Detailed Assessment Grangemouth AQMA

Falkirk Council

Falkirk Council

SWECO

Change list

Ver	Date	Description of the change	Reviewed	Approved by
1		Draft Issue	JS	JS
P02	Jun 2024	Updated modelling	DP	JS
C01	August 2024	Stakeholder comments Addressed Final version	DP	JS

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Executive Summary

Falkirk Council submitted a proposal for the revocation of the Grangemouth Air Quality Management Area to the Scottish Government in November 2023 under the Environment Act 1995. The Air Quality Management Area is declared for exceedances of the 15-minute objective for concentrations of sulphur dioxide.

Recent monitoring has shown a sustained improvement in concentrations over recent years and a drop in the number of exceedances. Plant improvement at the Grangemouth industrial facilities have reduced harmful emissions and Falkirk Council and the Scottish Environment Protection Agency consider that a proposal for revocation is appropriate.

This assessment has been produced to accompany the proposal for revocation and has been supported by the operators of the plant at the Grangemouth industrial facilities through the provision of emissions information for their industrial processes with emissions to air.

The assessment produced a new dispersion model for emissions of common pollutants and found that exceedances of the 15-minute objective were limited to very specific areas, mostly within the area of the industrial facilities themselves, and particularly only under exceptional operating procedures associated with tail gas flaring.

The results of the dispersion model showed that the pattern of air pollutant dispersion was changed compared to previous modelling exercises due to the changes in the operation of the facilities, addition of new emissions information not previously available, and the improvements in technology associated with emissions abatement. Despite all of this, the potential for isolated incidences of future exceedances cannot be ruled out.

This assessment supports the revocation of the Air Quality Management Area and suggests that monitoring continue at the existing locations. In addition to this, roadside or other similar sized monitors are suggested with potential locations for these including:

- Lawers Place, Grangemouth
- Cuillin Place, Grangemouth
- Polmonthill Snowsports Centre or adjacent golf club buildings.

1 Introduction

The Environment Act 1995 and subsequent regulations required local authorities to assess compliance of air quality in their area with the standards and objectives set out in the Air Quality Strategy for England, Scotland, Wales and Northern Ireland 2007 (AQS). The air quality standard and objectives are defined in the Air Quality (Scotland) Regulations 2000 and Air Quality (Scotland) Amendment Regulations 2002.

The process by which local authorities assess compliance with AQS objectives is known as Local Air Quality Management (LAQM). The LAQM process commenced in 1998, and since then Falkirk Council have regularly reviewed and assessed air quality within its boundaries. As part of that review and assessment the Council operates a monitoring network throughout its boundaries, targeting areas of anticipated poor air quality, and then reports on the results annually.

Sweco UK Ltd (Sweco) have been appointed by Falkirk Council to provide consultancy support on behalf of the council. The purpose of this report is to provide information suitable for a submission under the Local Air Quality Management review and assessment process. This report examines the industrial emissions within the Grangemouth Air Quality Management Area (AQMA) including a review of emission sources and dispersion modelling of the principle industrial sources of emissions to air. The results of the dispersion modelling are intended to inform decision-making processes regarding the future of the Grangemouth AQMA.

1.1 Background

Grangemouth is located in the Falkirk Council local authority area within the Central Belt of Scotland. The Central Belt is the most densely populated area of Scotland and includes the cities of Edinburgh and Glasgow, with the area between the two cities being the location of numerous large towns and industrial areas. The area has a history as the location of substantial industry with numerous former coal and shale mines alongside sites previously occupied by manufacturing of every kind.

An AQMA was declared in Grangemouth in 2005 due to exceedances of the 15-minute mean for sulphur dioxide (SO_2). The AQMA encompasses an area that includes the petro-chemical processing and receiving facilities at Grangemouth Port and the town of Grangemouth east of the M9 motorway as shown in Figure 1.1.

