute to exceedances of the AQNES. However, concentrations of $PM_{2.5}$ measured at the Takapuna monitoring site already approach or exceed the ARAQT on occasions. A detailed air quality assessment for the preferred option will have to address the contribution of exhaust emissions from vehicles using the AWHC on $PM_{2.5}$ concentrations in the surrounding area.

This summary of air quality in the project area does not account for ambient concentrations of air toxics (such as benzene). Again, these will have to be addressed in a detailed air quality assessment for the preferred option.

5.2 Sensitive Receptors

5.2.1 Overview

The MfE Transport GPG (MfE, 2008) recommends assessing the air quality effects of a proposed road on identified sensitive receptors. In this context, sensitive individuals include children, those engaged in outdoor recreational activity and those whose health is already compromised, such as elderly persons. These people are generally regarded as likely to be more sensitive than the general population to the effects of vehicle exhaust emissions. Sensitive receptors, therefore, include residential areas, childcare and early learning facilities, schools, hospitals, sports fields and residential care homes.

Concentrations of air pollutants from vehicles on surface roads tend to decrease fairly rapidly with increasing distance from the road. For example, the ARC has undertaken passive monitoring of NO_2 at a number of sites at varying distances from two motorways in Auckland (SH20 in Mangere and SH1 in Penrose) (ARC, 2006). The results of this monitoring indicated that elevated concentrations of NO_2 arising from motor vehicle emissions could be detected only up to 300m from the motorway. The MfE Transport GPG indicates that, beyond approximately 200m from a road, the contribution of vehicle emissions from the road to the local ambient air concentrations is not significant (MfE, 2008)[2].

Pollutants discharged from elevated sources, such as vent stacks and bridges, have the potential to be dispersed further than those from surface sections of road. The extent of this dispersion is dependent on a number of factors, including the height of the source above ground level, the height of any nearby structures, vertical discharge velocity (in the case or stacks), the surrounding terrain and local meteorology.

For the purposes of this report, only sensitive receptors within 200m of surface sections of the Project, 500m of elevated sections and 500m of tunnel vent stacks have been considered as potentially affected.

5.2.2 Northern Sector

Topography

Within the northern sector of the Project, both bridge and tunnel options follow the shore of the Waitemata Harbour from the Esmonde Road interchange southwards. On the landward side, between the Tank Farm tuff crater and the Onewa Road interchange and along Northcote Point, the terrain rises steeply to about 20m above sea level. Between the Onewa Road interchange and the northbound Stafford Road off-ramp, this steeply rising ground is set back about 200m from the existing alignment of SH1.

Sensitive Receptors

For the purposes of this assessment, north of and including the Onewa Road interchange there is no difference between the alignments and traffic flows (and the consequent air quality impacts) for either the bridge or the tunnel option.

South of the Onewa Road interchange, there are a number of residential receptors within 200m of both the bridge and tunnel options and within 500m of the elevated section of the bridge option.

5.2.3 Central Sector

The central sector of the project lies across the open water of the harbour. There are no receptors in this area that are regarded as sensitive to the effects of air quality.

5.2.4 Southern Sector

Topography

[2] For the purposes of this assessment, only sensitive receptors within 200m of surface roads or tunnel portals have been considered, since the available assessment tools (dispersion models such as AUSROADS and CALINE4; and the empirical relationships described in the MfE Transport GPG) only apply to distances up to 200m from the roadside.

Between the Harbour Bridge and Victoria Park, SH1 currently follows the southern shoreline of the Waitemata Harbour and the Westhaven Marina. The southern approach to the proposed bridge option runs above Westhaven Marina to the vicinity of Z-Pier. From this point to the CMJ, both route options run through cut and cover tunnels, emerging close to the southern portal of the Victoria Park Tunnel.

The terrain rises steeply immediately to the south of the existing SH1 alongside Westhaven Marina, reaching about 20m above sea level within 50m of the roadside. The slope then eases, the height of the terrain reaching about 35m within 200m of the road and a final height of 50-55m along Ponsonby Road and Jervois Road, over 500m from SH1.

The terrain is effectively flat to the north and west of the proposed alignments across the Wynyard Quarter and Victoria Park. To the south of Victoria Park, the land rises steadily to about 20-25m above sea level at the southern end of the study area and to a final height of about 65m along Karangahape Road.

Sensitive Receptors

There are a large number of residential premises within 200m to the south and west of the existing alignment of SH1 along St Mary's Bay and across Victoria Park. Some of these (at the eastern end of St Mary's Bay) will also be within 200m of the alignment of the southern approach to the proposed bridge option. In the vicinity of the CMJ, in the vicinity of the southern cut and cover tunnel portals for both route options, there are also a considerable number of residential premises.

To the east, parts of the proposed 'Mixed Use' areas of the Wynyard Quarter (along Gaunt Street) may be within 200m of the alignment of the southern approach to the proposed bridge option.

In addition to residential activities, there are sensitive receptors within 200m of the southern cut and cover tunnel portals for both route options (Freemans Bay School), while St Mary's College is located approximately 500m to the west of the two alternate locations for the southern vent station for the tunnel option. Victoria Park itself is used for a variety of sports at all times of the year.

6. Option Assessment

6.1 Approach to Option Assessment

Appendix 4 to the MfE Transport GPG presents methodologies for undertaking a simple, limited assessment of the health impacts associated with roading projects. This estimates the likely health effects as a result of change in exposure at properties for each option, taking account of all changes in exposure, whether on existing or new routes. The methodology for this is outlined in Appendix A.

Between Esmonde Road and Onewa Road, both road alignment options are identical and both follow the existing alignment of SH1. In addition, although there are residential premises within 200m of SH1 in this area, none are within 100m of the alignment. Consequently, the effects of vehicle exhaust emission in this area will be identical for both alignment options and are unlikely to be significantly greater than for the 'Do Nothing' scenario. Therefore, no attempt has been made to quantify the effects of vehicle exhaust emission in this area for either alignment option.

Likewise, surface sections of both sets of on and off ramps at the southern end of the project (Fanshawe Street and Cook Street) have been excluded from this assessment. There is likely to be a significant population exposed to vehicle exhaust emissions, particularly from Cook Street between the AHB to Cook St on and off ramp tunnel portals and Nelson Street. However, predicted traffic volumes and alignments of both are very similar between the tunnel and bridge options, so any assessment will not assist in informing the relative merits of the two route options, while the alignments of both Fanshawe Street and Cook Street will be very similar to the present situation.

Only one assessment year (2026, the projected year of opening) has been considered, although predicted traffic data is also available for the design year (2041). Using 2026 data allows ready comparison with the Waterview Connection Project, while predictions of emissions factors become more and more speculative for dates further into the future. Although traffic volumes are predicted to increase between 2026 and 2041, a reasonable assumption is that average exhaust emission rates per vehicle will decrease to an extent that largely offsets that increase in overall traffic numbers.

This assessment has not considered the impact of road gradient on exhaust emission rates. Emissions models published by the World Road Association (PIARC, 2008) indicate that a 4% uphill gradient can increase emission of NO_x by 2-3 times compared to level roads for vehicles travelling at 80 km/h. Conversely, emissions tend to decrease for vehicles travelling downhill, although not to a lesser extent. At lower speeds, this effect is proportionately reduced. Given the proposed gradients (up to 6%) for certain sections of the AWHC project (e.g. the southern ends of tunnels under Victoria Park and the AHB to Cook Street on and off ramps), this is a matter that should be considered in a more detailed assessment of the preferred option.

6.2 Assumptions and Limitations

Given the 'high-level' nature of this assessment, a number of assumptions have had to be made regarding the design, management and operation of the project and the nature of the receiving environment. These include:

- Exhaust ventilation systems for the main road tunnel have been assumed to prevent portal emissions at most times of the day. If the ventilation system is shut down during periods of very low traffic flow (e.g. between midnight and 06.00) it has been assumed that any portal emissions at those times will be negligible and will have minimal effects. The tunnel ventilation report assumes that the ventilation system will be capable of capturing all emissions during periods of congested traffic, but only 60% when traffic is free-flowing. The dispersion modelling that would be required to assess the impacts of such emissions was beyond the scope of this assessment. This is especially significant in the area of the southern portal, which is located in relatively close proximity to high density residential accommodation.

- The northern ventilation stack is assumed to be 25m tall, located approximately 100m offshore. The tunnel ventilation report notes that a height of only a few metres may be required to achieve sufficient dispersion of emission at this location. No sensitivity analysis or other assessment has been made on the location or height of this stack at this stage.

- The southern ventilation stack is assumed to be at least 25m tall, higher than immediately surrounding buildings. As with the northern stack, no sensitivity analysis or other assessment has been made on the location or height of this stack at this stage. The tunnel ventilation report notes that a height of about one diameter (6m) above surrounding buildings should be sufficient to achieve sufficient dispersion of emission at this location. However, no account has been taken of the locations of, for example, air conditioning intakes for nearby buildings, which can exacerbate the impacts of a discharge plume.

- No consideration has been given to any positive effects of either option – for example, the effects of reducing traffic on the existing harbour crossing, which will move the source of vehicle exhaust emissions further from sensitive receptors.

- It has been assumed that the relatively short road tunnels providing access to and from Cook Street and taking the southern approaches to the bridge option, do not have extract ventilation and will rely solely on portal emissions.

