LAQM Detailed Assessment Report

Summary Report

Belfast City Council

Project number: 60652891

30 March 2023

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Quality information

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1. Introduction

In view of recent public health concerns around fine particulate matter ($PM_{2.5}$), and in fulfilment of the Local Air Quality Management (LAQM) Review and Assessments requirements for Northern Ireland, Belfast City Council (BCC) has carried out a Detailed Assessment (DA) of air pollution in their administrative area. In addition to $PM_{2.5}$, the DA also assesses concentrations of nitrogen dioxide (NO_2) and particulate matter with a diameter less than 10 microns (PM_{10}) as these are the other main pollutants of concern across the city. NO_2 is the pollutant for which BCC's Air Quality Management Areas (AQMAs) are currently declared.

The DA aims to identify the key areas of the city where pollutant concentrations are exceeding or likely to be at risk of exceeding the legally-binding UK Air Quality Objectives (AQO) with a view to determining appropriate mitigation policies and measures to reduce ambient concentrations and public exposure. Comparisons are also made against the much more stringent World Health Organisation (WHO) Air Quality Guidelines (AQG). Whilst attainment of the WHO AQGs is not legally-binding, understanding which pollutants and locations are at risk of exceeding these AQGs can also help to formulate policies and actions aimed at reducing public exposure to air pollution.

The DA is divided into two parts: Part A covers monitoring undertaken by the Council to provide additional information on the pollutants of concern and Part B covers the assessment carried out to understand the spatial distribution of air pollution across the city through atmospheric dispersion modelling. This summary report provides an overview of the DA, presenting the key findings of the monitoring and modelling undertaken for the DA.

For a complete discussion of the methodologies employed and the full results, please refer to the following reports (available upon request from BCC):

- LAQM Detailed Assessment Report: Part A – Monitoring; and
- LAQM Detailed Assessment Report: Part B – Modelling

2. Part A – Monitoring

Part A of the DA consisted of the collation and analysis of recent air quality monitoring data collected by BCC from automatic air quality monitoring stations and NO_2 diffusion tubes within the Council's administrative area. In addition, Earthsense Zephyr sensors were installed at selected locations across the city to identify any areas of potential exceedance of the PM_{10}, $PM_{2.5}$ and NO_2 UK AQOs and corresponding WHO AQG values, and to provide additional monitoring data for the verification of the atmospheric dispersion modelling carried out in Part B of the DA.

Sensor Monitoring Locations

Earthsense Zephyr sensors, providing near-reference standard, real-time measurements of NO_2, PM_{10} and $PM_{2.5}$ concentrations were installed at six locations. The sensors were installed in mid-2021 and were operated by AECOM on behalf of the Council, until March 2022. Thereafter, the sensors have continued to be operated by BCC air quality officers.

Details of the monitoring locations are shown in Table 1. A map of the sensor monitoring locations, automatic monitoring locations, and diffusion tube monitoring locations is shown in Figure 1. A typical Zephyr installation is shown in Figure 2.

Table 1. Earthsense Zephyr Sensor Monitoring Locations

Site ID	Description	Type	X	Y	Height (m)	Distance to Kerb (m)
N1	A55	Roadside	335735	370740	2.5	6
N6	Clara Street	Urban Background	336030	373469	2.5	N/A
N8	Belfast City Airport Boundary	Other Sources	337110	375535	2.5	N/A
N10	Adjacent to the Westlink	Roadside	333645	375239	4	4
N12	Mt. Eagles Glen	Urban Background	326190	369255	2.5	N/A
ZAURN (AURN co-location)	Lombard Street AURN	Urban Background	333898	374358	4	N/A

The monitoring locations were chosen to represent a range of different environments within the city. Locations N1 (A55) and N10 (Westlink) were selected to represent roadside locations. Locations N6 (Clara Street) and N12 (Mt. Eagles Glen) were chosen to investigate domestic $PM_{2.5}$ concentrations in urban background settings, and N8 was selected for its proximity to the airport and the characterisation of $PM_{2.5}$ from aviation activities. ZAURN was a co-location with the Belfast Centre Automatic Urban and Rural Network (AURN), enabling the raw sensor data to be scaled appropriately and thereby improving the accuracy and reliability of the data.

Figure 1. Map of Monitoring Site Locations

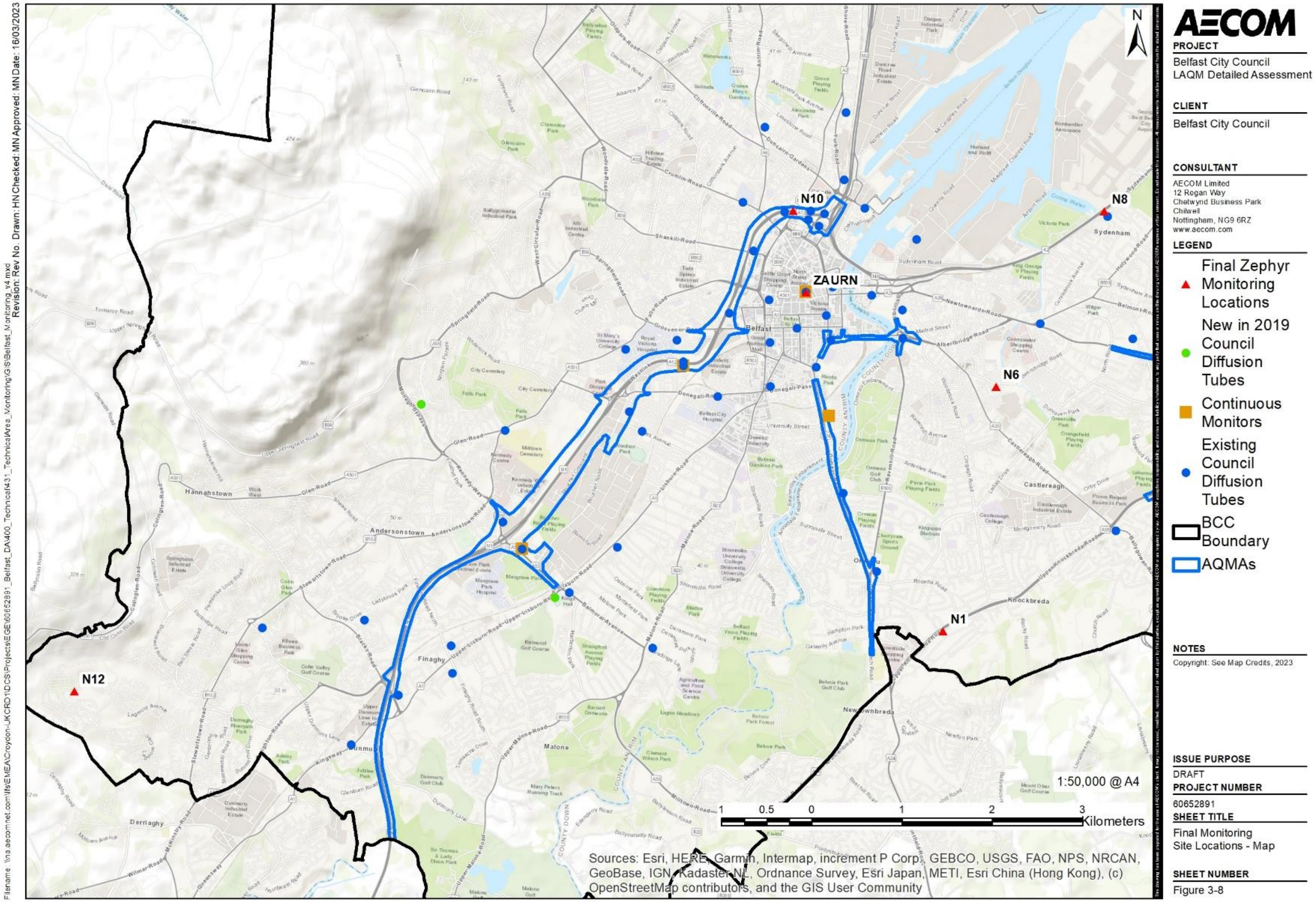


Figure 2. Typical Earthsense Zephyr Installation

Sensor Data Processing and Scaling

The data collected from the sensor network was processed and ratified in accordance with best-practice guidance. The raw data was collated and examined in detail to remove any negative concentrations or other spurious values. Data deemed to be related to instrument fault and/or noise was removed from consideration so as not to provide a false representation of ambient concentrations. Upon completion of this detailed examination the dataset is considered ‘ratified’.

The ratified data was then passed through a two-stage data scaling process to account for any bias in the measurement method and for variation between sensor cartridges. To do this, one Zephyr sensor was co-located with the Belfast Centre AURN monitoring station. Measurements obtained from the Zephyr were compared with the AURN station measurements and adjustment factors were calculated for each pollutant. These adjustment factors were used to scale the raw sensor data relative to the AURN station. To account for variations in response between sensor cartridges at different locations, a second cartridge, pre-calibrated against the AURN station, was periodically moved around the five Zephyr monitoring locations. A similar process of comparing the measurements from the two cartridges was used to derive a second set of adjustment factors, which were also applied to the raw data.

Further details on the data processing and scaling can be found in the LAQM Detailed Assessment Report: Part A – Monitoring.

Monitoring Results

For the purposes of the DA the monitoring data from the Zephyr sensors were adjusted (“annualised”) in accordance with best-practice guidance to be representative of a 2019 annual mean, to align with the year for which verification of the atmospheric dispersion modelling was carried out. The data were also annualised to 2021 annual means to enable BCC to report the results in subsequent LAQM Review and Assessment reports, if required.

The measured pollutant concentrations were compared against the relevant UK AQOs and WHO AQG as shown in Table 2. The WHO AQGs are not legally binding standards, but exceedance of the AQG level is associated with important risks to public health.