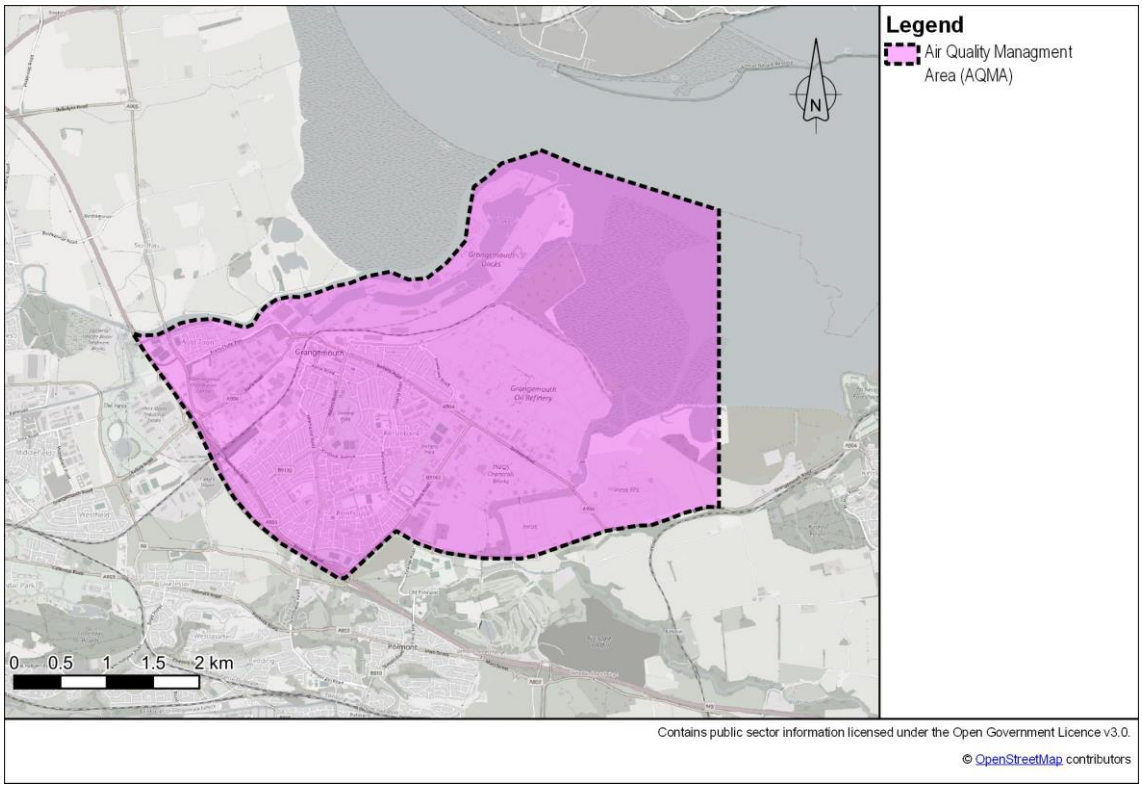

Figure 1.1 Grangemouth Air Quality Management Area Location and Extents

Operators of the petro-chemical facilities at Grangemouth have been working to improve emissions in recent years and a number of the emission points have had abatement equipment installed. Falkirk Council wishes to consider the possibility that the AQMA can be revoked, and this study will provide pollutant predictions and an analysis of recent monitoring that can be used to inform a decision on revocation.

Due to sustained reductions in sulphurous emissions from the Grangemouth facilities a Proposal for the Revocation of the Grangemouth AQMA[1] was submitted to the Scottish Environment Protection Agency (SEPA) and the Scottish Government by Falkirk Council in 2023.

[1] Falkirk Council (2023) Proposal for the Revocation of the Grangemouth AQMA. [Online] Available at https://www.falkirk.gov.uk/services/environment/environmental-policy/air-quality/

2 Legislation, Policy and Guidance

Scottish policy in relation to the LAQM process is set out in Local Air Quality Management LAQM TG (22)[2] and Policy Guidance (PG(S)(23))[3].

The policy guidance describes the air quality objectives to be applied in assessing air quality and the review and assessment process. The relevant aspects are described in Sections 2.1 and 2.2 below.

This guidance is intended to help local authorities with their local air quality management duties under Part IV of the Environment Act 1995. It sets out:

- The statutory background and the legislative framework within which local authorities have to work.
- The principles behind reviews and assessments of air quality and the recommended steps that local authorities should take.
- How local authorities should handle the designation of Air Quality Management Areas (AQMAs) and the drawing up and implementation of action plans.
- Suggestions for taking forward the development of local air quality strategies.
- Suggestions on how local authorities should consult and liaise with others.
- The role of transport-related measures in improving air quality
- The general principles behind air quality and land use planning
- The effects of biomass on air quality
- The relationships between air quality and noise policy.

This guidance was issued by the Scottish Ministers under section 88(1) of the 1995 Act. Local authorities should have regard to it when undertaking their local air quality management duties, as required under section 88(2) of the Act. The guidance should be considered by all local authority departments involved in local air quality management (LAQM), including environmental health, corporate services, planning, economic development and transport planning. The guidance complements the information and advice contained in Cleaner Air for Scotland 2 (CAFS2)[4], which was published in July 2021 which replaced the original strategy published in 2015.

2.1 National Legislation and Policy

The following legislation is relevant to this study.

2.1.1 Environment Act 1995

Part IV of the Environment Act 1995 places an obligation upon local authorities to review and report on air quality within their local authority area. The legislation stipulates that this should be undertaken “from time to time” however in practise this is undertaken on an annual basis through the production of Annual Progress Reports in Scotland in addition to ad-hoc specific studies on AQMAs or specific air pollutant sources.
The Act includes the provision for the declaration, revision or revocation of AQMAs within the local authority area on the basis of an air quality review.
The Act also requires of the UK Government and Devolved Authorities to produce an Air Quality Strategy detailing objectives for the concentrations of pollutants in ambient air and the time period in which those objectives should be achieved.

[2] Available at: https://laqm.defra.gov.uk/wp-content/uploads/2022/08/LAQM-TG22-August-22-v1.0.pdf
[3] Available at: https://www.gov.scot/publications/local-air-quality-management-policy-guidance/
[4] Available at: https://www.gov.scot/publications/cleaner-air-scotland-2-towards-better-place-everyone/

2.1.2 Environment Act 2021

The Environment Act 2021 made no changes to the obligations of local authorities in Scotland, with an amendment to Part IV of the Environment Act 1995 relating only to local authorities in England.
An amendment was made to the obligation of the UK Government and Devolved Authorities to produce an updated to the Air Quality Strategy within 12 months of the legislation coming into force.

2.1.3 The Air Quality (Scotland) Regulations 2000

The Air Quality (Scotland) Regulations 2000 revoked all previous devolved air quality legislation in Scotland and provided a new legislative basis and objectives for the regulation of pollutants in ambient air.

2.1.4 The Air Quality (Scotland) Amendment Regulations 2002

The Air Quality (Scotland) Amendment Regulations 2002 provides the legislative basis for the PM_{10} objective of 18 µg/m³ and the permitted number of exceedances of the 24-hour objective of 50 µg/m³ being on no more than seven occasions.

2.1.5 The Air Quality Standards (Scotland) Regulations 2010

The Air Quality Standards (Scotland) Regulations 2010 and subsequent amendments transpose EU Directive 2008/50/EC into Scottish law. The Regulations set out the limit values and target values for the ambient concentration of air pollutants and the requirement for exposure reduction of fine particulate matter ($PM_{2.5}$) within the general population and the requirements for action to be taken when levels of air pollutants persistently exceed the limit values. This legislation remains in force in Scotland following the UK exit from the European Union.

The current air quality objectives for Scotland that are relevant to this study are shown in Table 2.1.

Table 2.1 Relevant Air Pollutant Objectives

Pollutant	**Standard (µg/m³ unless stated)**	**Measured as**
SO_2	266	15-minute mean, not to be exceeded on more than 35 occasions per year
	350	1-hour mean, not to be exceeded on more than 24 occasions per year
	125	24-hour mean, not to be exceeded on more than 3 occasions per year

The NAQOs apply to external air where there is relevant exposure to the public over the associated averaging periods within each objective. Guidance is provided within the Local Air Quality Management Technical Guidance 2022(LAQM.TG (22)) issued for Local Authorities, on where the AQOs apply as detailed in Table 2.2. The objectives do not apply in workplace locations, to internal air or where people are unlikely to be regularly exposed (i.e. centre of roadways).