- No attempt has been made to assess the effects of either option in the Cook Street area (due to exhaust emissions via the Cook Street off-ramp portal). This is due to a lack of readily available information on the size of the population exposed in this area. This does not affect the conclusions of this report, since the off-ramps in both options are very similar (from an air quality perspective). However, it should be recognised that there are a number of apartment blocks in the vicinity of Cook Street, and more detailed assessment will be required of the effects of the preferred option on air quality.

6.3 Rail Tunnels

The proposed rail tunnels will be operated by electric trains, diesel power only being used for maintenance. Discharges of contaminants into air from the rail tunnel will, therefore, be minimal and will have negligible effects on air quality, the environment or human health. In consequence, air discharges from the proposed rail tunnels have not been considered further in this report.

6.4 Road Tunnel

For the purposes of this assessment, effects of vehicle exhaust emissions have been considered for the following sections of the tunnel option:

- Northern approach (i.e. Onewa Road Interchange to AWHC)

- SH1 between the tunnels and the CMJ

- Tunnel portals for the AHB to Cook St on and off ramps.

The effects of vehicle exhaust emissions between Esmonde Road and Onewa Road and from the Esmonde Road and Onewa Road interchanges and from Cook Street have been excluded from this assessment for the reasons outlined in the introduction to this section of the report.

As indicated in section 2.2 of this report, the NZTA has recently lodged a NoR application for the Western Ring Route: Waterview Connection. Table 6.1 presents a brief comparison of key tunnel parameters between the Waterview Connection and AWHC projects.

Table 6.1 : Comparison of Tunnel Parameters between the Project and Waterview

Parameter	Additional Waitemata Harbour Crossing	Western Ring Route: Waterview Connection
Overall Length (Driven Tunnel plus Cut and Cover)	4.2km	2.5km
Number of lanes	3 lanes per tunnel	3 lanes per tunnel
Posted Speed Limit	80 km/h	80 km/h
Annual Average Daily Traffic (2026)	72,216 (southbound) 71,462 (northbound)	39,030 (southbound) 40,771 (northbound)
Ventilation	Longitudinal with ventilation stacks	Longitudinal with ventilation stacks
Ventilation Stack Height	Not yet determined, but probably 32m in the southern sector and 25-35m in the northern sector	25m

Supporting documentation for the NoR application for the Waterview project included a detailed assessment of the potential air quality effects of vehicle exhaust emissions discharged via the tunnel portals and via stacks. Table 6.2 summarises the maximum ground level concentrations of PM_{10}, NO_x and CO predicted to occur at any of the specific receptors identified for the Waterview Project, caused by discharges via the tunnel vent stacks only.

Table 6.2: Maximum Predicted Contribution to Ground Level Concentrations via Tunnel Vent Stacks for Waterview Project

Parameter	Averaging Period	Maximum Predicted Contribution via Tunnel Vent Stacks	AQNES
PM_{10}	24-hour	0.3 µg/m^3	50 µg/m^3
NO_x	1-hour	26.6 µg/m^3 (as NO_2)	200 µg/m^3 (as NO_2)
CO	8-hour	0.009 mg/m^3	10 mg/m^3

Note: The contribution of vehicle exhaust emissions discharged via the tunnel vents to 1-hour average NO_x concentrations has been reported, rather than NO_2. The relationship between concentrations of NO_2 and of total NO_x is dependent on atmospheric chemistry, making it impossible to accurately predict the contribution of any individual source to short-term concentrations of NO_2.

Mass emission rates for vehicle exhaust emissions discharged via the tunnel vents are likely to be about two to three times greater for the AWHC Project compared to Waterview, based on the overall tunnel length being about 50% greater, with approximately double the number of vehicles each day. On this basis, the maximum contribution to ground level concentrations for the AWHC Project are likely to be about three times those shown in Table 6.2 (e.g. about 1 µg/m³ for PM_{10}).

These estimated concentrations are considerably lower than those predicted in the assessment of effects that accompanied the 2010 NoR application (Fisher, 2010) – e.g. maximum 24-hour average PM_{10} concentrations predicted by Fisher ranged from 12-16 µg/m³. In part, this may be due to the lower emissions factors used for the Waterview project, which were based on the Vehicle Emissions Prediction Model (VEPM, developed on behalf of the ARC), whereas those used by Fisher were based on the New Zealand Transport Emissions Rate model (NZ-TER) (MoT, 2000). Fisher used a 2004 PM_{10} emission factor of 0.182 g/km per vehicle (NZ-TER free-flow), whereas the PM_{10} emission factors in VEPM range from 0.03 to 0.08 g/km per vehicle (plus an additional 0.01 g/km to account for brake and tyre wear, which is not included in NZ-TER). The mass emission rates for PM_{10} listed in Appendix 4 to Fisher's report equate to an overall emission rate of 70 kg/day, whereas an estimated emission rate based on the vehicle emission modelling undertaken for the Waterview project approximates to 11 kg/day. Other factors to be considered include stack locations and their relative heights compared to surrounding buildings and terrain. Fisher assumed that both stacks were 25m tall, with 15m high buildings in the near vicinity, whereas the northern vent stack is likely to be over 100m from any buildings, while the southern vent stack will be tall enough (approximately 32m) to achieve effective dispersion of emissions in that area. In addition, Fisher used the dispersion model AUSPLUME, whereas the more advanced CALPUFF model was used for the Waterview project. CALPUFF handles complex terrain features (such as Nothcote Point) considerably better than AUSPLUME, and tends to predict lower impacts on such elevated areas than does AUSPLUME, which tend to be closer to concentrations that are observed in practice.

Even allowing for the higher traffic volumes currently predicted for the AWHC than those estimated by Fisher (AADT of 140,000 compared to Fisher's estimate of 107,000), had Fisher used emission rates from VEPM rather than NZ-TER, his predicted ground level concentrations of PM_{10} would probably have been similar to those estimated above.

The possibility of allowing some ventilation of the tunnels via portals was also considered for the Waterview project. Assuming that this only occurred when traffic flows were very light (e.g. between midnight and 06:00), it was concluded that this would have very little impact on ground level concentrations of pollutants in the surrounding area.

The assessment of air quality effects undertaken for the Waterview project concluded that:

- The highest concentrations due to emissions from ventilation stacks are predicted to be much less than concentrations due to nearby busy surface roads.
- Contaminant dispersion through use of tall vents is considered to be the most efficient way of dispersing vehicle related contaminants from the tunnels. Tunnel ventilation stacks 25m high are sufficient to provide effective dispersion of vehicle emissions.

For these reasons, at this stage, no attempt has been made to quantify the effects of discharges of vehicle exhaust emissions via tunnel vent stacks.

6.4.1 North Sector

Figure 6.1 shows residential areas within 200m of the surface section of the proposed alignment between Onewa Road and the northern tunnel portal. This figure, and each subsequent figure in section 0, shows a series of 50m wide bands at increasing distance from the road section in question, with buildings that fall within those bands highlighted in a similar colour. Different hatchings have been used to identify building use, based solely on the land use zoning (residential, commercial, mixed use or unknown).

Under the tunnel option, there is only one relevant surface road link in the northern sector of the study area – the section of SH1 between the Onewa Road interchange and the northern tunnel portal. Using Equation 1 of Appendix A, the increase in the annual average concentration of PM_{10} at the roadside is estimated to be 2.3 µg/m^3. The current population aged over 30 years within 200m of the roadside is 157 at an average property occupancy rate of 2.1[3].

Table 6.3 summarises the increased health cost due to vehicle exhaust emissions within the northern sector for the tunnel option in the year 2026, based on Equation 2 of Appendix A. The 'Estimated Health Cost' in column 8 of this table is derived from the current national annual mortality rate (5.8 per thousand per year) and the estimated population over 30 years old in the study area and represents the impact of the operation of the Project on annual mortality in the study area.

Table 6.3: Estimated Health Effect of Predicted Increases in Ground Level Concentrations of PM_{10} Caused by Vehicle Exhaust Emissions from Northern Sector of the Project – Tunnel Option (2026)

Distance from surface road link (m)	Number of dwellings	Population estimate	Weighting	Weighted number of dwellings	Weighted population over 30 exposed	Estimated health cost ($ per annum)
0-50	0	0	1.00	0	0.0	Nil
50-100	6	13	0.20	1	1.0	$ 40
100-150	41	86	0.10	4	3.6	$ 150
150-200	70	146	0.05	4	3.0	$ 130
Total	117	245	-	9	7.6	$ 320

[3] Property occupancy rates for each area assessed were estimated from the occupancy rate (total population divided by total number of dwellings) for each census mesh block that intersects that specific area.