Table 2. UK Air Quality Objectives and WHO Air Quality Guidelines

Pollutant	Averaging Period	AQS Objective (µg/m^3)	Not to be Exceeded More Than	WHO Guideline (µg/m^3)*	Not to be Exceeded More Than
Nitrogen dioxide (NO_2)	Annual	40	N/A	10	N/A
	1-hour	200	18 hours (99.79th percentile)	N/A	N/A
	Daily	N/A	N/A	25	3 days (99th percentile)
Particulate matter (PM_{10})	Annual	40	N/A	15	N/A
	Daily	50	35 days (90.4th percentile)	45	3 days (99th Percentile)
Particulate matter ($PM_{2.5}$)	Annual	20	N/A	5	N/A
	Daily	N/A	N/A	15	3 days (99th Percentile)

Data Capture and Quality

The Earthsense Zephyr sensors were deployed with solar panels to avoid the requirement for connections to mains power, which can be problematic in some locations. However, during the winter months, data capture was limited at some locations by the availability of daylight and solar power. Where possible, mains power connections were established and data capture improved, although this was not possible at all locations.

Sensor technology is an emerging market, with no type-approval or certification regime yet in place. Therefore, there are inherent uncertainties associated with the data as compared to reference standard monitoring, especially when “annualising” data to allow comparisons to calendar annual means not explicitly monitored. The Zephyr monitors used in the DA recently obtained MCERTS Performance Standards as an Indicative Ambient Particulate Monitor, which gives additional confidence in the performance of the monitors. The results obtained are considered to be representative of the localities within which each sensor was deployed, allowing useful conclusions drawn from the data.

NO_2

The scaled, annualised results for NO_2 in 2019 and 2021 indicated that the annual mean NO_2 AQO of 40 µg/m^3 was achieved at all monitoring locations except N10 (see Table 3 and Table 4). The 2019 annualised mean NO_2 concentration at N10 was 50.3 µg/m^3. The 2021 annualised mean NO_2 concentration at this location was 45.5 µg/m^3. This site is located immediately adjacent to the Westlink, so after adjustment for distance it is likely that the AQO would be achieved at the nearest location of relevant exposure. However, the results highlighted the likely need to retain the Westlink AQMA (AQMA 1).

The 1-hour mean NO_2 AQO was achieved at all monitoring locations based on 2019 and 2021 scaled, annualised concentrations. The only location to record any 1-hour mean NO_2 concentrations of greater than 200 µg/m^3 was N10 in 2019 with 4 exceedance hours. This was well below the 18 hours permitted to achieve the AQO. The 99.79th percentiles of hourly NO_2 concentrations were also less than 200 µg/m^3 at all sites with data capture lower than 85% indicating exceedances of the 1-hour NO_2 AQO were very unlikely to have occurred.

The more stringent WHO AQG for annual mean NO_2 concentrations of 10 µg/m^3 was exceeded at all sites, based on 2019 and 2021 scaled, annualised means. Analysis of both the Zephyr and the Council's wider continuous monitoring indicates that the 24-hour mean NO_2 WHO AQG was also exceeded in both 2019 and 2021 at all locations, given the 99th percentile concentrations were all above 25 µg/m^3.

Table 3. 2019 Annual Mean Results for NO_2

Site	Adjusted Annual Mean Data Capture (%)	Scaled 2019 Annualised Annual Mean µg/m^3	Scaled Number of 1-hour mean concentrations >200µg/m^3	99th Percentile of 24-hour Mean NO_2 (µg/m^3)
AURN Belfast Centre (AURN)	51.4	24.1	0 (92.9)	53
AURN co-location (ZAURN)	58.5	29.7	0 (116.9)	82
N1	63.1	20.3	0 (93.8)	82
N10	80.1	50.3	4 (168.3)	99
N12	59.7	13.2	0 (95.6)	83
N6	83.8	23.0	0 (108.1)	81
N8	84.7	25.6	0 (109.4)	81

Where data capture is below 85%, for short term mean objectives, 99.79th percentiles have been presented in brackets

Table 4. 2021 Annual Mean Results for NO_2

Site	Adjusted Annual Mean Data Capture (%)	Scaled 2021 Annualised Annual Mean µg/m^3	Scaled Number of 1-hour mean concentrations >200µg/m^3	99th Percentile of 24-hour Mean NO_2 (µg/m^3)
AURN Belfast Centre (AURN)	90.6	20.7	0	56
AURN co-location (ZAURN)	58.5	26.2	0 (104.9)	74
N1	63.1	18.6	0 (84.2)	74
N10	80.1	45.5	0 (151.0)	92
N12	59.7	12.0	0 (85.7)	74
N6	83.8	20.6	0 (97.0)	73
N8	84.7	22.9	0 (98.2)	73

Where data capture is below 85%, for short term mean objectives, 99.79th percentiles have been presented in brackets

PM_{10}

The scaled, annualised results for PM_{10} in 2019 and 2021 indicated that the annual mean PM_{10} AQO of 40 μg/m^3 was achieved at all monitoring locations (see Table 5 and Table 6). The highest PM_{10} concentration in both years was recorded at N6 at Clara Street (19.7 μg/m^3 and 18.3 μg/m^3 in 2019 and 2021, respectively), which may be indicative of the contribution of local domestic source emissions.

All monitoring locations achieved the 24-hour mean PM_{10} AQO of 50 μg/m^3 not to be exceeded more than 35 days per year on the basis of 2019 and 2021 scaled, annualised results. The 90.4th percentiles of daily PM_{10} concentrations were also less than 50 μg/m^3 at all sites with data capture lower than 85% indicating exceedances of the 24-hour mean PM_{10} AQO were very unlikely to have occurred. All sites did, however, record two or more exceedance days. These days of 24-hour mean PM_{10} concentrations greater than 50 μg/m^3 were largely related to a regional pollution event in late March 2022, caused by the importation of Saharan dust across the UK. There was also an isolated exceedance at N10 in November 2021, which may have been related to a localised event or source (e.g. fireworks, roadworks).

The more stringent PM_{10} annual mean WHO AQG of 15 μg/m^3 was exceeded at all Zephyr monitoring locations, except the Lombard Street AURN co-location site based on the scaled, annualised 2019 results. Based on the scaled, annualised 2021 period, the AQG was exceeded at N6, N8 and N10.

Table 5. 2019 Annual Mean Results for PM_{10}

Site	Adjusted Annual Mean Data Capture (%)	Scaled 2019 Annualised Annual Mean μg/m^3	Scaled Number of 24-hour Means >50μg/m^3
AURN Belfast Centre (AURN)	88.3	15.4	2
AURN co-location (ZAURN)	61.8	12.7	7 (28.0)
N1	62.6	15.4	6 (29.2)
N10	79.8	18.5	9 (33.5)
N12	62.2	16.2	3 (30.3)
N6	84.6	19.7	7 (30.7)
N8	85.0	17.2	6 (30.3)

Where data capture is below 85%, for short-term objectives, the 90.4th percentiles have been presented in brackets

Table 6. 2021 Annual Mean Results for PM_{10}

Site	Adjusted Annual Mean Data Capture (%)	Scaled 2021 Annualised Annual Mean μg/m^3	Scaled Number of 24-hour Means >50μg/m^3
AURN Belfast Centre (AURN)	99.3	12.7	0
AURN co-location (ZAURN)	61.8	13.7	4 (25.7)
N1	62.6	14.4	4 (26.1)
N10	79.8	17.3	8 (29.1)
N12	62.2	15.0	2 (25.4)
N6	84.6	18.3	6 (28.2)
N8	85.0	15.9	5 (27.2)

Where data capture is below 85%, for short-term objectives, the 90.4th percentiles have been presented in brackets

$PM_{2.5}$

The scaled, annualised results for $PM_{2.5}$ in 2019 and 2021 indicated that the annual mean $PM_{2.5}$ AQO of 20 µg/m^3 was achieved at all monitoring locations (see Table 7 and Table 8). The highest $PM_{2.5}$ concentration in both years was recorded at the ZAURN co-location site at Lombard Street (13.0 µg/m^3 and 12.1 µg/m^3 in 2019 and 2021, respectively).

The much more stringent $PM_{2.5}$ annual mean WHO AQG of 5 µg/m^3 was exceeded at all Zephyr monitoring locations, on the basis of scaled, annualised data for both 2019 and 2021.

Table 7. 2019 Annual Mean Results for $PM_{2.5}$

Site	Adjusted Annual Mean Data Capture (%)	Scaled 2019 Annualised Annual Mean µg/m^3
AURN Belfast Centre (AURN)	88.2	10.6
AURN co-location (ZAURN)	61.7	13.0
N1	62.6	8.5
N10	79.7	11.5
N12	62.2	7.6
N6	84.6	11.9
N8	84.7	9.9

Table 8. 2021 Annual Mean Results for $PM_{2.5}$

Site	Adjusted Annual Mean Data Capture (%)	Scaled 2021 Annualised Annual Mean µg/m^3
AURN Belfast Centre (AURN)	99.3	7.4
AURN co-location (ZAURN)	61.7	12.1
N1	62.6	7.8
N10	79.7	10.7
N12	62.2	7.5
N6	84.6	11.0
N8	84.7	9.2

3. Part B - Modelling

Part B of the DA consisted of the assembly of a comprehensive emissions inventory of the major sources of air pollutant emissions in the city and subsequent atmospheric dispersion modelling based on data in the emissions inventory to predict concentrations of NO_2, PM_{10} and $PM_{2.5}$ at sensitive locations.

An emissions inventory was compiled providing annual emissions estimates for a baseline assessment year of 2019 and a future assessment year of 2028. The 2019 base year was chosen as this represents the most recent year unaffected by the effects of the Covid-19 pandemic. The future assessment year of 2028 was chosen to align with the data available within the strategic transport model used for the DA. The emissions inventory covers all of the key sources of NO_2, PM_{10} and $PM_{2.5}$ in Belfast, including the major road network and a large number of local roads, major industrial facilities and associated operations, Belfast Harbour, Belfast City Airport and the rail network. The inventory also contains physical source characteristics required for dispersion modelling of each source.

