Waterview Operational Air Quality Monitoring Report January to March 2019

Document No: [Subject]

Waterview Tunnel Joint Operation
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DOCUMENT CONTENTS

1 INTRODUCTION

1.1 OVERVIEW

The Waterview Tunnel opened on 02 July 2017. This report includes analysis of validated air quality monitoring data for Waterview Tunnel Joint Operations (WTJO) for the period January to March 2019. This air quality monitoring report has been prepared in accordance with Waterview Connection BOI Operational Air Quality Condition OA.4.

1.2 WATERVIEW OPERATIONAL AIR QUALITY REQUIREMENTS

Waterview Connection BOI Operational Air Quality Conditions OA.2 – OA.8 (refer Appendix A) set out the requirements for monitoring of ambient air quality in the vicinity of the tunnel portals and of emissions from one of the tunnel portals.

Two ambient air quality stations (one near the northern end and one near the southern end of the Waterview Tunnel) and one portal analyser are required to be operated for a minimum period of 2 years. The two ambient stations measure concentrations of particulates ($PM_{2.5}$ & PM_{10}) and nitrogen dioxide (NO_2) as well as wind speed and wind direction. The portal analyser measures concentrations of NO_2.

Condition OA.2 stipulates that the results of ambient monitoring are to be compared with the National Environmental Standards for air quality and Auckland Regional air quality targets, which are shown in Table 1.

Table 1. WTJO ambient air quality criteria

Pollutant	Threshold concentration	Averaging period
Fine particles (PM_{10})	50 µg/m^3 20 µg/m^3	24-hour Annual
Fine particles ($PM_{2.5}$)	25 µg/m^3 10 µg/m^3	24-hour Annual
Nitrogen dioxide	200 µg/m^3 100 µg/m^3 40 µg/m^3	1-hour 24-hour Annual

1-hour average NO_2 concentrations at the portal air quality monitoring station have been expressed as a rolling average, in accordance with condition OA.8.

This monitoring is required to continue until the Air Quality Peer Review Panel (required under condition OA.7) recommend that it is no longer necessary. Results are required to be reported monthly for the first 12 months and quarterly thereafter (OA.4). The Waterview Tunnel has been operational for over 12 months. In accordance with condition OA.4, reporting is now required on a quarterly basis.

1.3 MONITORED PARAMETERS AND LOCATIONS

Monitoring locations are shown in Appendix B. Locations and types of instrumentation have been agreed with Auckland Council and the Air Quality Peer Review Panel.

A portal monitoring station with Cavity Attenuated Phase Shift Spectroscopy (CAPS) NO_2 analyser has been installed at the rear of 93 Hendon Avenue near the Southern portal, to monitor NO_2 in

accordance with the requirements of consent condition OA.2 and to demonstrate compliance with consent condition OA.8. The portal station is located approximately 80 m from the southern tunnel portal on the residential boundary (40 m from SH20). SH20 is screened from the nearest receptors within the southern approach trench.

Two ambient air quality monitoring stations have been installed to monitor particulates (BAM-1020 analysers, PM_{10} and $PM_{2.5}$), nitrogen dioxide (Chemiluminescence NO_x analyser), wind speed and wind direction in accordance with conditions OA.2 and OA.3.

The southern ambient air quality station is located in the approximate location of the original pre-construction baseline monitoring for the WTJO, near 5 Barrymore Road. The southern station is also located adjacent to the residential area at Hendon Avenue, approximately 470 m from the southern tunnel portal (25 m from SH20) where SH20 achieves grade.

Under condition OA.2, the northern ambient air quality station is required to be located at Waterview School subject to agreement by the School; this agreement was not secured. The northern station is therefore located in the approximate location of the original pre-construction baseline monitoring for the WTJO, near the operation maintenance building. This station is located approximately 100 m from the northern tunnel portal downwind in the prevailing wind direction (25 m from SH20, 330 m SH16 and 20 m from Great North Road), with no obstruction between the adjacent traffic sources and air quality station. This location is likely to experience higher levels than the proposed location at the School and is therefore considered conservative.

1.4 DATA MANAGEMENT

Data are downloaded and checked daily by suppliers Ecotech and monthly validated reports provided to the WTJO. A daily summary of results (non-validated data) is provided to the WTJO and, in the event that WTJO air quality criteria are exceeded, email/text alerts are sent, so investigation can be initiated.

Ecotech calibrates the air quality stations on a monthly basis, and attends the site if a fault is detected during the daily checks. Calibration and equipment fault reports are forwarded to the WTJO.

The valid data exception reports for January to March 2019 are attached as Appendix C.

2 MONITORING RESULTS AND ANALYSIS

2.1 SUMMARY STATISTICS

Monitoring sites used for compliance monitoring should achieve at least 95% data capture and a minimum of 75% valid data should be collected when calculating averages[1]. Where data did not meet the minimum 75% valid data requirement (i.e. due to calibration or data loss), averages were not calculated. As shown in Table 2, data capture meets the minimum requirement for all measured parameters at all air quality monitoring stations for the January to March 2019 period, with the exception of $PM_{2.5}$ measured at the southern ambient air quality station in January 2019 and NO_2 measured at the portal air quality station in February 2019.

In January 2019, a leak was identified during monthly calibration in the $PM_{2.5}$ instrument at the southern station. In February 2019, another leak was identified during monthly calibration of the PM_{10} instrument at the southern station. For this reason, $PM_{2.5}$ and PM_{10} data at the southern station for the period since the previous calibration ($PM_{2.5}$ between 1-31 January 2019; and PM_{10} between 1-27 February 2019) have not been validated due to uncertainty of when the leak occurred.

Low data capture of NO_2 at the portal air quality station in February 2019 was due to intermittent instrument faults (instrument cell temperature exceeded tolerance limits) and some overnight calibration checks were outside of tolerance.

These problems were resolved and data capture targets were met in March 2019.

Table 2. Data capture statistics

AQ Station	Parameter	% data capture		
		January 2019	February 2019	March 2019
Northern ambient air quality station	Nitrogen dioxide (NO_2)	100 %	96.5 %	96.7 %
	Particulate matter ($PM_{2.5}$)	100 %	99.9 %	100 %
	Particulate matter (PM_{10})	100 %	99.9 %	99.9 %
Southern ambient air quality station	Nitrogen dioxide (NO_2)	100 %	100 %	97.2 %
	Particulate matter ($PM_{2.5}$)	1.3 %	100 %	99.6 %
	Particulate matter (PM_{10})	100 %	5.5 %	99.7 %
Portal air quality station	Nitrogen dioxide (NO_2)	99.8 %	74.6 %	97.0 %

A comparison of the monitored levels of NO_2, $PM_{2.5}$ and PM_{10} against the WTJO air quality criteria is shown in Table 3 for January to March 2019. As requested by the Peer Review Panel, maximum rolling annual average PM_{10}, $PM_{2.5}$ and NO_2 have been included for comparison to the WTJO criteria.

This shows that measured air quality concentrations were below the WTJO ambient air quality criteria. Data measured in previous months is summarised in Appendix D and original baseline data in Appendix F.

Table 3. Air quality monitoring results

AQ Station	Description	Concentration in µg/m^3			WTJO air quality criteria in µg/m^3
		January 2019	February 2019	March 2019	
Northern ambient	Maximum 1-hour average NO_2	44.1	53.9	59.8	200
	Maximum 24-hour average NO_2	23.2	24.1	29.4	100

[1] Ministry for the Environment. 2009. Good Practice Guide for Air Quality Monitoring and Data Management 2009. Wellington: Ministry for the Environment.

AQ Station	Description	Concentration in µg/m^3			WTJO air quality criteria in µg/m^3
		January 2019	February 2019	March 2019	
air quality station	Maximum rolling annual average NO_2	24.7	24.9	24.8	40
	Maximum daily average $PM_{2.5}$	14.8	12.2	11.0	25
	Maximum rolling annual average $PM_{2.5}$	8.1	8.2	8.1	10
	Maximum daily average PM_{10}	37.7	20.8	19.1	50
	Maximum rolling annual average PM_{10}	17.3	17.2	17.0	20
Southern ambient air quality station	Maximum 1-hour average NO_2	38.1	44.4	46.9	200
	Maximum 24-hour average NO_2	14.6	20.8	28.1	100
	Maximum rolling annual average NO_2	17.1	17.2	17.4	40
	Maximum daily average $PM_{2.5}$	-[A]	11.3	7.8	25
	Maximum rolling annual average $PM_{2.5}$	7.9	7.9	7.9	10
	Maximum daily average PM_{10}	27.2	-[A]	18.6	50
	Maximum rolling annual average PM_{10}	14.2	14.2	14.3	20
Portal air quality station	Maximum rolling 1-hour average NO_2	48.5	47.6	50.7	200
	Maximum rolling annual average NO_2	17.1	17.3	17.5	40

A = Over 75 % of valid data is missing for this averaging period, thus the 24-hour average concentration was not calculated.

2.2 EXCEEDENCES OF AIR QUALITY CRITERIA

The Waterview Connection BOI Operational Air Quality Condition OA.5 requires that when an exceedance of the WTJO air quality criteria occur, an investigation shall be undertaken into the cause of the exceedance and that this be reported to the Air Quality Peer Review Panel and Auckland Council.

There were no exceedances of the WTJO air quality criteria in the January to March 2019 monitoring period.

2.3 POLLUTION ROSES

Pollution roses based on the hourly monitoring data are provided in Appendix E for January to March 2019.