Table 2.2: Locations Where Air Quality Objectives Apply

Averaging Period	Objectives Should Apply at:	Objectives Should Generally Not Apply at:
Annual mean	• All locations where members of the public might be regularly exposed. Building façades of residential properties, schools, hospitals, care homes etc.	• Building façades of offices or other places of work where members of the public do not have regular access. • Hotels, unless people live there as their permanent residence. • Gardens of residential properties. • Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
24-hour mean and 8-hour mean	• All locations where the annual mean objective would apply, together with hotels. • Gardens of residential properties*	• Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
1-hour mean	• All locations where the annual mean and: • 24- and 8-hour mean objectives apply. Kerbside sites (for example, pavements of busy shopping streets). • Those parts of car parks, bus stations and railway stations etc. which are not fully enclosed, where members of the public might reasonably be expected to spend one hour or more. • Any outdoor locations where members of the public might reasonably expect to spend one hour or longer	• Kerbside sites where the public would not be expected to have regular access.
15-minute mean	• All locations where members of the public might reasonably be exposed for a period of 15 minutes.	
* Such locations should represent parts of the garden where relevant public exposure to pollutants is likely, for example where there is seating or play areas. It is unlikely that relevant public exposure to pollutants would occur at the extremities of the garden boundary, or in front gardens, although local judgement should always be applied.		

2.2 Review and Assessment Process

The LAQM process requires that local authorities carry out regular reviews of air quality in the form of annual assessment reports. Where an assessment identifies that there is a risk that an air quality objective will be exceeded at a location with relevant public exposure then a Detailed Assessment is undertaken. Detailed assessments consider any risk of exceedance of an objective in greater depth to determine whether or not an exceedance is likely.

Where a likely exceedance of an objective is identified, the Council are required to declare an Air Quality Management Area (AQMA), a designated area in which the Council have an obligation to develop and implement an Air Quality Action Plan (AQAP) plan to improve air quality.

In designating an AQMA, policy guidance states:

'air quality management areas must encompass all known and predicted areas of exceedance where there is relevant exposure'

Where, however, it is identified that air quality within an AQMA meets air quality objectives, then local authorities can amend or revoke an AQMA. Policy guidance states:

'In order....to revoke an air quality management area the local authority is required to submit a Detailed Assessment clearly outlining the evidence for changes in the likelihood of exceedance of the objectives occurring and demonstrating the cause of these changes.'

'where a local authority considers it necessary to amend or revoke an air quality management area.... (necessary to) consult all the relevant statutory consultees.... local authorities should submit their reports for appraisal showing monitoring results and other evidence to justify their decision.'

To revoke an AQMA it is, therefore, necessary to demonstrate compliance with the relevant NAQS objective but also demonstrate or justify the cause for improvement in air quality.

2.3 Overview of the Assessment

Based on the continued compliance with 15-minute mean SO_2 objective since 2015 it is proposed to revoke the AQMA. This report forms a Detailed Assessment of SO_2 to identify whether the AQMA should remain or can safely be revoked.

The general approach taken in the assessment was:

- Collect and analyse all SO_2 emissions data, monitoring, meteorological and background concentration data for use in a dispersion modelling study.
- Review historic measurement data and trends.
- Use dispersion modelling to produce numerical predictions of 15-minute mean SO_2, 1-hour and daily mean SO_2 concentrations.
- Use dispersion modelling to produce contour plots showing the expected spatial variation of the short concentrations of pollutants.
- Recommend if Falkirk Council should retain or revoke the Grangemouth AQMA within the study area.
- Assess the likelihood of exceedance of the NAQS objectives in the future by considering differing meteorological conditions.

The modelling methodologies provided for Detailed Assessments are outlined in the Scottish Government and Defra Technical Guidance LAQM.TG (22) and were used throughout this study.

3 Baseline Air Quality

3.1 Local Air Quality Management

Automatic monitoring for SO_2 is undertaken at six locations, four of which are within the AQMA as shown in Figure 3.1.

