LAQM Detailed Assessment Report

Part B - Modelling

Belfast City Council

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Quality information

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1. Executive Summary

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.

This report comprises Part B of the DA, detailing the work undertaken to assemble a comprehensive emissions inventory of the major sources of air pollutant emissions in the city and the subsequent dispersion modelling based on data in the emissions inventory to predict pollutant concentrations 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.

Annual mean NO_2 concentrations for 2019 were predicted to be above the UK AQO level of 40 $\mu g/m^3$ 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 $\mu g/m^3$ at a receptor near to the Stockman's Lane roundabout.

Contour plots of annual mean NO_2 concentrations 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.

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 plots for 2028 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.

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 much of the city centre area. In many locations, background PM_{10} concentrations alone were found to approach or exceed the AQG level. 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 plots for 2028 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. The small reductions in concentrations between 2019 and 2028 illustrate 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.

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 plots 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 plots for 2028 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}, these 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 plots indicated that the AQG was exceeded throughout the Council's administrative area.

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, 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 (1.8%). 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.

For NO_2 in 2028, city-wide source apportionment 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 2.1% 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.

Based on city-wide source apportionment calculations, for PM_{10} in 2019, 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%.

For PM_{10} in 2028, the city-wide source apportionment 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%.

For $PM_{2.5}$ in 2019, the city-wide source apportionment 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%.

For $PM_{2.5}$ in 2028, the city-wide source apportionment 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%.

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 µg/m^3.

Based on the results of Part B of the DA, 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.

2. Introduction

This report has been prepared by AECOM on behalf of Belfast City Council (BCC) and, along with Part A – Monitoring, constitutes a comprehensive Local Air Quality Management (LAQM) Detailed Assessment (DA) of the entire city. The DA has been commissioned by BCC in view of recent public health concerns around fine particulate matter ($PM_{2.5}$), with a view to determining appropriate mitigation policies and measures to reduce ambient concentrations and public exposure. Nitrogen dioxide (NO_2) and particulate matter of aerodynamic diameter less than 10 micrometres (PM_{10}) have also been included within this assessment as the other pollutants of concern across the city. BCC's Air Quality Management Areas (AQMAs) are currently declared for NO_2.

This DA employs a combination of additional ambient monitoring across a network of sensors (Part A of the report) and atmospheric dispersion modelling for PM_{10}, $PM_{2.5}$ and NO_2 (Part B) in order to spatially and temporally quantify the concentrations of these pollutants across the city. The additional monitoring both provides concentrations at discrete locations for which data were not previously available, and supports the dispersion modelling process, which is required to identify the geographic location and spatial extent of any exceedances of the PM_{10}, $PM_{2.5}$ and NO_2 UK Air Quality Strategy (AQS) objectives and World Health Organisation (WHO) Air Quality Guideline (AQG) values. The additional monitoring, alongside the Council's existing monitoring data, has been used to inform and verify the dispersion modelling outputs, which forms the main basis of the DA's conclusions.

Six locations were identified for sensor-based monitoring across Belfast. The site locations cover a range of pollution sources (e.g. road traffic, airport, urban background), to help characterise these different types of emissions within the dispersion modelling. The sites include two roadside sites, two urban background sites, an airport site and a site co-located with the Automatic Urban and Rural Network (AURN) Belfast Centre monitoring station (later denoted as 'ZAURN'). The co-location data has been used to derive an adjustment factor for the annual mean sensor data. Monitoring commenced for the majority of the sites on 2nd July 2021 and ran, as managed by AECOM, for a period of nine months up until the end of March 2022. The data were then managed by BCC until the end of the purchased period, on 13th May 2022. The monitoring locations are detailed in the Part A report.

Given the documented uncertainties associated with use of low-cost sensor technologies[1][2], current advice from the Air Quality Expert Group (AQEG) is that: *"at least for now, low-cost sensors cannot be used as direct replacements for the reference monitors used by Defra."* The data collected from these types of monitors should therefore be interrogated for their inherent uncertainties, and where possible, compared against reference standard monitoring. The sensor data within the Part A report includes both ratified (i.e. that which is considered 'real' or useable data, and not instrument fault) and scaled data (i.e. data which has been adjusted using appropriate adjustment factors). Further details on the derivation of the adjustment factors are included in the Part A report.

Emissions of the pollutants of concern arise from a number of sources across the city, principally: roads, rail, shipping and port operations, the airport and industrial point sources. All of these sources have been included within the emissions inventory used in the dispersion modelling. Additional sources are not explicitly modelled but are accounted for within the background component of ambient concentrations, including other smaller industrial sources, domestic, institutional and commercial space heating, and regional pollutant contributions. Domestic emissions can arise from a multitude of different sources, but in particular from burning of solid fuels, liquid fuels and biomass for heating. The combined emissions from similar sources in commercial premises can also be an important source of air pollutant emissions. Solid and liquid fuel combustion is typically associated with elevated emissions of SO_2 and PM_{10}, biomass burners with PM_{10} emissions, and gas boilers are generally associated with NO_X emissions.

The emissions data supporting the dispersion modelling has been derived from a wide array of sources, as detailed in Section 4. Emissions and activity-based information for the sources listed have been sought for the year 2019 (as a baseline / current year, pre COVID-19 as worst case) and a future year of 2028 (based on availability of data). Information was requested from the relevant stakeholders, including BCC itself; Northern Ireland Environment Agency (NIEA); Department for Infrastructure (DfI); Translink; Northern Ireland Railways; George Best Belfast City Airport; and Belfast Harbour, Port of Belfast. Existing inventory data within the National Atmospheric Emissions Inventory (NAEI) has also been applied where relevant.

For road traffic sources, a bespoke Automatic Number Plate Recognition (ANPR) survey was also undertaken, the main aim of which was to inform the age and profile of the vehicles travelling in and around Belfast. Such information

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[1] Air Quality Expert Group (2022), AQEG advice on the use of 'low-cost' pollution sensors, available at: https://uk-air.defra.gov.uk/research/aqeg/pollution-sensors.php

[2] Defra (2022) FAQ 140 – Low-Cost Sensors, available at: https://laqm.defra.gov.uk/faqs/faq140/

has a significant impact on emissions from any given vehicle. This survey was undertaken over two days in 2021, a weekday and a weekend day, at five locations across major arterial roads in the City, allowing the vehicular fleet to be characterised in detail. A summary of the ANPR survey findings is presented in Section 4.1.3.

Emissions parameters have been input to CERC's[3] ADMS-Roads or ADMS-5 atmospheric dispersion modelling packages (depending on source type) to predict pollutant concentrations at discrete sensitive receptor locations across the BCC area. Modelling has also been performed across grids of points covering the existing AQMAs and a city-wide grid in order to generate pollutant concentration contour plots of these hotspot areas and at coarse resolution across the whole city. The dispersion model outputs have been added to source sector removed background concentrations, to derive the total predicted ambient concentrations. Source apportionment analysis has also been carried out to estimate the relative contributions of different sources to the overall pollutant concentrations.

From the pollutant concentration contour plots, the number of people exposed to concentrations in excess of the respective objectives and guidelines have been determined, and the maximum pollutant concentrations at relevant receptors have been identified. These are both key requirements of a DA. In addition, the extent of, and potential amendments to, AQMAs within the city have been defined, alongside a short list of LAQM recommendations that BCC will be investigating in the coming years alongside the current Air Quality Action Plan (AQAP).

This report comprises Part B of the DA, detailing the methodology and results of the detailed dispersion modelling exercise. The content of Part B is as follows:

- Legislation and Assessment Criteria – summarising the relevant policy and guidance relevant to the assessment;
- Emissions Inventory Methodology – summarising the emissions inventory compilation
- Dispersion Modelling – Sector-Specific Methodology and General Methodology – summarising the key methodologies employed in the dispersion modelling;
- Dispersion Modelling Results – presenting the outcomes of the dispersion modelling of the emissions inventory;
- Source – detailing the breakdown of the sources contributing to the total modelled concentrations;
- Conclusions
- Appendix A – emissions inventory metadata; and
- Appendix B – dispersion modelling metadata.

[3] https://cerc.co.uk/index.php

3. Legislation and Assessment Criteria

The Clean Air for Europe (CAFÉ) programme consolidated and replaced (with the exception of the 4th Daughter Directive) preceding EU directives with a single legal act, the Ambient Air Quality and Cleaner Air for Europe Directive 2008/50/EC ('EC Air Quality Framework Directive')[4]. This Directive is transcribed in Northern Ireland (NI) by the Air Quality Standards (AQS) Regulations (Northern Ireland) 2010[5].

EU legislation which applied directly or indirectly to the UK before 11.00 p.m. on 31st December 2020 has been retained in UK law as a form of domestic legislation known as 'retained EU legislation'. This is set out in sections 2 and 3 of the European Union (Withdrawal) Act 2018 (c.16)[6]. Section 4 of the 2018 Act ensures that any remaining EU rights and obligations, including directly effective rights within EU treaties, continue to be recognised and available in domestic law after exit. An amendment to the Air Quality Standards Regulations brought forward through the Environment (Miscellaneous Amendments) (EU Exit) Regulations 2020[7] lowered the $PM_{2.5}$ limit at a similar time.

These regulations place a duty on NI government departments to monitor levels of air pollutants specified in the Air Quality Directives and ensure compliance with limit values for these pollutants[8]. The Air Quality Standards Regulations (NI) 2010[5] prescribe the relevant authorities and set out the air quality objectives to be achieved, and cover aspects of air quality management areas (AQMAs) and action plans.

This report fulfils the Review and Assessment requirements of the LAQM process as set out in The Environment (Northern Ireland) Order 2002 Part III[9], the Air Quality Strategy for England, Scotland, Wales and Northern Ireland 2007[10] and the latest relevant Policy[11] and Technical[12] Guidance documents.

3.1 Air Quality Objectives and Guidelines

The measured pollutant concentrations can be compared against the following AQS objectives as per LAQM requirements, but also against the more stringent WHO AQG[13] as shown in Table 3-1.

The WHO AQGs applied are the September 2021 update, though these were released post project inception. The WHO AQGs are not legally binding standards, but exceedances of the AQG levels are associated with important risks to public health. Interim targets are given in the WHO update to guide reductions towards attaining AQG levels, though these are not highlighted within the DA. Whilst not presently adopted, it is expected that DAERA will implement an updated annual mean objective for $PM_{2.5}$ of 10 µg/m^3 in the near future

Measured and modelled pollutant concentrations can be compared against the following UK AQS objectives and WHO AQG as shown in Table 3-1.

[4] Council for European Communities, "Ambient air quality and cleaner air for Europe Directive, 2008/50/EC," 2008.
[5] H.M. Government (2010) The Air Quality Standards Regulations (Northern Ireland) 2010 https://www.legislation.gov.uk/nisr/2010/188/contents/made
[6] H.M. Government (2018) European Union (Withdrawal) Act 2018, Available at: https://www.legislation.gov.uk/ukpga/2018/16/contents/enacted
[7] H.M. Government (2020) Environment (Miscellaneous Amendments) (EU Exit) Regulations 2020, Available at: https://www.legislation.gov.uk/uksi/2020/1313/regulation/2/made
[8] https://www.daera-ni.gov.uk/
[9] H.M. Government (2002) The Environment (Northern Ireland) Order 2002, Available at: https://www.legislation.gov.uk/nisi/2002/3153/contents
[10] Department for Environment, Food and Rural Affairs in partnership with the Scottish Executive, Welsh Assembly Government and Department of the Environment Northern Ireland (2007). The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69336/pb12654-air-quality-strategy-vol1-070712.pdf
[11] DoENI (2010) Local Air Quality Management Policy Guidance – LAQM PGNI (09), Available at: https://www.airqualityni.co.uk/assets/documents/3100729_laqm_policy_guidance_final_version_may_2010_1_.pdf
[12] Defra (2022) Local Air Quality Management Technical Guidance (TG22), Available at: https://laqm.defra.gov.uk/wp-content/uploads/2022/08/LAQM-TG22-August-22-v1.0.pdf
[13] WHO global air quality guidelines. Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide. Geneva: World Health Organization; 2021.

Table 3-1 Air Quality Objectives (AQO) and Guidelines (AQG)

Pollutant	Averaging Period	AQS Objective ($\mu g/m^3$)	Not to be Exceeded More Than	WHO AQG ($\mu g/m^3$)*	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)	200	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)

**WHO AQG post September 2021 update*

3.2 Local Air Quality Management

In 2004, BCC completed its first review and assessment of ambient air quality for the city in accordance with the provisions of the government's LAQM technical guidance documents and identified four areas of 'poor' air quality, which were subsequently declared as AQMAs. The AQMAs were declared for a combination of exceedances of annual, 24-hour and 1-hour mean AQS objectives for NO_2 and particulate matter (PM_{10}). These AQMAs remain in place today following annual review of air quality concentrations, but only for exceedances of the 1-hour and annual mean AQS objectives for NO_2. The original declaration of AQMA 1 in 2004 covered PM_{10} as well as NO_2. However, in view of consistently low measured PM_{10} concentrations below the AQO levels over several years, the declaration was amended in 2015, revoking the declaration for PM_{10}.

Figure 3-1. Air Quality Management Area 1 - M1 Motorway / A12 Westlink Corridor.

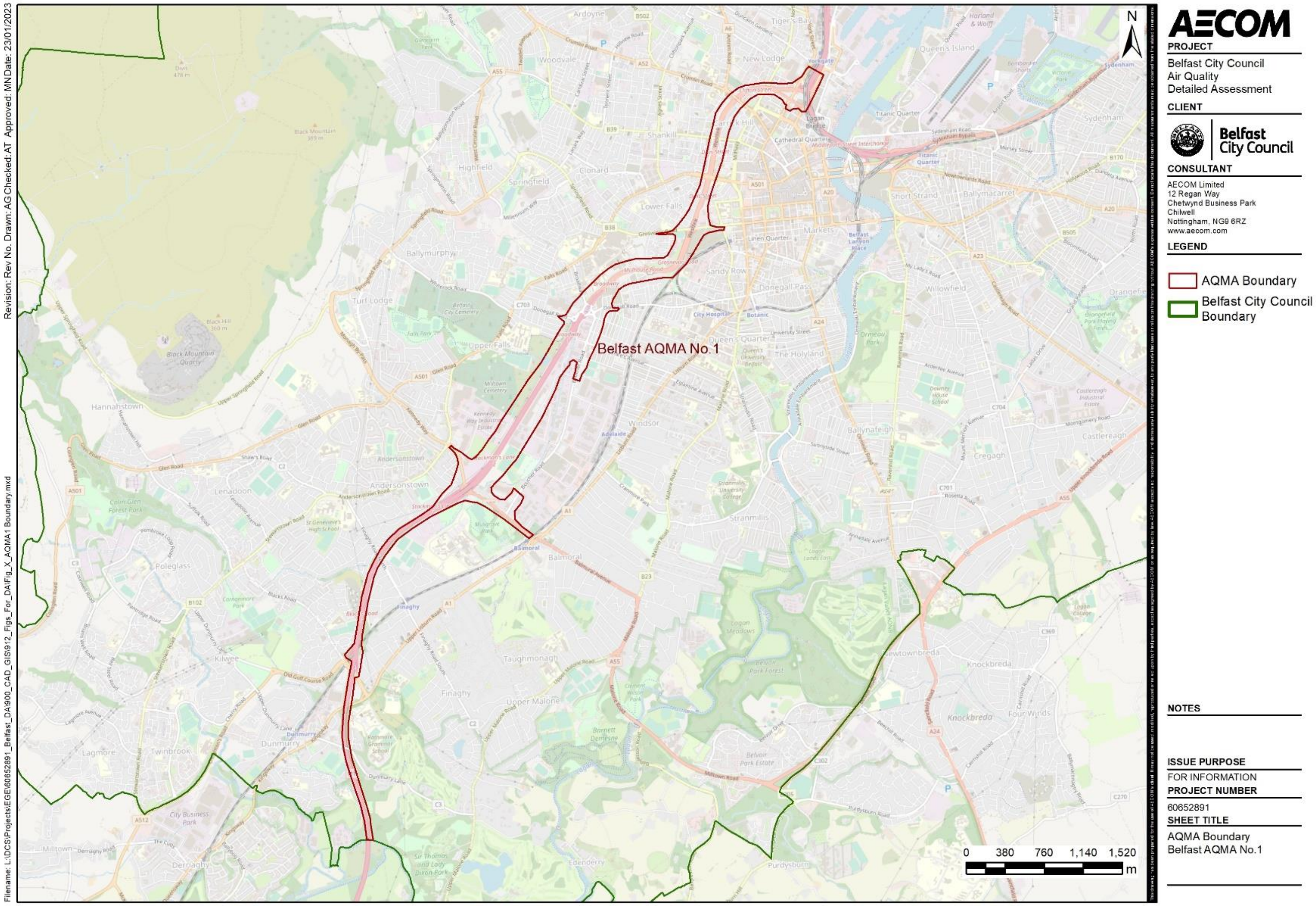


Figure 3-2. Air Quality Management Area 2 - Cromac Street, East Bridge Street and Albertbridge Road

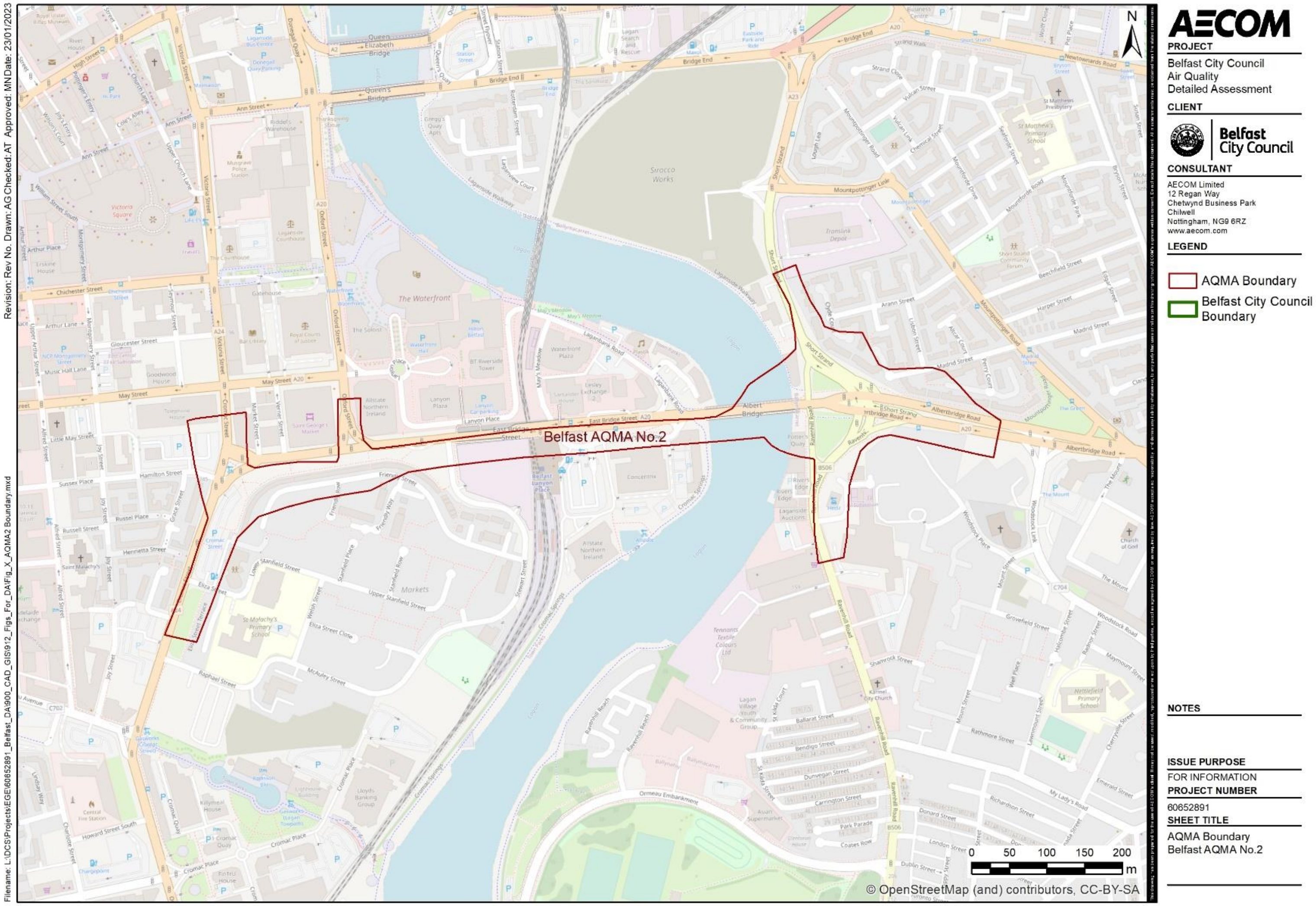


Figure 3-3. Air Quality Management Area 3 - Upper Newtownards Road

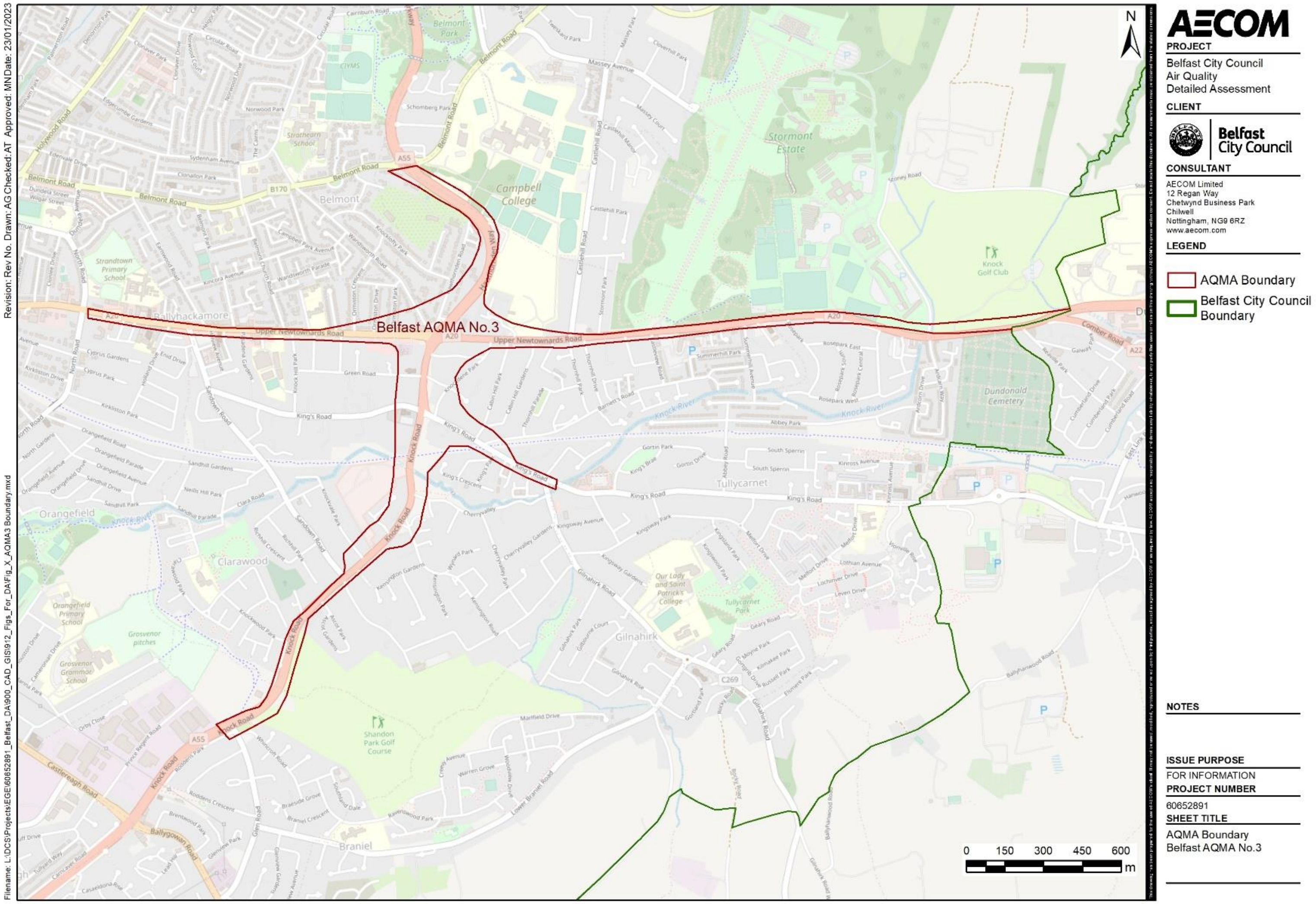


Figure 3-4. Air Quality Management Area 4 - Ormeau Road

The AQMAs, as illustrated in Figure 3-1 to Figure 3-4, are:

- AQMA 1, M1 Motorway / A12 Westlink corridor;
- AQMA 2, Cromac Street to the junction with East Bridge Street and then from East Bridge Street to the junction with the Ravenhill and Albertbridge Roads and Short Strand;
- AQMA 3, Upper Newtownards Road from the North Road junction to the former Belfast City boundary at the Ulster Hospital; and
- AQMA 4, Ormeau Road from its junction with Donegall Pass to the former Belfast City boundary at Galwally.

Further information relating to the four current AQMAs in Belfast can be found on the UK Air AQMAs webpage[14]

A new AQAP[15] has recently been produced as part of BCC's statutory duties required under the LAQM framework. It outlines the actions that will be taken to improve ambient air quality in Belfast during the years 2021-2026. This AQAP supersedes the previous AQAP, which covered the period 2015-2020. The Air Quality Action Plan 2015-2020 for the city drew upon all forms of ambient air quality and transport planning activities, including sustainable transport options as well as engineering solutions. The AQAP 2021 - 2026 sets out actions to reduce concentrations of NO_2 and $PM_{2.5}$ in Belfast under a number of broad themes including:

- Initiatives to promote greater levels of walking and cycling within Belfast;
- Initiatives to encourage increased public transport patronage within Belfast;
- Initiatives to promote better vehicle fleet management (e.g. cleaner and more efficient fleets);
- Initiatives to manage the demand for private vehicles commuting to Belfast City Centre and to hence encourage modal shift;
- Initiatives to encourage large organisations to consider greener energy options;
- Implementation of policies that contribute to lower air pollution levels;
- Engineering, highway and road improvements that contribute to lower air pollution levels; and
- Delivery of a Detailed Air Quality Assessment project to provide information on emissions and concentrations of $PM_{2.5}$ across the city to assist Belfast City Council and its partners in the development and prioritisation of abatement and mitigation policies and measures.

For the purpose of this DA, a baseline assessment year of 2019 has been chosen, as this is considered the most recent year before significant impact on ambient air pollution concentrations of the COVID-19 pandemic was felt. This is likely therefore to represent a 'worst-case' for exposure in the city, given reductions in activities associated with emissions during COVID-19 affected years. A forecast year of 2028 has also been modelled to determine future concentrations.

Comparisons with the relevant AQS objectives for 2021 based on monitored data was also undertaken, informed by the results from the Council's air quality monitoring network, and annualised 2021 data from the sensor study. The results and findings of the monitoring data analysis are detailed in Part A of this DA.

A review of monitoring data for Belfast in the Part A report indicates that there have been some recent improvements in NO_2 concentrations across the city. As a result, BCC considered in recent LAQM reporting that there may be an opportunity for revocation of AQMA 3 and AQMA 4 along Upper Newtownards Road and the Ormeau Road, respectively, where monitoring data demonstrates recent sustained improvements in annual mean NO_2 concentrations, with concentrations consistently below the annual mean AQS objective. This DA determines whether revocation of any AQMAs is appropriate in Section 9.

Since the DA and the LAQM regime are focused on AQS objectives, this report prioritises discussion of any exceedances of the AQS objectives. However, comparison with WHO AQG is also presented and discussed to help inform longer-term goals aimed at working towards attainment of these challenging guideline levels.

[14] UK Air (2022). Air Quality Management Areas (AQMAs) website. https://uk-air.defra.gov.uk/aqma/local-authorities?la_id=450. Accessed January 2023.
[15] Belfast Air Quality Action Plan (2021) https://www.belfastcity.gov.uk/documents/belfast-city-air-quality-action-plan-2021-2026

4. Emissions Inventory Methodology

4.1 Roads

4.1.1 Road Traffic Emissions

In accordance with LAQM.TG(22) guidance, emissions from road traffic in Belfast were calculated using Defra's Emissions Factors Toolkit (EFT) Version 11.0[16] using traffic data representative of 2019 and 2028, obtained from the Belfast Strategic Transport Model which covers the entire city, and fleet data informed by the ANPR surveys.

The Belfast Strategic Transport Model has been developed by the Department for Infrastructure. It is a multi-modal transport model that can assess the impact of a wide range of transport schemes. This model is maintained by consultants on behalf of the Department. It was recently updated as part of preparatory work by the Department to include BRT Phase 2 (BRT2). The focus of the update was to re-base the model base year to 2019. The model was also calibrated and validated to a link level (flow) and journey time along the corridors which were the focus of the BRT Phase 2 proposals, namely:

- Antrim Road;
- Shore Road;
- Ormeau Road; and
- Saintfield Road.

Modelling output files were supplied to AECOM for this DA commission. These included model outputs for the year 2019 as well as for 2028, containing:

- Actual Flow by user class;
- Demand Flow by user class;
- Network Speed;
- Cruise Speed; and
- Shapefiles of the network structure.

The future year Do-Minimum models also accounted for the following proposed schemes:

- York Street Interchange;
- Belfast Transport Hub; and
- Belfast Streets Ahead Phase 3.

The extraction and pre-processing of BRT2 traffic data is described in Section 4.1.2. A summary of the ANPR survey data and its use in the emissions calculations is discussed in Section 4.1.3.

4.1.2 Traffic Flows

Traffic flow data representative of 2019 and 2028 were obtained from the baselines of the Belfast Strategic Transport Model for the major road network in Belfast and a large number of minor roads. The 2019 assessment year was chosen to represent the most recent year unaffected by the COVID pandemic, whilst 2028 was chosen as the future assessment year as this is the first available future year within the Belfast Strategic Transport Model.

The extent of modelled road network for which traffic flow data is available is presented in Figure 5-1. The model provides estimates of traffic flows for cars, light goods vehicles (LGV) and heavy goods vehicles (HGV) for AM peak, PM peak and Inter-peak periods in units of Passenger Car Units (PCUs). To convert the traffic flows from PCU to actual vehicle numbers (as required for input to the EFT), the conversion factors shown in Table 4-1 were applied.

[16] Department for Environment Food and Rural Affairs (2021) *Emissions Factors Toolkit v11.0*. https://laqm.defra.gov.uk/air-quality/air-quality-assessment/emissions-factors-toolkit/

Table 4-1 Passenger Car Unit to Vehicle Number Conversion Factors

Conversion	PCU Value
Passenger Cars	1.0
LGV	1.0
HGV	2.3

Table adapted from Transport for London (2021) [17]. To convert PCU to Vehicle Number, divide by PCU Values shown above

The BRT2 model does not provide estimates of Off-Peak flows. Instead, the traffic flow for the Off-Peak period is calculated as Inter-Peak × 12 × 0.28 (i.e. Inter-Peak × 3.36).

Peak-hour traffic flows were converted to Annual Average Daily Traffic (AADT) using the following conversion factors provided by AECOM transportation specialists:

$$AADT = ((AM\ Peak + PM\ Peak) \times\ 2.5) + (Inter\text{-}Peak \times 6) + (Inter\text{-}Peak\ \times 3.36)$$

Vehicle speed information was also extracted from the BRT2 model for each of the modelled time periods. For use in the road traffic emissions calculations, a traffic-flow weighted average speed was calculated from the speeds in the traffic model.

The BRT2 model provides estimates of heavy goods vehicle numbers on each road link and these were used to determine the heavy-duty vehicle proportion on each modelled road link. The BRT2 model does not distinguish between numbers of rigid and articulated vehicles. However, from the ANPR survey data (see Section 4.1.3), the relative proportions of rigid and articulated HGVs were estimated for urban roads and motorways.

4.1.3 ANPR Data

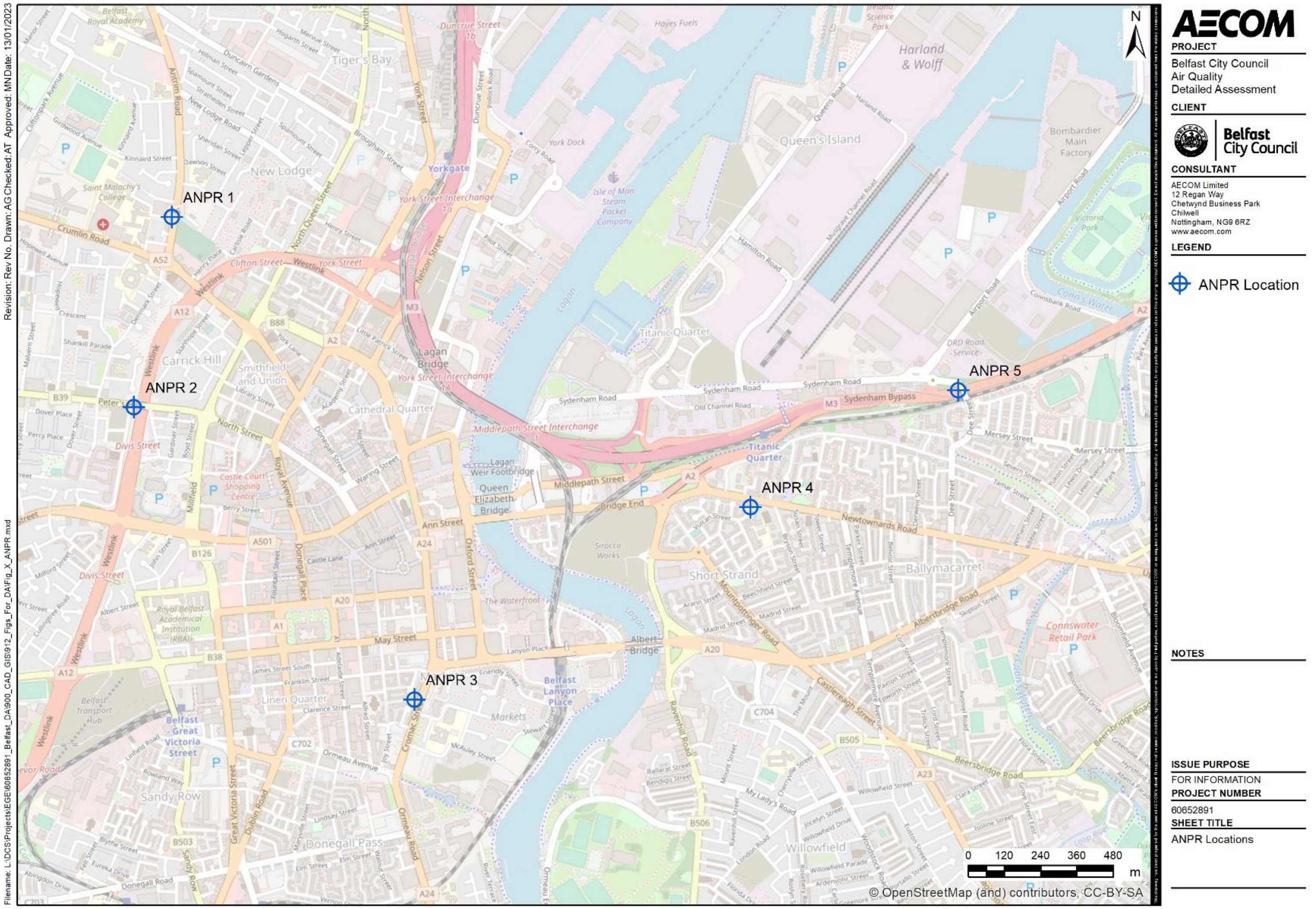
The vehicle fleet composition was informed by the local ANPR surveys that were undertaken, specifically for this study. ANPR cameras were installed at five locations across the city for two days in November 2021. The locations were:

- ANPR 1: A6 Antrim Road, north of Crumlin Road / Clifton Street;
- ANPR 2: A12 Westlink, near Peter's Hill overpass;
- ANPR 3: A24 Cromac Street, south of junction with East Bridge Street;
- ANPR 4: A20 Newtownards Road, east of A2 Interchange; and
- ANPR 5: A2 Sydenham Bypass.

ANPR locations 1, 3, and 4 were representative of urban roads in Belfast, whilst ANPR 2 and 5 were considered to represent motorways. The survey locations are shown in Figure 4-1.

[17] Transport for London (2021), Traffic Modelling Guidelines Version 4.0. https://content.tfl.gov.uk/traffic-modelling-guidelines.pdf

Figure 4-1. ANPR Survey Locations



Data from all five survey locations were aggregated to determine the vehicle age and technology profile of the local traffic fleet. The R statistical software package[18] was used to process the ANPR data and output the percentage of each Euro emissions standard for each vehicle type. The vehicle types present in the ANPR data were mapped to the corresponding vehicle types used in the EFT. This data is summarised in Table 4-2.

The vehicle fleet breakdown information presented in Table 4-2 was used in the EFT as input to the Fleet Projection Tool. This option allows users to project their user-defined Euro fleet information from a base year (e.g. a local Euro fleet derived from ANPR surveys) to a future or previous assessment year, thereby allowing local trends in the vehicle fleet to be captured in the emissions calculations. For this assessment, the 2021 ANPR-derived fleet was back-projected to the baseline assessment year of 2019 and forward-projected to the future assessment year of 2028.

Table 4-3 and Table 4-4 present the projected vehicle fleet breakdown for 2019 and 2028, respectively.

Table 4-2. Aggregated Vehicle Fleet by Emissions Standard as Derived from ANPR Survey Data (2021)

Vehicle Type	Pre-Euro	Euro 1 / I	Euro 2 / II	Euro 3 / III	Euro 4 / IV	Euro 5 / V	Euro 6 / VI
Petrol Car	0.00	0.00	0.00	0.04	0.16	0.26	0.54
Diesel Car	0.00	0.00	0.00	0.03	0.13	0.36	0.48
Taxi (Black Cab)	0.00	0.00	0.00	0.01	0.07	0.23	0.68
Petrol LGV	0.00	0.04	0.01	0.08	0.09	0.09	0.69
Diesel LGV	0.00	0.00	0.00	0.03	0.12	0.32	0.53
Full Hybrid Petrol Car	-	-	-	0.00	0.02	0.09	0.89
Plugin Hybrid Petrol Car	-	-	-	-	-	0.03	0.97
Full Diesel Hybrid Car	-	-	-	-	-	0.02	0.98
Rigid HGV	0.00	0.00	0.00	0.04	0.12	0.26	0.57
Artic HGV	0.00	0.00	0.00	0.02	0.04	0.20	0.74
Bus / Coach	0.00	0.00	0.01	0.16	0.17	0.10	0.56

Note: Figures provided are a proportion of total by vehicle type. Figures shown to 2 decimal places so rounded figures may not equal 1.

Table 4-3. Back-Projected Vehicle Fleet by Emissions Standard as Derived from ANPR Survey Data (2019)

Vehicle Type	Pre-Euro	Euro 1 / I	Euro 2 / II	Euro 3 / III	Euro 4 / IV	Euro 5 / V	Euro 6 / VI or above
Petrol Car	0.00	0.00	0.01	0.11	0.23	0.31	0.34
Diesel Car	0.00	0.00	0.00	0.05	0.19	0.40	0.35
Taxi (Black Cab)	0.00	0.00	0.00	0.02	0.13	0.31	0.54
Petrol LGV	0.00	0.01	0.02	0.16	0.15	0.18	0.48
Diesel LGV	0.00	0.01	0.00	0.05	0.20	0.41	0.33
Full Hybrid Petrol Car	-	-	-	0.00	0.04	0.17	0.79
Plugin Hybrid Petrol Car	-	-	-	-	-	0.07	0.93
Full Diesel Hybrid Car	-	-	-	-	-	0.06	0.94
Rigid HGV	0.00	0.01	0.01	0.09	0.14	0.39	0.36
Artic HGV	0.00	0.00	0.00	0.04	0.07	0.34	0.56
Bus / Coach	0.00	0.00	0.01	0.22	0.16	0.17	0.44

Note: Figures provided are a proportion of total by vehicle type. Figures shown to 2 decimal places so rounded figures may not equal 1.

[18] R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Table 4-4. Projected Vehicle Fleet by Emissions Standard as Derived from ANPR Survey Data (2028)

Vehicle Type	Pre-Euro	Euro 1 / I	Euro 2 / II	Euro 3 / III	Euro 4 / IV	Euro 5 / V	Euro 6 / VI or above
Petrol Car	0.00	0.00	0.00	0.00	0.01	0.05	0.94
Diesel Car	0.00	0.00	0.00	0.00	0.01	0.12	0.87
Taxi (Black Cab)	0.00	0.00	0.00	0.00	0.00	0.05	0.94
Petrol LGV	0.00	0.00	0.00	0.00	0.00	0.00	0.99
Diesel LGV	0.00	0.00	0.00	0.00	0.01	0.08	0.91
Full Hybrid Petrol Car	-	-	-	0.00	0.00	0.01	0.99
Plugin Hybrid Petrol Car	-	-	-	-	-	0.00	1.00
Full Diesel Hybrid Car	-	-	-	-	-	0.00	1.00
Rigid HGV	0.00	0.00	0.00	0.00	0.02	0.05	0.93
Artic HGV	0.00	0.00	0.00	0.00	0.00	0.01	0.99
Bus / Coach	0.00	0.00	0.00	0.03	0.03	0.02	0.92

Note: Figures provided are a proportion of total by vehicle type. Figures shown to 2 decimal places so rounded figures may not equal 1.

The R statistical package was also used to extract basic vehicle fleet information from the ANPR survey data, namely the percentage of each vehicle body-fuel type combination present in the vehicle fleet. The vehicle types were mapped to the corresponding vehicle categories defined in the EFT. Data from ANPR locations 1, 3 and 4 were used to derive a 2021 basic fleet split representative of urban roads, and locations 2 and 5 were used to derive the equivalent split for motorways. These are summarised in Table 4-5.

To estimate equivalent fleet splits for the assessment years of 2019 and 2028, the default vehicle fleet splits for Urban and Motorway road types in NI were extracted from the EFT. For each vehicle type, the ratio of the default 2019 fleet to the 2021 default fleet was calculated. The ratio was then used to scale the ANPR survey data from 2021 to 2019. The process was then repeated for 2028. These calculations are summarised in Table 4-6 and Table 4-7 for Urban roads and Motorways, respectively. Overall, there are higher proportions of petrol and diesel cars on urban roads than motorways. This is due, in part, to the higher proportions of rigid and articulated HGVs and diesel LGVs making preferential use of the motorway network to access destinations such as the Port of Belfast or the north and west of the province.

Table 4-5. Basic Vehicle Fleet Split as Derived from ANPR Survey Data (2021)

Vehicle Type	Urban (%)	Motorway (%)
Petrol Car	39.38	36.22
Diesel Car	48.24	46.69
Taxi (Black Cab)	0.14	0.07
Petrol LGV	0.04	0.03
Diesel LGV	7.36	10.55
Rigid HGV	0.52	1.21
Artic HGV	0.17	1.57
Bus / Coach	0.33	0.36
Motorcycle	0.04	0.05
Petrol Hybrid Car	2.84	2.43
Plugin Hybrid Car	0.01	0.00
Diesel Hybrid Car	0.06	0.02
Electric Car	0.83	0.78
Electric LGV	0.05	0.04
TOTAL	**100**	**100**

Table 4-6. Basic Vehicle Fleet Split as Derived from ANPR Survey Data (Urban Roads)

Vehicle Type	EFT Default (Northern Ireland, Urban)			Ratio of Default EFT 2019:2021	Ratio of Default EFT 2028:2021	2019 ANPR Fleet	2028 ANPR Fleet
	2019	2021	2028				
Petrol Car	39.28	38.98	37.31	1.008	0.957	39.47	39.04
Diesel Car	47.67	46.17	36.49	1.033	0.790	49.54	39.48
Taxi (Black Cab)	0.00	0.00	0.00	1.000	1.000	0.14	0.15
Petrol LGV	0.09	0.08	0.06	1.116	0.677	0.04	0.03
Diesel LGV	6.35	6.44	6.38	0.987	0.992	7.23	7.56
Rigid HGV	1.74	1.69	1.58	1.030	0.939	0.53	0.50
Artic HGV	0.93	0.92	0.90	1.010	0.975	0.17	0.17
Bus / Coach	0.55	0.52	0.50	1.044	0.947	0.35	0.33
Motorcycle	0.75	0.72	0.67	1.040	0.933	0.04	0.04
Petrol Hybrid Car	1.47	2.13	3.74	0.687	1.752	1.94	5.15
Plugin Hybrid Car	0.41	0.88	4.70	0.469	5.318	0.00	0.05
Diesel Hybrid Car	0.32	0.73	1.93	0.442	2.631	0.03	0.16
Electric Car	0.42	0.71	5.48	0.592	7.709	0.49	6.60
Electric LGV	0.01	0.02	0.26	0.786	14.596	0.04	0.75
TOTAL	**100**	**100**	**100**	**-**	**-**	**100**	**100**

Table 4-7. Basic Vehicle Fleet Split as Derived from ANPR Survey Data (Motorways)

Vehicle Type	Emission Factors Toolkit Default (Northern Ireland, Urban)			Ratio of Default EFT 2019:2021	Ratio of Default EFT 2028:2021	2019 ANPR Fleet	2028 ANPR Fleet
	2019	2021	2028				
Petrol Car	40.00	40.23	39.08	0.994	0.971	35.74	36.85
Diesel Car	46.93	45.02	34.91	1.043	0.776	48.32	37.93
Taxi (Black Cab)	0.00	0.00	0.00	1.000	1.000	0.00	0.00
Petrol LGV	0.06	0.05	0.03	1.135	0.650	0.03	0.02
Diesel LGV	3.78	3.77	3.59	1.004	0.953	10.51	10.53
Rigid HGV	2.46	2.36	2.30	1.043	0.977	1.25	1.24
Artic HGV	3.07	3.01	2.76	1.019	0.917	1.58	1.50
Bus / Coach	0.60	0.57	0.52	1.053	0.927	0.37	0.34
Motorcycle	0.45	0.44	0.44	1.006	0.984	0.05	0.05
Petrol Hybrid Car	1.49	2.20	3.92	0.678	1.778	1.63	4.52
Plugin Hybrid Car	0.42	0.91	4.93	0.463	5.397	0.00	0.02
Diesel Hybrid Car	0.32	0.72	1.85	0.446	2.583	0.01	0.07
Electric Car	0.42	0.71	5.52	0.591	7.741	0.46	6.33
Electric LGV	0.01	0.01	0.15	0.799	14.023	0.03	0.62
TOTAL	**100**	**100**	**100**	**-**	**-**	**100**	**100**

4.2 Rail

4.2.1 Guidance Review/Screening

As outlined in LAQM.TG22[12], rail locomotives can contribute to both short-term NO_2 and SO_2 concentrations close railway stations or depots. Additionally, moving locomotives can contribute to elevated short-term NO_2 and SO_2 concentrations close to the track. BCC ensures that assessments are carried out through Air Quality Impact Assessments (AQIAs) at the planning stage for any new exposure locations where locomotives may present a risk of causing an exceedance, applying the following criteria in the guidance:

<u>Stationary diesel or steam locomotives</u>

- *Identify locations where diesel or steam locomotives are regularly (at least three times a day) stationary for periods of 15-minutes or more; and*
- *Determine relevant exposure within 15m of the locomotives.*

<u>Moving diesel locomotives</u>

- *Determine relevant exposure within 30m of the relevant railway tracks (Table 7-2 [in TG22] provides information on which lines should be considered); and*
- *Identify whether the background annual mean NO_2 concentration is above 25 µg/m^3.*

LAQM.TG22 explains *"If the above criteria are matched, then the local authority should conclude that there is a risk of exceedance of the SO_2 15-minute mean objective (for stationary locomotives) or the NO_2 annual mean objective (for moving locomotives) and carry out a monitoring survey (6-month period minimum) at relevant receptors."* As none of the SO_2 criteria are relevant to this assessment, this pollutant has been scoped out.

From Defra's 2018 reference year background maps[19], there is one location within Belfast with a background annual mean NO_2 concentration exceeding 25 ug/m^3 during 2019: the grid square centred on OSGB coordinates

[19] Department for Environment Food and Rural Affairs (2022) Background Mapping data for local authorities – 2018, Background Mapping data for local authorities - 2018 - Defra, UK. Accessed November 2022.

146500, 529500[20] which is located within the city centre, in the area of Chichester Street and May Street. There are no railway lines within this grid square and therefore no relevant exposure within 30m of railway tracks where background NO_2 concentrations also exceed 25 µg/m^3. Therefore, it is concluded that train sources are unlikely to be a significant contributor to ambient NO_2 concentrations in Belfast. This is confirmed by the source apportionment data presented within Chapter 8 of this report.

There are no rail lines within Northern Ireland that are listed in Table 7-2 of TG22, identified as having heavy traffic of diesel passenger trains. It is therefore highly unlikely that that a significant impact on NO_2 or SO_2 concentrations will occur in Belfast due to the locomotives on the rail line.

For accuracy, completeness and comprehensiveness, the contributions of NO_2, PM_{10} and $PM_{2.5}$ from rail sources were derived and included within the emissions inventory and dispersion modelling for this DA. The methodology for determining these emissions is described in the following section.

4.2.2 Rail Fleet

Translink provided information regarding the types of engines that currently make up the NI (and in particular Belfast) rail fleet. The fleet includes the following types of trains, fuelled by gas oil:

- Multi-Purpose Vehicle/ On Track Plant (MPV/OTP) – used on the track for maintenance purposes;
- Class 4000 (can be either 3 or 6 carriages);
- Class 3000 fleet (3 carriages); and
- Enterprise trains (1 locomotive train with multiple carriages).

Translink also provided total fuel consumption data for 2018/19. Class 4000 railcars are more economical than 3000 railcars and have a greater fuel efficiency (lower miles per gallon, mpg). Due to differing driving styles of the trains, fuel efficiency varies between journeys. Fuel consumption is recorded on a monthly basis, but provided to AECOM as an annual total. The 2018/19 total has been assumed to be representative of the 2019 calendar year, for the purposes of this assessment.

4.2.3 Rail Emissions

Total emissions of NOx, PM_{10} and $PM_{2.5}$ were calculated from the Translink fuel consumption data using NAEI emission factors[21] for regional railways, presented in Table 4-8. The distribution of NAEI emissions in Northern Ireland, across a 1x1 km grid, was used to inform the distribution of the calculated emissions. The 1x1 km emissions data were joined to the rail line sources, which were provided as shapefiles by Translink. The emissions were then uniformly distributed over the length of the track within the 1x1 km grid square to calculate emissions in grammes per kilometres per second (g/km/s) – this provides a representation of the emissions along the railway track.

Table 4-8. NAEI emission factors used to calculate rail emissions

Pollutant	Emission Factor	Units
Nitrogen oxides (NO_x expressed as NO_2)	4.885×10^{-4}	kt / TJ (net)
PM_{10}	1.586×10^{-5}	kt / TJ (net)
$PM_{2.5}$	1.506×10^{-5}	kt / TJ (net)

Note: Emissions are calculated using NAEI 2019 emission factors for regional railways using gas oil. kt/TJ = kilotonnes per terajoule.

Those rail links within the Belfast area, with assigned emission rates (g/km/s), were extracted for inclusion in the emissions inventory. The range in emission rates in g/km/s for the three pollutants is presented in Table 4-9.

[20] The coordinates of the corners of the grid square in TM65 are 333637 373510, 333552 374507, 334548 374592, 334633 373596

[21] National Atmospheric Emissions Inventory Emission Factors Database. https://naei.beis.gov.uk/data/ef-all. Accessed January 2023.

Table 4-9. Calculated Rail Emission rates (g/km/s)

Pollutant	Minimum Emission Rate	Maximum Emission Rate	Average Emission Rate
NO_X	1.851×10^{-2}	1.023×10^{-1}	5.018×10^{-2}
PM_{10}	6.006×10^{-4}	3.321×10^{-3}	1.628×10^{-3}
$PM_{2.5}$	5.705×10^{-4}	3.155×10^{-3}	1.547×10^{-3}

4.2.4 Limitations

Within the emissions inventory methodology, although fuel consumption data had been provided by Translink, it should be noted that fuel efficiency will not be consistent due to different driving styles of train drivers. There are also a number of 'special' trains that run on the network which are put on for large events (e.g. sport matches or music concerts) which are outside of the normal scheduled timetable. These can change the amount of fuel consumption used and therefore the overall emissions calculations.

It should also be noted that the emissions from the NAEI have been evenly distributed along the railway tracks within the 1x1 km grid square, however this does not account for changes in emissions due to acceleration, deceleration or idling at signals.

As outlined in TG22, SO_2 can be emitted from diesel trains, however this pollutant is not considered within this assessment as it has not been identified as a pollutant of concern in Belfast in the LAQM regime. Moreover, exceedances of the SO_2 15-minute mean objective are given only to occur where diesel locomotives are regularly (at least three times a day) stationary for periods of 15-minutes or more; and there is relevant human exposure within 15m of such locomotives.

4.2.5 Rail Projections

In future years, an increase in rail activity due to the anticipated shift to more sustainable modes of transport and increased demand is predicted. Under Action 4 of BCC's AQAP 2021-2026[15], Translink is committed to carrying out a feasibility assessment to decarbonise the rail network including the potential roll out of electrification, battery traction and hydrogen technologies. As part of this commitment, Translink has confirmed that the Class 4000 railcars will be replaced with more fuel-efficient trains in the near future. It is therefore expected that any increase in activity will be offset by a simultaneous improvement in fuel efficiency. Due to the limitations and lack of information on future emissions outlined above and the TG22 screening guidance, it has been assumed that there will be no change in total rail emissions between the base year (2019) and the future year (2028).

4.3 Shipping

4.3.1 Guidance Review/screening

As outlined in TG22[12], large ships can cause elevated short term SO_2 concentrations due to the high sulphur content oils that are generally burnt within them, which might lead to exceedances of the 15-minute or 1-hour mean sulphur dioxide objectives. The bunker oils used in ships may also cause NO_2, PM_{10} and $PM_{2.5}$ concentrations to be elevated. The screening criteria outlined in TG22 is as follows:

- *Are there more than 5,000 large ship movements (i.e. cross-channel ferries, roll on-roll off shops, bulk cargo, container ships, cruise liners, etc – one ship generating two movements (arrival and departure), with relevant exposure within 250 m of the berths and main areas of manoeuvring: or*
- *Are there more than 15,000 large ship movements per year, with relevant exposure within 1km of these areas?*

As confirmed by Belfast City Council in the 2021 Updating and Screening Assessment Report[22], "*the number of ship movements during 2020 was around 12,300*", but "*there is no relevant exposure within 250m of the berths*'. Therefore, there is no shipping within the Belfast area which meets the TG22 guidance criteria.

[22] Belfast City Council (2021) *Air Quality 2021 Updating and Screening Assessment for Belfast City Council* Belfast City Council AQ USA 2021.pdf (airqualityni.co.uk)

Nevertheless, for accuracy, completeness and comprehensiveness, emissions of NO_2, PM_{10} and $PM_{2.5}$ from Belfast Harbour were included in the emissions inventory and dispersion modelling for the DA.

4.3.2 Shipping Fleet and Port Operations

Vessel movements and fuel consumption data for both 2018 and 2019 were provided by Belfast Harbour along with the site boundary of the port. The vessel movement data also provided a breakdown of vessel type, including port-owned vessels such as pilot boats.

Belfast Harbour also provided fuel consumption data in kWh for a range of land-based equipment, including mobile cranes, sweepers and other plant and equipment. This information was used to estimate emissions from land-based operations at the port.

4.3.3 Shipping Emissions

For Harbour Channels and Berthed Ships, the NO_2 and PM_{10} emissions have been taken from the Belfast Harbour Air Quality Emissions Inventory Report[23], provided by Belfast Harbour. This report used 2018 activity data to estimate emissions. For this DA, the 2018 NO_2 and PM_{10} emissions estimates were scaled to 2019 using the 2018 and 2019 vessel movement data provided by Belfast Harbour. Vessel related $PM_{2.5}$ emissions were calculated by multiplying the PM_{10} emissions by the PM_{10}:$PM_{2.5}$ ratio of 0.9474 obtained from the NAEI emission factors database[21].

For port owned vessels and plant, consumption data in kilowatt hours (kWh) were provided by Belfast Harbour. These data were converted to emissions (kilotonnes) using the NAEI emission factors[21], with variations for the different types of engine and fuel. This information is presented in Table 4-10 and Table 4-11.

Table 4-10. NAEI factors used to calculate Port off-road vehicles / plant emissions

Pollutant	Fuel Name	Emission Factor	Units
Nitrogen oxides (NO_x expressed as NO_2)	Diesel Engine Road Vehicle (DERV)	3.776×10^{-4}	kt / TJ (net)
	Gas oil	3.801×10^{-4}	kt / TJ (net)
	Petrol	1.397×10^{-4}	kt / TJ (net)
PM_{10}	DERV	4.160×10^{-5}	kt / TJ (net)
	Gas oil	4.190×10^{-5}	kt / TJ (net)
	Petrol	7.700×10^{-7}	kt / TJ (net)
$PM_{2.5}$	DERV	4.160×10^{-5}	kt / TJ (net)
	Gas oil	4.190×10^{-5}	kt / TJ (net)
	Petrol	7.700×10^{-7}	kt / TJ (net)

Note: Emissions are calculated using NAEI 2019 emission factors for industrial off-road mobile machinery. DERV = Diesel Engine Road Vehicle. kt/TJ = kilotonnes per terajoule.

Table 4-11. NAEI factors used to calculate Port-owned vessel emissions

Pollutant	Emission Factor	Units
Nitrogen oxides (NO_x expressed as NO_2)	9.984×10^{-4}	kt / TJ (net)
PM_{10}	9.679×10^{-5}	kt / TJ (net)
$PM_{2.5}$	9.679×10^{-5}	kt / TJ (net)

Note: Emissions are calculated using NAEI 2019 emission factors for Motorboats / workboats (e.g. canal boats, dredgers, service boats, tourist boats, river boats) using gas oil. kt/TJ = kilotonnes per terajoule.

In order to spatially distribute the emissions from port activities, polygons representing areas where different activities were most likely to occur were digitised using Geographical Information System (GIS) mapping software, and the area of each polygon calculated.

[23] Prof. Alan Wells and Seckin Tataroglu from Redshift Associates Ltd (2020) *Belfast Harbour Air Quality Emission Inventory*

The calculated emission rate in g/m^2/s was then allocated to the respective emission activity and area(s). These emissions rates are presented in Table 4-12.

Table 4-12. Calculated Port Emission rates (g/m^2/s)

Pollutant	Berthed Emission Rate (g/m^2/s)	Harbour Channels Emission Rate (incl. Port Owned Vessels) (g/m^2/s)	Land Based Emission Rate (g/m^2/s)
NO_X	2.160 x 10^{-4}	6.493 x 10^{-6}	4.610 x 10^{-8}
PM_{10}	2.357 x 10^{-5}	7.130 x 10^{-7}	5.082 x 10^{-9}
$PM_{2.5}$	2.251 x 10^{-5}	6.812 x 10^{-7}	5.082 x 10^{-9}

4.3.4 Limitations

Information regarding the exact areas where the emissions from berthed and moving vessels, and land-based plant and equipment was not provided by Belfast Harbour. The areas where emissions are likely to occur have therefore been estimated, informed by examination of aerial imagery and professional judgement. For example, the land-based emissions have been spread equally around the edges of the Harbour to represent plant and equipment emissions, and berthed emissions have been positioned according to known berth locations around the Harbour.

Emissions from port activities have been modelled as area sources in ADMS-5, meaning that the emissions are assumed to be evenly distributed over a selected area. This does not allow for any variations in emissions, for example due to vessels travelling in Harbour channels having to alter speed or direction, or temporal variations in fuel consumption.

Data have been taken directly from Belfast Harbour Air Quality Emissions Inventory Report[24] and have been assumed to be correct. The emissions estimates contained therein have been scaled to 2019 from 2018 based on known vessel movements.

4.3.5 Shipping Projections

In future years, it is expected that there will likely be an increase in port activity due to increased demand. However, it is also expected that the efficiency of ships and the fuels they use are likely to improve. At the present time, Belfast Harbour was not able to provide growth projections to 2028. Due to the lack of future projections, the limitations outlined above and the screening guidance outlined in TG22, it has been assumed that there will be no change in emissions between the base year (2019) and the future year (2028).

[24] Prof. Alan Wells and Seckin Tataroglu from Redshift Associates Ltd (2020) *Belfast Harbour Air Quality Emission Inventory*

4.4 Airport

4.4.1 Guidance review/screening

During take-off, aircraft can be significant sources of NO_X emissions. As outlined in TG22[12], the screening criteria for local authorities is based on the following:

- *Determine relevant exposure within 1km of the airport boundary;*
- *If exposure has been identified, determine whether the airport total equivalent passenger throughput is more than 10 million passengers per annum (mppa). Freight should also be considered, and converted to equivalent mppa using 100,000 tonnes = 1mppa; and*
- *Identify whether the background annual mean NO_x concentration is above 25µg/m^3 in these areas.*

BCC has undertaken monitoring to consider the impact of the George Best Belfast City Airport on air quality. Annual mean NO_2 concentrations at monitoring locations in the vicinity of the airport have been well below the annual mean NO_2 objective at relevant human health receptor locations since 2007[25]. On this basis, it is concluded that there are no airports within the Belfast area which meet the TG22 screening criteria. Notwithstanding this, for accuracy, completeness and comprehensiveness, emissions of NO_X, PM_{10} and $PM_{2.5}$ from George Best Belfast City Airport have been derived and included in the dispersion modelling for this DA.

TG22 also makes reference to contribution of airports to Ultra-Fine Particulates (UFP). As noted in the 2021 Updating and Screening Assessment Report[22], BCC has carried out monitoring of fine particulate matter ($PM_{2.5}$) at one location in the vicinity of the George Best Airport. The findings of the monitoring study are reported in the Part A report.

4.4.2 Aircraft Fleet

The Airport's aircraft fleet composition and frequency were determined by AECOM by logging the daily flights for one week in June 2022. This covered both the arrivals and departures of passenger flights from George Best Belfast City Airport. The weekly flight arrivals and departures were used to estimate the annual movements by each aircraft type, by multiplying the weekly totals by a factor of 52.14. As the data were collected in 2022, the fleet movements were then scaled to 2019 using Civil Aviation Authority (CAA)' s Aircraft Movements 2019 data[26] for George Best Belfast City Airport. The summary of aircraft types and associated estimated number of arrivals and departures in 2019 is presented in Table 4-13.

The data presented in Table 4-13 relates only to passenger flights as no information was available for cargo flights for 2019. However, CAA statistics on freight volumes passing through George Best Belfast City Airport in 2019 indicate that 196 tonnes of freight were transported on board passenger aircraft and no freight was transported on cargo aircraft. This would suggest there were no cargo flights from George Best Belfast City Airport in 2019.

[25] Belfast City Council (2021) *Air Quality 2021 Updating and Screening Assessment for Belfast City Council* Belfast City Council AQ USA 2021.pdf (airqualityni.co.uk)
[26] UK Civil Aviation Authority (2019) *Annual airport data 2019* https://www.caa.co.uk/data-and-analysis/uk-aviation-market/airports/uk-airport-data/uk-airport-data-2019/annual-2019/

Table 4-13. Number of Arrivals and Departures by aircraft type in 2019 at Belfast City Airport

Aircraft	Arrivals / Departures in June 2022	Arrivals / Departures in June 2022 As Percent of Total (%)	Estimated Arrivals / Departures in 2022	Arrivals / Departures in 2019
A319	33	5.9	1,721	2,071
A320	69	12.4	3,598	4,329
AT45	7	1.2	339	408
AT7	228	41.0	11,875	14,290
C25A	2	0.4	104	125
DH8D	123	22.1	6,400	7,702
E135	7	1.2	339	408
E145	28	5.0	1,460	1,757
E190	34	6.1	1,773	2,133
E75	6	1.1	326	392
E75L	8	1.4	404	486
E75S	8	1.4	404	486
JS41	3	0.4	130	157
LJ35	2	0.4	104	2,071
Total	**556**	**100**	**28,977**	**34,871** [A]

Note: percentages are shown to 1 decimal place. [A] Total number of commercial aircraft movements in 2019 as reported by CAA

4.4.3 Aircraft Emissions

The pollutants emitted by aviation activities are mainly due to the combustion of jet fuel and aviation gasoline that are used as fuel for the aircraft. The latter is used only in small aircraft and helicopters equipped with piston engines. Whilst aviation activities are associated with the emission of many different pollutants, the main pollutants of concern for this DA are NO_X, PM_{10} and $PM_{2.5}$.

Aircraft have varying emissions according to their engine type and level of thrust. With reference to Chapter 1.A.3.a of the European Monitoring and Evaluation Programme (EMEP) European Environment Agency (EEA) Air Pollutant Emissions Inventory Guidebook 2019[27], emissions from each aircraft type were calculated using the following tools:

- Aviation 1 Master emissions calculator 2019[28]; and
- Aviation 2 'Landing and Take-off' (LTO) emissions calculator 2019[29].

The above tools enable emissions to be calculated for a given aircraft model type from individual phases of flight, as illustrated in Figure 4-2. This study considers the emissions from aircraft during arrival and departure phases up to an altitude of 3000 ft (914.4 m). This LTO cycle includes taxi-out, take-off, climb-out, final approach, landing and taxi-in phases of the flight. The aviation emissions calculation tools provide emissions estimates for a range of pollutants, including NO_X and total PM. As noted in the Aviation 1 Master emissions calculator 2019[28], as practically all PM emitted by modern transport aircraft has an aerodynamic diameter of less than 0.1 microns, it is assumed that the masses of $PM_{0.1}$, $PM_{2.5}$, PM_{10} and total PM are identical.

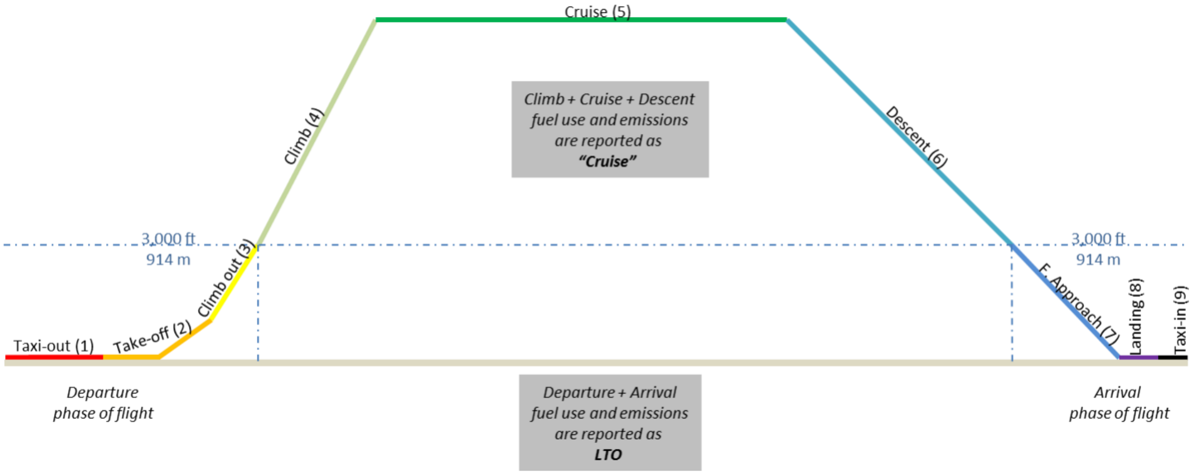
NO_x and $PM_{2.5}$ emissions per LTO cycle were calculated for each aircraft type listed in Table 4-13. Annual total emissions were calculated by multiplying the emissions per LTO cycle for each aircraft type by the number of movements of those aircraft types in 2019.

For the dispersion modelling, the LTO emissions were separated into ground-level emissions (taxi-in, taxi-out, landing) and airborne emissions (climb-out, approach). Area sources representing the runway, taxiways and apron, and flight and approach paths were digitised using GIS based on OpenStreetMap open-source mapping and

[27] European Environment Agency (2019) *1.A.3.a Aviation 2019* https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation/view
[28] European Environment Agency (2019) *1.A.3.a Aviation 1 Master emissions calculator 2019* 1.A.3.a Aviation 1 Master emissions calculator 2019 — European Environment Agency (europa.eu)
[29] European Environment Agency (2019) *1.A.3.a Aviation 2 LTO emissions calculator 2019* 1.A.3.a Aviation 2 LTO emissions calculator 2019 — European Environment Agency (europa.eu)

International Civil Aviation Organization (ICAO) aeronautical charts, and the aircraft emissions were spatially distributed across these areas according to the flight phase.

Figure 4-2. Typical Phases of Flight



Source: European Environment Agency (2019)[27]

A summary of the total emissions from all aircraft, broken down by flight phase, is presented in Table 4-14.

Table 4-14. Aircraft Emissions as used in the Emissions Inventory Modelling

Total emissions	NOx - Approach and Take off	NOx - Taxi	$PM_{2.5}$ - Approach and Take off	$PM_{2.5}$ - Taxi	PM_{10} - Approach and Take off	PM_{10} - Taxi
Total emissions for all aircraft (kg/year)	119,294.0	15,945.9	359.7	180.3	359.7	180.3

Note: NAEI emissions factors for aviation for PM_{10} and $PM_{2.5}$ are identical, therefore estimated PM_{10} emissions are equal to $PM_{2.5}$ emissions

Emissions from Ground-Support Equipment were estimated using annual fuel consumption data for 2021 (assumed representative of 2019 due to lack of better data) provided by George Best Belfast City Airport, and NAEI emission factors[21] for aircraft support vehicles, as detailed in Table 4-15.