In summary, the pollution roses show that:

- The highest NO_2 concentrations at the northern station were measured in winds from the west quadrant, from the direction of the adjacent SH20 alignment.
- The highest concentrations of $PM_{2.5}$ at the northern station were measured in wind directions ranging from the west-southwest through to north, from the direction of the SH20 alignment. The highest concentrations of PM_{10} at the northern station were distributed over a range of directions encompassing conditions when the station was upwind and downwind of the SH20 alignment.
- The highest NO_2 concentrations at the portal and southern stations were measured in wind directions ranging from east to southwest, from the direction of the SH20 alignment.
- The highest concentrations of PM_{10} and $PM_{2.5}$ at the southern station came from two different directions: from the east to southwest, from the direction of the adjacent SH20 alignment, and from the west-northwest to north direction, from the direction of the nearby residential area (upwind of the SH20 alignment).

The NO_2 pollution roses indicate that the main source of NO_2 at the monitoring sites is likely to be traffic emissions. The PM_{10} and $PM_{2.5}$ pollution roses at the monitoring sites indicate that the highest

concentrations were measured in winds from the direction of the SH20 alignment and indicate that traffic emissions were likely to have been a predominant source. Elevated $PM_{2.5}$ and PM_{10} concentrations measured at the southern station when the station was upwind of the SH20 alignment indicate the presence of other influences on fine particulate concentrations (most likely the nearby residential area).

2.4 TRAFFIC DATA AND POLLUTANT TRENDS

The daily traffic flow through the Waterview tunnel during January to March 2019 is shown in Figure 1 below with daily average NO_2 concentrations measured at the three stations. The traffic flow generally shows a distinct weekly pattern, with traffic flows generally increasing from Monday to Friday and dropping off at the weekend, with the lowest traffic flow on Sundays.

The northern air quality station recorded the highest NO_2 concentrations over the period. The northern station is located close to other high traffic routes (330 m SH16 and 20 m from Great North Road). The portal and southern stations show similar NO_2 concentrations.

The weekly pattern of $PM_{2.5}$ and PM_{10} concentrations show a weak correspondence with daily traffic flows, as shown in Figure 2. PM_{10} and $PM_{2.5}$ concentrations at the northern station were generally higher than those measured at the southern station.

The hourly average diurnal patterns of NO_2 concentrations show the highest concentration occurring in the morning, which is likely to correspond to peak traffic times, as shown in Figure 3. $PM_{2.5}$ and PM_{10} concentrations are relatively consistent throughout the day with a small reduction of $PM_{2.5}$ and PM_{10} concentrations during night-time hours, as shown in Figure 4. Only limited hourly traffic data was available for the monitoring period (available for the period 18 February to 31 March 2019), for this reason, averaged diurnal traffic trends have not been included in Figures 3 and 4.

Trends in the monthly average NO_2 concentration measured each month since May 2017 are shown in Figure 5. The figure shows the changes in NO_2 after tunnel opening in July 2017 and the seasonality of NO_2 concentrations. Monthly average NO_2 concentrations increased from an overall annual low in January through to March 2019. This appeared to continue the seasonal trend in monthly NO_2 concentrations that was measured over the corresponding period in 2018, with NO_2 concentrations likely to increase to a winter peak in June/July 2019.

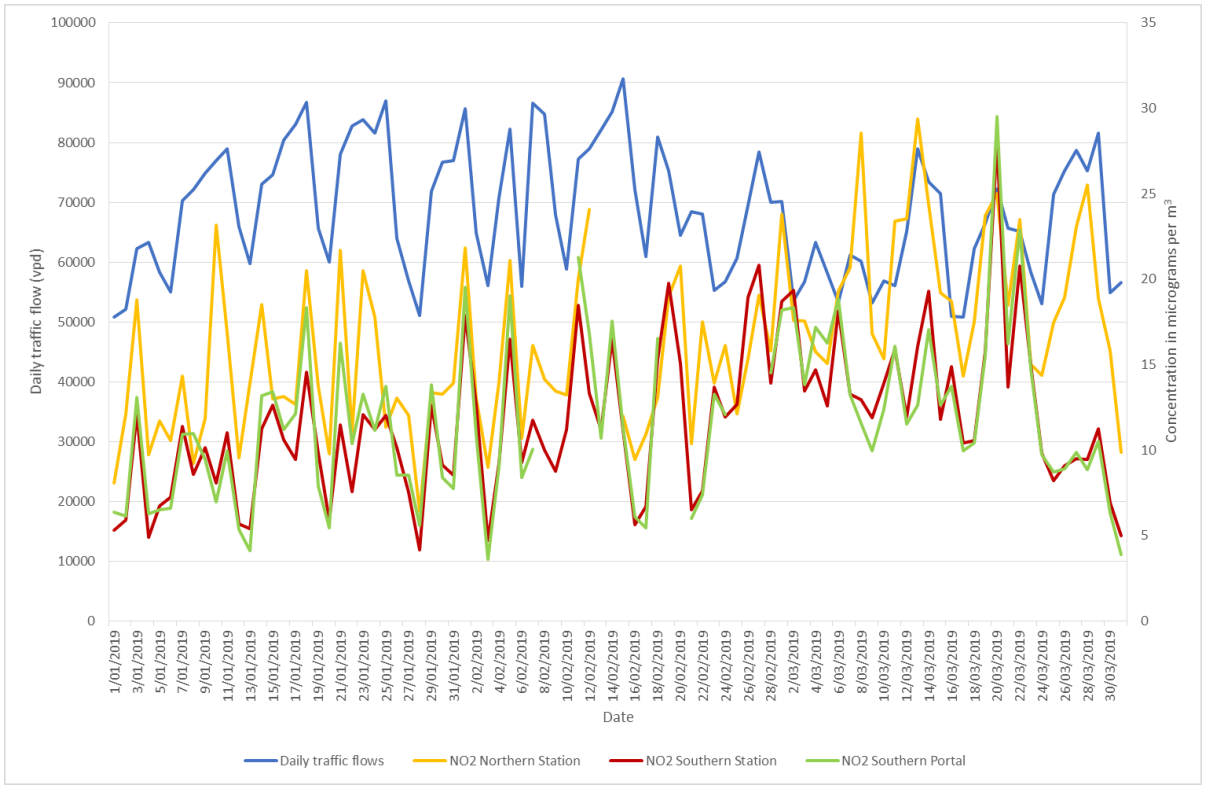

Figure 1: Waterview tunnel daily traffic flows and daily average NO_2

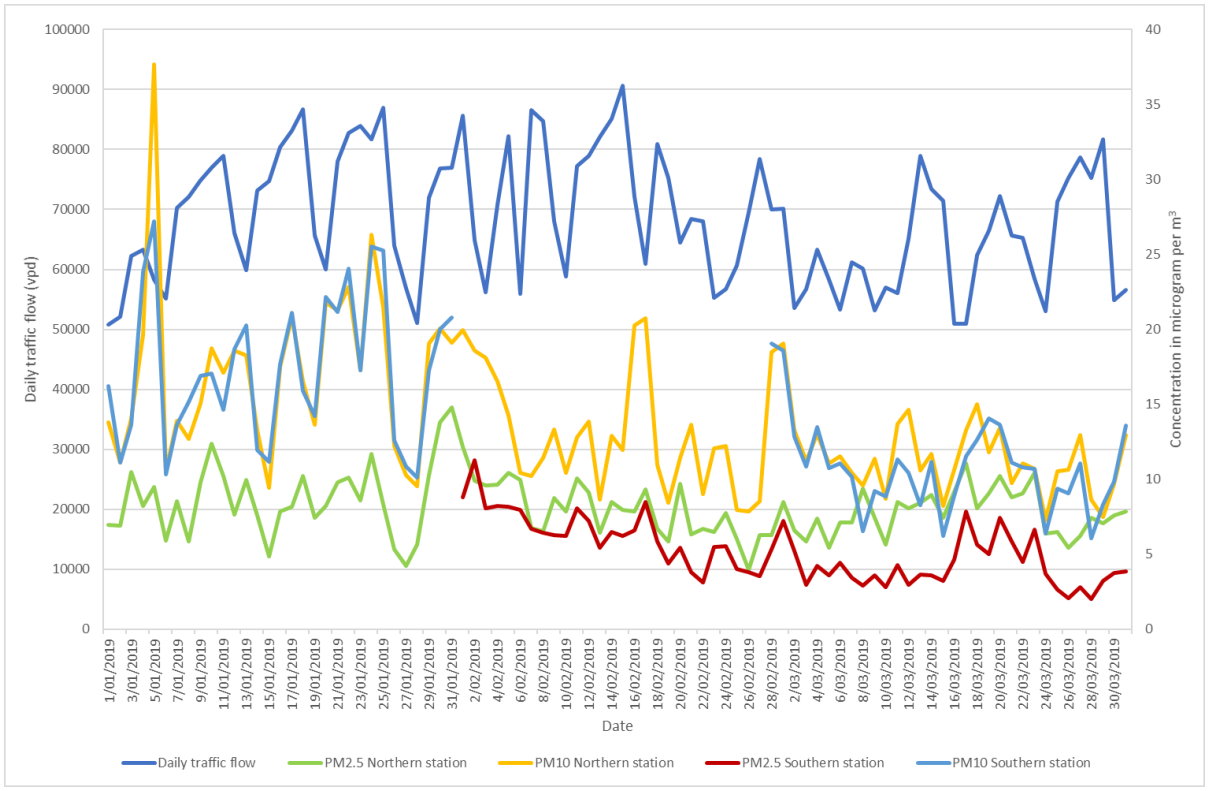

Figure 2: Waterview tunnel daily traffic flows and daily average $PM_{2.5}$ and PM_{10}