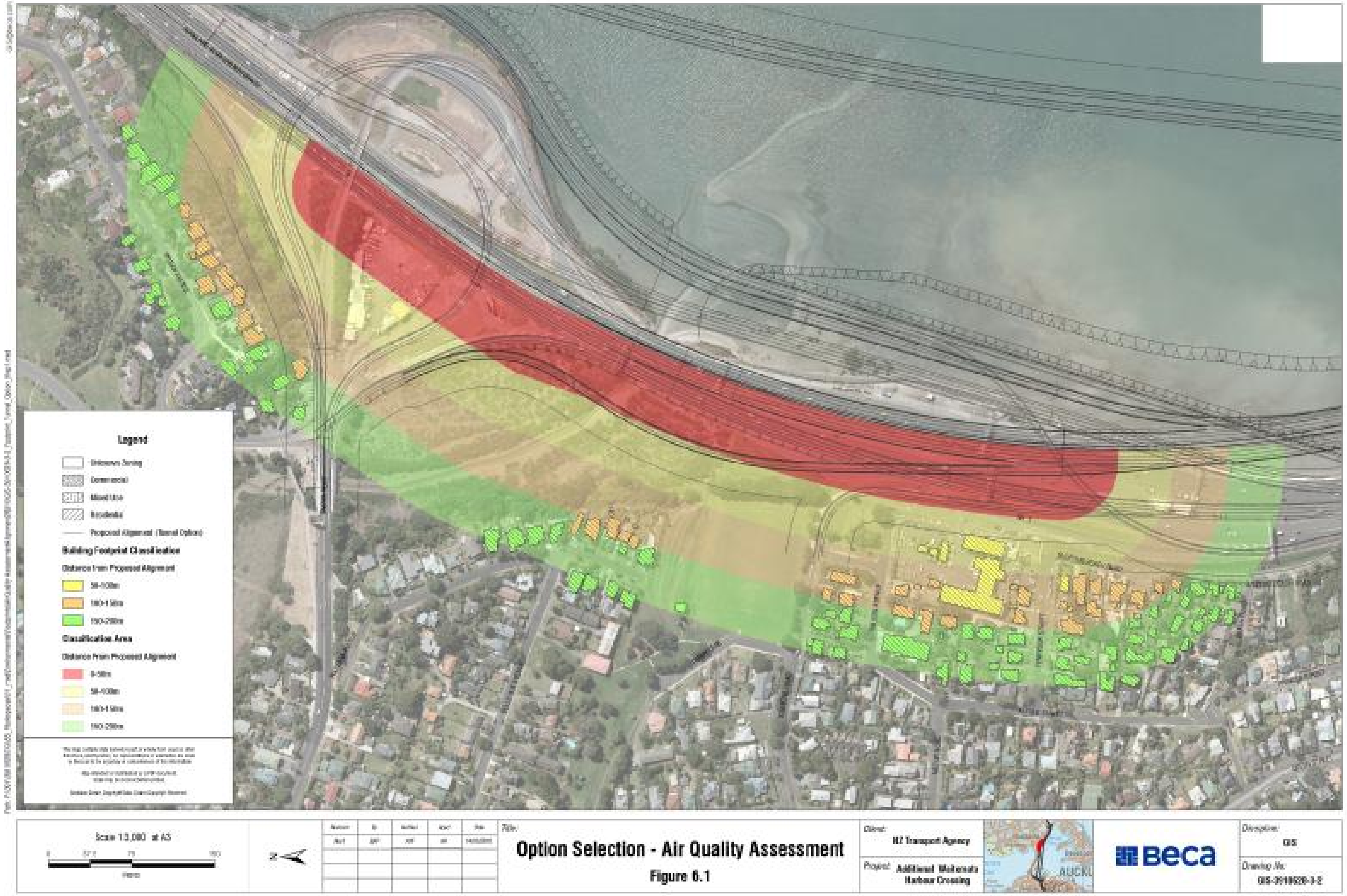

Figure 6.1: Residential Dwellings within 200m of the Northern Sector – Tunnel Option

6.4.2 Central Sector

The central section of the tunnel option will be completely submerged, without any direct discharges into air – all ventilation being via ventilation stations located in the northern and southern sectors.

6.4.3 South Sector

Figure 6.2 shows residential areas within 200m of the surface sections of the southern sector of the proposed tunnel alignment, while Figure 6.3 shows residential areas within 300m of the tunnel portal for the Cook Street to AHB on ramp.

Under the tunnel option, there is one relevant surface road link in the southern sector of the study area – the section of SH1 between the southern tunnel portal and the CMJ. Using Equation 1 of Appendix A, the increases in the annual average concentration of PM_{10} is estimated to be 2.3 µg/m^3 at the roadside of SH1. The current population aged over 30 years within 200m of the roadside is 331 at an average property occupancy rate of 4.0.Table 6.4 summarises the increased health cost due to vehicle exhaust emissions from this section of surface road for the tunnel option in the year 2026, based on Equation 2 of Appendix A

Table 6.4: Estimated Health Effect of Predicted Increases in Ground Level Concentrations of PM_{10} Caused by Vehicle Exhaust Emissions from Surface Roads in the Southern Sector of the Project – Tunnel Option (2026)

Distance from surface road link (m)	Number of dwellings	Estimated population	Weighting	Weighted number of dwellings	Weighted population over 30 exposed	Estimated health cost ($ per annum)
0-50	38	152	1.00	38	80.0	$ 3,440
50-100	35	140	0.20	7	14.7	$ 630
100-150	47	188	0.10	5	9.9	$ 430
150-200	37	148	0.05	2	3.9	$ 170
Total	157	628	-	52	108.5	$4,670

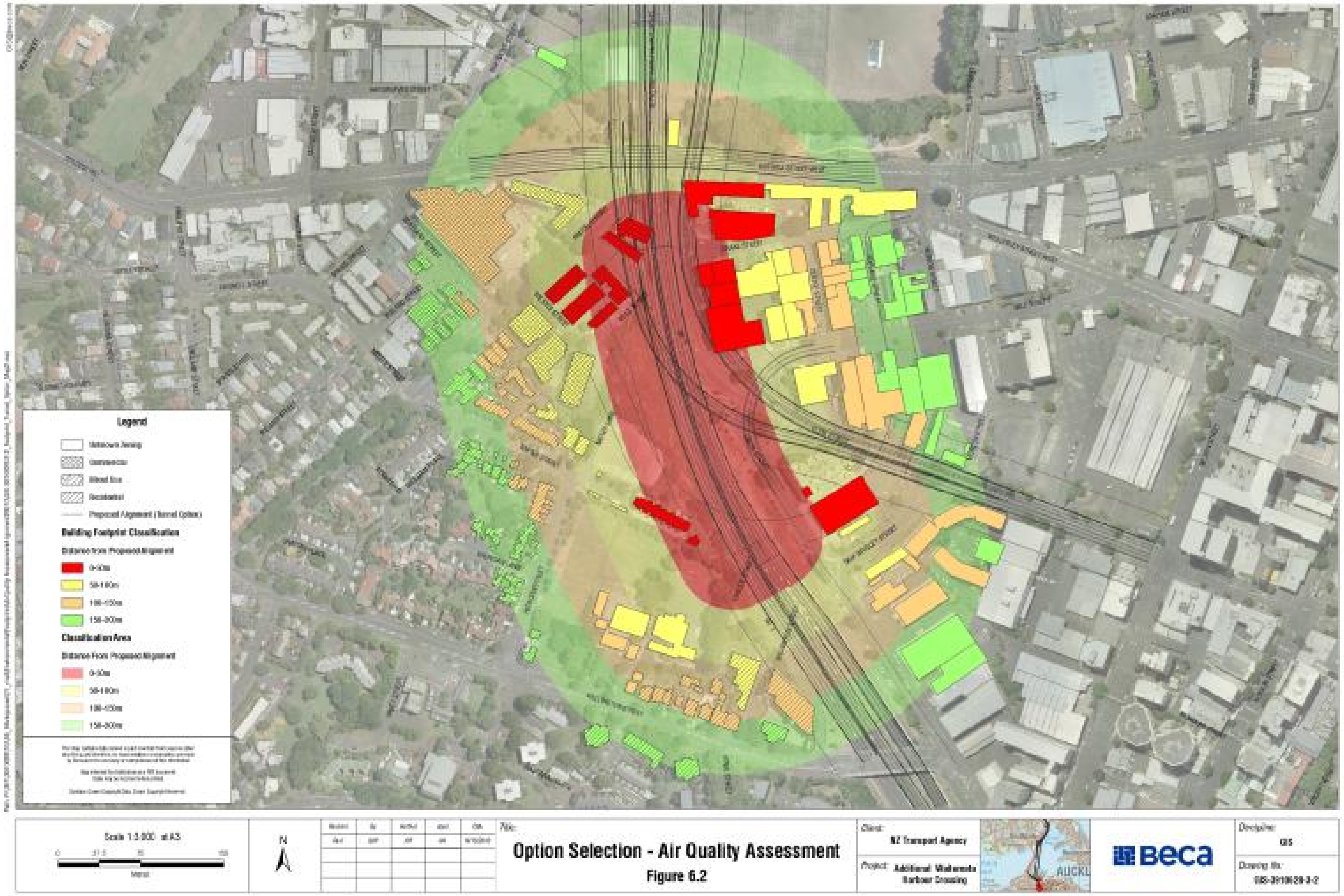

Figure 6.2: Residential Dwellings within 200m of New or Upgraded Surface Sections of SH1 in the Southern Sector – Tunnel Option