Dispersion modelling of the emissions inventory was carried out using ADMS-Roads and ADMS-5 atmospheric dispersion models. The models were configured to predict annual mean NO_2, PM_{10} and $PM_{2.5}$ concentrations at 1,797 discrete receptor points representing residential properties, health care facilities, hospitals and education facilities and other locations that are considered sensitive to air pollution. To provide an indication of the spatial patterns of pollutant concentrations across the city, contour plots of pollutant concentrations were generated using model predictions made across a detailed network of receptor points covering the four AQMAs, supplemented by a less-detailed network of points covering the whole BCC administrative area. Model outputs were verified by comparing against monitoring data collected by BCC during 2019 and data obtained from the network of sensors operated during 2021 and 2022. Good agreement was found between modelled and measured NO_2, PM_{10} and $PM_{2.5}$ concentrations across the majority of the monitoring network, indicating good model performance and providing confidence in the modelling results.

NO_2

Annual mean NO_2 concentrations for 2019 were predicted to be above the UK AQO level of 40 µg/m^3 at 25 discrete sensitive receptor locations. All of these receptors were within or near to the boundaries of the existing AQMAs along the Westlink (AQMA 1) and East Bridge Street / Cromac Street (AQMA 2), with the highest predicted concentration of 55.9 µg/m^3 at a receptor near to the Stockman's Lane roundabout.

The contour plot of modelled 2019 annual mean NO_2 concentrations (Figure 3) indicated these exceedances at locations outside of the AQMA boundaries were localised and likely to affect very few locations of relevant exposure. Within the uncertainties of the modelling, it was concluded that these exceedances do not warrant any amendment to the boundaries of AQMA 1 and AQMA 2 at this time.

Predicted 2019 annual mean NO_2 concentrations within AQMA 3, which covers a section of Upper Newtownards Road, Knock Road and Hawthornden Way, and AQMA 4 which covers Ormeau Road from the junction with Donegall Pass to the Belfast City boundary at Galwally, were below the UK AQO level at locations of relevant exposure. The results of recent years' monitoring at locations within AQMA 3 and AQMA 4 have also indicated that the AQO is now being met. Consideration should therefore be given to the revocation of AQMA 3 and AQMA 4, subject to a continuation of monitored NO_2 concentrations below the AQO in these AQMAs.

With the exception of the rural areas in the western part of the BCC administrative area, predicted 2019 annual mean NO_2 concentrations throughout the city exceeded the much more stringent WHO AQG of 10 µg/m^3.

For the future assessment year of 2028, predicted annual mean NO_2 concentrations were below the UK AQO of 40 µg/m^3 at locations of relevant exposure throughout the city. The highest predicted concentration at a discrete sensitive receptor location was 31.1 µg/m^3 at a receptor near to the Stockman's Lane roundabout. Consistent with 2019, the contour plot for 2028 (Figure 4) indicated that the highest levels of NO_2 are likely to be at locations along the main road corridors, in particular the Westlink and connecting routes.

In comparison to the much more stringent WHO AQG for annual mean NO_2 concentrations of 10 $\mu g/m^3$, most of the city centre and surrounding areas, particularly close to the major road network, were predicted to exceed this AQG in 2028.

Figure 3. City-wide Modelled 2019 Annual Mean NO_2 Concentrations

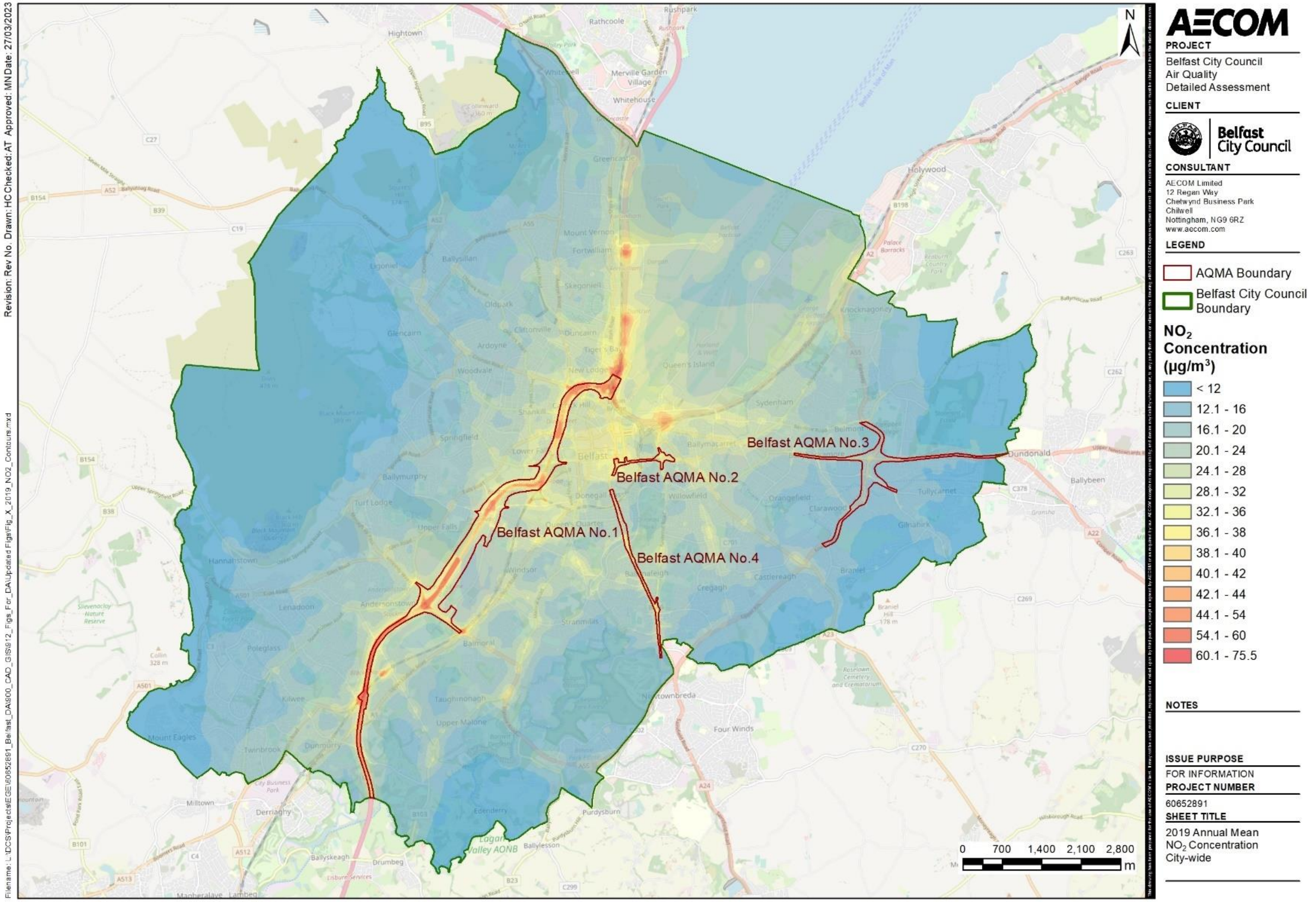
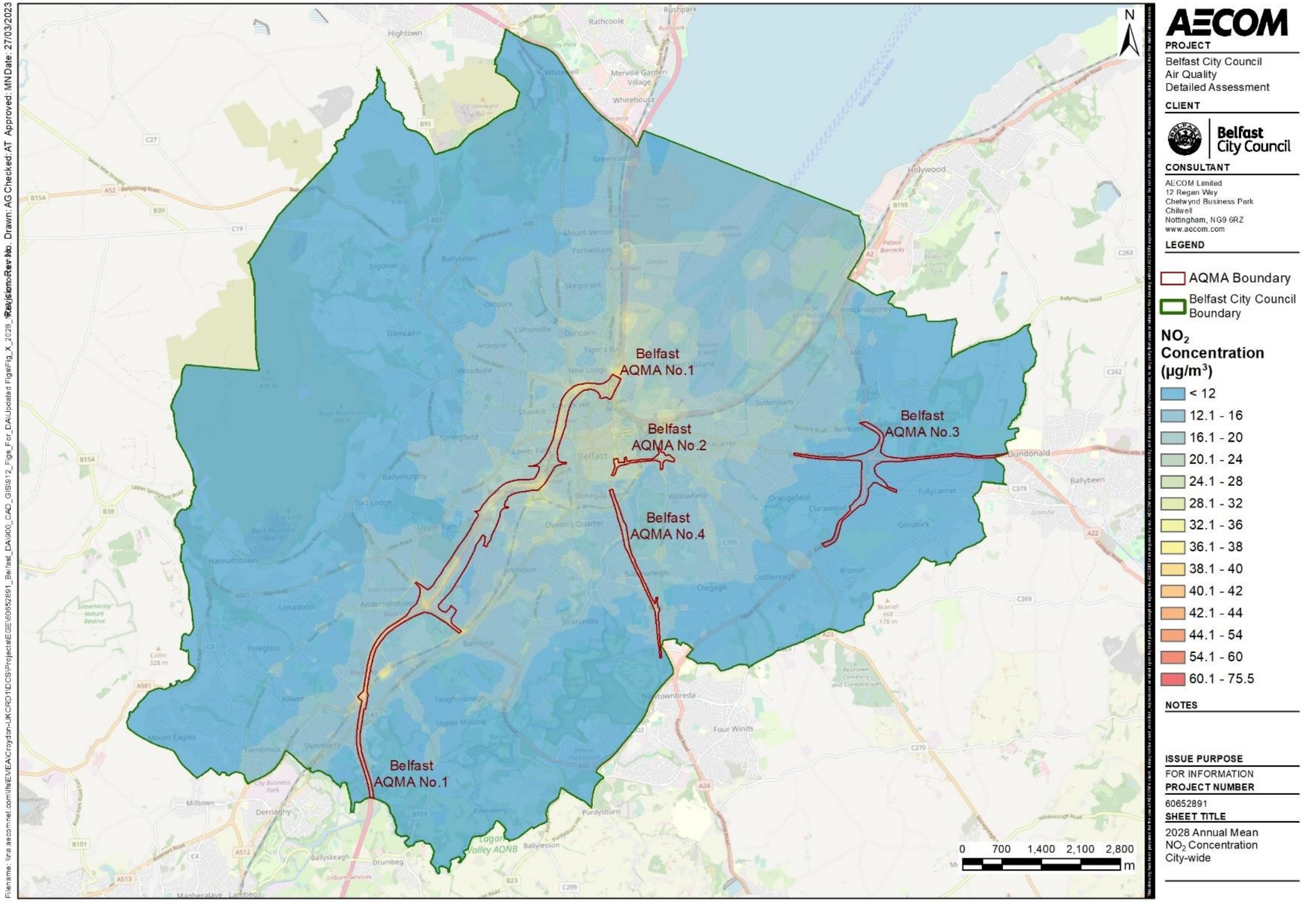