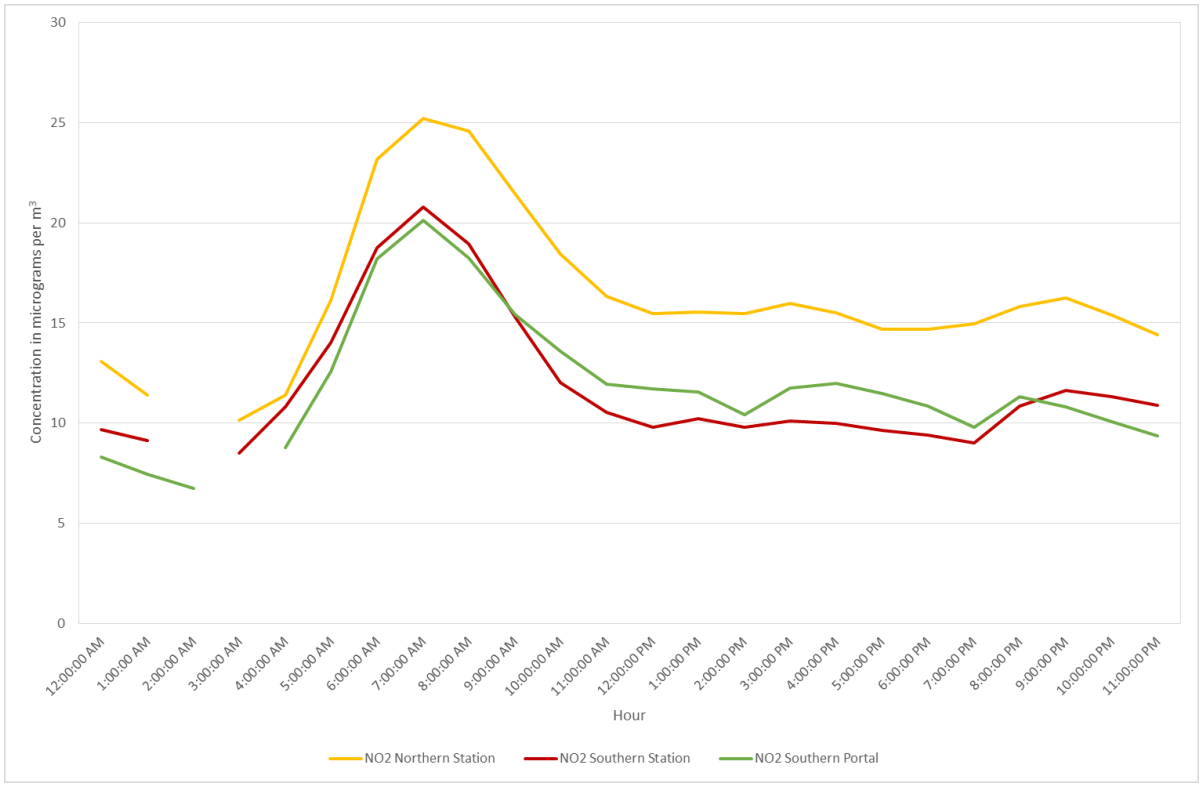

Figure 3: Diurnal hourly average nitrogen dioxide concentrations

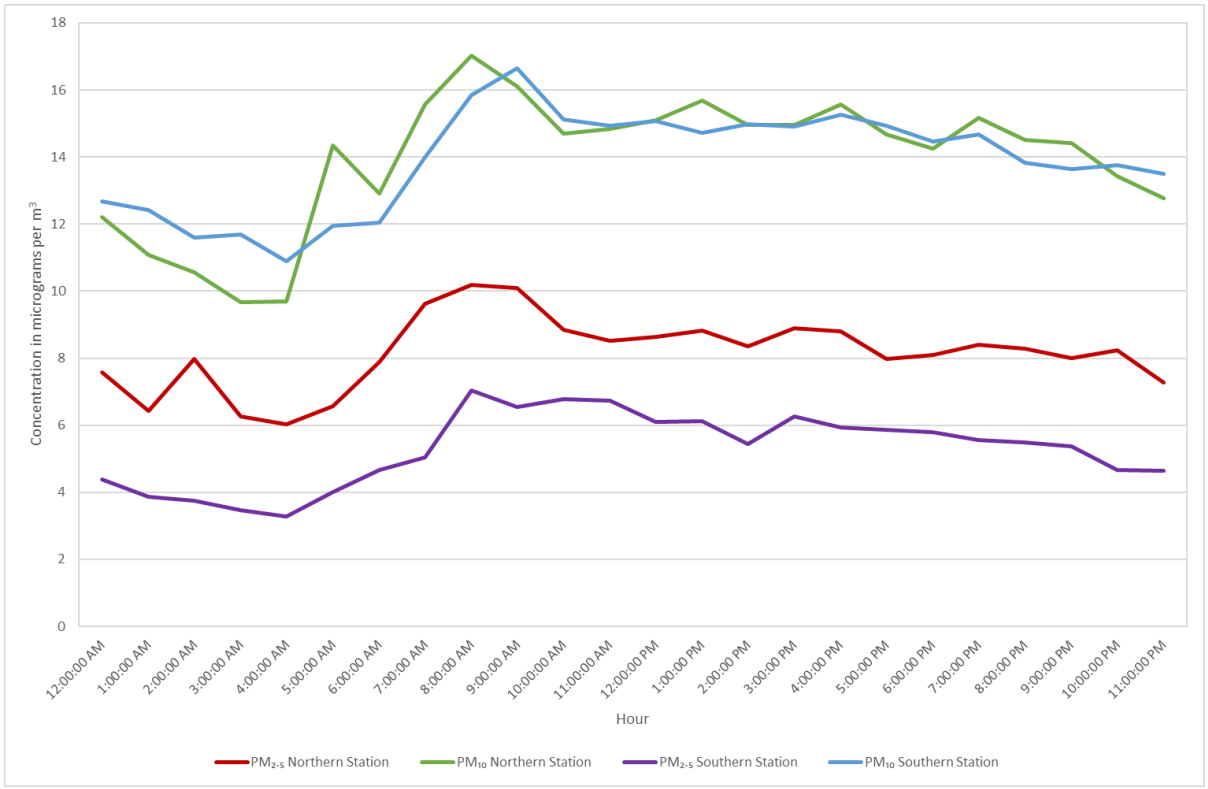

Figure 4: Diurnal hourly average $PM_{2.5}$ and PM_{10} concentrations

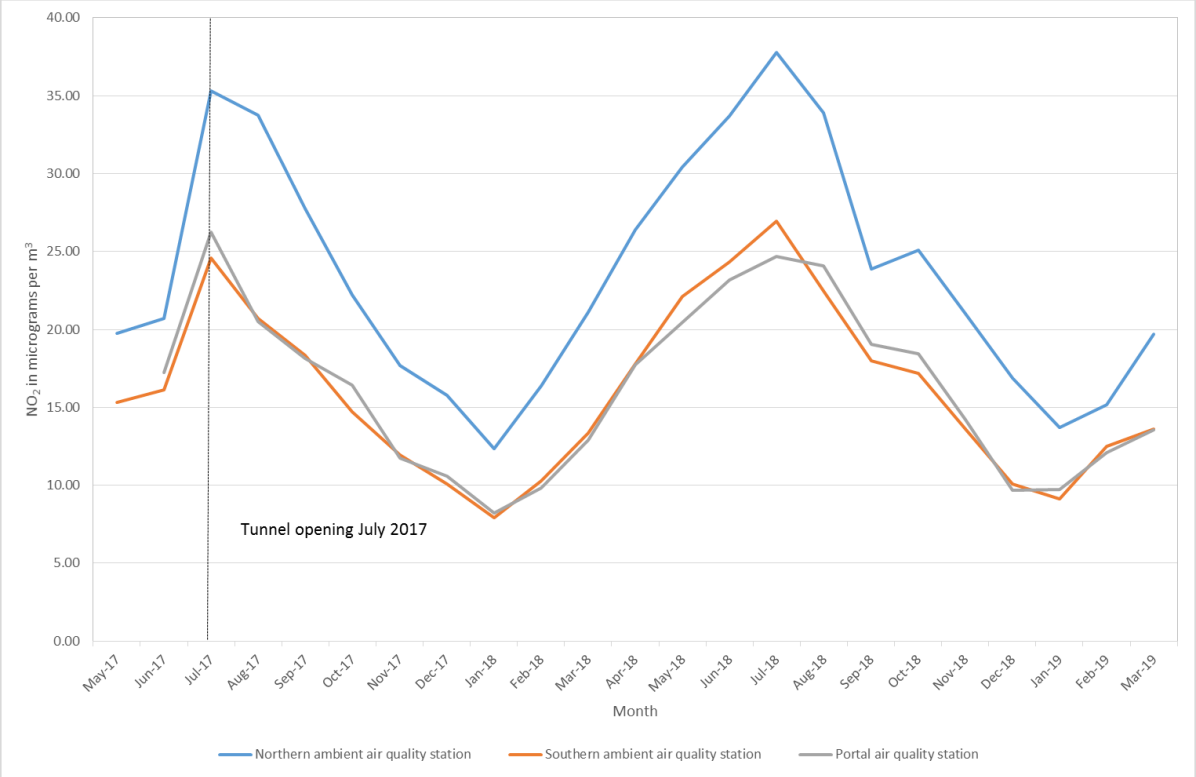

Figure 5: Monthly average nitrogen dioxide concentrations

3 CONCLUSION

This air quality monitoring report has been prepared in accordance with Waterview Connection BOI Operational Air Quality Condition OA.4, and includes analysis of validated air quality monitoring data for January to March 2019.