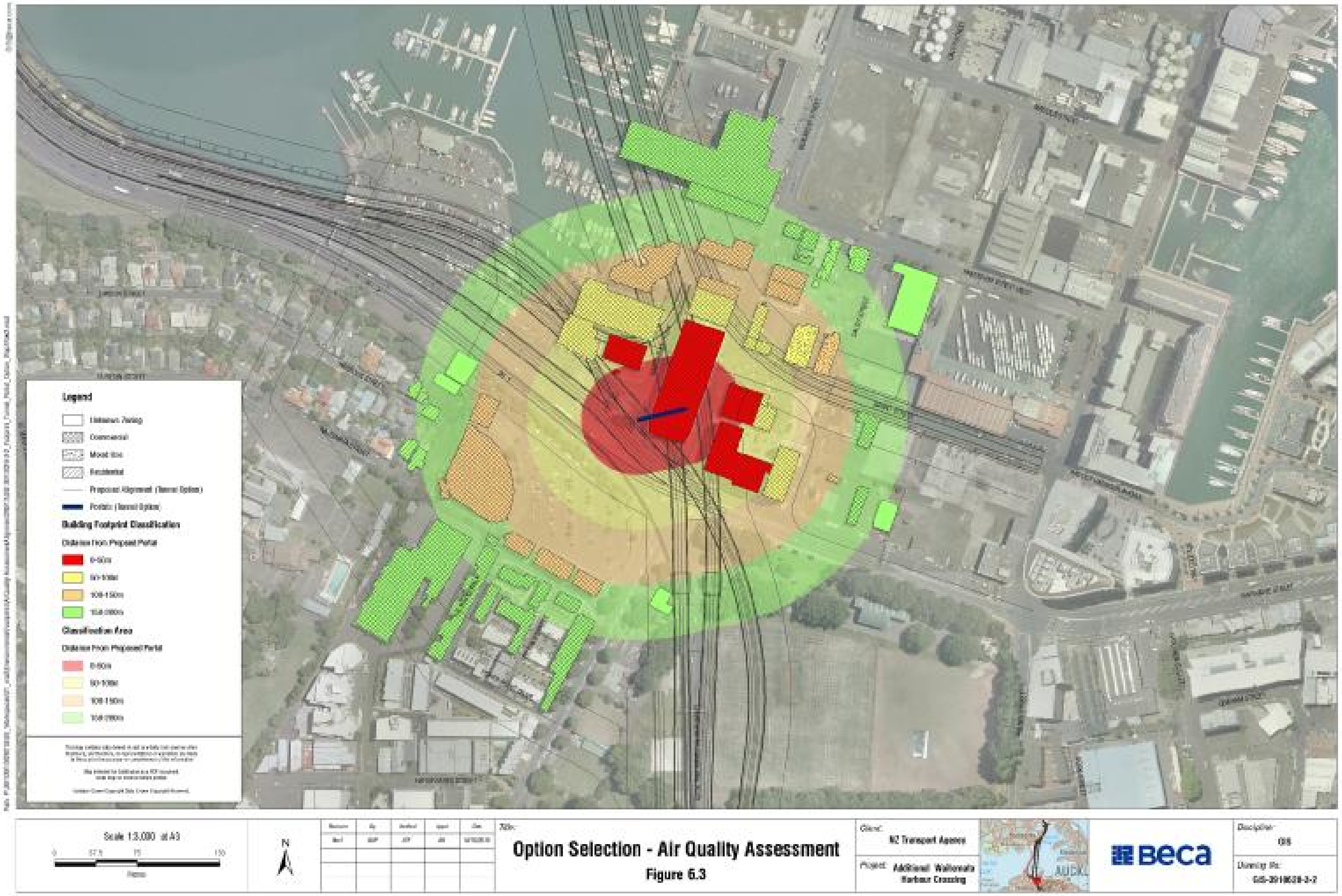

Figure 6.3: Residential Dwellings within 300m of Tunnel Portals in the Southern Sector – Tunnel Option

Table 6.5 summarises the increased health cost due to vehicle exhaust emissions from the tunnel portal for the AHB to Cook Street tunnel on ramp for the tunnel option in the year 2026, based on Equation 3 of Appendix A.

Table 6.5: Estimated Health Effect of Predicted Increases in Ground Level Concentrations of PM_{10} Caused by Vehicle Exhaust Emissions via Tunnel Portals in the Southern Sector the Project – Tunnel Option (2026)

Portal	Distance from tunnel portal (m)	Number of dwellings	Estimated Population	Estimated population over 30 exposed	ΔPM_{10} (annual) ($\mu g/m^3$)	Estimated health cost ($ per annum)
Cook Street On-ramp	0-50	0	0	0	0.41	-
	50-100	0	0	0	0.14	-
	100-200	16	73	43.7	0.07	$ 60
	Total	16	73	43.7	-	$ 60

6.4.4 Summary of Effects – Tunnel Option

Based on the individual effects of vehicle exhaust emissions from the various sectors of the Project (excluding the section from Esmonde road to Onewa Road, Cook Street and the Cook Street off-ramp portal), the overall health cost for the tunnel option is estimated to be $5,050 per annum, as follows:

- Estimated health cost for Northern sector — $320 per annum
- Estimated health cost for Central sector — Nil
- Estimated health cost for Southern sector — $4,670 per annum (surface roads)
  $60 per annum (portal emissions)

6.5 Bridge

For the purposes of this assessment, effects of vehicle exhaust emissions have been considered for the following sections of the Bridge option:

- Northern approach (i.e. Onewa Road Interchange to AWHC
- Southern approach between AWHC and the proposed SH1 tunnels under Victoria Park

- SH1 between the Victoria Park tunnels and the CMJ
- The following tunnel portals – SH1 under Victoria Park and AHB to Cook St on and off ramps.

The effects of vehicle exhaust emissions between Esmonde Road and Onewa Road and from the Esmonde Road and Onewa Road interchanges and from Cook Street have been excluded from this assessment for the reasons outlined in the introduction to the section of the report.

6.5.1 North Sector

Figure 6.4 shows residential areas within 200m of the surface sections of the proposed bridge alignment between Onewa Road and the northern tunnel portal.

Under the bridge option, there is only one relevant surface road link in the northern sector or the study area – the section of SH1 between the Onewa Road interchange and Northcote Point. Using Equation 1 of Appendix A, the increase in the annual average concentration of PM_{10} at the roadside is estimated to be 2.3 µg/m^3. The current population aged over 30 years within 200m of the roadside is 384 at an average property occupancy rate of 2.4.

Table 6.6 summarises the increased health cost due to vehicle exhaust emissions within the northern sector for the tunnel option in the year 2026, based on Equation 2 of Appendix A.

Table 6.6 : Estimated Health Effect of Predicted Increases in Ground Level Concentrations of PM_{10} Caused by Vehicle Exhaust Emissions in the Northern Sector of the Project – Bridge Option (2026)

Distance from surface road link (m)	Number of dwellings	Population estimate	Weighting	Weighted number of dwellings	Weighted population over 30 exposed	Estimated health cost ($ per annum)
0-50	0	0	1.00	0	0.0	Nil
50-100	36	85	0.20	7	17.1	$ 470
100-150	90	214	0.10	9	21.4	$ 590
150-200	125	297	0.05	6	14.8	$ 410
Total	251	596	-	22	53.3	$1,470

6.5.2 Central Sector

The central section of the bridge option will be located more than 200m from any sensitive receptor. Therefore, air quality impacts in this sector will be negligible.

6.5.3 South Sector

Figure 6.5 shows residential areas within 200m of the surface sections of the southern sector of the proposed tunnel alignment, while Figure 6.7 shows residential areas within 300m of the tunnel portals for the SH1 tunnels under Victoria Park.

Figure 6.4a: Residential Dwellings within 200m of the AWHC – Northern Sector, Bridge Option

Figure 6.4b: Residential Dwellings within 200m of the AWHC – Northern Sector, Bridge Option