Table 4-15. Ground Support Equipment Emissions as used in the Emissions Inventory Modelling

Pollutant	Fuel Consumption (litres)	Fuel Consumption (TJ)	Emission Factor (kg/TJ)	Emissions (kg)
Nitrogen oxides (NOx expressed as NO_2)	16,716	0.641	200	128.2
PM_{10}			9.8	6.3
$PM_{2.5}$			9.8	6.3

Note: Emissions are calculated using NAEI 2019 emission factors for aircraft support vehicles using gas oil

4.4.4 Limitations

The composition of the aircraft fleet has been calculated based on one week of measured data, gathered by AECOM in June 2022. This period is considered to be broadly representative of the types of aircraft (and their relative numbers) serving the airport over the year. Since the focus of the DA is on annual average pollutant concentrations, the scaling of emissions based on annual total aircraft movements is appropriate; however, it is recognised that this approach does not account for the likely seasonal variation in flight numbers. The number of flights during June 2018 and June 2019 were higher than in the winter months and comparable to monthly numbers between April and September[30]. The use of annual average emission rates for aviation activities will therefore result

[30] George Best Belfast City Airport – 2019 Annual Performance Report. https://www.belfastcityairport.com/getmedia/8a77d2ef-813f-40b2-bf9b-037e57bed01f/Annual-Performance-Report-2019-with-appendices.pdf

in a slight overestimate during winter months and slight underestimate during summer months. This approach is considered appropriate for the purpose of this DA.

It has also been assumed that the composition of the aircraft fleet during June 2022 is representative of the 2019 fleet. Aircraft numbers by type have been estimated by applying the 2022 fleet composition to the total flight numbers in 2019 obtained from the CAA' s Aircraft Movements 2019 data[31] for George Best Belfast City Airport. The total number of aircraft movements for 2019 extracted from the CAA data covers commercial flight movements only as the emissions calculation tools relate to commercial aircraft (Air Passenger Transport movements). There were an additional 511 aircraft movements associated with positioning flights, test flights and private charter flights. These movements were excluded as it was unclear if these movements would constitute a full LTO cycle. Inclusion of these flights, assuming a full LTO cycle, would result in a 1.4% increase in total pollutant emissions associated with aircraft movements, which would not affect the overall conclusions of the DA.

Although aircraft emit multiple pollutants, only NO_x and PM have been accounted for within this assessment. Whilst emissions of other pollutants may be of importance for consideration of greenhouse gases, but are not within the scope of this DA.

The EMEP EEA aircraft emission calculation tools did not always contain the specific engine data type for all of the aircraft types observed during the June 2022 survey period. In these cases, the nearest corresponding engine type was selected to predict the emissions from these aircraft.

4.4.5 Aircraft Projections

York Aviation have prepared a forecasting model to predict the number of passengers travelling in Northern Ireland in the future. York Aviation have considered a number of factors to inform this forecast model to predict a variety of different scenarios with varying probability, including:

- Load Factors;
- Economic Growth;
- Carbon Costs;
- Air Passenger Duty (APD);
- Airline Pricing; and
- Market Maturity.

In 2019, approximately 11.91 million passengers per annum were travelling within Northern Ireland, and 13.78 million passengers per annum are predicted to be travelling by 2028 based on the central (or most likely) scenario. This means an increase of 18% aircraft movements to accommodate extra passengers. As the improvements in efficiency of aircraft will be somewhat offset by the increase in activity, it has been assumed that there will be no change in emissions between 2019 and 2028.

4.5 Industrial Point Sources

Estimates of NO_X, PM_{10}, and $PM_{2.5}$ emissions for the thirteen major point sources located within BCC were extracted from the NAEI, which includes information on major point sources in the UK. In addition, consultation with the Pollution Prevention and Control Officer at BCC identified four point sources not covered by the NAEI data for possible inclusion in the emissions inventory and dispersion modelling. Three sources were included within the modelling as one source was deemed to have an insignificant emissions.

Initial information for these sources was provided by BCC, including data sheets for some of the plant equipment. This was supplemented by facility report documentation gathered from the Department of Agricultural, Environment and Rural Affairs (DAERA) website[32]. The proposed list of sources to be modelled was shared by the Council with the Industrial Pollution and Radiochemical Inspectorate (IPRI) within DAERA to request any further information on industrial sources, and whether there was any additional plant that should be modelled. No further sources were suggested.

[31] UK Civil Aviation Authority (2019) *Annual airport data 2019* https://www.caa.co.uk/data-and-analysis/uk-aviation-market/airports/uk-airport-data/uk-airport-data-2019/annual-2019/
[32] DAERA, Public Register of Pollution Prevention and Control permitted processes. https://public-registers.daera-ni.gov.uk/pollution-prevention-control . Accessed November 2022.

Emissions data was not available for all identified industrial sources and information provided by the various stakeholders was based on many different sources and reports so will have inherent assumptions. The NAEI emissions information is based on national-scale emissions estimates, which are then distributed across known sources on the basis of capacity and other surrogate parameters.

In order to model point source emissions, a number of additional parameters are required, including stack locations, stack heights and diameters, and exit velocity and temperature. The data acquired on industrial sources to inform the emissions inventory development did not include all these parameters for all sources. Efforts were made to infill data gaps based on professional judgement and knowledge of similar facilities and processes, but several sources could not be included in the emissions inventory or dispersion modelling due to insufficient information.

The point sources included in the emissions inventory are shown below in Table 4-16.

Table 4-16. Point Sources Included in the Emissions Inventory Modelling

X	Y	Operator	Annual Emissions (tonnes / year)		
			NO_X	PM_{10}	$PM_{2.5}$
332278	373783	Belfast Health & Social Care Trust	No data	0.55	0.51
332722	372964	Belfast Health and Social Care Trust (RVH)	13.11	0.19	0.18
335057	376863	Belfast Sewage Sludge Incinerator	45.16	0.26	0.15
334769	376765	Devenish Nutrition Ltd	No data	0.6	0.18
334625	377161	Duncrue Food	No data	1.93	0.58
334685	376815	Irish Waste Services Ltd	45.16	0.26	0.15
334274	376019	John Thompson & Sons Ltd	13.98	0.76	0.34
336942	376645	Full Circle Generation Ltd	244.16	14.36	14.36
336487	375720	Short Brothers Plc	22.32	1.22	0.78
332098	373283	The Royal Group of Hospitals	28.1	No data	No data
334393	375529	Trouw Nutrition Ltd	No data	0.6	0.18
334770	376352	United Feeds Ltd	No data	0.6	0.18
335244	376953	Veolia Water Outsourcing Ltd.	11.41	0.52	0.45
340789	374635	AFBI – Veterinary Science Division	No data	1.36	1.36
335078	378438	Landfill Gas Utilisation Plant (North Foreshore)	37.53	No data	No data
336946	377089	Belfast Power Ltd.	398.3	66.23	66.23

Source: BCC and NAEI. Note Belfast Power Ltd. is a proposed future industrial facility. It is only assessed in the 2028 future year scenario.

4.6 Source Apportionment

Source apportionment calculations have been carried out as per paragraph 7.103 of LAQM.TG22 onwards. The total modelled pollutant concentrations were disaggregated into the following categories:

- Regional background, which the authority is unable to influence;
- Local background, which the authority should have some influence over; and
- Local sources, which are the principal sources for the local authority to control and which have been explicitly modelled in this DA, namely:
  - Roads
  - Rail
  - Port
  - Airport
  - Point sources

LAQM.TG22, paragraph 7.109 advises that:

"Apportionment for NO_2 is not straightforward due to the non-linear relationship between the emissions of NO_2 and nitrous oxides (NOx). This is additionally complicated by the different proportions of NO_2 in the NOx emissions for different sources, for example, for petrol cars or diesel cars. The following advice therefore applies to NO_2 source apportionment:

- *Background contributions: the national maps will give the total background NO_2 concentration. This should be apportioned to regional and local background using the ratio of the background NOx concentrations attributable to these two sources, which are also available in the national maps; and*
- *Local contributions: the local contribution to NO_2 is the difference between the total (measured or modelled) NO_2 and the total background NO_2. This is then apportioned to the local sources, for example, buses, HGVs, taxis, cars, using the relative contributions of these sources to the local NOx concentration."*

As this assessment takes into account the emissions from various sectors, the local contribution has been apportioned to the different sectors (roads, point sources, airport, port and rail). Once determined, the roads contribution has then been apportioned to each vehicle class according to results obtained from the ANPR survey and within the EFT.

2019 and 2028 background estimates for NO_2 and NOx have been obtained from the relevant Defra 2018-based background maps[33]. Following the procedure laid out in LAQM.TG22 Box 7.5, these values have been used to calculate the local nitrogen dioxide contribution at each relevant receptor.

The background contribution obtained from the background maps has been apportioned further into regional background and domestic backgrounds. The NO_2 regional background has been obtained from the 'Rural' column of the background maps. The PM_{10} and $PM_{2.5}$ regional background has been obtained by adding columns 'PM_secondary' and 'Residual + Salt' of corresponding background maps. The NO_2, PM_{10} and $PM_{2.5}$ domestic background has been obtained by adding columns 'Domestic_in' and 'Domestic_out' of corresponding background maps.

Regional background contributions arise from sources located outside the Belfast City Council area, and therefore the Council has no influence over these contributions. By its nature, air pollution is transboundary, and pollution may be transported hundreds of kilometres from the point of emission. For example, emissions of precursors pollutants from sources in continental Europe can be transported over the UK leading to summertime ozone pollution episodes, whilst the formation of secondary PM_{10} and $PM_{2.5}$ through the reaction of primary emissions of ammonia (NH_3) with other substances can lead to elevated concentrations of PM_{10} and $PM_{2.5}$ considerable distances downwind from the point of emission. Other regional sources of PM_{10} and $PM_{2.5}$ include wind-blown dust and sea salt aerosol, which are natural sources and cannot be influenced[34].

[33] https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2018

[34] Air pollutants may be termed either primary or secondary pollutants. A primary pollutant is one emitted from a source directly into the atmosphere, either through natural processes (e.g. sandstorms and volcanic eruptions) or through human activities, such as industrial and vehicle emissions. NOx, PM_{10} and $PM_{2.5}$ can be primary pollutants. Secondary pollutants are formed in the atmosphere through chemical or the physical processes involving primary pollutants themselves or between the primary pollutants and other atmospheric components. Common examples include ozone and secondary particulate matter.

In the context of this DA and source apportionment, local background is a component of the total background that lie within a local authority area and therefore which the local authority may have some influence over. This can include a whole range of sources, including road traffic, other transport (e.g. rail, aviation, shipping), industry and combustion in domestic, commercial and institutional premises. The ‘Domestic’ component of the Defra background maps of air pollution actually corresponds to the collective contribution of domestic, institutional and commercial space heating, but is considered an appropriate proxy in this DA for estimating the contribution of emissions from domestic combustion in Belfast.

An example source apportionment calculation for NO_2 is presented in Table 4.17 and Table 4.18. This describes the methodology employed in the source apportionment presented in Section 8.

To apportion the contributions of local sources explicitly modelled, the individual verified process contributions from the atmospheric dispersion modelling are divided by the total modelled NO_x concentration (i.e. the sum of the process contributions of all modelled source sectors, excluding background) (see Table 4.17).

In line with LAQM.TG22, it is assumed that the relative proportions of the NO_x contributions apply to NO_2 concentrations, and the NO_2 process contributions for the source sectors explicitly modelled are estimated by calculating the product of the percentage of modelled total NO_x (from Table 4.17) and the total modelled NO_2 (excluding background)(see Table 4.18).

Finally, the local and regional background source contributions (obtained from Defra background maps of air pollutant concentrations) are combined with the estimated NO_2 process contributions for the source sectors explicitly modelled, and the contributions of each sector calculated as a percentage of the total modelled NO_2 concentration (including background).

Table 4.17 Example NO_2 Source Apportionment Calculation (1)

Full ID	Roads	Point	Airport	Port	Rail	Total Modelled NO_x (excl. background)
Modelled NO_x Process Contribution ($\mu g/m^3$)[A]	53.46	1.08	0.04	0.49	0.57	55.64
Percentage of Modelled Total	96.09	1.94	0.07	0.88	1.02	100.00

[A] Modelled NO_x process contributions are the adjusted (verified) outputs from the atmospheric dispersion model

Table 4.18 Example NO_2 Source Apportionment Calculation (2)

Full ID	Roads [A]	Point [A]	Airport [A]	Port [A]	Rail [A]	Regional Background [B]	Domestic Background [B]	Other Local Background [B]	Total Modelled NO_2 (excl. background)	Total Modelled NO_2 (incl. background)
Estimated NO_2 Process Contribution ($\mu g/m^3$)	25.61	0.52	0.02	0.23	0.27	3.62	7.55	7.27	26.65	45.09
Percentage of Modelled Total	56.79	1.15	0.04	0.52	0.60	8.03	16.75	16.12		100.00

[A] Estimated NO_2 process contributions for the source sectors explicitly modelled are the product of the percentage of modelled total NO_x (from Table 4.17) and the Total Modelled NO_2 (excl. background).

[B] Background source sector contributions obtained from Defra background maps of air pollutant concentrations.

5. Dispersion Modelling – Sector-Specific Methodology

5.1 Overview

Detailed atmospheric dispersion modelling for this DA was carried out using ADMS-Roads and ADMS-5 modelling software developed by CERC. The following sections describe the modelling methodology for each of the modelled source types and the definition of key model inputs, including meteorological data, receptors and background concentrations.

The following scenarios have been modelled:

- 2019 Baseline assessment year, representative of the most recent year unaffected by the COVID pandemic. The 2019 assessment year has also been used for model verification; and
- 2028 Future assessment year, to provide an indication of future air quality under a business-as-usual scenario.

5.2 Roads

Emissions from road traffic were modelled using ADMS-Roads Version 5.0.1 to generate predictions of NO_2, PM_{10} and $PM_{2.5}$ concentrations at sensitive receptor locations.

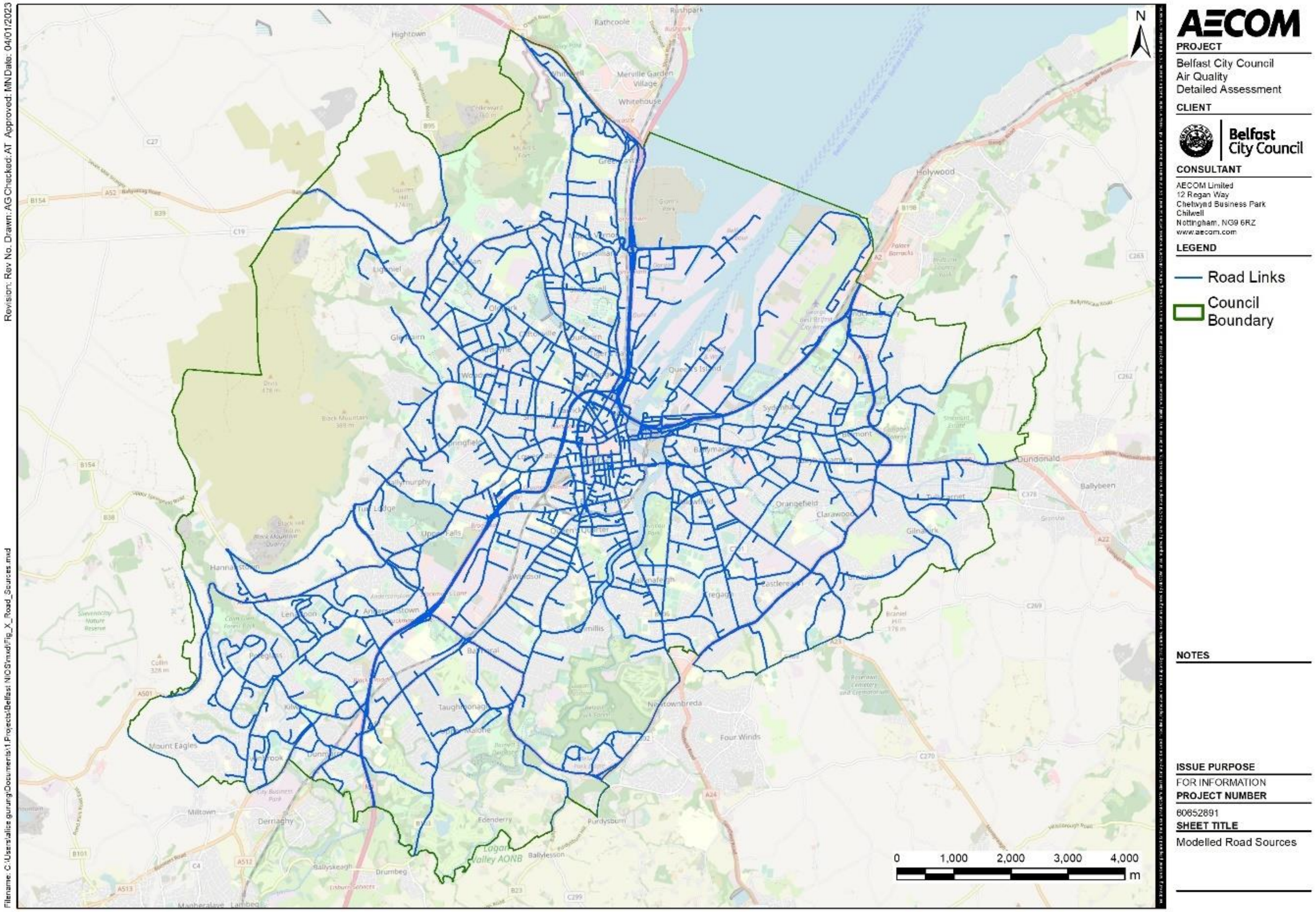
In accordance with LAQM.TG(22)[12], emission rates for input to the model were calculated using Defra's EFT version 11.0[16]. The emissions calculations and traffic data inputs used for these calculations are described in detail in Section 4.1. Road parameters such as elevation of the road, street canyons and tunnels were considered. Road elevation was applied to flyovers located along M1, M2 and M3 in order to capture local micro-scale impacts on pollutant concentrations.

Street canyons, road gradients and tunnels were reviewed but have not been modelled specifically as the model performed acceptably across the domain without additional input from these options. There are several areas where the implementation of street canyons was considered; these included Great Victoria Street and Chichester Street (and adjacent streets) in the city centre, and the section of the Westlink between the Divis Street / Westlink junction and just east of the Clifton Street / Westlink junction.

In the case of Great Victoria Street and Chichester Street, although the inclusion of a street canyon slightly improved the agreement between modelled and monitored concentrations at diffusion tube locations along these streets, it did not bring about any overall improvement in model performance across the city centre area as a whole. The canyon-like nature of the Westlink was accounted for by defining a unique verification zone based on model predictions at the monitoring locations at heights above the carriageway. Further details on this can be found in Section 6.5.

The modelled road network across the city is represented in Figure 5-1.

Figure 5-1. Map Showing Modelled Road Network



5.3 Rail

Emissions from railways in Belfast were modelled using ADMS-Roads to predict concentrations of NO_2, PM_{10} and $PM_{2.5}$.

Rail emissions were modelled as road sources, based upon professional judgement and AECOM's previous experience of modelling railways, as the linear geometry of a railway line is analogous to a road. Each railway line was digitised using GIS, split into shorter segments to represent links between key junctions on the rail network. In total, 118 segments were digitised for modelling.

In parts of Belfast, the rail network is elevated relative to the surrounding terrain and receptors. These elevated track sections were identified using GIS and assigned a release height of between 1 m and 10 m to represent an elevated height of emissions. Each rail segment was assigned a width of 4 m in the model.

As described in Section 4.2, rail emissions (in tonnes/year) were calculated at the national scale using fuel consumption data provided by Translink, and emission factors for railways from the NAEI. To spatially distribute these emissions, the NAEI 1x1 km grided emissions estimates were used to determine the proportion of the national total emissions that occur within each individual grid square. The calculated national total emissions estimates were multiplied by the calculated proportion for each grid square to estimate the emissions attributable to rail sources within that grid square.

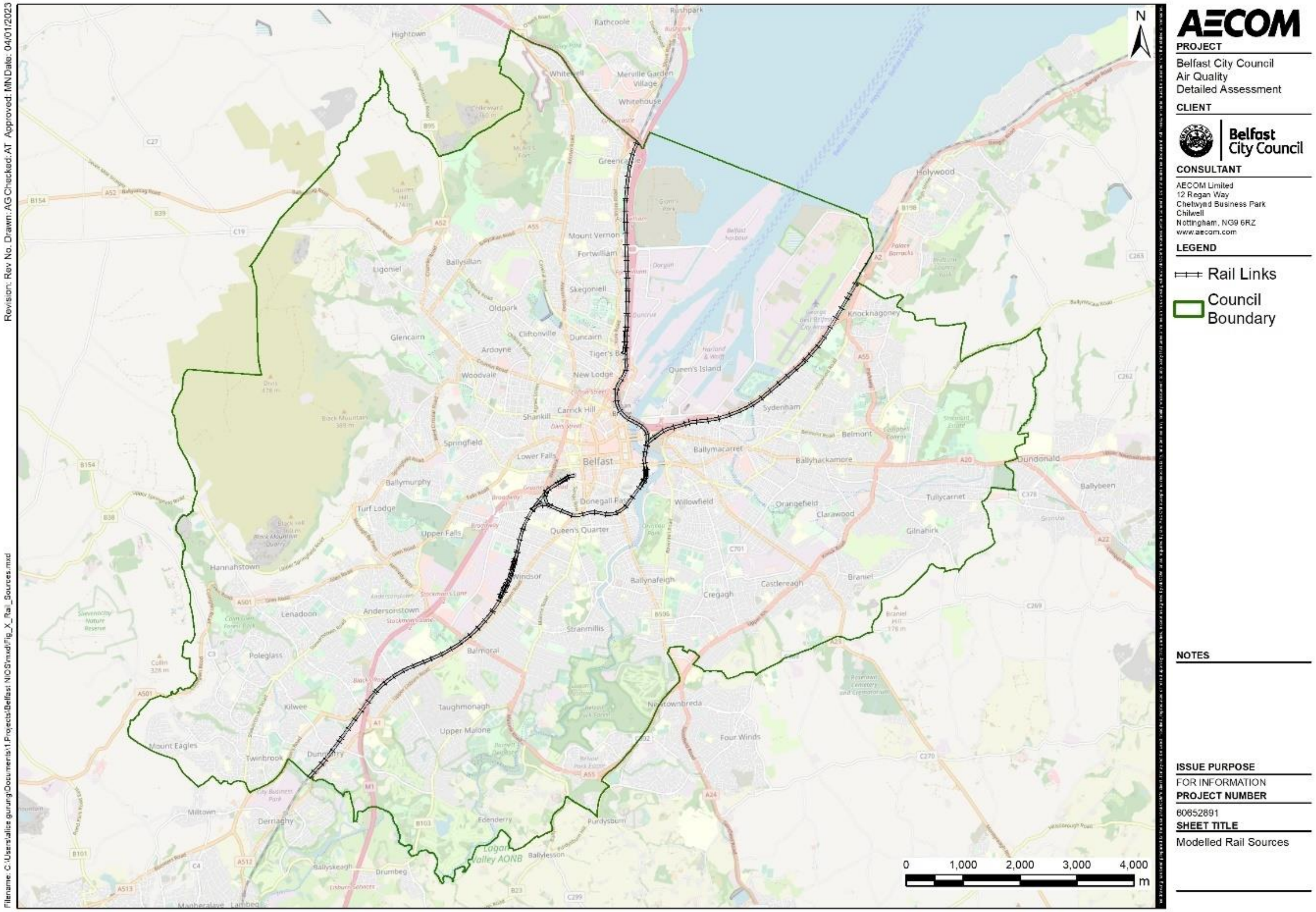
GIS was used to calculate the total length of railway track within each grid square. The emissions within each grid square (in tonnes/year) were divided by the total length of track within the grid square to give an emission rate in tonnes/km/year. Finally, the emission rates were converted to units of grammes/km/s (for input to the dispersion model) by dividing by 31.536.

The key input parameters used for the modelling of rail emissions are summarised in Table 5-1. A map showing the digitised area sources is shown in Figure 5-2.

Table 5-1. ADMS-Roads Input Parameters for Modelling Rail Activities

Parameter	Rail Activities
Source type	Road
Number of sources	118
Emission Rates (g/km/s)	Minimum - Maximum
NO_X	1.851×10^{-2} - 1.023×10^{-1}
PM_{10}	6.006×10^{-4} - 3.321×10^{-3}
$PM_{2.5}$	5.705×10^{-4} - 3.155×10^{-3}
Release Height (m)	0 to 10 m
Source Width (m)	4

Figure 5-2. Map Showing Modelled Area Sources for Rail Activities



5.4 Shipping

Emissions from shipping activities were modelled using ADMS-5 to predict concentrations of NO_2, PM_{10} and $PM_{2.5}$.

As described in Section 4.3, emissions from moving and berthed vessels and land-based emissions associated with port activities were modelled as area sources. This included areas representing moving vessels in Belfast Lough on the approach to the Port, areas covering the key mooring locations to represent emissions from ships at berth, and areas covering port-side cranes and warehouses to represent land-based emissions associated with Port activities.

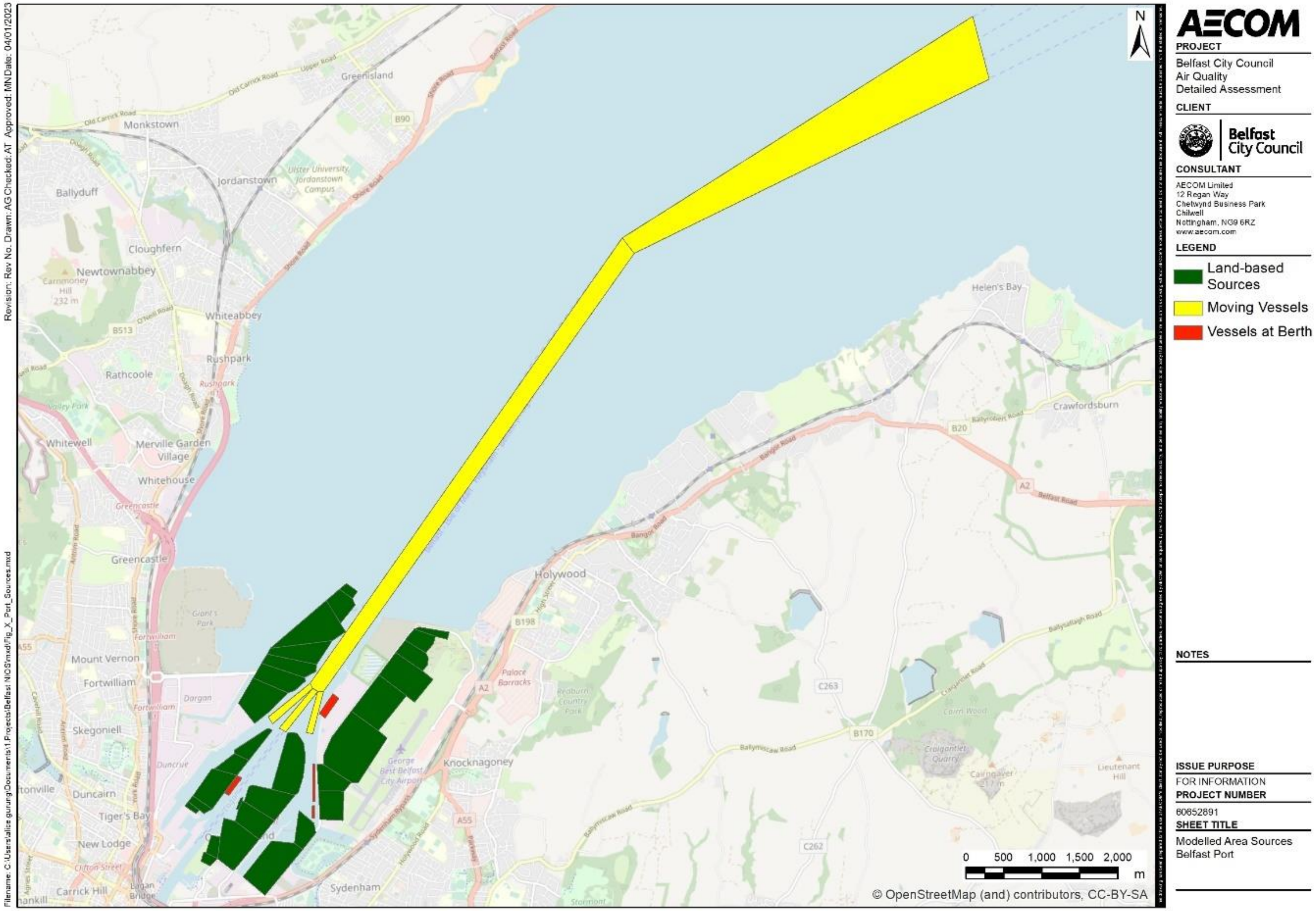
As specific information about the locations of Port emissions was not available, the facility-wide total emissions from moving vessels, vessels and berth and land-based port activities have been equally distributed across the digitised area sources (see emission rates in Table 4-12 and Table 5-2).

The key input parameters used for the modelling of port emissions are summarised in Table 5-2. A map of showing the digitised area sources is shown in Figure 5-3.

Table 5-2. ADMS 5 Input Parameters for Modelling Port Activities

Parameter	Vessels at Berth	Moving Vessels	Land-Based Port Activities
Source type	Area	Area	Area
Emission Rates ($g/m^2/s$)			
NO_X	2.160×10^{-4}	6.493×10^{-6}	4.610×10^{-8}
PM_{10}	2.357×10^{-5}	7.130×10^{-7}	5.082×10^{-9}
$PM_{2.5}$	2.251×10^{-5}	6.812×10^{-7}	5.082×10^{-9}
Release Height (m)	20	20	5
Emission Velocity (m/s)	5	5	1

Figure 5-3. Map Showing Modelled Area Sources for Port Activities



5.5 Airport

Emissions from aviation activities at the Belfast City Airport were modelled as volume sources using ADMS-5 to predict concentrations of NO_2, PM_{10} and $PM_{2.5}$.

Ground-level emission sources included aircraft taxiing to / from departure gates to the runway, runway emissions prior to take-off and after landing, and ground support vehicles. Emissions during take-off and approach were assigned to volume sources increasing incrementally in height with distance from the runway (up to a ceiling height of 3,000 feet (914 m)) based on the typical angle of departure / approach.

Detailed information regarding temporal variations in activities at the airport were not available, so it was assumed that emissions were distributed equally across the year. The use of annual average emission rates for aviation activities is considered appropriate for the purpose of this DA as the main focus is on annual average pollutant concentrations. Similarly, facility-wide total emissions from aircraft taxiing in / out were assumed to be equally distributed across all modelled taxiways and departure gates, and ground support vehicle emissions were assumed to be equally distributed across the departure gates. Aircraft emissions were similarly distributed along the runway and flight paths according to the flight phase (i.e. runway, take-off and approach).

The key input parameters used for the modelling of airport emissions are summarised in Table 5-3. A map showing the digitised volume sources is shown in Figure 5-4. A map showing modelled flight paths is shown in Figure 5-5.

Table 5-3. ADMS 5 Input Parameters for Modelling Airport Activities

Parameter	Aircraft Approach & Take-Off	Taxiing & Ground Support Vehicles
Source type	Volume	Volume
Number of sources	83	97
Emission Rates ($g/m^2/s$)		
NO_X	1.630×10^{-7}	1.921×10^{-6}
PM_{10}	4.913×10^{-10}	2.231×10^{-8}
$PM_{2.5}$	4.913×10^{-10}	2.231×10^{-8}
Release Height (m)	5 to 900	5
Line Width (m)	20	10

Figure 5-4. Map Showing Modelled Volume Sources for Airport Activities

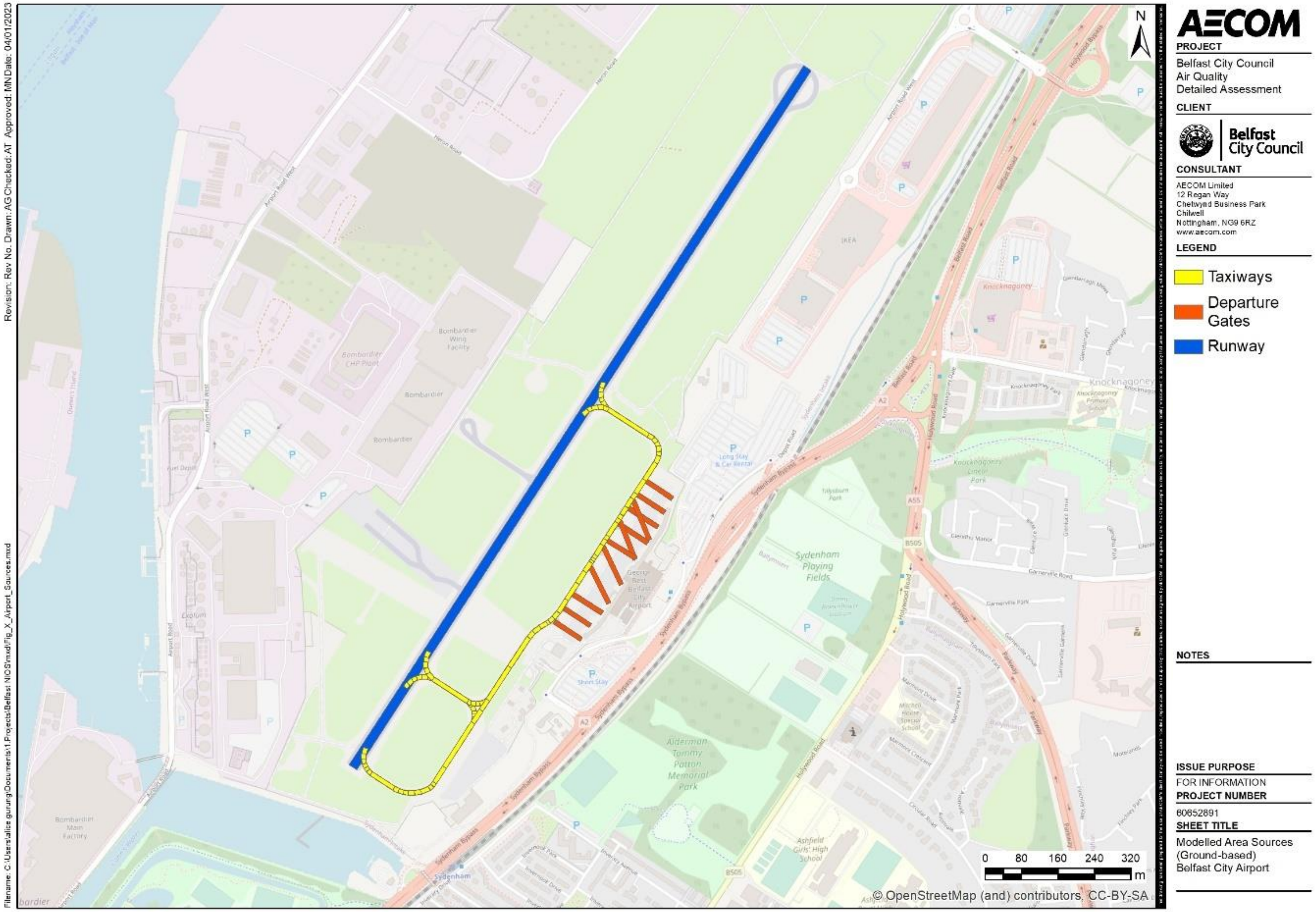
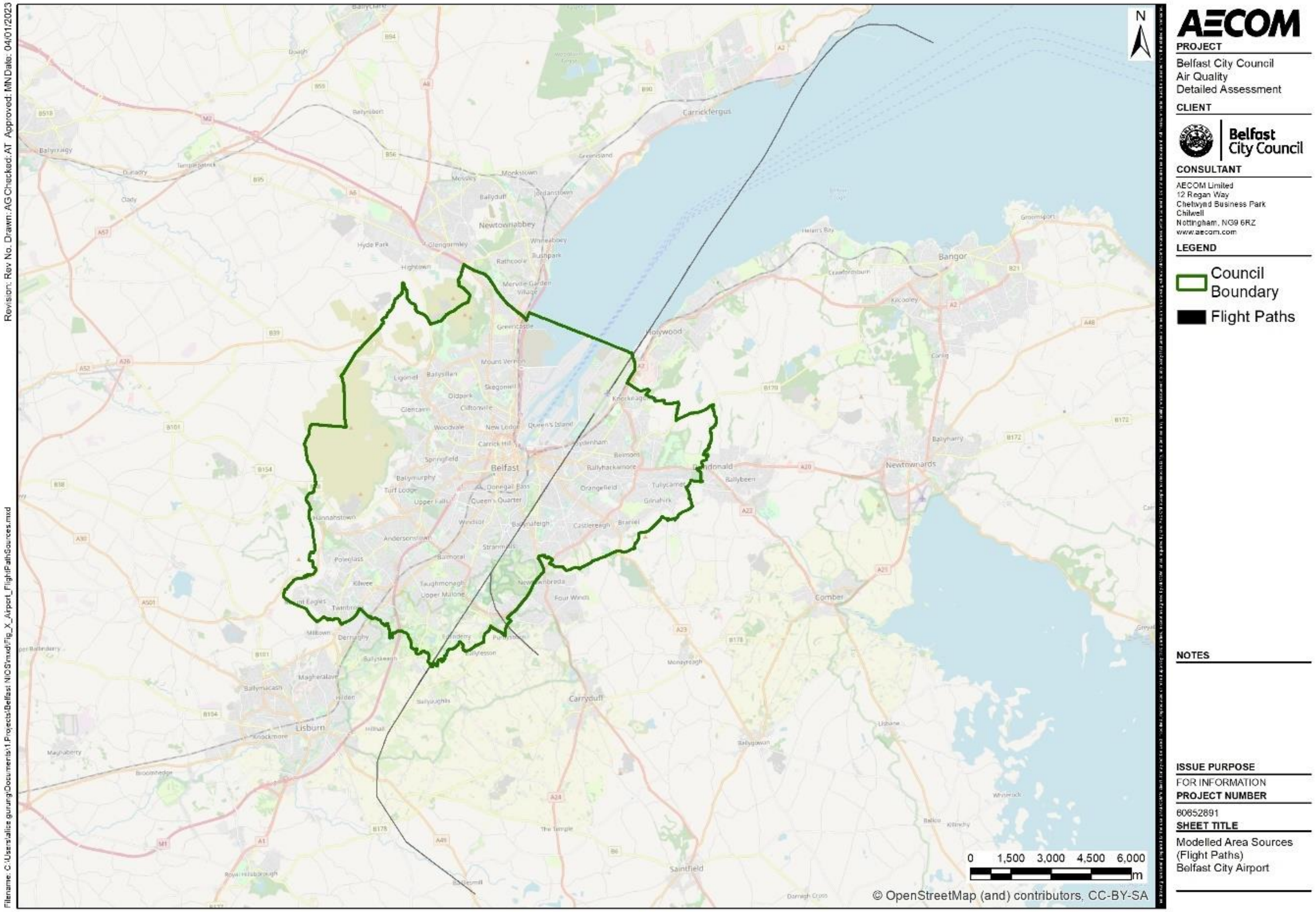


Figure 5-5. Map Showing Modelled Flight Paths for George Best Airport



5.6 Industrial Point Sources

Emissions from point sources activities were modelled using ADMS-5 to predict concentrations of NO_2, PM_{10} and $PM_{2.5}$.

Pollutant emission rates, in grams/second, for each industrial point source were calculated by dividing the annual emissions estimates in tonnes/year (see Table 4-16) by 31.536. This approach assumes emissions from the modelled sources are constant throughout the year.

A range of other parameters are required to model point sources, including stack locations, stack heights and diameters, and exit velocity and temperature. These parameters are summarised in Table 5-4. The data acquired on industrial sources to inform the emissions inventory development did not include all of these parameters for all sources. Where possible, data gaps have been infilled using information obtained via other methods such as visual inspection of aerial imagery to estimate stack heights and diameters, or professional judgement to assign appropriate values based on knowledge of similar sources and processes. Where assumptions have been made, these are clearly marked in Table 5-4.

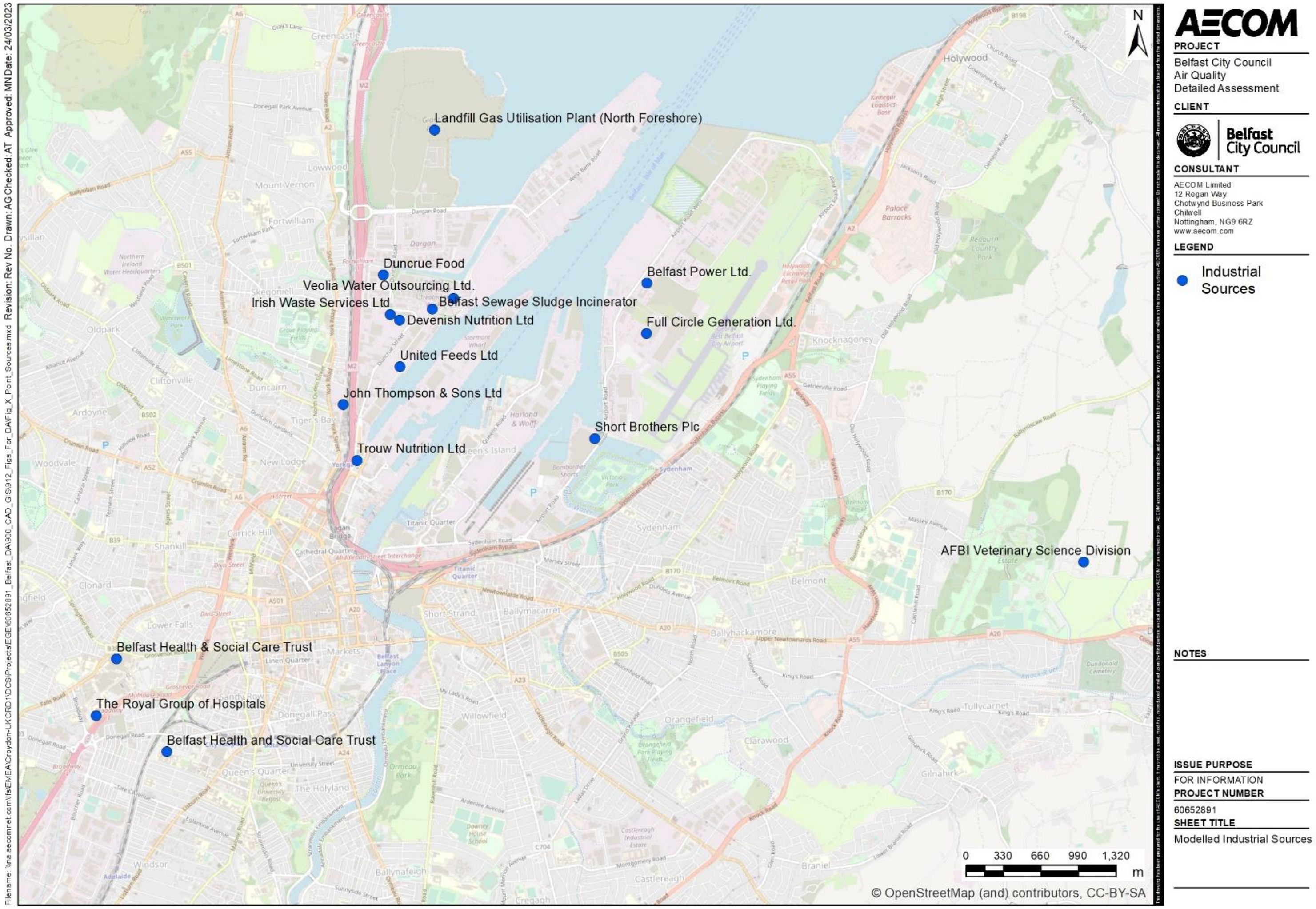
The modelled point sources are shown in Figure 5-6.

Table 5-4. ADMS 5 Input Parameters for Point Sources Activities

X	Y	Operator	Stack height (m)	Stack diameter (m)	Exit velocity (m/s)	Exit temperature (ºC)	NOx (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)
332278	373783	Belfast Health & Social Care Trust	40[A]	0.8	4.8	179.0	No data	0.0176	0.0162
332722	372964	Belfast Health and Social Care Trust (RVH)	20[A]	0.9	15	80.0	0.4158	0.0059	0.0057
335057	376863	Belfast Sewage Sludge Incinerator	70	0.89	20.3	115.0	1.4321	0.0083	0.0047
334769	376765	Devenish Nutrition Ltd	15[A]	0.5[B]	15[B]	40.0[B]	No data	0.0192	0.0058
334625	377161	Duncrue Food	10	0.5[B]	15[B]	40.0[B]	No data	0.0613	0.0184
334685	376815	Irish Waste Services Ltd	16[A]	0.5	15	80.0	1.4321	0.0083	0.0047
334274	376019	John Thompson & Sons Ltd	30.5	0.45	15	40.0	0.4433	0.0242	0.0108
336942	376645	Full Circle Generation Ltd.	51	1.73	23	155.0	7.7422	0.4554	0.4554
336487	375720	Short Brothers Plc	40[A]	1.73	23	155.0	0.7077	0.0387	0.0248
332098	373283	The Royal Group of Hospitals	40	0.9	9.8	225.0	0.8910	No data	No data
334393	375529	Trouw Nutrition Ltd	15[A]	0.5[B]	15[B]	40.0[B]	No data	0.0192	0.0058
334770	376352	United Feeds Ltd	30[A]	0.73	12.2	38.1	No data	0.0192	0.0058
335244	376953	Veolia Water Outsourcing Ltd.	15[A]	0.89	20.3	60.0	0.3617	0.0165	0.0143
340789	374635	AFBI – Veterinary Science Division	23	0.8	16.3	238.0	No data	0.0432	0.0432
335078	378438	Landfill Gas Utilisation Plant (North Foreshore)	7.0	0.71	18.4	479.0	1.1902	No data	No data
336946	377089	Belfast Power Ltd.	50	8	14.8	87.9	12.6300	2.1000	2.1000

Notes: Where no data is listed for stack parameters, the source could not be included within dispersion modelling [A] Stack height estimated based on aerial imagery. [B] Stack parameters assumed based on professional judgement of similar sources/processes.

Figure 5-6. Map Showing Modelled Point Sources



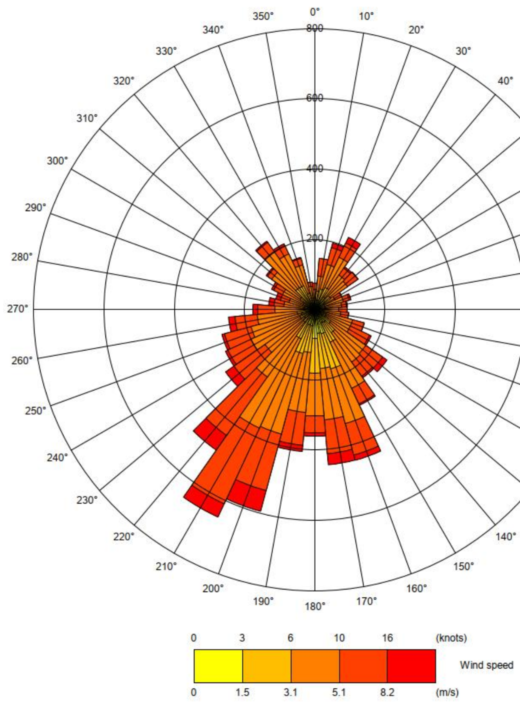
Note: Belfast Power Ltd. is a proposed industrial facility that is due to be operational by 2028 and is therefore only included in the 2028 modelling scenarios

6. Dispersion Modelling – General Methodology

6.1 Meteorology

Meteorological data for Belfast City Airport (Station ID 3924) in 2019 were used in the dispersion modelling, consistent with the verification year and the base year of the road traffic model. The wind rose based on the 2019 meteorological data is shown in Figure 6-1. This meteorological station is considered to be representative of the conditions in the model domain and appropriate for use in the modelling for the DA.

Figure 6-1. Wind Rose for 2019 George Best Belfast City Airport Meteorological Station



6.2 Receptors

Pollutant concentrations were predicted at 1,797 discrete sensitive receptor locations throughout Belfast. The receptors are representative of residential properties, schools, hospitals and healthcare facilities. The receptors were selected using GIS based on their proximity to modelled sources to ensure that locations of both typical and worst-case exposure are likely to be captured. A map showing the modelled discrete receptors can be found in Appendix B.3.

To generate contour plots of pollutant concentrations across the whole city, a Cartesian grid of receptors was created. Due to the extent of the study area, the receptor spacing was set to 200 metres to optimise model run times whilst allowing city-scale concentration patterns to be captured. A map showing the city-wide Cartesian grid can be found in Appendix B.3.

To supplement the coarse-scale Cartesian grid of receptors, and to provide higher-resolution data of hotspot locations, an intelligent gridding approach was adopted covering each of the AQMAs (plus a 200-metre buffer) and other areas of elevated concentrations. Since the primary modelled source is road traffic, points were created at 5m, 15m, 30m, 50m, 100m and 200m perpendicular from each road link (measured from the carriageway edge), and every 30m longitudinally along each road link. This allows the generation of high-resolution, accurate contour plots, particularly in the near-road environment where concentrations are often near to / in exceedance of the AQOs. The intelligent grids were used to examine the likely areas of exceedance of AQOs and to estimate population exposure. A map showing the grids across the AQMAs can be found in Appendix B.3.

6.3 Background Concentrations

A large number of small sources of air pollutants exist, which individually may not be significant, but collectively, over a large area, need to be considered in the modelling process. Pollutant emissions from these sources contribute to background air quality, which when added to modelled emissions, allow the total ambient pollutant concentration to be predicted.

Background data for NO_2, PM_{10} and $PM_{2.5}$ concentrations for the 2019 baseline year and the 2028 future assessment year have been sourced from Defra's 2018 reference year background maps[19]. Defra provides background maps by default in OSGB coordinates but are also available in OSNI coordinates. The OSNI background maps are calculated from the OSGB maps using an area-weighted average approach.

The OSGB maps were used in this DA as the OSNI background maps are not compatible with Defra's Sector Removal Tool (which enables the contributions of sources explicitly modelled to be removed from the background concentrations). Furthermore, the OSGB background concentrations are calibrated against UK national network monitoring stations, hence would be expected to align closely with measured background concentrations. Table 6-1 presents a comparison between mapped background pollutant concentrations and monitored concentrations at the Belfast Centre AURN continuous monitor location in 2019.

Table 6-1. Comparison of Monitored and Mapped Pollutant Concentrations for 2019

Monitoring Location	Defra 1-km Grid Square [B]	Pollutant	Monitored Background Concentration ($\mu g/m^3$) [A]	Mapped Background Concentration ($\mu g/m^3$)
Belfast Centre AURN	146500, 529500	NO_2	26	26.7
		PM_{10}	15	15.5
		$PM_{2.5}$	11	10.5

[A] Monitored concentrations taken from Belfast City Council Air Quality Progress Report 2020[35]. [B] Coordinates are OSGB. The corresponding OSNI (TM65) coordinates for the corners of this grid square are 333636.9 373510.4, 333551.7 374506.6, 334547.9 374591.9, 334633.1 373595.7, 333636.9 373510.4

The comparison in Table 6-1 shows that the mapped and monitored pollutant concentrations are very similar and, as such, it is considered appropriate to use the Defra mapped background data to establish background air quality at the receptor locations modelled within this study.

Due to the large study area, it is not practical to list the mapped background pollutant concentrations for all of the 1x1 km grid squares used in this assessment. Table 6-2 provides a summary of the background concentrations, showing the maximum, minimum and average background pollutant concentrations in the study area, adjusted for sector removal to avoid double-counting of emissions from sources that have been explicitly modelled. Maps of the sector-removed background concentrations used in the assessment can be found in Appendix B.4.

Table 6-2. Summary of Mapped Pollutant Concentrations (Sector-Removed) for 2019 and 2028

Year	Pollutant	Pollutant Concentration ($\mu g/m^3$)		
		Maximum	Minimum	Average
2019	NO_2	23.4	6.2	11.0
	PM_{10}	17.5	10.4	13.4
	$PM_{2.5}$	12.0	6.7	9.0
2028	NO_2	18.8	4.9	8.8
	PM_{10}	16.4	9.5	12.3
	$PM_{2.5}$	11.2	6.0	8.2

[35] https://www.airqualityni.co.uk/assets/documents/dc-reports/BCC_AQ_Progress_Report_2020.pdf

6.4 Model Outputs

6.4.1 NOx to NO_2 Conversion

The proportion of NO_2 in NOx varies greatly with location and time according to a number of factors including the amount of ozone available and the distance from the emission source.

Defra has produced a NOx to NO_2 Calculator[36] spreadsheet tool which provides a methodology for converting modelled NOx concentrations to NO_2 concentrations for any given year up to 2030. This conversion methodology has been used for the purpose of this assessment for all scenarios as the best representation of the NO_2/NOx relationship for the study area.

Since it was not possible to verify each of the modelled source sectors individually, the NO_X to NO_2 calculator has been used for all NO_X to NO_2 conversions in this DA. Modelled NO_X process contributions from each of the modelled source sectors were added together prior before being input into the NO_X to NO_2 calculator to calculate NO_2 concentrations. In the absence of alternative approaches, this is considered a robust and appropriate method for the conversion of road transport, aviation, shipping and rail NO_X concentrations, consistent with LAQM guidance. For industrial point sources, possible alternative approaches include assuming fixed-ratio conversions of NO_X to NO_2 ranging from 100% to 50% for long-term concentrations and 50% to 25% conversion for short-term concentrations. However, sensitivity tests carried out during model verification indicated that the use of fixed ratios offered no improvement in model performance compared to using the NO_X to NO_2 calculator.

Version 8.1 of the NOx to NO_2 Calculator has been used as it is designed to be used in combination with Defra's 2018-reference year background maps[19] and EFT version 11.0[16] – which have also been used in this assessment. The traffic mix option used was the 'All other urban UK traffic' option and Belfast was selected as the local authority area.

6.4.2 Short-Term Results

6.4.2.1 1-Hour Mean NO_2

Atmospheric dispersion models cannot predict short-term concentrations as reliably as annual mean concentrations, making predicting exceedances of short-term AQOs and AQGs challenging. A study carried out on behalf of Defra and the Devolved Administrations identified that exceedances of the NO_2 1-hour mean are unlikely to occur where the annual mean is below 60 $\mu g/m^3$. As per the recommendation in paragraph 7.96 to 7.99 of LAQM.TG(22), this assumption has been used in this DA as a proxy for identifying potential areas of exceedance of the 1-hour mean NO_2 AQO and is considered to be the most appropriate method for the present study, i.e. where modelled annual mean NO_2 concentrations exceed 60 $\mu g/m^3$ it is considered possible that the 1-hour NO_2 AQO would be exceeded.

6.4.2.2 24-hour Mean PM_{10}

As per paragraph 7.100 to 7.102 of LAQM.TG(22), the following empirical relationship has been applied to modelled PM_{10} concentrations to estimate potential exceedances of the PM_{10} 24-hour mean AQO:

No. 24-hour mean exceedances = -18.5 + 0.00145 × annual mean^3 + (206/annual mean)

where 'annual mean' is the modelled annual mean PM_{10} concentration.

LAQM.TG(22) notes that this relationship is limited to use when the annual mean PM_{10} concentration is greater than 14.8 $\mu g/m^3$. Due to this limitation, for annual mean PM_{10} concentrations lower than 14.8 $\mu g/m^3$, it has been assumed that the exceedances are equal to the predicted number for an annual mean of 14.8 $\mu g/m^3$.

6.4.2.3 WHO Short-Term NO_2 AQG

The WHO AQG for short-term NO_2 is for the 99th percentile of 24-hour mean concentrations not to exceed 25 $\mu g/m^3$. There is no prescribed methodology in LAQM.TG(22)[12] for the assessment of this AQG and the complex, non-linear relationship between NO_X and NO_2 (particularly for short-term averages) introduces additional uncertainty into the dispersion modelling. Consequently, assessment of modelled NO_2 concentrations against the short-term WHO AQG has not been carried out. Instead, comparisons have been made against the WHO AQG for 24-hour mean NO_2 using recent years' monitoring data collected at the Council's six automatic monitoring stations and six Zephyr sensor monitoring locations. Full details are provided in the Part A – Monitoring report of this DA, and summarised here for ease of reference.

[36] https://laqm.defra.gov.uk/air-quality/air-quality-assessment/nox-to-no2-calculator/

The monitoring results indicated that the 24-hour mean NO_2 WHO AQG was exceeded at all the Council's automatic monitoring sites in all years from 2019 to 2021, inclusive. The highest concentrations were, as expected, recorded at the busiest roadside sites (i.e. Stockman's Lane, Westlink Roden Street). However, even at the Belfast Centre Urban Background monitoring station in Lombard Street, NO_2 concentrations were calculated to be above the WHO AQG.

Consistent with the results from the automatic monitoring network stations, the Zephyr results indicate that the 24-hour mean NO_2 WHO AQG was exceeded at all monitoring sites in the 2019 and 2021 assessment years covered by the Zephyr monitoring. The highest NO_2 concentrations were measured at N10 (Westlink) but elevated concentrations in excess of the WHO AQG were also monitored at urban background locations.

The monitoring results would suggest that the 24-hour mean NO_2 WHO AQG is likely to be exceeded across much of the Council's administrative area, particularly in the city centre area and near busy roads.

6.4.2.4 WHO Short-Term PM_{10} and $PM_{2.5}$ AQGs

The WHO AQGs include short-term guideline levels for PM_{10} and $PM_{2.5}$ based on the 99th percentile of 24-hour mean concentrations. For PM_{10}, the AQG is 45 µg/m^3 and for $PM_{2.5}$ it is 15 µg/m^3.

The ADMS models were configured to output the 24-hour process contributions for each source sector for the whole assessment year. The process contributions from each source sector were added together and the 99th percentile calculated using the R statistical software package.

Paragraphs 7.530 to 7.535 and Box 7-16 of LAQM.TG(22) set out suggested approaches for the addition of short-term process contributions to background concentrations in order to predict short-term percentiles. The equations are designed primarily for adding industrial source short-term contributions to background concentrations; however, in the absence of any alternative methods and based on the available information, these equations have been adapted, as shown below, for use in the present assessment to estimate the 99th percentile of 24-hour means for PM_{10} and $PM_{2.5}$:

99th percentile total 24-hour mean = Modelled 99th percentile process contribution + (2 × Annual Mean Background Concentration)

Where the calculated 99th percentile total 24-hour mean concentration is above the relevant WHO AQG level it can be concluded there is a likelihood of the AQG being exceeded.

6.5 Verification

The predicted results from a dispersion model may differ from measured concentrations for many reasons, including uncertainties associated with model inputs, for example activity data such as traffic flows and emission factors, uncertainties in the monitoring data itself and limitations inherent to the modelling software.

To minimise the uncertainties associated with the model predictions, it is best practice, as recommended in LAQM.TG(22), to perform a comparison of modelled results with local monitoring data. Model verification aims to improve the agreement between modelled and measured pollutant concentrations in order to provide greater confidence in the model results.

Initial efforts should also be made to check and refine activity data and other parameters to reduce uncertainties associated with the model inputs. When all reasonable efforts have been made to refine the model inputs, it may then be necessary to adjust the model outputs by applying a verification factor. The verification of the model outputs for this DA has been carried out in accordance with the procedures described in Chapter 7 of LAQM.TG(22).

BCC operates an extensive network of air quality monitoring sites, of which approximately 60 NO_2 diffusion tube locations and five automatic monitoring stations were operational in 2019. All of the Council's automatic monitoring stations measure NO_2. Particulate matter monitoring is carried out at Stockman's Lane (PM_{10}) and Belfast Centre (PM_{10} and $PM_{2.5}$). Additionally, a network of six low-cost sensors, measuring NO_2, PM_{10} and $PM_{2.5}$, was commissioned to support this DA (more details of which can be found in Part A of the DA).

Seventeen monitoring locations for NO_2 were excluded from the verification process. These were sites that were either defined as kerbside or urban background or located too far from any modelled sources. Kerbside sites are generally not recommended for the adjustment of road traffic modelling results as the inclusion of these sites may lead to an over-adjustment of modelling at roadside sites. Of the overall seventeen sites excluded, some diffusion tube sites were also excluded based on being affected by very localised sources not possible to adequately characterise within the dispersion modelling (e.g. near to taxi ranks or bus stops) or other micro-siting issues (e.g.

presence of street signage or vegetation). There were eight monitoring locations considered in PM_{10} verification (Stockman's Lane, Belfast Centre, and six Zephyr monitors). Of these, four were excluded from the verification as being urban background sites. For $PM_{2.5}$, there were seven locations considered in the verification, of which four were excluded as being urban background sites.

Further details of these exclusions in the verification process can be found in Appendix B, along with model predictions for all monitoring locations.

6.5.1 NO_2 Verification

In total, 49 monitoring sites were included in the verification process for NO_2. Initially, the model predictions deviated from monitored NO_2 concentrations and it was noted that the model performed differently in distinct areas across the model domain. Model inputs were revisited and, where appropriate, refined. Following this process, it was deemed necessary to adjust the model outputs to improve the agreement between modelled and measured NO_2 concentrations.

Based on the model outputs, the model domain was split into five verification "zones" within which model performance was similar. The ratio of modelled NOx to measured NOx was calculated for each monitoring location. The monitoring locations were then grouped based on geographic location and similarities in model performance. Using GIS, proximal zones were then created around each monitoring site point to determine the extents of each zone. The proximal zones define the polygonal areas where any location within a given polygon is closer to its associated monitoring location point than to any other monitoring location point.

The dispersion models were run for each source type independently (i.e. roads, rail, point sources, aviation and shipping) for all receptor points across the entire model domain. GIS software was then used to determine which model verification zone each receptor point is located in, and the appropriate zone's verification factor applied to the raw modelled NOx concentrations.

The zones, depicted in Figure 6-2., are described in the following sections.

6.5.1.1 City Centre Zone

An area covering the city centre bounded to the east by the River Lagan, to the north by Westlink and Duncairn Gardens, to the west by A501 and Shankill Road, and to the south by River Lagan. In this zone, the unadjusted modelled concentrations were found, on average, to slightly overpredict monitored NO_2 concentrations. This may be due to uncertainties associated with the traffic model data used as input to the dispersion model. There are uncertainties associated with the factoring up of peak hour flows to AADT, and emissions estimates are also sensitive to HDV proportions and vehicle speeds, both of which are sources of uncertainty in the traffic model. There is a degree of overlap between larger light goods vehicles and smaller heavy goods vehicles, and it is possible that on some roads in the city centre area the proportion of HDVs is being slightly overestimated, resulting in higher emissions and a tendency for the model to overpredict.

Localised congestion associated with some areas of the city centre may also not be well represented in a macro scale model of this nature.

The topography of the roads in this locality is also likely to contribute, where several carriageways operate in parallel at varying heights, which cannot always be well represented in the dispersion model, potentially leading to the slight over-estimate of emissions at a given location.

6.5.1.2 A55

The area of the model domain to the south-west of the A55 Stockman's Lane / Kennedy Way. Unadjusted modelled NO_2 concentrations in this zone were, on average, found to underestimate monitored NO_2 concentrations. This underestimation may again be due to uncertainties in the traffic model, as road traffic is the predominant contributing source. Uncertainties include the proportion of HDVs, vehicle speeds, and the factoring up of peak hour flows to AADT. Traffic in this area is likely to be more transient in nature than is seen in the city centre.

6.5.1.3 Airport Zone

The area along the A2 Sydenham bypass corridor encompassing residential properties and premises to the south-east of the A2. The unadjusted model appeared to perform quite differently at monitoring locations along the A2, near to the carriageway and the rail station at Sydenham. The main contributing sources to modelled concentrations are road traffic, the railway and the airport. The land-based operations of the airport have a very localised effect, which may be impacting verification in this location. There is also the change that the Harbour operations influence the modelled concentrations along this stretch, which again would not strongly influence other areas across the rest of the city.

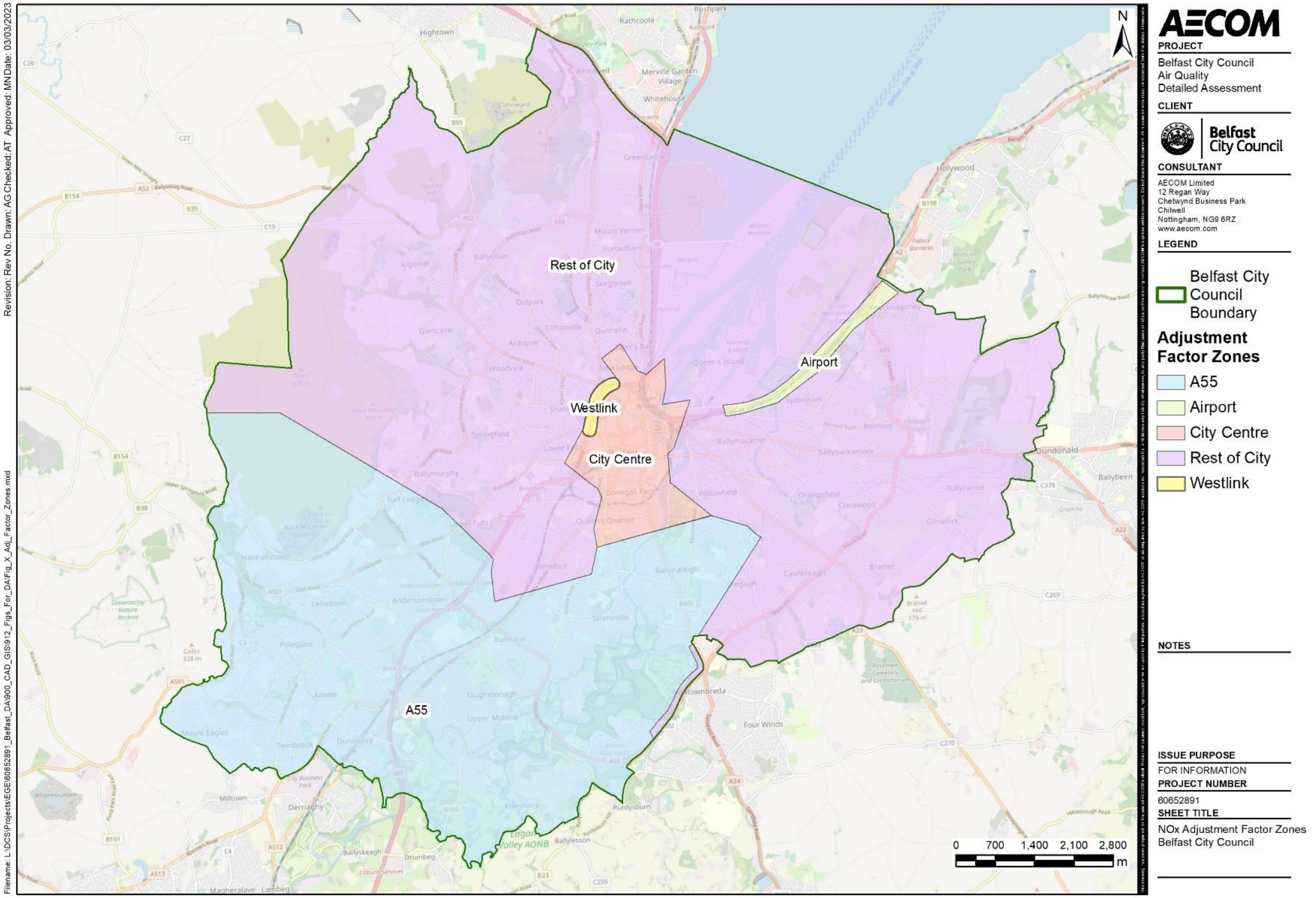
6.5.1.4 Westlink Zone

The area along the Westlink corridor between the Divis Street / Westlink junction and just east of the Clifton Street / Westlink junction. Due to the canyon-like nature of this section of the Westlink, a separate verification zone was defined to account for the relative difference in height between the Westlink carriageway and adjacent monitoring locations and sensitive receptors. Modelled concentrations are dominated by road traffic contributions in this zone with minor contributions from other modelled sources,

6.5.1.5 Rest of the City Zone

All other areas of the model domain. Within this zone, the unadjusted model showed a tendency to slightly underpredict monitored NO_2 concentrations. Again, with road traffic being the predominant source, it is likely that the underestimate is related to traffic data uncertainties and the difficulties with determining appropriate HDV proportions and vehicle speeds for some road links.

Figure 6-2. Map of Model Verification Zones for NO_2



For the city centre zone (see Table 6-3), prior to adjustment the model showed a tendency to over-predict NO_2 concentrations by approximately 10% on average. An adjustment factor of 0.80 was calculated for this zone. After the adjustment of model outputs by this factor, the model showed a good agreement with measured NO_2 concentrations with no tendency to under-predict or over-predict (Fractional Bias very close to 0). Post-adjustment, all modelled concentrations were within ±25% of the corresponding measured concentrations, and 15 out of 16 locations were within ±10%. The Root Mean Squared Error (RMSE) was 2.4 μg/m^3, which illustrates acceptable model performance as per LAQM.TG(22)[12].