The Waterview Tunnel has been operational for over 12 months. In accordance with condition OA.4, reporting is now required on a quarterly basis.

The analysis of NO_2, $PM_{2.5}$ and PM_{10} data for the two ambient air quality stations and NO_2 data for the portal air quality station has shown that measured air quality concentrations were below the WTJO ambient air quality criteria for the period January to March 2019.

The recommended minimum data capture rate of 95% was achieved at all locations for the period January to March 2019 with the exception of $PM_{2.5}$ at the southern station in January 2019, PM_{10} at the southern station in February 2019 and NO_2 at the portal station in February 2019. Low data capture of $PM_{2.5}$ and PM_{10} at the southern station were caused by instrument leaks, which were identified during monthly calibration. Low data capture of NO_2 at the portal air quality station in February 2019 was the result of intermittent instrument faults (instrument cell temperature exceeding limits of tolerance) and some overnight calibration checks being outside tolerance limits.

The highest concentrations of NO_2 were recorded at the northern station. This station is located closer to major traffic sources than the other two stations and there are no obstructions between the adjacent sources and air quality station. The concentrations of PM_{10} and $PM_{2.5}$ were slightly higher at the northern station than at the southern station.

Analysis of NO_2 pollution roses and diurnal trends indicates that the main source of NO_2 at the monitoring locations is traffic emissions.

The highest concentrations of $PM_{2.5}$ at the northern station were measured in winds from the direction of the SH20 alignment. The highest concentrations of PM_{10} were measured in a range of winds when the northern station was upwind and downwind of the SH20 alignment. The highest concentrations of $PM_{2.5}$ and PM_{10} at the southern station were measured in winds from the directions of the SH20 alignment and from the nearby residential area to the north (upwind of the SH20 alignment).

Diurnal $PM_{2.5}$ and PM_{10} concentrations are relatively consistent throughout the day and do not appear to correspond strongly with expected peak traffic flow patterns. This indicates other sources may also contribute to measured $PM_{2.5}$ and PM_{10} concentrations.

APPENDIX A: AIR QUALITY CONDITIONS

OA.1 The vents used to discharge emissions in the tunnels shall discharge vertically into air at a height of 15m, as follows: (a) The northern ventilation stack will be at a height of 15m. This height shall be calculated from the lowest existing ground level along the Great North Road boundary, adjacent to the ventilation stack; and (b) The southern ventilation stack will be at a height of 15m calculated from the post-construction ground level of the Alan Wood Reserve averaged at a distance of 10m from the exterior walls the ventilation stack location and shall not be impeded by any obstruction that may in the opinion of the Peer Review Panel (Condition OA. 7) decrease the vertical efflux velocity (in other words, the average velocity of material emitted into the atmosphere).

OA.2 Prior to the tunnels becoming operational, the NZTA shall establish two ambient air quality monitoring stations and one portal air quality monitoring station. The location and types of these monitoring stations shall be selected by the NZTA in consultation with the Auckland Council and Peer Review Panel (Condition OA.7), providing that one ambient monitoring station will be located within the Waterview Primary School (subject to agreement by the School).

Ambient air quality shall be monitored continuously in real time, to monitor potential effects associated with the operation of the ventilation system from the tunnels. Ambient monitoring shall include fine particulates (PM_{10} and $PM_{2.5}$) and nitrogen dioxide. Portal monitoring shall include nitrogen dioxide. Results shall be compared with the relevant National Environmental Standards for air quality and Auckland Regional air quality targets (as identified in Chapter 4 of the Auckland Regional Plan: Air, Land and Water, 2010). Monitoring shall be undertaken at each site until the Peer Review Panel recommends that monitoring is no longer necessary. The locations, operation and maintenance schedules of the continuous monitors shall, as far as practicable, comply with the requirements of AS/NZ 3580.1.1: 2007 Method for Sampling and Analysis of Ambient Air – Guide to Siting Air Monitoring Equipment, and with methods specified in the National Environment Standards.

OA.3 Continuous monitoring of wind speed and direction shall be undertaken at each ambient air quality monitoring location as required by Condition OA.2. The locations of wind speed and direction monitors shall, as far as practicable, comply with the requirements of AS 2923:1987 Ambient Air – Guide for the Measurement of Horizontal Wind for Air Quality Applications.

OA.4 For the first 12 months of tunnel operation, the results of the ambient air quality monitoring shall be reported via validated reports and issued for information via the Project website (monthly). Following this period, and for a period of at least 12 months, reporting shall take place quarterly as follows: Quarter 1 (December to February) by 31 March, Quarter 2 (March to May) by 30 June, Quarter 3 (June to August) by 30 September and Quarter 4 (September to December) by 31 December.

OA.5. If the monitoring required by Condition OA.2 shows that concentrations of contaminants in ambient air at the monitoring locations exceeds the relevant National Environmental Standards for air quality, or Regional Air Quality Targets (as identified in Chapter 4 of the Auckland Regional Plan: Air, Land and Water), the NZTA shall undertake an investigation into the cause of the exceedance and report this to the Peer Review Panel (Condition OA.7) and the Major Infrastructure Team Manager, Auckland Council.

OA.6. The air quality monitoring shall be undertaken in general accordance with the Operational Air Quality Management Procedure (Appendix O of Technical Report G.1 Assessment of Air Quality Effects) submitted with this application.

OA.7. A Peer Review Panel shall be appointed by NZTA with the agreement of Major Infrastructure Team Manager, Auckland Council for the purpose of reviewing the ambient air quality monitoring programme and results. The Peer Review Panel shall consist of two independent experts in air quality with experience in ambient air quality monitoring and emissions from motor vehicles. The Peer Review Panel shall review all ambient monitoring, relevant traffic data and tunnel emissions and provide a summary report including any interpretation and recommendations to NZTA, Auckland Council and the Community Liaison Group(s) within 6 months of the tunnels becoming operational and annually thereafter.

O.A.8 The tunnel ventilation system shall be designed and operated to ensure that any air emitted from the tunnel portals does not cause the concentration of nitrogen dioxide (NO_2) in ambient air to exceed 200 micrograms per cubic metre, expressed as a rolling 1 hour average, at any point beyond the designation boundary that borders an air pollution sensitive land use.

Advice Note: The above standard reflects the National Environmental Standard for Nitrogen Dioxide (NO_2) concentration in ambient air.

APPENDIX B: MONITORING LOCATIONS

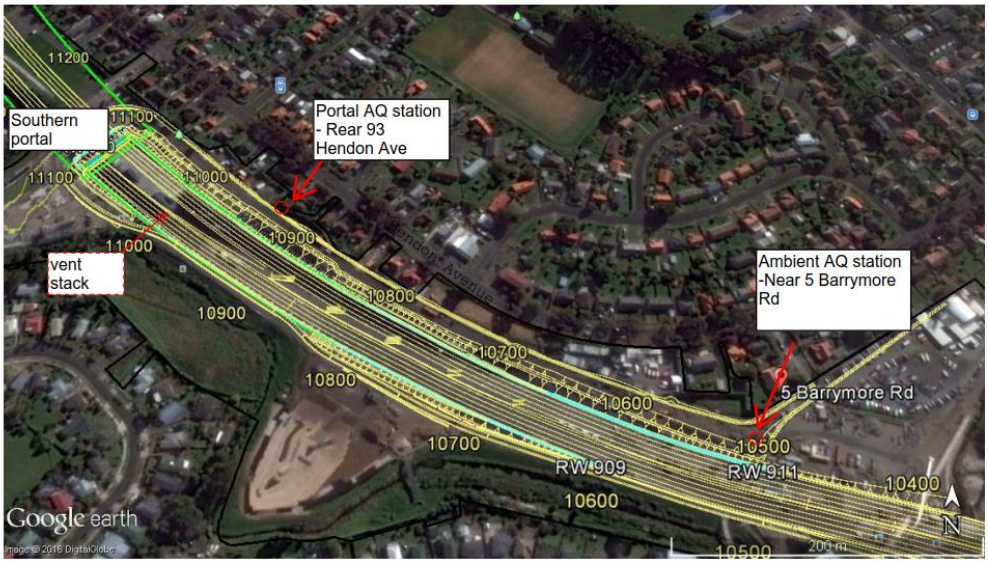

Figure B 1: Southern area stations

Figure B 2: Northern area station

APPENDIX C: VALID DATA EXCEPTION REPORT

North ambient air quality station

Start Date	End Date	Reason	Change Details
01/01/19 01:00	31/03/19 01:40	Automatic daily overnight span calibration check from approximately 1:00 - 1:40	NO, NO_2, NO_x
31/01/19 09:00	31/01/19 10:00	Scheduled monthly maintenance	$PM_{2.5}$,PM_{10}
31/01/19 09:40	31/01/19 10:10	Scheduled monthly maintenance	NO, NO_2, NO_x
11/02/19 01:45	13/02/19 15:15	Applied static multiplier A = 0.9195 to correct baseline	NO, NO_2, NO_x
11/02/19 21:00	11/02/19 21:25	Power interruption and instrument stabilisation	All channels
13/02/19 15:20	14/02/19 15:20	Non scheduled maintenance performed over 2 days - instrument calibration and stabilisation	NO, NO_2, NO_x
27/02/19 14:00	27/02/19 15:25	Scheduled 3 monthly maintenance	All channels
26/03/19 13:50	26/03/19 15:00	Scheduled monthly maintenance - instrument remote calibration	NO, NO_2, NO_x
26/03/19 22:00	26/03/19 22:00	Instrument fault - flow error	PM_{10}