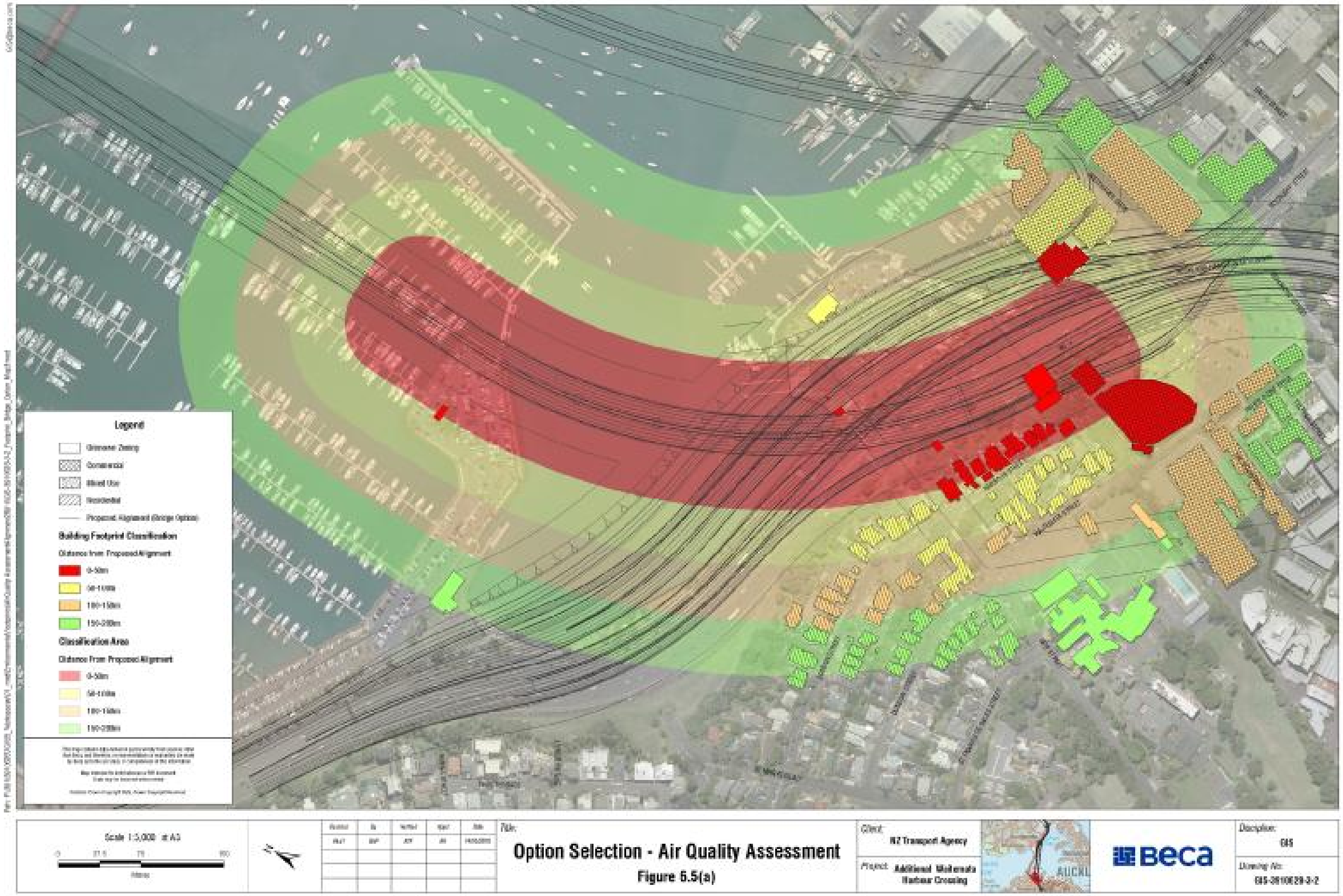

Figure 6.5a: Residential Dwellings within 200m of New or Upgraded Surface Sections of SH1 in the Southern Sector – Bridge Option

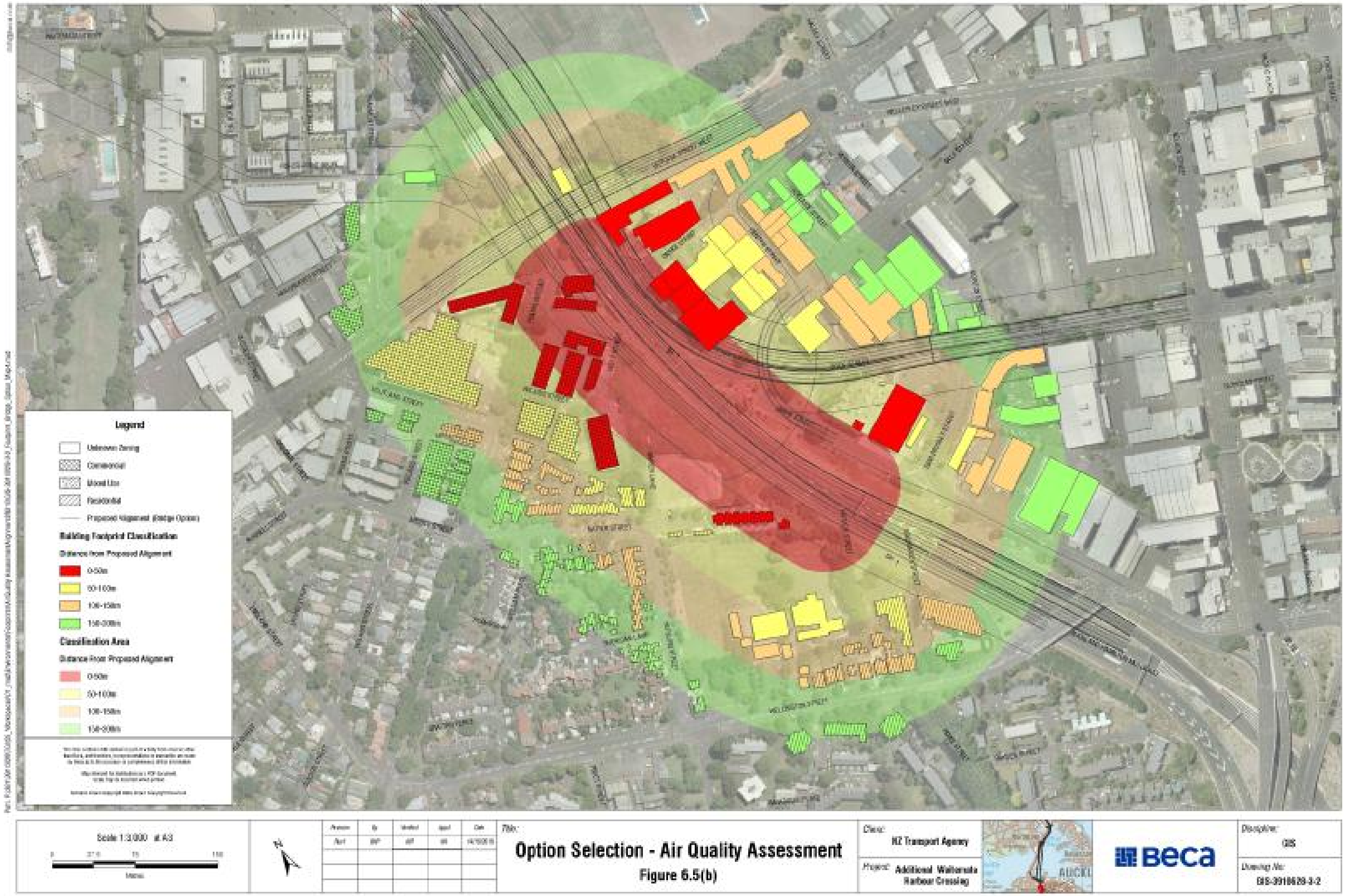

Figure 6.5b: Residential Dwellings within 200m of New or Upgraded Surface Sections of SH1 in the Southern Sector – Bridge Option

Under the bridge option, there are two relevant surface road links in the southern sector or the study area – the southern approach to the AWHC and the section of SH1 between the southern tunnel portal and the CMJ. For both of these road links, the increase in roadside annual average PM_{10} concentrations is estimated to be 2.3 µg/m³. The population aged over 30 resident within 200m of the southern approach to the AWHC is estimated to be 180 at an average occupancy rate of 3.6, while that within 200m of SH1 between the southern tunnel portal and the CMJ is estimated to be 331 at an average occupancy rate of 4.0.

Table 6.7 summarises the increased health cost due to vehicle exhaust emissions from new or upgraded surface roads within the southern sector for the bridge option in the year 2026, based on Equation 2 of Appendix A. The 'Estimated Health Cost' in column 8 of this table is derived from the current national annual mortality rate (5.8 per thousand) and the estimated population over 30 years old in the southern sector of the study area and represents the impact of the operation the Project on annual mortality in that area.

Table 6.7: Estimated Health Effect of Predicted Increases in Ground Level Concentrations of PM_{10} Caused by Vehicle Exhaust Emissions from Surface Roads in the Southern Sector of the Project – Bridge Option (2026)

Surface road link	Distance from surface road link (m)	Number of dwellings	Estimated population	Weighting	Weighted number of dwellings	Weighted population over 30 exposed	Estimated health cost ($ per annum)
Southern approach to AWHC	0-50	11	39	1.00	11	25.1	$ 1,080
	50-100	21	75	0.20	4	9.6	$ 410
	100-150	19	68	0.10	2	4.3	$ 190
	150-200	28	100	0.05	1	3.2	$ 140
SH1 between southern tunnel portal and CMJ	0-50	38	152	1.00	38	80.0	$ 3,440
	50-100	35	140	0.20	7	14.7	$ 630
	100-150	47	188	0.10	5	9.9	$ 430
	150-200	37	148	0.05	2	3.9	$ 170
	Total	236	910	-	70	150.7	$6,490