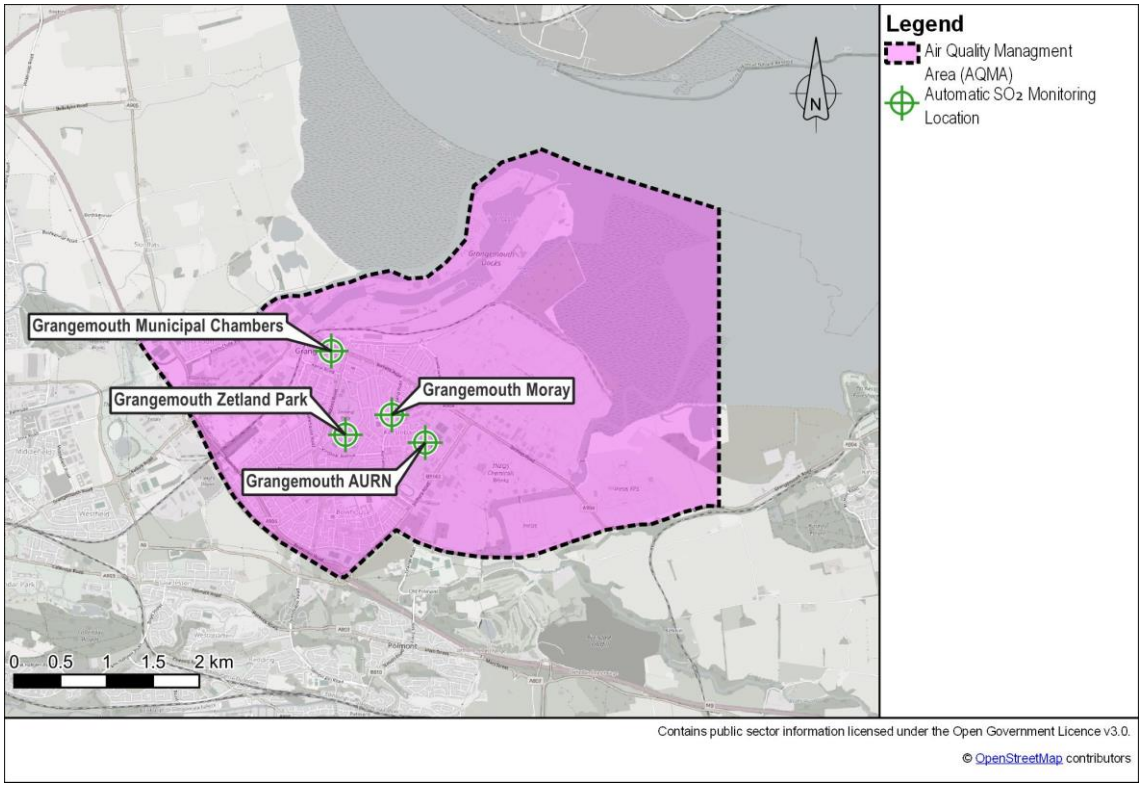

Figure 3.1 Grangemouth AQMA Automatic Monitor Locations

Monitoring data has been compared to the three short-term objectives for SO_2.ie 15-minute mean, 1-hour mean and 24-hour mean. A summary of the findings for each is provided below:

- Table 3.1 shows a summary of the exceedances of the 15-minute objective of 266 µg/m³ for SO_2. This shows an inconsistent pattern for exceedances, except for 2020 and 2021 where exceedances were zero or minimal due to the likely effects of the Scottish Government Covid-19 restrictions. In all years where exceedances of the 266 µg/m³ did occur this was on less than the permitted 35 occasions in a calendar year. This is shown graphically in Figure 3.2.
- Table 3.2 shows a summary of the exceedances of the 1-hour objective for SO_2 of 350 µg/m³. Very few exceedances of this limit have occurred over the time period studied, and in every year, exceedances were less than the 24 permitted occasions in a calendar year.
- Table 3.3 shows a summary of the exceedances of the 24-hour objective of 125 µg/m³. This shows since 2015 there has been only two exceedances of the daily mean objective. This occurred at Grangemouth Municipal Chambers in 2016 this was just below the permitted 3 occasions in any calendar year.

Table 3.1 Summary of Exceedances of the 15-minute Objective for SO_2

Year	15-minute SO_2 Exceedances (Max. Concentration in µg/m³)					
	Bo'ness	**Grangemouth Municipal Chambers**	**Zetland Park**	**Grangemouth Moray**	**Falkirk Hope Street**	**Grangemouth**
2015	0 (0.0)	8 (375.2)	0 (42.6)	2 (345.9)	0 (165.0)	1 (306.7)
2016	0 (77.2)	28 (1082.7)	0 (22.9)	26 (450.2)	3 (320.4)	3 (396.2)
2017	0 (86.3)	4 (390.1)	0 (26.2)	10 (417.2)	0 (110.7)	0 (221.9)
2018	0 (93.1)	0 (230.7)	0 (40.7)	1 (270.9)	0 (92.7)	0 (201.4)
2019	0 (84.9)	0 (253.5)	0 (120.8)	12 (518.7)	0 (131.0)	2 (406.2)
2020	0 (87.3)	0 (171.2)	0 (50.8)	0 (179.1)	0 (78.1)	6 (358.6)
2021	0 (71.1)	0 (100.6)	0 (12.6)	0 (78.0)	0 (21.9)	0 (141.9)
2022	0 (97.3)	0 (162.6)	0 (55.6)	0 (227.5)	0 (234.6)	5 (358.6)
2023	0 (93.5)	7 (371.6)	1 (282.6)	16 (593.0)	0 (122.3)	16 (466.2)