Table 6-3. Comparison of Modelled and Measured NO_2 Annual Mean Concentrations in 2019 – City Centre Zone

Site ID	Site Type	NO_2 Concentration (μg/m^3)			% Difference (Unadjusted Modelled vs. Measured)	% Difference (Adjusted Modelled vs. Measured)
		Monitored	Modelled (Unadjusted)	Modelled (Adjusted)		
Belfast Ormeau Rd AURN	Roadside	24.0	28.4	26.2	+18.5	+9.0
61 Cromac Street	Roadside	36.0	**41.3**	37.9	+14.7	+5.2
Queens Bridge	Roadside	27.0	32.1	29.1	+18.7	+7.9
Donegall Square South	Roadside	32.0	34.7	32.4	+8.3	+1.3
Albert Clock	Roadside	**40.0**	36.5	33.9	-8.8	-15.2
College Square East	Roadside	33.0	34.4	31.2	+4.2	-5.5
Creche on M1/Westlink	Roadside	28.0	32.3	29.5	+15.4	+5.3
Queens Square	Roadside	34.0	**40.7**	37.3	+19.6	+9.8
North Queen Street	Roadside	33.0	35.2	32.0	+6.8	-3.0
Portland Place	Roadside	30.0	34.8	31.6	+16.0	+5.5
Sailortown	Roadside	28.0	29.6	27.4	+5.6	-2.2
Ravenhill Road	Roadside	28.0	28.1	25.9	+0.5	-7.4
Cromac & Ormeau Avenue	Kerbside	31.0	35.6	33.2	+14.8	+7.1
Little Georges Street	Roadside	33.0	38.1	34.3	+15.3	+4.0
Great Georges Street	Kerbside	**45.0**	**47.0**	**41.8**	+4.5	-7.2
Shaftesbury Square	Kerbside	31.0	34.9	31.8	+12.5	+2.5

Exceedances of the annual mean AQO level of 40 μg/m^3 are shown in ***bold***

For the A55 zone (see Table 6-4), prior to adjustment the model showed a tendency to under-predict NO_2 concentrations by approximately 34% on average. An adjustment factor of 2.38 was calculated for this zone. After the adjustment of model outputs by this factor, the model showed a good agreement with measured NO_2 concentrations with no tendency to under-predict or over-predict (Fractional Bias very close to 0). Post-adjustment, modelled NO_2 concentrations were within ±25% of the corresponding measured concentrations at all of the 13 monitoring locations within this zone, and 9 of those 13 locations within ±10%. The RMSE was 3.3 μg/m^3, which illustrates acceptable model performance.

Table 6-4. Comparison of Modelled and Measured Annual Mean NO_2 Concentrations in 2019 – A55 Zone

Site ID	Site Type	NO_2 Concentration (µg/m^3)			% Difference (Unadjusted Modelled vs. Measured)	% Difference (Adjusted Modelled vs. Measured)
		Monitored	Modelled (Unadjusted)	Modelled (Adjusted)		
Blacks Road	Roadside	**42.0**	24.2	**40.9**	-42.4	-2.7
301 Ormeau Road	Roadside	30.0	20.3	29.8	-32.3	-0.7
Malone Road	Roadside	31.0	19.7	32.3	-36.4	+4.2
Ormeau Road (junction with Ravenhill Road)	Roadside	36.0	20.5	32.6	-43.0	-9.4
Poleglass	Roadside	24.0	15.2	21.9	-36.6	-8.8
Dunmurry Lane	Roadside	26.0	14.9	21.1	-42.6	-18.8
Diamond Gardens	Roadside	24.0	18.1	27.2	-24.5	+13.2
Orpen Road	Roadside	18.0	14.5	19.0	-19.4	+5.8
Balmoral Avenue	Roadside	39.0	22.4	36.3	-42.5	-6.9
Belfast Stockmans Lane AURN	Roadside	**45.0**	25.8	**43.2**	-42.8	-4.1
Ardmore Park	Roadside	30.0	22.8	36.7	-23.9	+22.3
Falls Road and Andersonstown	Roadside	27.0	17.6	24.6	-34.9	-8.8
Lisburn Road	Roadside	27.0	20.5	32.0	-24.2	+18.3

Exceedances of the annual mean AQO level of 40 µg/m^3 are shown in ***bold***

For the Airport zone (see Table 6-5), prior to adjustment the model showed a tendency to over-predict NO_2 concentrations by approximately 22% on average. An adjustment factor of 0.62 was calculated for this zone. After the adjustment of model outputs by this factor, the model showed a good agreement with measured NO_2 concentrations with no tendency to under-predict or over-predict (Fractional Bias very close to 0). Post-adjustment, modelled NO_2 concentrations were within ±6% of the corresponding measured concentrations at both monitoring locations within this zone, and RMSE was 1.1 µg/m^3, illustrating good model performance.

Table 6-5. Comparison of Modelled and Measured Annual Mean NO_2 Concentrations in 2019 – Airport Zone

Site ID	Site Type	NO_2 Concentration (µg/m^3)			% Difference (Unadjusted Modelled vs. Measured)	% Difference (Adjusted Modelled vs. Measured)
		Monitored	Modelled (Unadjusted)	Modelled (Adjusted)		
Station Road	Roadside	22.0	27.9	23.2	+26.6	+5.5
N8	Roadside	25.6	30.0	24.6	+17.2	-3.9

For the Westlink zone (see Table 6-6), prior to adjustment the model showed a tendency to under-predict NO_2 concentrations by approximately 21% on average. An adjustment factor of 1.60 was calculated for this zone. After the adjustment of model outputs by this factor, the model showed a good agreement with measured NO_2 concentrations with no tendency to under-predict or over-predict (Fractional Bias very close to 0). Post-adjustment, modelled NO_2 concentrations were within ±2% of the corresponding measured concentrations at the 3 monitoring locations within this zone, and RMSE was 0.5 µg/m^3, illustrating good model performance.

Table 6-6. Comparison of Modelled and Measured Annual Mean NO_2 Concentrations in 2019 – Westlink Zone

Site ID	Site Type	NO_2 Concentration (µg/m^3)			% Difference (Unadjusted Modelled vs. Measured)	% Difference (Adjusted Modelled vs. Measured)
		Monitored	Modelled (Unadjusted)	Modelled (Adjusted)		
Peters Hill	Roadside	**40.0**	31.6	39.9	-21.1	-0.2
Henry Place	Roadside	**53.0**	40.9	**52.4**	-22.8	-1.2
N10	Roadside	**50.3**	39.9	**51.0**	-20.6	+1.4

Exceedances of the annual mean AQO level of 40 µg/m^3 are shown in ***bold***

For the Rest of the City zone (see Table 6-7), prior to adjustment the model showed a tendency to under-predict NO_2 concentrations by approximately 12% on average. An adjustment factor of 1.28 was calculated for this zone. After the adjustment of model outputs by this factor, the model showed a good agreement with measured NO_2 concentrations with no tendency to under-predict or over-predict (Fractional Bias very close to 0). Post-adjustment, modelled NO_2 concentrations were within ±25% of the corresponding measured concentrations at all of the 15 monitoring locations within this zone, and within ±10% at 11 locations. The RMSE was 3.3 µg/m^3, which illustrates acceptable model performance.

Table 6-7. Comparison of Modelled and Measured Annual Mean NO_2 Concentrations in 2019 – Rest of the City Zone

Site ID	Site Type	NO_2 Concentration (µg/m^3)			% Difference (Unadjusted Modelled vs. Measured)	% Difference (Adjusted Modelled vs. Measured)
		Monitored	Modelled (Unadjusted)	Modelled (Adjusted)		
Belfast Ballyhackamore AURN	Roadside	27.0	23.8	26.8	-12.0	-0.9
Belfast Westlink Roden Street AURN	Roadside	34.0	30.6	34.6	-10.0	+1.7
Knock Road	Roadside	35.0	24.9	28.7	-29.0	-18.0
Glenmachan Street	Roadside	38.0	30.5	34.5	-19.7	-9.2
Upper Newtownards Road & Holywood Road	Roadside	27.0	28.9	32.3	+7.1	+19.5
Crumlin Road	Roadside	27.0	24.2	26.5	-10.4	-2.0
228 Antrim Road	Roadside	31.0	24.1	26.8	-22.3	-13.5
Shore Road (Ivan Street end)	Roadside	30.0	28.7	32.1	-4.3	+7.1
York Street	Roadside	36.0	34.7	39.5	-3.7	+9.7
Opposite Westlink AQMS	Roadside	**45.0**	40.0	**46.0**	-11.2	+2.3
RVH Falls Road	Roadside	33.0	24.4	26.8	-26.2	-18.9
Tates Avenue	Roadside	27.0	23.1	25.2	-14.4	-6.6
N1	Roadside	20.3	19.1	21.3	-6.1	+4.9
Donegall Road	Kerbside	31.0	28.8	31.5	-7.2	+1.5
Short Strand	Roadside	**40.0**	37.0	**42.1**	-7.5	+5.3

Exceedances of the annual mean AQO level of 40 µg/m^3 are shown in ***bold***

The adjustment factors and corresponding model performance statistics for NO_2 are summarised in Table 6-8.

Table 6-8. Summary of Model Verification for NO_2

Zone	Adjustment Factor	RMSE	Fractional Bias	Model Predictions		
				±10%	±25%	>±25%
City Centre	0.80	2.4	<0.01	15	1	0
A55	2.38	3.3	<0.01	9	4	0
Airport	0.62	1.1	<0.01	2	0	0
Westlink	1.60	0.5	<0.01	3	0	0
Rest of the City	1.28	3.3	<0.01	11	4	0

6.5.2 PM_{10} Verification

Four monitoring sites were included in the verification process for PM_{10} and four sites were excluded due to being urban background locations. Initially, the model predictions showed very good agreement with monitored PM_{10} concentrations with agreement between modelled and measured concentrations within ±25% at all four sites.

For PM_{10} (see Table 6-9), the model did not exhibit any evident difference in performance across the model domain and so zoning was considered unnecessary. A single adjustment factor of 1.04 was calculated. Post-adjustment, modelled PM_{10} concentrations were within ±25% of the corresponding measured concentrations at all four PM_{10} monitoring locations, and within ±10% at three of these locations. The RMSE was 1.5 μg/m^3 and Fractional Bias was very close to zero, illustrating good model performance and a tendency to neither over-predict nor under-predict PM_{10} concentrations.

Table 6-9. Comparison of Modelled and Measured Annual Mean PM_{10} Concentrations

Site ID	Site Type	PM_{10} Concentration (μg/m^3)			% Difference (Unadjusted Modelled vs. Measured)	% Difference (Adjusted Modelled vs. Measured)
		Monitored	Modelled (Unadjusted)	Modelled (Adjusted)		
Belfast Stockmans Lane AURN	Roadside	18.0	15.4	15.5	-14.5	-14.1
N1	Roadside	15.4	16.1	16.1	+4.2	+4.6
N8	Roadside	17.2	17.1	17.2	-0.3	+0.2
N10	Roadside	18.5	19.7	19.8	+6.2	+6.8

The adjustment factor and corresponding model performance statistics for PM_{10} are summarised in Table 6-10.

Table 6-10 . Summary of Model Verification for PM_{10}

Adjustment Factor	RMSE	Fractional Bias	Model Predictions		
			±10%	±25%	>±25%
1.04	1.5	<0.01	3	1	0

6.5.3 $PM_{2.5}$ Verification

For $PM_{2.5}$, the model verification factor for PM_{10} was applied. Three suitable $PM_{2.5}$ monitoring locations were identified for inclusion in the verification process; however, the monitored $PM_{2.5}$ concentrations for two of these locations were lower than Defra background $PM_{2.5}$ concentrations. This would have resulted in a negative adjustment factor and a subsequent subtraction of modelled $PM_{2.5}$, which is not considered appropriate. Use of the PM_{10} verification factor represents a conservative approach and will result in higher modelled $PM_{2.5}$ concentrations.

7. Dispersion Modelling Results

7.1 Baseline 2019

7.1.1 Nitrogen Dioxide

7.1.1.1 Sensitive Receptors

Annual mean NO_2 concentrations have been predicted at 1,797 sensitive receptor locations. Table 7-1 shows the 24 receptors with predicted 2019 annual mean NO_2 concentrations greater than 40 µg/m^3 and therefore likely to be locations of exceedance of the UK annual mean NO_2 AQO. A map of these receptors is shown in Figure 7-1.

The highest predicted annual mean NO_2 concentration in 2019 is 55.9 µg/m^3 at Receptor ID DO 969 located next to Stockmans Lane. This receptor is a residential property located at Stockmans Lane within AQMA 1.

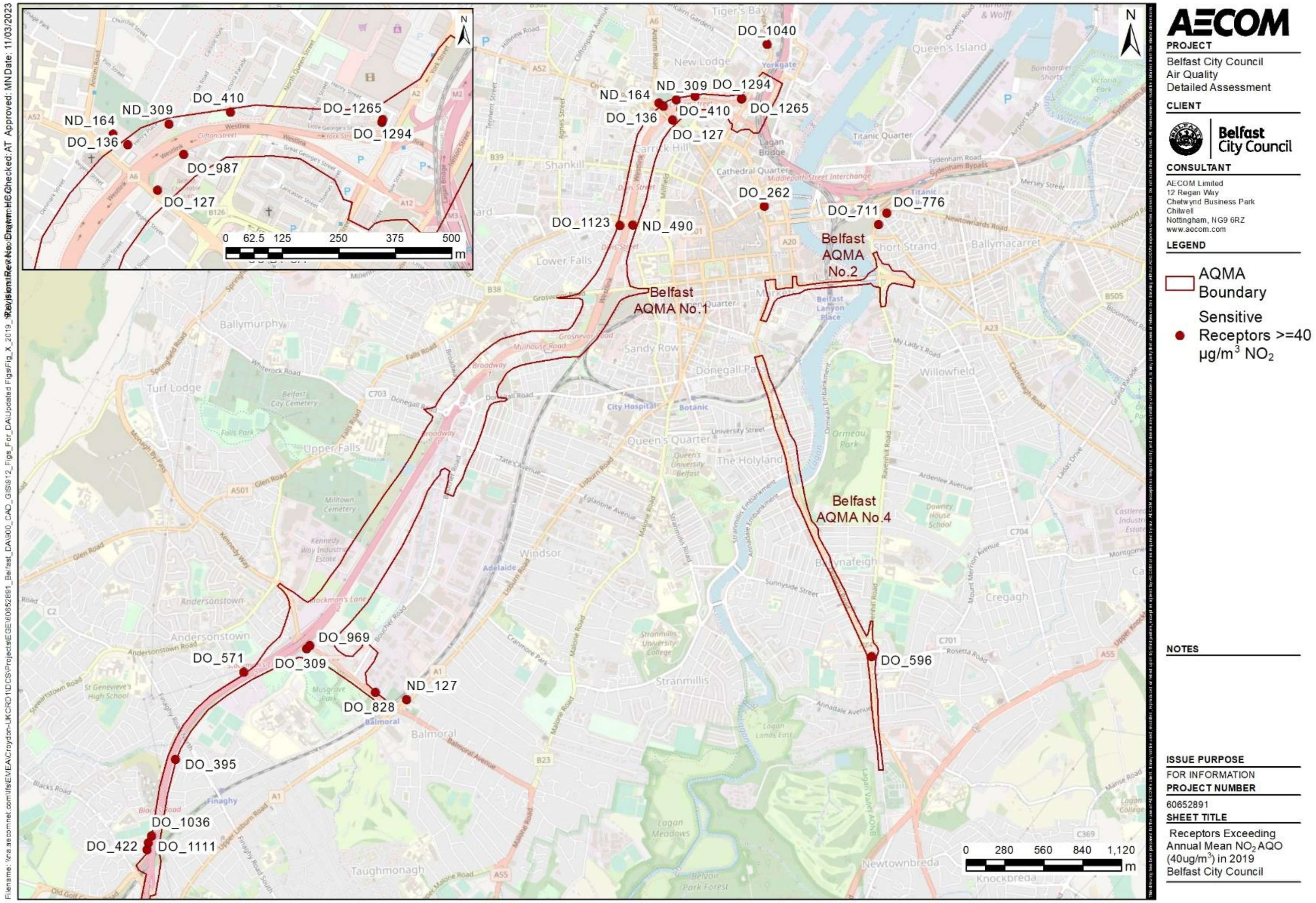
LAQM.TG(22) states that the hourly mean NO_2 objective is unlikely to be exceeded if annual mean concentrations are less than 60 µg/m^3. The assessment, therefore, evaluates the likelihood of exceeding the hourly mean NO_2 objective by comparing predicted annual mean NO_2 concentrations at all receptors to an annual mean equivalent threshold of 60 µg/m^3 NO_2. As the predicted concentrations are below this value for all receptors in 2019, it can be concluded that the hourly mean NO_2 objective (200 µg/m^3 NO_2 not to be exceeded more than 18 times per year) is likely to have been achieved. It should be noted that the council's automatic nitrogen dioxide monitoring site at Stockmans Lane has not recorded exceedances of the hourly mean NO_2 objective (200 µg/m^3 NO_2 not to be exceeded more than 18 times per year) since 2012, when the corresponding annual mean (to date) was 58 µg/m^3.

There are a further 41 receptors that have predicted concentrations of less than 40 µg/m^3 but greater than 36 µg/m^3, and there is a chance of exceedance for these receptors within the uncertainties of the model.

Table 7-1. Sensitive Receptors with Predicted 2019 Annual Mean NO_2 Concentrations >40 µg/m^3

Receptor ID	Location	Annual Mean NO_2 Concentration (µg/m^3)
DO_969	Stockmans Lane (AQMA 1)	55.9
DO_309	Stockmans Lane (AQMA 1)	52.0
DO_127	Clifton House Mews (AQMA 1)	46.1
DO_1265	Molyneaux Street (AQMA 1)	46.1
DO_410	Cu Chulainn House (AQMA 1)	46.0
DO_987	Clifton House Mews (AQMA 1)	45.5
ND_309	Henry Place (AQMA 1)	45.1
DO_136	Henry Place (AQMA 1)	44.9
DO_1036	St Anne's Close (near AQMA 1)	44.9
DO_1294	Molyneaux Street (AQMA 1)	43.7
ND_490	Divis Street / Westlink (AQMA 1)	43.0
DO_422	St Anne's Crescent (near AQMA 1)	42.6
DO_571	Owenvarragh Park (near AQMA 1)	42.4
ND_127	Kingsbridge Private Hospital (near AQMA 1)	42.1
DO_1111	St Anne's Close (near AQMA 1)	42.0
ND_164	Clifton Street (AQMA 1)	41.8
DO_395	Northlands Park (AQMA 1)	41.2
DO_828	Stockmans Lane (AQMA 1)	40.9
DO_711	A23 Short Strand (near AQMA 2)	40.8
DO_596	Northlands Park (AQMA 1)	40.8
DO_1123	Divis Street / Westlink (AQMA 1)	40.6
DO_262	Queen's Square	40.5
DO_776	Strand Close	40.4
DO_1040	York Street	40.3

Figure 7-1. Location of Sensitive Receptors with Predicted 2019 Annual Mean NO_2 Concentrations >40 µg/m^3



7.1.1.2 AQMA 1 - M1 Motorway / A12 Westlink Corridor.

Predicted 2019 annual mean NO_2 concentrations within and around AQMA 1 are shown in Figure 7-2. It can be seen that exceedance areas (where predicted NO_2 concentrations are greater than the UK AQO of 40 µg/m^3) are largely within the existing extents of AQMA 1.

The highest concentrations are predicted near to Junction 3 of the M1 and at the northern end of Westlink around the A12 / M2 / M3 interchange. In these locations there are small areas where the predicted annual mean NO_2 concentrations exceeds 60 µg/m^3; however, these are areas within the road carriageway boundaries and there is no relevant human health exposure.

There are a number of locations where the 40 µg/m^3 contour extends outside the existing AQMA boundary:

- An area around the A12 / M2 / M3 interchange, extending northwards along the M2, encompassing short sections of Brougham Street, Dock Street, York Street and Nelson Street, and southwards along the M3;
- Clifton Street between Carlisle Circus and the Donegall Street / Clifton Street junction, and part of North Queen Street;
- A small area covering the rail corridor adjacent to the Westlink, near to Weaver's Business Park and Blythefield Park;
- A small area near to Balmoral rail station, covering the intersection of Stockmans Lane and Lisburn Road; and
- Areas adjacent to the M1 corridor between Junction 2 and Junction 3, including Appleton Park, short sections of Finaghy Road North, Woodland Grange and St. Anne's Lane / St. Anne's Close, and a small section of Black's Road and A512 Old Golf Course Road around M1 Junction 3.

The area of exceedance near to Weaver's Business Park and Blythefield Park does not include any locations of relevant exposure, but the other exceedance areas do include one or more locations of relevant human health exposure where the UK AQOs apply. Within the uncertainties of the model, these areas of exceedance outside of the existing AQMA boundaries are not considered to warrant any amendment to the AQMA boundary at this time. However, it is recommended that identification of relevant human health exposure and consideration of the consequent need for additional monitoring is carried out in these areas to verify the model predictions and to determine whether there is a likelihood of exceedance of the NO_2 UK AQOs.

7.1.1.3 AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road.

Predicted 2019 annual mean NO_2 concentrations within and around AQMA 2 are shown in Figure 7-3. NO_2 concentrations within the extents of AQMA 2 are largely below the annual mean NO_2 AQO. However, there is one small exceedance area (where predicted NO_2 concentrations are greater than the UK AQO of 40 µg/m^3) near to the Cromac Street / East Bridge Street junction, extending northwards along Cromac Street.

The exceedance area extends slightly beyond the existing AQMA boundary but encompasses predominantly commercial properties and areas where there is no relevant human health exposure. Within the uncertainties of the model, it is considered that these areas of exceedance do not warrant any amendment to the AQMA boundary at this time. It is recommended that identification of relevant human health exposure and consideration of the consequent need for additional monitoring is carried out in this area to verify the model predictions and to determine whether there is a likelihood of exceedance of the NO_2 UK AQOs.

Two additional exceedance areas are predicted to the north of AQMA 2, along Short Strand between the junctions with Mountpottinger Link, and around the Bridge End / Middlepath Street / Short Strand junction. These exceedance areas cover residential properties in Lough Lea and Strand Close. It is recommended therefore that additional monitoring is carried out in these areas to verify the model predictions and confirm whether there is a likelihood of exceedance of the NO_2 UK AQOs. On the basis of additional NO_2 monitoring, the boundary of AQMA 2 may need to be amended subsequently to cover these locations.

7.1.1.4 AQMA 3 - Upper Newtownards Road.

Predicted 2019 annual mean NO_2 concentrations within and around AQMA 3 are shown in Figure 7-4. NO_2 concentrations within the extents of AQMA 3 are below the annual mean NO_2 AQO at all locations. This is supported by the results of recent years' monitoring at locations within AQMA 3 (e.g. Upper Newtownards Road AQMS). Within the uncertainties of the model, it is considered that concentrations within AQMA 3 are below the NO_2 UK AQOs at locations of relevant exposure and the AQMA should be revoked subject to a continuation of monitored NO_2 concentrations below the NO_2 UK AQOs at locations within AQMA 3.

7.1.1.5 AQMA 4 - Ormeau Road.

Predicted 2019 annual mean NO_2 concentrations within and around AQMA 4 are shown in Figure 7-5. NO_2 concentrations within the extents of AQMA 4 are largely below the annual mean NO_2 AQO, with two very small exceedance areas (where predicted NO_2 concentrations are greater than the UK AQO of 40 µg/m^3) near to the Ormeau Road / Ravenhill Road junction. However, these areas are wholly within the road carriageway and do not cover any locations of relevant exposure.

Within the uncertainties of the model, it is considered that concentrations within AQMA 4 are below the NO_2 UK AQOs at locations of relevant exposure and the AQMA should be revoked subject to a continuation of monitored NO_2 concentrations below the NO_2 UK AQOs at locations within AQMA 4.

7.1.1.6 City-wide grid

City-wide predicted 2019 annual mean NO_2 concentrations are shown in Figure 7-6. As discussed in the previous AQMA-specific sections, it can be seen that predicted NO_2 concentrations exceeding the annual mean NO_2 UK AQO are largely confined to the existing AQMAs 1 and 2, with a small number of areas of exceedance outside the boundaries of AQMA 1, near to the A12 / M2 / M3 interchange and along the A12 / M1 route corridor. Elsewhere predicted NO_2 concentrations are generally below 40 µg/m^3.

The corresponding WHO AQG for annual mean NO_2 concentrations is 10 µg/m^3. With the exception of the rural areas in the western part of the BCC administrative area, predicted annual mean NO_2 concentrations exceed this AQG throughout the city.

Figure 7-2. Modelled 2019 Annual Mean NO_2 Concentrations Contour Plot AQMA 1 - M1 Motorway / A12 Westlink Corridor.

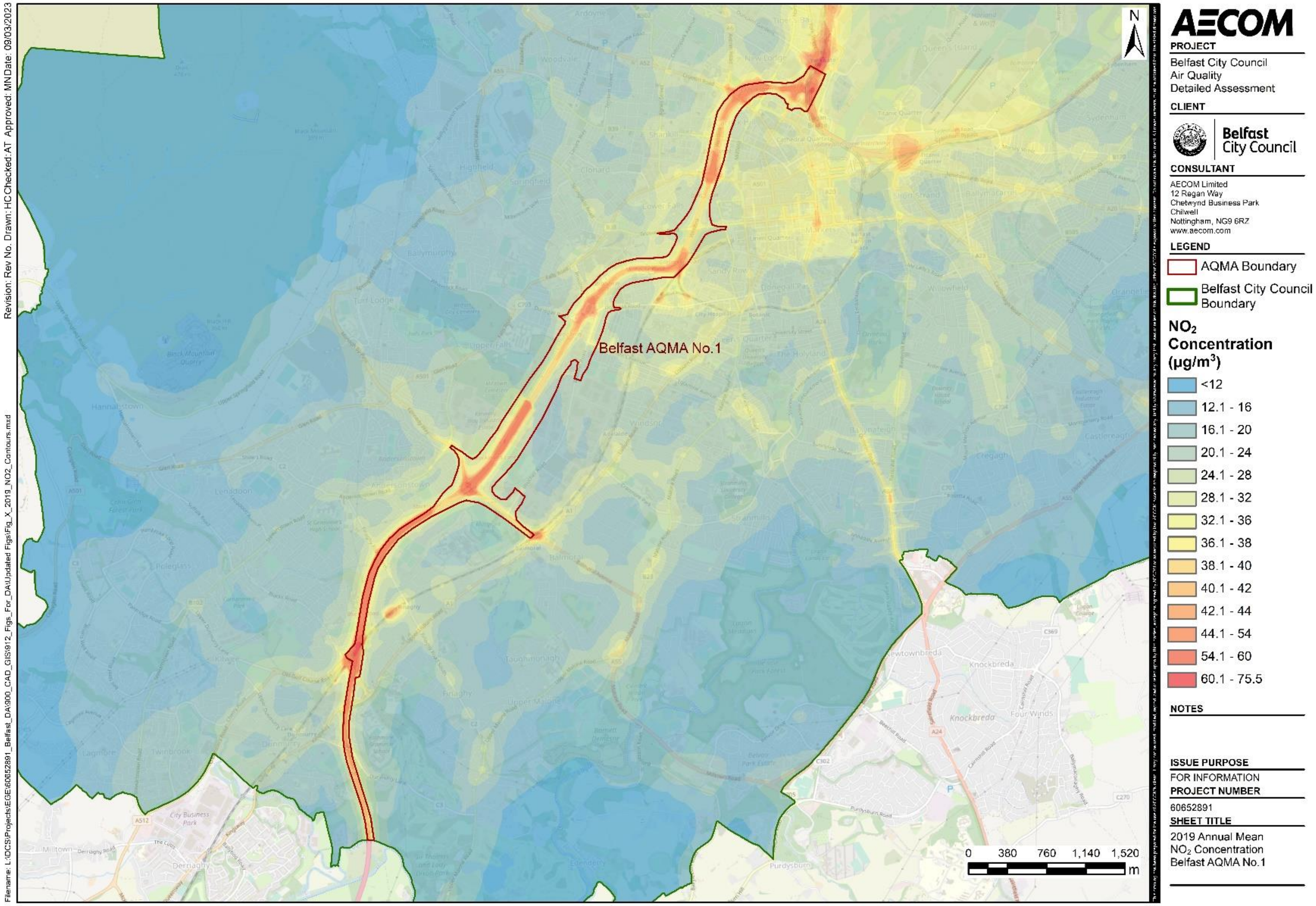


Figure 7-3. Modelled 2019 Annual Mean NO_2 Concentrations Contour Plot AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

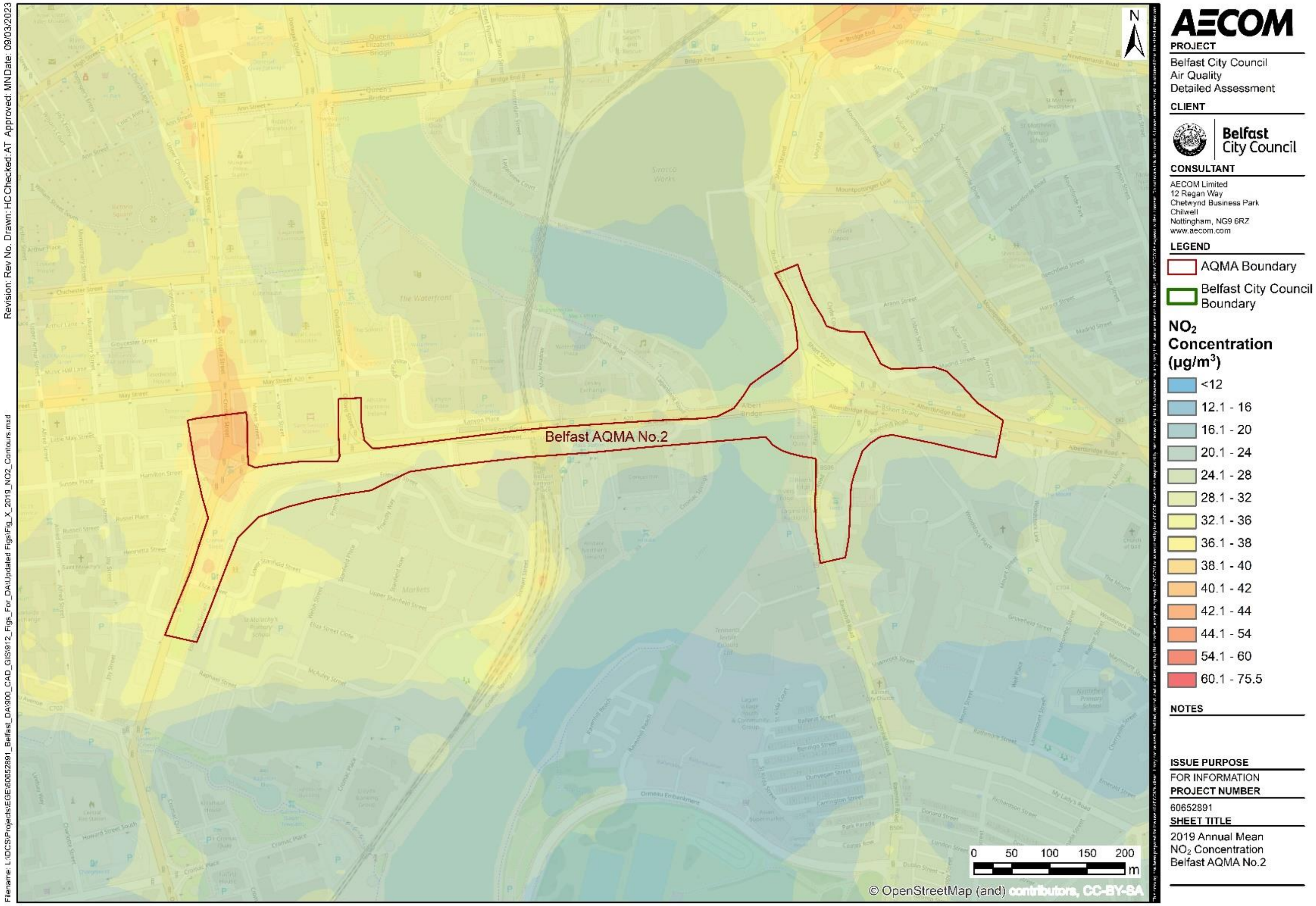


Figure 7-4. Modelled 2019 Annual Mean NO_2 Concentrations Contour Plot AQMA 3 - Upper Newtownards Road

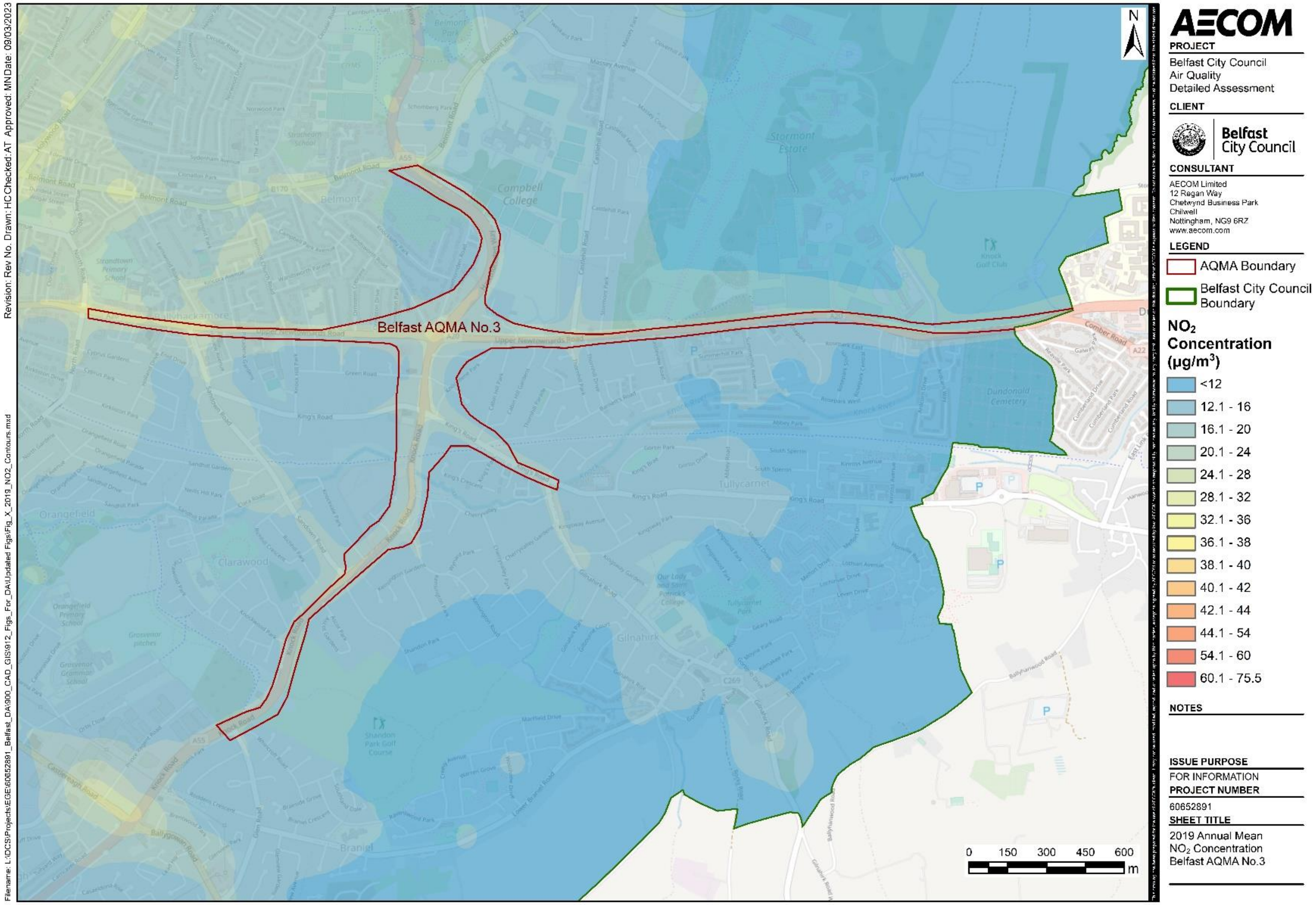


Figure 7-5. Modelled 2019 Annual Mean NO_2 Concentrations Contour Plot AQMA 4 – Ormeau Road

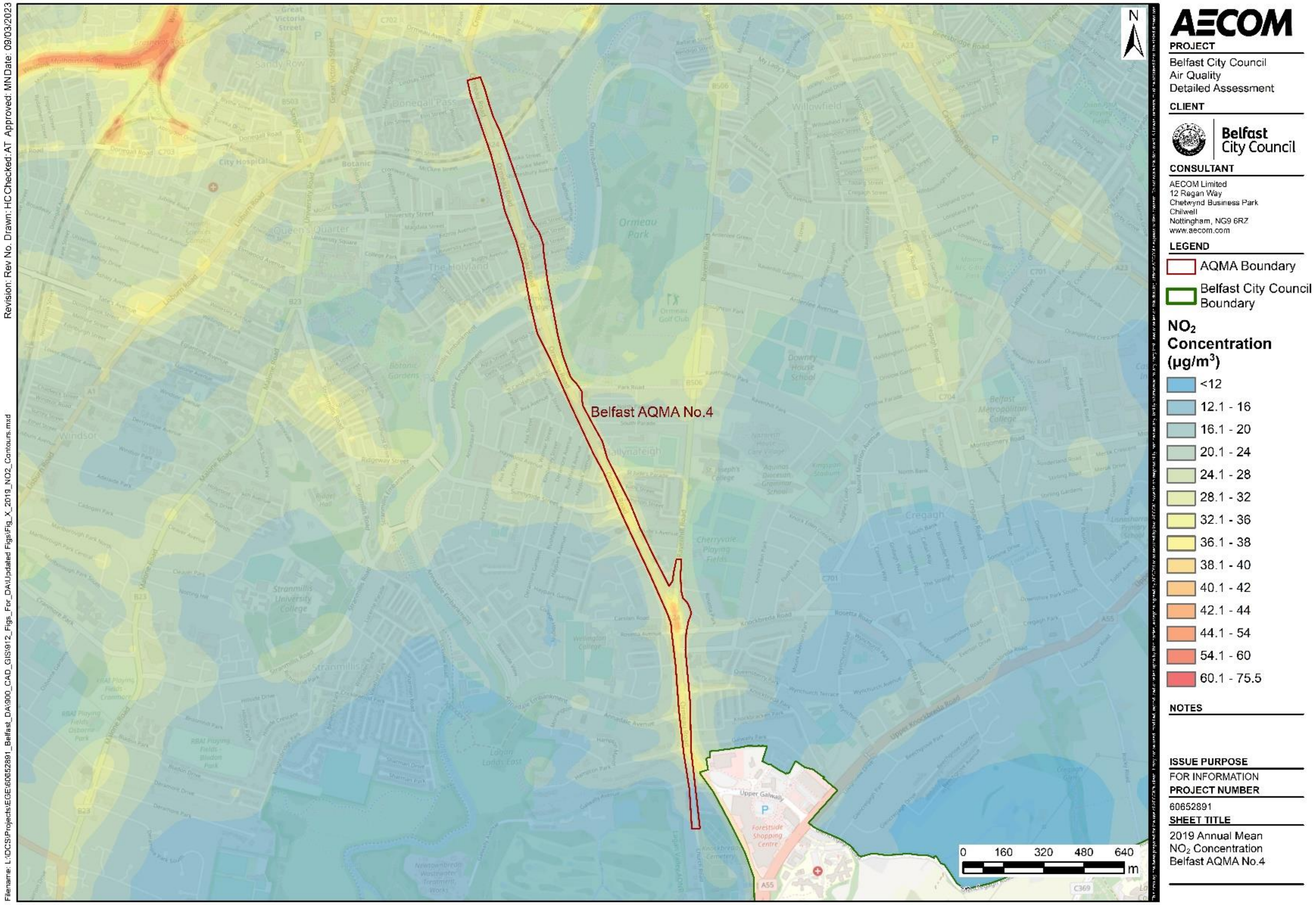
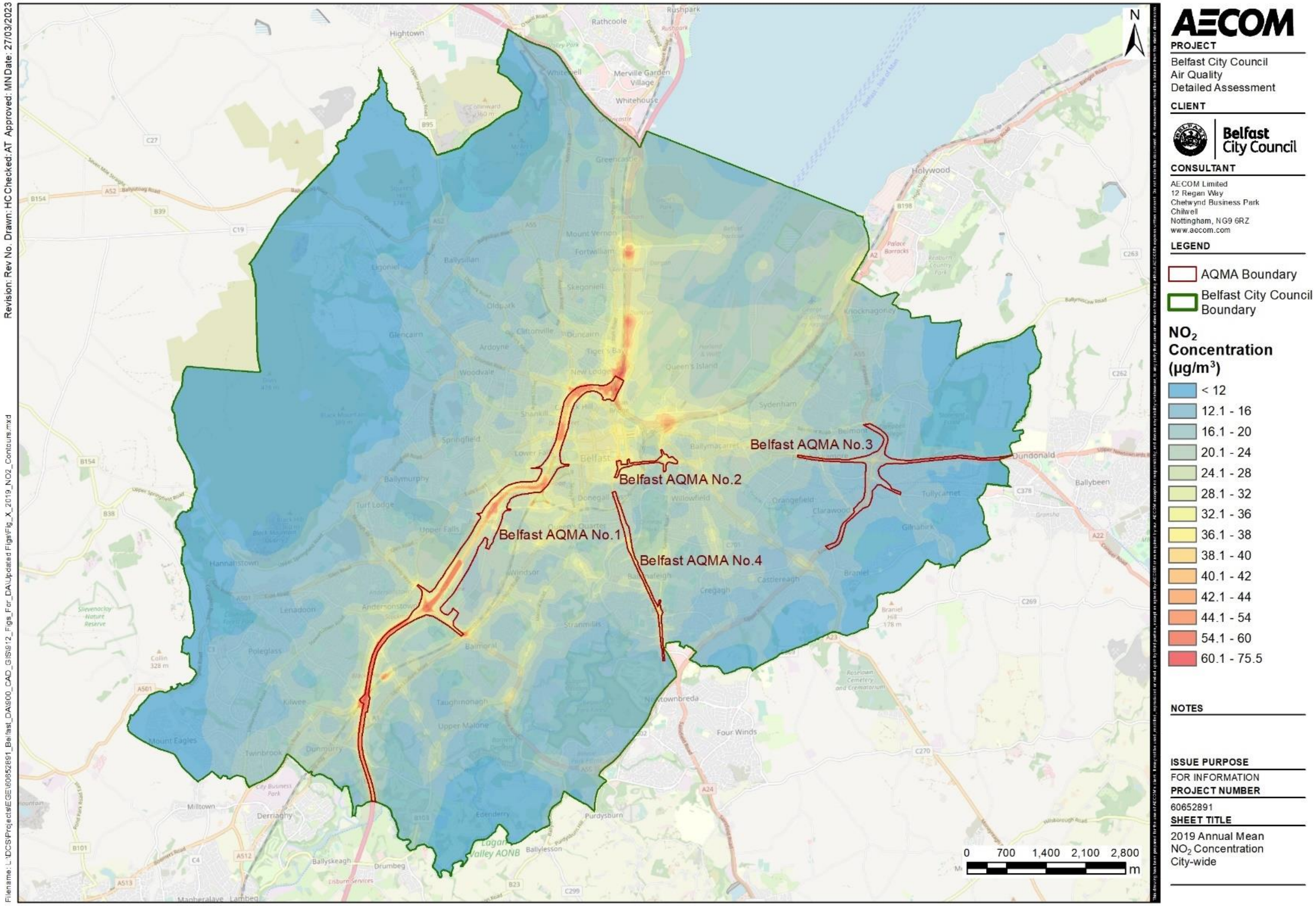


Figure 7-6. City-wide Modelled 2019 Annual Mean NO_2 Concentrations Contour Plot



7.1.2 PM_{10}

7.1.2.1 Sensitive Receptors

There are no sensitive receptor locations where predicted 2019 annual mean PM_{10} concentrations are greater than 40 µg/m^3 and therefore it is unlikely that there are any areas of exceedance of the UK annual mean PM_{10} AQO. The receptors with the ten highest predicted annual mean PM_{10} concentrations are shown in Table 7-2. A map of these receptors is shown in Figure 7-7. All of the ten highest locations are located within the boundaries of AQMA 1.

The highest predicted annual mean PM_{10} concentration in 2019 is 21.2 µg/m^3 at Receptor ID ND_414. This receptor is an educational non-residential property located at Barrack Street in AQMA 1. The highest predicted PM_{10} concentration at a residential property is 20.7 µg/m^3 at Receptor ID DO_913, also at Barrack Street. Compared with the more stringent WHO annual mean PM_{10} AQG level of 15 µg/m^3, there are 1,100 receptor locations that have predicted annual mean PM_{10} concentrations in exceedance of this AQG level.

Based on the empirical relationship between annual mean PM_{10} concentrations and the number of exceedances of the 24-hour mean PM_{10} standard of 50 µg/m^3 described in section 6.4.2.2, it is estimated that there would be between 5 and 6 exceedance days at the sensitive receptor with the highest annual mean PM_{10} concentration (Receptor ND_414). This is well below the permitted 35 days of exceedance in order to achieve the AQO.

The receptors with the ten highest predicted 99th percentile of daily mean PM_{10} concentrations are presented in Table 7-3. It is shown that the WHO short-term PM_{10} AQG level (99th percentile of daily mean PM_{10} concentrations not to exceed 45 µg/m^3) is not predicted to be exceeded at any modelled sensitive receptor locations. The highest predicted 99th percentile of daily mean PM_{10} concentrations is 42.0 µg/m^3 at Receptor ID ND_414. This receptor is an educational property located at Barrack Street in AQMA 1. The highest predicted PM_{10} concentration at a residential property is 41.2 µg/m^3 at Receptor ID DO 913, also located in Barrack Street.

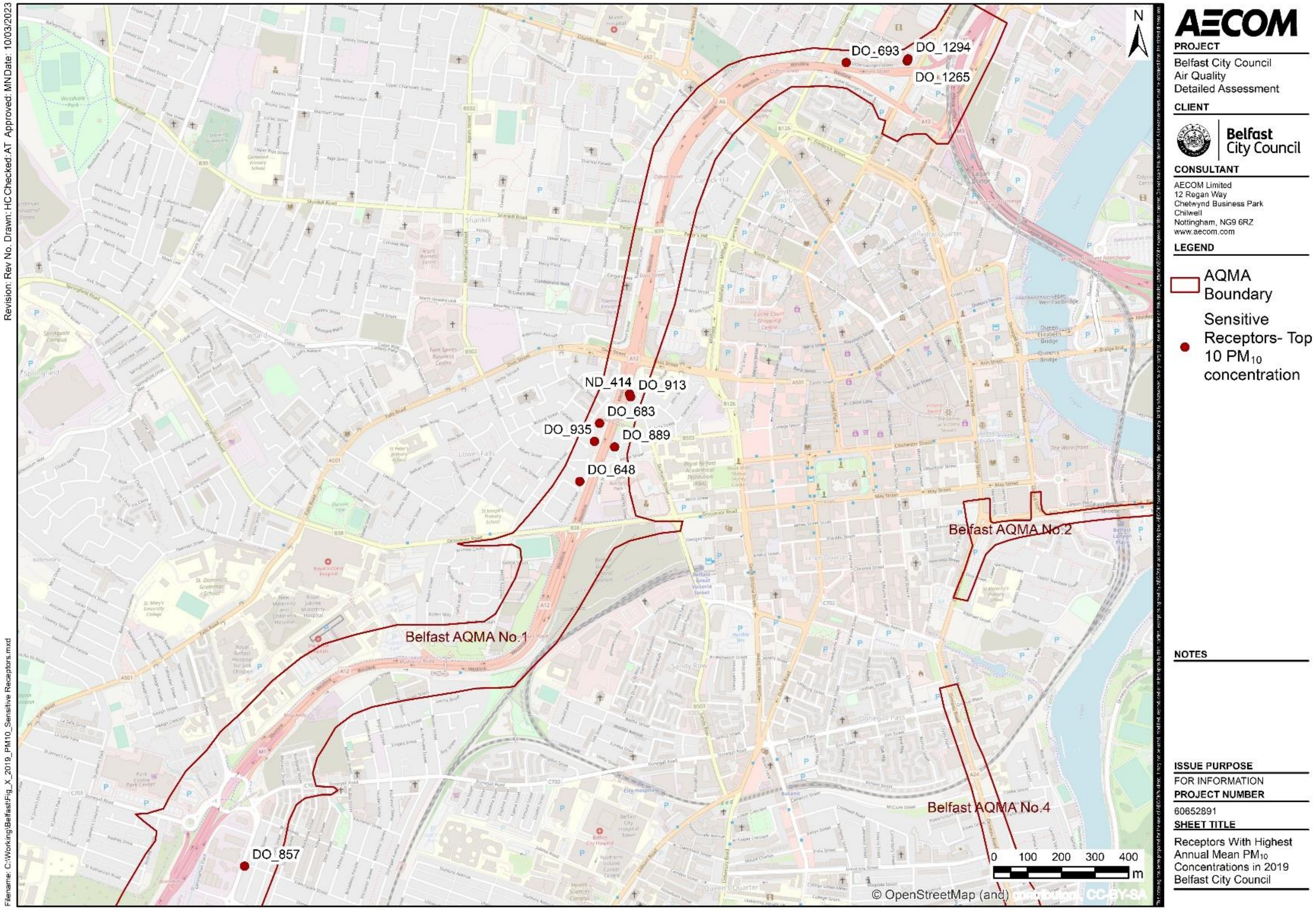
Table 7-2. Top 10 Sensitive Receptors with Highest 2019 Annual Mean PM_{10} Concentrations

Receptor ID	Location	Annual Mean PM_{10} Concentration (µg/m^3)
ND_414	Barrack Street (AQMA 1)	21.2
DO_913	Barrack Street (AQMA 1)	20.7
DO_693	Little Georges Street (AQMA 1)	20.4
DO_1265	Molyneaux Street (AQMA 1)	20.3
DO_889	Stanley Court (AQMA 1)	20.2
DO_648	Devonshire Place (AQMA 1)	20.1
DO_935	Cullingtree Road (AQMA 1)	20.1
DO_683	Cullingtree Road (AQMA 1)	20.0
DO_1294	Molyneaux Street (AQMA 1)	20.0
DO_857	Glenmachan Street (AQMA 1)	19.9

Table 7-3. Top 10 Sensitive Receptors with Highest 2019 99th Percentile of Daily Mean PM_{10} Concentrations

Receptor ID	Location	99th Percentile of Daily Mean PM_{10} Concentration (µg/m^3)
ND_414	Barrack Street (AQMA 1)	42.0
DO_913	Barrack Street (AQMA 1)	41.2
DO_1265	Molyneaux Street (AQMA 1)	41.1
DO_935	Cullingtree Road (AQMA 1)	40.7
DO_683	Cullingtree Road (AQMA 1)	40.7
DO_648	Devonshire Place (AQMA 1)	40.7
DO_1294	Molyneaux Street (AQMA 1)	40.6
DO_857	Glenmachan Street (AQMA 1)	40.4
DO_889	Stanley Court (AQMA 1)	40.3
DO_1286	Devonshire Place (AQMA 1)	40.3

Figure 7-7. Location of Top 10 Sensitive Receptors with Highest 2019 Annual Mean PM_{10} Concentrations



7.1.2.2 AQMA 1 - M1 Motorway / A12 Westlink Corridor.

Predicted 2019 annual mean PM_{10} concentrations within and around AQMA 1 are shown in Figure 7-8. It can be seen that predicted PM_{10} concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA 1.

The highest predicted PM_{10} concentrations of around 21 – 22 µg/m^3 are found near to the Broadway interchange (M1 Junction 1), around the M2 / M3 intersection, and along the Westlink near to the Divis Street / Westlink and A12 / Grosvenor Road junctions. The contour plot indicates that background PM_{10} concentrations represent a large proportion of the total modelled PM_{10} concentrations, as higher modelled concentrations coincide with locations where background concentrations are highest.

7.1.2.3 AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

Predicted 2019 annual mean PM_{10} concentrations within and around AQMA 2 are shown in Figure 7-9. It can be seen that predicted PM_{10} concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA 2. The highest predicted PM_{10} concentrations are approximately 18 – 19 µg/m^3 along East Bridge Street near to Belfast Lanyon Place Station and close to the East Bridge Street / Short Strand junction.

7.1.2.4 AQMA 3 - Upper Newtownards Road

Predicted 2019 annual mean PM_{10} concentrations within and around AQMA 3 are shown in Figure 7-10. It can be seen that predicted PM_{10} concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA. The highest predicted PM_{10} concentrations are approximately 18 µg/m^3 at the western end of the AQMA along Upper Newtownards Road, coinciding with the location where background PM_{10} concentrations are elevated.

7.1.2.5 AQMA 4 – Ormeau Road

Predicted 2019 annual mean PM_{10} concentrations within and around AQMA 4 are shown in Figure 7-11. It can be seen that predicted PM_{10} concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA 4. The highest predicted PM_{10} concentrations are approximately 17 µg/m^3 along the Ormeau Road corridor and near to the Ormeau Road / Ravenhill Road junction.

7.1.2.6 City-wide grid

City-wide predicted 2019 annual mean PM_{10} concentrations are shown in Figure 7-12. As discussed in the previous AQMA-specific sections, predicted annual mean PM_{10} concentrations are well below the UK AQOs throughout the city, with the highest concentrations towards the city centre area and near to the major road network.

Model predictions indicate that the WHO annual mean PM_{10} AQG level of 15 µg/m^3 is exceeded across much of the city centre area; background PM_{10} concentrations alone often approach or exceed the AQG level. Background sources of PM_{10} represent a large proportion of total modelled PM_{10} in many locations and the highest predicted PM_{10} concentrations generally coincide with locations where background concentrations are also elevated.

A more detailed examination of Defra background maps for 2019 indicate that, on average across the Belfast City Council area, secondary PM_{10} (4.6 µg/m^3) and Residual and Salt PM_{10} [37] (4.9 µg/m^3) collectively account for 9.5 µg/m^3 of ambient PM_{10}. The collective contribution of these two regional background components comprises 63% of the WHO annual mean PM_{10} AQG level of 15 µg/m^3 making attainment of this target very challenging.

Taking the maximum predicted annual mean PM_{10} concentration in the city to be around 21 µg/m^3, it is estimated that around 45% of ambient PM_{10} in Belfast is due to sources which BCC is unable to influence. As mentioned in Section 4.6, secondary PM_{10} is not emitted directly but is formed in the atmosphere through chemical and physical processes involving primary pollutants and other atmospheric constituents that may be emitted many kilometres upwind. Secondary pollutant contributions are very difficult to influence and control because their formation processes are complex and often poorly understood. Furthermore, due to the transboundary nature of air pollutants – in particular secondary pollutants – local action is unlikely to bring about the level of reduction in concentration required in order to achieve the WHO AQG level across the whole city. Contributions from sea salt and wind-blown dust/soils are natural sources of PM_{10}, which are also very difficult to influence.

[37] Sea salt, calcium and iron rich dusts and regional primary PM and residual non-characterised sources (residual is 1.0 µg/m^3). For further detail see https://laqm.defra.gov.uk/documents/2018-based-background-maps-user-guide-v1.0.pdf

Figure 7-8. Modelled 2019 Annual Mean PM_{10} Concentrations Contour Plot AQMA 1 - M1 Motorway / A12 Westlink Corridor.

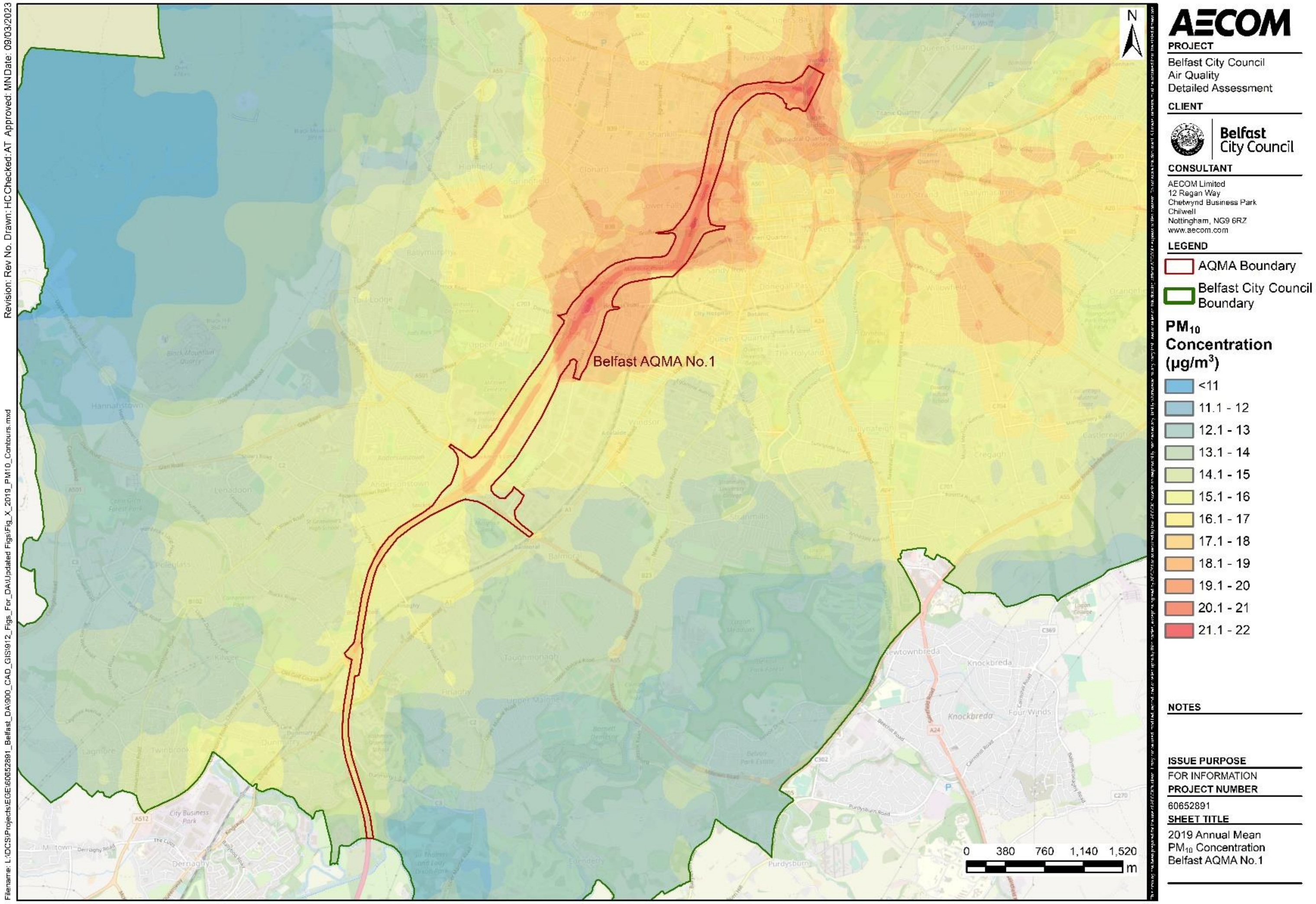


Figure 7-9. Modelled 2019 Annual Mean PM_{10} Concentrations Contour Plot AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

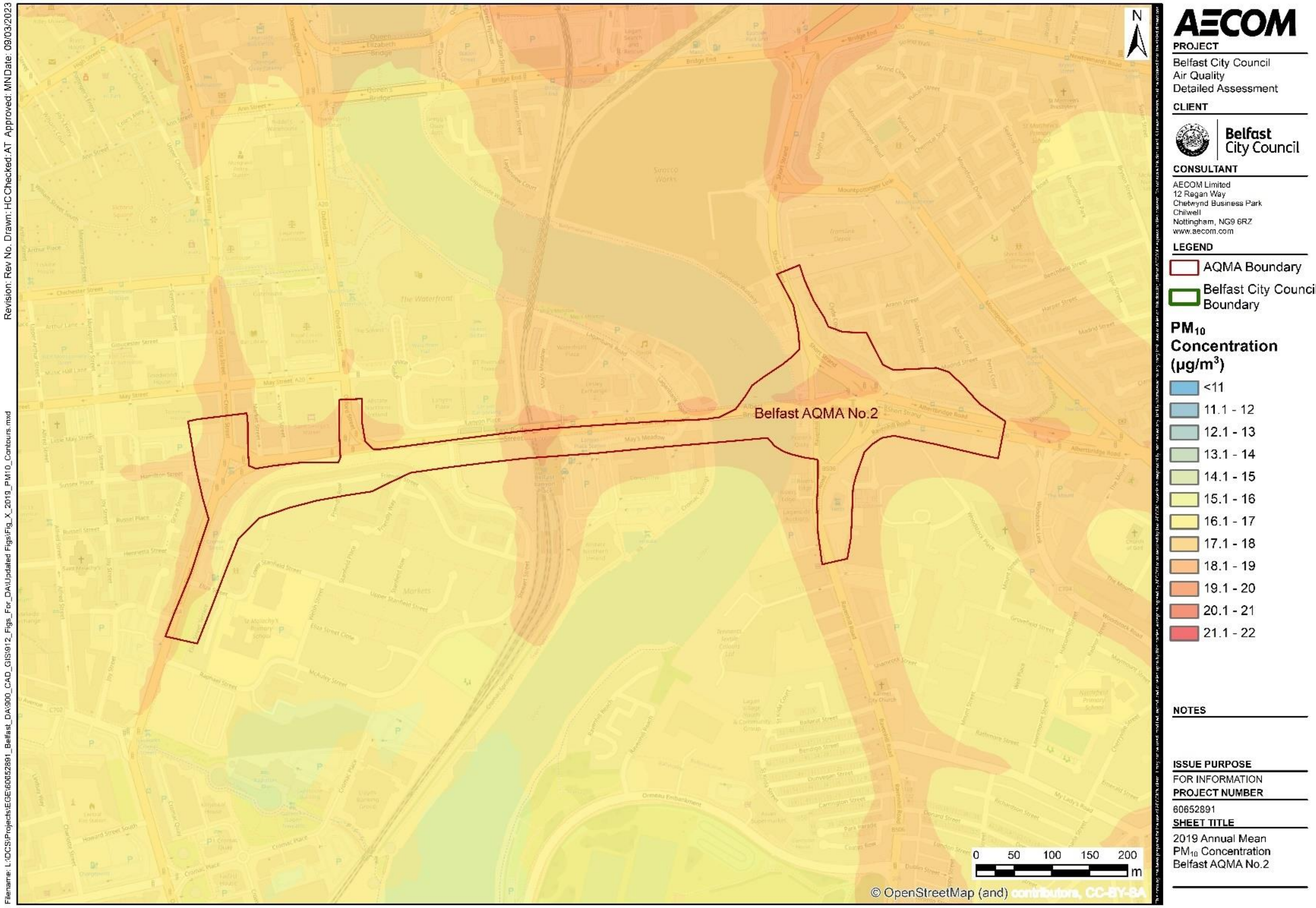


Figure 7-10. Modelled 2019 Annual Mean PM_{10} Concentrations Contour Plot AQMA 3 - Upper Newtownards Road

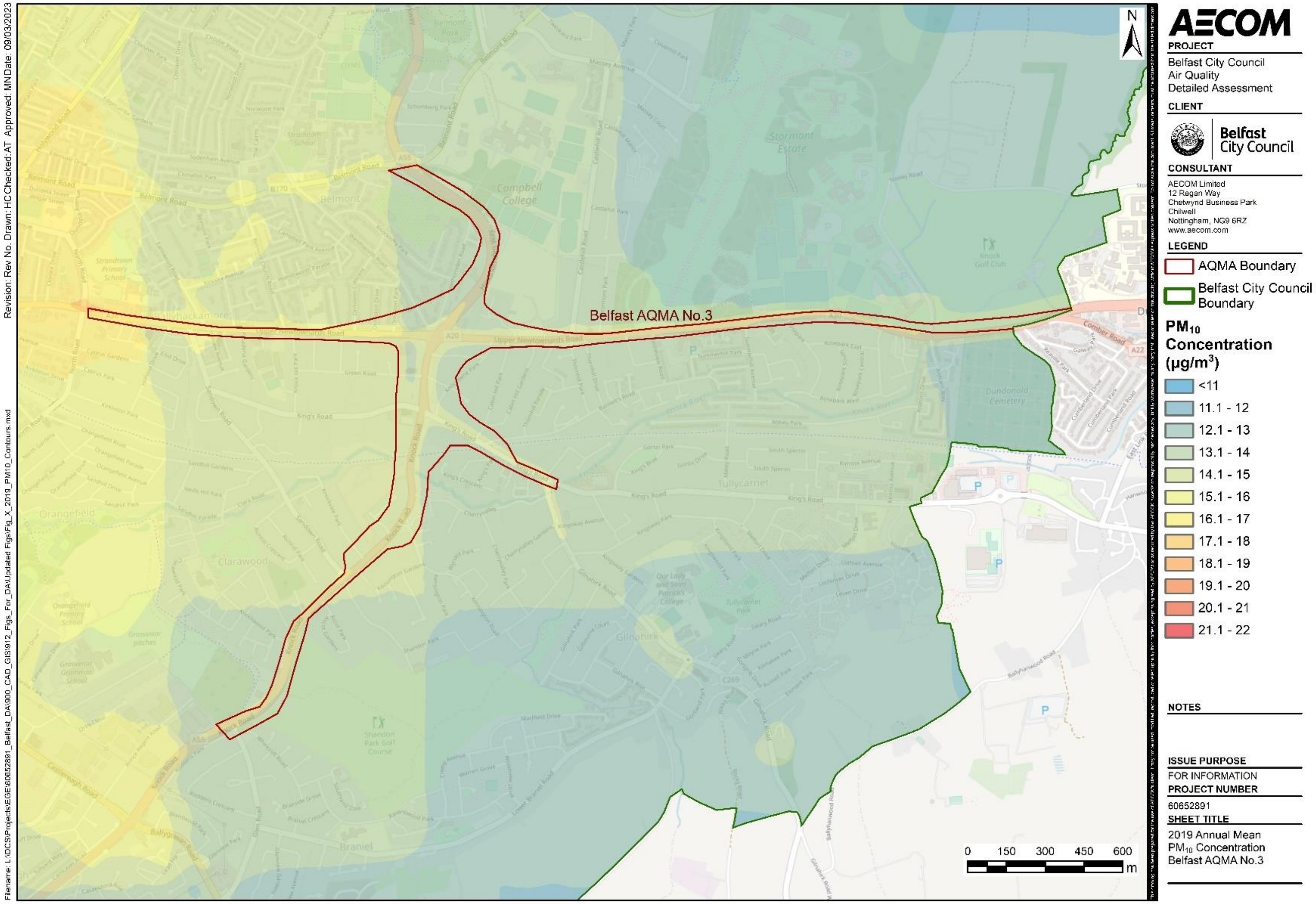


Figure 7-11. Modelled 2019 Annual Mean PM_{10} Concentrations Contour Plot AQMA 4 - Ormeau Road

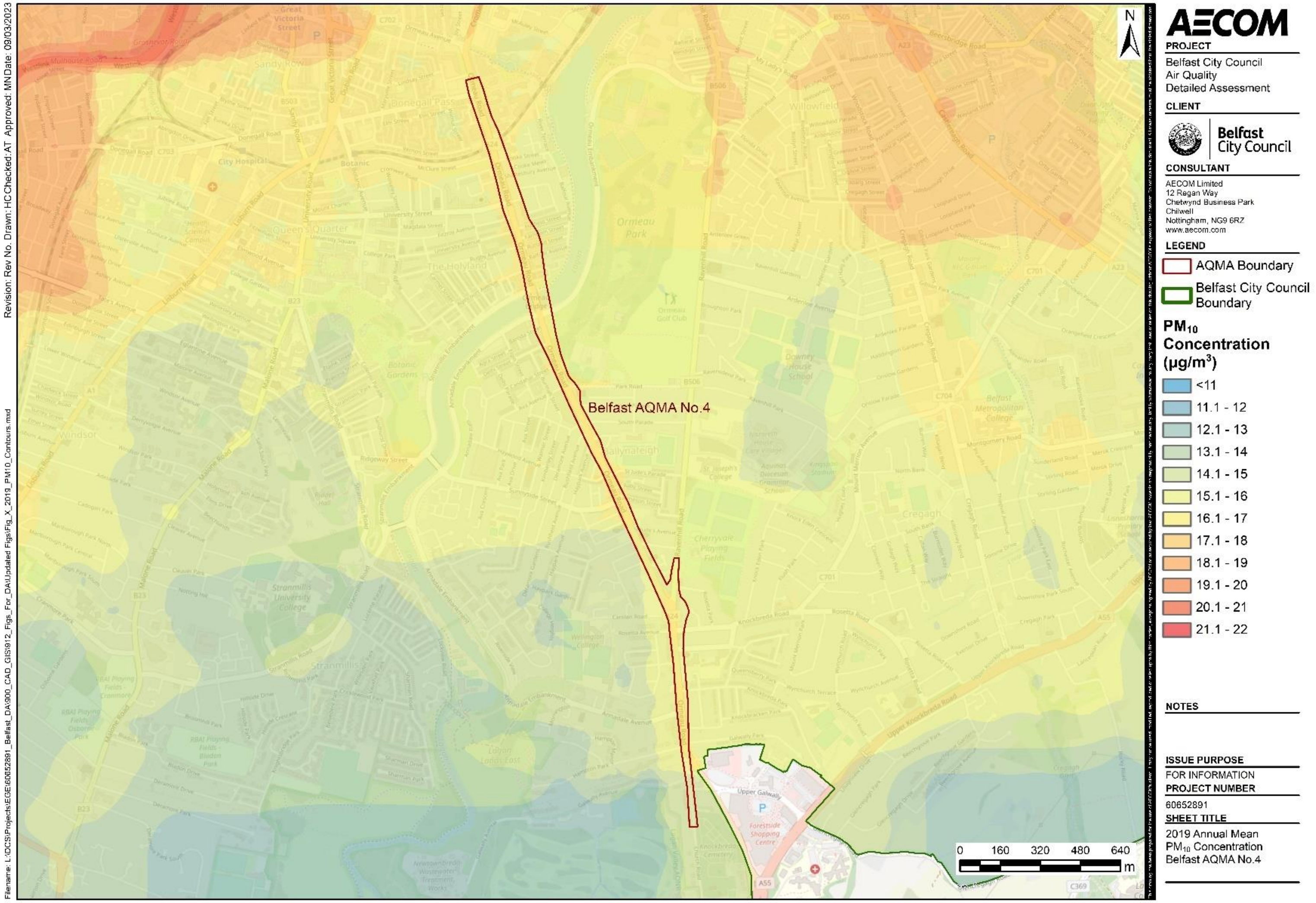
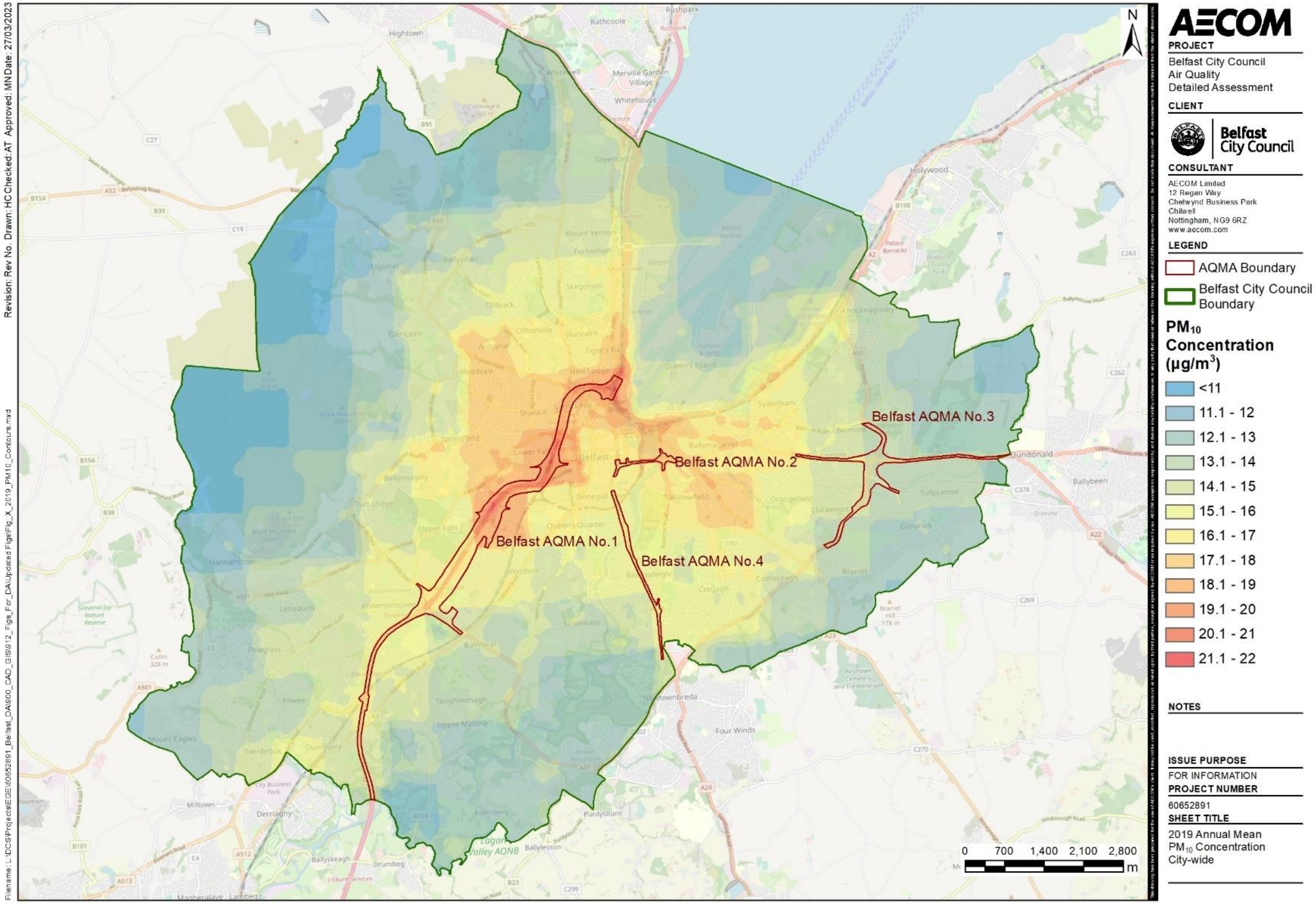


Figure 7-12. City-wide Modelled 2019 Annual Mean PM_{10} Concentrations Contour Plot



7.1.3 $PM_{2.5}$

7.1.3.1 Sensitive Receptors

There are no sensitive receptor locations where predicted 2019 annual mean $PM_{2.5}$ concentrations are greater than 20 µg/m^3 and therefore unlikely to be locations of exceedance of the UK annual mean $PM_{2.5}$ AQO. The receptors with the ten highest predicted annual mean $PM_{2.5}$ concentrations are shown in Table 7-4. A map of these receptors is shown in Figure 7-13. All of the ten highest locations are located within the boundaries of AQMA 1.