Figure 4. City-wide Modelled 2028 Annual Mean NO_2 Concentrations



PM_{10}

Annual mean PM_{10} concentrations in 2019 were predicted to be well below the UK AQO level of 40 µg/m^3 at locations of relevant exposure throughout the city. The highest predicted concentration at a discrete sensitive receptor location was 21.2 µg/m^3 at a receptor near to the Westlink at Barrack Street. Annual mean PM_{10} concentrations in 2019 exceeded the much more stringent WHO AQG for PM_{10} of 15 µg/m^3 at 1,100 of the 1,797 modelled discrete receptors and the contour plots indicated that the AQG was exceeded across most of the city centre area. In many areas background PM_{10} concentrations alone were found to approach or exceed the AQG level.

The contour plot of modelled annual mean PM_{10} concentrations in 2019 (Figure 5) indicated that the AQG was exceeded across much of the city centre area. The highest PM_{10} concentrations were predicted in areas where local source contributions coincide with elevated background concentrations, such as the Westlink corridor and the city centre.

For the future assessment year of 2028, predicted annual mean PM_{10} concentrations were well below the UK AQO of 40 µg/m^3 at locations of relevant exposure throughout the city. The contour plot for 2028 (Figure 6) indicated that the highest levels of PM_{10} occur where local source contributions coincide with elevated background concentrations. The highest predicted concentration at a discrete sensitive receptor location was 20.3 µg/m^3 at a receptor near to the Westlink at Barrack Street. Compared to NO_2, there were relatively small reductions in concentrations between 2019 and 2028. This illustrates the limited scope for further reductions in road traffic PM_{10} emissions as the majority of PM_{10} emitted by road vehicles is from non-exhaust sources (i.e. brake wear, tyre wear, road abrasion) that are more difficult to control, and the large contribution from regional background sources, outside the Council's control.

Annual mean PM_{10} concentrations in 2028 exceeded the much more stringent WHO AQG for PM_{10} of 15 µg/m^3 at 645 of the 1,797 modelled discrete receptors, and the contour plots indicated that the AQG was exceeded across a large part of the city centre area. In many areas background PM_{10} concentrations alone were found to approach or exceed the AQG level.

Figure 5. City-wide Modelled 2019 Annual Mean PM_{10} Concentrations

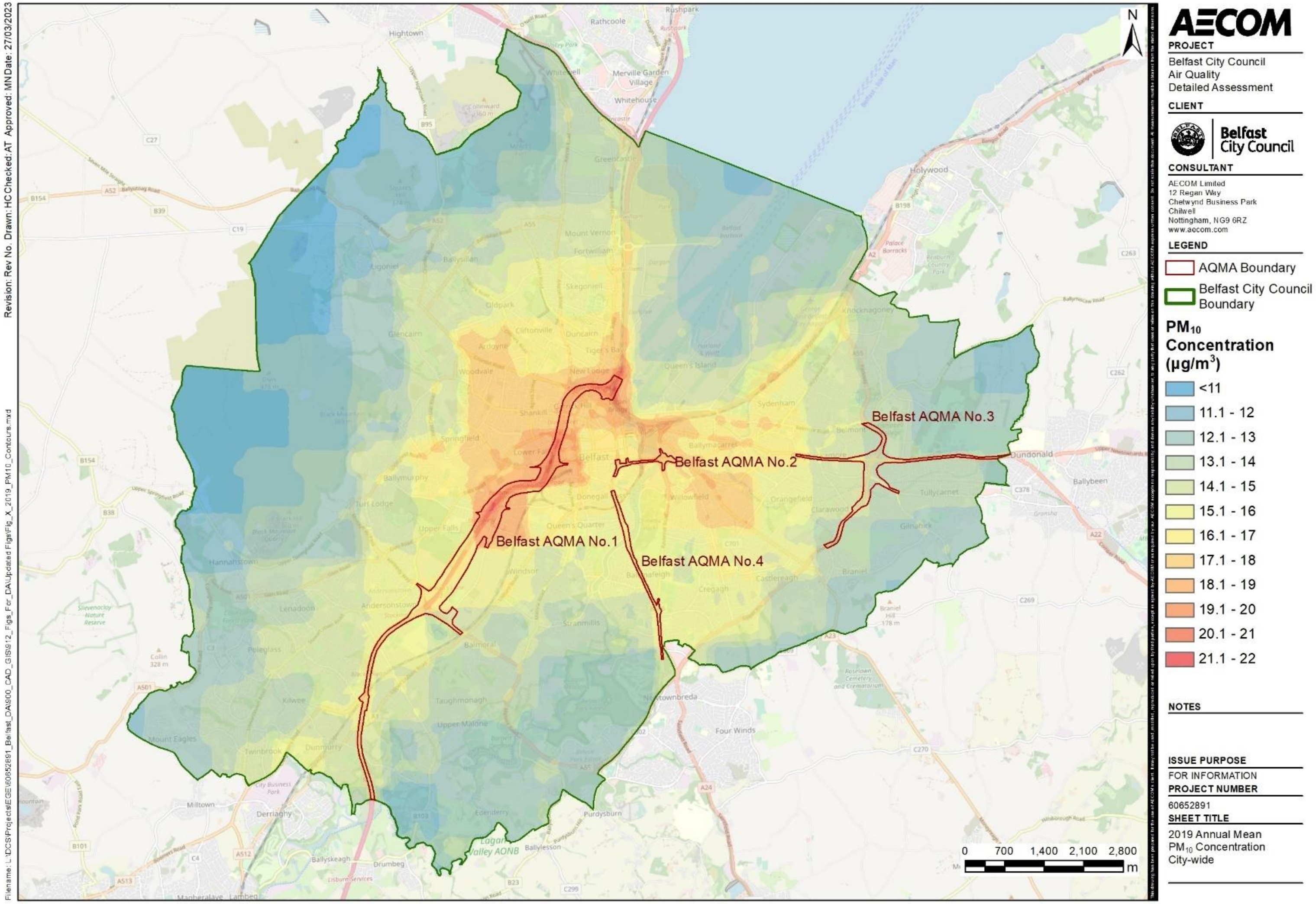
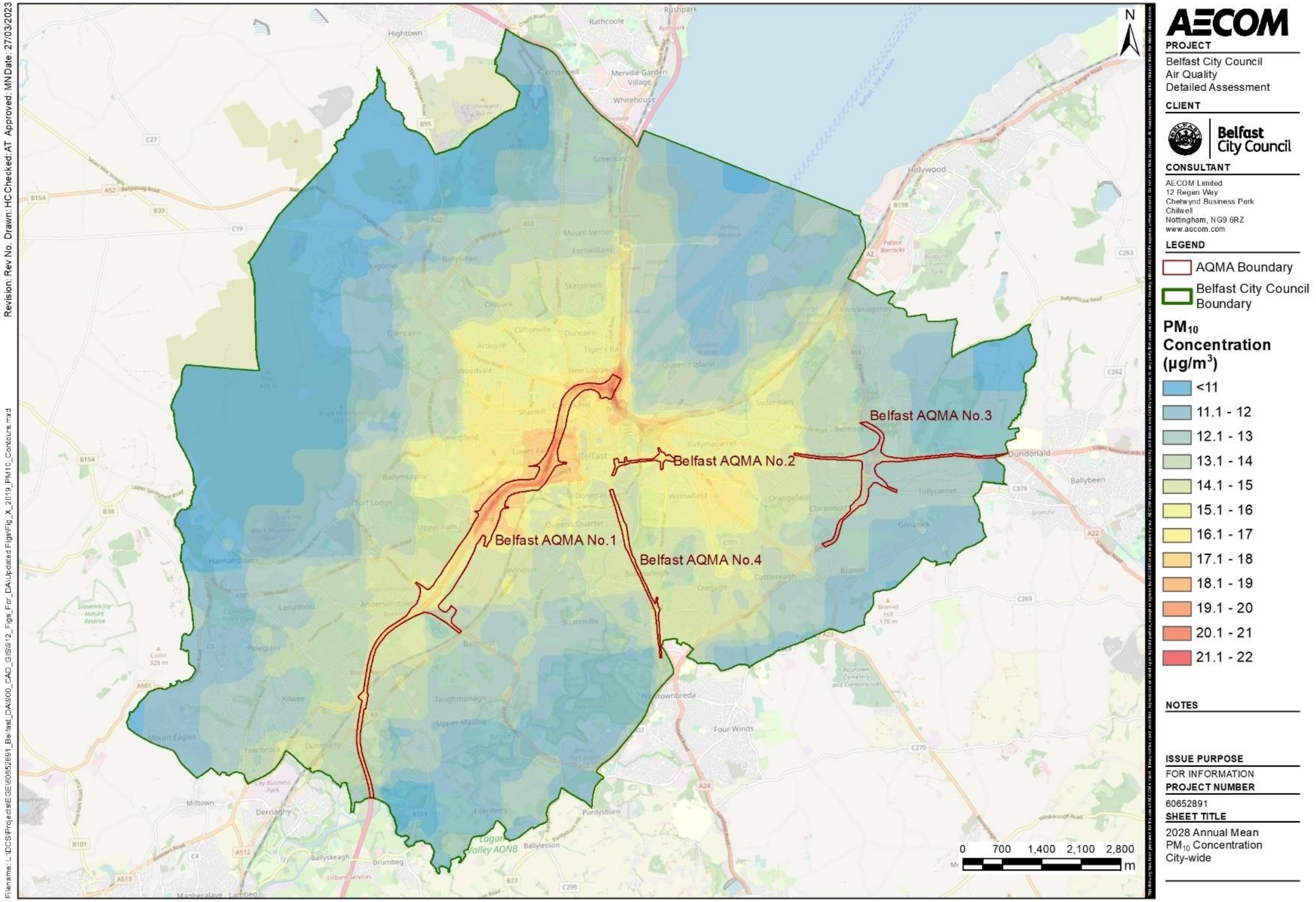