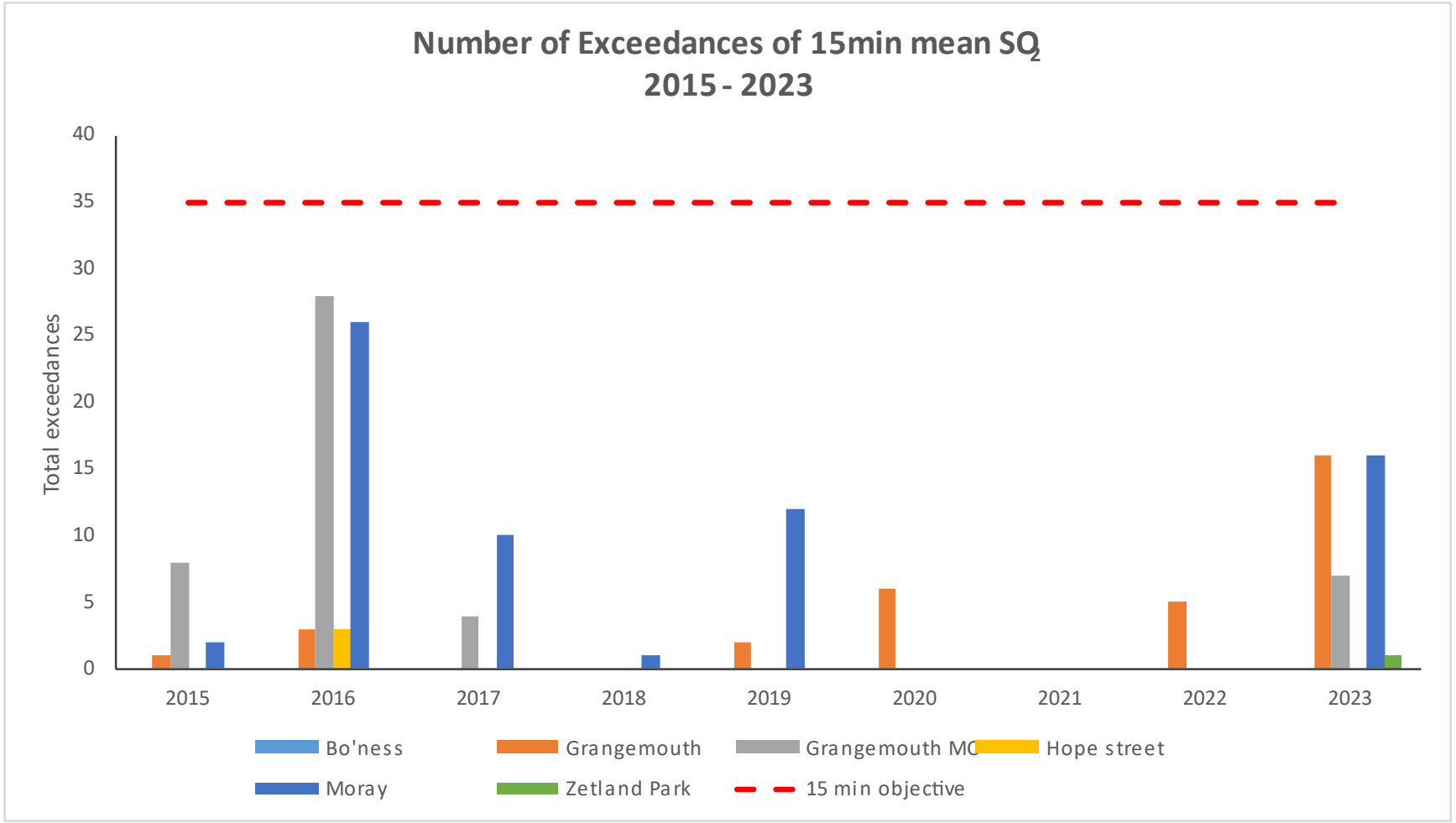

Figure 3.2 Summary of Exceedances of the 15-minute Objective for SO2 (2015 to 2023)