The highest predicted annual mean $PM_{2.5}$ concentration in 2019 is 14.1 µg/m^3 at Receptor ID ND 414. This receptor is an educational property located at Barrack Street near AQMA 1. The highest predicted $PM_{2.5}$ concentration at a residential property is 13.8 µg/m^3 at Receptor ID DO_913, also located in Barrack Street.

Compared with the much more stringent WHO annual mean $PM_{2.5}$ AQG level of 5 µg/m^3, all modelled receptors have predicted $PM_{2.5}$ concentrations of 5 µg/m^3 or higher. It should be noted that the lowest $PM_{2.5}$ background concentration at any location across the city in 2019 is 6.6 µg/m^3, which itself exceeds the AQG level of 5 µg/m^3.

The WHO short-term $PM_{2.5}$ AQG level (99th percentile of daily mean $PM_{2.5}$ concentrations not to exceed 15 µg/m^3) is predicted to be exceeded at all except one of the modelled sensitive receptor locations. The receptors with the ten highest predicted 99th percentile of daily mean $PM_{2.5}$ concentrations are presented in Table 7-5. The highest predicted 99th percentile of daily mean $PM_{2.5}$ concentrations is 28.0 µg/m^3 at Receptor ID ND 414. This receptor is an educational property located at Barrack Street in AQMA 1. The highest predicted 99th percentile of daily mean $PM_{2.5}$ concentrations at a residential property is 27.4 µg/m^3 at Receptor ID DO 857 located in Glenmachan Street. It should be noted, the background $PM_{2.5}$ contribution to the 99th percentile of daily mean $PM_{2.5}$ concentrations alone is greater than the WHO AQG level at most modelled locations.

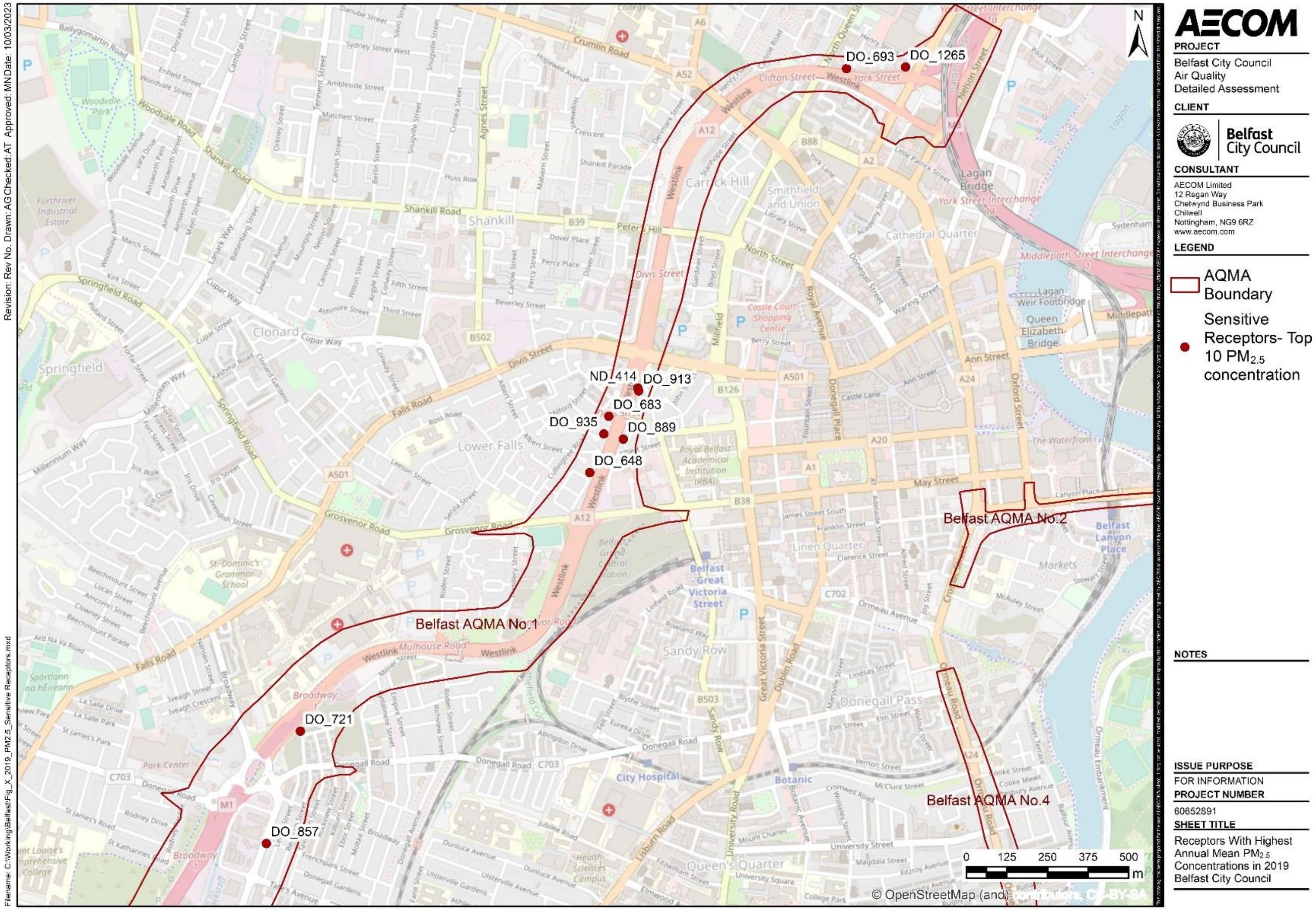
Table 7-4. Top 10 Sensitive Receptors with Highest 2019 Annual Mean $PM_{2.5}$ Concentrations

Receptor ID	Location	Annual Mean $PM_{2.5}$ Concentration (µg/m^3)
ND_414	Barrack Street (AQMA 1)	14.1
DO_913	Barrack Street (AQMA 1)	13.8
DO_857	Glenmachan Street (AQMA 1)	13.5
DO_1265	Molyneaux Street (AQMA 1)	13.5
DO_889	Stanley Court (AQMA 1)	13.5
DO_693	Little Georges Street (AQMA 1)	13.4
DO_721	Monarch Parade (AQMA 1)	13.4
DO_648	Devonshire Place (AQMA 1)	13.4
DO_935	Cullingtree Road (AQMA 1)	13.4
DO_683	Cullingtree Road (AQMA 1)	13.4

Table 7-5. Top 10 Sensitive Receptors with Highest 2019 99th Percentile of Daily Mean $PM_{2.5}$ Concentrations

Receptor ID	Location	99th Percentile of Daily Mean $PM_{2.5}$ Concentration (µg/m³)
ND_414	Barrack Street (AQMA 1)	28.0
DO_857	Glenmachan Street (AQMA 1)	27.4
DO_913	Barrack Street (AQMA 1)	27.4
DO_1265	Molyneaux Street (AQMA 1)	27.4
DO_683	Cullingtree Road (AQMA 1)	27.2
DO_935	Cullingtree Road (AQMA 1)	27.1
DO_648	Devonshire Place (AQMA 1)	27.1
DO_721	Monarch Parade (AQMA 1)	27.1
DO_1294	Molyneaux Street (AQMA 1)	27.0
DO_1286	Devonshire Place (AQMA 1)	26.9

Figure 7-13. Location of Top 10 Sensitive Receptors with Highest 2019 Annual Mean $PM_{2.5}$ Concentrations



7.1.3.2 AQMA1 - M1 Motorway / A12 Westlink Corridor.

Predicted 2019 annual mean $PM_{2.5}$ concentrations within and around AQMA 1 are shown in Figure 7-14. It can be seen that predicted $PM_{2.5}$ concentrations are below the UK AQO of 20 µg/m^3 at all locations in and around AQMA 1.

The highest predicted $PM_{2.5}$ concentrations of around 15 µg/m^3 are near to the Broadway interchange (M1 Junction 1) and along Westlink near to the A12 / A501 and A12 / Grosvenor Road junctions. The contour plot indicates that background $PM_{2.5}$ concentrations represent a large proportion of the total modelled $PM_{2.5}$ concentrations, as higher modelled concentrations coincide with locations where background concentrations are highest.

7.1.3.3 AQMA2 - Cromac Street, East Bridge Street and Albertbridge Road

Predicted 2019 annual mean $PM_{2.5}$ concentrations within and around AQMA 2 are shown in Figure 7-15. It can be seen that predicted $PM_{2.5}$ concentrations are well below the UK AQO of 20 µg/m^3 at all locations in and around AQMA 2. The highest predicted $PM_{2.5}$ concentrations are approximately 13 µg/m^3 along East Bridge Street and around the junction with Short Strand. There is also an area of slightly elevated $PM_{2.5}$ concentrations extending south along the rail network south of East Bridge Street.

7.1.3.4 AQMA3 - Upper Newtownards Road

Predicted 2019 annual mean $PM_{2.5}$ concentrations within and around AQMA 3 are shown in Figure 7-16. It can be seen that predicted $PM_{2.5}$ concentrations are well below the UK AQO of 20 µg/m^3 at all locations in and around AQMA 3. The highest predicted $PM_{2.5}$ concentrations are approximately 13 µg/m^3 at the western end of the AQMA along Upper Newtownards Road, coinciding with the location where background $PM_{2.5}$ concentrations are elevated.

7.1.3.5 AQMA4 - Ormeau Road

Predicted 2019 annual mean $PM_{2.5}$ concentrations within and around AQMA 4 are shown in Figure 7-17. It can be seen that predicted $PM_{2.5}$ concentrations are well below the UK AQO of 20 µg/m^3 at all locations in and around AQMA 4. The highest predicted $PM_{2.5}$ concentrations are approximately 12 µg/m^3 along the Ormeau Road corridor, coinciding with the locations where background $PM_{2.5}$ concentrations are elevated.

7.1.3.6 City-wide grid

City-wide predicted 2019 annual mean $PM_{2.5}$ concentrations are shown in Figure 7-18. As discussed in the previous AQMA-specific sections, predicted annual mean $PM_{2.5}$ concentrations are below the UK AQO throughout the city, with the highest concentrations towards the city centre area and near to the major road network.

Model predictions indicate that the WHO annual mean $PM_{2.5}$ AQG level of 5 µg/m^3 is exceeded across the whole of the city. This is because background $PM_{2.5}$ concentrations alone exceed the AQG level across the BCC area. Background sources of $PM_{2.5}$ appear to represent a large proportion of total modelled $PM_{2.5}$ in many locations and the highest predicted $PM_{2.5}$ concentrations generally coincide with locations where background concentrations are also elevated.

An examination of Defra background maps for 2019 indicate that, on average across the Belfast City Council area, secondary $PM_{2.5}$ (3.9 µg/m^3) and Residual and Salt $PM_{2.5}$ (1.8 µg/m^3) collectively account for 5.7 µg/m^3 of ambient $PM_{2.5}$. Taking the maximum predicted annual mean $PM_{2.5}$ concentration in the city to be around 14 µg/m^3, it is estimated that around 40% of ambient $PM_{2.5}$ in Belfast is due to sources which BCC is unable to influence. Furthermore, the collective contribution of these two regional background components exceeds the WHO annual mean $PM_{2.5}$ AQG level of 5 µg/m^3 making attainment of this target highly improbable.

Secondary $PM_{2.5}$ forms in the atmosphere through chemical and physical processes involving primary pollutants and other atmospheric constituents that may be emitted many kilometres upwind. Secondary pollutant contributions are very difficult to influence and control because their formation processes are complex and often poorly understood. Similarly, contributions from sea salt and wind-blown dust/soils are natural sources of $PM_{2.5}$ and thus very difficult to influence.

Figure 7-14. Modelled 2019 Annual Mean $PM_{2.5}$ Concentrations Contour Plot AQMA 1 - M1 Motorway / A12 Westlink Corridor.

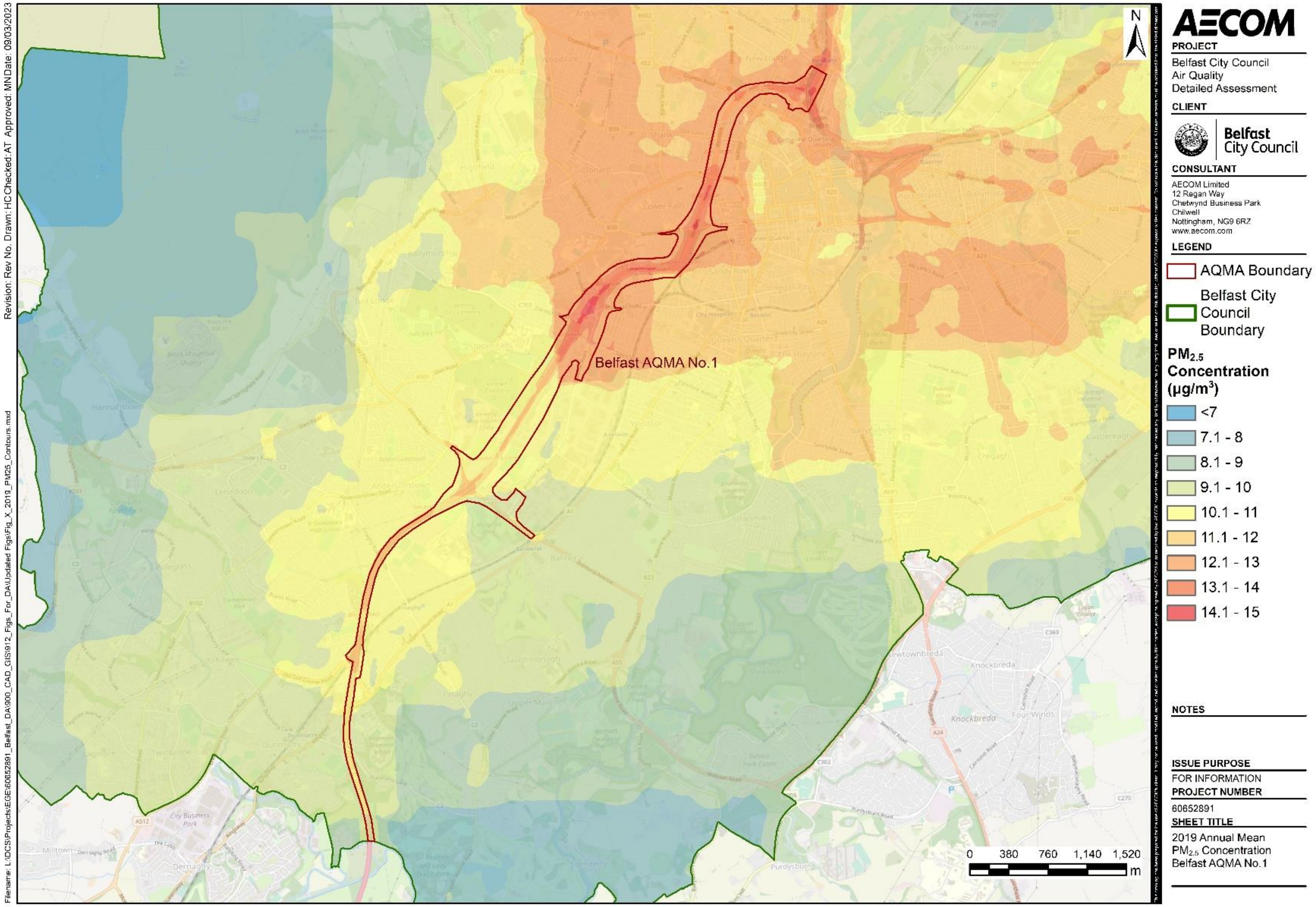


Figure 7-15. Modelled 2019 Annual Mean $PM_{2.5}$ Concentrations Contour Plot AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

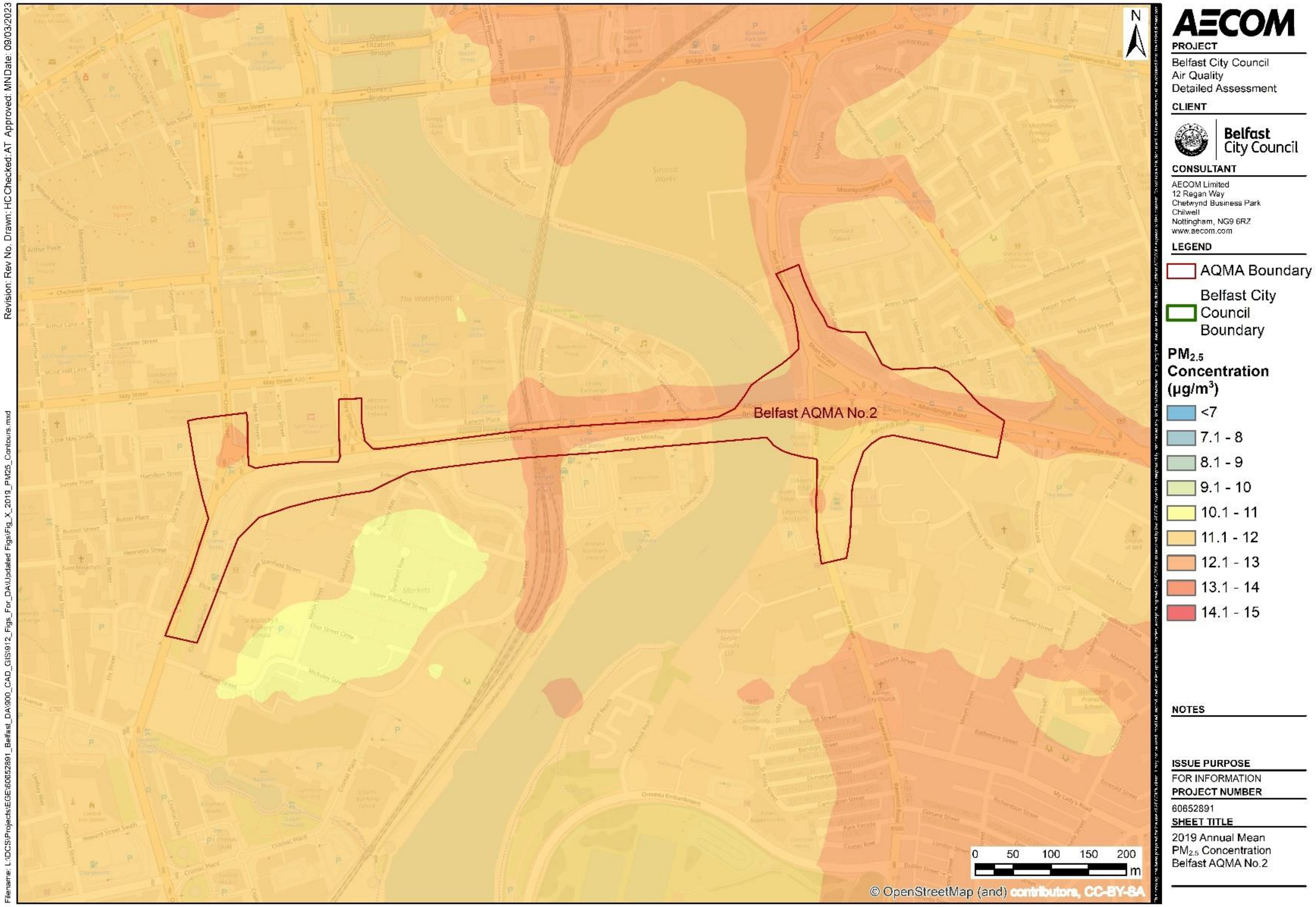


Figure 7-16. Modelled 2019 Annual Mean $PM_{2.5}$ Concentrations Contour Plot AQMA 3 - Upper Newtownards Road

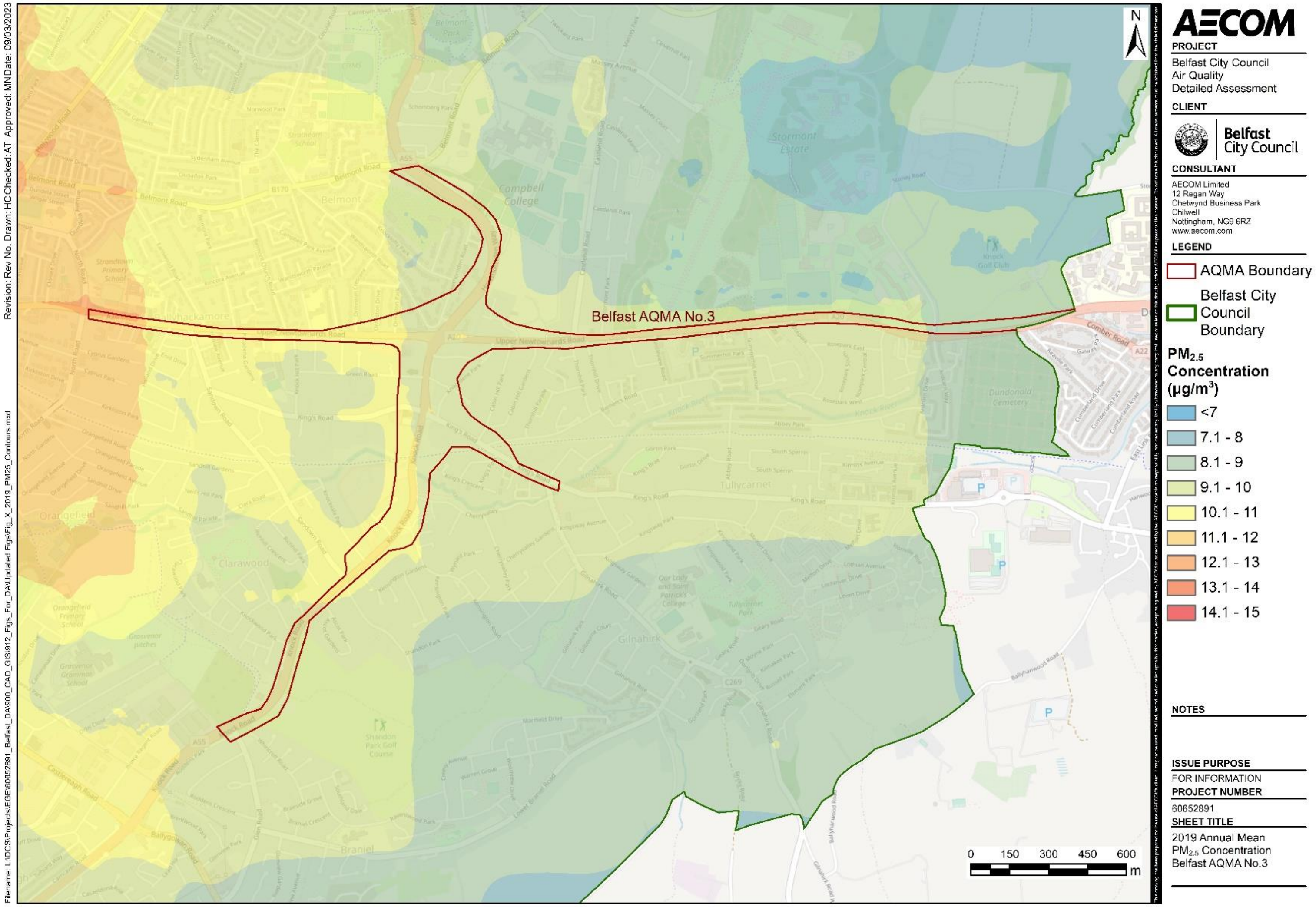


Figure 7-17. Modelled 2019 Annual Mean $PM_{2.5}$ Concentrations Contour Plot AQMA 4 - Ormeau Road

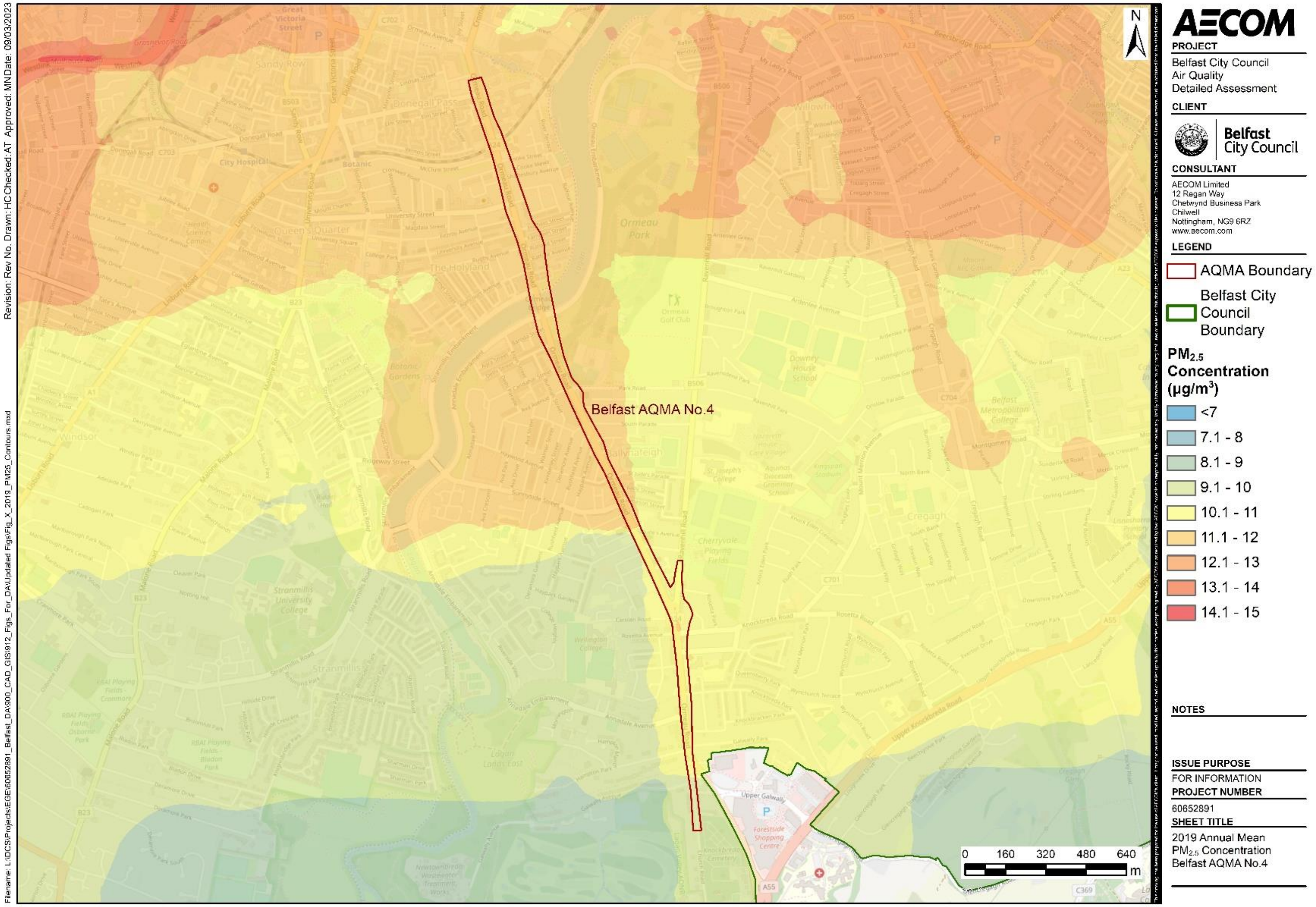
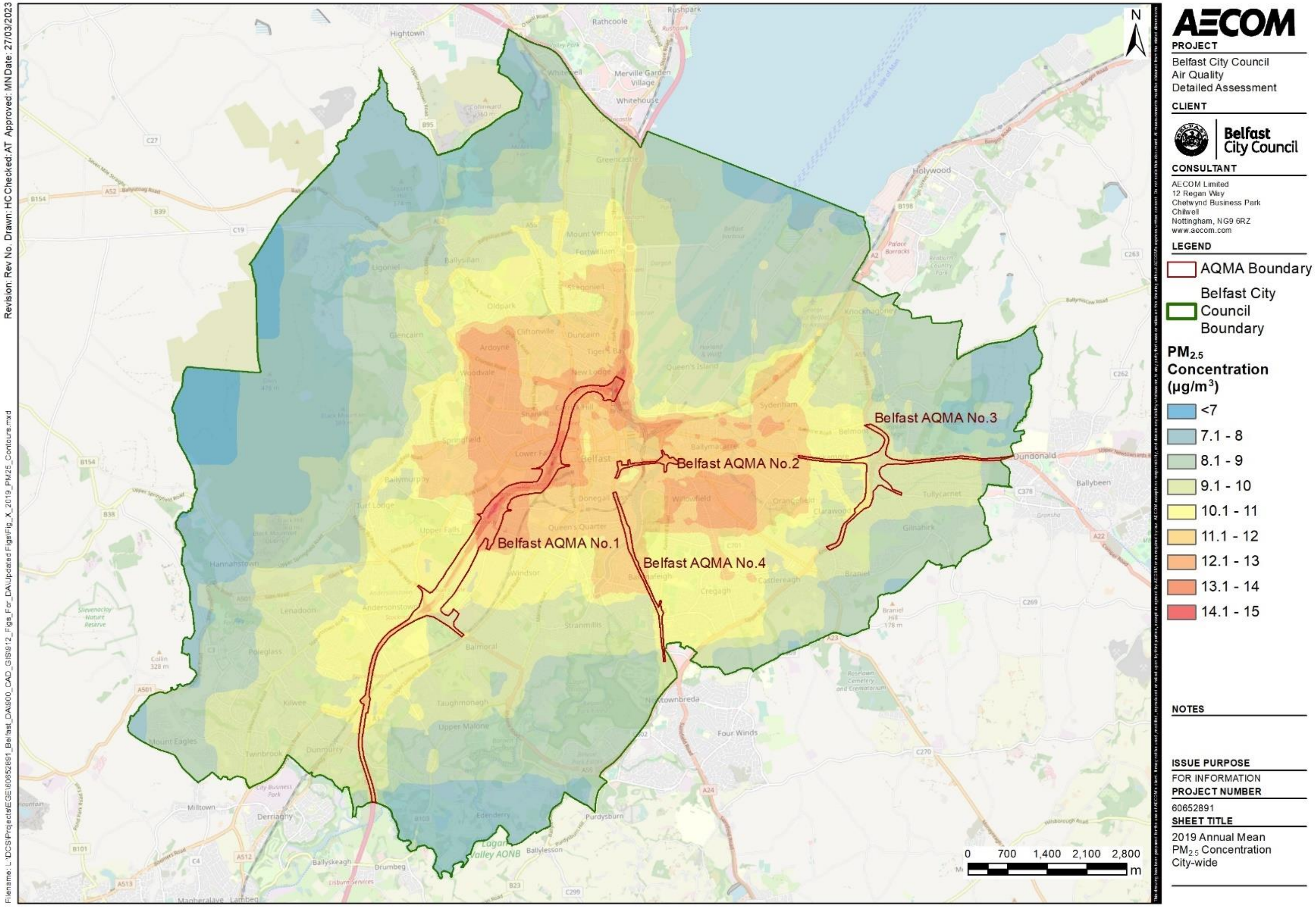


Figure 7-18. City-wide Modelled 2019 Annual Mean $PM_{2.5}$ Concentrations Contour Plot



7.2 Future year 2028

7.2.1 Nitrogen Dioxide

7.2.1.1 Sensitive Receptors

Annual mean NO_2 concentrations have been predicted at 1,797 sensitive receptor locations. There are no predicted 2028 annual mean NO_2 concentrations greater than 40 µg/m^3 and therefore unlikely to be locations of exceedance of the UK annual mean NO_2 AQO. Although there are no receptors that exceed the annual mean NO_2 AQO, receptors with the ten highest concentrations are shown in Table 7-6. A map of these receptors is shown in Figure 7-19.

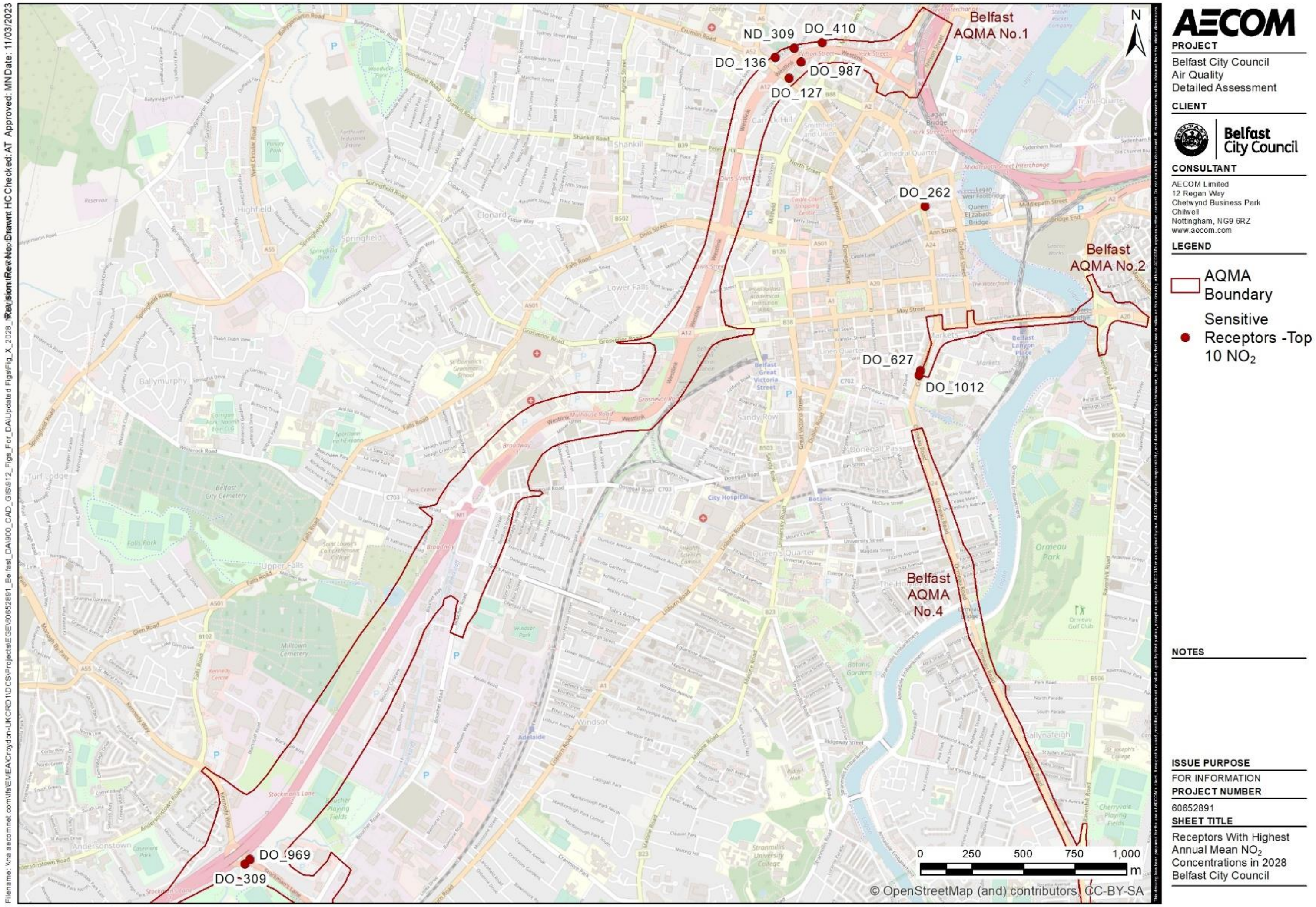
The highest predicted annual mean NO_2 concentration in 2028 is 31.1 µg/m^3 at Receptor ID DO 969. This receptor is a residential property located at Stockmans Lane within AQMA 1. In 2019, the highest predicted annual mean NO_2 concentration of 55.9 µg/m^3 was also observed at Receptor ID DO 969.

LAQM.TG(22) states that the hourly mean NO_2 objective is unlikely to be exceeded if annual mean concentrations are less than 60 µg/m^3. The assessment, therefore, evaluates the likelihood of exceeding the hourly mean NO_2 objective by comparing predicted annual mean NO_2 concentrations at all receptors to an annual mean equivalent threshold of 60 µg/m^3 NO_2. As the predicted concentrations are below this value for all receptors in 2019, it can be concluded that the hourly mean NO_2 objective (200 µg/m^3 NO_2 not more than 18 times per year) is likely to be achieved.

Table 7-6. Top 10 Sensitive Receptors with Highest 2028 Annual Mean NO_2 Concentrations

Receptor ID	Location	Annual Mean NO_2 Concentration (µg/m^3)
DO_969	Stockmans Lane (AQMA 1)	31.1
DO_309	Stockmans Lane (AQMA 1)	28.7
DO_987	Clifton House Mews (AQMA 1)	27.6
DO_410	Cu Chulainn House (AQMA 1)	27.3
DO_262	Queen's Square	26.7
ND_309	Henry Place (AQMA 1)	26.4
DO_127	Clifton House Mews (AQMA 1)	25.6
DO_136	Henry Place (AQMA 1)	25.3
DO_627	Cromac Street (near AQMA 2)	25.2
DO_1012	Cromac Street (near AQMA 2)	25.2

Figure 7-19. Location of Top 10 Sensitive Receptors with Highest 2028 Annual Mean NO_2 Concentrations



7.2.1.2 AQMA 1 - M1 Motorway / A12 Westlink Corridor

Predicted 2028 annual mean NO_2 concentrations within and around AQMA 1 are shown in Figure 7-20. It can be seen that predicted NO_2 concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA 1.

The highest predicted NO_2 concentrations of approximately 32 - 34 µg/m^3 are along Westlink / M1 corridor, near to the Blacks Road, Stockmans Lane and Broadway junctions. Other areas of elevated NO_2 concentrations include Clifton Street, the Stockmans Lane / Lisburn Road junction, and isolated points along the rail network.

7.2.1.3 AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

Predicted 2028 annual mean NO_2 concentrations within and around AQMA 2 are shown in Figure 7-21. It can be seen that predicted NO_2 concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA 2. The highest predicted NO_2 concentrations are approximately 30 µg/m^3 along East Bridge Street near to Belfast Lanyon Place Station and south along the rail corridor. Slightly elevated concentrations are also apparent near to the East Bridge Street / Cromac Street junction.

7.2.1.4 AQMA 3 - Upper Newtownards Road

Predicted 2028 annual mean NO_2 concentrations within and around AQMA 3 are shown in Figure 7-22.. It can be seen that predicted NO_2 concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA. The highest predicted NO_2 concentrations are approximately 24 µg/m^3 at the western end of the AQMA along Upper Newtownards Road, and near to the Upper Newtownards Road / Knock Road intersection.

7.2.1.5 AQMA 4 – Ormeau Road

Predicted 2028 annual mean NO_2 concentrations within and around AQMA 4 are shown in Figure 7-23. It can be seen that predicted NO_2 concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA 4. The highest predicted NO_2 concentrations are approximately 30 µg/m^3 along the Ormeau Road corridor and near to the Ormeau Road / Ravenhill Road junction.

7.2.1.6 City-wide grid

City-wide predicted 2028 annual mean NO_2 concentrations are shown in Figure 7-24. As discussed in the previous AQMA-specific sections, predicted annual mean NO_2 concentrations are well below the UK AQOs throughout the city, with the highest concentrations towards the city centre area and near to the major road network.

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

Figure 7-20. Modelled 2028 Annual Mean NO_2 Concentrations Contour Plot AQMA 1 - M1 Motorway / A12 Westlink Corridor.

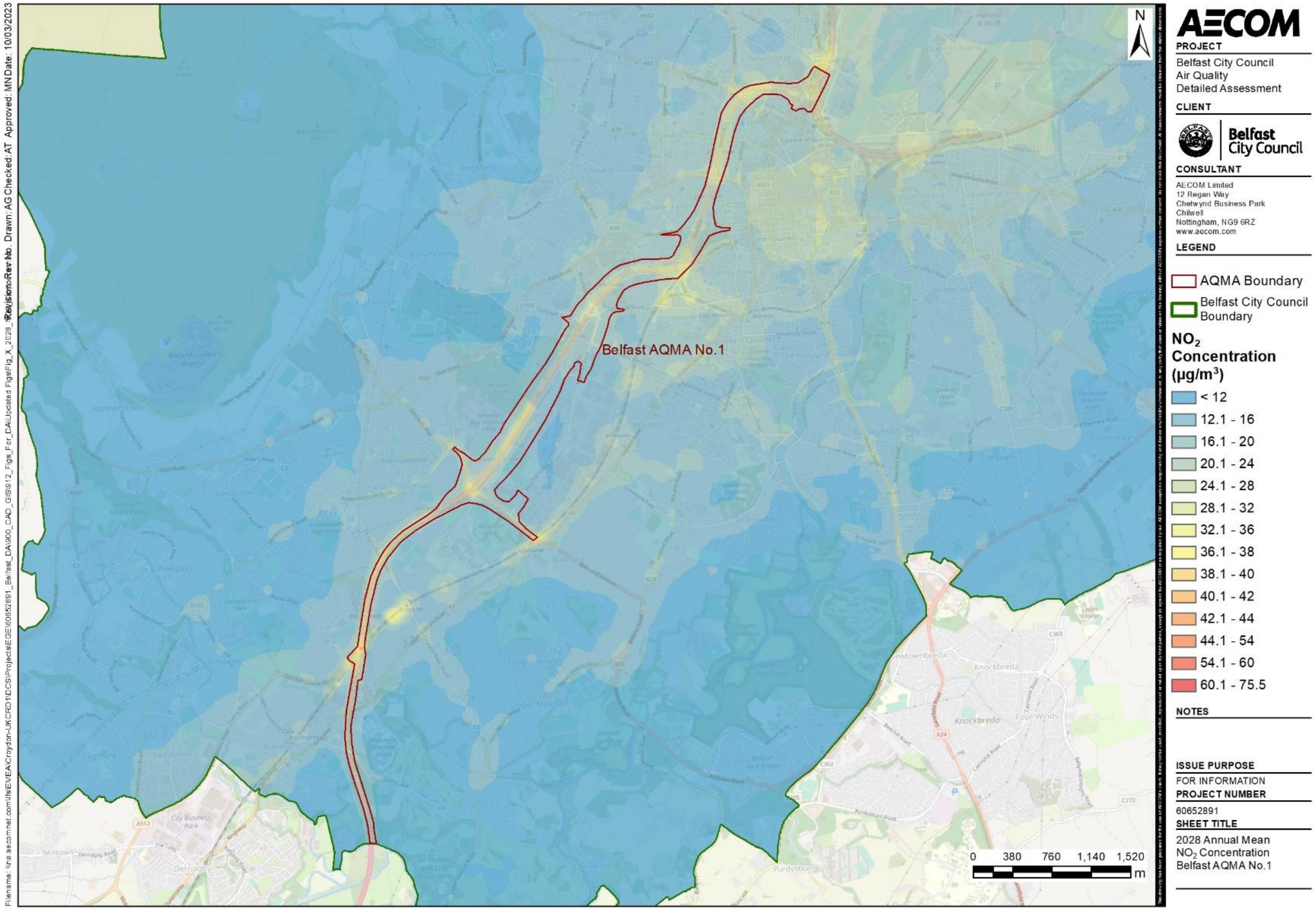


Figure 7-21. Modelled 2028 Annual Mean NO_2 Concentrations Contour Plot AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

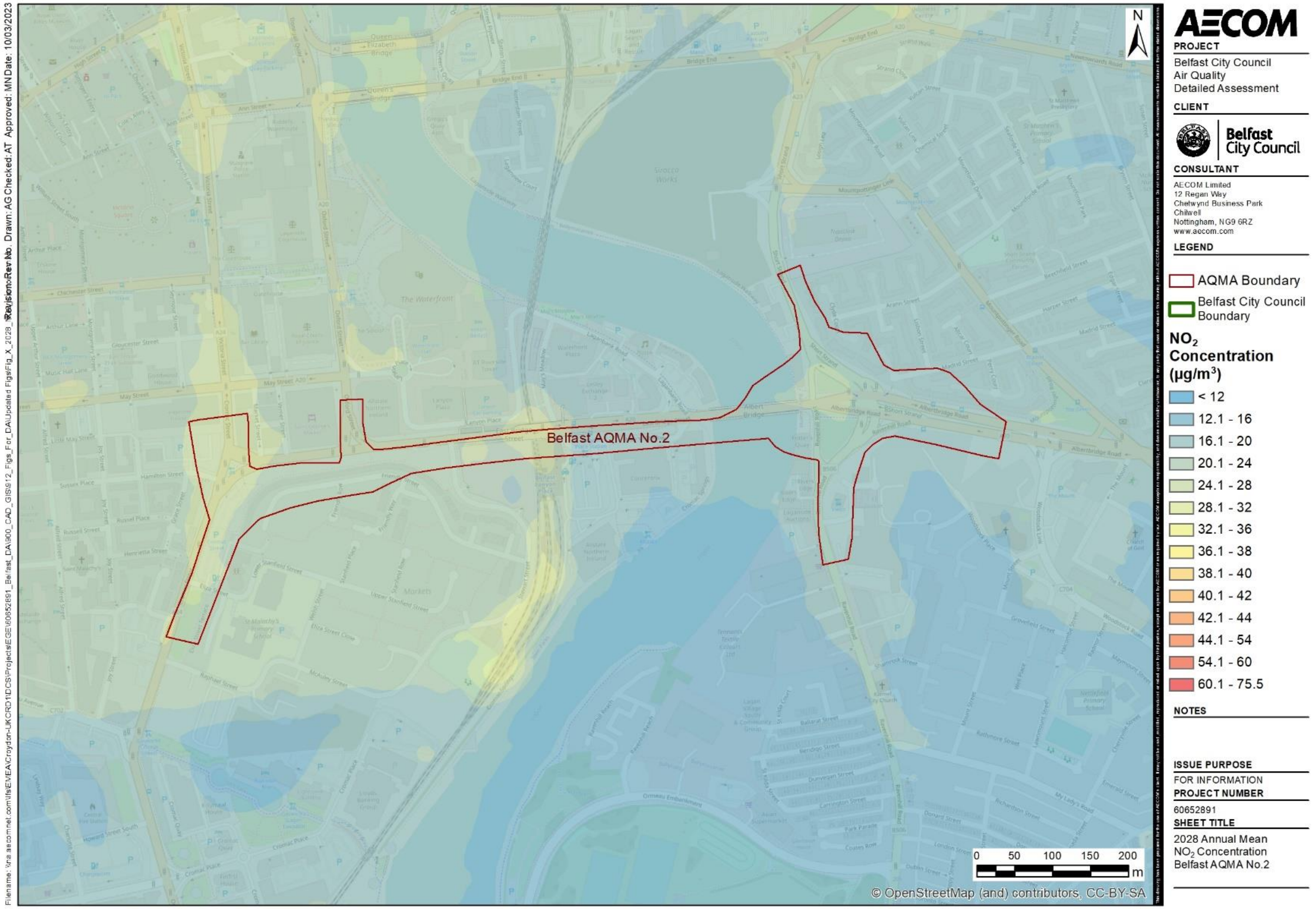


Figure 7-22. Modelled 2028 Annual Mean NO_2 Concentrations Contour Plot AQMA 3 - Upper Newtownards Road

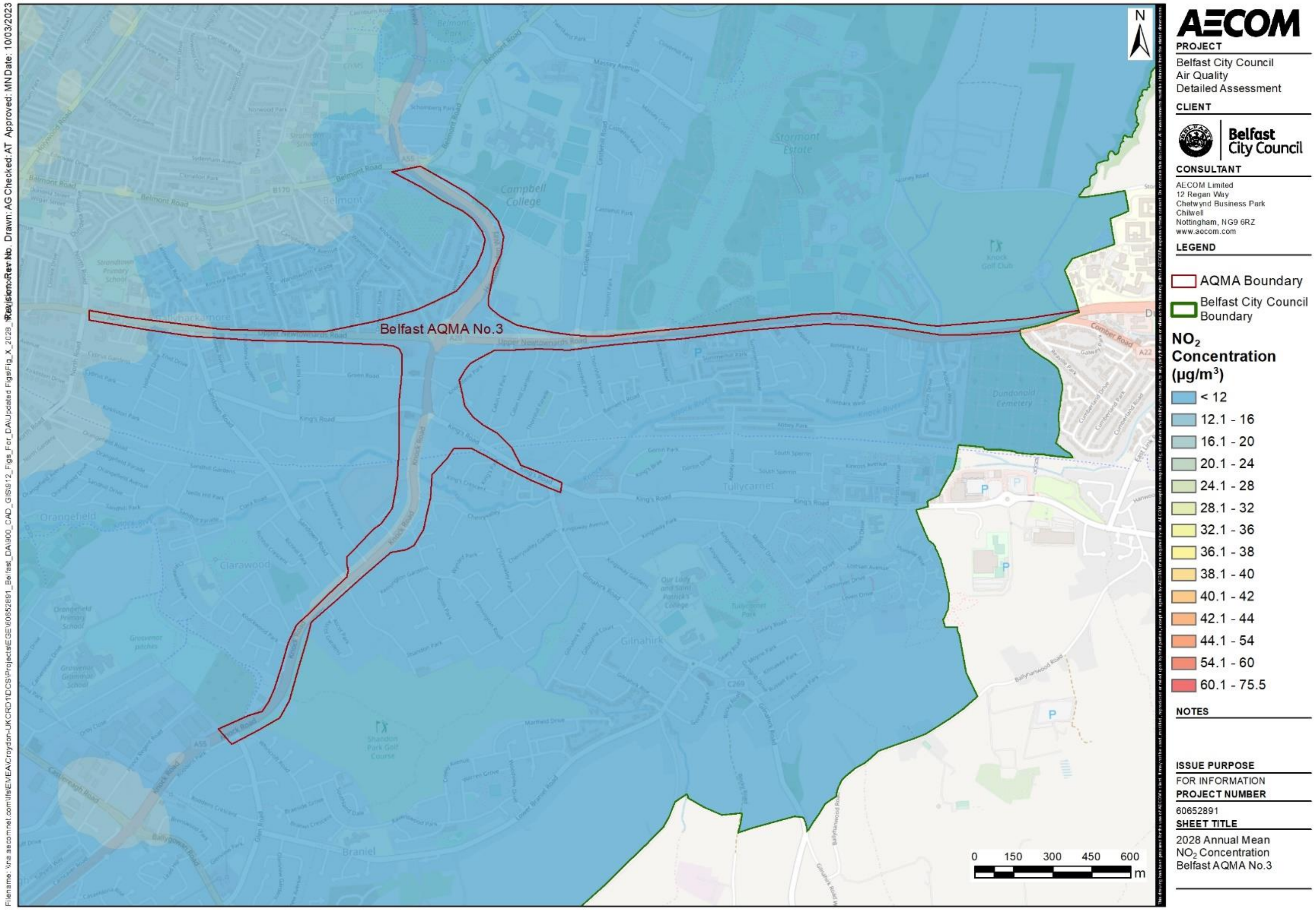


Figure 7-23. Modelled 2028 Annual Mean NO_2 Concentrations Contour Plot AQMA 4 – Ormeau Road

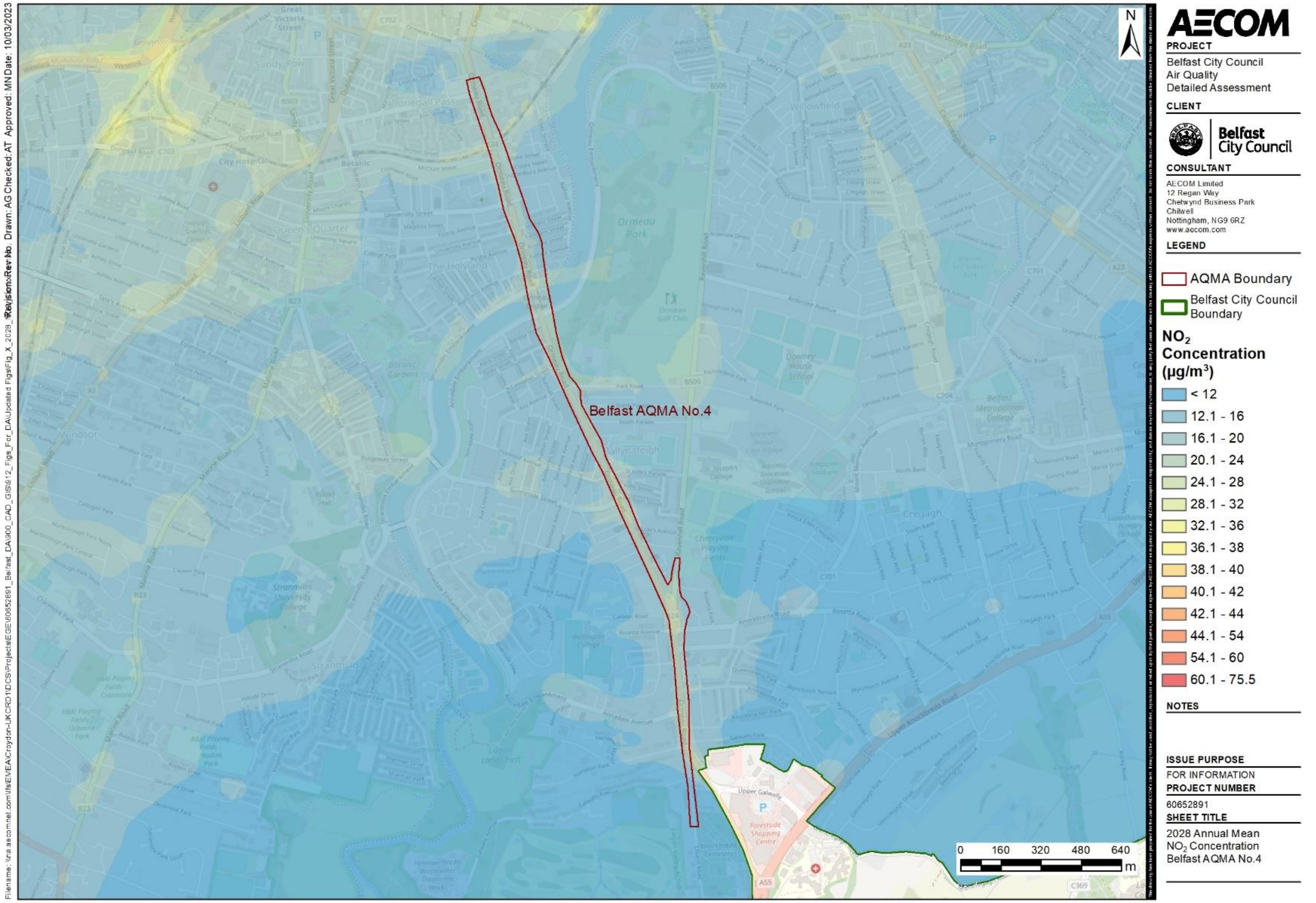
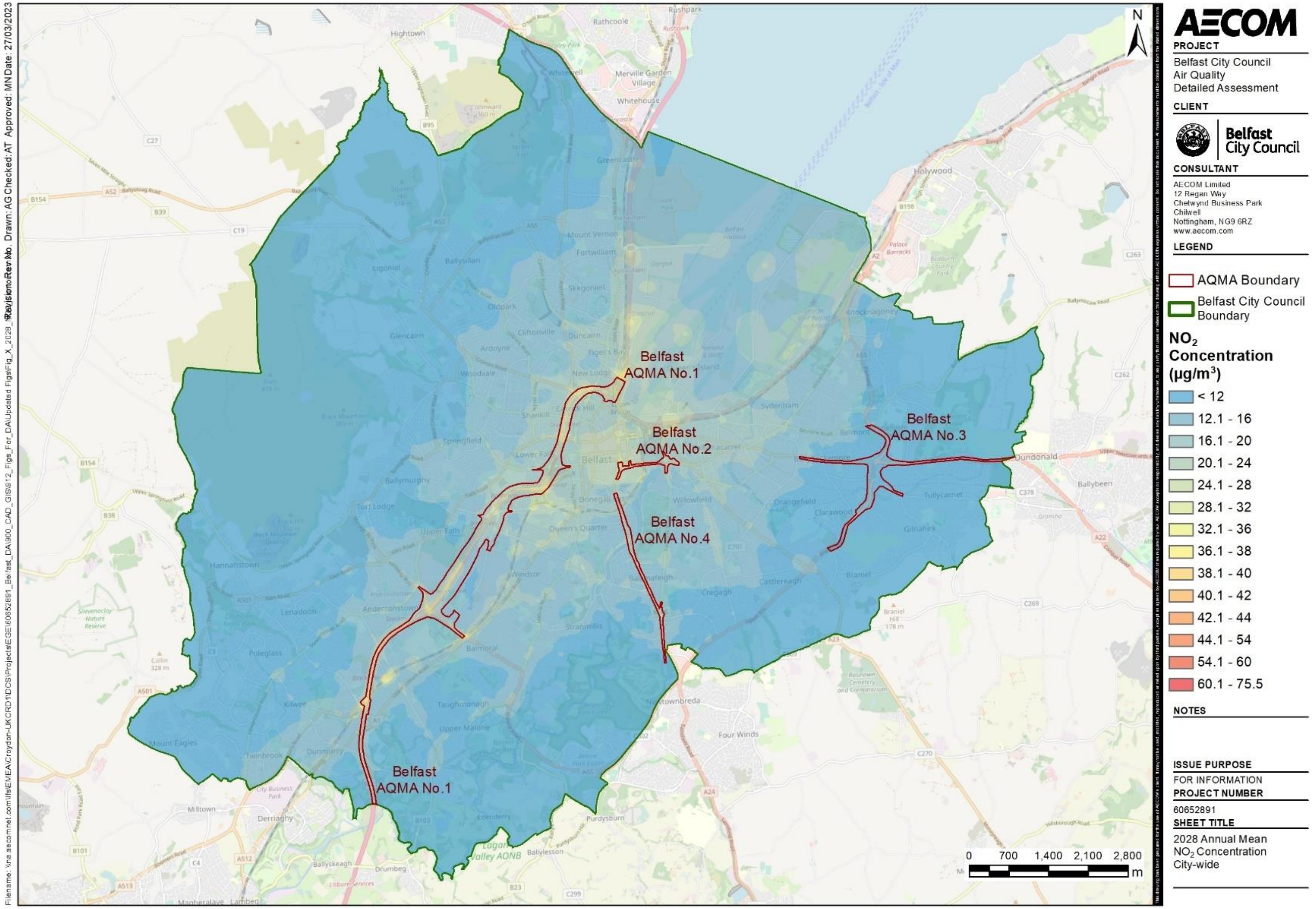


Figure 7-24. City-wide Modelled 2028 Annual Mean NO_2 Concentrations Contour Plot



7.2.2 PM_{10}

7.2.2.1 Sensitive Receptors

Annual mean PM_{10} concentrations have been predicted at 1,797 sensitive receptor locations. There are no predicted 2028 annual mean PM_{10} concentrations greater than 40 µg/m^3 and therefore unlikely to be locations of exceedance of the UK annual mean PM_{10} AQO. Although there are no receptors that exceed the annual mean PM_{10} AQO, receptors with the ten highest concentrations are shown in Table 7-7. A map of these receptors is shown in Figure 7-25.

The highest predicted annual mean PM_{10} concentration in 2028 is 20.3 µg/m^3 at Receptor ID ND 414, an educational building located on Barrack Street within AQMA 1. The highest predicted annual mean PM_{10} concentration in 2028 at a residential property is 19.7 µg/m^3 at Receptor ID DO_693, a property located at Little Georges Street.

Compared with the more stringent WHO annual mean PM_{10} AQG level of 15 µg/m^3 there are predicted exceedances at 645 modelled sensitive receptor locations.

Based on the empirical relationship between annual mean PM_{10} concentrations and the number of exceedances of the 24-hour mean PM_{10} standard of 50 µg/m^3 described in section 6.4.2.2, it is estimated that there would be 4 exceedance days at the sensitive receptor with the highest annual mean PM_{10} concentration (Receptor ND_414). This is well below the permitted 35 days of exceedance in order to achieve the AQO.

The receptors with the ten highest predicted 99th percentile of daily mean PM_{10} concentrations are presented in Table 7-8. It is shown that the WHO short-term PM_{10} AQG level (99th percentile of daily mean PM_{10} concentrations not to exceed 45 µg/m^3) is not predicted to be exceeded at any modelled sensitive receptor locations. The highest predicted 99th percentile of daily mean PM_{10} concentrations is 41.0 µg/m^3 at Receptor ID ND_414. This receptor is an educational property located at Barrack Street in AQMA 1. The highest predicted 99th percentile of daily mean PM_{10} concentrations at a residential property is 39.7 µg/m^3 at Receptor ID DO 648 located at Devonshire Place.

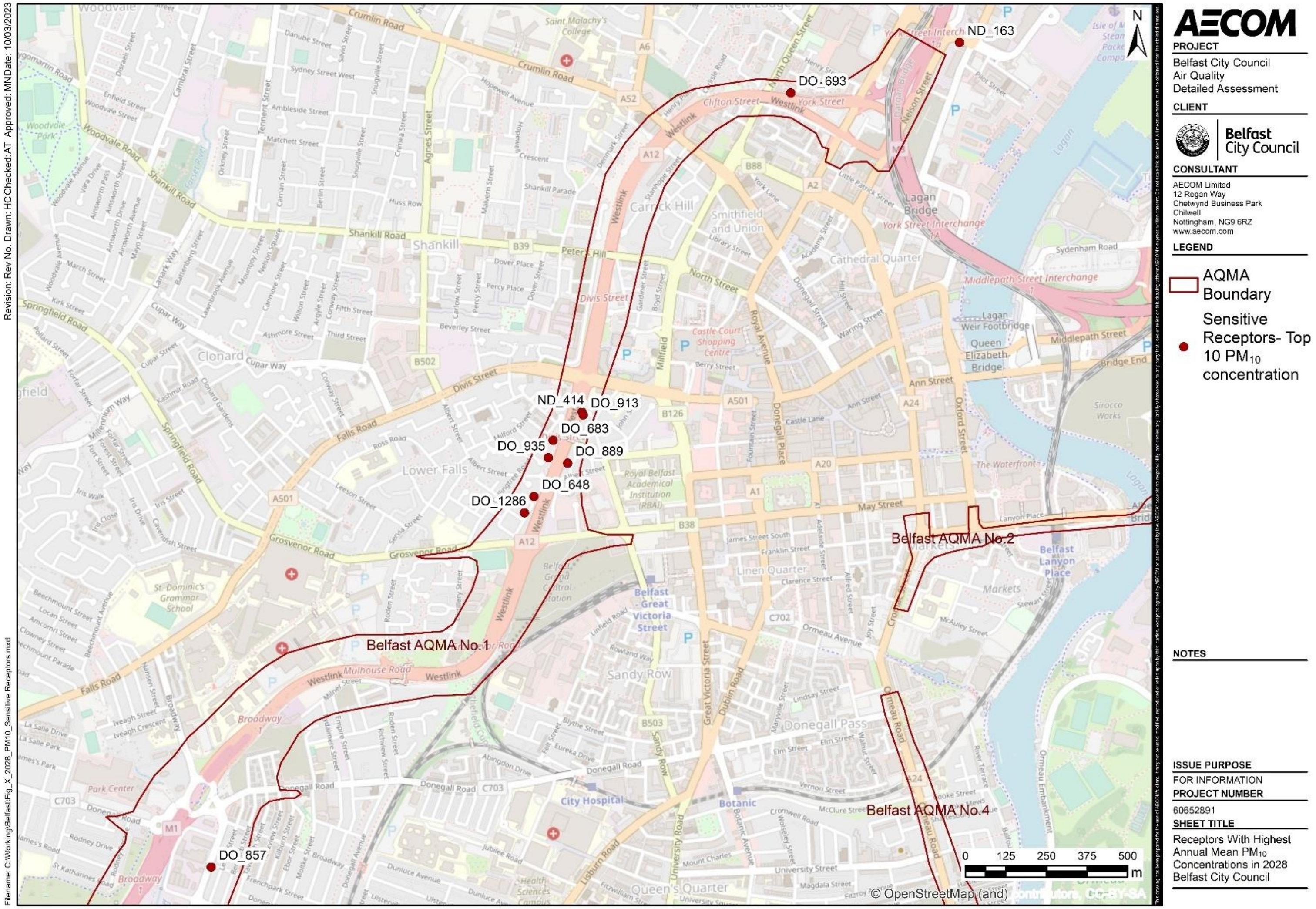
Table 7-7. Top 10 Sensitive Receptors with Highest 2028 Annual Mean PM_{10} Concentrations

Receptor ID	Location	Annual Mean PM_{10} Concentration (µg/m^3)
ND_414	Barrack Street (AQMA 1)	20.3
DO_693	Little Georges Street (AQMA 1)	19.7
DO_913	Barrack Street (AQMA 1)	19.5
ND_163	Dock Street (near AQMA 1)	19.3
DO_648	Devonshire Place (AQMA 1)	19.3
DO_935	Cullingtree Road (AQMA 1)	19.2
DO_889	Stanley Court (AQMA 1)	19.1
DO_683	Cullingtree Road (AQMA 1)	18.9
DO_1286	Devonshire Place (AQMA 1)	18.8
DO_857	Glenmachan Street (AQMA 1)	18.6

Table 7-8. Top 10 Sensitive Receptors with Highest 2028 99th Percentile of Daily Mean PM_{10} Concentrations

Receptor ID	Location	99th Percentile of Daily Mean PM_{10} Concentration ($\mu g/m^3$)
ND_414	Barrack Street (AQMA 1)	41.0
DO_648	Devonshire Place (AQMA 1)	39.7
DO_693	Little Georges Street (AQMA 1)	39.5
DO_935	Cullingtree Road (AQMA 1)	39.5
DO_913	Barrack Street (AQMA 1)	39.4
DO_683	Cullingtree Road (AQMA 1)	38.9
ND_163	Dock Street (near AQMA 1)	38.9
DO_1286	Devonshire Place (AQMA 1)	38.7
DO_889	Stanley Court (AQMA 1)	38.6
DO_857	Glenmachan Street (AQMA 1)	38.1

Figure 7-25. Location of Top 10 Sensitive Receptors with Highest 2028 Annual Mean PM_{10} Concentrations



7.2.2.2 AQMA 1 - M1 Motorway / A12 Westlink Corridor.

Predicted 2028 annual mean PM_{10} concentrations within and around AQMA 1 are shown in Figure 7-26. It can be seen that predicted PM_{10} concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA 1.