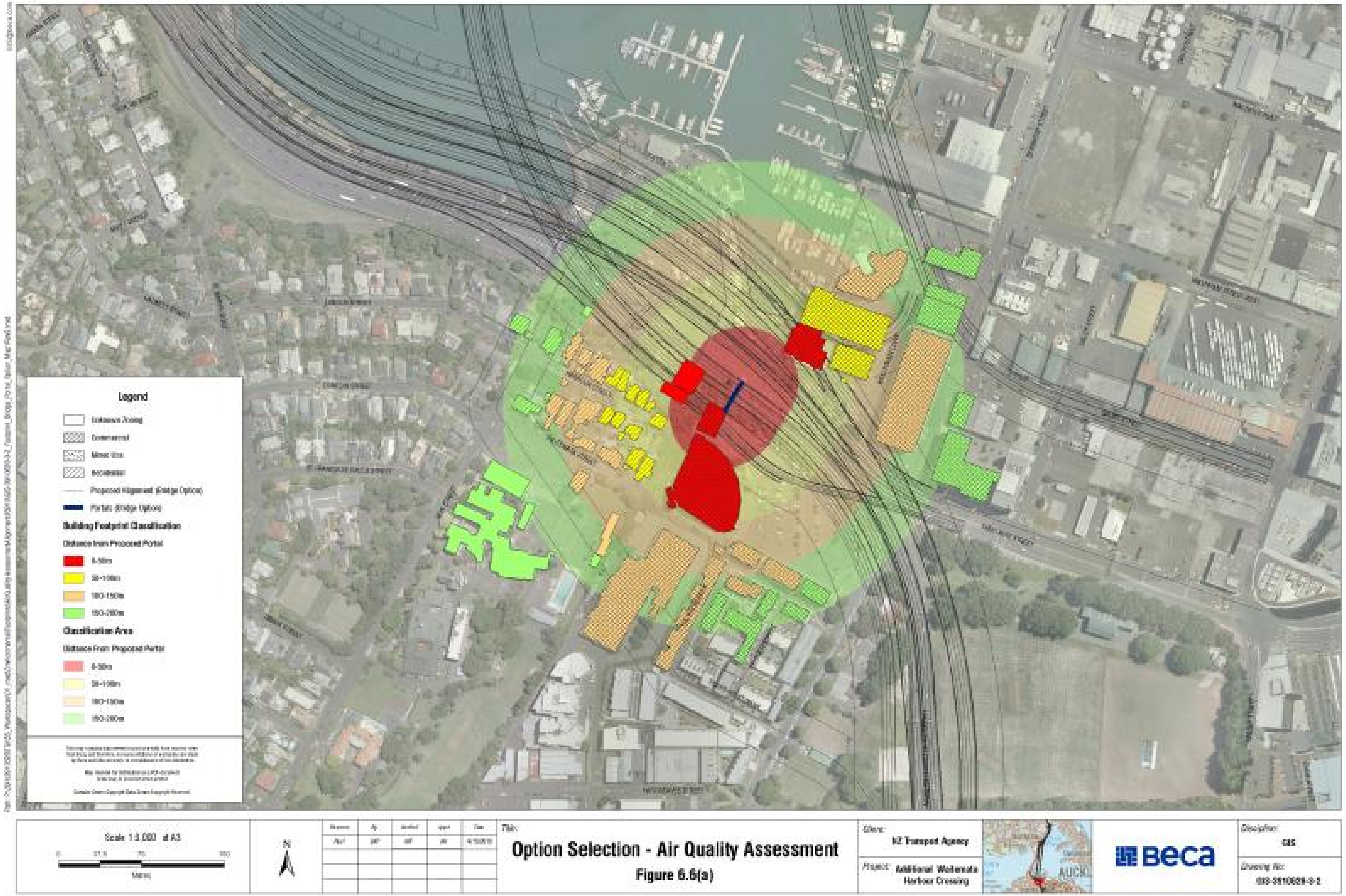

Figure 6.6a: Residential Dwellings within 200m of Tunnel Portals in the Southern Sector – Bridge Option

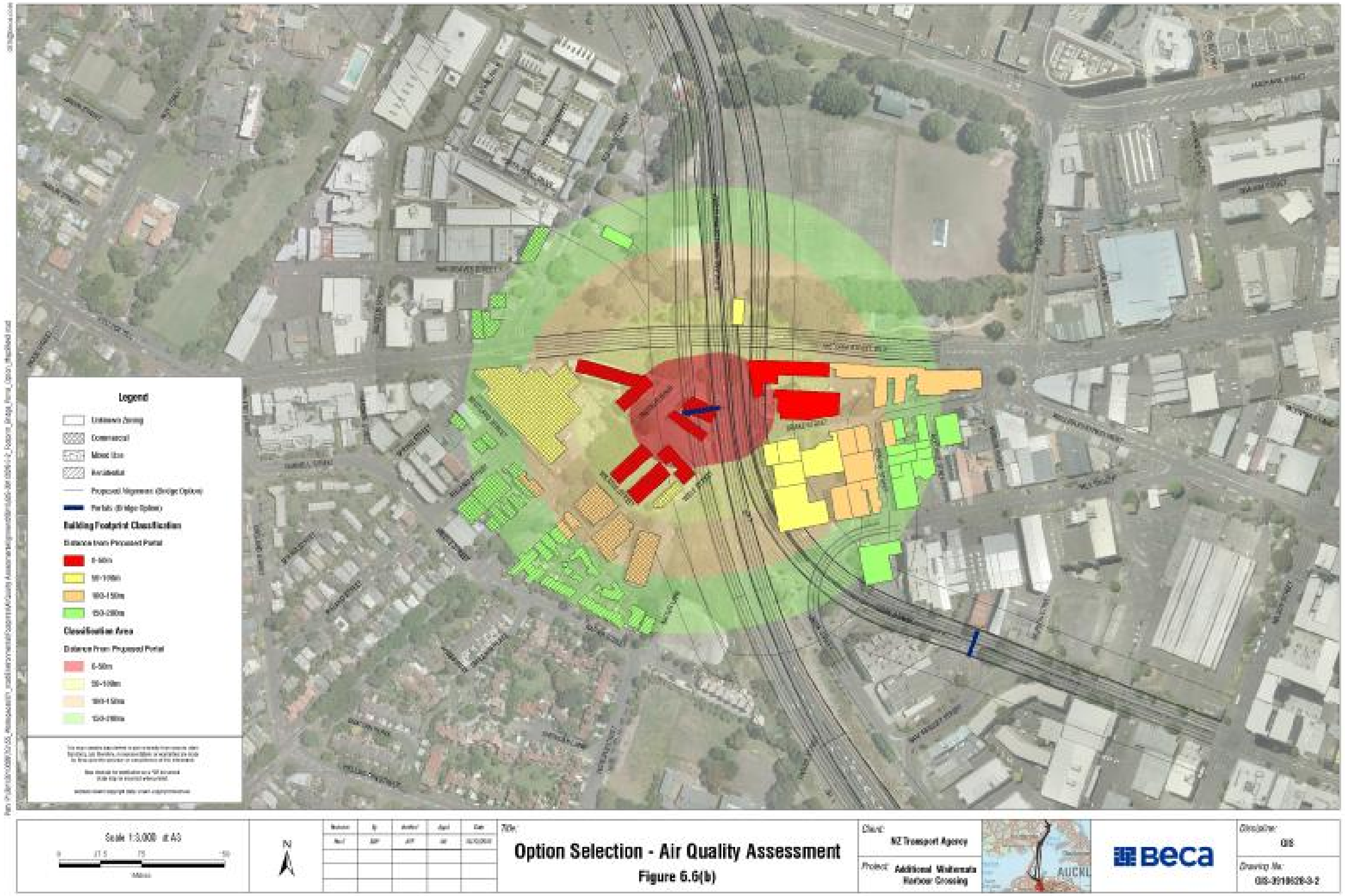

Figure 6.7b: Residential Dwellings within 200m of Tunnel Portals in the Southern Sector – Bridge Option

Under the bridge option, there are four tunnel portals in the southern sector of the study area for tunnels without ventilation stacks – the AHB to Cook Street on and off ramps and the SH1 tunnels under Victoria Park. As noted in section 6.1, effects of vehicle exhaust emissions from the AHB to Cook Street off-ramp portals are not being considered in this assessment. For the other tunnel portals, the populations aged over 30 resident within 300m of each and average occupancy rates are estimated to be: 164 at an average occupancy rate of 4.5 for the southbound SH1 tunnel portal; and 90 at an average occupancy rate of 3.8 for the northbound SH1 and Cook Street on ramp tunnel portals.

Table 6.8 summarises the increased health cost due to vehicle exhaust emissions from the tunnel portals for the bridge option in the year 2026, based on Equation 3 of Appendix A. The 'Estimated Health Cost' in column 8 of this table is derived from the current national annual mortality rate (5.8 per thousand) and the estimated population over 30 years old in the southern sector of the study area and represents the impact of the operation the Project on annual mortality in that area.

Table 6.8 : Estimated Health Effect of Predicted Increases in Ground Level Concentrations of PM_{10} Caused by Vehicle Exhaust Emissions via Tunnel Portals in the Southern Sector of the Project – Bridge Option (2026)

Portal	Distance from tunnel portal (m)	Number of dwellings	Estimated Population	Estimated Population over 30 exposed	ΔPM_{10} (annual) (µg/m^3)	Estimated Health Cost
SH1 northbound and Cook St on-ramp	0-50	0	0	0.0	2.14	$ -
	50-100	12	46	29.3	0.71	$ 390
	100-200	25	96	61.0	0.36	$ 410
SH1 southbound	0-50	18	81	27.8	2.20	$1,140
	50-100	42	189	64.8	0.73	$ 890
	100-200	46	207	71.0	0.37	$ 490
	Total	143	619	253.9	-	$3,320

6.5.4 Summary of Effects – Bridge Option

Based on the individual effects of vehicle exhaust emissions from the various sectors of the Project, the overall health cost for the bridge option is estimated to be $11,280 per annum, as follows:

- Estimated health cost for Northern sector $1,470 per annum

- Estimated health cost for Central sector — Nil
- Estimated health cost for Southern sector — $6,490 per annum (surface roads)
  $3,320 per annum (portal emissions).

Aside from the surface section of SH1 between the southbound SH1 cut and cover tunnel portal and the CMJ (which is common to both route options), the largest contributions to the health effects of the bridge option (and, consequently, to the difference between the two options) are from the southern approach to the bridge and from the southbound SH1 cut and cover tunnel portal. For each of these two sources, there are a number of residential receptors within 50m, which contribute to more than half of the health effects for each source.

Although similar traffic numbers are predicted for both the northbound and southbound SH1 cut and cover tunnel portals, there is a much greater population in the vicinity of the southern portal than near the northern one. Under the bridge option, the northbound SH1 cut and cover tunnel portal is the northern portal of the Victoria Park Tunnel currently under construction.