South ambient air quality station

Start Date	End Date	Reason	Change Details
01/01/19 00:00	31/01/19 11:00	Instrument fault - during the maintenance visit on 31/01/19 a flow leak was found and repaired. It's not identifiable from the data when this leak started. Data were invalidated between 01/01/19 00:00 and 31/01/19 11:00	$PM_{2.5}$
01/01/19 01:00	31/03/19 01:30	Automatic daily overnight span calibration check from approximately 1:00 - 1:30	NO, NO_2, NO_x
31/01/19 12:00	31/01/19 13:00	Scheduled monthly maintenance	$PM_{2.5}$,PM_{10}
31/01/19 12:10	31/01/19 12:35	Scheduled monthly maintenance	NO, NO_2, NO_x
01/02/19 00:00	27/02/19 08:00	Instrument fault - during the maintenance visit on 27/02/19 a flow leak was found and repaired. It's not identifiable from the data when this leak started. Data were invalidated between 01/02/19 00:00 and 27/02/19 08:00	PM_{10}
25/02/19 14:00	27/02/19 07:00	Intermittent instrument fault - tape error	PM_{10}
27/02/19 09:00	27/02/19 12:20	Scheduled 3 monthly maintenance	All channels
21/03/19 04:00	22/03/16 04:25	Intermittent power interruption and instrument stabilisation	All channels
22/03/19 10:50	22/03/19 11:30	Non scheduled maintenance - instrument remote calibration	NO, NO_2, NO_x

Start Date	End Date	Reason	Change Details
26/03/19 15:15	26/03/19 15:55	Scheduled monthly maintenance - instrument remote calibration	NO, NO_2, NO_x

Portal air quality station

Start Date	End Date	Reason	Change Details
01/01/19 02:00	31/03/19 02:30	Automatic daily overnight span calibration check from approximately 2:00 - 2:30	NO_2
01/01/19 23:45	31/03/19 23:50	Automatic daily background check, nightly for 5 minutes between 23:45 and 23:50	NO_2
31/01/19 11:55	31/01/19 12:25	Scheduled monthly maintenance	NO_2
05/02/19 03:00	27/02/19 09:25	Intermittent instrument fault - instrument cell temperature exceeding limits	NO_2
09/02/19 02:40	11/02/19 01:55	Overnight calibration check outside tolerance	NO_2
19/02/19 03:10	21/02/19 01:55	Overnight calibration check outside tolerance	NO_2
21/02/19 16:15	21/02/19 16:20	Non scheduled maintenance - instrument calibration check and stabilisation	NO_2
25/02/19 09:40	27/02/19 09:35	Overnight calibration check outside tolerance	NO_2
27/02/19 09:40	27/02/19 13:05	Scheduled monthly maintenance	NO_2
27/03/19 11:00	27/03/19 12:25	Scheduled monthly maintenance - instrument remote calibration	NO_2

APPENDIX D: PREVIOUS MONTHLY DATA

AQ Station	Description	Pre Tunnel Opening Concentration in µg/m^3		Post Tunnel Opening Concentration in µg/m^3																				Project air quality criteria in µg/m^3
		May 2017	June 2017	July 2017	Aug 2017	Sept 2017	Oct 2017	Nov 2017	Dec 2017	Jan 2018	Feb 2018	Mar 2018	Apr 2018	May 2018	June 2018	July 2018	Aug 2018	Sept 2018	Oct 2018	Nov 2018	Dec 2018	Jan 2019	Feb 2019	Mar 2019	
Northern ambient air quality station	Maximum 1-hour average NO_2	65.5	58.2	96.8	93.2	91.3	77.9	62.1	57.8	53.6	62.9	62.1	69.8	83.5	87.5	101.5	101.1	75.8	83.4	63.2	65.5	44.1	53.9	59.8	200
	Maximum 24-hour average NO_2	30.2	36.9	46.4	54.1	44.8	39.4	26.5	31.7	24.7	30.2	34.3	42.7	46.4	45	50.3	50.3	44.2	43.4	33.5	27.3	23.2	24.1	29.4	100
	Maximum daily average $PM_{2.5}$	**32.7**	24.9	24.8	16.9	14.0	10.5	11.3	10.8	16.0	13.1	11.3	14.4	21.8	27	19	14.8	11.2	10.3	12.8	11.7	14.8	12.2	11.0	25
	Maximum daily average PM_{10}	35.7	33.3	31.0	26.4	26.9	31.3	35.1	24.4	36.0	27.6	31	32.8	29.9	36.8	31.4	24.5	22.1	25.7	29.5	28.5	37.7	20.8	19.1	50
Southern ambient air quality station	Maximum 1-hour average NO_2	64.1	70.3	73.3	63.5	73.4	61.9	50.5	44.7	32.8	51.7	41.1	57.0	64.8	62.4	73.5	72.7	56.9	61.1	50.7	41.3	38.1	44.4	46.9	200
	Maximum 24-hour average NO_2	30.0	30.8	38.2	34.7	27.4	25.5	20.7	16.9	18.5	17.9	22.8	29.6	36.5	38.8	39.7	38.9	27.7	25.9	26.0	17.1	14.6	20.8	28.1	100
	Maximum daily average $PM_{2.5}$	23.2	19.1	**26.5**	12.6	12.1	13.3	9.8	8.1	14.0	9.8	11	15.9	21.9	**26.4**	21.3	16.1	12	9.8	12.8	13.7	-	11.3	7.8	25
	Maximum daily average PM_{10}	35.8	31.8	31.8	28.8	31.6	37.9	22.0	20.1	34.0	26.7	23.9	27.3	26.5	34.1	30.2	21.7	18.5	20.3	25.8	28.8	27.2	-	18.6	50
Portal air quality station	Maximum rolling 1-hour average NO_2	70.8	80.6	86.9	73.8	84.9	62.6	63.5	51.2	46.7	46	51	67.4	78.7	87.8	86.9	75.5	76.1	70.5	65.8	16.9	48.5	47.6	50.7	200

It should be noted that construction activities on site in the vicinity of the stations, including vehicle movements on haul roads, will have contributed to measured particulate levels pre tunnel opening. Baseline measurements of $PM_{2.5}$ were also elevated in May 2017 during the night time due to domestic smoke from adjacent residential properties.