Figure 6. City-wide Modelled 2028 Annual Mean PM_{10} Concentrations



$PM_{2.5}$

Annual mean $PM_{2.5}$ concentrations in 2019 were predicted to be well below the UK AQO level of 20 µg/m^3 at locations of relevant exposure throughout the city. The highest predicted concentration at a discrete sensitive receptor location was 14.1 µg/m^3 at a receptor near to the Westlink at Barrack Street.

Annual mean $PM_{2.5}$ concentrations in 2019 exceeded the much more stringent WHO AQG for $PM_{2.5}$ of 5 µg/m^3 at all of the 1,797 modelled discrete receptors, and the contour plot for 2019 (Figure 7) indicated that the AQG was exceeded throughout the Council's administrative area. Background $PM_{2.5}$ concentrations alone were found to exceed the AQG level. The highest $PM_{2.5}$ concentrations were predicted in areas where local source contributions coincide with elevated background concentrations, such as the Westlink corridor and the city centre.

For the future assessment year of 2028, predicted annual mean $PM_{2.5}$ concentrations were well below the UK AQO of 20 µg/m^3 at locations of relevant exposure throughout the city. The contour plot for 2028 (Figure 8) indicated that the highest levels of PM_{10} occur where local source contributions coincide with elevated background concentrations. The highest predicted concentration at a discrete sensitive receptor location was 13.1 µg/m^3 at a receptor near to the Westlink at Barrack Street.

As was noted for PM_{10}, the relatively small reductions in $PM_{2.5}$ concentrations between 2019 and 2028 illustrate the limited scope for further reductions in road traffic $PM_{2.5}$ emissions, the majority of which is from non-exhaust sources (i.e. brake wear, tyre wear, road abrasion), and the large contribution from regional background sources, over which the Council has no control.

Annual mean $PM_{2.5}$ concentrations in 2028 exceeded the much more stringent WHO AQG for $PM_{2.5}$ of 5 µg/m^3 at all of the 1,797 modelled discrete receptors, and the contour plot indicated that the AQG was exceeded throughout the Council's administrative area.

Figure 7. City-wide Modelled 2019 Annual Mean $PM_{2.5}$ Concentrations

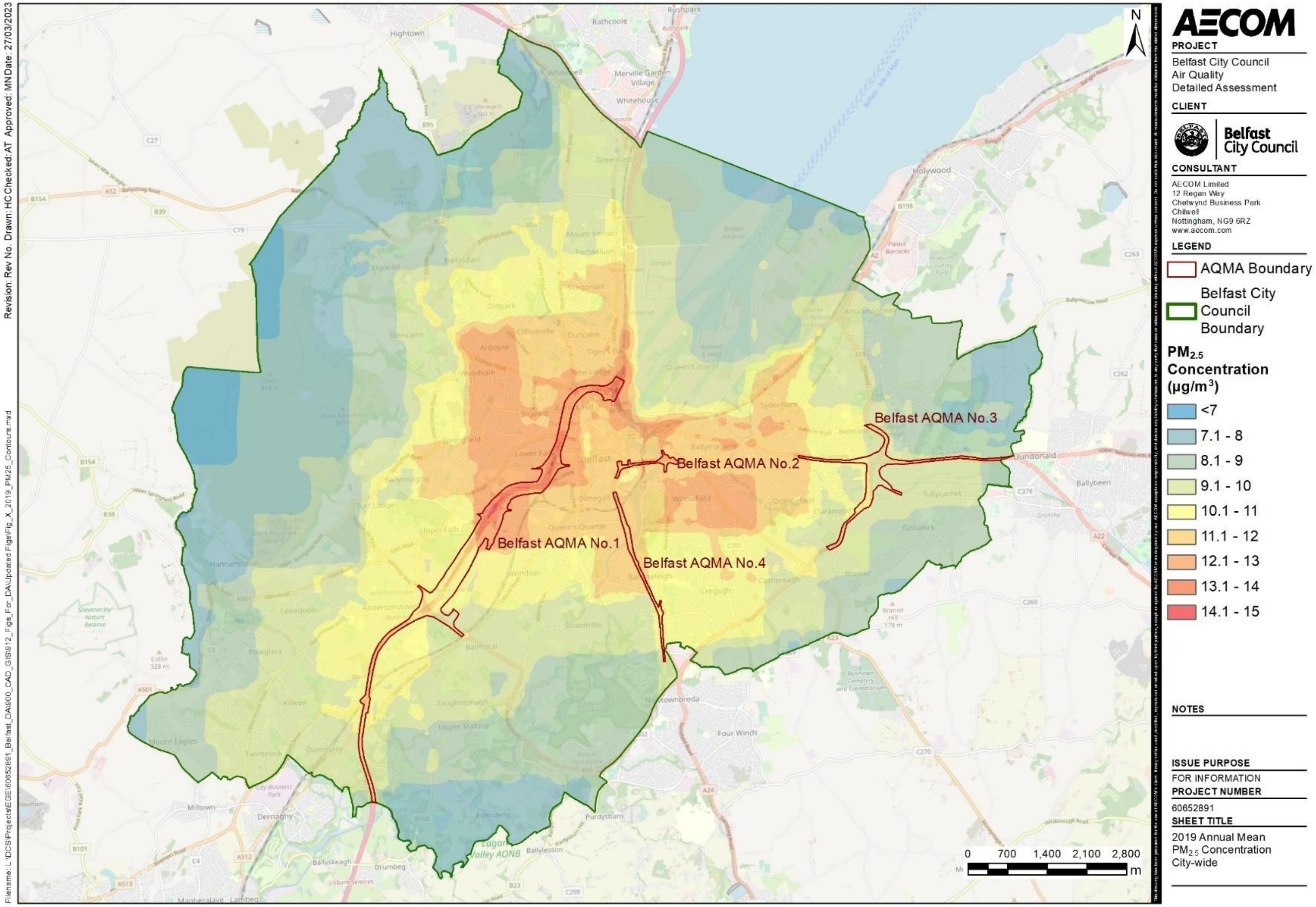
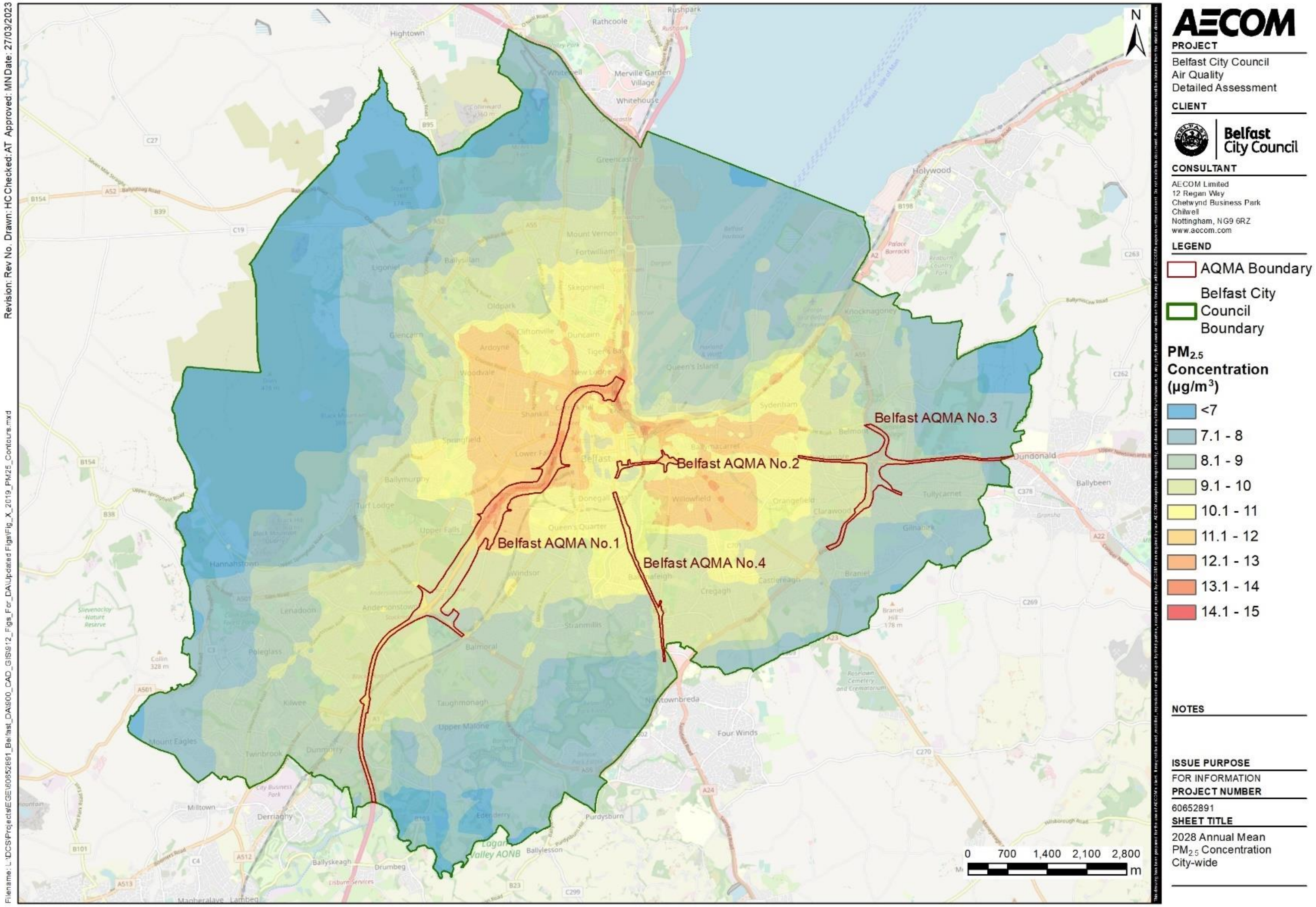