The highest predicted PM_{10} concentrations of approximately 21 µg/m^3 are near to the Broadway interchange (M1 Junction 1), around the M2 / M3 intersection, and along Westlink near to the Divis Street / Westlink and A12 / Grosvenor Road junctions. The contour plot indicates that background PM_{10} concentrations represent a large proportion of the total modelled PM_{10} concentrations, as higher modelled concentrations coincide with locations where background concentrations are highest.

7.2.2.3 AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

Predicted 2028 annual mean PM_{10} concentrations within and around AQMA 2 are shown in Figure 7-27. It can be seen that predicted PM_{10} concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA 2. The highest predicted PM_{10} concentrations are approximately 18 µg/m^3 along East Bridge Street near to Belfast Lanyon Place Station and close to the East Bridge Street / Short Strand junction.

7.2.2.4 AQMA 3 - Upper Newtownards Road

Predicted 2028 annual mean PM_{10} concentrations within and around AQMA 3 are shown in Figure 7-28.. It can be seen that predicted PM_{10} concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA. The highest predicted PM_{10} concentrations are approximately 17 µg/m^3 at the western end of the AQMA along Upper Newtownards Road, coinciding with the location where background PM_{10} concentrations are elevated.

7.2.2.5 AQMA 4 - Ormeau Road

Predicted 2028 annual mean PM_{10} concentrations within and around AQMA 4 are shown in Figure 7-29. It can be seen that predicted PM_{10} concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA 4. The highest predicted PM_{10} concentrations are approximately 17 µg/m^3 along the Ormeau Road corridor and near to the Ormeau Road / Ravenhill Road junction.

7.2.2.6 City-wide grid

City-wide predicted 2028 annual mean PM_{10} concentrations are shown in Figure 7-30. As discussed in the previous AQMA-specific sections, predicted annual mean PM_{10} concentrations are well below the UK AQOs throughout the city, with the highest concentrations towards the city centre area and near to the major road network.

Model predictions indicate that the WHO annual mean PM_{10} AQG level of 15 µg/m^3 is exceeded across much of the city centre area; background PM_{10} concentrations alone often approach or exceed the AQG level. Background sources of PM_{10} represent a large proportion of total modelled PM_{10} in many locations and the highest predicted PM_{10} concentrations generally coincide with locations where background concentrations are also elevated.

A more detailed examination of Defra background maps for 2028 indicate that, on average across the Belfast City Council area, secondary PM_{10} (3.9 µg/m^3) and Residual and Salt PM_{10} [38] (4.8 µg/m^3) collectively account for 8.7 µg/m^3 of ambient PM_{10}. The collective contribution of these two regional background components comprises almost 58% of the WHO annual mean PM_{10} AQG level of 15 µg/m^3 making attainment of this target very challenging.

Taking the maximum predicted annual mean PM_{10} concentration in the city in 2028 to be around 20 µg/m^3, it is estimated that around 43% of ambient PM_{10} in Belfast is due to sources which BCC is unable to influence. As mentioned in Section 4.6, secondary PM_{10} is not emitted directly but is formed in the atmosphere through chemical and physical processes involving primary pollutants and other atmospheric constituents that may be emitted many kilometres upwind. Secondary pollutant contributions are very difficult to influence and control because their formation processes are complex and often poorly understood. Furthermore, due to the transboundary nature of air pollutants – in particular secondary pollutants – local action is unlikely to bring about any meaningful reduction in concentration. Contributions from sea salt and wind-blown dust/soils are natural sources of PM_{10}.

[38] Sea salt, calcium and iron rich dusts and regional primary PM and residual non-characterised sources (residual is 1.0 µg/m^3). For further detail see https://laqm.defra.gov.uk/documents/2018-based-background-maps-user-guide-v1.0.pdf

Figure 7-26. Modelled 2028 Annual Mean PM_{10} Concentrations Contour Plot AQMA 1 - M1 Motorway / A12 Westlink Corridor

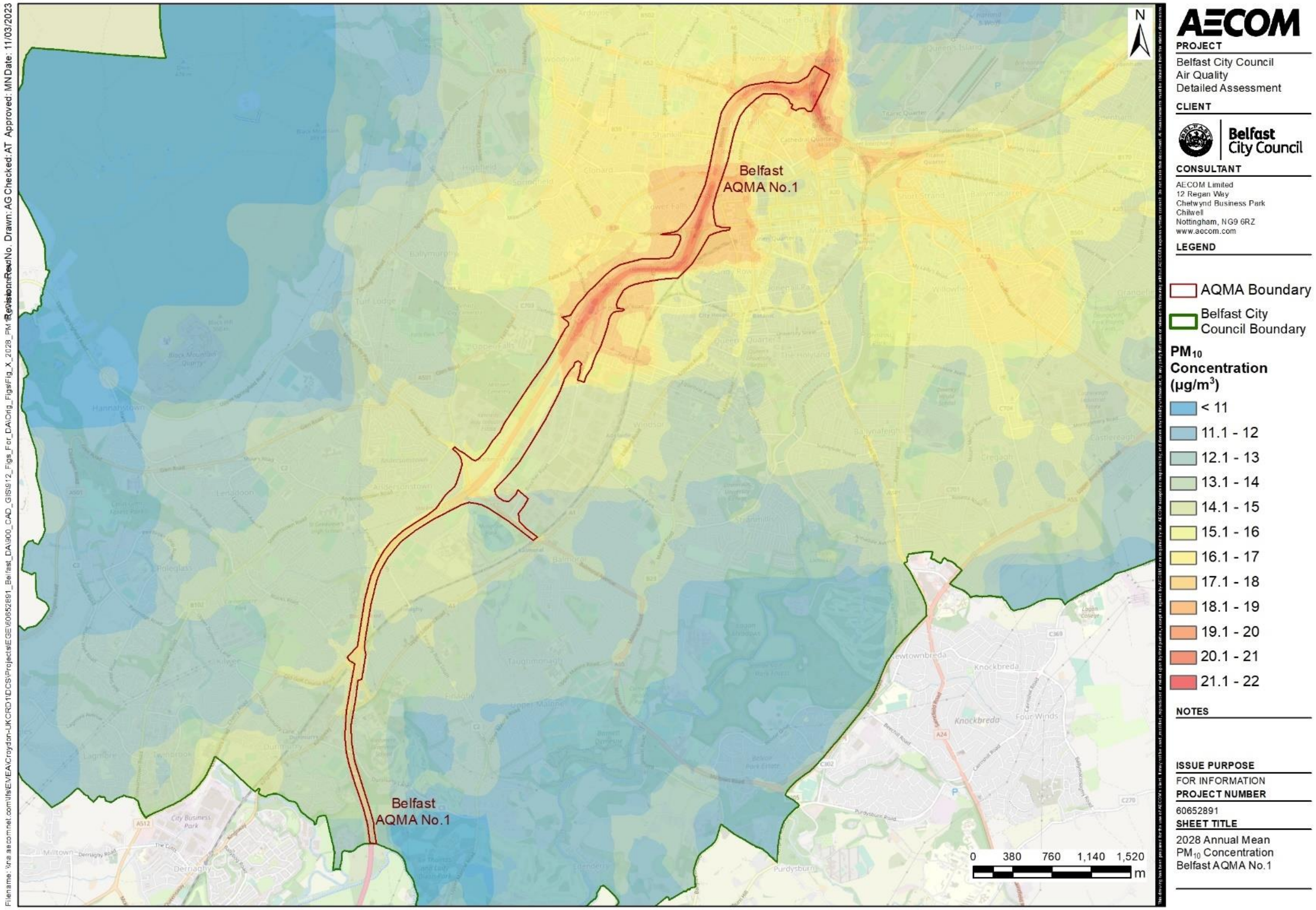


Figure 7-27. Modelled 2028 Annual Mean PM_{10} Concentrations Contour Plot AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

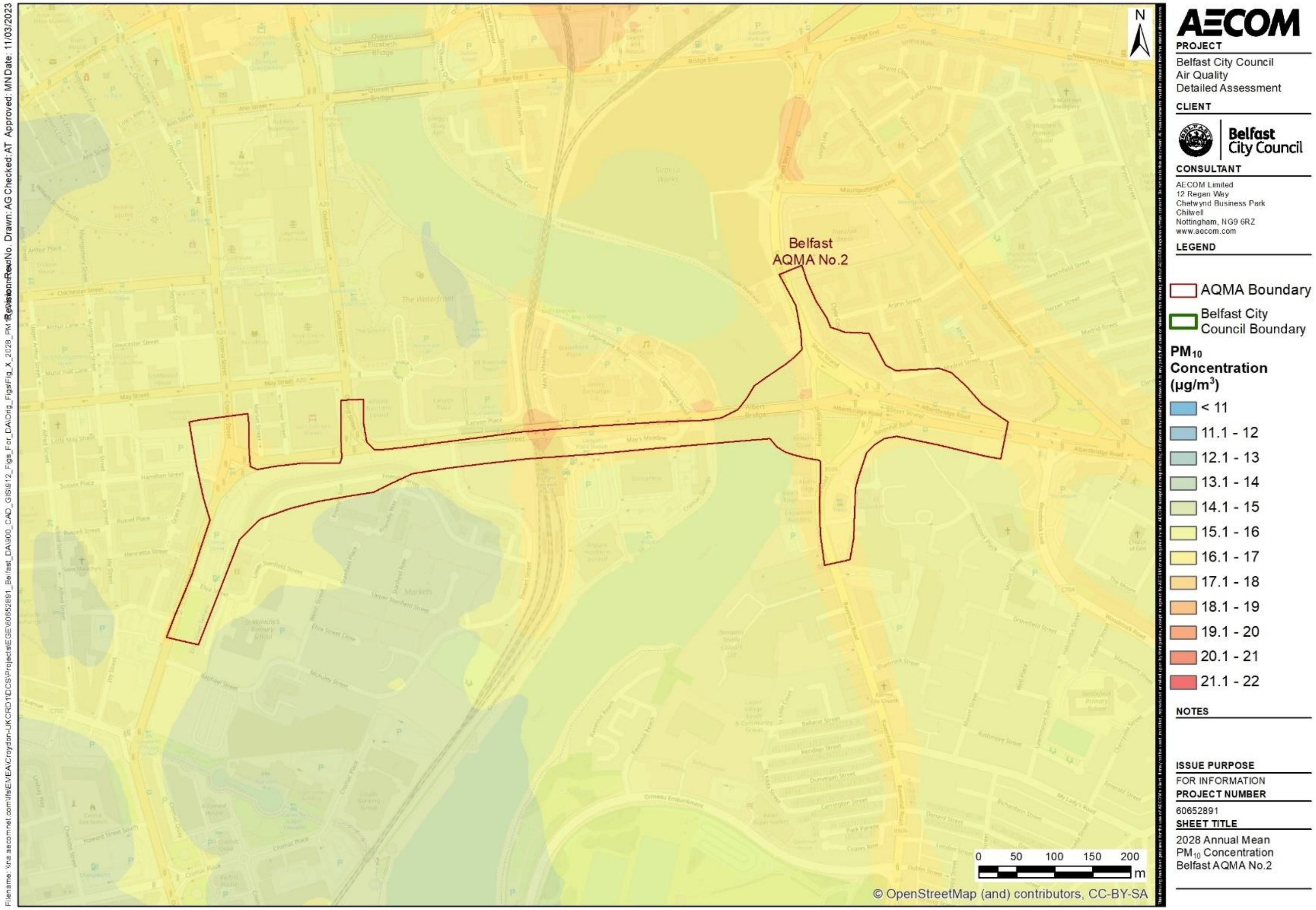


Figure 7-28. Modelled 2028 Annual Mean PM_{10} Concentrations Contour Plot AQMA 3 - Upper Newtownards Road

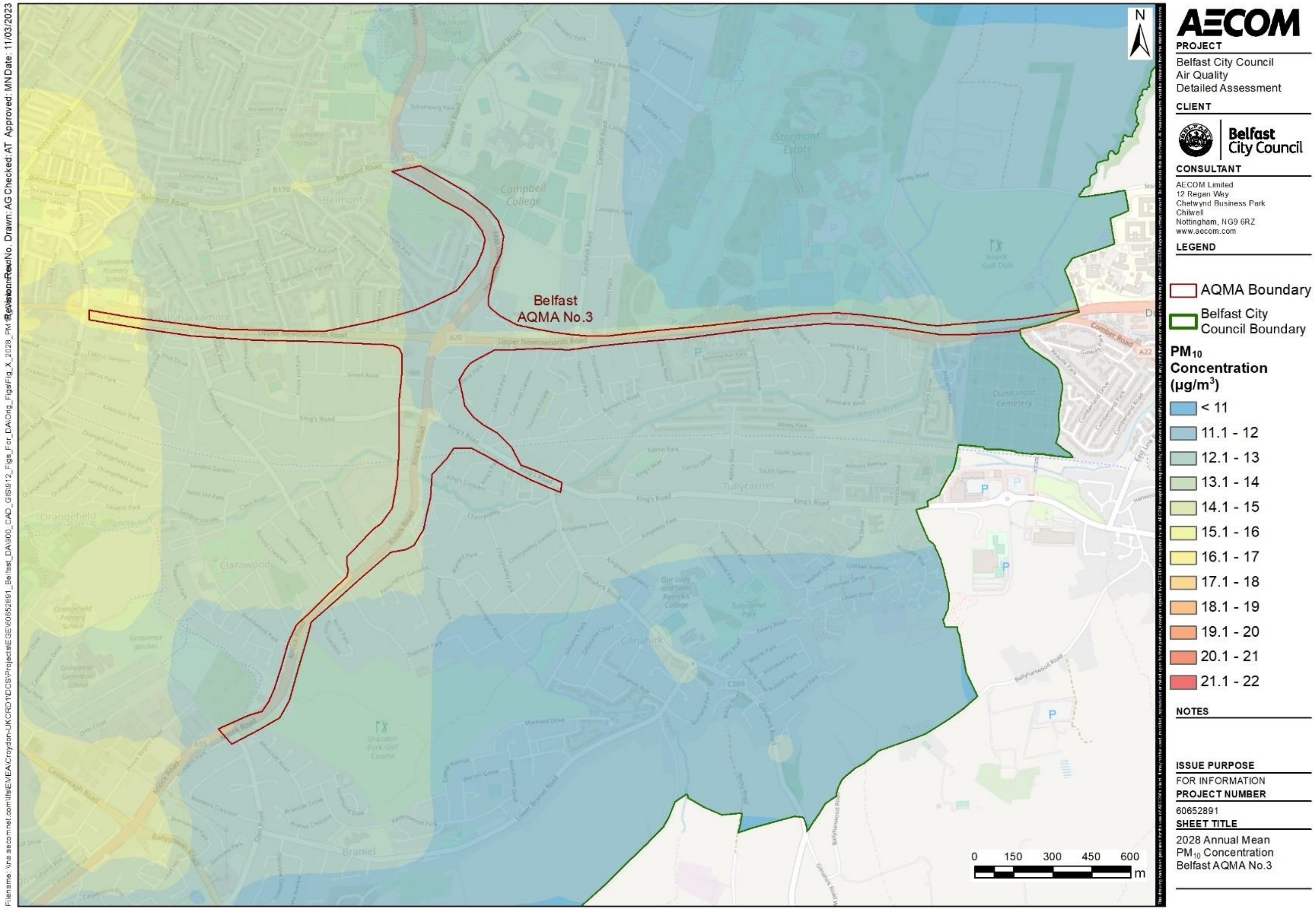


Figure 7-29. Modelled 2028 Annual Mean PM_{10} Concentrations Contour Plot AQMA 4 - Ormeau Road

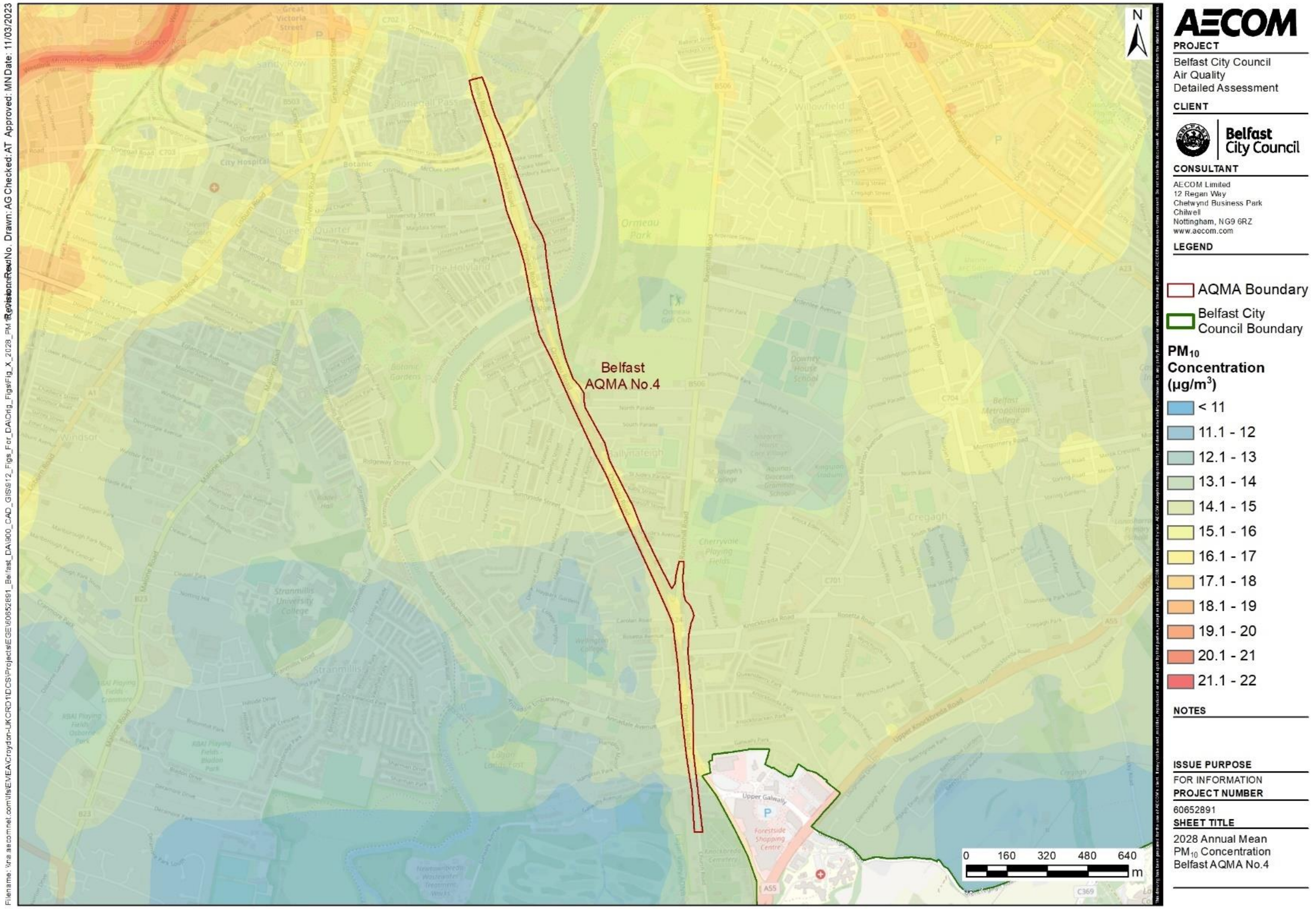
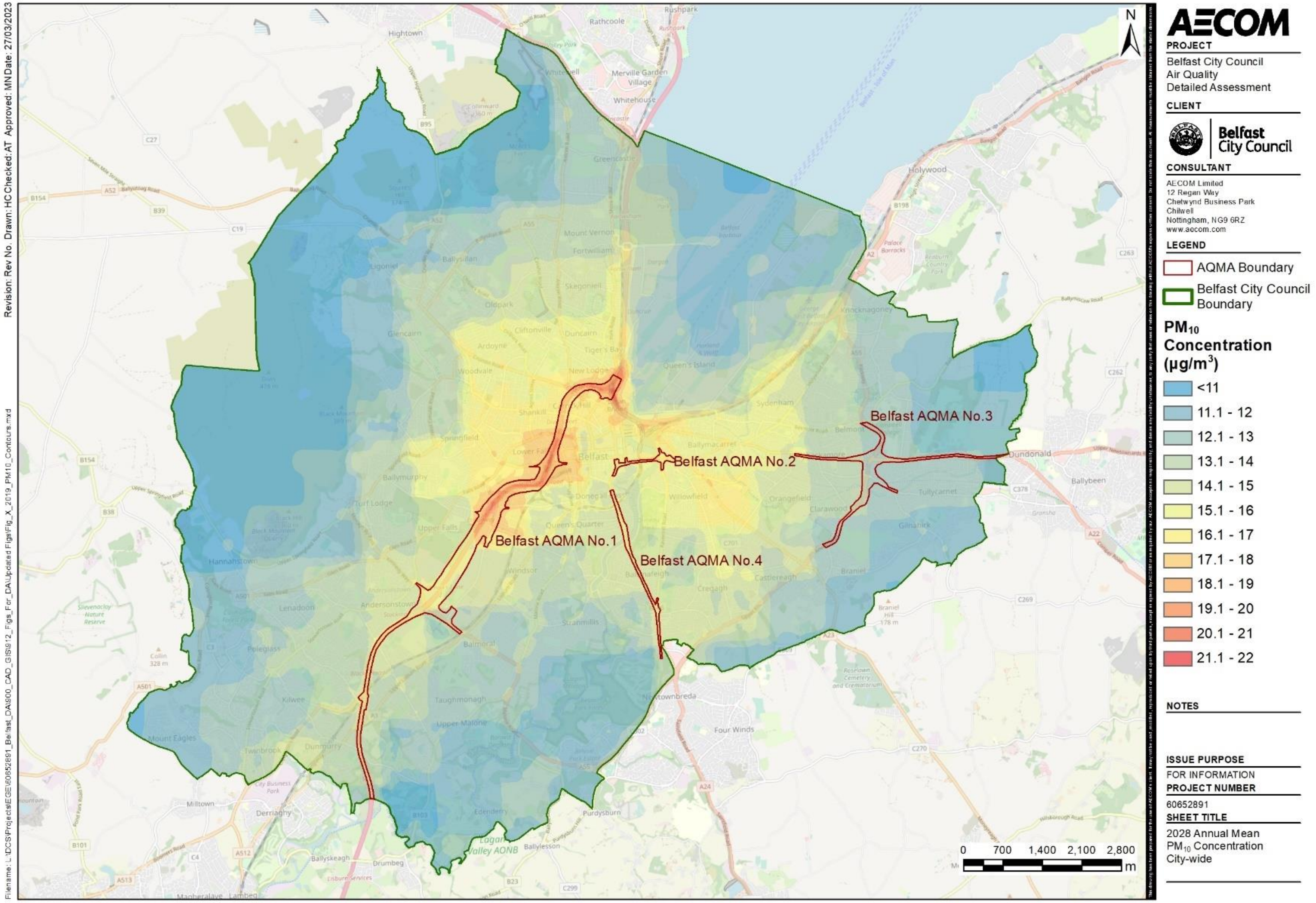


Figure 7-30. City-wide Modelled 2028 Annual Mean PM_{10} Concentrations Contour Plot



7.2.3 $PM_{2.5}$

7.2.3.1 Sensitive Receptors

Annual mean $PM_{2.5}$ concentrations have been predicted at 1,797 sensitive receptor locations. There are no predicted 2028 annual mean $PM_{2.5}$ concentrations greater than 20 µg/m^3 and therefore unlikely to be locations of exceedance of the UK annual mean $PM_{2.5}$ AQO. Although there are no receptors that exceed the annual mean $PM_{2.5}$ AQO, receptors with the ten highest concentrations are shown in Table 7-9. A map of these receptors is shown in Figure 7-31.

The highest predicted annual mean $PM_{2.5}$ concentration in 2028 is 13.1 µg/m^3 at Receptor ID ND_414, an educational building located on Barrack Street within AQMA 1. The highest predicted $PM_{2.5}$ concentration at a residential property is 12.7 µg/m^3 at Receptor ID DO_913, also located in Barrack Street.

Compared with the much more stringent WHO annual mean $PM_{2.5}$ Air Quality Guideline level of 5 µg/m^3, all 1,797 receptors have predicted concentration of 5 µg/m^3 or higher. It should be noted that the lowest $PM_{2.5}$ background concentration at any location across the city in 2028 is 5.9 µg/m^3, which itself exceeds the AQG level of 5 µg/m^3.

The WHO short-term $PM_{2.5}$ AQG level (99th percentile of daily mean $PM_{2.5}$ concentrations not to exceed 15 µg/m^3) is predicted to be exceeded at 1,785 out of the 1,797 modelled sensitive receptor locations. The receptors with the ten highest predicted 99th percentile of daily mean $PM_{2.5}$ concentrations are presented in Table 7-10.

The highest predicted 99th percentile of daily mean $PM_{2.5}$ concentrations is 26.4 µg/m^3 at Receptor ID ND 414. This receptor is an educational property located at Barrack Street in AQMA 1. The highest predicted 99th percentile of daily mean $PM_{2.5}$ concentrations at a residential property is 25.7 µg/m^3 at Receptor ID DO 648, a property located at Devonshire Place. It should be noted, the background $PM_{2.5}$ contribution to the 99th percentile of daily mean $PM_{2.5}$ concentrations alone is greater than or approaching the WHO AQG level at most modelled locations.

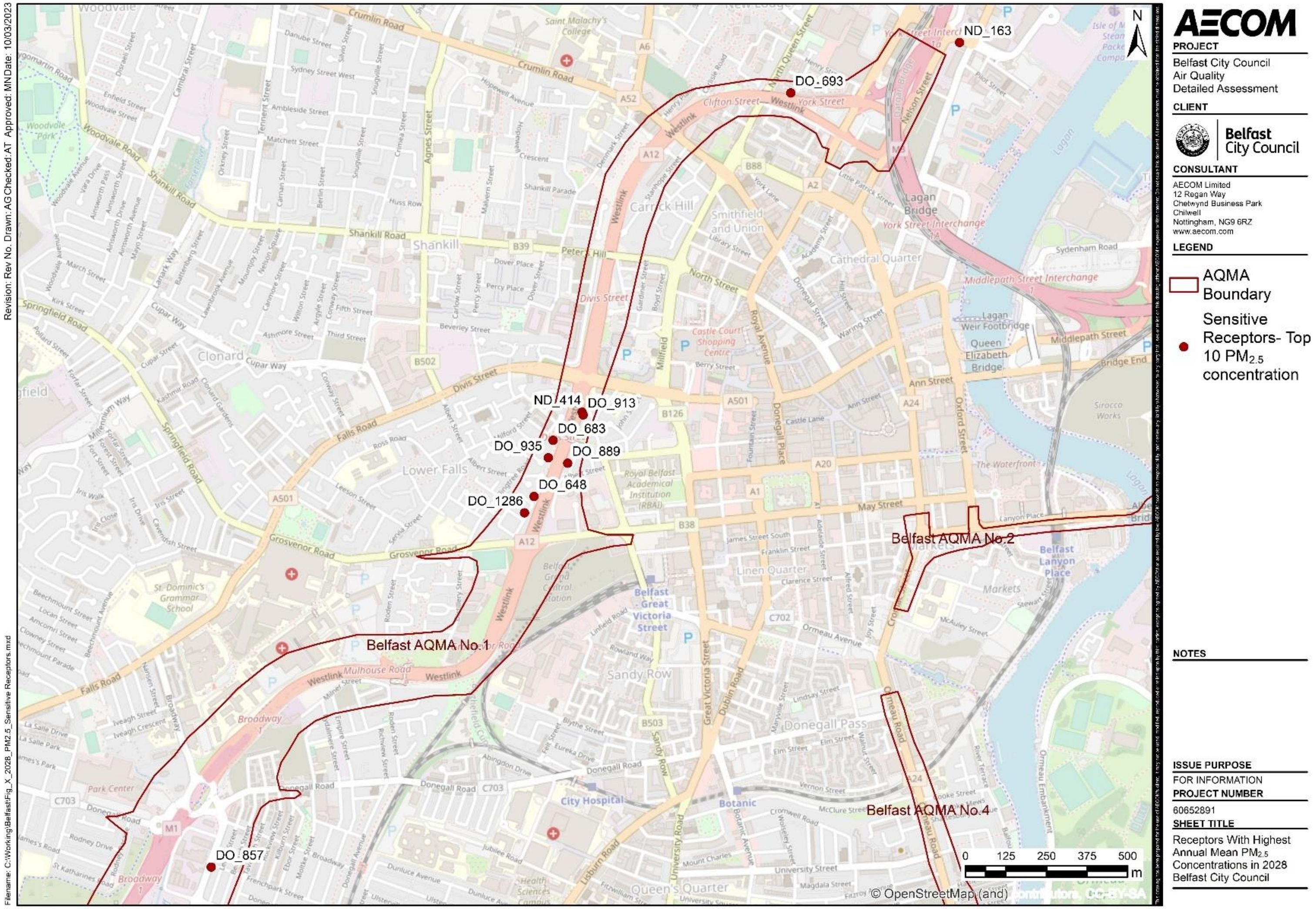
Table 7-9. Top 10 Sensitive Receptors with Highest 2019 Annual Mean $PM_{2.5}$ Concentrations

Receptor ID	Location	Annual Mean $PM_{2.5}$ Concentration (µg/m^3)
ND_414	Barrack Street (AQMA 1)	13.1
DO_913	Barrack Street (AQMA 1)	12.7
DO_693	Little Georges Street (AQMA 1)	12.5
DO_381	Stanhope Street (AQMA 1)	12.5
DO_648	Devonshire Place (AQMA 1)	12.5
DO_935	Cullingtree Road (AQMA 1)	12.5
DO_1044	Brown Square (AQMA 1)	12.5
DO_889	Stanley Court (AQMA 1)	12.5
DO_857	Glenmachan Street (AQMA 1)	12.4
ND_490	St Mary's Primary School (AQMA 1)	12.4

Table 7-10. Top 10 Sensitive Receptors with Highest 2028 99th Percentile of Daily Mean $PM_{2.5}$ Concentrations

Receptor ID	Location	99th Percentile of Daily Mean $PM_{2.5}$ Concentration (μg/m^3)
ND_414	Barrack Street (AQMA 1)	26.4
DO_648	Devonshire Place (AQMA 1)	25.7
DO_935	Cullingtree Road (AQMA 1)	25.6
DO_913	Barrack Street (AQMA 1)	25.5
DO_857	Glenmachan Street (AQMA 1)	25.3
DO_683	Cullingtree Road (AQMA 1)	25.3
DO_721	Monarch Parade (AQMA 1)	25.2
DO_1286	Devonshire Place (AQMA 1)	25.1
DO_889	Stanley Court (AQMA 1)	25.1
DO_100	Roden Street (AQMA 1)	25.1

Figure 7-31. Location of Top 10 Sensitive Receptors with Highest 2028 Annual Mean $PM_{2.5}$ Concentrations



7.2.3.2 AQMA 1 - M1 Motorway / A12 Westlink Corridor

Predicted 2028 annual mean $PM_{2.5}$ concentrations within and around AQMA 1 are shown in Figure 7-32. It can be seen that predicted $PM_{2.5}$ concentrations are well below the UK AQO of 20 µg/m^3 at all locations in and around AQMA 1.

The highest predicted $PM_{2.5}$ concentrations of approximately 15 µg/m^3 are near to the Broadway interchange (M1 Junction 1) and along the Westlink near to the A12 / A501 and A12 / Grosvenor Road junctions. The contour plot indicates that background $PM_{2.5}$ concentrations represent a large proportion of the total modelled $PM_{2.5}$ concentrations, as higher modelled concentrations coincide with locations where background concentrations are highest.

7.2.3.3 AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

Predicted 2028 annual mean $PM_{2.5}$ concentrations within and around AQMA 2 are shown in Figure 7-33. It can be seen that predicted $PM_{2.5}$ concentrations are well below the UK AQO of 20 µg/m^3 at all locations in and around AQMA 2. The highest predicted $PM_{2.5}$ concentrations are approximately 12 µg/m^3 along East Bridge Street near to Belfast Lanyon Place Station and close to the East Bridge Street / Short Strand junction.

7.2.3.4 AQMA 3 - Upper Newtownards Road

Predicted 2028 annual mean $PM_{2.5}$ concentrations within and around AQMA 3 are shown in Figure 7-34. It can be seen that predicted $PM_{2.5}$ concentrations are well below the UK AQO of 20 µg/m^3 at all locations in and around AQMA. The highest predicted $PM_{2.5}$ concentrations are approximately 11 µg/m^3 at the western end of the AQMA along Upper Newtownards Road, coinciding with the location where background $PM_{2.5}$ concentrations are elevated.

7.2.3.5 AQMA 4 - Ormeau Road

Predicted 2028 annual mean $PM_{2.5}$ concentrations within and around AQMA 4 are shown in Figure 7-35. It can be seen that predicted $PM_{2.5}$ concentrations are well below the UK AQO of 40 µg/m^3 at all locations in and around AQMA 4. The highest predicted $PM_{2.5}$ concentrations are approximately 11 µg/m^3 along the Ormeau Road corridor, particularly at the northern end nearer to the city centre.

7.2.3.6 City-wide grid

City-wide predicted 2028 annual mean $PM_{2.5}$ concentrations are shown in Figure 7-36. As discussed in the previous AQMA-specific sections, predicted annual mean $PM_{2.5}$ concentrations are well below the UK AQOs throughout the city, with the highest concentrations towards the city centre area and near to the major road network.

Model predictions indicate that the WHO annual mean $PM_{2.5}$ AQG level of 5 µg/m^3 is exceeded across the whole of the city. This is largely because background $PM_{2.5}$ concentrations alone exceed the AQG level across the BCC area. Background sources of $PM_{2.5}$ represent a large proportion of total modelled $PM_{2.5}$ in many locations and the highest predicted $PM_{2.5}$ concentrations generally coincide with locations where background concentrations are also elevated.

An examination of Defra background maps for 2028 indicate that, on average across the Belfast City Council area, secondary $PM_{2.5}$ (3.3 µg/m^3) and Residual and Salt $PM_{2.5}$ (1.8 µg/m^3) collectively account for 5.1 µg/m^3 of ambient $PM_{2.5}$. Secondary $PM_{2.5}$ forms in the atmosphere through chemical and physical processes involving primary pollutants and other atmospheric constituents that may be emitted many kilometres upwind. Secondary pollutant contributions are very difficult to influence and control because their formation processes are complex and often poorly understood. Similarly, contributions from sea salt and wind-blown dust/soils are natural sources of $PM_{2.5}$ and thus very difficult to influence.

Taking the maximum predicted 2028 annual mean $PM_{2.5}$ concentration in the city to be around 15 µg/m^3, it is estimated that around 34% of ambient $PM_{2.5}$ in Belfast is due to sources which BCC is unable to influence. The collective contribution of the secondary $PM_{2.5}$ and Residual and Salt $PM_{2.5}$ regional background components exceeds the WHO annual mean $PM_{2.5}$ AQG level of 5 µg/m^3 making attainment of this target highly improbable.

Figure 7-32. Modelled 2028 Annual Mean $PM_{2.5}$ Concentrations Contour Plot AQMA 1 - M1 Motorway / A12 Westlink Corridor.

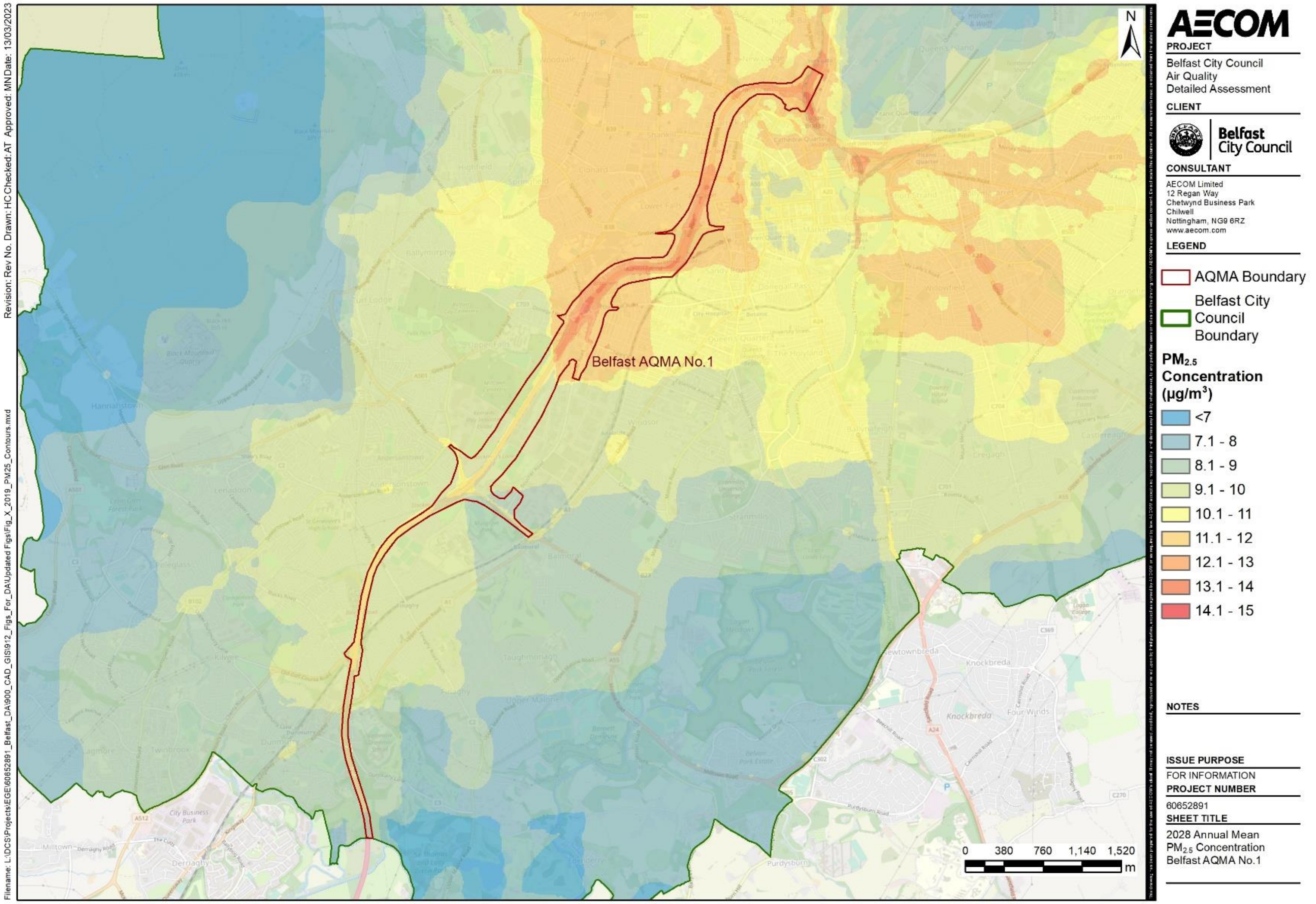


Figure 7-33. Modelled 2028 Annual Mean $PM_{2.5}$ Concentrations Contour Plot AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

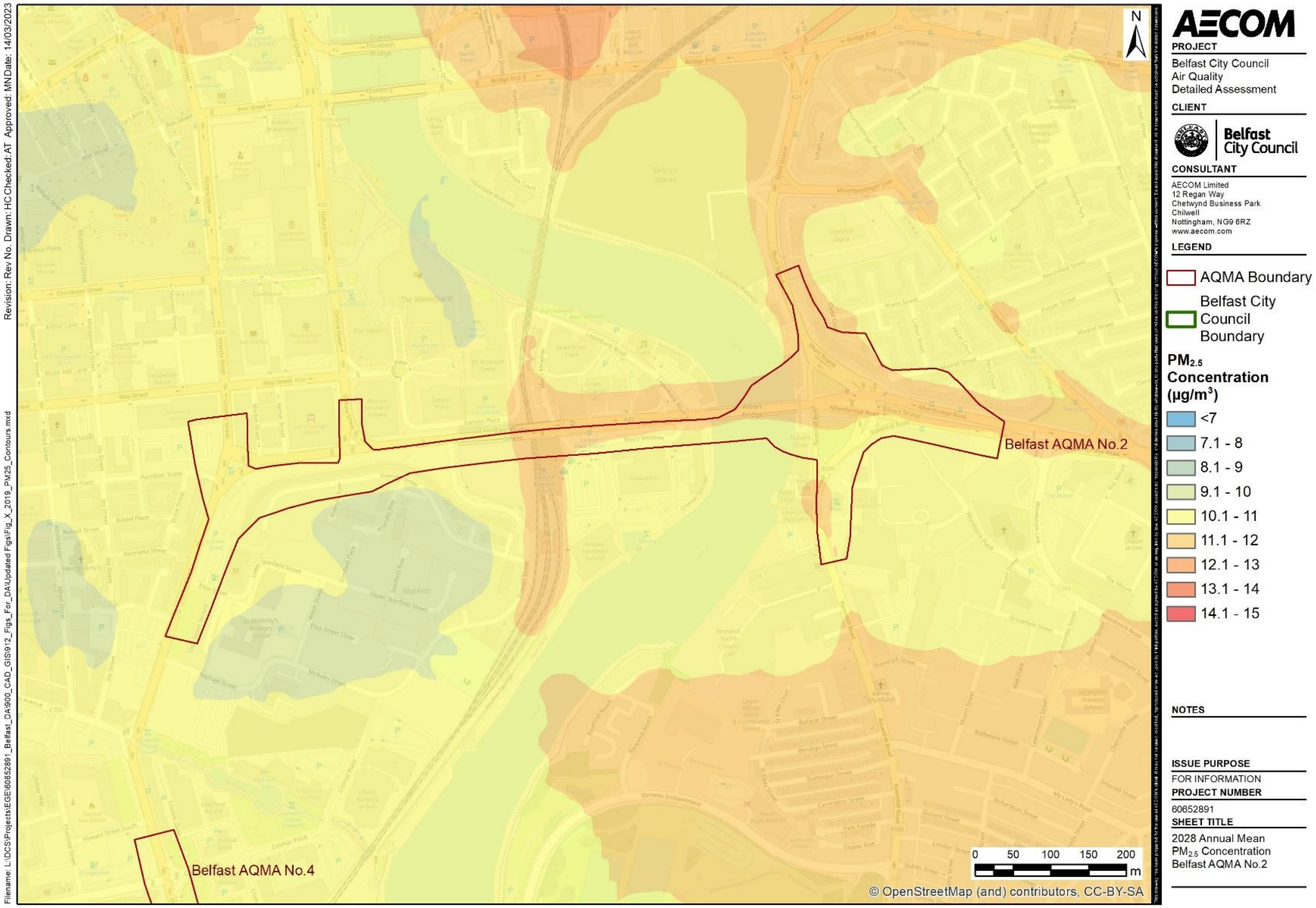


Figure 7-34. Modelled 2028 Annual Mean $PM_{2.5}$ Concentrations Contour Plot AQMA 3 - Upper Newtownards Road

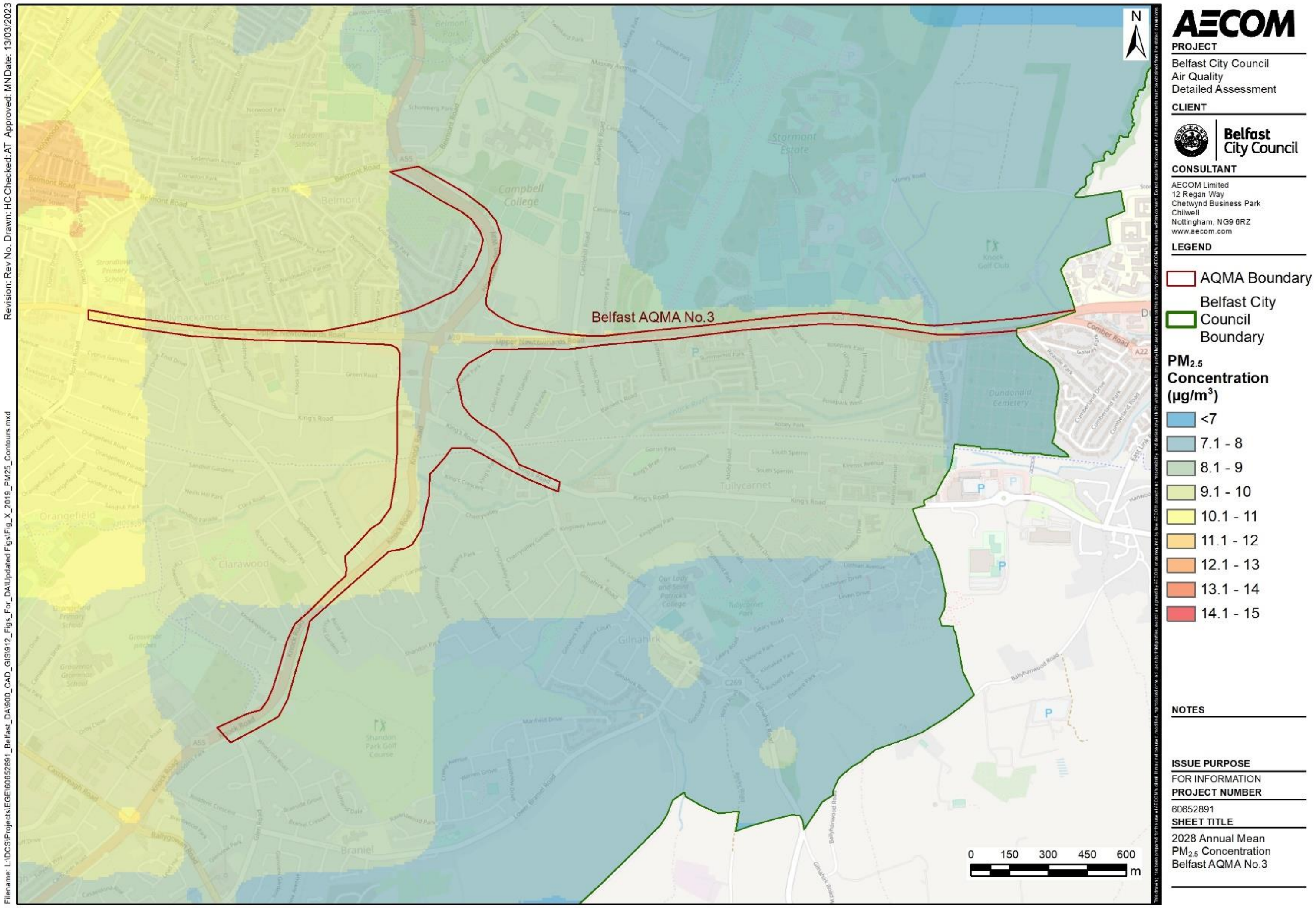


Figure 7-35. Modelled 2028 Annual Mean PM2.5 Concentrations Contour Plot AQMA 4 - Ormeau Road

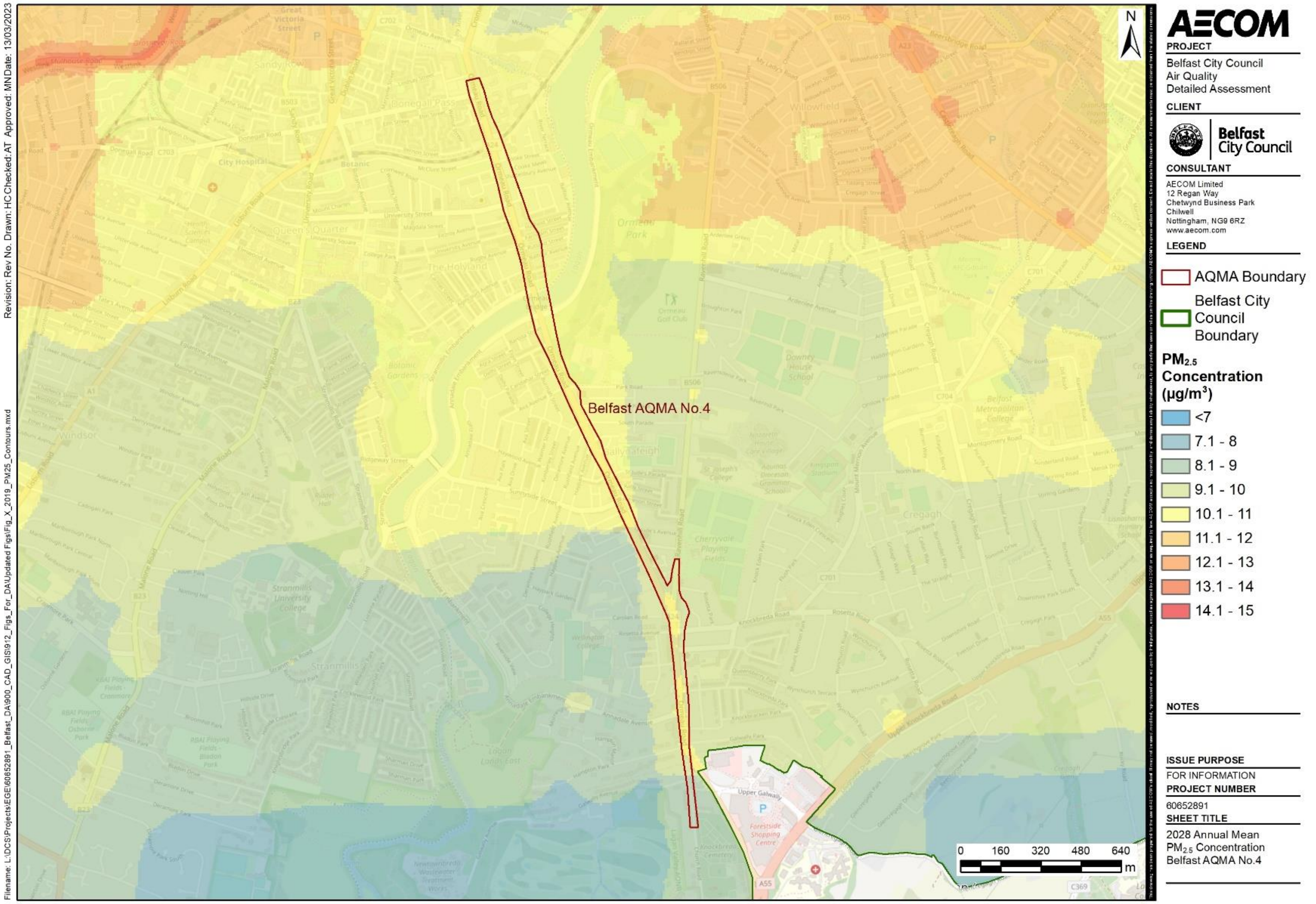
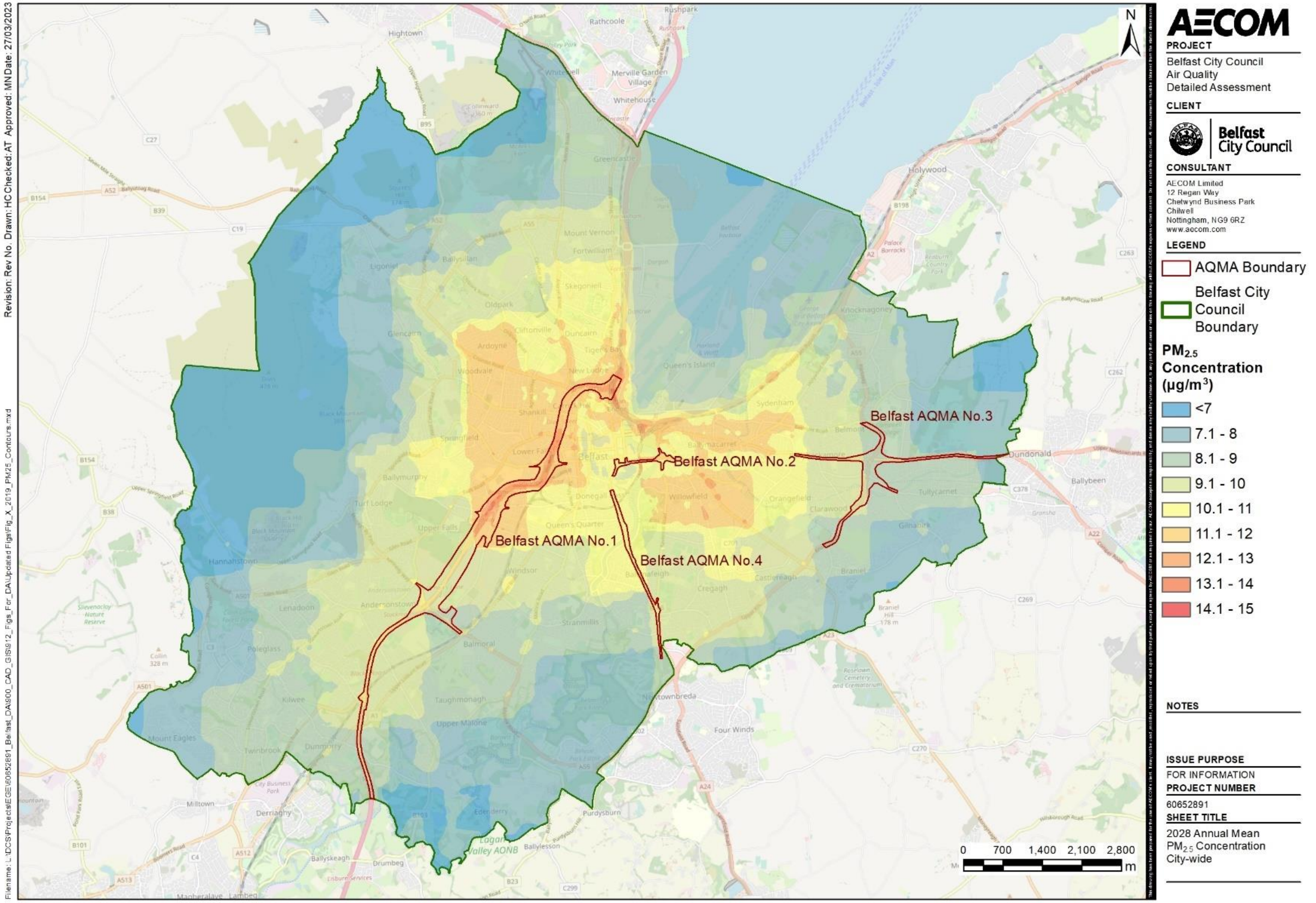


Figure 7-36. City-wide Modelled 2028 Annual Mean $PM_{2.5}$ Concentrations Contour Plot



8. Source Apportionment

Source apportionment has been carried out for all modelled sensitive receptors to determine the relative contributions from each of the modelled source sectors. The following sections present tables and pie charts to summarise the source apportionment for selected receptors where modelled pollutant concentrations were found to be highest. Since the relative contributions of sources are largely determined by proximity to source, weighted-average source apportionment pie charts based on all modelled receptors within each AQMA are also presented.

8.1 Baseline 2019

8.1.1 Nitrogen Dioxide

The estimated contributions of each modelled source sector to the 2019 annual mean NO_2 concentrations are presented in tabular form in Table 8-1 for selected receptors with the highest predicted NO_2 concentrations in 2019. Figure 8-1 and Figure 8-2 show the source apportionment in graphical form for two selected receptors, to illustrate the some of the key trends of the source apportionment results and the differences observed between receptor locations.

The predominant source sector contribution to 2019 annual mean NO_2 concentrations for these selected receptors is road traffic emissions, accounting for between approximately 56% and 77% depending on receptor location. Road traffic is therefore likely to be the key source in areas of exceedance of the annual mean NO_2 UK AQO.

Of the other sectors explicitly modelled, the point sources are typically the next largest contributor to modelled NO_2 concentrations after road traffic, accounting for up to approximately 1.2% of total modelled NO_2. The rail sector is predicted to typically account for around 0.6 % to 0.8% of the modelled 2019 NO_2 concentration, emissions from the port typically contributes around 0.5% and the airport less than 0.1%. This indicates that these sectors are unlikely to be driving exceedances of the annual mean NO_2 UK AQO.

Domestic background (which includes domestic, commercial and institutional space heating) is an important contributor at some receptor locations. Of the selected receptors, domestic background is estimated to account for more than 10% of total modelled NO_2 concentrations at Receptor IDs DO 987 (residential property at Clifton House Mews), DO 1294 (residential property at Molyneaux Street), DO 410 (Cu Chulainn House, Victoria Parade), and DO 136 (residential property at Henry Place). These results indicate that in certain areas of the city, the domestic background sector is an important secondary contributor, after road traffic, to exceedances of the annual mean NO_2 UK AQO.

The regional background sector is estimated to account for between 6.5% and 8.3% of total modelled NO_2 concentrations at the selected receptor locations. The other background sector shows a wider variation in relative contribution, accounting for between approximately 7.6% and 16.6% of total modelled NO_2.

Table 8-1. Estimated Contribution of each Source Sector to the 2019 Annual Mean NO_2 Concentration (Selected Receptors)

Receptor ID	Roads	Point Sources	Airport	Port	Rail	Regional Background	Domestic Background	Other Local Background
DO_969	76.5%	0.6%	<0.1%	0.3%	0.6%	6.5%	7.8%	7.6%
DO_410	57.5%	1.2%	<0.1%	0.5%	0.7%	7.9%	16.4%	15.8%
DO_987	57.2%	1.1%	<0.1%	0.5%	0.6%	8.0%	16.6%	16.0%
ND_309	56.8%	1.1%	<0.1%	0.5%	0.6%	8.0%	16.7%	16.1%
DO_136	62.2%	1.1%	<0.1%	0.5%	0.6%	8.1%	15.4%	12.1%
DO_1294	55.9%	0.7%	<0.1%	0.3%	0.8%	8.3%	17.3%	16.6%

Figure 8-1. Estimated Contribution of each Source Sector to the 2019 Annual Mean NO_2 Concentration at Receptor ID DO 969 (Stockmans Lane (AQMA 1))

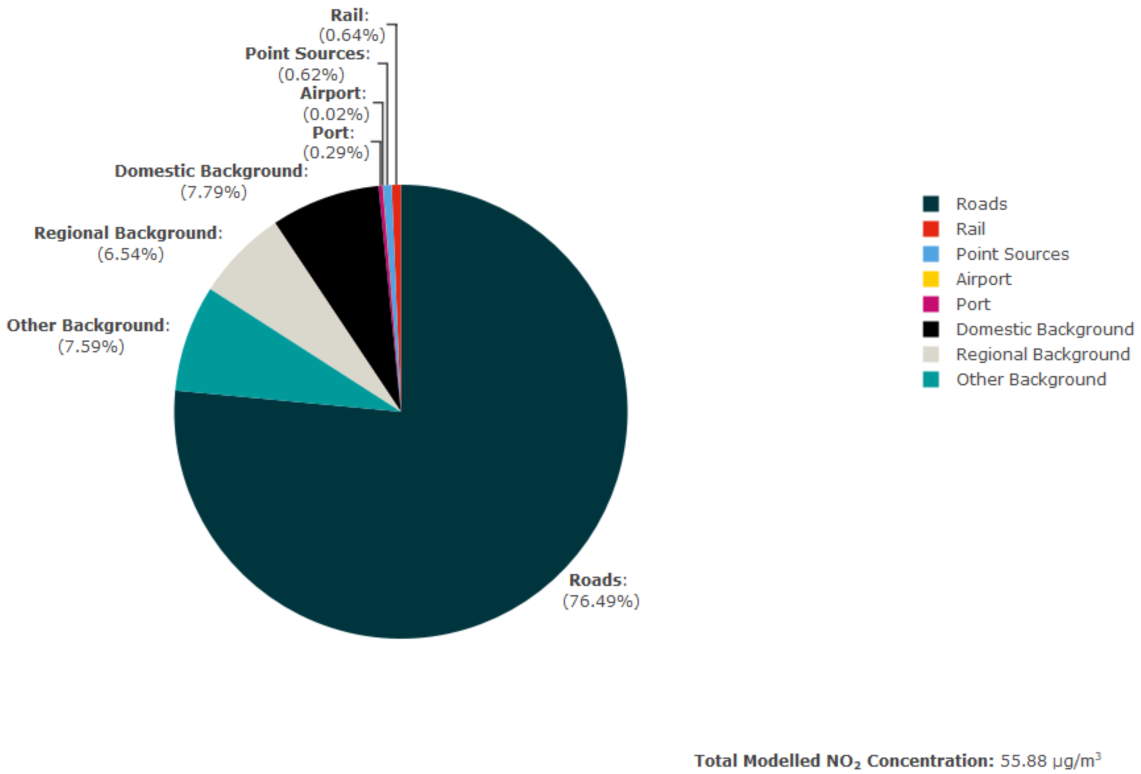
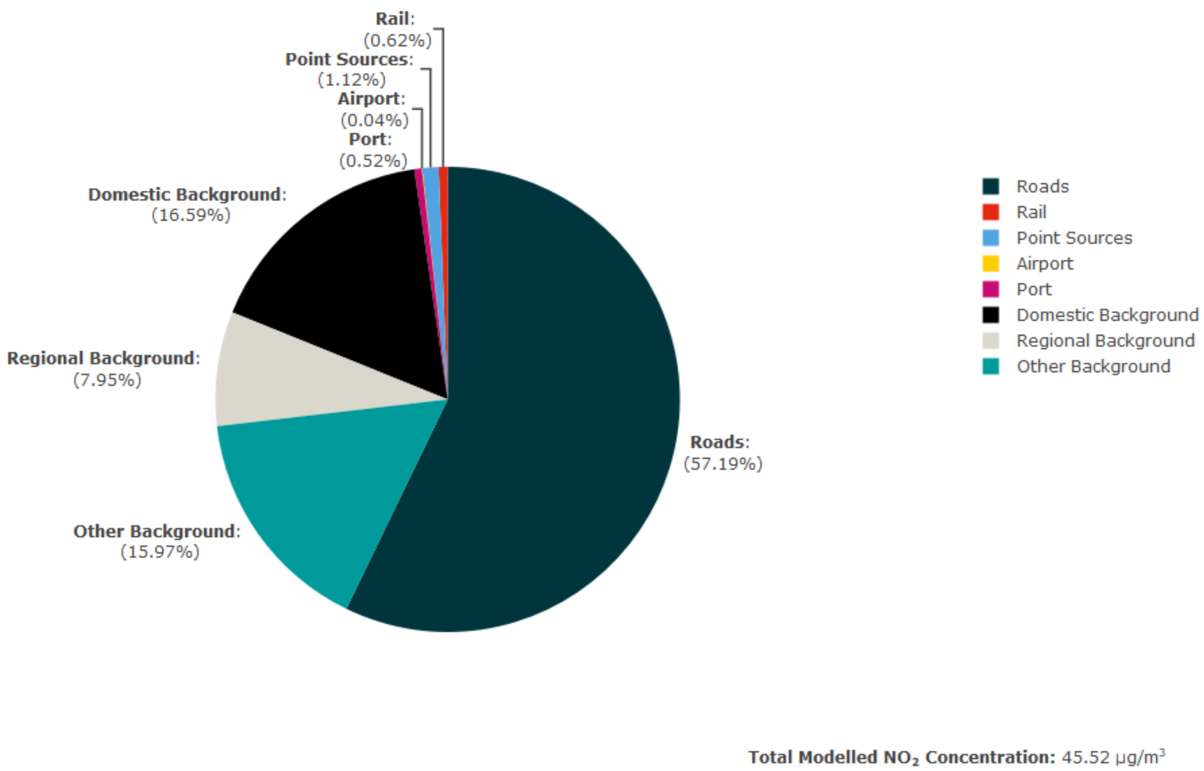


Figure 8-2. Estimated Contribution of each Source Sector to the 2019 Annual Mean NO_2 Concentration at Receptor ID DO 987 (Clifton House Mews (AQMA 1))



At the selected receptor locations (Table 8-1 above), the relative contributions of different sources will be largely determined by their proximity to a given source type (e.g. for a receptor situated close to a busy road, road traffic will be the dominant source contribution). To give an indication of the relative source contributions across the whole city in 2019 and AQMAs, weighted average source contributions (weighted according to the total modelled

NO_2 concentration) have been calculated and are shown in the pie charts in Figure 8-3 to Figure 8-7. The weighted average contributions are calculated as follows:

1. All modelled receptor points within the relevant area of the model domain are selected (e.g. all modelled points within the AQMA 1 area of the model – see maps in Appendix B.3)
2. The percentage contributions for each of the source sectors calculated as per the methodology described in Section 4.6 (i.e. roads, rail, port, airport, point sources, regional background, domestic background, other background) are collated;
3. The sum-product of the source-sector percentage contribution and the total modelled pollutant concentration across the selected receptor points is calculated, and;
4. The sum-product values for each sector from Step 2 is divided by the sum of the total modelled pollutant concentrations of all selected receptor points to obtain weighted average percentage contributions for each sector.

It should be noted that the weighted average pie charts for the AQMAs include points both within and just outside the AQMA boundaries.

The dominant source sector contribution to 2019 annual mean NO_2 concentrations for AQMA 1 is road traffic emissions, representing 49%. Road traffic is likely to be a key source to exceedances of the annual mean NO_2 UK AQO within this AQMA. Domestic background sources are the next biggest contributor, accounting for 18%. The other background and regional background sectors are also significant sources, accounting for 16% and 12% respectively. Emissions from rail is estimated to contribute 2.4% to NO_2 concentrations. The remaining sources (Point, Airport and Port) each represent less than 2% of modelled NO_2 concentrations in AQMA 1. Contributions from the airport and port are expected to be small given their position downwind of AQMA 1.

Domestic background sources account for 33% of modelled 2019 NO_2 concentrations in AQMA 2 and is therefore an important contributor to exceedances of the 2019 annual mean NO_2 UK AQO in this AQMA. This, in part, reflects the inclusion of modelled receptor points in neighbouring urban background areas just outside the AQMA boundaries when calculating the weighted-average contributions. Nevertheless, the importance of the contribution of domestic background sources should not be discounted. Road traffic is the second largest source at 26%, followed by other background sources at 24%, regional background sources at 13% and rail at 2.3%. Point, airport and port sources each are estimated to account for less than 1%.

Road traffic emissions are the dominant source sector contribution in AQMA 3, accounting for 31% of 2019 annual mean NO_2 concentrations. Road traffic is likely to be the key source of exceedances of annual mean NO_2 UK AQO within AQMA 3. 24% of modelled 2019 NO_2 concentrations in AQMA 3 is from domestic background sources, whilst regional background sources account for 23% and other background sources account for 20%. The port source sector is estimated to contribute 1.7% of NO_2 concentrations in AQMA 3. The remaining sources represent 1% or less.

In AQMA 4, road traffic emissions are again estimated to be the primary source sector contribution to 2019 NO_2 annual mean concentrations, accounting for 38%. Domestic background is estimated to account for 26% of NO_2 annual mean concentrations in AQMA 4. The other background and regional background sectors are also significant sources, each accounting for 16%. Point, rail and port sources contribute between 1.0% to 1.5% each, whilst Airport is estimated to be less than 1%.

The city-wide relative source contributions in 2019 indicate road traffic emissions are the largest source sector contribution to 2019 annual mean NO_2 concentrations, accounting for 30% of concentrations across the city. Other background is source sectors are the next largest sector accounting for 24%. Regional background contributes 21% and domestic background contributes 20% to NO_2 concentrations across the city in 2019. Emissions from point, port and rail sources contribute 1.9%, 1.5% and 1.4% respectively each and airport sources are estimated to account for 0.3% of 2019 annual mean NO_2 concentration.

Figure 8-3. Estimated Average Contribution of each Source Sector to the 2019 Annual Mean NO_2 Concentration at Receptors in AQMA 1 - M1 Motorway / A12 Westlink Corridor.