Figure 3.3 Wind Directions of the 15-minute Objective Exceedances 2015-2023

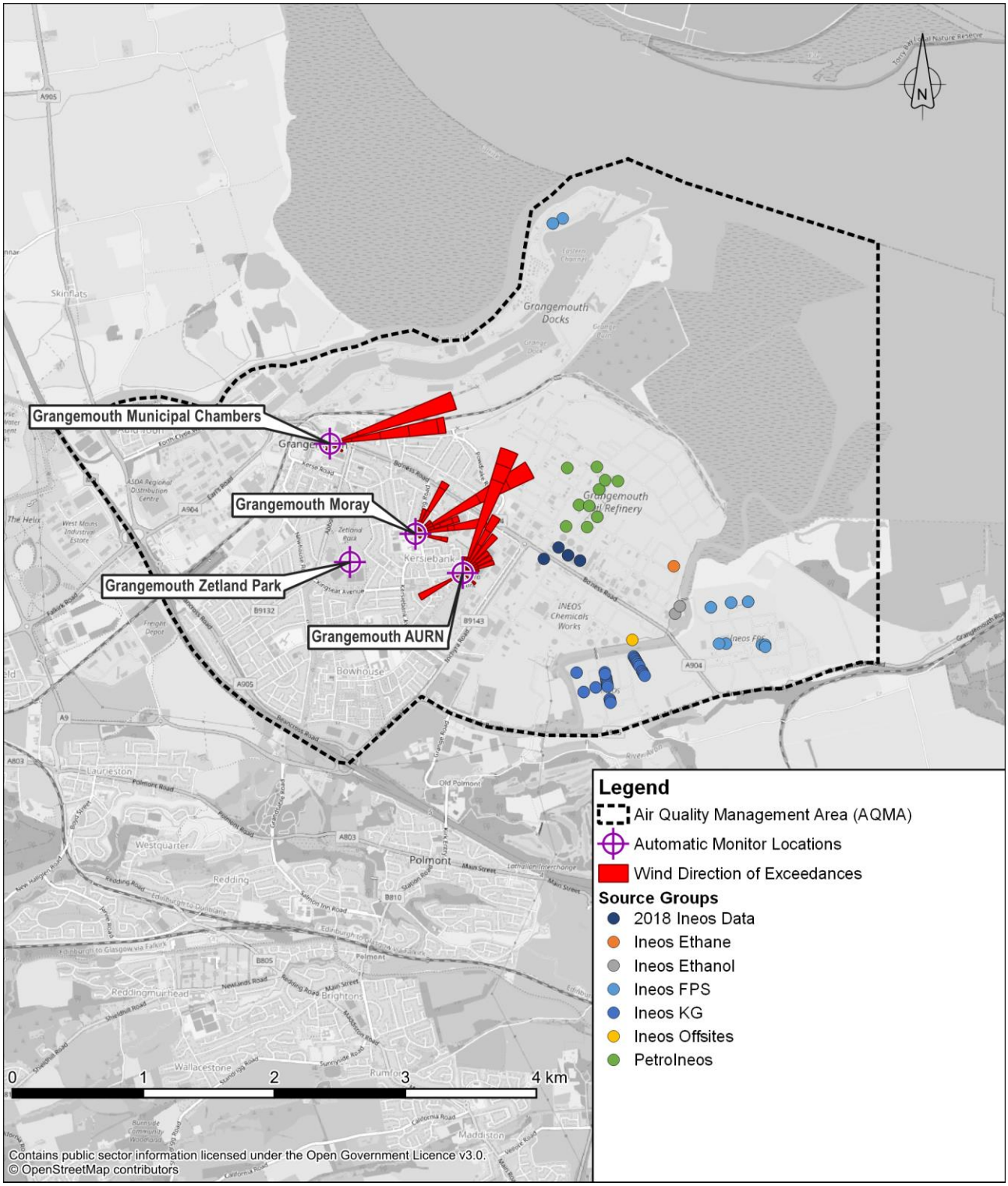

Table 3.2 Summary of Exceedances of the 1-hour Objective for SO_2

Year	1-hour SO_2 Exceedances (Max. Concentration in µg/m³)					
	Bo'ness	Grangemouth Municipal Chambers	Zetland Park	Grangemouth Moray	Falkirk Hope Street	Grangemouth
2015	0 (0.0)	0 (244.8)	0 (21.3)	0 (180.9)	0 (111.8)	0 (166.3)
2016	0 (55.7)	3 (755.2)	0 (16.9)	1 (353.8)	0 (266.6)	0 (153.9)
2017	0 (67.7)	0 (215.1)	0 (18.5)	0 (324.7)	0 (67.6)	0 (136.1)
2018	0 (57.9)	0 (207.5)	0 (25.4)	0 (218.3)	0 (82.6)	0 (129.3)
2019	0 (63.7)	0 (197.9)	0 (85.4)	1 (382.8)	0 (81.8)	0 (218.0)
2020	0 (67.5)	0 (95.3)	0 (34)	0 (102.2)	0 (51.8)	0 (210.6)
2021	0 (45.6)	0 (89.9)	0 (8.7)	0 (42.4)	0 (16.8)	0 (86.2)
2022	0 (74.4)	0 (63.9)	0 (32.0)	0 (102.3)	0 (70.1)	0 (196.8)
2023	0 (64.9)	0 (237.6)	0 (219.0)	1 (455.7)	0 (68.9)	0 (277.7)

Table 3.3 Summary of Exceedances of the Daily Objective for SO_2

Year	Daily SO_2 Exceedances (Max. Concentration in µg/m³)					
	Bo'ness	Grangemouth Municipal Chambers	Zetland Park	Grangemouth Moray	Falkirk Hope Street	Grangemouth
2015	0 (0.0)	0 (64.6)	0 (6.4)	0 (45.8)	0 (24.5)	0 (29.2)
2016	0 (12.3)	2 (146.3)	0 (7.4)	0 (103.1)	0 (30)	0 (45.6)
2017	0 (25.5)	0 (38.5)	0 (5.5)	0 (85.3)	0 (15.9)	0 (26.8)
2018	0 (9.4)	0 (106.6)	0 (10.2)	0 (46.8)	0 (14.1)	0 (31.1)
2019	0 (12.5)	0 (50.5)	0 (18.1)	0 (91.7)	0 (22.7)	0 (21.4)
2020	0 (15.2)	0 (15.9)	0 (12.6)	0 (28.1)	0 (13.4)	0 (39.0)
2021	0 (9.8)	0 (21.9)	0 (2.0)	0 (11.5)	0 (6.8)	0 (12.3)
2022	0 (19.0)	0 (8.0)	0 (5.6)	0 (26.8)	0 (7.1)	0 (37.1)
2023	0 (9.7)	0 (85.0)	0 (26.1)	0 (83.0)	0 (12.5)	0 (29.3)

3.2 Background Concentrations

Modelled background concentration maps for SO_2 are no longer maintained by DEFRA and are published for a base year of 2001 only.

Background concentrations of SO_2 are the unadjusted values from 2001, following the guidance published by Defra[5]. It can be seen from Figure 3.4 that there are areas where the background maps reflect the position of facilities that are no longer present, e.g. Longannet Power Station, therefore it may not be appropriate to use such data as an indication of background SO_2. Numerous improvements have been made to sulphurous emissions as a result of agreements such as:

[5] Department for Environment Food and Rural Affairs and the Devolved Administrations (2020) Background Concentrations Maps User Guide. [Online] https://laqm.defra.gov.uk/air-quality/air-quality-assessment/background-maps/, accessed November 2020

- UNECE Convention on Long Range Transboundary Air Pollution;
- Directive (EU) 2015/2193 of the European Parliament and of the Council on the limitation of emissions of certain pollutants into the air from medium combustion plants.; and
- Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).

As a result it is likely that actual SO_2 background is substantially lower than that recorded in the 2001 dataset and is certain to exhibit a different spatial distribution. Therefore, a five-year average of the annual averages from the Falkirk Hope St automatic monitor has been used for the years 2019-2023 (Dec 23), 1.4 µg/m^3. While 2023 data is not yet complete nor fully ratified this should not change the annual average to any degree which would change the conclusions of the report.