Figure 8. City-wide Modelled 2028 Annual Mean $PM_{2.5}$ Concentrations

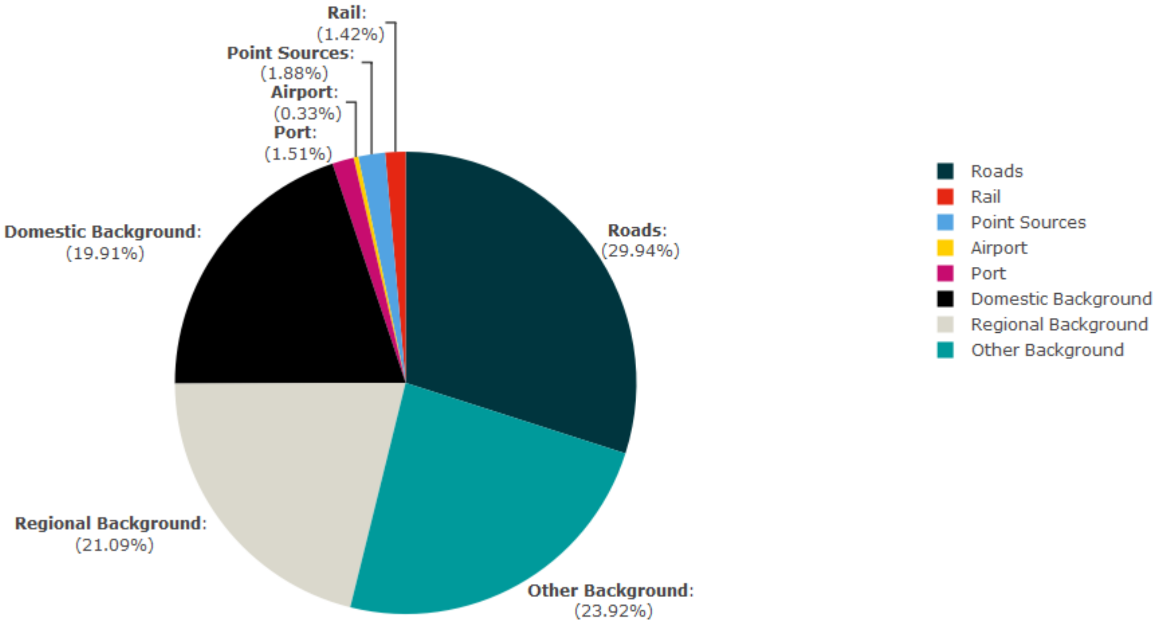


Source Apportionment

Source apportionment calculations were carried out for NO_2, PM_{10} and $PM_{2.5}$ to examine the relative contributions of different sources to modelled concentrations across the city. The relative contributions of different sources are strongly influenced by proximity to source. Therefore, source apportionment calculations were carried out at individual receptor level, but also at the city-wide level in order to give a balanced representation of the relative importance of different source contributions.

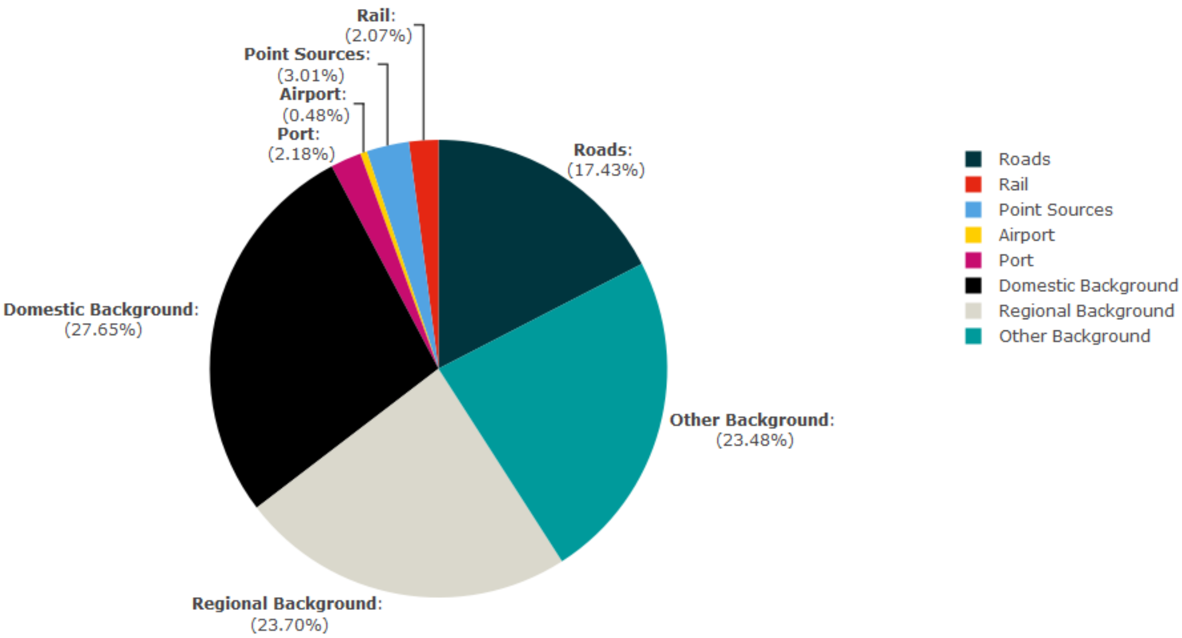
Based on city-wide source apportionment calculations, for NO_2 in 2019 (Figure 9), road transport was identified as the main source of modelled NO_2 concentrations, accounting for almost 30% of total modelled NO_2 concentrations. At receptor locations near to the major road network these contributions were typically much higher (greater than 60%). Of the other sources explicitly modelled, industrial point sources were the next largest contributor after roads (1.9%). The rail sector was found to make notable contributions at some locations near to railway lines, but at the city-wide scale accounted for 1.4% of the total modelled NO_2. Belfast Harbour was estimated to contribute approximately 1.5% and the airport 0.3%. Background sources that weren't explicitly modelled were found to be an important contributor to modelled NO_2 concentrations. The domestic background sector (domestic, commercial and institutional space heating) accounted for an estimated 19.9% and emissions from distant, regional sources outside of Belfast, collectively accounted for almost 45% of the total modelled NO_2 concentration in 2019.

Figure 9. City-Wide Weighted Average Source Apportionment, 2019 Annual Mean NO_2 Concentration



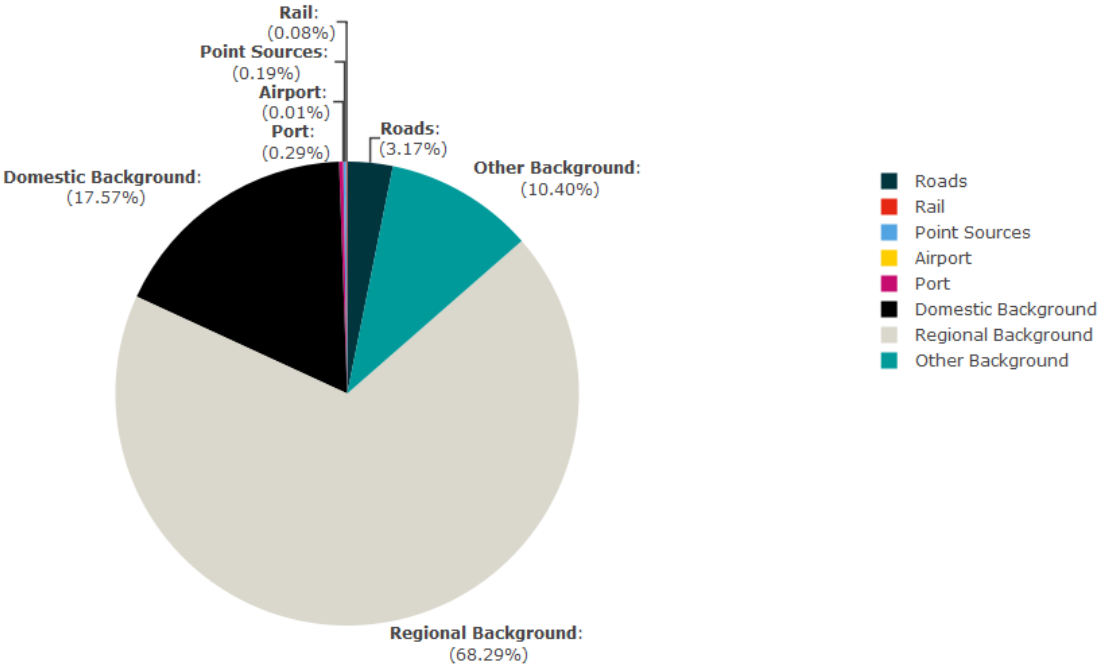
For NO_2 in 2028, city-wide source apportionment (Figure 10) calculations revealed a similar pattern to 2019 with road transport identified as the main source of modelled NO_2 concentrations, accounting for approximately 17% of total modelled NO_2 concentrations. Modelled road traffic emissions were assumed to decrease between 2019 and 2028 in line with Defra projections whereas emissions from other sources explicitly modelled (i.e. industrial point sources, rail, shipping, aviation) were assumed to remain at 2019 levels. Consequently, the relative contribution of road traffic was predicted to decrease, whilst the other source sectors increased in relative proportion. Industrial point sources were calculated to contribute approximately 3% to modelled NO_2 concentrations, the Harbour around 2.2%, rail around 2.2% and the airport approximately 0.5%. The domestic background sector contribution increased to an estimated 27.6%, whilst the collective contribution of other background sources, including emissions from distant, regional sources outside of Belfast, increased slightly to approximately 47% of the total modelled NO_2 concentration in 2028.