APPENDIX E: POLLUTION ROSES

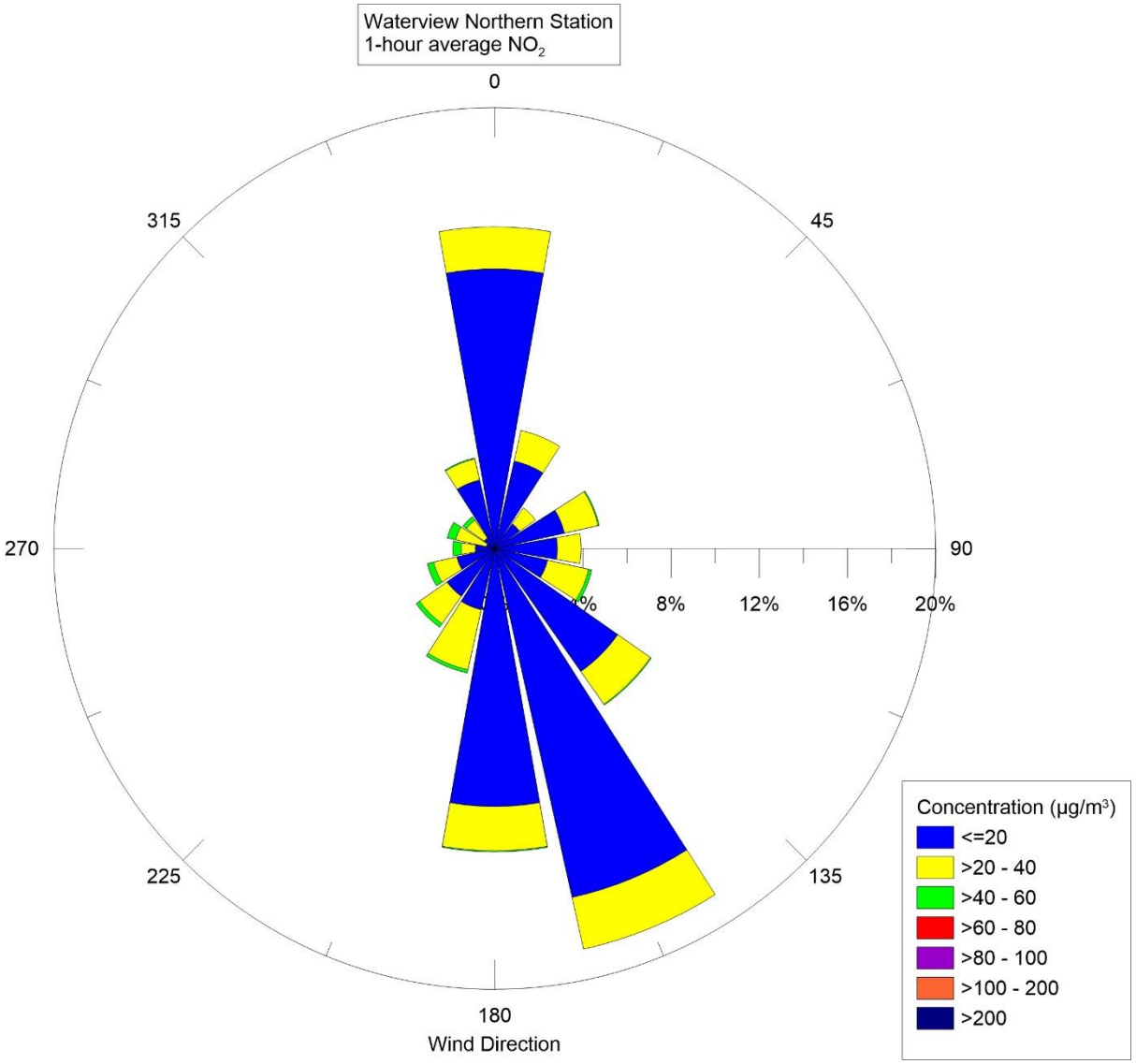

Figure D 1: Northern station 1-hour average NO_2, January to March 2019

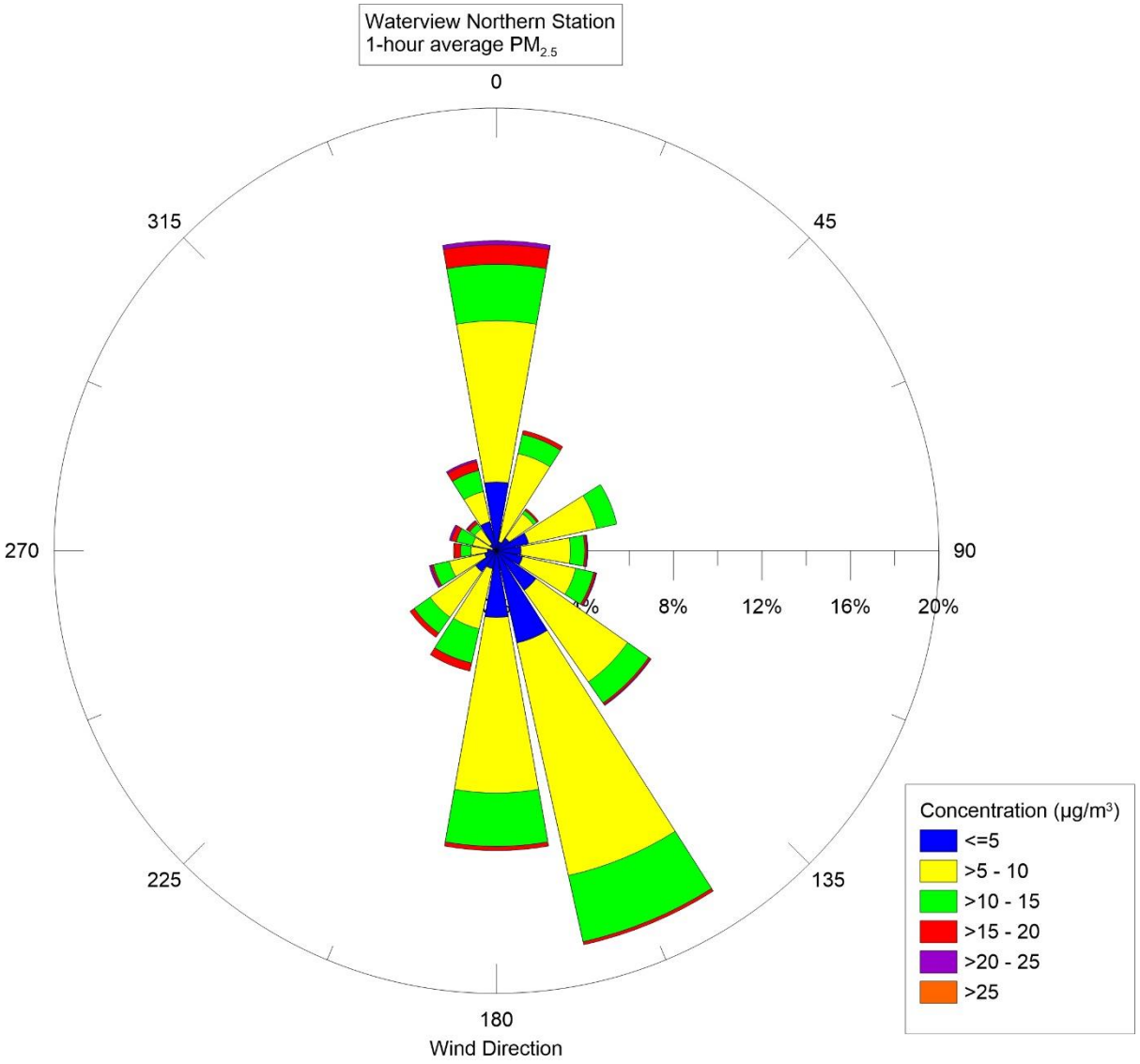

Figure D 2: Northern station 1-hour average $PM_{2.5}$, January to March 2019