6.6 Discussion / Comparison

An assessment of the relative effects of vehicle exhaust emissions has been undertaken for the preferred bridge and tunnel options using an approach based on Appendix 4.2 of the MfE Transport GPG. For both options, the population exposed to vehicle exhaust emissions from the project has been estimated from 2006 census data, building footprints obtained from North Shore and Auckland City Councils and aerial photography.

This assessment has been based on 2006 census data, a ‘value of life’ from 2008 and predicted traffic volumes for 2026. Although predicted increases in populations, improvements in vehicle emissions and changes to currency values could have been factored into the assessment, these would have had similar impacts on the results for both options and would not contribute to any comparative assessment of the options.

The overall health impacts due to exhaust emissions from vehicles using the AWHC are relatively similar for the two options (a difference of approximately $6,200 per annum). Over a probable life of the Project (e.g. 100 years), this represents the bridge option would result in a whole-of-life cost (due to effects of air pollutants on human health) that is approximately $620,000 greater than that for the tunnel option.

In most circumstances, such a comparison between a surface road (or bridge) option with a similar length tunnel where emissions are discharged via vent stacks would indicate a much higher health impact from the surface or bridge option compared to the tunnel. The lack of difference between the two options for the AWHC project is probably due to the fact that much of the length of the project is over water, well away from residential areas. There is, therefore, a relatively small population exposed to the effects of vehicle exhaust emission from either option.

The main contribution to the difference between the two options arises from discharges via portals for the tunnels required to take SH1 under Victoria Park, especially the southbound portal for this section. Although a southbound portal is proposed at the same location under the tunnel option, operationally this would form part of the main tunnel running under the harbour, which will incorporate extract ventilation discharging via tall vent stacks. Any residual portal emissions for the tunnel option would, therefore, be relatively minor and have not been considered in this assessment. Measures that could be taken to reduce the health impact from the bridge option include:

- Increasing the separation between the southern approach to the bridge and residential properties in St Mary's Bay (by purchasing properties within 50m of the alignment and turning them to non-residential uses)
- Installing extract ventilation on the southbound cut-and-cover tunnel under Victoria Park that discharges via a tall vent stack, rather than discharging via the portal only.

As previously noted, the surface section SH1 between the southbound SH1 cut and cover tunnel portal and the CMJ is common to both route options. It also follows the same alignment as the existing SH1. This assessment has not considered the difference between 'With Project' and 'Do Nothing' options (i.e. comparing effect with either the bridge or tunnel in place and those for the same year without the AWHC). Such a comparison would be generally be regarded as essential in support of a NoR for such a heavily trafficked urban motorway such as SH1.

This assessment has not considered potential effects of vehicle exhaust emissions from SH1 between Esmonde Road and Onewa Road, from the Esmonde Road and Onewa Road interchanges and from the upgraded section of Cook Street or the proposed AHB to Cook Street off-ramp portal. The sections of road present additional complexity that is beyond the scope of this assessment to address, and are common to both options. Thus, the results of any comparative assessment of the effects of air discharges from these sections would contribute little to any consideration of the relative merits of either a tunnel or a bridge option. Were the potential health impacts of vehicle exhaust emissions from these sections to be included in the assessment, it would increase the estimated health cost of both options by the same amounts, without altering the differential between them.

7. Conclusions and Recommendations

Based on the limited assessment of effects of vehicle exhaust emissions from the two proposed alternate alignment options for the Additional Waitemata Harbour Crossing, the health costs (and associated impact on human health) of the bridge option and tunnel option appear to be relatively similar.

In regards to the consentability of either option arising from this assessment, the most significant issues are likely to be:

- Discharges from the southbound SH1 tunnel portal for the bridge option. Discharges via the northbound SH1 tunnel portal are likely to be similar to those currently consented for the Victoria Park Tunnel.

- The relative proximity of a number (about 10) residential properties to the southern approach to the bridge in St Mary's Bay.

- The relative proximity of a one or two apartment blocks to the southern portal of the cut and cover tunnel under Victoria Park (bridge option).

- The need for large, tall ventilation stacks (>25m tall, 7m diameter) near Northcote Point and Victoria Park for the tunnel option.

This assessment has not compared either project option to the 'Do Nothing' option. This is generally regarded as an essential matter in support of a NoR for such a heavily trafficked urban motorway such as SH1. The assessment of air quality effects prepared in support of the current NoR (Fisher, 2010) does address this in a limited way for the tunnel option, since it focuses on the key difference between 'With Project' and 'Do nothing' (discharges via tunnel vent stacks). However, it does not consider the impact (positive or negative) of changes in traffic flows on surface sections of SH1 or the AHB, nor does it consider the effects of portal emissions for the AHB to Cook St on and off-ramp tunnels. It is, therefore, recommended that further air quality assessment be undertaken in support of whichever option is taken forward to a NoR. This assessment should largely correspond to a Tier 3 assessment under the MfE Transport GPG (MfE, 2008).

In addition, two areas of mitigation may be considered appropriate for the bridge option:

- Installing extract ventilation for the southbound SH1 cut and cover tunnel with a discharge via a tall vent stack, so as to avoid the impact of portal emission on apartments in the vicinity of the southern tunnel portal or purchasing those apartment blocks and turning them to some use other than long-term residential.

- Purchasing those residential properties that are within 50m of the southern approach to the bridge in St Mary's Bay, and turning them to some use other than long-term residential.

The tunnel ventilation report (Stacey Agnew, 2010) notes, in regard to the effects of vehicle exhaust emissions discharged via northern vent stack and portals for the tunnel option, that "there will have to be some analysis at a later stage, considering all combinations of tunnel operation and weather conditions". This view is strongly supported, and should apply to both northern and southern ends of the tunnel option.

It should be noted that these conclusions and recommendations are based on an limited input data (e.g. annual average daily traffic flows, estimated population density and dispersion modelling undertaken for other projects) and on empirical relationships between traffic volumes and near-road concentrations of PM_{10}. No consideration has been given to the effects of vehicle related air pollutants other than PM_{10} (e.g. NO_2, CO and benzene). This assessment should not be regarded as an absolute assessment of the potential health impacts of either route option, but is intended to provide a comparison between the two options and to identify potentially significant issues that may affect the consentability of the preferred option.

8. References

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APPENDIX A

Approach to the Health Risk assessment of Air Discharges from Surface Roads and Tunnel Portals

Approach to the Health Risk assessment of Air Discharges from Surface Roads and Tunnel Portals

Appendix 4 to the MfE Transport GPG presents methodologies for undertaking a simple, limited assessment of the health impacts associated with roading projects. This estimates the likely health effects as a result of change in exposure at properties for each option, taking account of all changes in exposure, whether on existing or new routes. Although Fisher (Fisher, 2010) includes the results of dispersion modelling for discharges via tunnel vent stacks (refer section 6.4 of the main report), no dispersion modelling of emissions has yet been undertaken for the surface road links of the AWHC project. Therefore, the approach adapted from the *Design Manual for Roads and Bridges* (National Roads Authority & DEFRA, 1992/2003) was adopted, as described below (MfE, 2008).

New Surface or Elevated Road Links Within the Project area

Annual average PM_{10} concentrations (PM_{10} roadside) were calculated from the predicted traffic flows using Equation 1, (MfE, 2008):

Equation 1 – Calculation of annual average PM_{10} concentrations

$$\text{Annual average } PM_{10} \text{ roadside } (\mu g/m^3) = 0.007 \times N \times EF$$

where: N = number of vehicles in 1 hour
EF = PM_{10} emission factor in g/km.

It was assumed that these concentrations are in addition to existing ambient concentrations of PM_{10} (which include a contribution from the existing AHB).

Other than in the Auckland CBD, banded property counts were made from aerial photography and building footprints (i.e. the number of residential dwellings within 50m bands up to 200m from the roadside). For this purpose, it was assumed that all buildings with a footprint of $20m^2$ to $600m^2$ within residentially zoned areas are residential dwellings, while all buildings in commercial or industrial zoned areas are non-residential. Within the Auckland CBD, an assessment of whether buildings were residential was made on a case by case basis. Within each band, these counts were then weighted, as indicated below:

Bands (measured from edge of the carriageway)	Weighting*
Roadside to 50 m from roadside	1.00
51 to 100 m from roadside	0.20
101 to 150 m from roadside	0.10
151 to 200 m from roadside	0.05

A property occupancy rate was estimated from the occupancy rate within each census mesh block that intersected with the study area – i.e. the total population within each mesh block from the 2006 census divided by the number of dwellings within each mesh block. No attempt was made to adjust for population growth.

This occupancy rate was then adjusted to account for the proportion of the affected population aged over 30 - the MfE Transport GPG (MfE, 2008) notes that the method used in this assessment has only been validated for people aged over 30.

A health cost was then estimated using Equation 2, (MfE, 2008):

Equation 2 – Calculation of health cost for each link

Effect = [health effect factor] x [normal death rate] x [value of life] x {[ΔPM_{10} roadside] x [number of weighted properties] x [property occupancy rate]}

where: [*health effect factor*] is the percentage increase in daily mortality for a 1 $\mu g/m^3$ increase in PM_{10} concentration. A value of 0.43% has been used (Fisher et al, 2005)

{*normal death rate*] is taken from the published life tables in New Zealand and is currently 5.8 per year per thousand people, calculated in 2008 (www.stats.govt.nz)

[*value of life*] is derived from the analysis conducted by the NZTA and Ministry of Transport in relation to crash deaths, currently assessed at $750,000.