Figure 10. City-Wide Weighted Average Source Apportionment, 2028 Annual Mean NO_2 Concentration



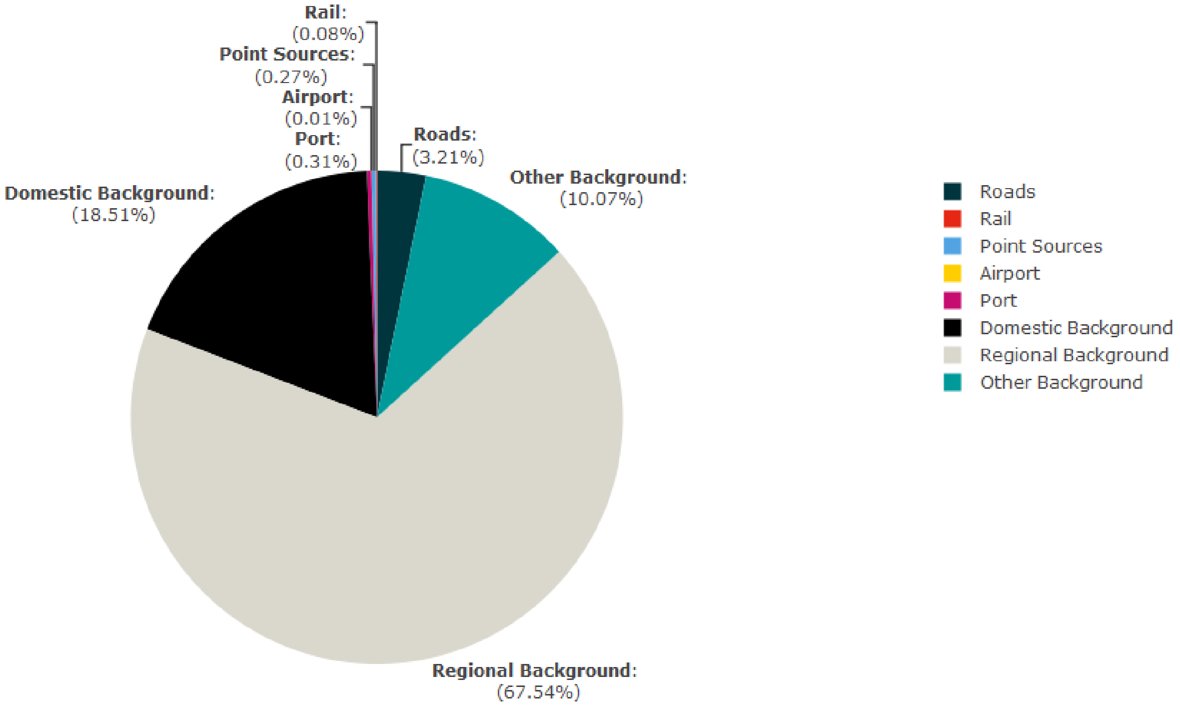
Based on city-wide source apportionment calculations, for PM_{10} in 2019 (Figure 11), the contributions of sources explicitly modelled were minor compared to the contributions of background PM_{10} sources. Regional background was estimated to account for more than 68% of the total modelled PM_{10}. The regional background sector includes contributions from sources outside of Belfast that the Council has no influence over, including natural sources such as windblown dust and sea salt, and secondary particulates. The domestic background sector, which includes the contribution of domestic heating, contributed an estimated 17.6% to modelled PM_{10} concentrations in 2019. Of the sources explicitly modelled, road transport accounted for an estimated 3.2% of the total modelled PM_{10} concentrations. The combined contribution of emissions from industrial point sources, rail, the Harbour and the airport to modelled PM_{10} concentrations was approximately 0.5%.

Figure 11. City-Wide Weighted Average Source Apportionment, 2019 Annual Mean PM_{10} Concentration



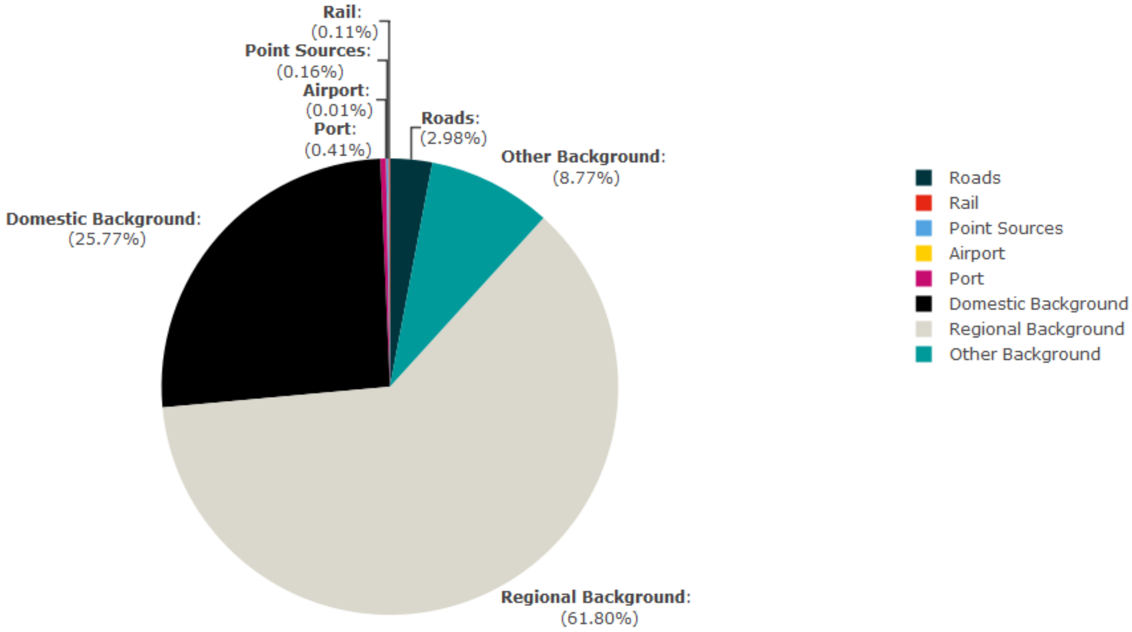
For PM_{10} in 2028, the city-wide source apportionment (Figure 12) calculations showed a similar pattern to 2019. Regional background was again the dominant contributor to modelled PM_{10} concentrations, accounting for 67.5% of the total modelled PM_{10}. The domestic background sector, which includes the contribution of domestic heating, contributed an estimated 18.5% to modelled PM_{10} concentrations in 2028. Of the sources explicitly modelled, road transport accounted for an estimated 3.2% of the total modelled PM_{10} concentrations, whilst the combined contribution of emissions from industrial point sources, rail, the Harbour and the airport to modelled PM_{10} concentrations was approximately 0.7%.

Figure 12. City-Wide Weighted Average Source Apportionment, 2028 Annual Mean PM_{10} Concentration



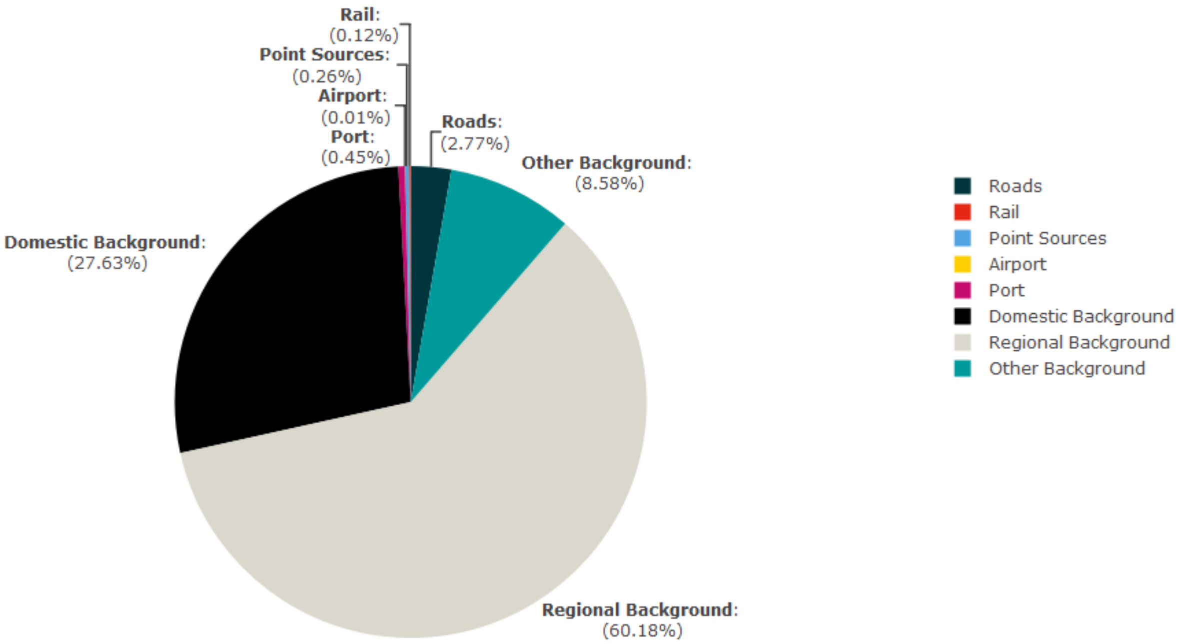
For $PM_{2.5}$ in 2019, the city-wide source apportionment (Figure 13) calculations exhibited similar patterns to those seen for PM_{10}. Background sources were the majority contributor. The regional background sector accounted for an estimated 61.8% of the total modelled $PM_{2.5}$ concentrations across the city. The regional background sector includes contributions from sources outside of Belfast that the Council has no influence over, including natural sources such as windblown dust and sea salt, and secondary particulates. The domestic background sector, which includes the contribution of domestic heating, contributed an estimated 25.8% to modelled $PM_{2.5}$ concentrations in 2019. Of the sources explicitly modelled, road transport accounted for an estimated 3.0% of the total modelled $PM_{2.5}$ concentrations. The combined contribution of emissions from industrial point sources, rail, the Harbour and the airport to modelled $PM_{2.5}$ concentrations was approximately 0.7%.