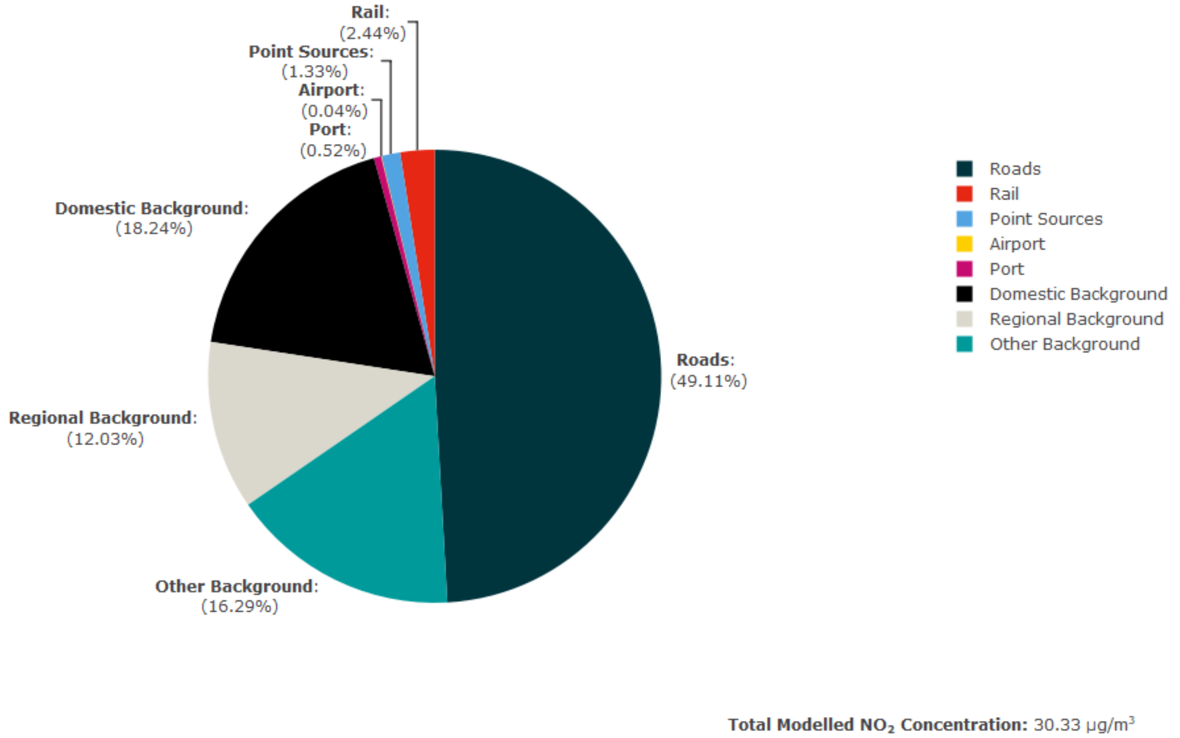


Figure 8-4. Estimated Average Contribution of each Source Sector to the 2019 Annual Mean NO_2 Concentration at Receptors in AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

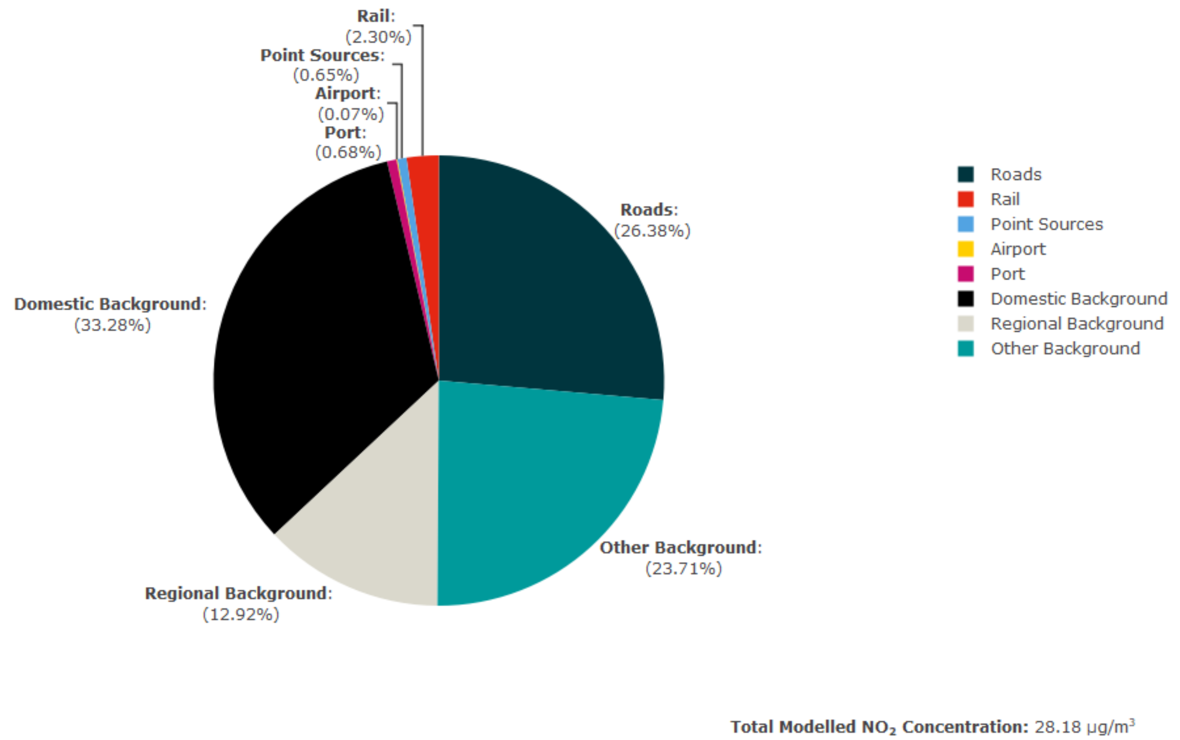


Figure 8-5. Estimated Average Contribution of each Source Sector to the 2019 Annual Mean NO_2 Concentration at Receptors in AQMA 3 - Upper Newtownards Road

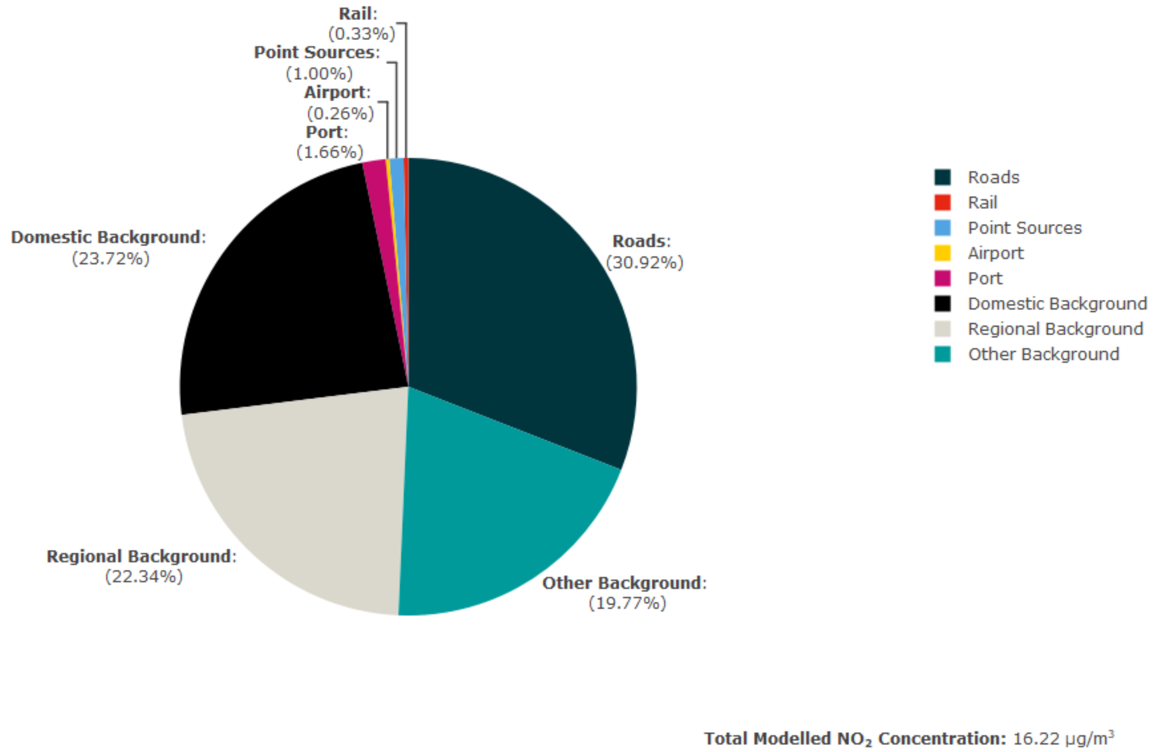


Figure 8-6. Estimated Average Contribution of each Source Sector to the 2019 Annual Mean NO_2 Concentration at Receptors in AQMA 4 - Ormeau Road

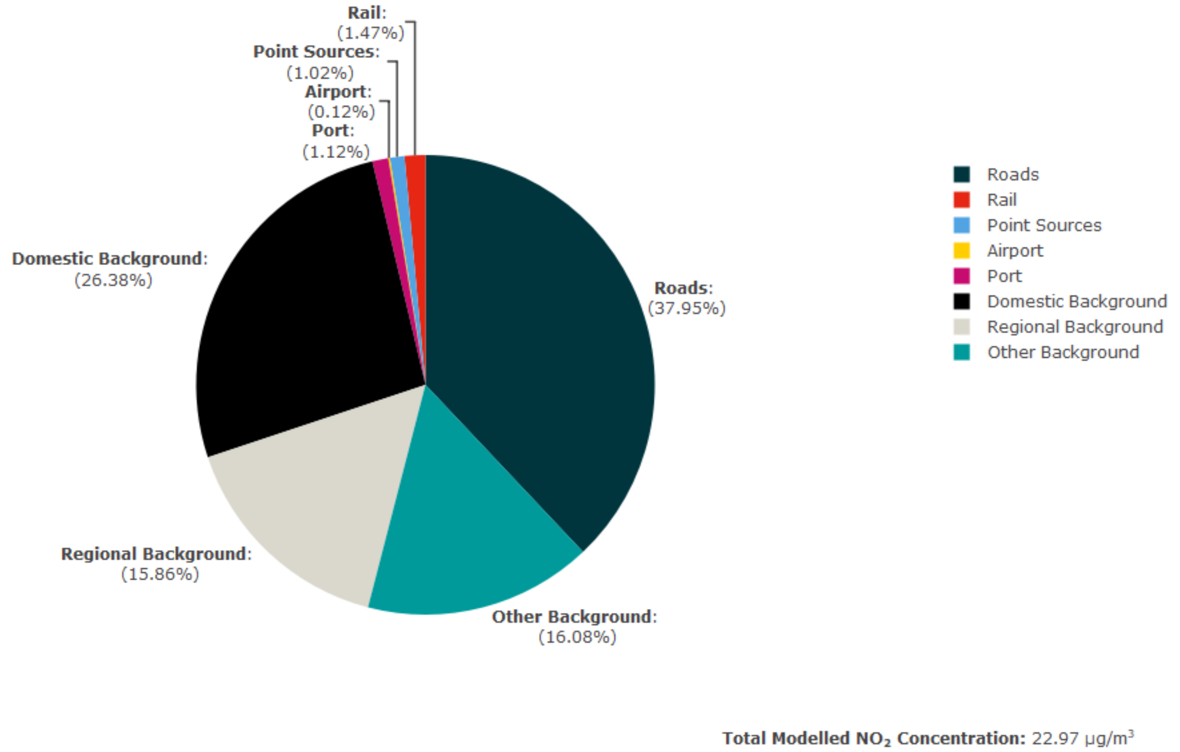
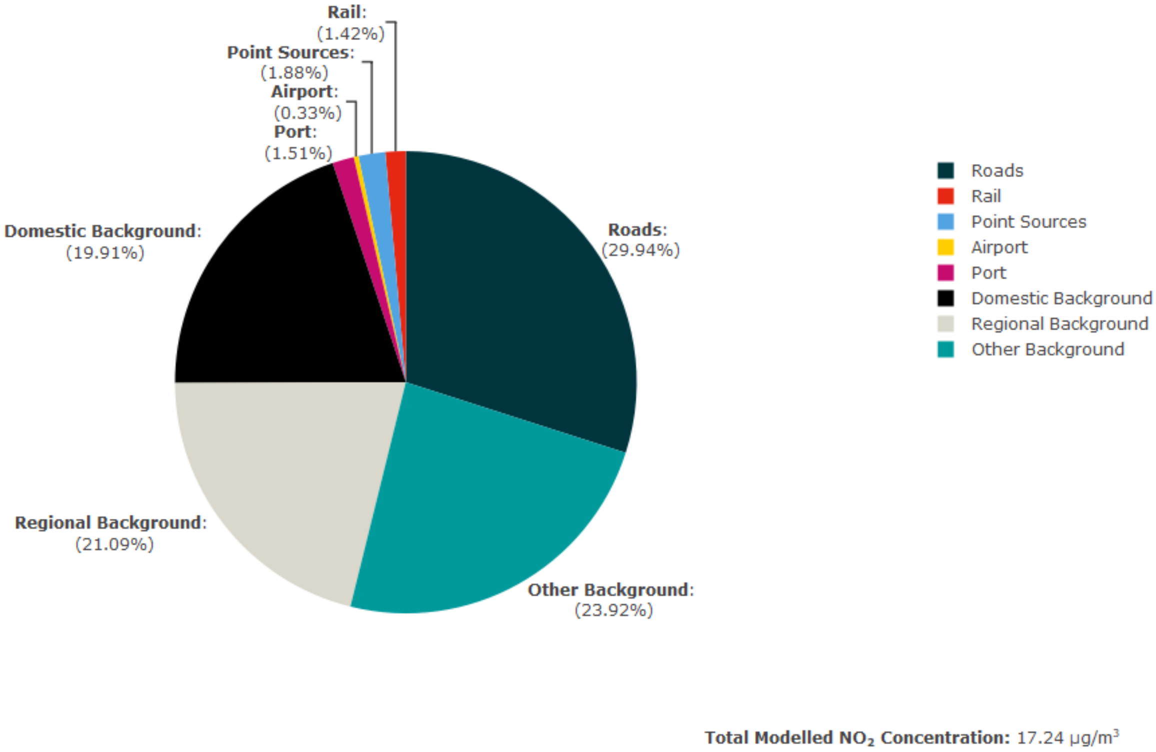


Figure 8-7. City-Wide Weighted Average Contribution of each Source Sector to the 2019 Annual Mean NO_2 Concentration



8.1.2 PM_{10}

The estimated contributions of each modelled source sector to the 2019 annual mean PM_{10} concentrations are presented in tabular form in Table 8-2 for receptors with the highest predicted PM_{10} concentrations. Figure 8-8 and Figure 8-9 show the source apportionment in graphical form for two selected receptors, to illustrate the some of the key trends of the source apportionment results and the differences observed between receptor locations.

The regional background sector is the predominant contributor to 2019 annual mean PM_{10} concentrations, accounting for more than 53% of the total modelled PM_{10} concentrations. The regional background includes sources from outside of Belfast that the Council has no control over, including natural sources such as windblown dust and sea salt, and secondary particulates (as discussed in Section 7.1.2.6). The large contributions from regional sources present a significant challenge to BCC's efforts to bring about reductions in PM_{10} concentrations.

Domestic background (which includes domestic, commercial and institutional space heating) is estimated to typically account for 15% to 19% of the total modelled PM_{10} concentrations, but is greater than 20% at some locations, indicating that this is a significant contributor to ambient PM_{10} concentrations. The other background sector, which includes all other local background sources of air pollution, accounts for approximately 11% to 12%.

Of the source sectors explicitly modelled, road traffic is the main contributor to total modelled PM_{10} concentrations, responsible for approximately 12% to 17% of the modelled total PM_{10} concentrations at the selected sensitive receptor locations.

The point sources, airport, port and rail sectors are estimated to make minimal contributions to annual mean PM_{10} concentrations, collectively accounting for less than 1% of the total modelled PM_{10} concentrations at the selected sensitive receptors.

Table 8-2. Estimated Contribution of each Source Sector to the 2019 Annual Mean PM_{10} Concentrations (Selected Receptors)

Full ID	Roads	Point Sources	Airport	Port	Rail	Regional Background	Domestic Background	Other Local Background
ND_414	17.1%	0.1%	<0.1%	0.1%	0.1%	53.5%	18.1%	11.0%
DO_889	12.9%	0.1%	<0.1%	0.1%	0.2%	56.2%	19.0%	11.5%
DO_648	12.6%	0.1%	<0.1%	0.1%	0.2%	56.4%	19.0%	11.6%
DO_935	12.5%	0.1%	<0.1%	0.1%	0.1%	56.5%	19.1%	11.6%
DO_1294	15.9%	0.3%	<0.1%	0.2%	0.2%	55.8%	15.1%	12.6%
DO_857	12.2%	0.1%	<0.1%	0.1%	0.1%	54.2%	23.2%	10.1%

Figure 8-8. Estimated Contribution of each Source Sector to the 2019 annual mean PM_{10} Concentration at ND 414 (Barrack Street (AQMA 1))

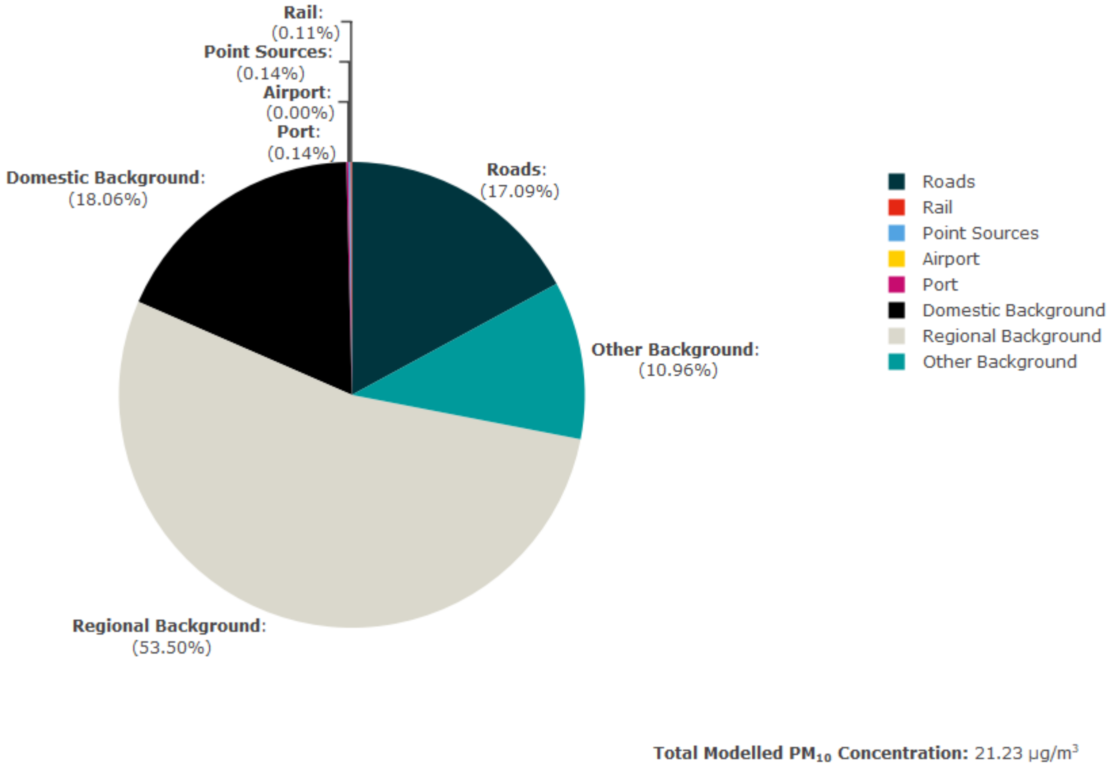
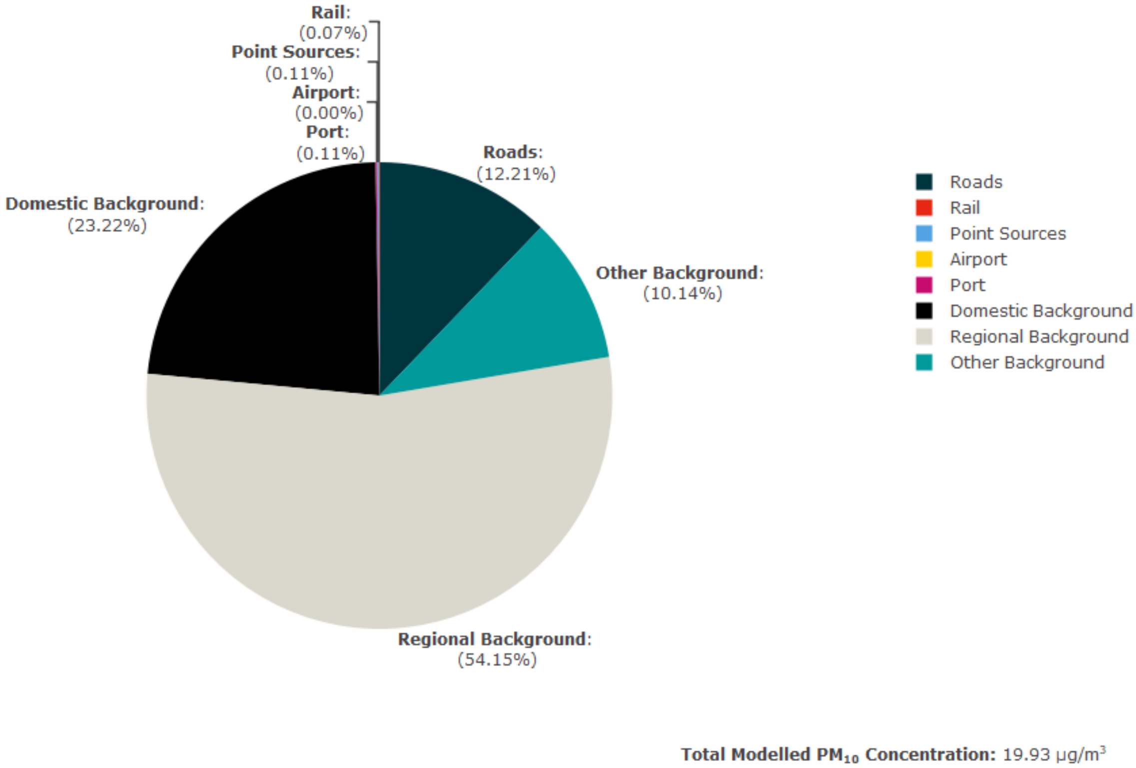


Figure 8-9. Estimated Contribution of each Source Sector to the 2019 Annual Mean PM_{10} Concentration at DO 857 (Glenmachan Street (AQMA 1))



To give an indication of the relative source contributions across the whole city in 2019 and AQMAs, weighted average source contributions (weighted according to the total modelled PM_{10} concentration) have been calculated and are shown in the pie charts in Figure 8-10 to Figure 8-14.

The relative sector source contributions of annual mean PM_{10} concentrations in 2019 is similar between the four AQMAs. The regional background sector is the predominate contributor to 2019 annual mean PM_{10} concentrations in all four AQMAs, ranging from 59% at AQMA 2 to 65% for AQMA 3. Domestic background is the next largest proportion and is estimated to account for 19% for AQMA 1 to 24% for AQMA 4. The other background source sector contributes 10% to 13%. Road traffic emissions are the primary contributor to 2019 annual mean PM_{10} emissions of the sources explicitly modelled, road traffic emissions account for 7%, 6%, 4% and 4% of PM_{10} concentrations in AQMAs 1 to 4 respectively. The point sources, airport, port and rail sectors are estimated to make minimal contributions to annual mean PM_{10} concentrations, collectively accounting for less than 1% of the total modelled PM_{10} concentrations at each of the AQMAs.

The city-wide relative source contributions in 2019 indicate regional background is the largest source sector contribution to 2019 annual mean PM_{10} concentrations, accounting for 68% of concentrations across the city. domestic background sources account for 18% of 2019 annual mean PM_{10} concentrations across the city, whilst Other background contributes 10%. Road traffic emissions are the largest contributor to annual mean PM_{10} concentrations across the city amongst sources explicitly modelled, accounting for 3%. The point sources, airport, port and rail sectors are estimated to make minimal contributions to annual mean PM_{10} concentrations, collectively accounting for less than 1%.

Figure 8-10. Estimated Average Contribution of each Source Sector to the 2019 Annual Mean PM_{10} Concentration at Receptors in AQMA 1 - M1 Motorway / A12 Westlink Corridor

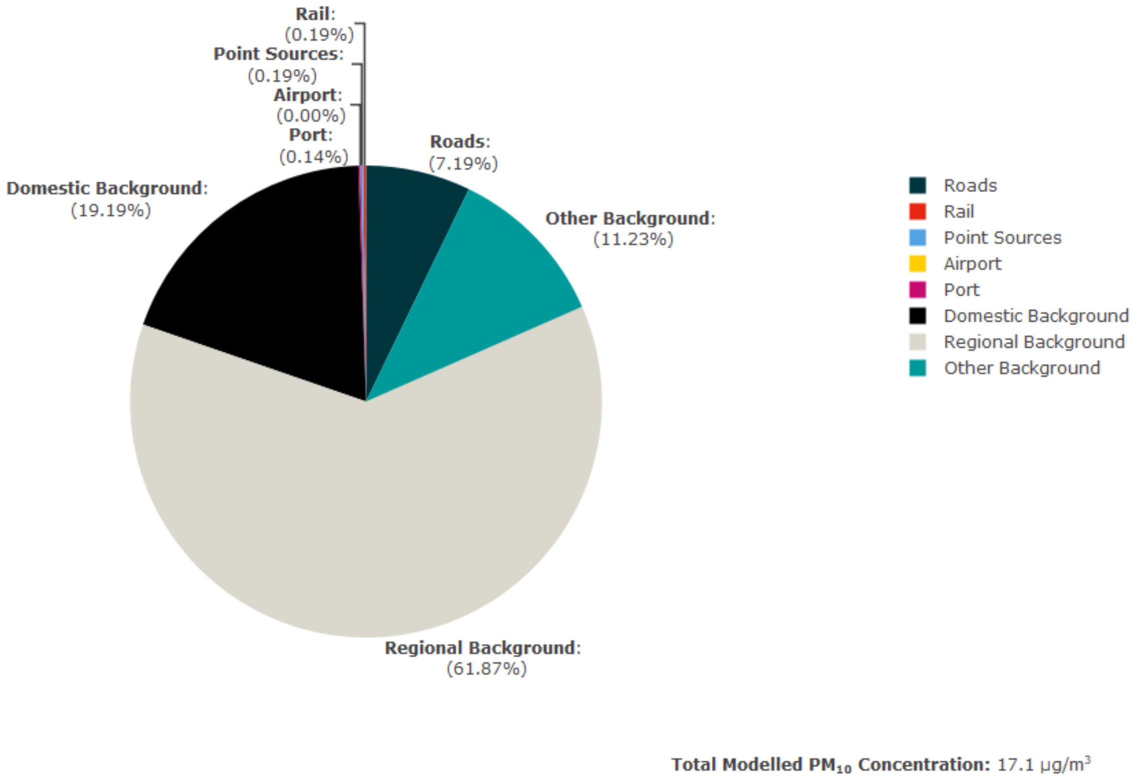


Figure 8-11. Estimated Average Contribution of each Source Sector to the 2019 Annual Mean PM_{10} Concentration at Receptors in AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

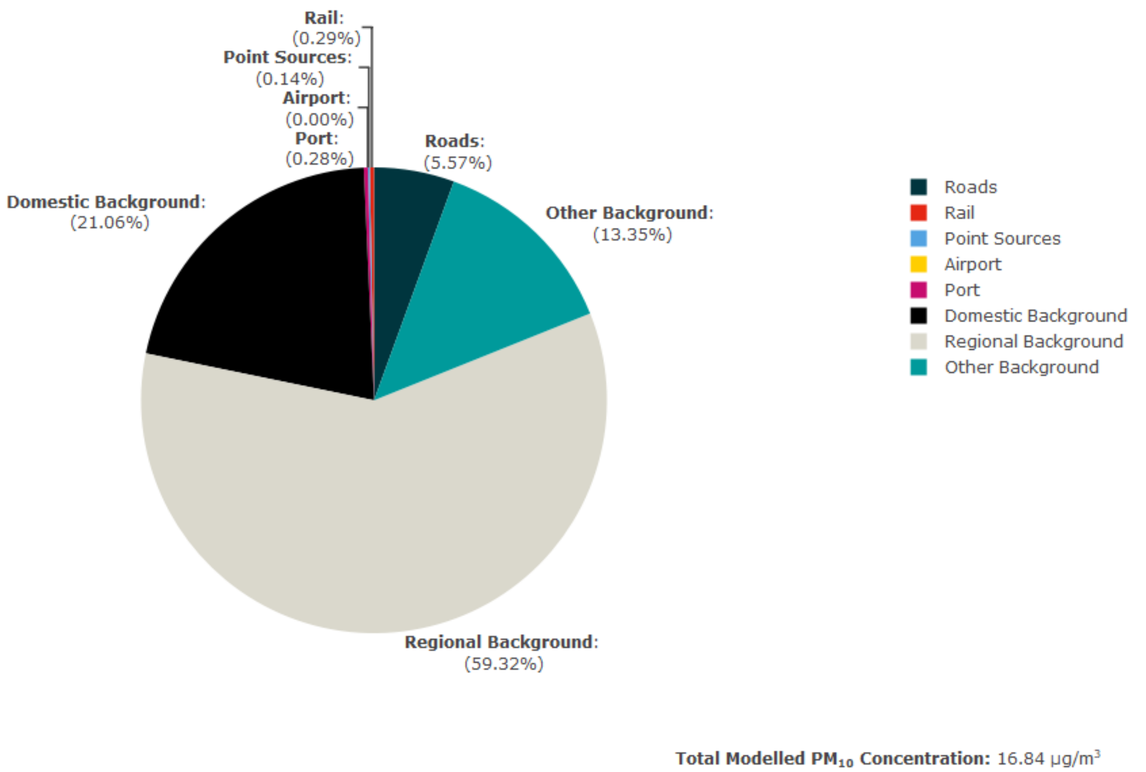
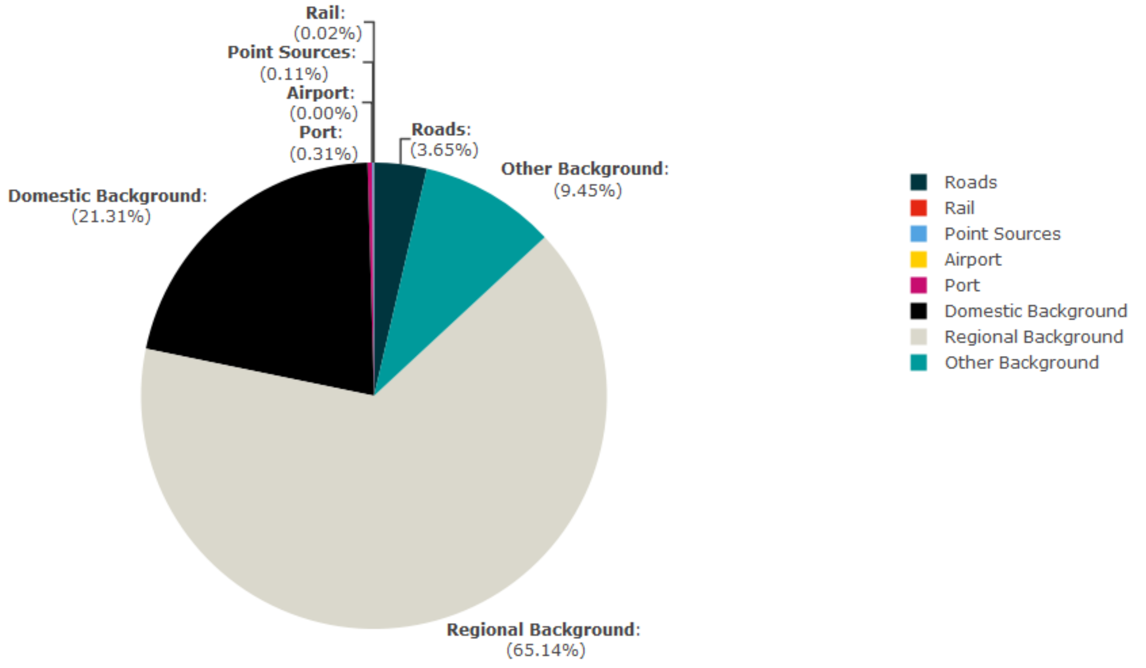
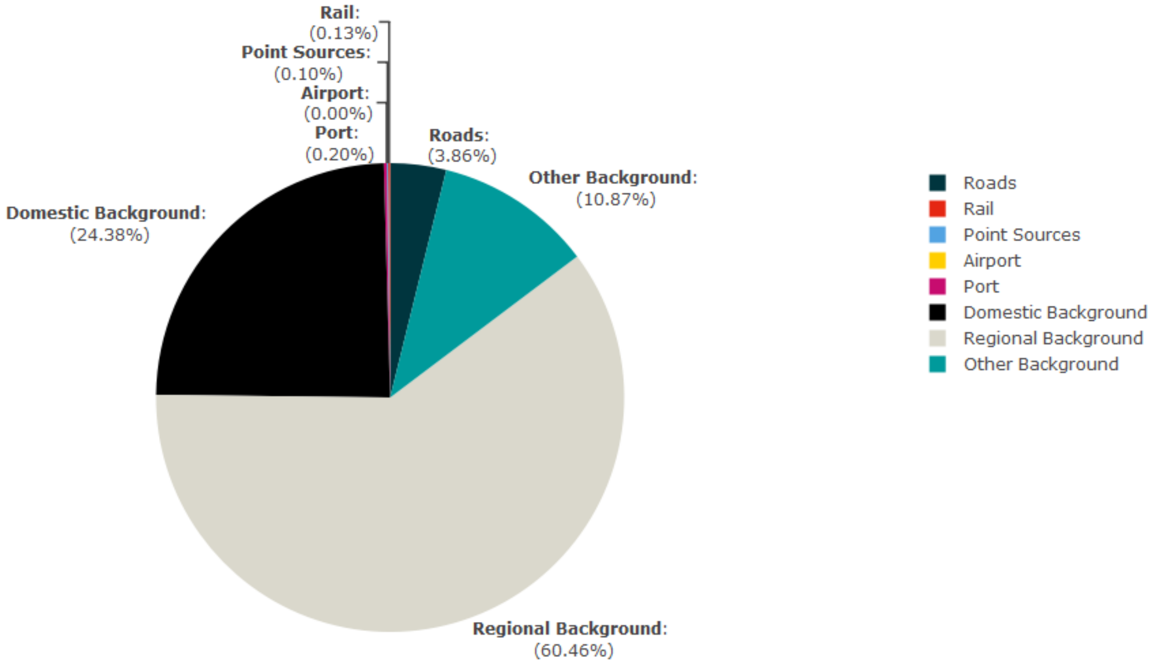


Figure 8-12. Estimated Average Contribution of each Source Sector to the 2019 Annual Mean PM_{10} Concentration at Receptors in AQMA 3 - Upper Newtownards Road



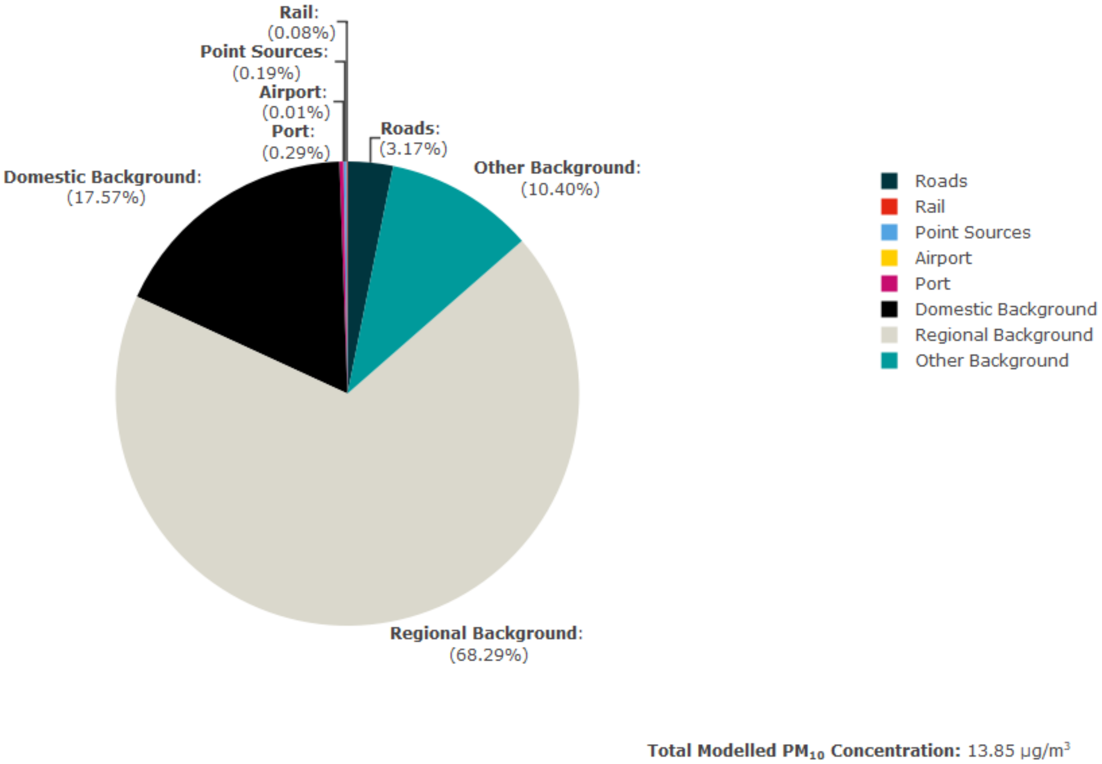
Total Modelled PM_{10} Concentration: 14.05 μg/m^3

Figure 8-13. Estimated Average Contribution of each Source Sector to the 2019 Annual Mean PM_{10} Concentration at Receptors in AQMA 4 - Ormeau Road



Total Modelled PM_{10} Concentration: 15.63 μg/m^3

Figure 8-14. City-Wide Weighted Average Contribution of each Source Sector to the 2019 Annual Mean PM_{10} Concentration



8.1.3 $PM_{2.5}$

The estimated contributions of each modelled source sector to the 2019 annual mean $PM_{2.5}$ concentrations are presented in tabular form in Table 8-3 for receptors with the highest predicted $PM_{2.5}$ concentrations. Figure 8-15 and Figure 8-16 show the source apportionment in graphical form for two selected receptors, to illustrate the some of the key trends of the source apportionment results and the differences observed between receptor locations.

The source apportionment for $PM_{2.5}$ follows a similar pattern to PM_{10}. The Regional Background sector is the predominant contributor to 2019 annual mean $PM_{2.5}$ concentrations, accounting for around 47% to 50% of the total modelled $PM_{2.5}$ concentrations. The Regional Background includes sources from outside of Belfast that the Council has no control over, including natural sources such as windblown dust and sea salt and secondary particulates (as discussed in 7.1.3.6). The large contributions from regional sources present a significant challenge to BCC's efforts to bring about reductions in $PM_{2.5}$ concentrations.

Domestic Background is estimated to account for approximately 22% to 34% of the total modelled $PM_{2.5}$ concentrations, indicating that this is a significant contributor to ambient $PM_{2.5}$ concentrations. The Other Background sector accounts for an estimated 8% to 11%.

Of the source sectors explicitly modelled, road traffic is the main contributor to total modelled $PM_{2.5}$ concentrations, responsible for between approximately 10% and 17% of the modelled total $PM_{2.5}$ concentrations at the selected sensitive receptor locations. The point sources, airport, port and rail sectors are estimated to make minimal contributions to annual mean $PM_{2.5}$ concentrations, collectively accounting for less than 1% of the total modelled $PM_{2.5}$ concentrations at the selected sensitive receptors.

Table 8-3. Estimated Contribution of each Source Sector to the 2019 Annual Mean $PM_{2.5}$ Concentration (Selected Receptors)

Full ID	Roads	Point Sources	Airport	Port	Rail	Regional Background	Domestic Background	Other Local Background
ND_414	15.8%	0.1%	<0.1%	0.2%	0.2%	47.8%	26.7%	9.1%
DO_913	13.7%	0.1%	0.0%	0.2%	0.2%	49.0%	27.4%	9.3%
DO_857	11.2%	0.1%	<0.1%	0.2%	0.1%	46.9%	33.6%	7.9%
DO_1265	16.8%	0.2%	<0.1%	0.3%	0.2%	49.5%	22.1%	10.9%
DO_889	11.8%	0.1%	<0.1%	0.2%	0.2%	50.1%	28.0%	9.5%
DO_721	10.4%	0.1%	<0.1%	0.2%	0.1%	47.3%	33.9%	8.0%
DO_935	11.5%	0.1%	<0.1%	0.2%	0.2%	50.3%	28.1%	9.6%

Figure 8-15. Estimated Contribution of each Source Sector to the 2019 Annual Mean $PM_{2.5}$ Concentration at DO_913 (Barrack Street (AQMA 1))

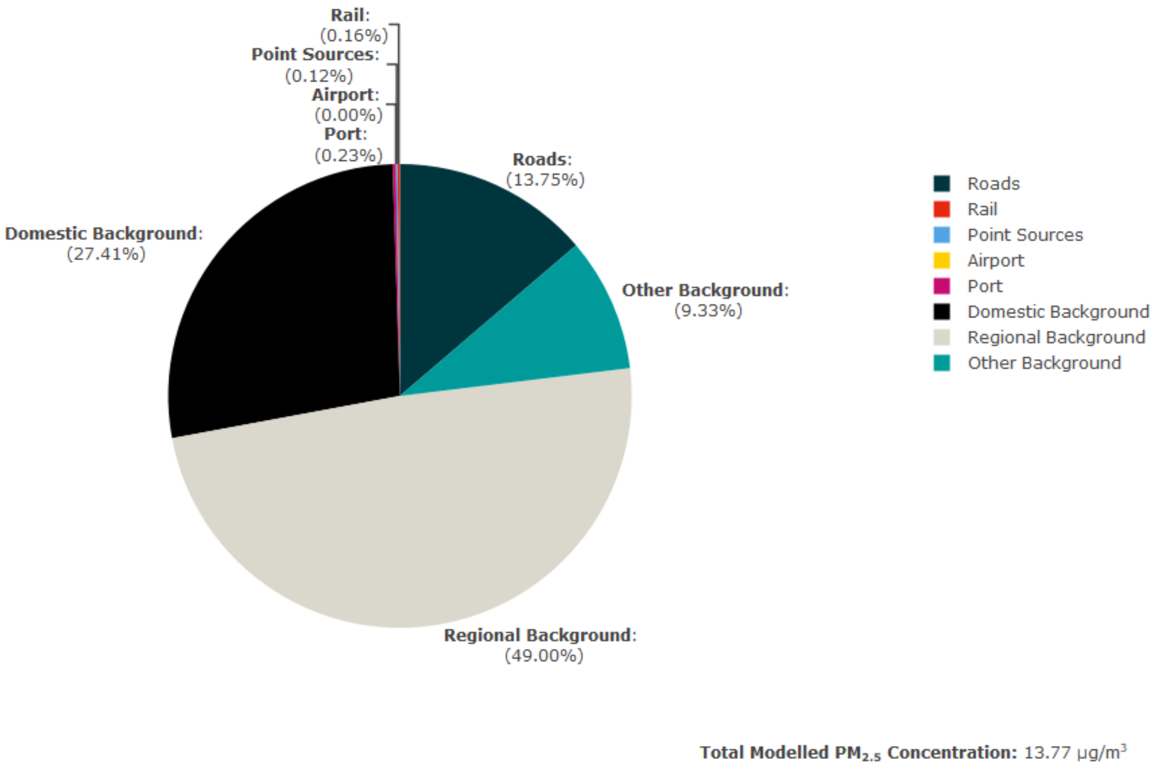
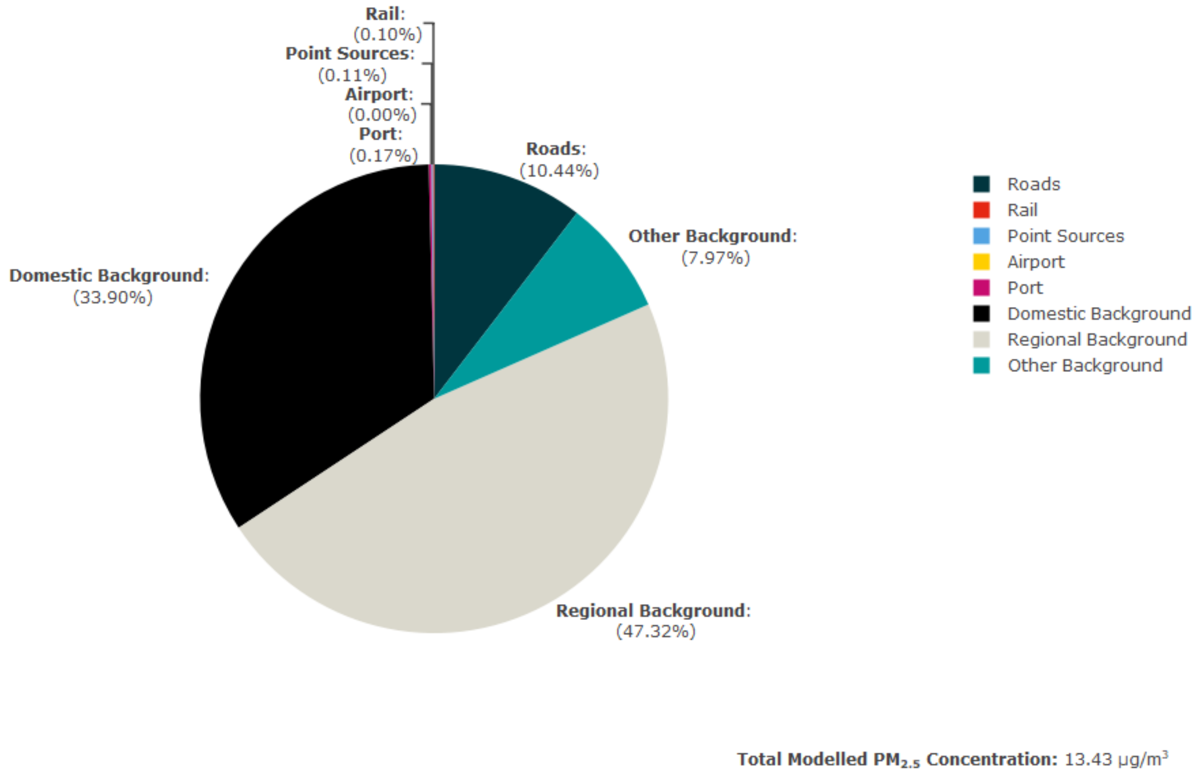


Figure 8-16. Estimated Contribution of each Source Sector to the 2019 Annual Mean $PM_{2.5}$ Concentration at DO_721 (Monarch Parade (AQMA 1))



To give an indication of the relative source contributions across the whole city in 2019 and AQMAs, weighted average source contributions (weighted according to the total modelled $PM_{2.5}$ concentration) have been calculated and are shown in the pie charts in Figure 8-17 to Figure 8-21.

The relative sector source contributions of annual mean $PM_{2.5}$ concentrations in 2019 averaged across AQMAs and the city is similar to PM_{10}, with Regional Background sector as the predominate contributor to 2019 annual mean $PM_{2.5}$ concentrations. The city-wide weighted average attributes 62% to Regional Background, and ranges between 53% to 58% between each AQMA. Domestic Background is the second largest contributor to 2019 annual mean $PM_{2.5}$ concentrations, with an estimated 26% contribution across the city-wide average. Within the AQMAs, the Domestic Background contribution is higher, ranging between 28% to 35%. The Other Background source sector contributes 9% to 2019 annual mean $PM_{2.5}$ concentrations across the city. Within AQMAs, the Other Background source sector is estimated to attributed to 7% to 11%. Road traffic emissions are the primary contributor to 2019 annual mean $PM_{2.5}$ emissions of the sources explicitly modelled, accounting for 3% across the city-wide weighted average. The road traffic emissions contributions to 2019 annual mean $PM_{2.5}$ concentrations within the AQMAs range from 3% to 7%. The point sources, airport, port and rail sectors are estimated to make minimal contributions to annual mean $PM_{2.5}$ concentrations, collectively accounting for less than 1% of the total modelled $PM_{2.5}$ concentrations both within AQMAs and across the city.

Figure 8-17. Estimated Average Contribution of each Source Sector to the 2019 Annual Mean $PM_{2.5}$ Concentration at Receptors in AQMA 1 - M1 Motorway / A12 Westlink Corridor

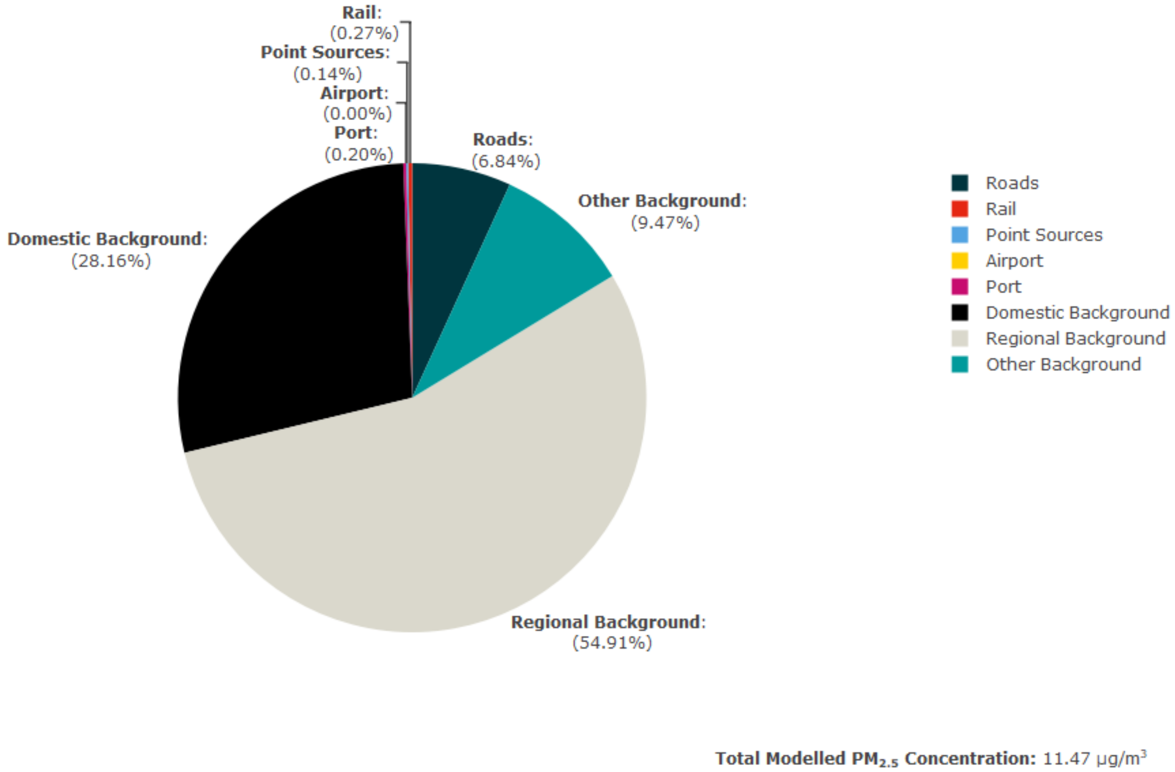


Figure 8-18. Estimated Average Contribution of each Source Sector to the 2019 Annual Mean $PM_{2.5}$ Concentration at Receptors in AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

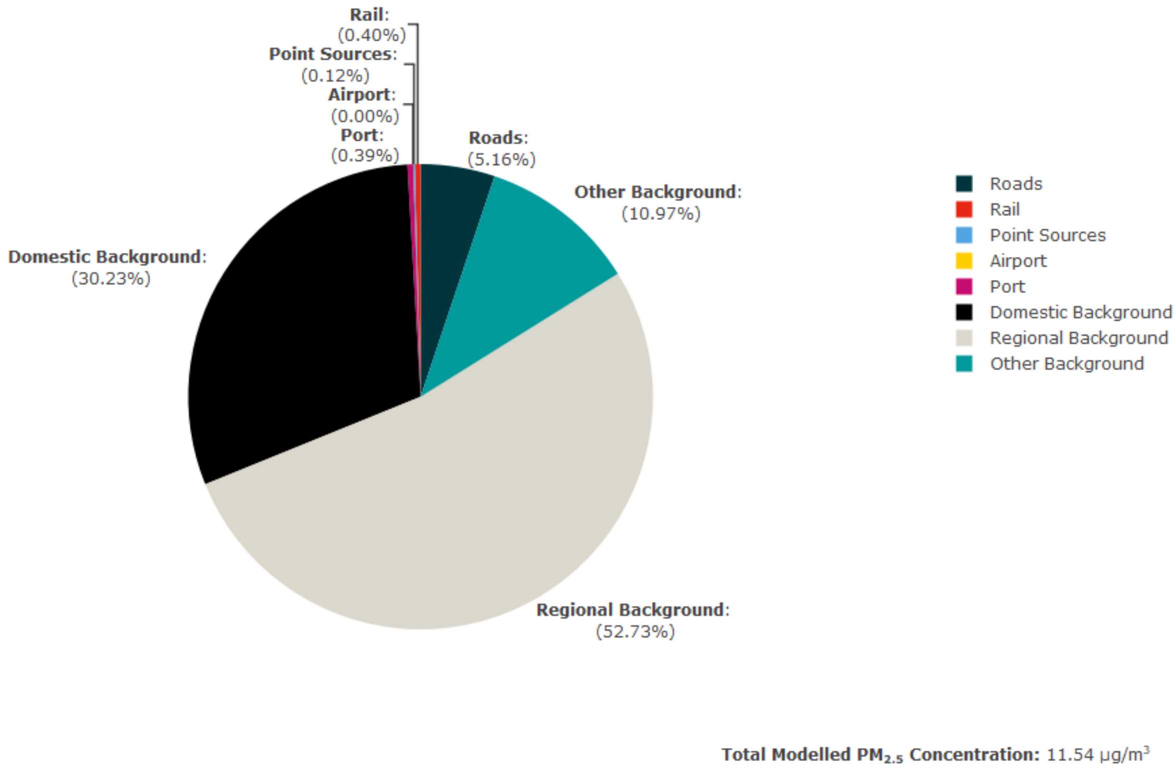


Figure 8-19. Estimated Average Contribution of each Source Sector to the 2019 Annual Mean $PM_{2.5}$ Concentration at Receptors in AQMA 3 - Upper Newtownards Road

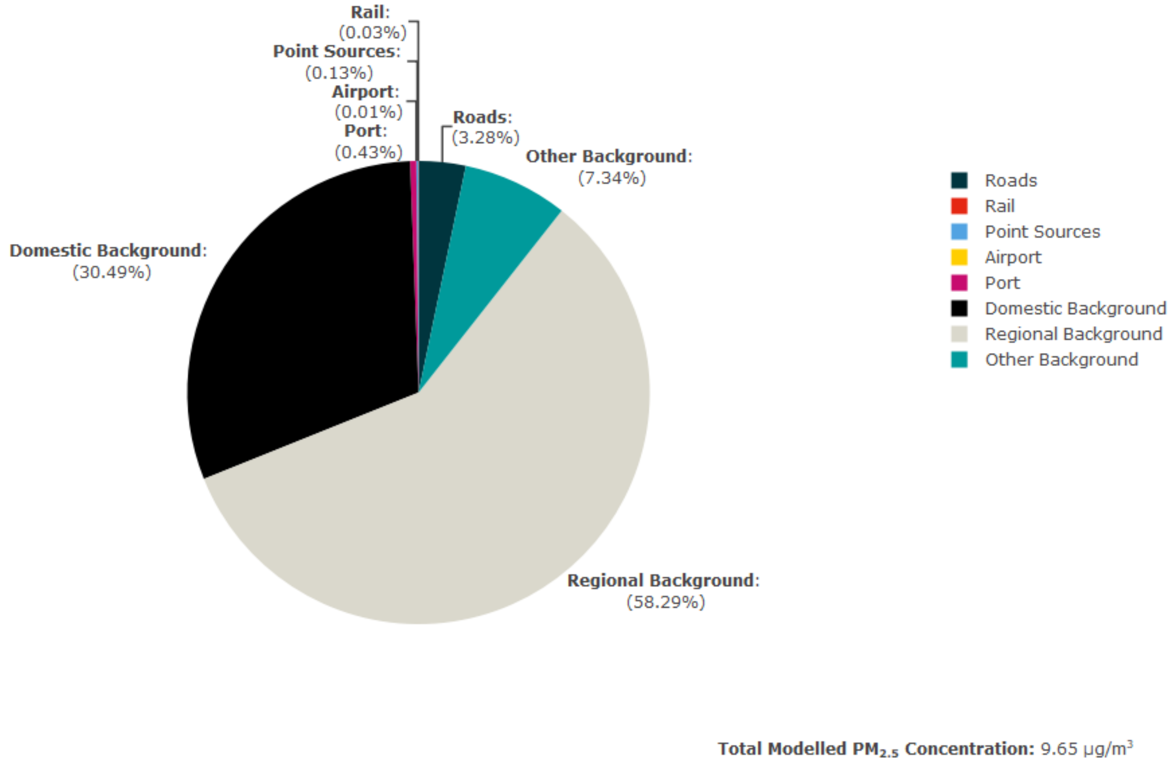


Figure 8-20. Estimated Average Contribution of each Source Sector to the 2019 Annual Mean $PM_{2.5}$ Concentration at Receptors in AQMA 4 - Ormeau Road

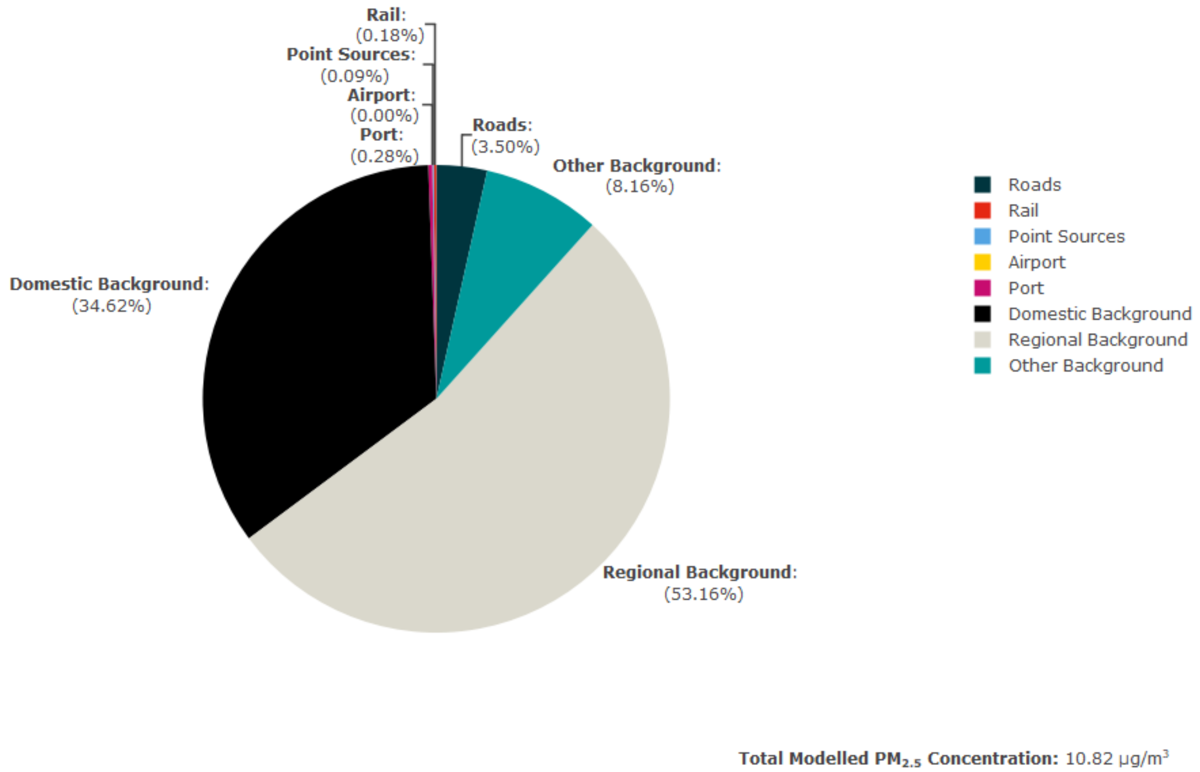
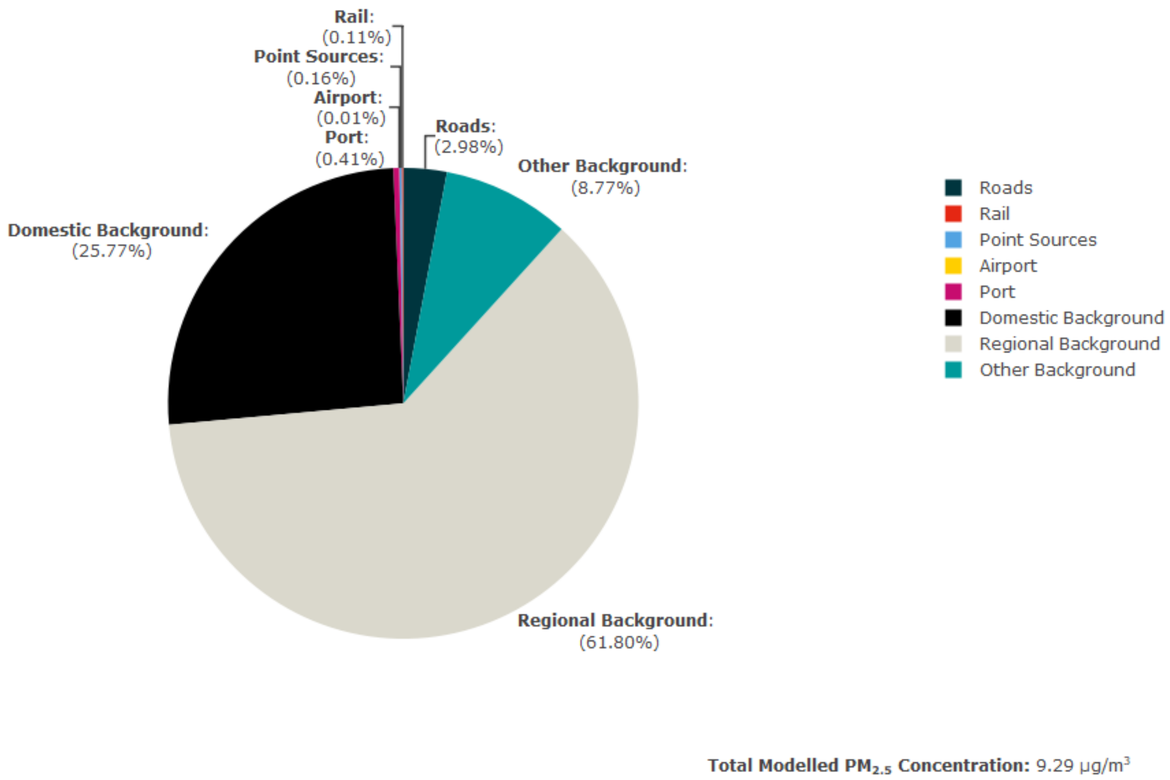


Figure 8-21. City-Wide Weighted Average Contribution of each Source Sector to the 2019 Annual Mean $PM_{2.5}$ Concentration



8.2 Future Year 2028

8.2.1 Nitrogen Dioxide

The estimated contributions of each modelled source sector to the 2028 annual mean NO_2 concentrations are presented in tabular form in Table 8-4 for selected receptors with the highest predicted NO_2 concentrations. Figure 8-22 and Figure 8-23 show the source apportionment in graphical form for two selected receptors, to illustrate the some of the key trends of the source apportionment results and the differences observed between receptor locations.

The predominant source sector contribution to 2028 annual mean NO_2 concentrations at most of the selected receptors is still road traffic emissions, accounting for between approximately 27% and 66% depending on receptor location. Road traffic remains a dominant contributor at Stockmans Lane (e.g. Receptor IDs DO_969 and DO_309). However, there are several receptor locations where domestic background is the largest contributor (e.g. Receptor IDs DO_262 (residential properties at Queen's Square), DO_627 and DO_1012 (residential locations in Cromac Street)).

Of the other sectors explicitly modelled, the point sources are typically the next largest contributor to modelled NO_2 concentrations after road traffic, accounting for up to approximately 2.2% of total modelled NO_2. The rail sector is predicted to typically account for around 1.0 % to 1.4% of the modelled 2028 NO_2 concentration, the port typically contributes around 0.6% to 1.0% and the airport 0.1% or less. Whilst still representing a very small proportion of the total modelled concentrations at these selected receptor locations, it is notable that the relative contributions of all these source sectors are higher in 2028 than 2019. This reflects the projected future year reductions in road traffic emissions, whilst for the other source sectors emissions are expected to remain constant in the future.

As noted above, domestic background is an important contributor at some receptor locations. At Receptor IDs DO 627 (residential property at Clifton House Mews) and DO 1012 (residential property at Cromac Street) the domestic background contribution to modelled NO_2 concentrations in 2028 is predicted to be greater than 48%. The results indicate that in certain areas of the city, the domestic background sector is an important secondary contributor, after road traffic, and may become the dominant sector of NOx emissions in some localities.

The Regional Background sector is estimated to account for between 9.1% and 11.3% of total modelled NO_2 concentrations at the selected receptor locations. The Other Background sector shows a wider variation in relative contribution, accounting for between approximately 7.9% and 17.1% of total modelled NO_2.

Table 8-4. Estimated Contribution of each Source Sector to the 2028 Annual Mean NO_2 Concentrations (Selected Receptors)

Full ID	Roads	Point Sources	Airport	Port	Rail	Regional Background	Domestic Background	Other Local Background
DO_969	66.0%	1.3%	0.0%	0.6%	1.3%	9.1%	13.7%	7.9%
DO_309	63.1%	1.4%	0.0%	0.6%	1.4%	9.9%	14.9%	8.6%
DO_987	42.5%	2.0%	0.1%	0.9%	1.1%	10.2%	27.3%	15.9%
DO_410	41.6%	2.1%	0.1%	1.0%	1.2%	10.3%	27.6%	16.1%
DO_262	27.3%	0.8%	0.0%	0.6%	0.9%	10.6%	45.7%	14.0%
ND_309	40.0%	2.1%	0.1%	0.9%	1.1%	10.7%	28.5%	16.6%
DO_127	38.1%	2.2%	0.1%	1.0%	1.2%	11.0%	29.4%	17.1%
DO_136	45.8%	2.2%	0.1%	0.9%	1.1%	11.1%	26.7%	12.0%
DO_627	23.1%	0.7%	0.0%	0.6%	1.2%	11.2%	48.3%	14.8%
DO_1012	22.8%	0.7%	0.0%	0.6%	1.2%	11.3%	48.4%	14.9%

Figure 8-22. Estimated Contribution of each Source Sector to the 2028 Annual Mean NO_2 concentration at DO_262 (Queen's Square)

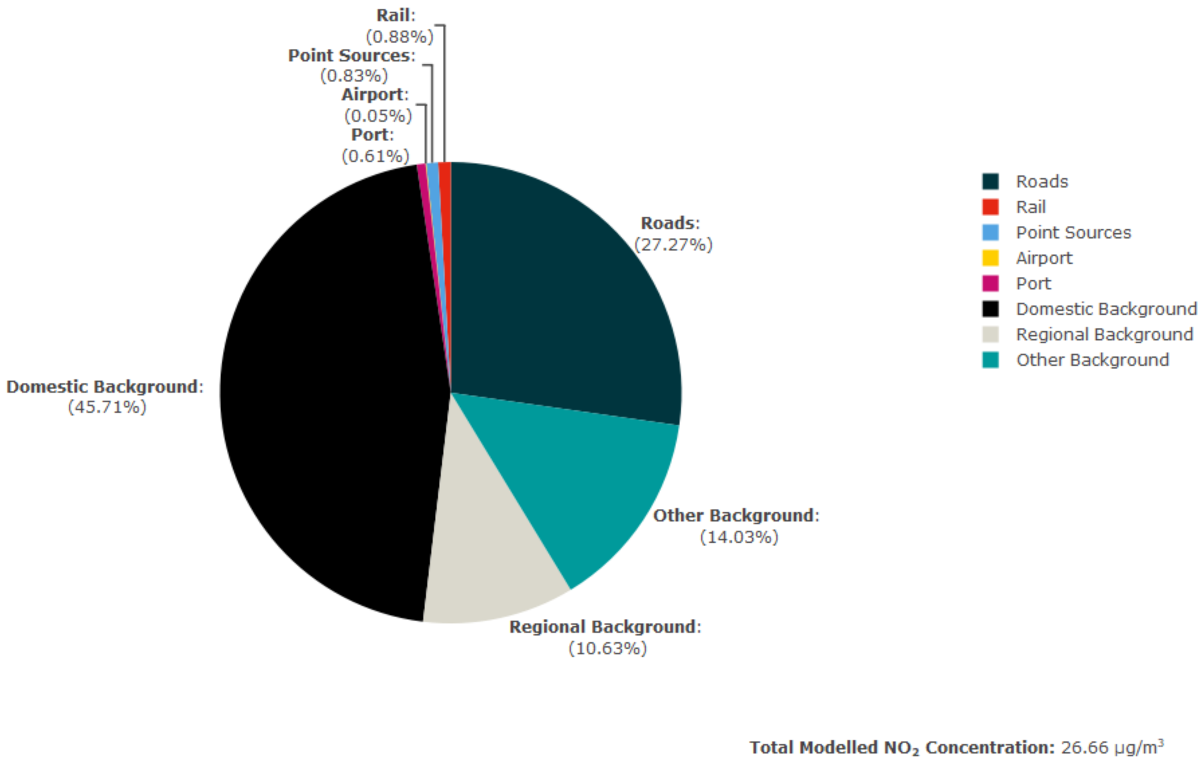
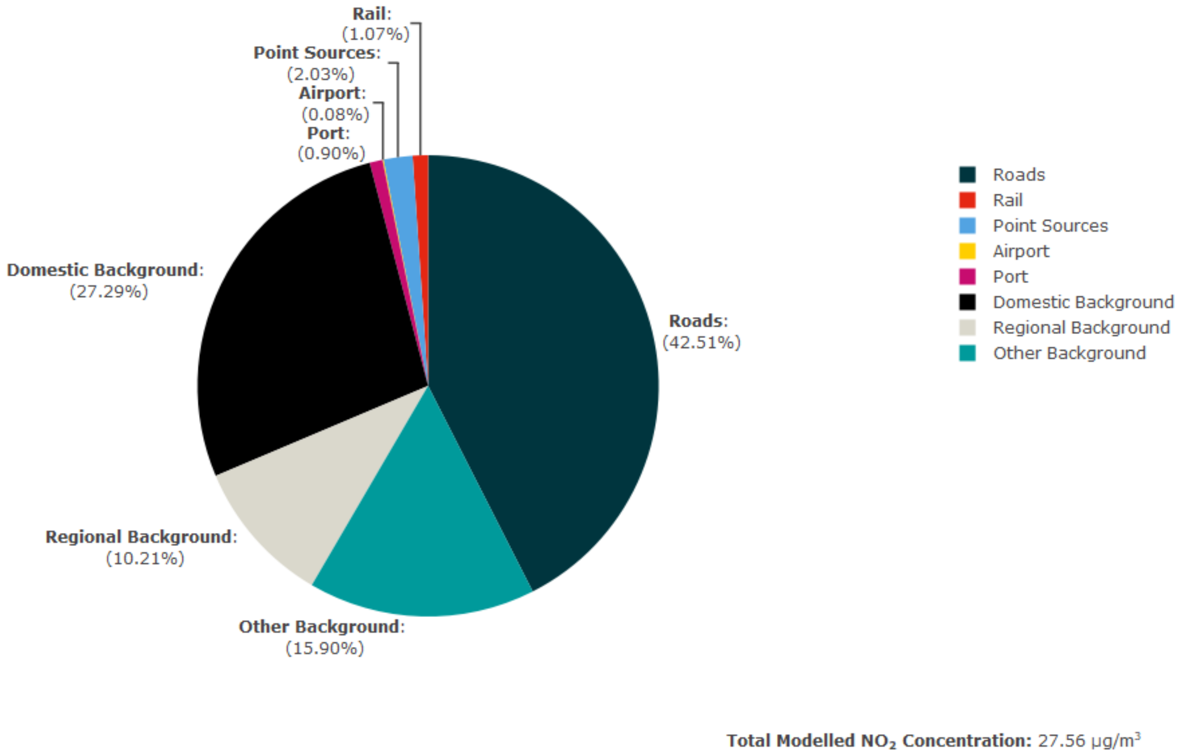


Figure 8-23. Estimated Contribution of each Source Sector to the 2028 Annual Mean NO_2 Concentration at DO_987 (Clifton House Mews)



To give an indication of the relative source contributions across the whole city in 2019 and AQMAs, weighted average source contributions (weighted according to the total modelled NO_2 concentration) have been calculated and are shown in the pie charts in Figure 8-3 to Figure 8-7.