Tunnel Portals for Tunnels Without Vent Stacks

Both route options include relatively short sections of cut and cover tunnels under Victoria Park (the Cook St on and off ramps for both options and for the main SH1 alignment in the bridge option).

Potential ground level concentrations of PM_{10} caused by discharges via the SH1 tunnel portals for the bridge option were estimated from the results of dispersion modelling undertaken for the Waterview Connection project, adjusted for the relative length of the tunnels and predicted traffic volumes for AWHC. Banded property counts and property occupancy rates at 100m intervals were calculated in a similar manner to those for surface road links, for properties up to 300m from each tunnel portal. These were used to calculate a 'population exposed' within each band.

A health cost was then estimated using Equation 3, (MfE, 2008):

Equation 3 – Calculation of health cost for tunnel portals

Effect = [health effect factor] x [normal death rate] x [value of life] x $\sum_{\text{each band}}$ {[ΔPM_{10}] x [population exposed]}

where: [*health effect factor*] is the percentage increase in daily mortality for a 1 $\mu g/m^3$ increase in PM_{10} concentration. A value of 0.43% has been used (Fisher et al, 2005)

{*normal death rate*] is taken from the published life tables in New Zealand and is currently 5.8 per year per thousand people, calculated in 2008 (www.stats.govt.nz)

[*value of life*] is derived from the analysis conducted by the NZTA and Ministry of Transport in relation to crash deaths, currently assessed at $750,000.

Overall Health Cost

For each option, an overall health cost was calculated from the sum of health costs for each surface road link and tunnel portal.

APPENDIX B

Derivation of Annual Average Concentrations of PM_{10} at Tunnel Portals

Derivation of Annual Average Concentrations of PM_{10} at Tunnel Portals.

Discharges of vehicle exhaust emissions via tunnel portals (for tunnels without ventilations stacks) have the potential to make a significant contribution to ground level concentrations or air pollutants in the vicinity of those portals. At this stage, no attempt has been made to model the dispersion of vehicle exhaust emissions from the various tunnel portals proposed for the AWHC, this being beyond the scope of the assessment at this stage. Therefore, in order to inform the option selection, annual average ground concentrations of PM_{10} have been estimated from the results of dispersion modelling undertaken for the Waterview Connection project.

As part of the assessment of air quality effects for the Waterview Connection project, detailed dispersion modelling was undertaken using the Graz Lagragian model (GRAL), focussing on vehicle exhaust emissions discharged during periods of low traffic flow (midnight to 06:00). The GRAL model is specifically designed to assess dispersion of pollutants discharged via tunnel portals. In addition to this work, the results of which were presented as an appendix to the main assessment of air quality effects for the Waterview Connection project, Beca also undertook a screening assessment of likely ground concentrations of pollutants assuming a continuous discharge of vehicle exhaust emissions via the tunnel portals (i.e. with no stack discharge). Although the results of this screening assessment have not been published, they have been made available to inform the options assessment for the AWHC. It should be noted that this screening assessment made use of a screening meteorological dataset that is not representative of actual meteorology at any specific location and tends to predict absolute worst case ground level concentrations. In practice, 24-hour average ground level concentrations predicted using this type of screening meteorology are typically at least double those predicted using actual meteorological data.

In the screening assessment, predicted ground level concentrations of PM_{10} were only reported as 24-hour averages, whereas annual average concentrations are required for the comparative health risk assessment presented in this report. The results of dispersion modelling shown in the screening assessment, reproduced as Figure B1 below, indicate that, in most directions, discharges of PM_{10} via the tunnel portals would make a significant contribution to ambient concentrations relatively close to the portal (i.e. within about 200-300m). The exception to this is directly in line with the portal, where significant effects may extend several hundred metres further. Because these effects appear to be reasonably localised, a conservative estimate of annual average concentrations of PM_{10} can be made by multiplying the predicted 24-hour concentrations by 0.5[4].

Within the two options being considered for the AWHC project, the only tunnels that are proposed to not have exhaust ventilation discharging via stacks are those for the AHB to Cook Street on and off ramps (both options) and the SH1 tunnels under Victoria Park (bridge option only). These are substantially shorter than the Waterview tunnels, with different predicted traffic flows. However, the tunnel portals are of similar size, all except the Cook Street to AHB being designed for three lanes of traffic. Therefore, it is reasonable to assume that ground level concentrations of PM_{10} caused by discharges via the tunnel portals will be roughly proportional to the mass emission rate of PM_{10}, which, in turn, is dependent on the overall traffic volume in each tunnel and the length of that tunnel.

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[4] Based on the results of continuous ambient monitoring of PM_{10} undertaken by the ARC, annual average concentrations of PM_{10} typically range between 30%-45% of maximum 24-hour average concentrations at urban monitoring locations.

Table B1 shows the 24-hour average PM_{10} concentrations predicted to occur at different distances from the southern tunnel portal for the Waterview Connection project, the equivalent annual average PM_{10} concentrations, and the comparable annual average PM_{10} concentrations for tunnel portals for the AWHC project. The southern Waterview tunnel portal was selected because its geometry (three lanes with an estimated cross-sectional area or $88m^2$) is likely to be more similar to the tunnel portals for the AWHC project than would the northern Waterview tunnel portals. At the northern end of the proposed Waterview tunnels, the road widens to four lanes through the cut and cover section, with a cross-sectional area increasing to about $120m^2$, which reduces the 'stiffness' of the discharge via the portal.

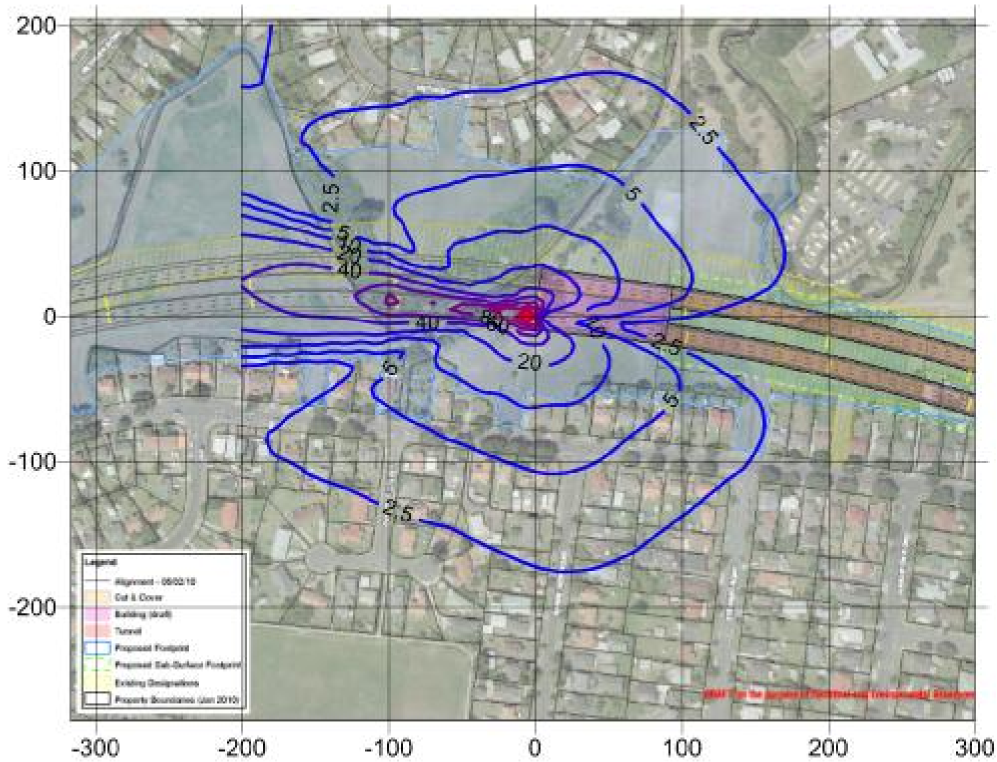

Figure B1 : Predicted Maximum 24-Hour Average PM_{10} Concentrations ($\mu g/m^3$) for the Southern Portals of the Waterview Tunnels (2026)

Table B1 : Comparative Annual Average PM_{10} Concentrations for the Northern Portals of the Waterview Tunnels and the Cook Street and SH1 Victoria Park Tunnels for the AWHC (2026)

		Waterview Southern Portals	AHB to Cook Street Tunnel Option		AHB to Cook Street Bridge Option		SH1 Victoria Park Bridge Option	
			On	Off	On	Off	NB	SB
Tunnel length (km)		2.46	0.5	0.85	1.05	0.95	0.5	0.5
Vehicles per day		40,000	13,600	17,000	13,600	17,000	70,200	72,000
PM_{10} mass emission rate (kg/day)		3.7	0.26	0.54	0.54	0.61	1.32	1.35
Predicted PM_{10} (24-hour) (µg/m^3)	<50m	15	-	-	-	-	-	-
	50-100m	5	-	-	-	-	-	-
	100-200m	2.5	-	-	-	-	-	-
Estimated PM_{10} (annual) (µg/m^3)	<50m	7	0.48	1.03	1.02	1.15	2.50	2.56
	50-100m	5	0.35	0.73	0.73	0.82	1.78	1.83
	100-200m	2.5	0.17	0.37	0.36	0.41	0.89	0.91