Figure 13. City-Wide Weighted Average Source Apportionment, 2019 Annual Mean $PM_{2.5}$ Concentration



For $PM_{2.5}$ in 2028, the city-wide source apportionment (Figure 14) calculations displayed similar patterns to the 2019 source apportionment. The regional background sector accounted was estimated to account for slightly more than 60% of the total modelled $PM_{2.5}$ concentration across the city. The domestic background sector, which includes the contribution of domestic heating, contributed an estimated 27.6% to modelled $PM_{2.5}$ concentrations. Of the sources explicitly modelled, road transport accounted for an estimated 2.8% of the total modelled $PM_{2.5}$ concentrations. The combined contribution of emissions from industrial point sources, rail, the Harbour and the airport to modelled $PM_{2.5}$ concentrations was approximately 0.8%.

Figure 14. City-Wide Weighted Average Source Apportionment, 2019 Annual Mean $PM_{2.5}$ Concentration



For PM_{10} and $PM_{2.5}$, the dispersion modelling and source apportionment results highlight an important finding with respect to potential future adoption and attainment of more stringent air quality standards based on the WHO AQGs. Should the WHO AQGs be adopted in the future, achievement of the AQGs will be highly challenging, not just within Belfast, but across much of the UK. Within Belfast, the source apportionment calculations indicated that a major proportion of ambient PM_{10} and $PM_{2.5}$ concentrations is likely to be attributable to regional sources originating outside of the city and which the Council will have little or no influence over. Whilst there remains the potential to target and reduce emissions from local PM_{10} and $PM_{2.5}$ sources, notably those sources which contribute to the domestic heating, attainment of the annual mean PM_{10} WHO AQG will be extremely challenging. In the case of $PM_{2.5}$, even the complete eradication of emissions from the domestic background sector appears unlikely to be sufficient to achieve the annual mean $PM_{2.5}$ WHO AQG of 5 $\mu g/m^3$.

4. Conclusions and Recommendations

In view of recent public health concerns around fine particulate matter ($PM_{2.5}$), and in fulfilment of the Local Air Quality Management (LAQM) Review and Assessments requirements for Northern Ireland, Belfast City Council (BCC) has carried out a Detailed Assessment (DA) of air pollution in their administrative area.

The main conclusions and recommendations from Part A (Monitoring) and Part B (Atmospheric Dispersion Modelling) are summarised below.

Part A – Monitoring

Near-reference sensors for the real-time measurement of NO_2, PM_{10} and $PM_{2.5}$ were installed at six locations across the city. The monitoring locations were chosen to provide information on a range of different environments within the city (roadside, urban background, airport) and to provide additional data for use in verification of the atmospheric dispersion modelling outputs under Part B.

The monitoring results, annualised to 2019 and 2021, indicated that:

- The UK AQO for annual mean NO_2 was achieved at all monitoring locations in 2019 and 2021, except for sensor N10, located adjacent to the Westlink. This location is within the existing Westlink AQMA, indicating that the current AQMA declaration should remain. The sensor monitoring results indicated that NO_2 exceedances were unlikely elsewhere.
- The more stringent WHO AQG for annual mean NO_2 was exceeded at all sites in 2019 and 2021.
- The UK AQO for 1-hour mean NO_2 was achieved at all monitoring locations in 2019 and 2021. At all sites, except N10 (Westlink), there were no recorded hours of NO_2 concentrations greater than 200 $\mu g/m^3$. The WHO AQG for 24-hour mean NO_2 was also exceeded at all continuous monitoring sites in 2019 and 2021.
- The UK AQOs for annual mean PM_{10} and $PM_{2.5}$ were achieved at all monitoring locations in 2019 and 2021. For PM_{10}, the highest concentrations in both years were measured at N6 (Clara Street) indicating the possible contribution of domestic sources in this area. For $PM_{2.5}$, the highest concentrations occurred at the AURN co-location site at Lombard Street; again, this indicates that local and regional background sources may be an important contributor.
- The more stringent WHO AQG for annual mean PM_{10} was exceeded at all monitoring locations, except Lombard Street in 2019. In 2021, this AQG was exceeded at N6 (Clara Street), N8 (Airport) and N10 (Westlink), but achieved elsewhere.
- The more stringent WHO AQG for annual mean $PM_{2.5}$ was exceeded at all monitoring locations in 2019 and 2021.

Other conclusions drawn from the monitoring survey, include:

- The additional sensor monitoring provided good spatial coverage and captured a range of different site types in a more cost-effective manner than could be achieved with reference standard monitoring.
- The sensor monitoring has largely confirmed the Council's existing understanding of air quality in Belfast, re-enforcing the conclusions of previous LAQM assessments.
- The units were not vandalised, damaged or removed unexpectedly over the course of the survey, showing that they can be securely deployed in the city and are relatively robust.
- A regime to ratify and scale the data was established, that can be applied moving forward should the Council continue with the monitoring longer term.

Based on the results of the monitoring, and the experiences of operating the sensor network, the following recommendations are made:

- The monitoring indicated that there is not presently the need to declare any new AQMAs for any area of previously unidentified elevated concentrations.

- BCC should continue the Zephyr / AURN co-location for QA/QC purposes in order to minimise uncertainties associated with sensor monitoring. Re-location of a second cartridge with the AURN site for a period and subsequent rotation of the second cartridge around the sensor network is also recommended.
- Co-location of one or more sensors with NO_2 diffusion tubes could be considered, as a relatively low-cost way of building in an additional data quality check.
- A review of the monitoring sites is recommended, as the Council may wish to characterise other sources (e.g. rail, or specific point sources) or investigate other areas of the city. The elevated PM_{10} concentrations at N6 (Clara Street) may warrant further monitoring in this vicinity to see if this is a localised effect.
- The Zephyr monitors have confirmed that roadside NO_2 is still likely to be the principal concern with regard to exceedance of statutory objectives, as indicated by the results from N10 (Westlink). N1 (A55) did not record concentrations that would be expected of a roadside site, so could either be re-located or reclassified.
- As per manufacturer specification, it will be necessary to consider the replacement of sensor cartridges in July 2023, and for these to be replaced with newly calibrated cartridges due to length of exposure.
- If the monitoring survey is intended to be continued over a much longer duration for continued LAQM compliance monitoring, it is recommended that options are explored to connect each of the Zephyrs to continuous power. Some of the units suffered from a lack of solar power, especially in winter with fewer hours of sunlight.

Part B – Modelling

To understand the spatial distribution of air pollution across the city, an emissions inventory of the main sources of air pollution in Belfast was assembled. Atmospheric dispersion modelling was then carried out to predict levels of NO_2, PM_{10} and $PM_{2.5}$ at sensitive receptors and across the city and comparisons made against the relevant UK AQOs and WHO AQGs.

Based on the findings and results, the following recommendations are made:

- With reference to predicted exceedances of the UK AQO level for annual mean NO_2 concentrations at locations outside of existing AQMA boundaries, identify the presence of relevant exposure, examine existing monitoring data and, as necessary, carry out additional monitoring in these areas to confirm or otherwise the modelled NO_2 concentrations. Should monitored concentrations support the model predictions then amendments to the boundaries of AQMA 1 and AQMA 2 may need to be considered. These areas of predicted exceedance include Short Strand / Bridge End, York Street / Dock Street / Brougham Street, Clifton Street, and Stockman's Lane / Lisburn Road / Balmoral Avenue.
- On the basis of model predictions at locations of relevant exposure and subject to a continuation of monitored NO_2 concentrations within AQMA 3 and AQMA 4, consider the revocation of these AQMAs with respect to the annual mean NO_2 UK AQO.
- Continue to update, refine and enhance the emissions inventory to support future modelling studies and LAQM Review and Assessment obligations. A comprehensive emissions inventory has been assembled as part of this DA, which provides a strong foundation upon which to build and refine the inventory in the future. Any emissions inventory will have limitations and areas for improvement. The cyclical nature of inventory development allows these limitations to be frequently revisited and, where possible, addressed. It also ensures the emissions inventory remains current and up-to-date and is regularly updated with the latest information.
- Targeted action to reduce public exposure to PM_{10} and $PM_{2.5}$ should focus on the sources which contribute to the domestic background sector, as source apportionment has indicated that this sector is accountable for more than 25% of the total modelled PM concentrations across the city. Source apportionment calculations indicate that targeting of the domestic background sector will also reduce NO_2 concentrations.

- For NO_2, local action aimed at road traffic is likely to remain the most effective action for reducing ambient concentrations at hotspot locations in the city. Fleet projections indicate that the next few years will see accelerated uptake of low-emissions / zero-emission vehicles and efforts should continue to be made to support the improvement of the vehicle fleet alongside the continued incentivisation of other transport modes and active travel options.

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