Road traffic emissions remain a dominant source contributing to 2028 annual mean NO_2 concentrations in AQMA 1, representing 32%. Domestic Background sources are the next biggest contributor, accounting for 30%. The Other Background and Regional Background sectors are also significant sources, each accounting for 16%. Emissions from Rail are estimated to contribute 4% to NO_2 concentrations, and Point sources are estimated to account for 2.4%. The remaining sources (Airport and Port) each represent less than 1% of modelled NO_2 concentrations in AQMA 1.

Domestic Background sources account for 48% of modelled 2028 NO_2 concentrations in AQMA 2 and is therefore estimated to be the key source in 2028. Other Background sources are the second largest contributor at 18%. Road traffic emissions and Regional Background sources are predicted to both account for 14%. Point, Airport and Port sources each are estimated to account for less than 5%.

Road traffic emissions are estimated to account for 11% of 2028 annual mean NO_2 concentrations in AQMA 3. Domestic, Regional and Other Background sector source are predicted to be more significant contributions to annual mean NO_2 concentrations than road traffic emissions in AQMA 3 by 2028, accounting for 36%, 28% and 19% respectively. The Port source sector is estimated to contribute 2.7% of NO_2 concentrations in AQMA 3, and Point sources contributing 2.0%. The remaining sources are estimated to account for less than 1%.

In AQMA 4, Domestic Background is estimated to be the primary source sector contribution to 2028 NO_2 annual mean concentrations, accounting for 39%. Road traffic emissions are predicted to be the second largest source, accounting for 24% of NO_2 annual mean concentrations in AQMA 4. The Regional Background and Other Background sectors are also significant sources, accounting for 19% and 13% respectively. Point, Rail and Port sources contribute between 1.7% to 2.2% each, whilst Airport is attributed to less than 1%.

In 2028, Road traffic emissions are predicted to account for 17% of annual mean NO_2 concentrations across the city-wide weighted average. Domestic, Regional and Other Background sector source are all predicted to be more significant contributions to annual mean NO_2 concentrations than road traffic emissions in across the city by 2028, accounting for 28%, 24% and 24% respectively. Emissions from Point sources are estimated to contribute 3.0% across the city in 2028, followed by Port (2.2%), Rail (2.0%) and Airport (0.5%).

Figure 8-24. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean NO_2 Concentration at Receptors in AQMA 1 - M1 Motorway / A12 Westlink Corridor

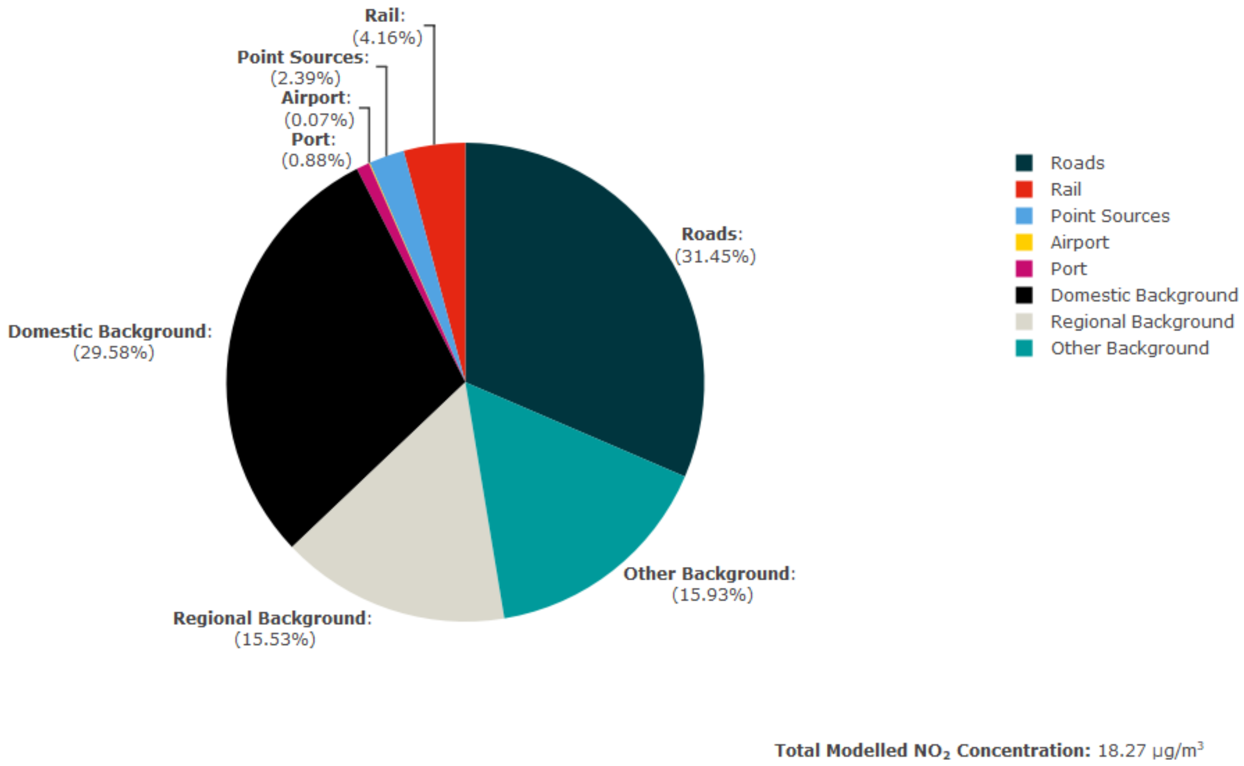


Figure 8-25. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean NO_2 Concentration at Receptors in AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

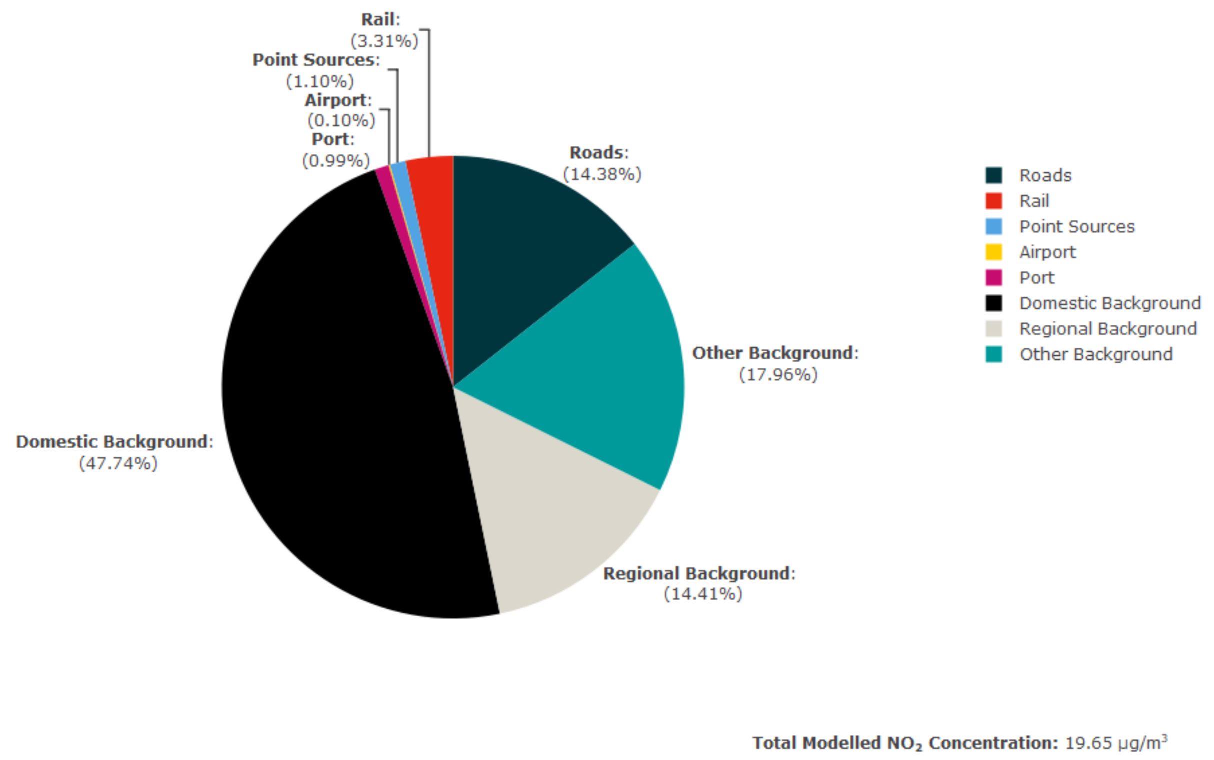


Figure 8-26. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean NO_2 Concentration at Receptors in AQMA 3 - Upper Newtownards Road

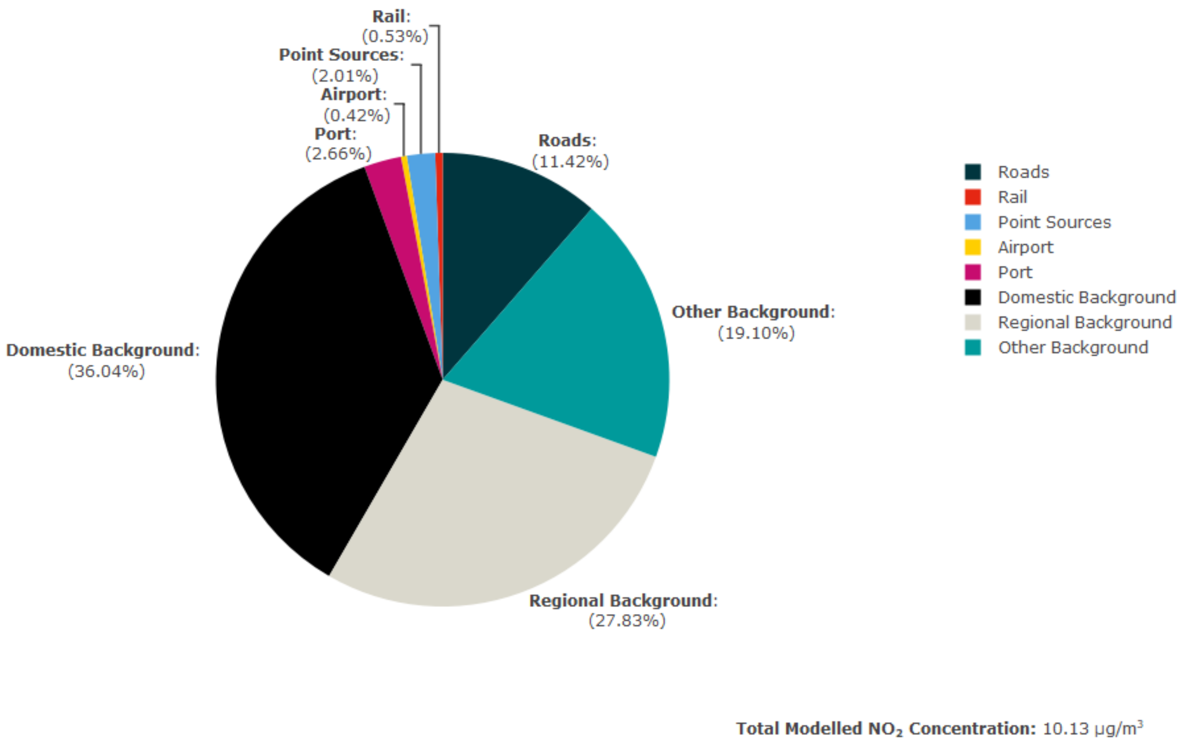


Figure 8-27. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean NO_2 Concentration at Receptors in AQMA 4 - Ormeau Road

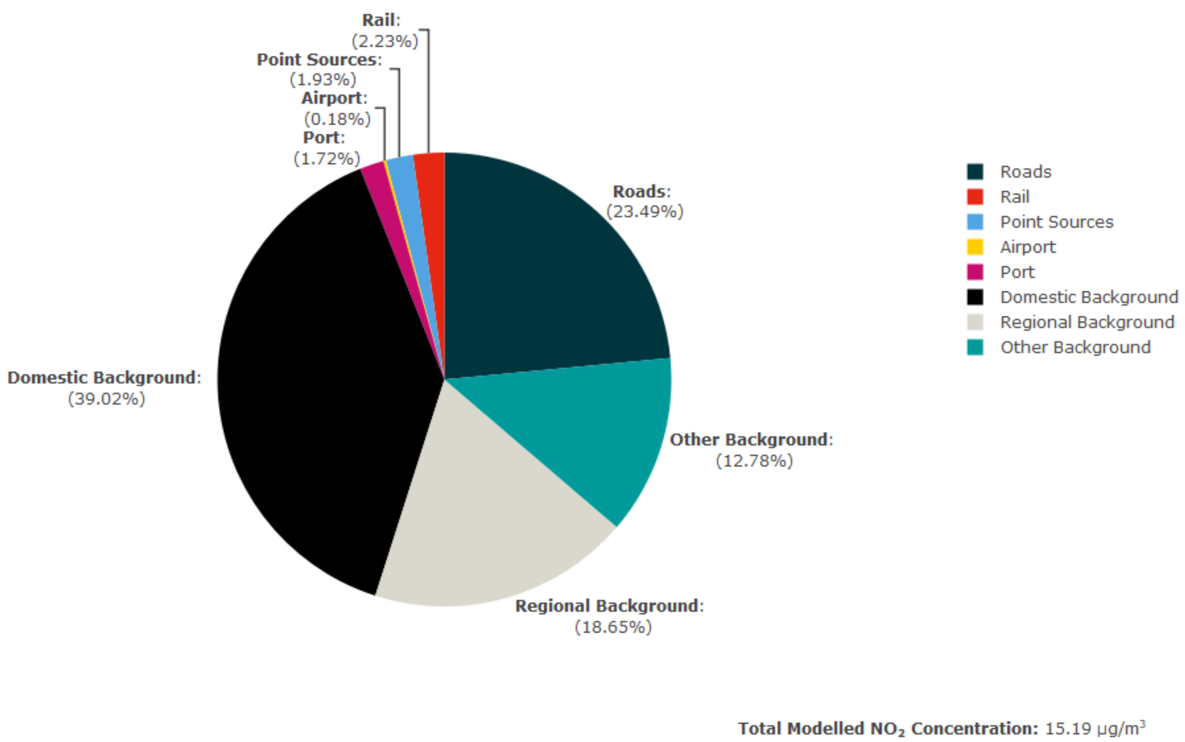
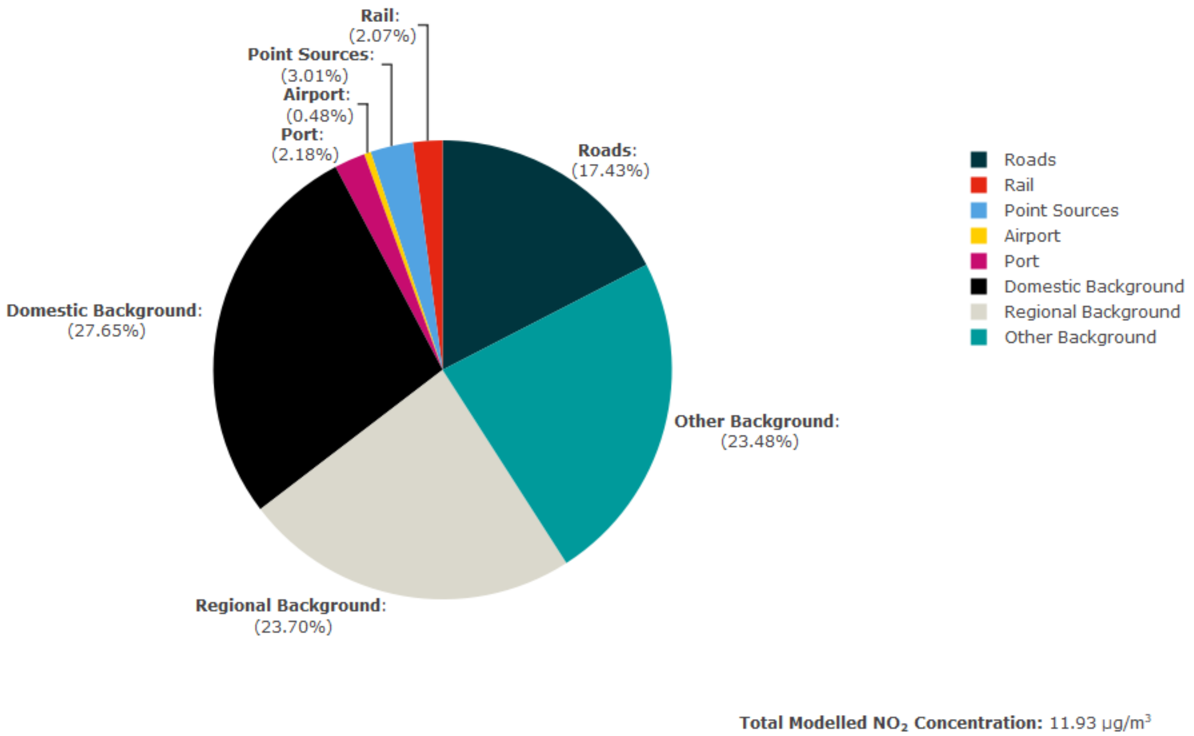


Figure 8-28. City-Wide Weighted Average Contribution of each Source Sector to the 2028 Annual Mean NO_2 Concentration



8.2.2 PM_{10}

The estimated contribution of each source sector to the 2028 annual mean PM_{10} concentration is presented in tabular form in Table 8-5. Figure 8-29 and Figure 8-30 show the source apportionment in graphical form for two selected receptors, to illustrate the some of the key trends of the source apportionment results and the differences observed between receptor locations.

The primary contribution to 2028 annual mean PM_{10} concentration for these selected receptors comes from regional background, accounting for more than 50% of the total modelled PM_{10} concentrations. The Regional Background includes sources from outside of Belfast that the Council has no control over, including natural sources such as windblown dust and sea salt, and secondary particulates (as discussed in Section 7.1.2.6). The large contributions from regional sources present a significant challenge to BCC's efforts to bring about reductions in PM_{10} concentrations.

Domestic Background (which includes domestic, commercial and institutional space heating) is estimated to typically account for 15% to 20% of the total modelled PM_{10} concentrations. The 'other background' sector, which includes all other local background sources of air pollution, accounts for approximately 11% to 12%.

Of the source sectors explicitly modelled, road traffic is the main contributor to total modelled PM_{10} concentrations, responsible for approximately 14% to 21% of the modelled total PM_{10} concentrations at the selected sensitive receptor locations.

The point sources, airport, port and rail sectors are estimated to make minimal contributions to annual mean PM_{10} concentrations, collectively accounting for less than 1% of the total modelled PM_{10} concentrations at the selected sensitive receptors.

Table 8-5. Estimated Contribution of each Source Sector to the 2028 Annual Mean PM_{10} Concentration (Selected Receptors)

Full ID	Roads	Point Sources	Airport	Port	Rail	Regional Background	Domestic Background	Other Local Background
ND_163	18.5%	0.2%	0.0%	0.3%	0.2%	53.8%	15.2%	12.0%
ND_490	13.6%	0.1%	0.0%	0.2%	0.1%	55.5%	19.6%	11.0%
DO_693	20.6%	0.1%	0.0%	0.2%	0.1%	52.6%	14.8%	11.7%

Figure 8-29. Estimated Contribution of each Source Sector to the 2028 Annual Mean PM_{10} Concentration at ND_163 (Dock Street)

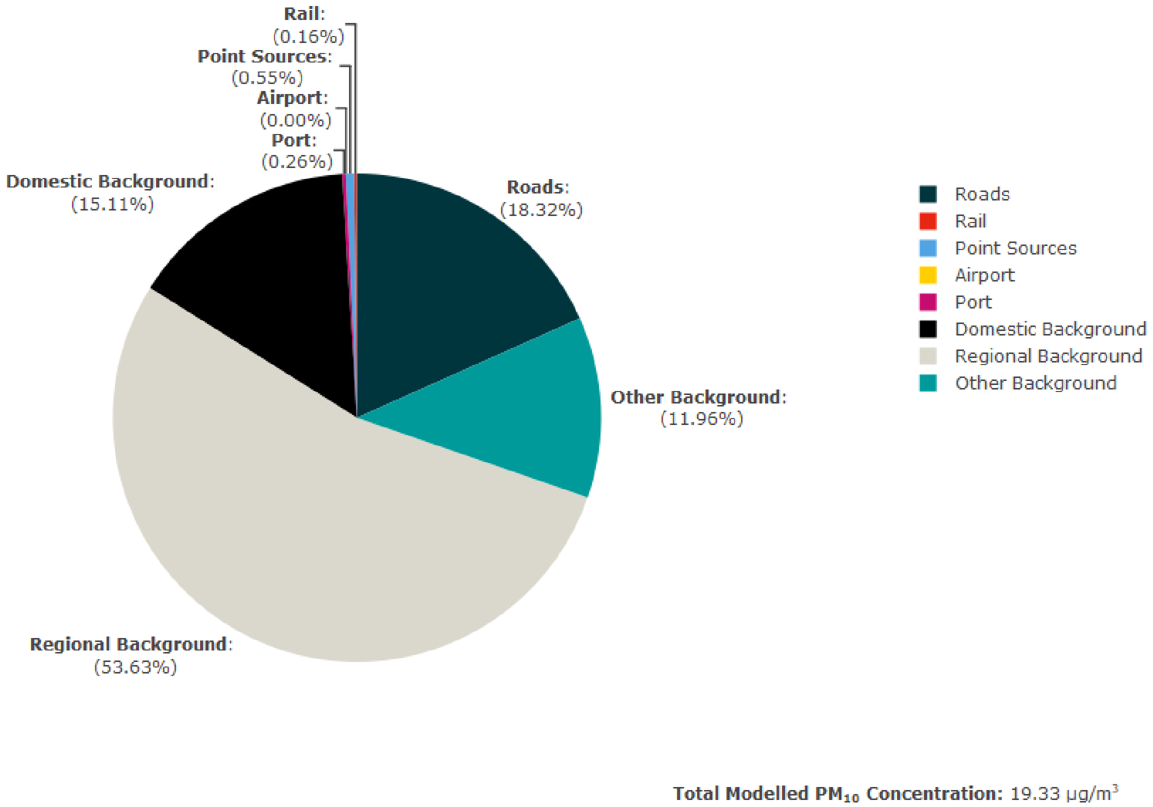
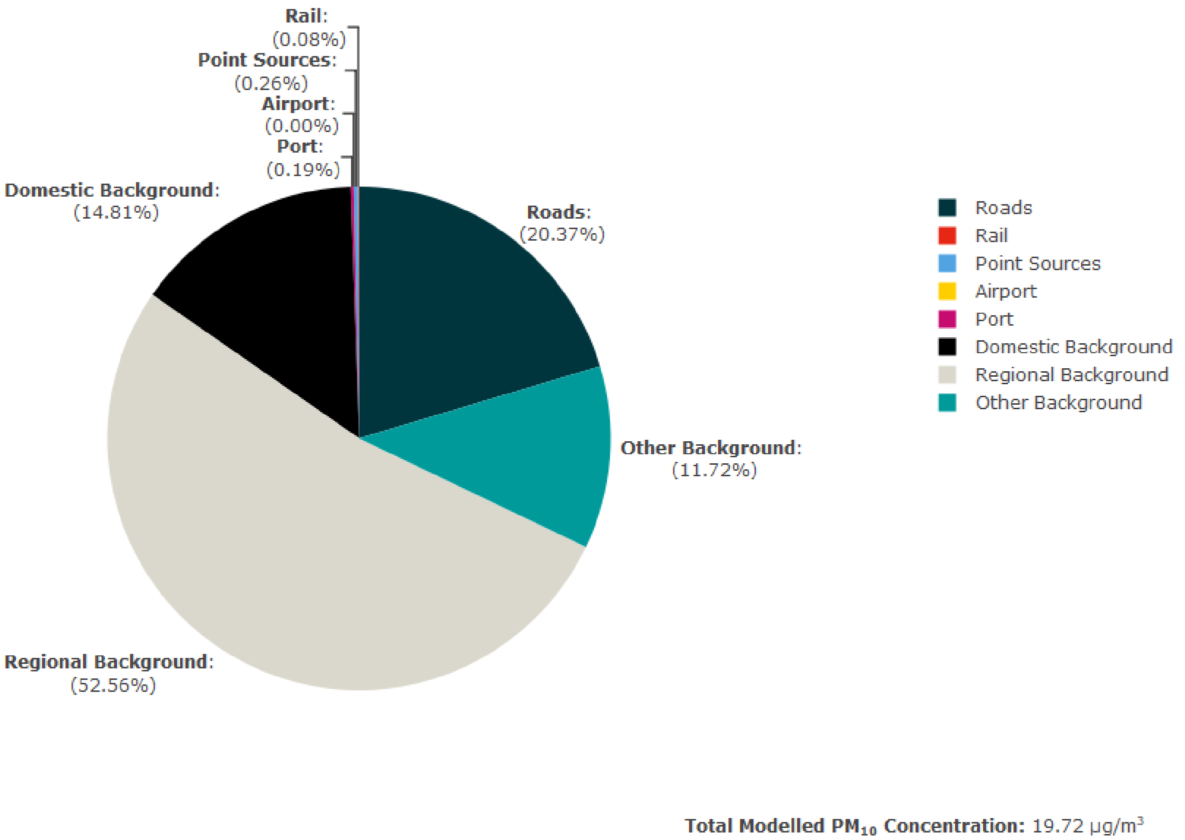


Figure 8-30. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean PM_{10} Concentration at DO_693 (Little Georges Street)



To give an indication of the relative source contributions across the whole city and within AQMAs, weighted average source contributions (weighted according to the total modelled PM_{10} concentration) have been calculated and are shown in the pie charts in Figure 8-31 to Figure 8-35.

The relative sector source contributions of annual mean PM_{10} concentrations in 2028 is similar between the four AQMAs. The Regional Background sector is the predominate contributor to 2028 annual mean PM_{10} concentrations in all four AQMAs, ranging from 59% at AQMA 2 to 65% for AQMA 3. Domestic Background is the next largest proportion and is estimated to account for 20% for AQMA 1 to 26% for AQMA 4. The Other Background source sector contributes 9% to 13%. Road traffic emissions are the primary contributor to 2019 annual mean PM_{10} emissions of the sources explicitly modelled, road traffic emissions account for 7%, 5%, 2% and 4% of PM_{10} concentrations in AQMAs 1 to 4 respectively. The point sources, airport, port and rail sectors are estimated to make minimal contributions to annual mean PM_{10} concentrations, collectively accounting for less than 1% of the total modelled PM_{10} concentrations at each of the AQMAs.

The city-wide relative source contributions indicate Regional Background is the largest source sector contribution to 2028 annual mean PM_{10} concentrations, accounting for 68% of concentrations across the city. Domestic Background sources account for 19% of 2028 annual mean PM_{10} concentrations across the city, whilst Other Background contributes 10%. Road traffic emissions are the largest contributor to annual mean PM_{10} concentrations across the city amongst sources explicitly modelled, accounting for 3%. The Point Sources, Airport, Port and Rail sectors are estimated to make minimal contributions to annual mean PM_{10} concentrations, collectively accounting for less than 1%.

Figure 8-31. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean PM_{10} Concentration at Receptors in AQMA 1 - M1 Motorway / A12 Westlink Corridor

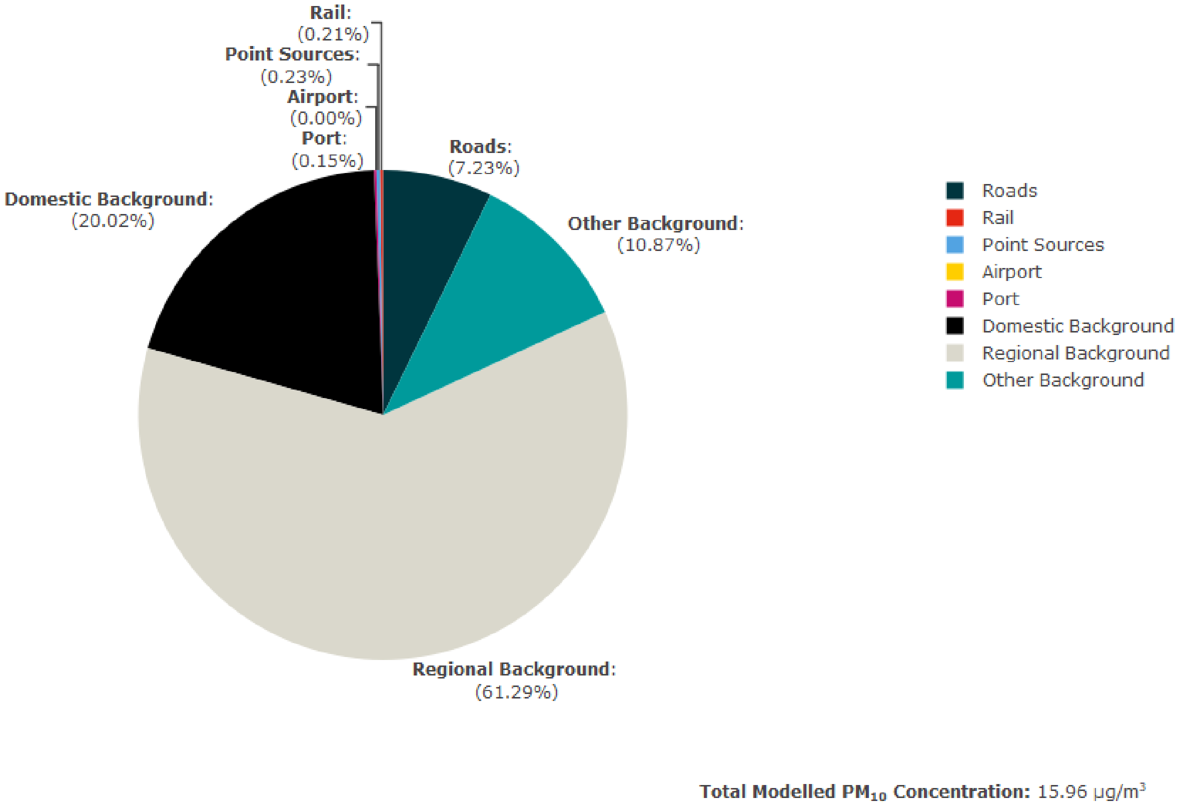


Figure 8-32. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean PM_{10} Concentration at Receptors in AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

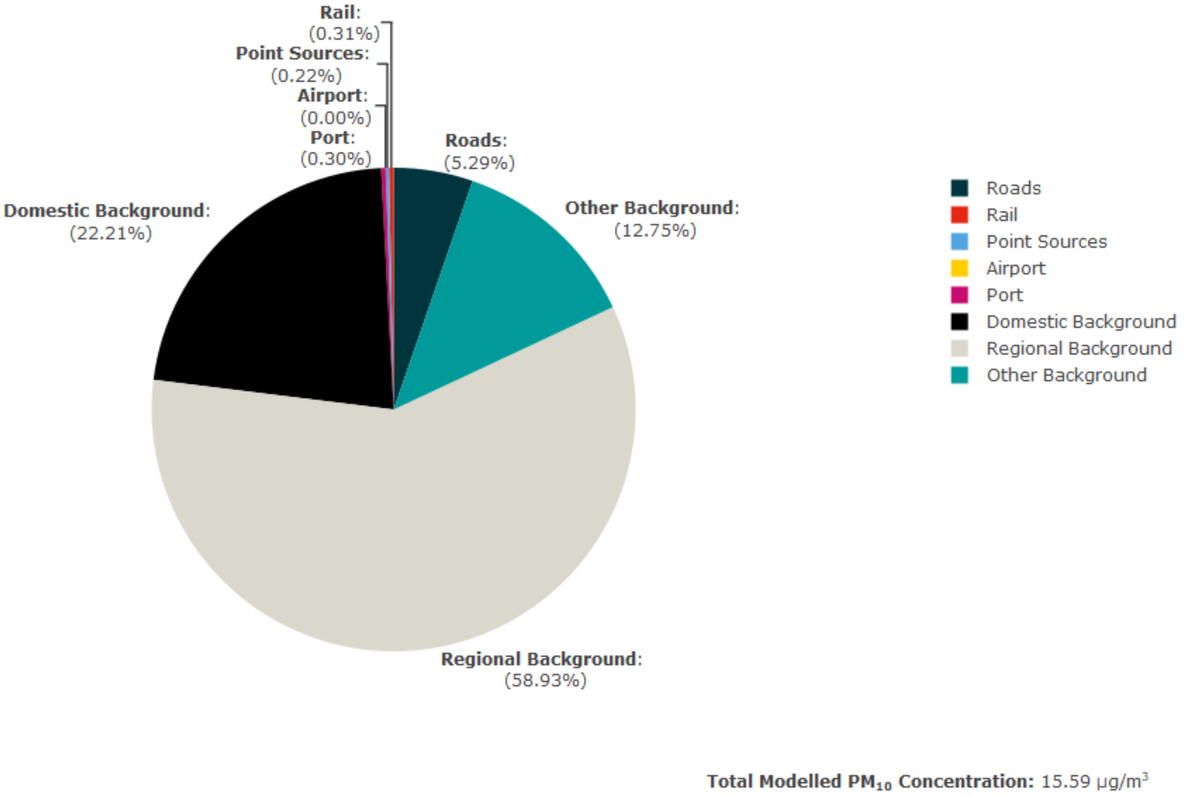


Figure 8-33. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean PM_{10} Concentration at Receptors in AQMA 3 - Upper Newtownards Road

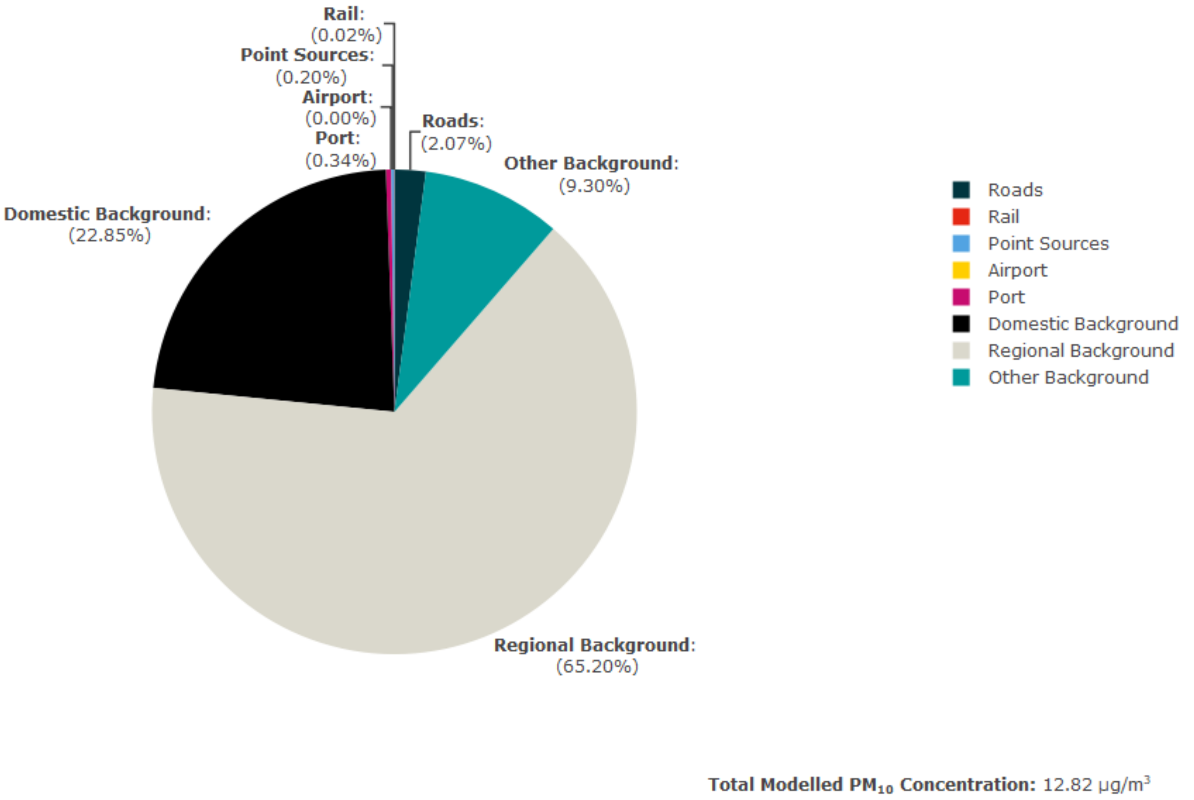


Figure 8-34. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean PM_{10} Concentration at Receptors in AQMA 4 - Ormeau Road

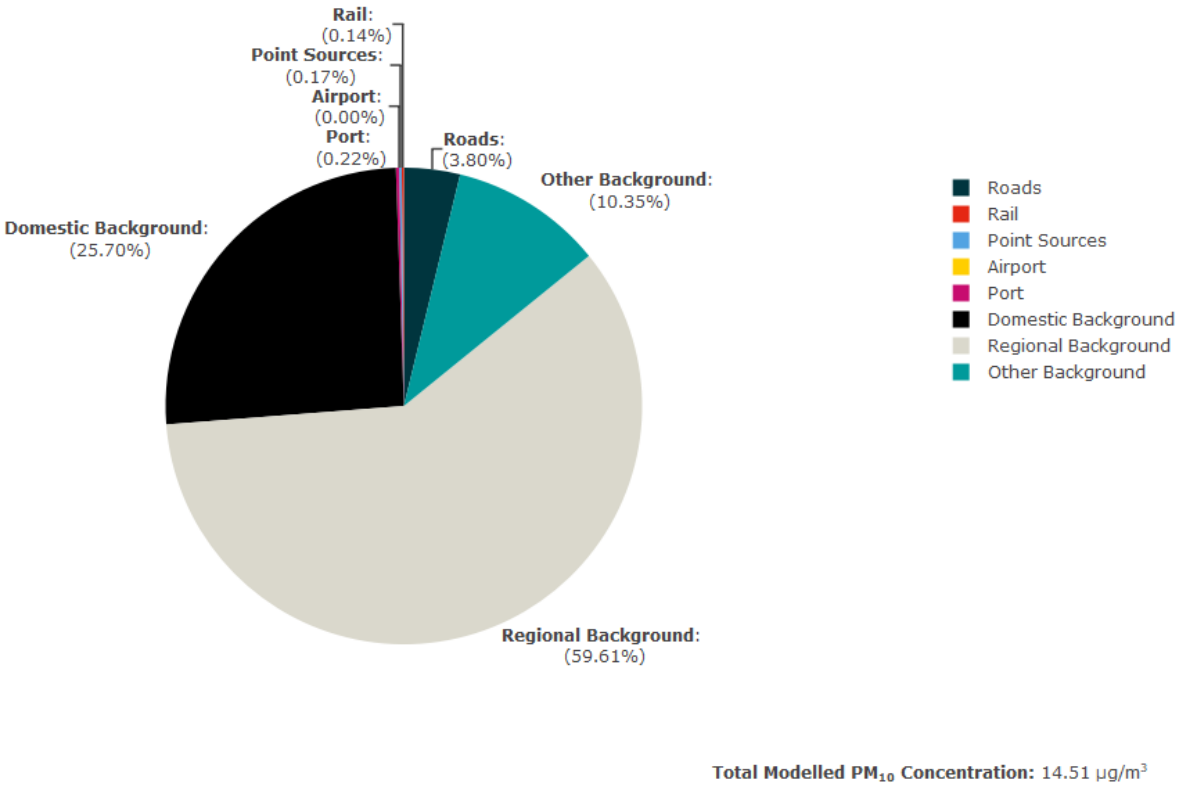
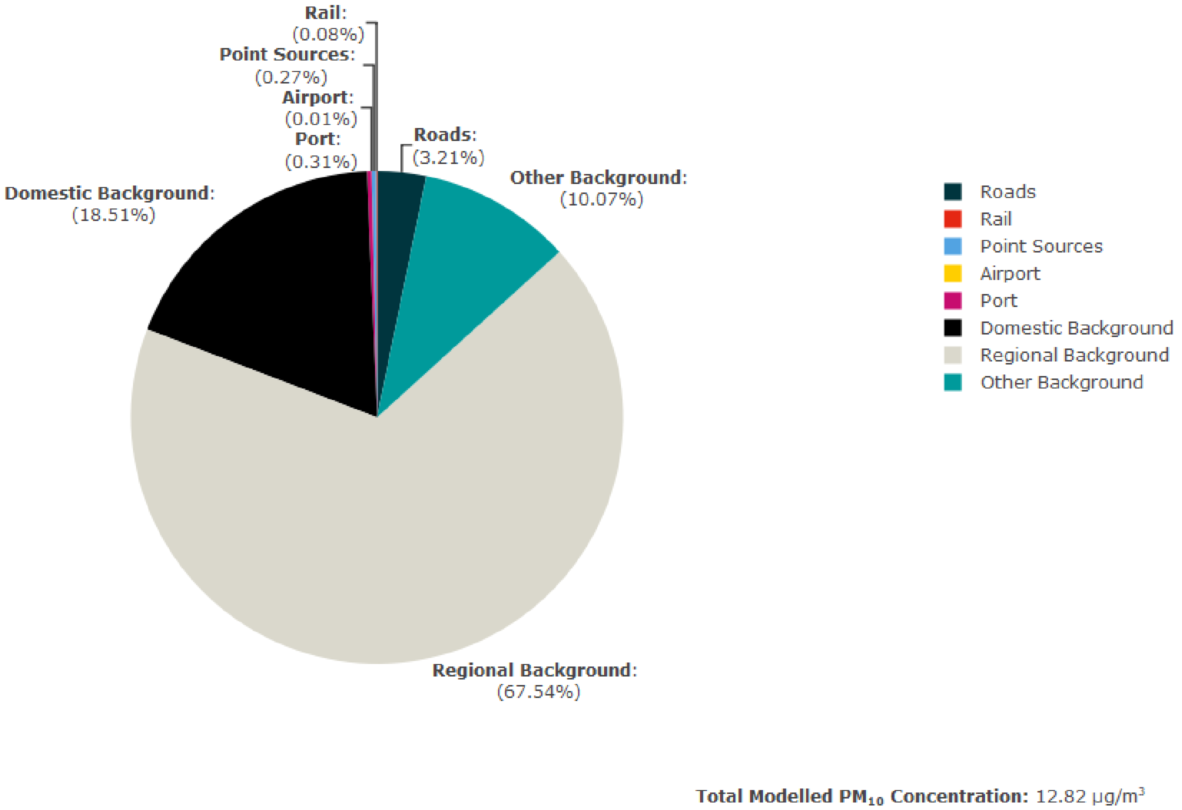


Figure 8-35. City-Wide Weighted Average Contribution of each Source Sector to the 2019 Annual Mean PM_{10} Concentration



8.2.3 $PM_{2.5}$

The Estimated Average Contribution of each Source Sector to the 2028 annual mean $PM_{2.5}$ concentration is presented in tabular form in Table 8 6 and in graphical form in Figure 8-36 and Figure 8-37.

The source apportionment for $PM_{2.5}$ follows a similar pattern to PM_{10}. The primary contribution to 2028 annual mean $PM_{2.5}$ concentration for these selected receptors comes from regional background, accounting for around 44% to 48% of the total modelled $PM_{2.5}$ concentrations. The Regional Background includes sources from outside of Belfast that the Council has no control over, including natural sources such as windblown dust and sea salt and secondary particulates (as discussed in 7.1.3.6). The large contributions from regional sources present a significant challenge to BCC's efforts to bring about reductions in $PM_{2.5}$ concentrations.

Domestic Background is estimated to account for approximately 23% to 36% of the total modelled $PM_{2.5}$ concentrations, indicating that this is a significant contributor to ambient $PM_{2.5}$ concentrations. The Other Background sector accounts for an estimated 8% to 11%.

Of the source sectors explicitly modelled, road traffic is the main contributor to total modelled $PM_{2.5}$ concentrations, responsible for between approximately 10% and 18% of the modelled total $PM_{2.5}$ concentrations at the selected sensitive receptor locations. The point sources, airport, port and rail sectors are estimated to make minimal contributions to annual mean $PM_{2.5}$ concentrations, collectively accounting for less than 1% of the total modelled $PM_{2.5}$ concentrations at the selected sensitive receptors.

Table 8-6. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean $PM_{2.5}$ Concentrations (Selected Receptors)

Full ID	Roads	Point Sources	Airport	Port	Rail	Regional Background	Domestic Background	Other Local Background
ND_414	16.3%	0.1%	0.0%	0.2%	0.2%	46.5%	28.0%	8.6%
DO_381	15.6%	0.1%	0.0%	0.3%	0.1%	44.1%	31.8%	8.1%
DO_693	17.9%	0.1%	0.0%	0.3%	0.1%	48.1%	23.0%	10.5%
DO_857	10.4%	0.1%	0.0%	0.2%	0.1%	45.9%	35.7%	7.7%

Figure 8-36. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean $PM_{2.5}$ Concentration at DO_693 (Little Georges Street)

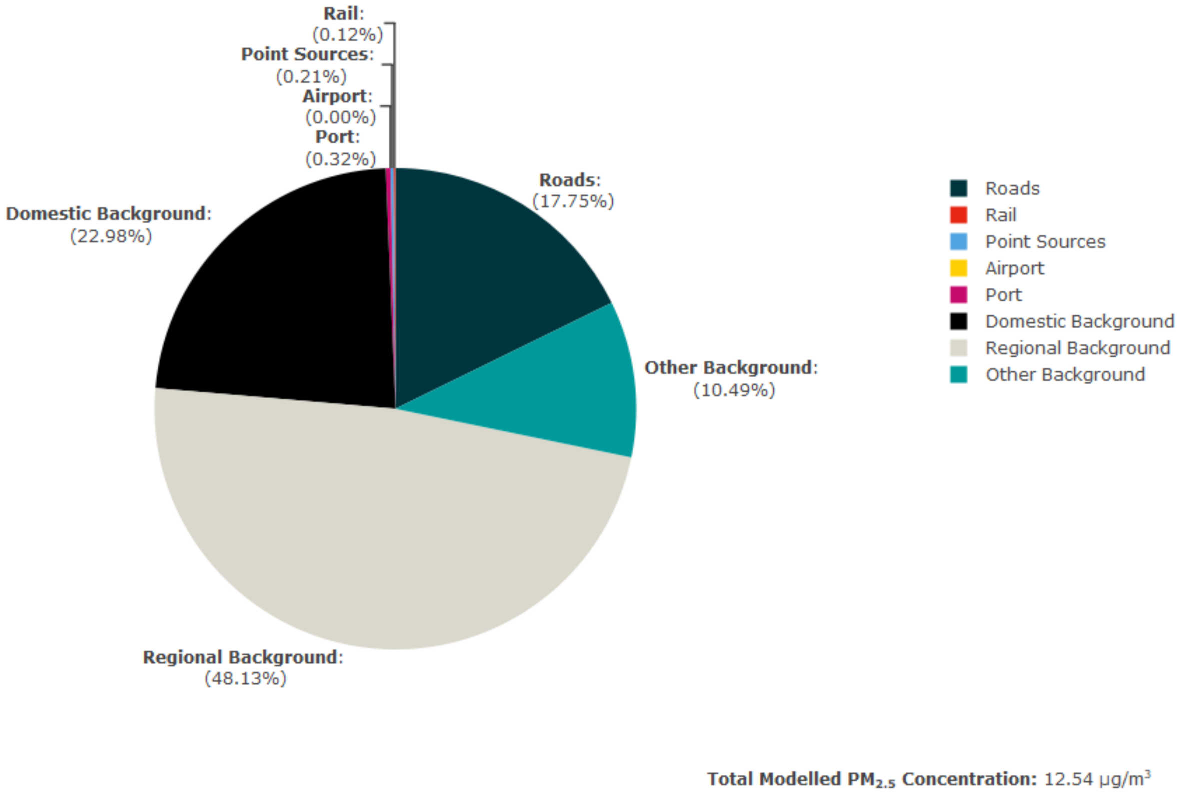
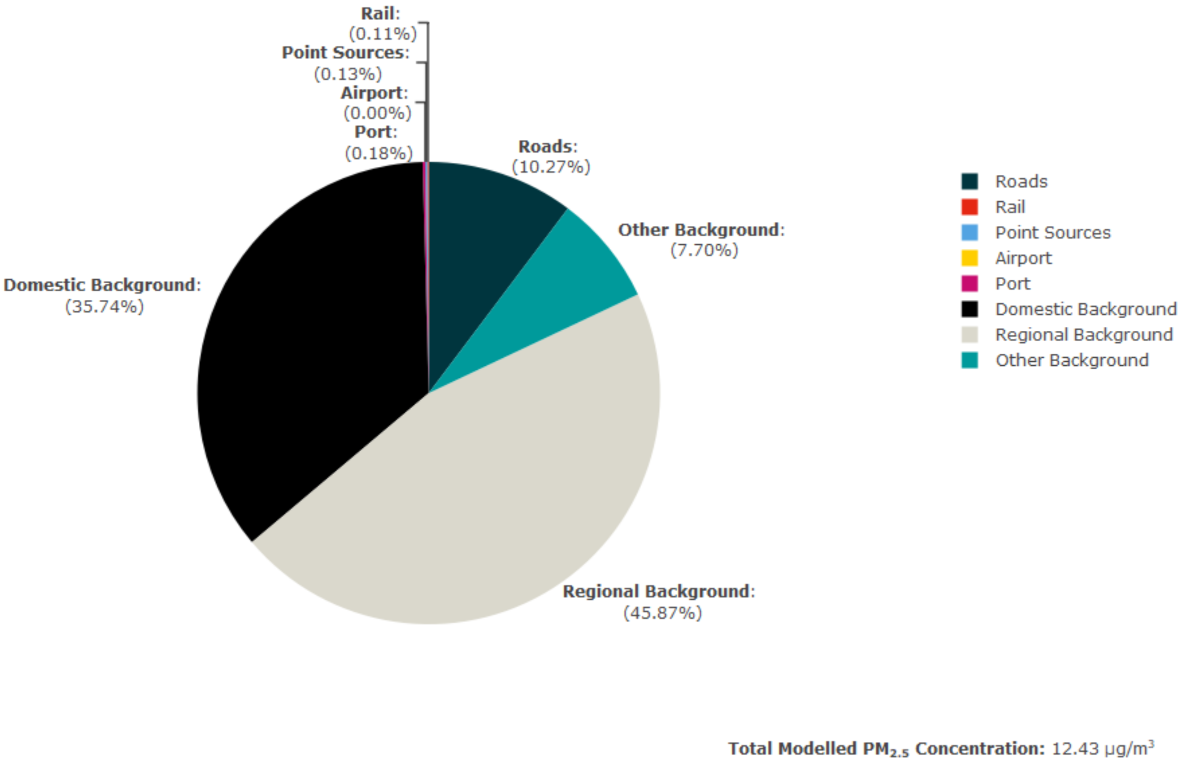


Figure 8-37. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean $PM_{2.5}$ Concentration at DO_857 (Glenmachan Street)



To give an indication of the relative source contributions across the whole city in 2028 and AQMAs, weighted average source contributions (weighted according to the total modelled $PM_{2.5}$ concentration) have been calculated and are shown in the pie charts in Figure 8-38 to Figure 8-42.

The relative sector source contributions of annual mean $PM_{2.5}$ concentrations in 2028 averaged across AQMAs and the city is similar to PM_{10}, with Regional Background sector as the predominate contributor to 2028 annual mean $PM_{2.5}$ concentrations. The city-wide weighted average attributes 60% to Regional Background, and ranges between 51% to 57% between each AQMA. Domestic Background is the second largest contributor to 2028 annual mean $PM_{2.5}$ concentrations, with an estimated 27.6% contribution across the city-wide average. Within the AQMAs, the Domestic Background contribution is higher, ranging between 30% to 37%. The Other Background source sector contributes 9% to 2028 annual mean $PM_{2.5}$ concentrations across the city. Within AQMAs, the Other Background source sector is estimated to attributed to 7% to 10%. Road traffic emissions are the primary contributor to 2028 annual mean $PM_{2.5}$ emissions of the sources explicitly modelled, accounting for 3.0% across the city-wide weighted average. The road traffic emissions contributions to 2019 annual mean $PM_{2.5}$ concentrations within the AQMAs range from 2% to 6%. The point sources, airport, port and rail sectors are estimated to make minimal contributions to annual mean $PM_{2.5}$ concentrations, collectively accounting for less than 1% of the total modelled $PM_{2.5}$ concentrations both within AQMAs and across the city.

Figure 8-38. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean $PM_{2.5}$ Concentration at Receptors in AQMA 1 - M1 Motorway / A12 Westlink Corridor

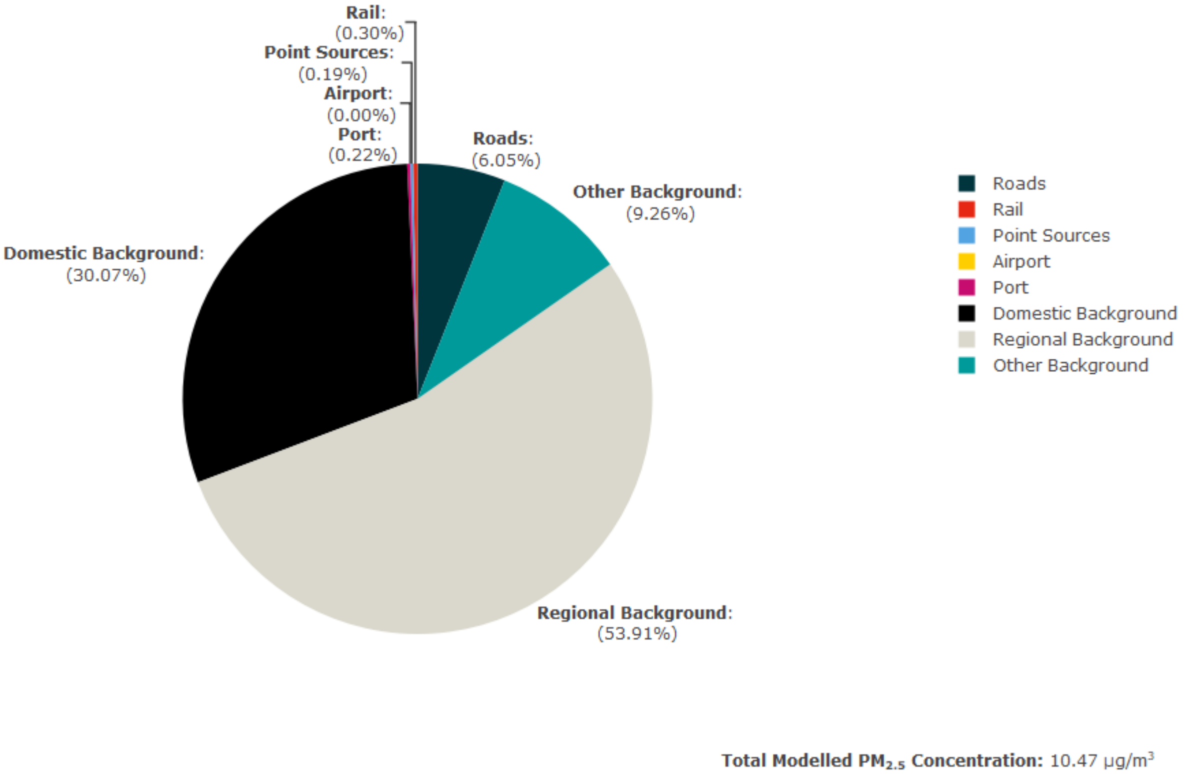


Figure 8-39. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean $PM_{2.5}$ Concentration at Receptors in AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

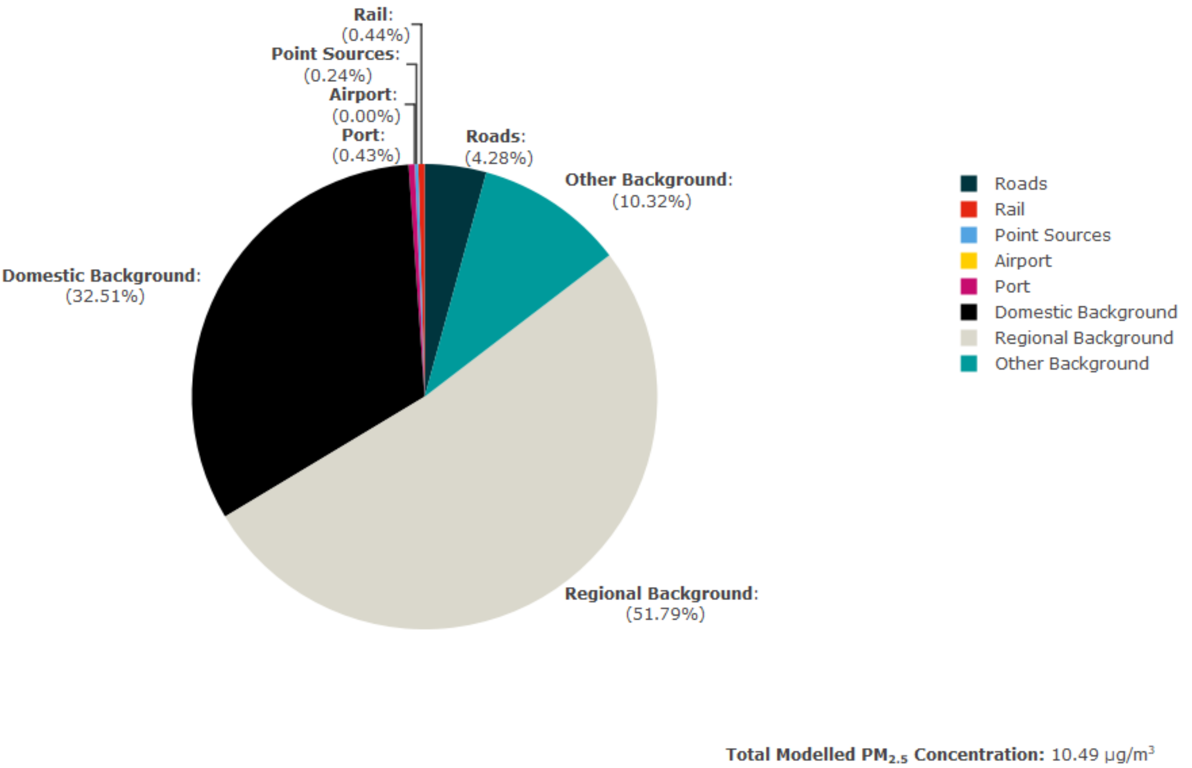


Figure 8-40. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean $PM_{2.5}$ Concentration at Receptors in AQMA 3 - Upper Newtownards Road

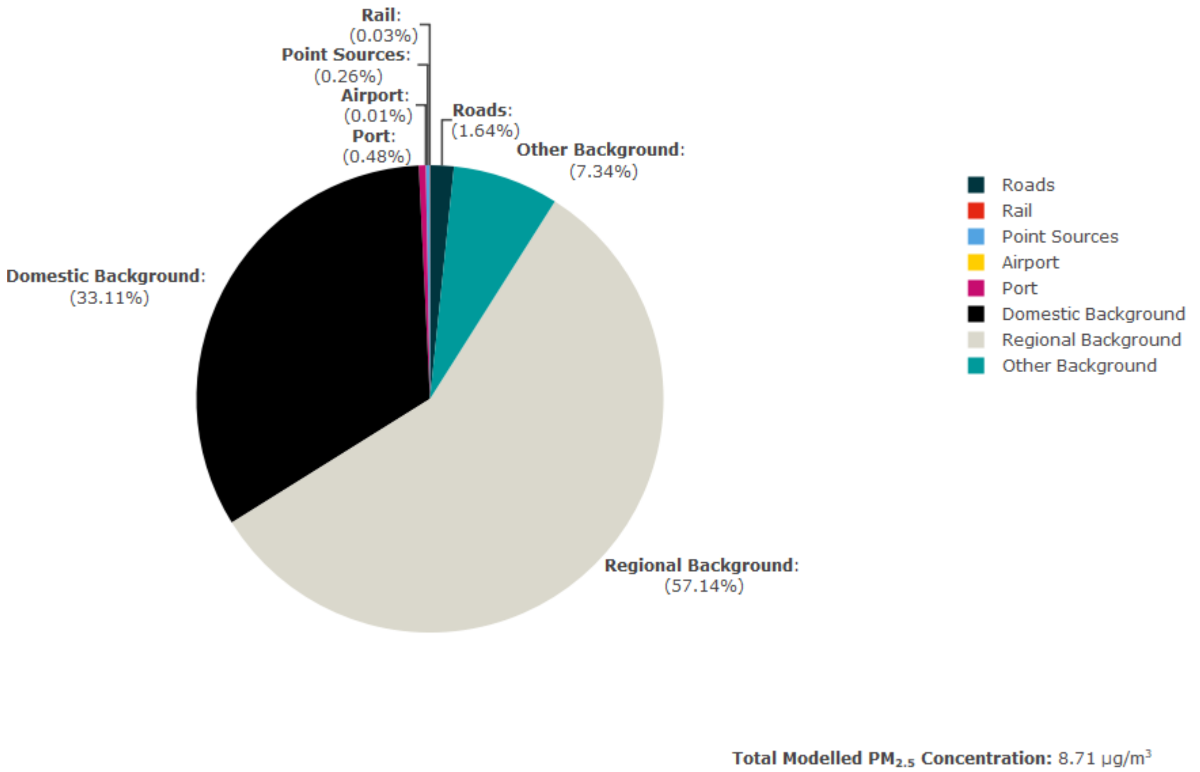


Figure 8-41. Estimated Average Contribution of each Source Sector to the 2028 Annual Mean $PM_{2.5}$ Concentration at Receptors in AQMA 4 - Ormeau Road

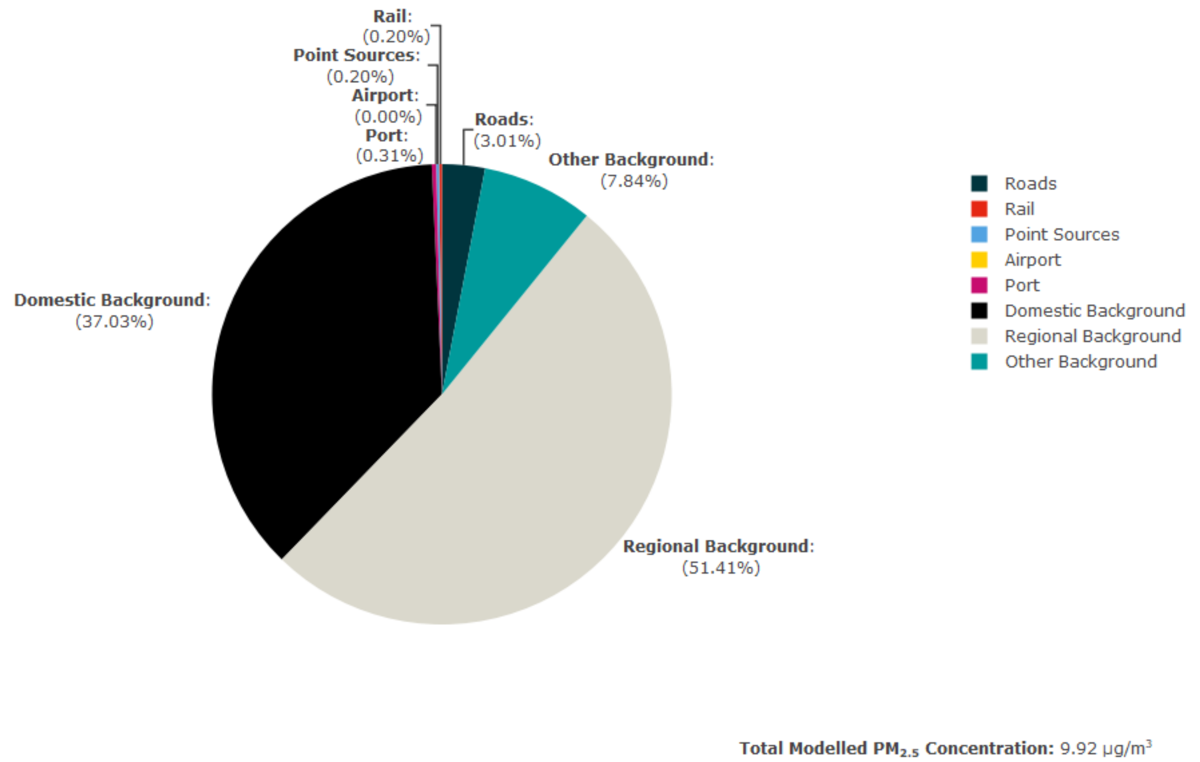
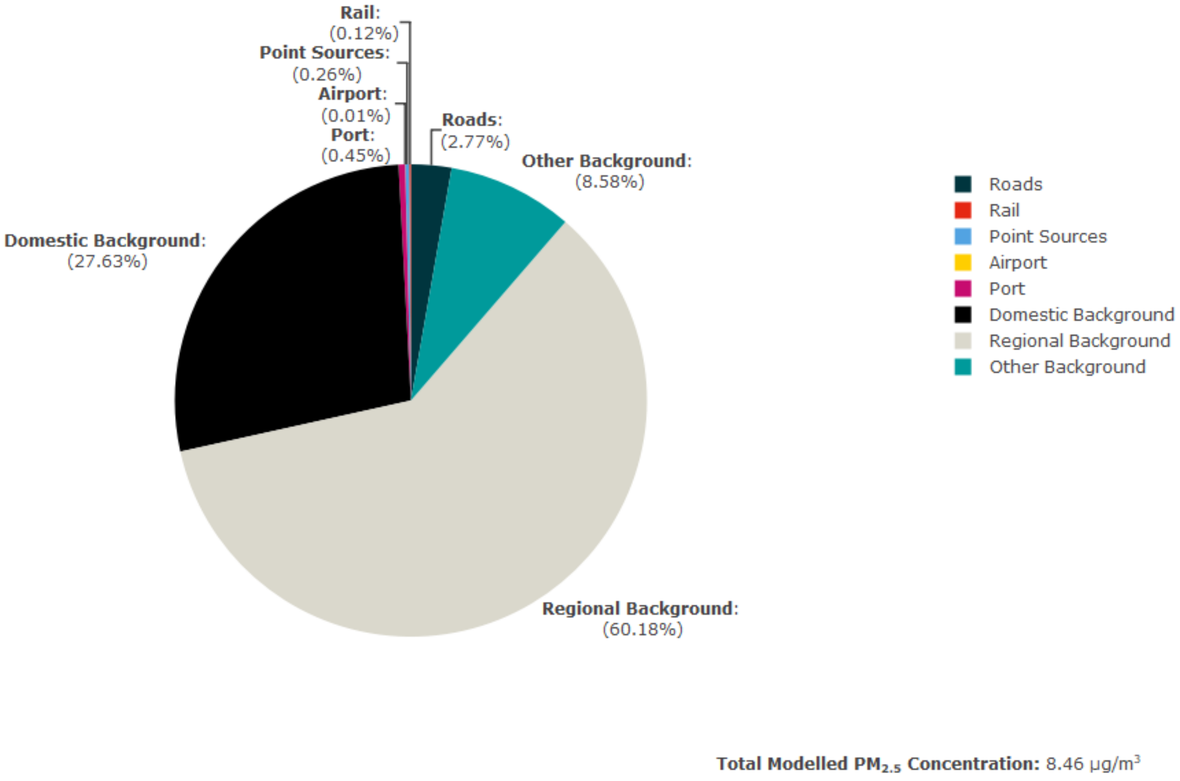


Figure 8-42. City-Wide Weighted Average Contribution of each Source Sector to the 2028 Annual Mean $PM_{2.5}$ Concentration



9. Conclusions

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 addition to $PM_{2.5}$, the DA also includes 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 AQOs 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.