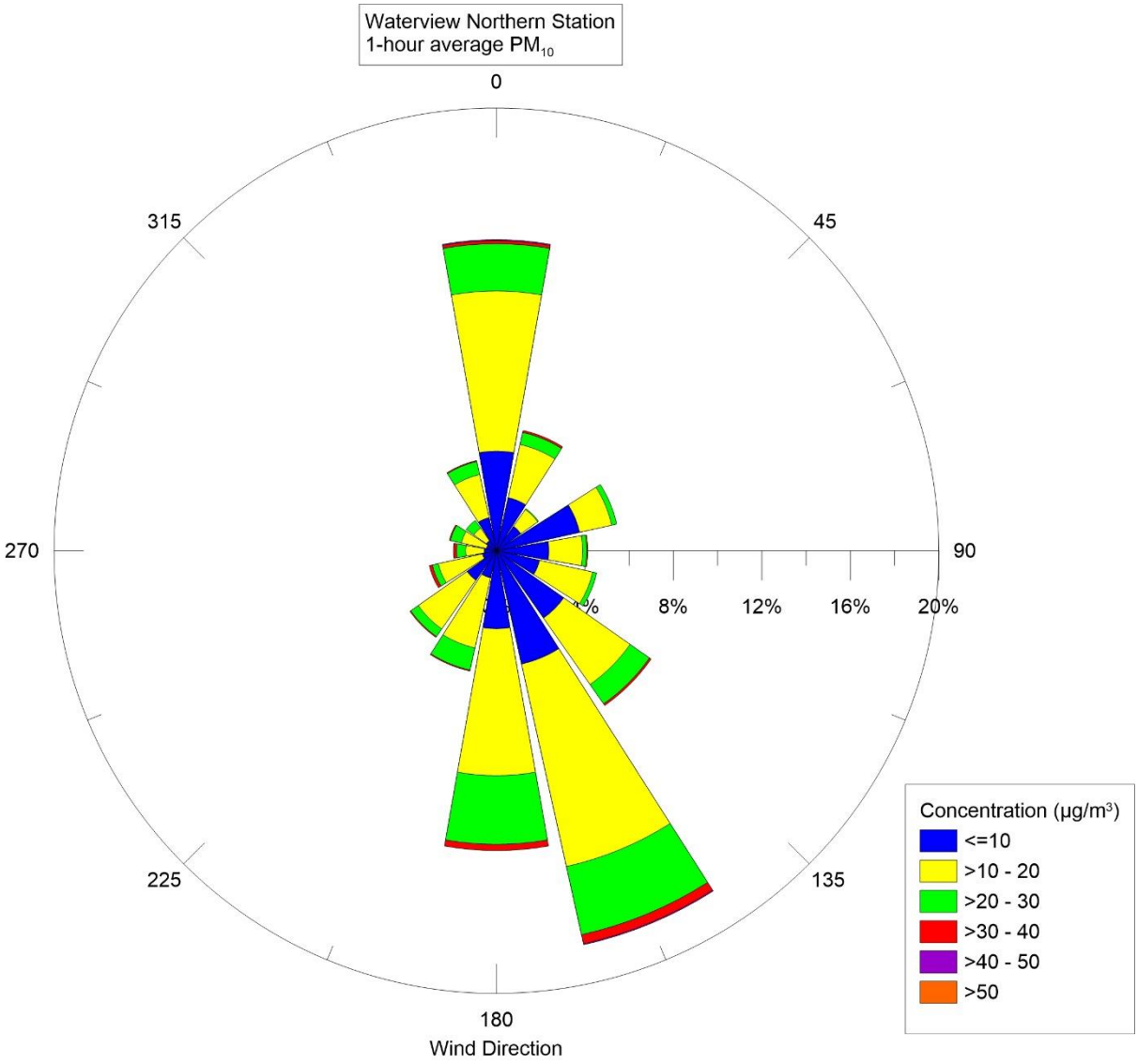

Figure D 3: Northern station 1-hour average PM_{10}, January to March 2019

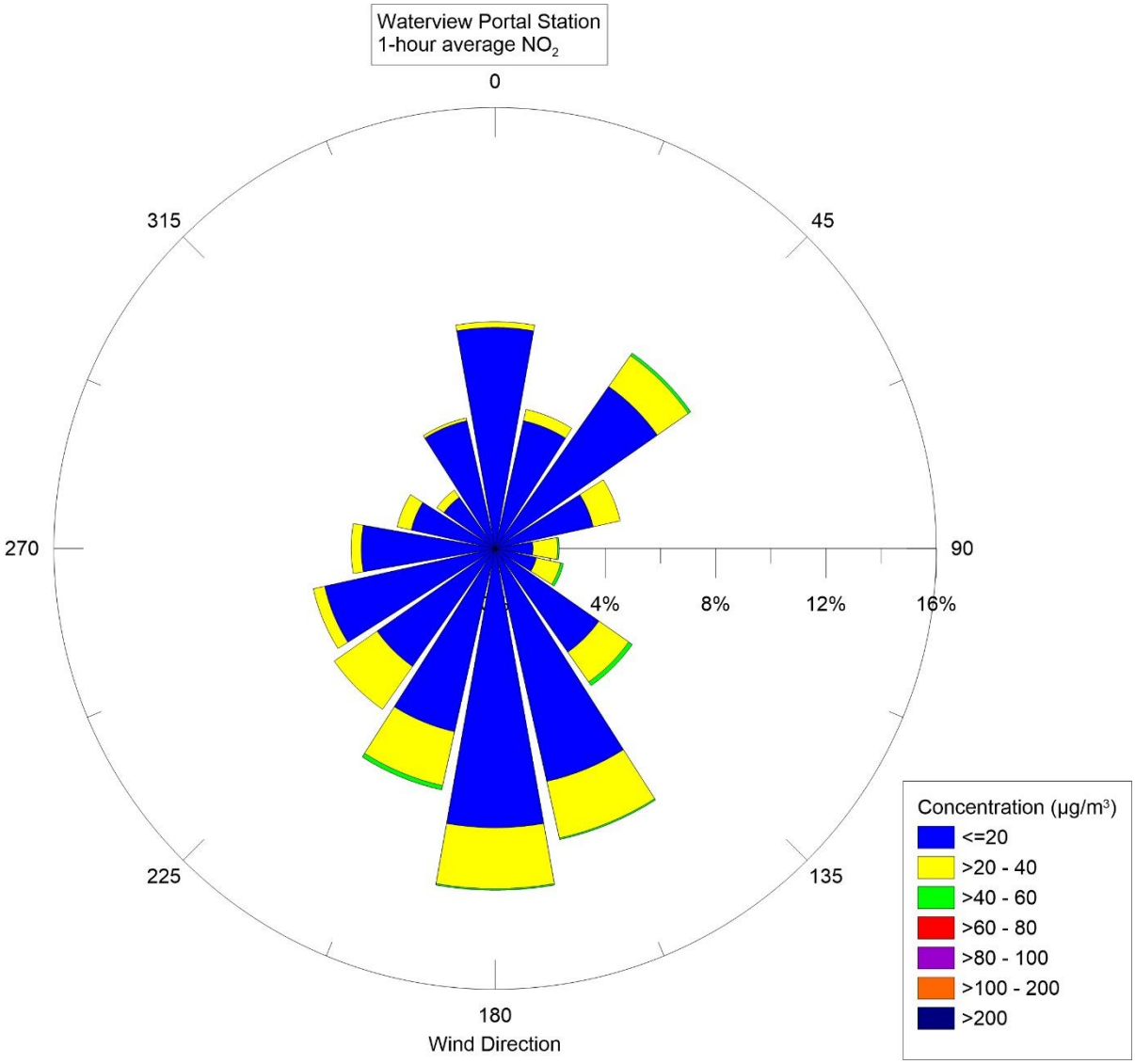

Figure D 4: Portal station 1-hour average NO_2, January to March 2019 (wind measured at Southern Station)