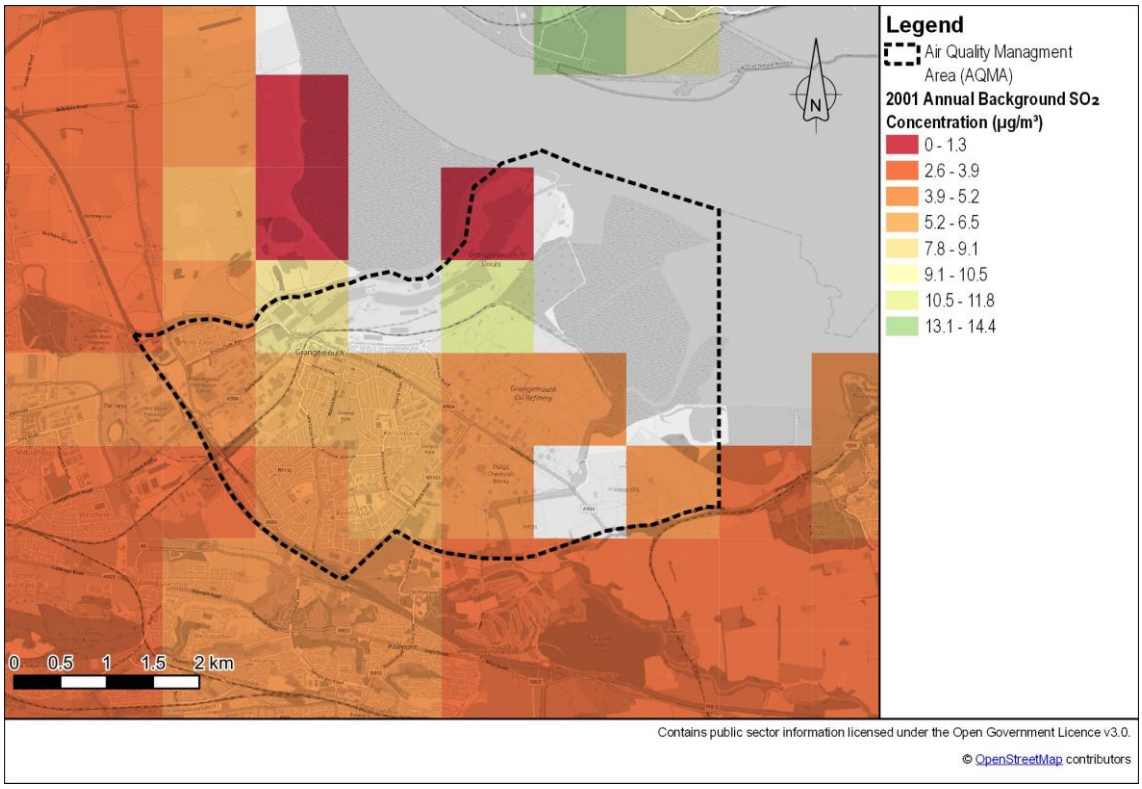

Figure 3.4 2001 Background SO_2 Concentrations

3.3 National Atmospheric Emission Inventory

The UK National Atmospheric Emission Inventory (NAEI) aggregates information submitted to the Environment Agency, the Scottish Environment Protection Agency (SEPA) and Natural Resources Wales to provide a national summary of emissions to air of various pollutants. With reference to the Grangemouth AQMA emissions of SO_2 up to 2021 (the latest year available) for the Falkirk Council local authority area are presented in Table 3.4 and Figure 3.5. At this time the Scottish Pollutant Release Inventory (SPRI) cannot be used for total emissions within the Falkirk Council local authority area as it is incomplete following the cyber-attack inflicted upon SEPA in 2019.

Table 3.4 Falkirk Council Area Annual SO_2 Emissions

Year	2015	2016	2017	2018	2019	2020	2021
Tonnes	4,703	5,337	5,020	4,575	3,446	1,529	2,181

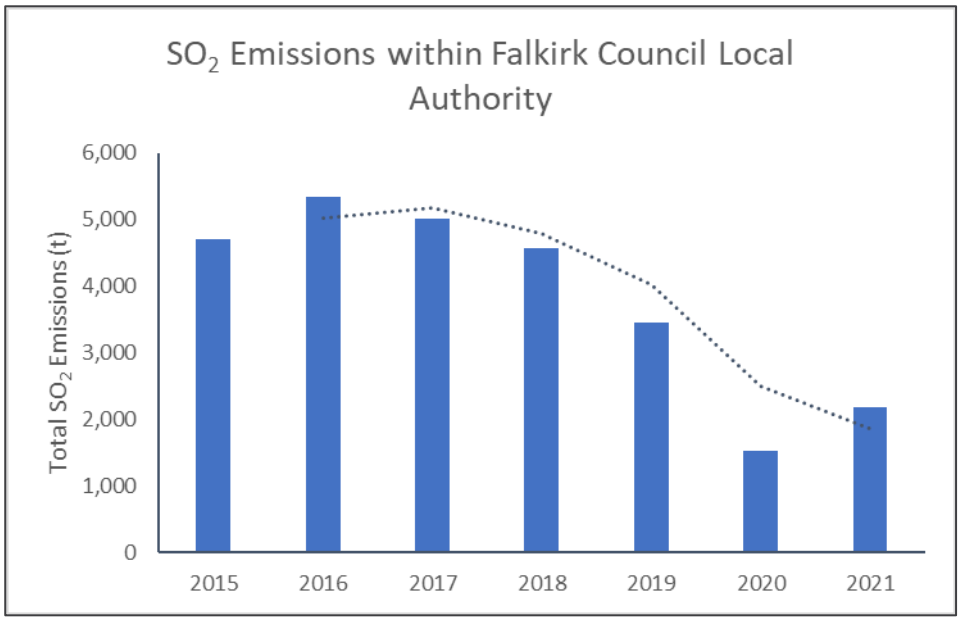

Figure 3.5 Falkirk Council Area Annual SO_2 Emissions with Moving Average

Table 3.4 shows a reduction in total SO_2 emissions within the Falkirk Council local authority area up to the initiation of Covid-19 restrictions, after which emissions were drastically reduced. What can be observed from Figure 3.5 is that emissions were steadily falling from a peak in 2016. The rate of reduction within the moving average applied to the annual emissions shows that, despite the continuation of Scottish Government Covid-19 restrictions, emissions in the year 2021 appear visually to have returned to the reducing trend apparent in the years preceding 2020.

4 Methodology

Falkirk Council have also commissioned Sweco to prepare an update to the Grangemouth Road traffic study – Grangemouth Phase 2 study. As part of this package of work Sweco has identified all industrial operators which have emission to air from stack emission points, emitting NOx, SOx, PM_{10} and VOCs. This package of work has also informed the work undertaken for this Detailed Assessment.

4.1 Data Request

To inform both this study and the Grangemouth Phase 2 study Sweco have liaised directly with SEPA and the Industrial Operators to obtain all relevant data for the Detailed Assessment.

It was agreed at project kick off that a data request proforma would be developed and approved by both SEPA and Falkirk Council for issue to each Industrial Operator. This was in the form of a simple spreadsheet which contained a request for all relevant data required as input parameters to an air quality dispersion model. A copy of an incomplete form is presented in Appendix B.

Returns were received from the following operators:

- Ineos KG;
- Ineos Ethane;
- Ineos Ethanol;
- Ineos Offsite;
- Ineos Polymers;
- Ineos FPS; and
- PetroIneos.

4.2 Air Quality Dispersion Model

In common with previous assessments of this area, this investigation has been undertaken using Cambridge Environmental Research Consultants (CERC) Atmospheric Dispersion Modelling System (ADMS). The latest available version 6.01 was used.

The ADMS software is a gaussian plume dispersion modelling system that is accepted for use by the UK Government and Devolved Administrations as suitable and fit for purpose. The modelling system has been extensively validated for use in the UK.