Detailed dispersion modelling was carried out to assess the major sources of air pollutant emissions in Belfast to predict NO_2, PM_{10} and $PM_{2.5}$ concentrations at locations across the Council's administrative area, in order to identify locations where the UK AQOs and WHO AQG levels are being exceeded or are at risk of being exceeded in the future. Model predictions were made for a base year of 2019 and a future year of 2028 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. 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.

The key findings of the dispersion modelling are as follows.

9.1.1 Nitrogen Dioxide

Annual mean NO_2 concentrations for 2019 were predicted to be above the UK AQO level of 40 $\mu g/m^3$ at 25 discrete sensitive receptor locations. The highest predicted concentration at a discrete sensitive receptor location was 55.9 $\mu g/m^3$ at a receptor near to the Stockmans Lane roundabout. 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).

Contour plots of annual mean NO_2 concentrations 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.

For the future assessment year of 2028, predicted annual mean NO_2 concentrations were below the UK AQO of 40 $\mu g/m^3$ at locations of relevant exposure throughout the city. The highest predicted concentration at a discrete sensitive receptor location was 31.1 $\mu g/m^3$ at a receptor near to the Stockmans Lane roundabout. Consistent with 2019, the contour plots for 2028 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 with the more stringent WHO AQG value for annual mean NO_2 of 10 μg/m^3, it is predicted that large areas of the city, in particular in locations near to the road network, will be in exceedance of this AQG in both 2019 and 2028. Whilst not modelled, the monitoring results would suggest that the 24-hour mean NO_2 WHO AQG is also likely to be exceeded across much of the Council's administrative area, particularly in the city centre area and near busy roads.

City-wide source apportionment calculations for NO_2 in 2019 identified road transport as the main source of modelled NO_2 concentrations. On average across the whole city, road transport is estimated to account for almost 30% of total modelled NO_2 concentrations, although contributions of greater than 60% were frequently found at roadside locations. Of the other sources explicitly modelled, industrial point sources were the next largest contributor after roads (1.8%). 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 concentrations are contributions from sources not explicitly modelled. The domestic background sector (which includes domestic, commercial and institutional space heating) was an important contributor to modelled NO_2 concentrations, accounting for an estimated 19.9% of the modelled total NO_2 concentration across the city, on average. Other background sources, including emissions from distant, regional sources outside of Belfast, collectively accounted for almost 45% of the total modelled NO_2 concentration in 2019.

City-wide source apportionment calculations for NO_2 in 2028 revealed a similar pattern to 2019. Road transport remained the main source of NO_2 of those sources explicitly modelled, accounting for, on average, 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. On average, across the whole city, industrial point sources were calculated to contribute approximately 3% to modelled NO_2 concentrations, the Harbour around 2.2%, rail around 2.1% 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.

9.1.2 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 much of the city centre area. In many locations, background PM_{10} concentrations alone were found to approach or exceed the AQG level. 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 plots for 2028 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. The small reductions in concentrations between 2019 and 2028 illustrate 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 difficult to control, and the large contribution from regional background sources, over which the Council has no control. The 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.

City-wide source apportionment calculations for PM_{10} in 2019 showed that 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, on average, 3.2% of the total modelled PM_{10}

concentrations. The combined contribution of industrial point sources, rail, the Harbour and the airport to modelled PM_{10} concentrations was approximately 0.5%.

City-wide source apportionment calculations for PM_{10} in 2028 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 3.2% of the total modelled PM_{10} concentrations, whilst the combined contribution of industrial point sources, rail, the Harbour and the airport to modelled PM_{10} concentrations was approximately 0.7%.

9.1.3 $PM_{2.5}$

Annual mean $PM_{2.5}$ concentrations in 2019 were predicted to be 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 plots 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 below the UK AQO of 20 µg/m^3 at locations of relevant exposure throughout the city. The contour plots for 2028 indicated that the highest levels of $PM_{2.5}$ 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}, these 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 plots indicated that the AQG was exceeded throughout the Council's administrative area.

The city-wide source apportionment calculations for $PM_{2.5}$ in 2019 exhibited similar patterns to those seen for PM_{10}. Background sources were the majority contributor. The regional background sector accounted for, on average, 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 industrial point sources, rail, the Harbour and the airport to modelled $PM_{2.5}$ concentrations was approximately 0.7%.

For $PM_{2.5}$ in 2028, the city-wide source apportionment 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 industrial point sources, rail, the Harbour and the airport to modelled $PM_{2.5}$ concentrations was approximately 0.8%.

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, source apportionment calculations indicate 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 background (domestic, commercial and institutional space 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 insufficient to achieve the annual mean $PM_{2.5}$ WHO AQG of 5 µg/m^3.

9.2 Recommendations

Based on the results of the dispersion modelling and source apportionment undertaken as Part B of this DA, the following recommendations are made:

- With reference to predicted exceedances of the UK AQO 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 Stockmans 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.
- 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 have benefits in terms of reducing 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-emissions 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.

There are also a number of suggested areas for refinement and improvement of the emissions inventory. The emissions inventory that has been prepared during the DA represents an accurate and, based on the information available within the timeframes, complete representation of emissions sources in Belfast and provides a solid foundation upon which to build and refine the Emissions Inventory in the future. However, as with any emissions inventory, there are recognised limitations and shortcomings. Emissions inventory development is a cyclical process through which new and updated information is regularly gathered and inputted into the inventory to ensure it remains current and up to date. This cyclical nature also enables limitations and data gaps to be revisited and, where possible, addressed. Potential areas for future refinement and improvement of the Emissions Inventory include:

- Better characterisation of emissions from shipping in terms of disaggregation of activity data and identification of specific source locations. Due to uncertainties surrounding the locations of emissions associated with port activities, emissions estimates were prepared at the facility level (i.e. for the whole port) split broadly into moving vessels, vessels at berth, and land-side operations. Future refinements could look at obtaining a better understanding of where emissions occur and their individual magnitudes.
- Better characterisation of emissions from aviation. The use of annual total emissions distributed evenly across the year is appropriate for this DA where the main focus is on annual mean pollutant concentrations; however, the incorporation of monthly variations in emissions could be considered to capture the temporal variations in emissions from aviation activities over the year.
- Improved spatial distribution of rail emissions. In the present DA, rail emissions were spatially distributed according to the total length of rail track present within each 1-km grid square within the model domain. The total calculated emissions for each grid square were then equally distributed across all tracks within that grid square such that a constant g/km/s emission rate was assigned to all track segments in any given grid square. Further refinement to better characterise the relative levels of activity (i.e. train movements) along each track segment would likely provide an improved spatial distribution of rail emissions.
- For all modelled sources, except road traffic, future year (2028) emissions have been assumed to remain equal to the assessed base year (2019). Forecasting of future years is always problematic and in this present case, has been further complicated by the effects of the Covid-19 pandemic introducing additional uncertainty. However, the development of appropriate methods for emissions forecasts for all sources within the Emissions Inventory could be considered.

Appendix A Emissions Inventory Metadata

A series of calculation spreadsheets have been provided in electronic format containing the emissions inventory information, calculations and all necessary input information in order to set up and run dispersion modelling simulations. Electronic files are provided for:

- Road traffic sources;
- Industrial point sources;
- Rail sources;
- Belfast Harbour sources; and
- Belfast City Airport sources.

Appendix B Dispersion Modelling Metadata

B.1 Belfast City Council Monitoring Locations

Table B-1. List of Monitoring Sites

Site Name	X (m)	Y (m)	Site Type	Included/Excluded in Model Verification
Belfast Centre AURN	333898	374358	Urban Background	Excluded – Urban Background not recommended for model verification as per TG22 guidance
Belfast Ormeau Road	334272	373012	Roadside	Included – Zone City Centre
Belfast Ballyhackamore	337930	373972	Roadside	Included – Zone Rest of the city
Belfast Stockmans Lane AURN	331010	371252	Roadside	Included – Zone A55
Belfast Westlink Roden Street	332609	373431	Roadside	Included – Zone Rest of the city
Royal Victoria Hospital	332522	373708	Urban Background	Excluded – Urban Background not recommended for model verification as per TG22 guidance
Blacks Road	329782	369522	Roadside	Included – Zone A55
61 Cromac Street	334220	373853	Roadside	Included – Zone City Centre
Ravenhill Road	335014	373942	Roadside	Included – Zone City Centre
Queens Bridge	334630	374382	Roadside	Included – Zone City Centre
North Road	337551	374151	Urban Background	Excluded – Urban Background not recommended for model verification as per TG22 guidance
Donegall Square South	333838	373955	Roadside	Included – Zone City Centre
Short Strand	334983	374261	Roadside	Included – Zone Rest of the city
301 Ormeau Road	334503	372176	Roadside	Included – Zone A55
Knock Road	338718	373918	Roadside	Included – Zone Rest of the city
Great Georges Street	333981	375102	Kerbside	Included – Zone City Centre
Lisburn Road	332056	371364	Roadside	Included – Zone A55
Shaftesbury Square	333595	373283	Kerbside	Included – Zone City Centre
Lombard Street	333898	374358	Urban Background	Excluded – Diffusion tube co-located with Belfast Centre AURN for the purpose of diffusion tube triplicate co-location. Urban Background not recommended for model verification as per TG22 guidance
Albert Clock	334215	374485	Roadside	Included – Zone City Centre
Stockmans Lane	331010	371252	Roadside	Excluded – Diffusion tube co-located with Belfast Stockmans Lane AURN for the purpose of diffusion tube triplicate co-location

Site Name	X (m)	Y (m)	Site Type	Included/Excluded in Model Verification
Ballyhackamore	337930	373972	Roadside	Excluded – Diffusion tube co-located with Belfast Ballyhackamore AURN for the purpose of diffusion tube triplicate co-location
Whitewell Road	333230	380877	Roadside	Excluded – significant pollution contribution from the M2, which is outside the Belfast City Council boundary at this locality and is not within the modelled road network.
Donegall Road	333022	373122	Kerbside	Included – Zone Rest of the city
Falls Road and Andersonstown Road	330716	372524	Roadside	Included – Zone A55
Station Road	337162	375480	Roadside	Included – Zone Airport
Malone Road	332544	370283	Roadside	Included – Zone A55
Great Victoria Street	333548	373772	Roadside	Excluded – Monitoring location is next to taxi rank and bus stop; localised sources.
College Square East	333501	374238	Roadside	Included – Zone City Centre
Chichester Street	334146	374127	Roadside	Excluded
Cromac Street & Ormeau Avenue	334045	373556	Kerbside	Included – Zone City Centre
Glenmachan Street	332063	372871	Roadside	Included – Zone Rest of the city
Creche on M1/Westlink	333069	374055	Roadside	Included – Zone City Centre
Ormeau Road (junction with Ravenhill Road)	334943	371342	Roadside	Included – Zone A55
Upper Newtownards Road & Holywood Road	336519	374233	Roadside	Included – Zone Rest of the city
Crumlin Road	333116	375291	Roadside	Included – Zone Rest of the city
228 Antrim Road	333289	376143	Roadside	Included- Zone Rest of the city
Shore Road (Ivan Street end)	334177	376376	Roadside	Included- Zone Rest of the city
York Street	334213	375638	Roadside	Included- Zone Rest of the city
Queens Square	334195	374450	Roadside	Included- Zone City Centre
Westlink AQMS	332609	373431	Roadside	Excluded – Diffusion tube co-located with Westlink AQMS for the purpose of diffusion tube triplicate co-location
Opposite Westlink AQMS	332610	373474	Roadside	Included – Zone Rest of the city
Peters Hill	333587	375225	Roadside	Included – Zone Westlink

Site Name	X (m)	Y (m)	Site Type	Included/Excluded in Model Verification
Henry Place	333281	374767	Kerbside	Included – Zone Westlink
Ardmore Park	329922	370299	Roadside	Included – Zone A55
Titanic Quarter	335073	375049	Roadside	Excluded
Poleglass	328214	370138	Roadside	Included – Zone A55
Molyneaux Street	334028	375241	Roadside	Excluded
North Queen Street	333857	375412	Roadside	Included – Zone City Centre
Portland Place	333856	375163	Roadside	Included – Zone City Centre
Sailortown	334469	375341	Roadside	Included – Zone City Centre
Little Georges Street	333877	375260	Roadside	Included – Zone City Centre
RVH at Falls Road	331962	373560	Roadside	Included – Zone Rest of the city
Dunmurry Lane	329305	368931	Roadside	Included – Zone A55
Upper Knockbreda Road	337547	372019	Kerbside	Excluded – Kerbside monitoring location not recommended for model verification as per TG22 guidance.
Tates Avenue	332250	372644	Roadside	Included – Zone Rest of the city
Stockmans Crescent	330772	371532	Roadside	Excluded – Monitoring location is within a cul-de-sac that is shielded from the main source of emissions (A55)
Diamond Gardens	330311	370120	Roadside	Included – Zone A55
Orpen Road	330355	369817	Roadside	Included – Zone A55
Balmoral Avenue	331568	370818	Roadside	Included – Zone A55
N1	335804	370795	Roadside	Included – Zone Rest of the city
N6	335998	373442	Urban Background	Excluded – Urban Background not recommended for model verification as per TG22 guidance
N8	337120	375534	Other sources	Included – Zone Airport
N10	333684	375245	Roadside	Included – Zone Westlink
N12	326663	369321	Urban Background	Excluded- Urban Background not recommended for model verification as per TG22 guidance
ZAURN (AURN co-location)	333904	374354	Urban Background	Excluded – Urban Background not recommended for model verification as per TG22 guidance. Co-located with AURN site for the purpose of scaling the Zephyr sensor data.

B.2 Model Verification

Table B-2. Comparison of Modelled and Monitored NO_2 Concentrations

Site ID	Zone	Used in Verification	Adjustment Factor	NO_2 Concentration (µg/m³)				% Difference (Unadjusted Modelled vs. Measured)	% Difference (Adjusted Modelled vs. Measured)
				Background	Monitored Total	Modelled Total (Unadjusted)	Modelled Total (Adjusted)		
61 Cromac Street	City Centre	Yes	0.80	23.4	36.0	41.3	37.9	+14.7	+5.2
Albert Clock	City Centre	Yes	0.80	23.4	**40.0**	36.5	33.9	-8.8	-15.2
Belfast Centre AURN	City Centre	No	0.80	23.4	26.0	31.2	29.6	+19.8	+13.9
Belfast Ormeau Road AURN	City Centre	Yes	0.80	16.8	24.0	28.4	26.2	+18.5	+9.0
Chichester Street	City Centre	No	0.80	23.4	**40.0**	32.4	30.6	-19.0	-23.5
College Square East	City Centre	Yes	0.80	17.7	33.0	34.4	31.2	+4.2	-5.5
Creche on M1/Westlink	City Centre	Yes	0.80	17.7	28.0	32.3	29.5	+15.4	+5.3
Cromac & Ormeau Avenue	City Centre	Yes	0.80	23.4	31.0	35.6	33.2	+14.8	+7.1
Donegall Square South	City Centre	Yes	0.80	23.4	32.0	34.7	32.4	+8.3	+1.3
Great Georges Street	City Centre	Yes	0.80	18.4	**45.0**	47.0	**41.8**	+4.5	-7.2
Great Victoria Street	City Centre	No	0.80	17.7	36.0	28.3	26.2	-21.3	-27.1
Little Georges Street	City Centre	Yes	0.80	18.4	33.0	38.1	34.3	+15.3	+4.0
Lombard Street	City Centre	No	0.80	23.4	26.0	31.0	29.5	+19.3	+13.4
Molyneux Street	City Centre	No	0.80	18.4	36.0	52.9	**46.7**	+47.1	+29.8
North Queen Street	City Centre	Yes	0.80	18.4	33.0	35.2	32.0	+6.8	-3.0
Portland Place	City Centre	Yes	0.80	18.4	30.0	34.8	31.6	+16.0	+5.5
Queens Bridge	City Centre	Yes	0.80	17.0	27.0	32.1	29.1	+18.7	+7.9
Queens Square	City Centre	Yes	0.80	23.4	34.0	40.7	37.3	+19.6	+9.8
Ravenhill Road	City Centre	Yes	0.80	17.0	28.0	28.1	25.9	+0.5	-7.4
Sailortown	City Centre	Yes	0.80	18.4	28.0	29.6	27.4	+5.6	-2.2
Shaftesbury Square	City Centre	Yes	0.80	18.8	31.0	34.9	31.8	+12.5	+2.5
ZAURN	City Centre	No	0.80	23.4	29.7	31.0	29.5	+4.4	-0.7

Site ID	Zone	Used in Verification	Adjustment Factor	Background	NO₂ Concentration (µg/m³)			% Difference (Unadjusted Modelled vs. Measured)	% Difference (Adjusted Modelled vs. Measured)
					Monitored Total	Modelled Total (Unadjusted)	Modelled Total (Adjusted)		
301 Ormeau Road	A55	Yes	2.38	12.9	30.0	20.3	29.8	-32.3	-0.7
Ardmore Park_V2	A55	Yes	2.38	11.6	30.0	22.8	36.7	-23.9	+22.4
Balmoral Avenue	A55	Yes	2.38	11.2	39.0	22.4	36.3	-42.5	-6.9
Belfast Stockmans Ln AURN	A55	Yes	2.38	11.2	**45.0**	25.8	**43.2**	-42.8	-4.1
Blacks Road	A55	Yes	2.38	10.3	**42.0**	24.2	**40.9**	-42.4	-2.7
Diamond Gardens	A55	Yes	2.38	11.1	24.0	18.1	27.2	-24.5	+13.2
Dunmurry Lane	A55	Yes	2.38	10.2	26.0	14.9	21.1	-42.6	-18.8
Falls Road and Andersonstown	A55	Yes	2.38	12.2	27.0	17.6	24.6	-34.9	-8.8
Lisburn Road	A55	Yes	2.38	11.3	27.0	20.5	32.0	-24.2	+18.4
Malone Road	A55	Yes	2.38	9.7	31.0	19.7	32.3	-36.4	+4.2
N12	A55	No	2.38	8.3	13.2	9.3	10.8	-29.3	-18.1
Ormeau Road (junction with Ravenhill Road)	A55	Yes	2.38	10.9	36.0	20.5	32.6	-43.0	-9.4
Orpen Road	A55	Yes	2.38	11.1	18.0	14.5	19.0	-19.4	+5.8
Poleglass	A55	Yes	2.38	10.1	24.0	15.2	21.9	-36.6	-8.8
Stockmans Crescent	A55	No	2.38	11.9	24.0	20.7	31.9	-13.7	+32.7
Stockmans Lane	A55	No	2.38	11.2	**45.0**	24.0	39.6	-46.6	-12.0
N8	Airport	Yes	0.62	15.3	25.6	30.0	24.6	+17.2	-3.9
Station Road	Airport	Yes	0.62	15.3	22.0	27.9	23.2	+26.6	+5.5
Henry Place	Westlink	Yes	1.60	18.4	**53.0**	40.9	**52.4**	-22.8	-1.2
N10	Westlink	Yes	1.60	18.4	**50.3**	39.9	**51.0**	-20.6	+1.4
Peters Hill	Westlink	Yes	1.60	15.9	**40.0**	31.6	39.9	-21.1	-0.2
228 Antrim Road	Rest of the city	Yes	1.28	14.0	31.0	24.1	26.8	-22.3	-13.5
Ballyhackamore	Rest of the city	No	1.28	12.6	27.0	20.4	22.5	-24.5	-16.6
Belfast Ballyhackamore AURN	Rest of the city	Yes	1.28	12.6	27.0	23.8	26.8	-12.0	-0.9

Site ID	Zone	Used in Verification	Adjustment Factor	NO₂ Concentration (µg/m³)				% Difference (Unadjusted Modelled vs. Measured)	% Difference (Adjusted Modelled vs. Measured)
				Background	Monitored Total	Modelled Total (Unadjusted)	Modelled Total (Adjusted)		
Belfast Westlink Roden Street AURN	Rest of the city	Yes	1.28	15.4	34.0	30.6	34.6	-10.0	+1.7
Crumlin Road	Rest of the city	Yes	1.28	15.9	27.0	24.2	26.5	-10.4	-2.0
Donegall Road	Rest of the city	Yes	1.28	18.8	31.0	28.8	31.5	-7.2	+1.5
Glenmachan Street	Rest of the city	Yes	1.28	15.3	38.0	30.5	34.5	-19.7	-9.2
Knock Road	Rest of the city	Yes	1.28	10.3	35.0	24.9	28.7	-29.0	-18.0
N1	Rest of the city	Yes	1.28	10.9	20.3	19.1	21.3	-6.1	+4.9
N6	Rest of the city	No	1.28	14.8	23.0	21.2	23.0	-8.0	-0.3
North Road	Rest of the city	No	1.28	14.6	14.0	18.6	19.7	+32.9	+40.8
Opposite Westlink AQMS	Rest of the city	Yes	1.28	15.4	**45.0**	40.0	**46.0**	-11.2	+2.3
Royal Victoria Hospital	Rest of the city	No	1.28	15.4	21.0	23.0	25.1	+9.6	+19.4
RVH Falls Road	Rest of the city	Yes	1.28	15.4	33.0	24.4	26.8	-26.2	-18.9
Shore Road (Ivan Street end)	Rest of the city	Yes	1.28	15.8	30.0	28.7	32.1	-4.3	+7.1
Short Strand	Rest of the city	Yes	1.28	17.0	**40.0**	37.0	**42.1**	-7.4	+5.3
Tates Avenue	Rest of the city	Yes	1.28	15.3	27.0	23.1	25.2	-14.4	-6.6
Titanic Quarter	Rest of the city	No	1.28	19.5	22.0	29.3	31.9	+33.0	+45.0
Upper Knockbreda Road	Rest of the city	No	1.28	11.2	34.0	18.2	20.2	-46.4	-40.7
Upper Newtownards Road & Holywood Road	Rest of the city	Yes	1.28	16.4	27.0	28.9	32.3	+7.1	+19.5
Westlink AQMS	Rest of the city	No	1.28	15.4	34.0	30.4	34.4	-10.5	+1.1
Whitewell Road	Rest of the city	No	1.28	8.9	25.0	13.7	15.1	-45.1	-39.7
York Street	Rest of the city	Yes	1.28	15.8	36.0	34.7	39.5	-3.7	+9.7

*Exceedances of the annual mean NO_2 AQO level of 40 µg/m³ are shown in **bold***

B.3 Modelled Receptors

Figure B. 1 Modelled Discrete Sensitive Receptors

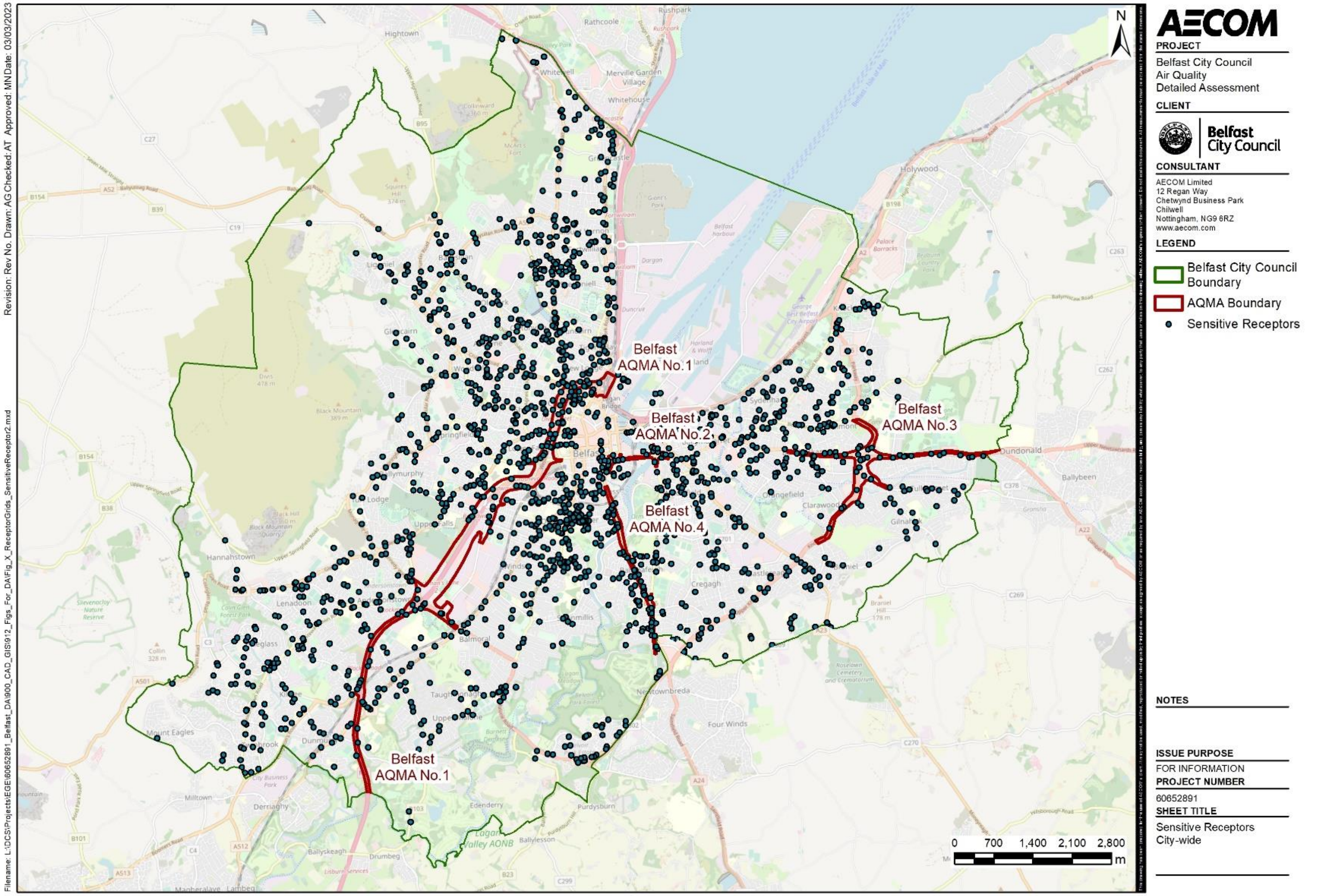


Figure B. 2 Modelled Intelligent Grid Receptor Points, AQMA 1 - M1 Motorway / A12 Westlink Corridor

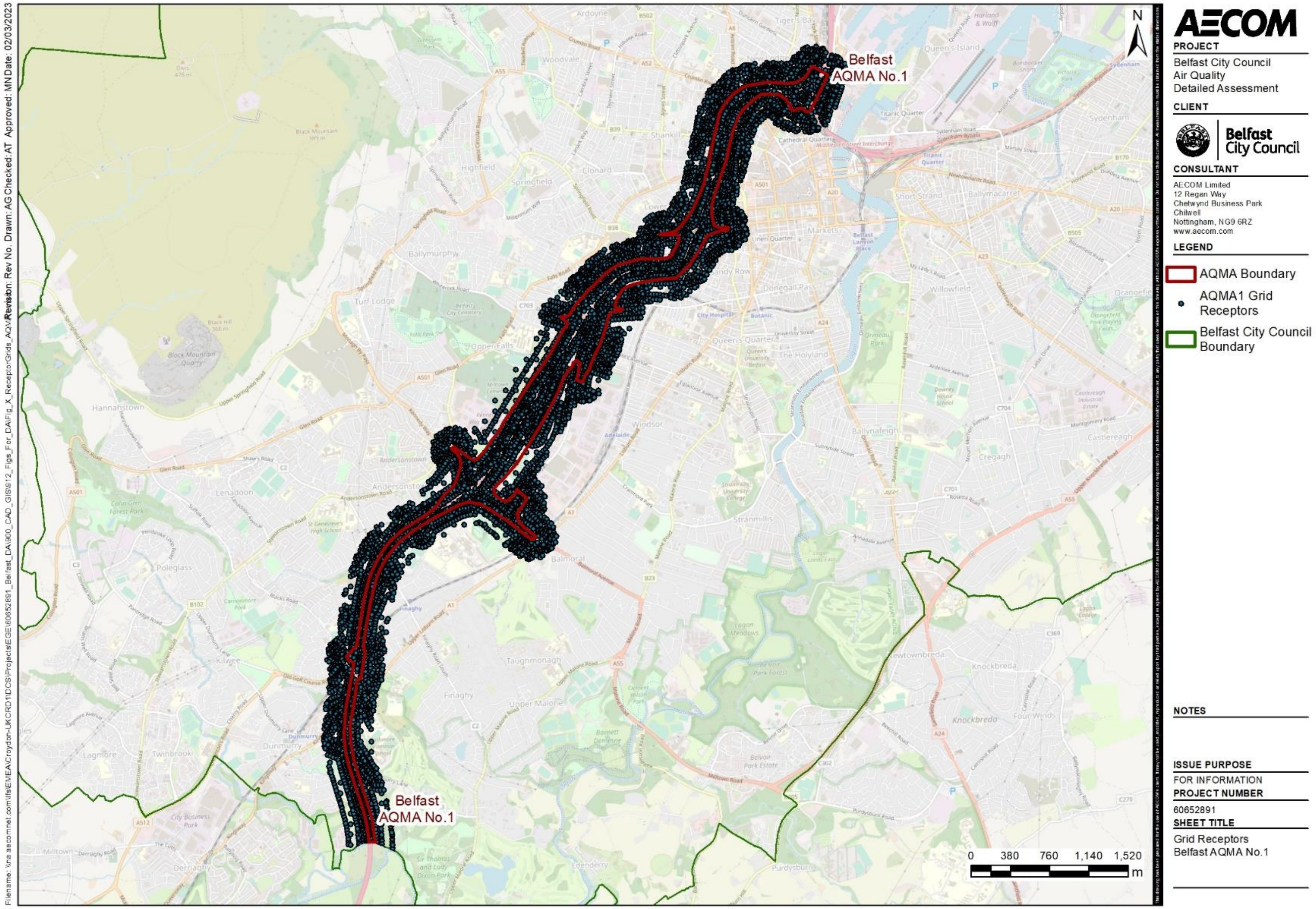


Figure B. 3 Modelled Intelligent Grid Receptor Points, AQMA 2 - Cromac Street, East Bridge Street and Albertbridge Road

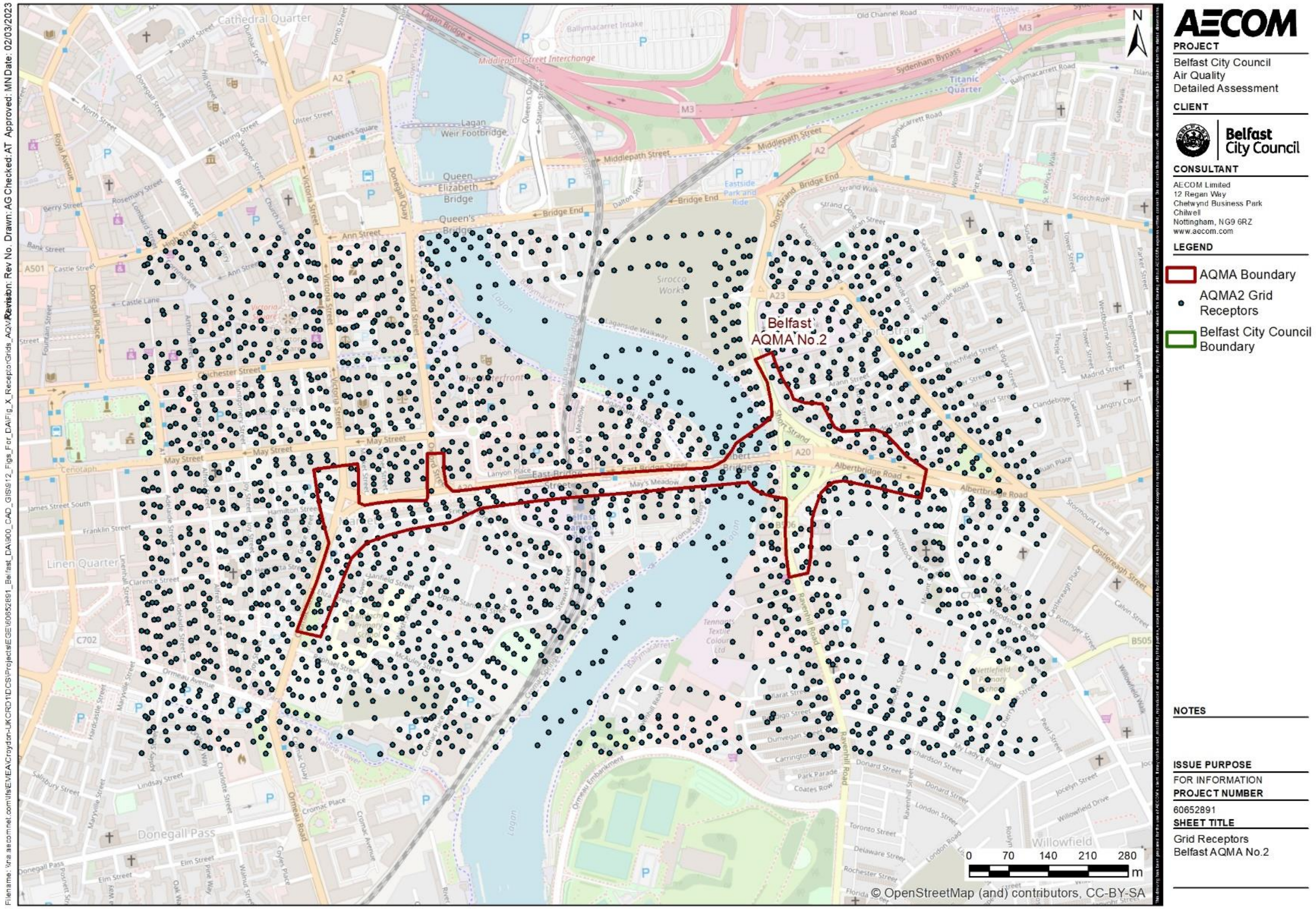


Figure B. 4 Modelled Intelligent Grid Receptor Points, AQMA 3 - Upper Newtownards Road

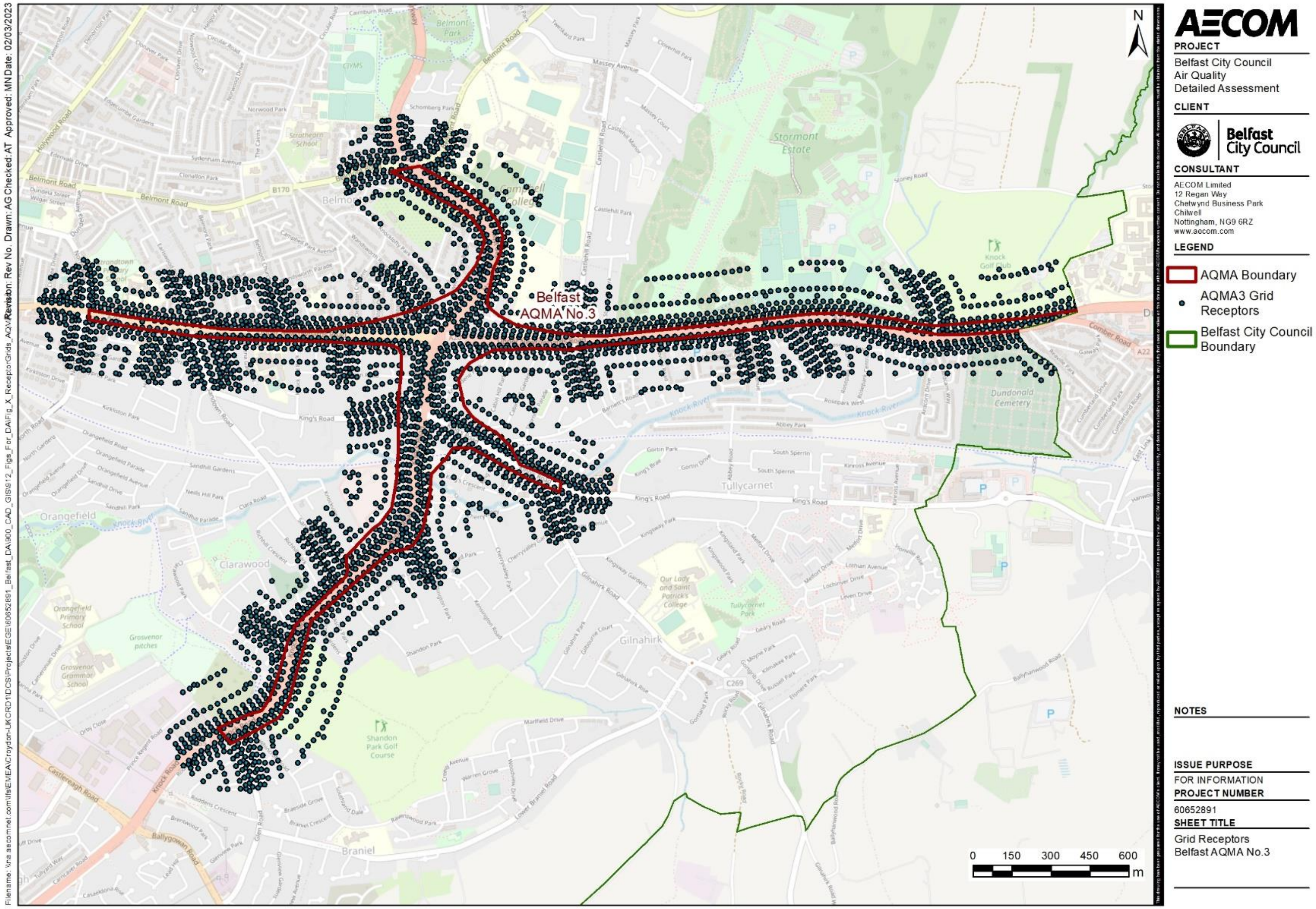


Figure B. 5 Modelled Intelligent Grid Receptor Points, AQMA 4 – Ormeau Road

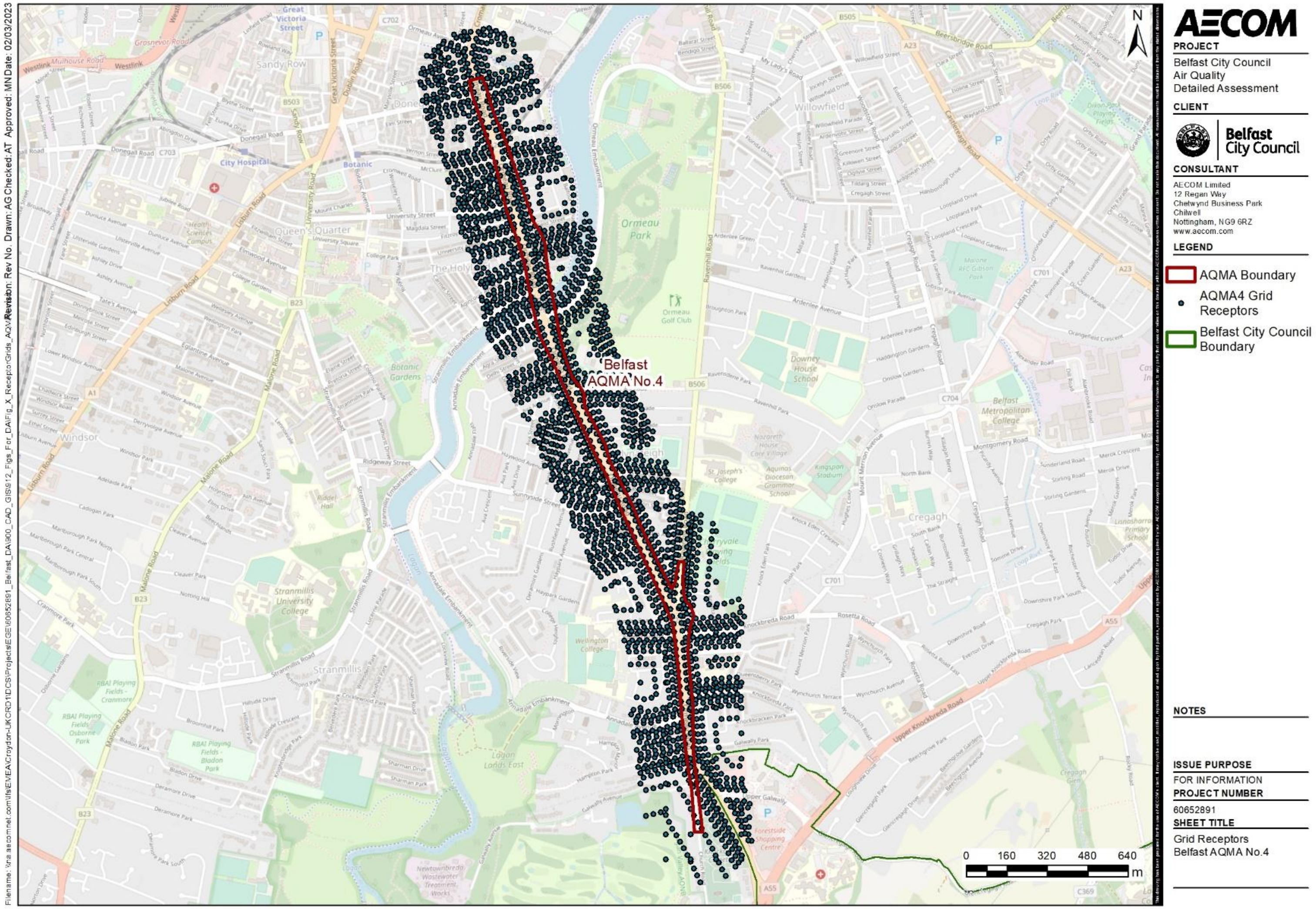
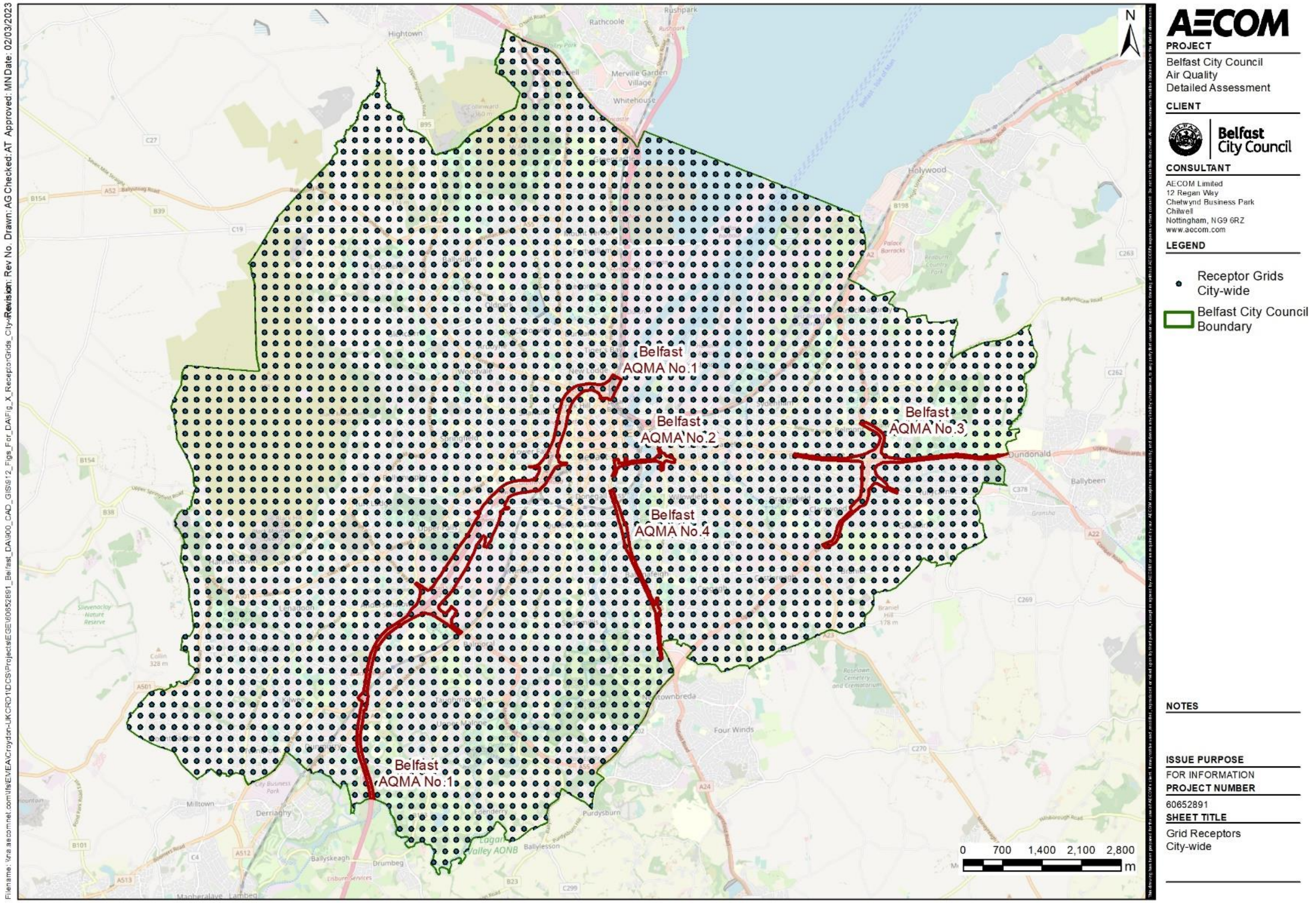


Figure B. 6 Modelled Coarse Resolution Grid Receptor Points, City-Wide



B.4 Maps of Background Pollution Concentrations

Figure B. 7 Mapped Background Concentrations (Sector-Removed), NO_2 2019

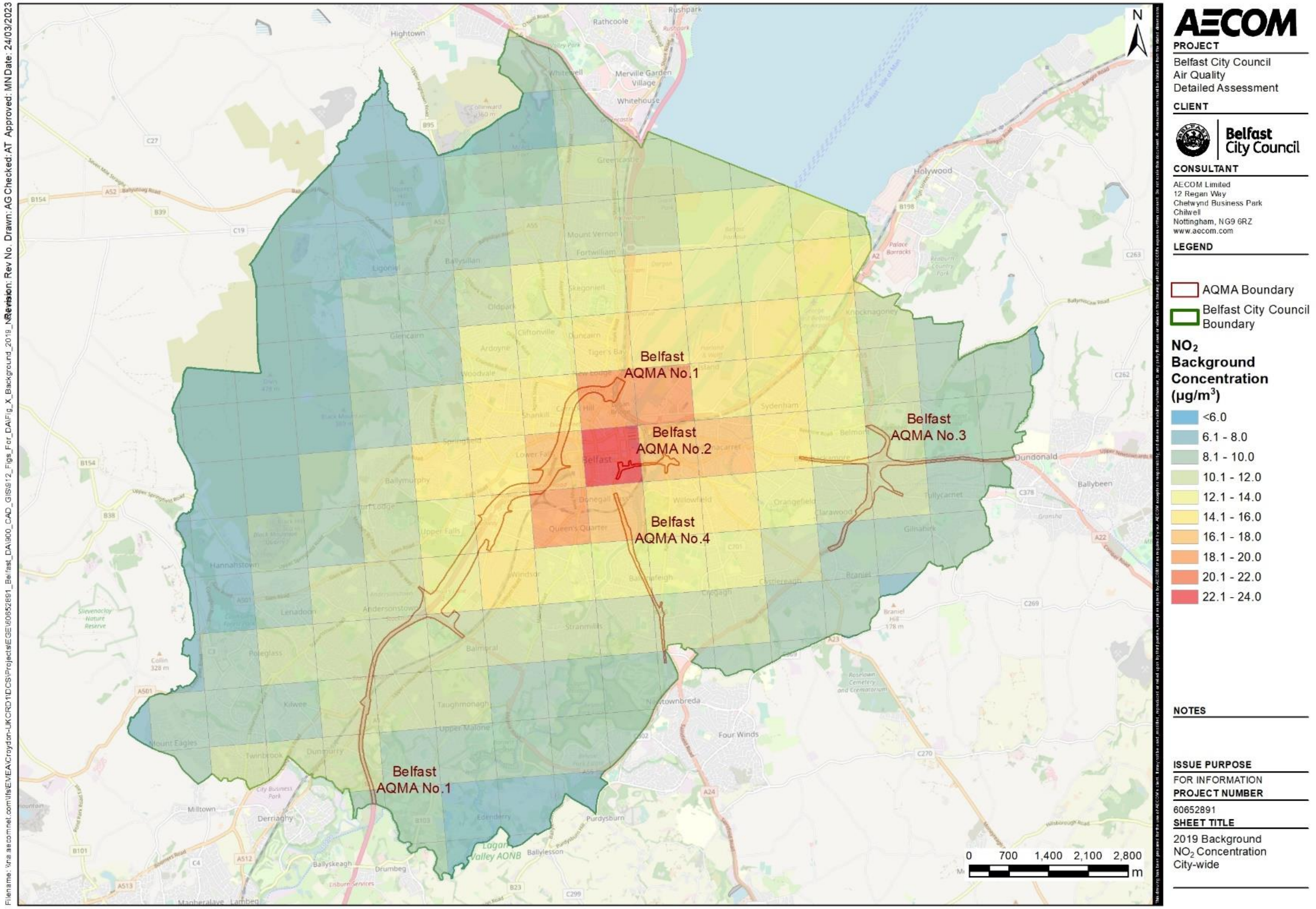


Figure B. 8 Mapped Background Concentrations (Sector-Removed), NO_2 2028

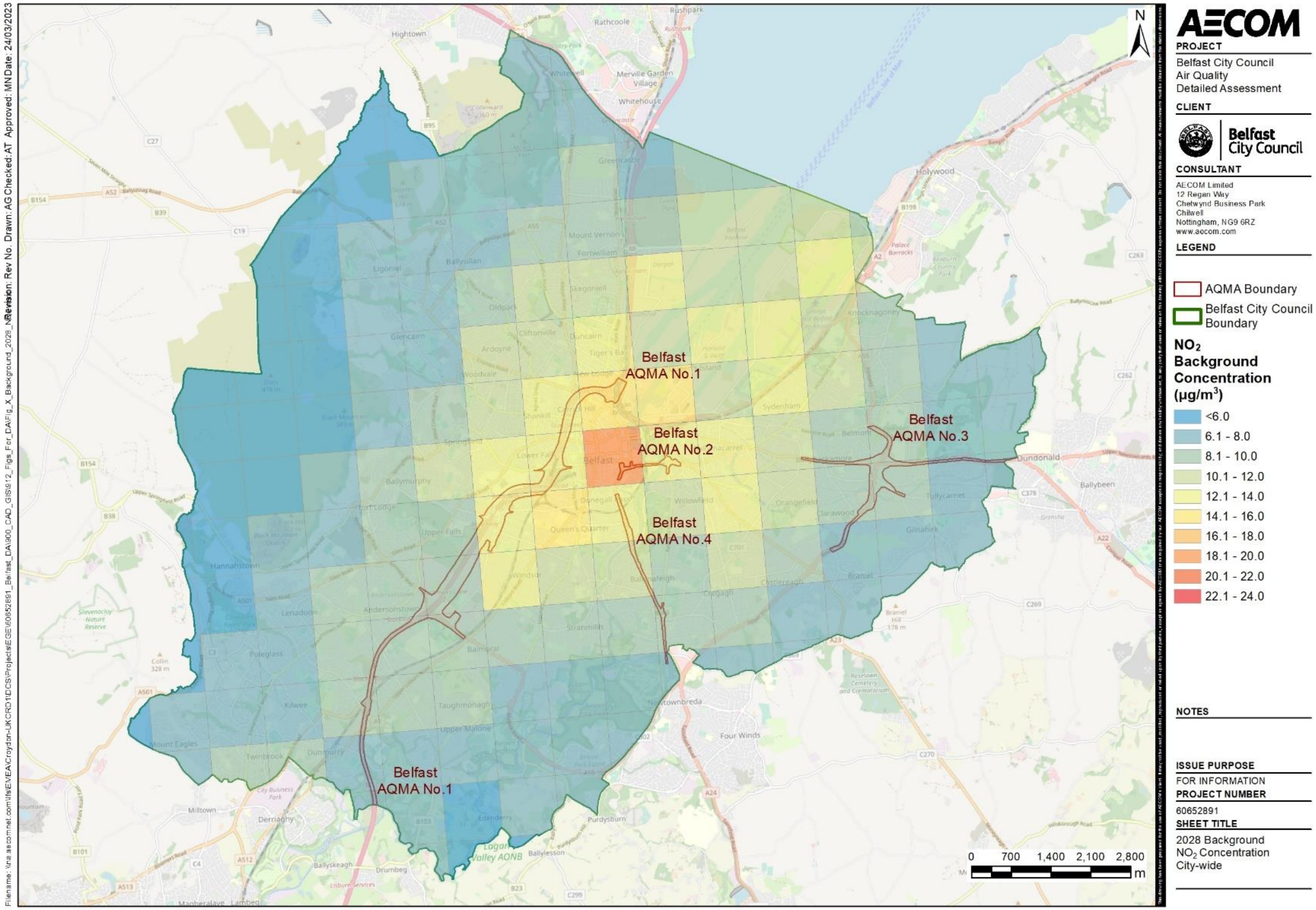


Figure B. 9 Mapped Background Concentrations (Sector-Removed), PM_{10} 2019

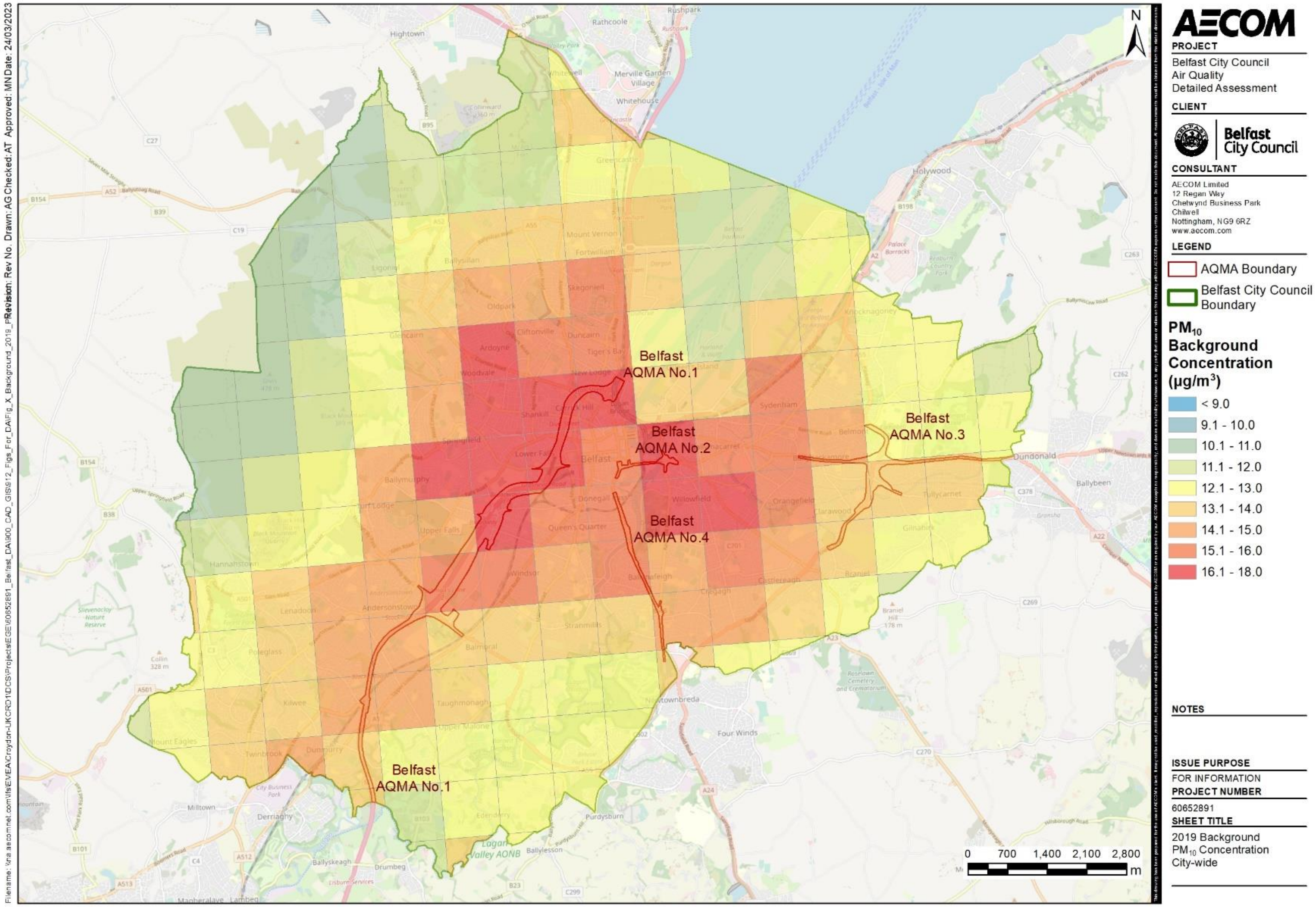


Figure B. 10 Mapped Background Concentrations (Sector-Removed), PM_{10} 2028

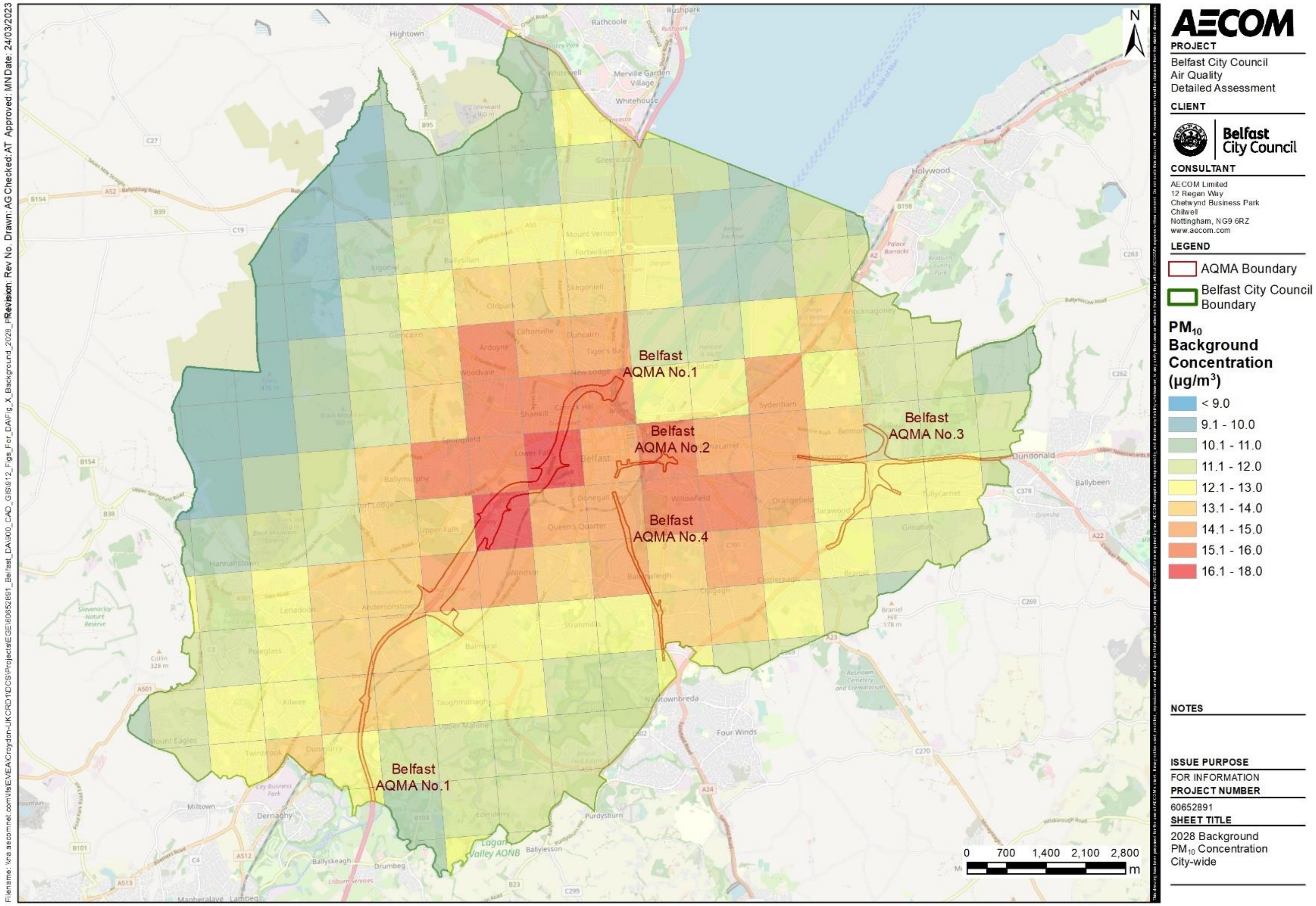


Figure B. 11 Mapped Background Concentrations (Sector-Removed), $PM_{2.5}$ 2019

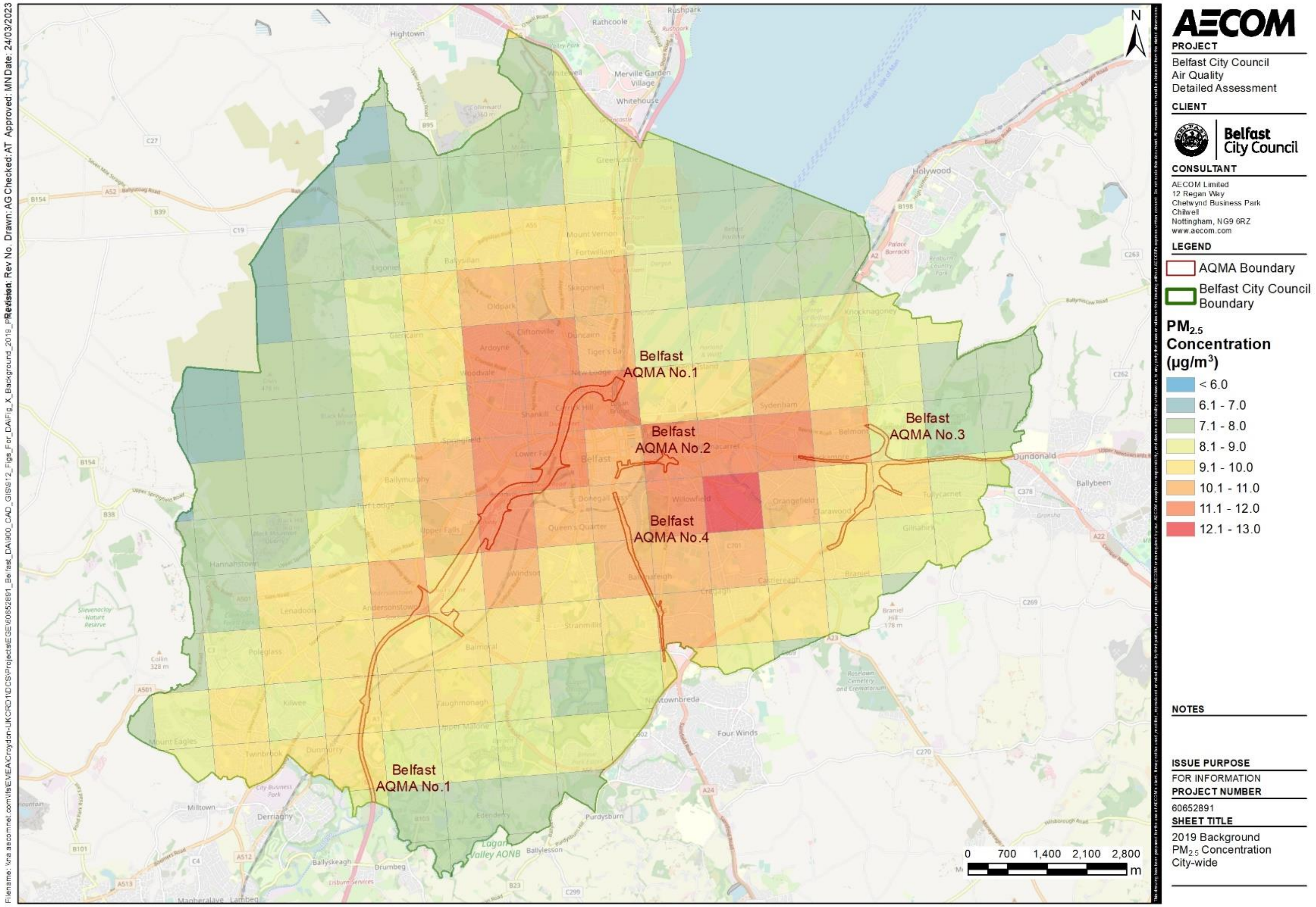
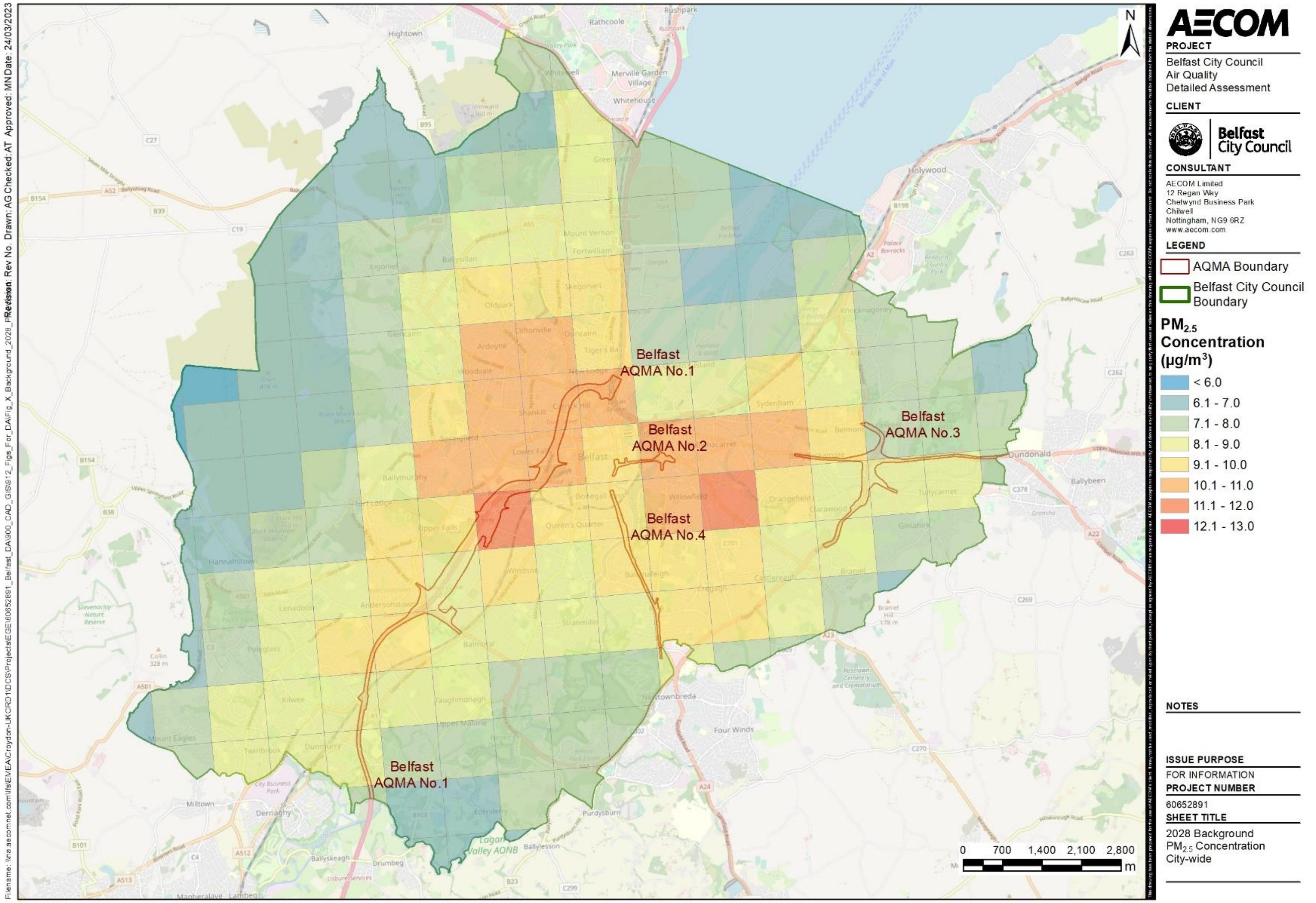


Figure B. 12 Mapped Background Concentrations (Sector-Removed), $PM_{2.5}$ 2028



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