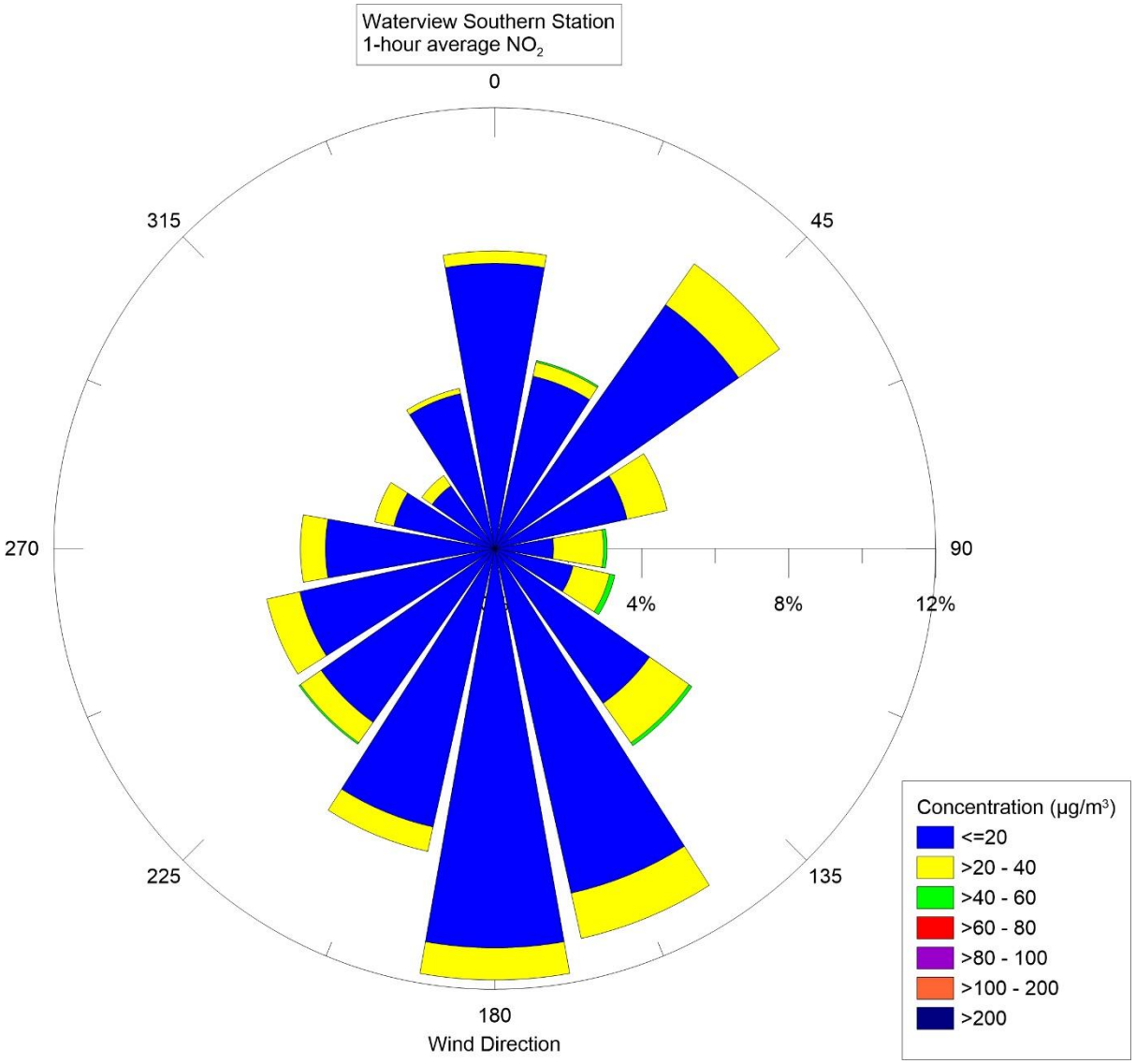

Figure D 5: Southern station 1-hour average NO_2, January to March 2019

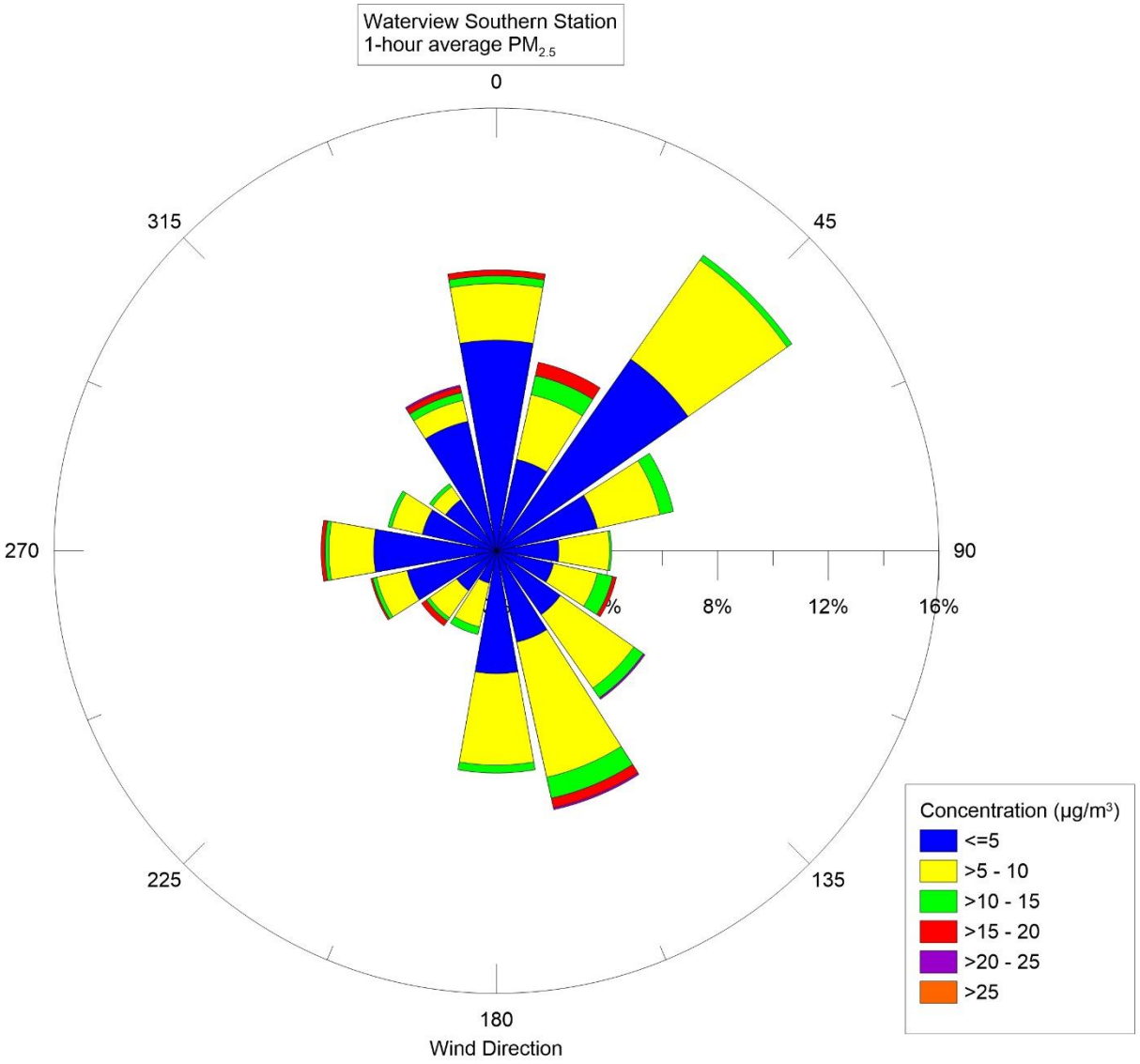

Figure D 6: Southern station 1-hour average $PM_{2.5}$, January to March 2019

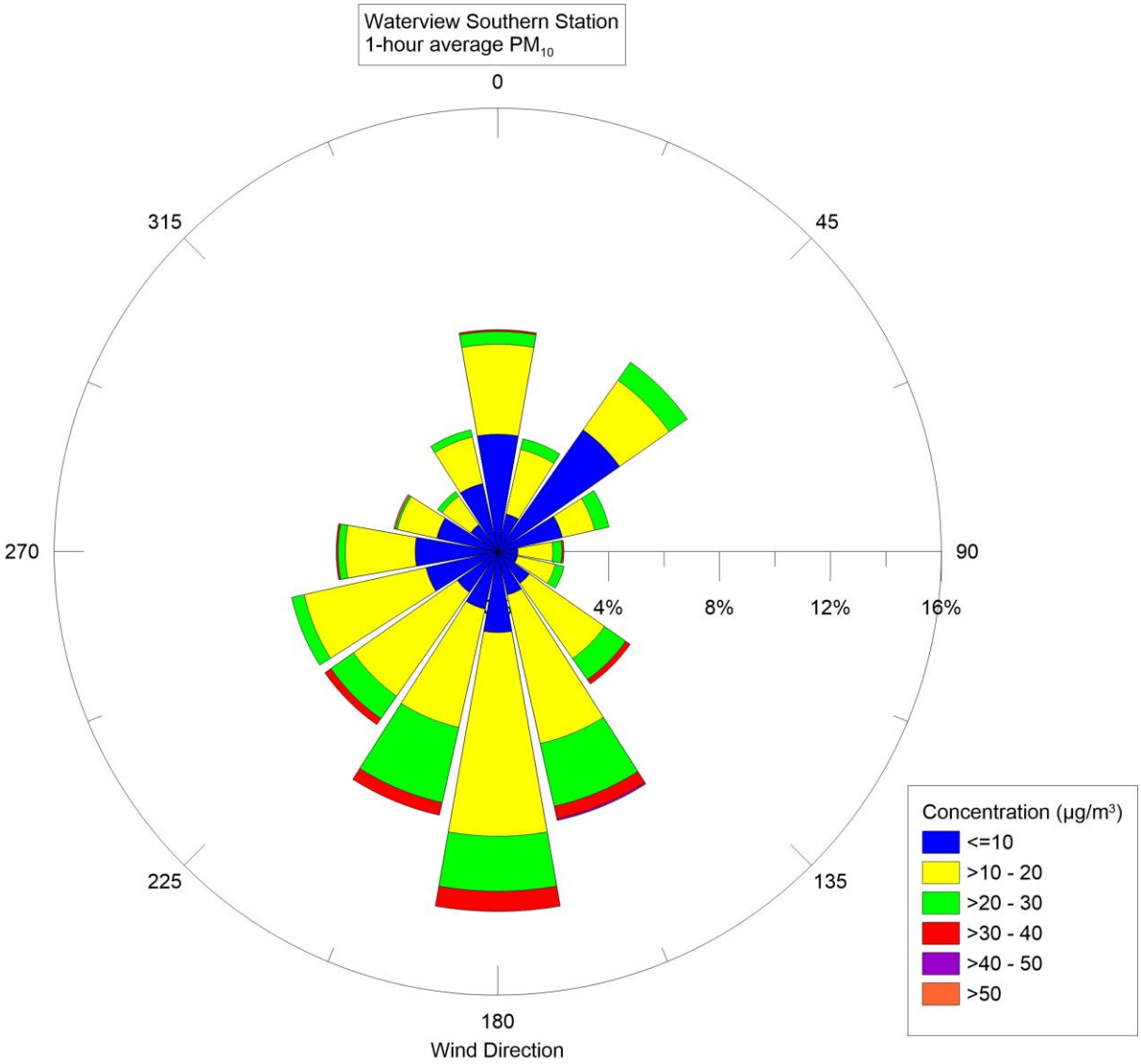

Figure D 7: Southern station 1-hour average PM_{10}, January to March 2019

APPENDIX F: ORIGINAL BASELINE MONITORING DATA

Air Quality Station	Description	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
Northern Area - Cowley St air quality station	Maximum rolling 1-hour average NO_2							
	Maximum 24-hour average NO_2							
	Maximum daily average $PM_{2.5}$							
	Maximum daily average PM_{10}							
Southern Area - Alan Wood air quality station	Maximum rolling 1-hour average NO_2	55	59	59	53	112	39	57
	Maximum 24-hour average NO_2	25	34	31	26	86	17	19
	Maximum daily average $PM_{2.5}$							
	Maximum daily average PM_{10}	32	44	23	22	19	63	22

Air Quality Station	Description	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07
Northern Area - Cowley St air quality station	Maximum rolling 1-hour average NO_2								55	66	61	50	44
	Maximum 24-hour average NO_2								29	36	28	30	23
	Maximum daily average $PM_{2.5}$												
	Maximum daily average PM_{10}								25	32	28	28	24
Southern Area - Alan Wood air quality station	Maximum rolling 1-hour average NO_2	28	35	37	53	56	56	61	51	61	44	42	38
	Maximum 24-hour average NO_2	10	13	15	27	34	32	28	20	25	18	17	13
	Maximum daily average $PM_{2.5}$												
	Maximum daily average PM_{10}	21	19	19	19	32	35	22	31	17	24	24	14

Air Quality Station	Description	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08
Northern Area - Cowley St air quality station	Maximum rolling 1-hour average NO_2	38	43	46	57	71	71	81	71	62	66	119	62
	Maximum 24-hour average NO_2	20	23	27	27	39	42	41	38	34	35	35	30
	Maximum daily average $PM_{2.5}$												
	Maximum daily average PM_{10}	29	21	22	24	37	31	33	16	18	20	27	18
Southern Area - Alan Wood air quality station	Maximum rolling 1-hour average NO_2	26	38	42	54	59	67	58	52	45	43	34	36
	Maximum 24-hour average NO_2		20	19	25	30	38	32	21	21	16	13	14
	Maximum daily average $PM_{2.5}$												
	Maximum daily average PM_{10}	24	18	21	19	37	27	30	17	15	19	22	15

Air Quality Station	Description	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09
Northern Area - Cowley St air quality station	Maximum rolling 1-hour average NO_2	74	265				55	103	99	77	93	83	80
	Maximum 24-hour average NO_2	37	48				26	56	48	44	45	30	39
	Maximum daily average $PM_{2.5}$												
	Maximum daily average PM_{10}	20	29	26	29	27	50	43	32	135	31	33	25
Southern Area - Alan Wood air quality station	Maximum rolling 1-hour average NO_2	29	32	38	40	51	62	44	51	37			
	Maximum 24-hour average NO_2	9	15	18	20	24	30	22	20	18			
	Maximum daily average $PM_{2.5}$												
	Maximum daily average PM_{10}	17	26	20	21	25	38	30	28	117			
Air Quality Station	**Description**	**Jan-10**	**Feb-10**	**Mar-10**	**Apr-10**	**May-10**	**Jun-10**	**Jul-10**	**Aug-10**	**Sep-10**	**Oct-10**	**Nov-10**	**Dec-10**
Northern Area - Cowley St air quality station	Maximum rolling 1-hour average NO_2	52	57	58	56	55	23	265	70	41	93	101	85
	Maximum 24-hour average NO_2	29	30	33	33	28	11	46	22	22	30	34	27
	Maximum daily average $PM_{2.5}$						16	29	34	10	10	13	8
	Maximum daily average PM_{10}	21	27	23	20	28	20	35	39	26	27	22	30
Southern Area - Alan Wood air quality station	Maximum rolling 1-hour average NO_2												
	Maximum 24-hour average NO_2												
	Maximum daily average $PM_{2.5}$												
	Maximum daily average PM_{10}						44	40	37	24	26	22	30

Results taken from: *Ambient Air Quality Monitoring Summary Report, Beca 09 May 2011*.