4.3 Modelling Scenarios

Data provided by the Industrial Operations identified there are two operating modes normal flaring and peak short term flaring episodes. Therefore to reflect these different emission profiles different emission scenarios were considered.

Emissions information were supplied covering the Normal Operation of all point sources Ineos KG and Ineos FPS provided both normal flaring emissions data as well as peak flaring information. Ineos FPS were also able to advise that Train 1 flares and Flare 2 trains would not operate at the same time.

Therefore, to account for the combination of flare stack sources in operation at any one time along with the emissions during flaring three emissions profiles were developed:

- **Normal Operation Scenario**
  Annual SO_2 emissions were provided for all industrial sources. This scenario includes all sources with emissions from Flares under standby operation. Whilst this includes flare sources it does not

include any flaring operations. A summary of the emissions associated with this operating scenario is provided in Appendix A

- **Peak Operation Scenario A**
  This scenario includes all sources operating as per the Normal Operation scenario with the inclusion of emissions from Flares during a flaring episode. Specific to this scenario are the Ineos FPS Train 1 and 2 flares.
- **Peak Operation Scenario B**
  This scenario includes all sources operating as per the Normal Operation scenario with the inclusion of emissions from Flares during a flaring episode. Specific to this scenario are the Ineos FPS Train 3 flares.

In order to understand how these emissions may affect ground concentrations under all meteorological conditions. In the absence of time varying emissions data the model assumes these emissions are running continuously. In reality the flaring happens sporadically throughout the year so the meteorological conditions would vary. As meteorological conditions will have an impact on the plume dispersion it is therefore important to assess these emissions under all meteorological conditions.

Therefore, five years of meteorological data have been used for this assessment. Thereby predicting the worst-case concentrations for comparison with the 15-min mean, 1-hour mean and 24-hour mean SO_2 objectives.

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Future operation

As future Permit controls for example Emission Limit Values (ELVs) on site will not be increased and Best Available Technique (BAT) will continue to drive improvements on site, current emissions are considered worst case. Therefore, no future emissions profile has been assessed.

4.4 Terrain and Surface Roughness

Digital Terrain Model (DTM) data was obtained from the Scottish Remote Sensing Portal from the Phase 5 LiDAR data. Data for the model input was sampled from the DTM at a varying resolution as shown in Figure 4.1.

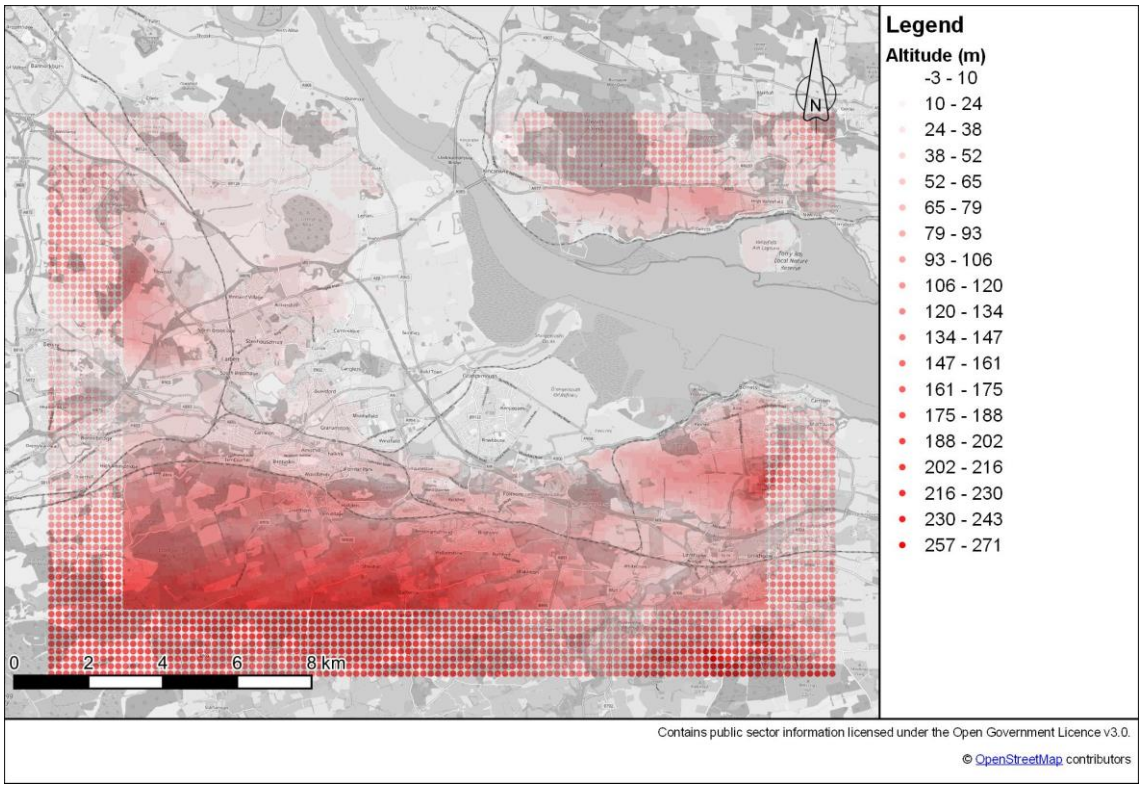


Figure 4.1 Variable Terrain

Surface roughness data was derived from the following datasets:

- Ordnance Survey (OS) Openmap Local (Surface water, tidal water and woodland datasets);
- OS Open Greenspace;
- OS Open Built-up Areas; and
- Scottish Government Settlements 2020 Boundaries.

The following roughness values were ascribed:

- 0.0001 - Open water;
- 0.02 - Green space and amenity grasslands;
- 0.03 - Surrounding arable and livestock fields;
- 0.5 – Suburban areas; and
- 1 – Urban areas and woodland.

The geographical assignment of surface roughness is shown in Figure 4.2 and was sampled at the same varying resolution as for the terrain data.

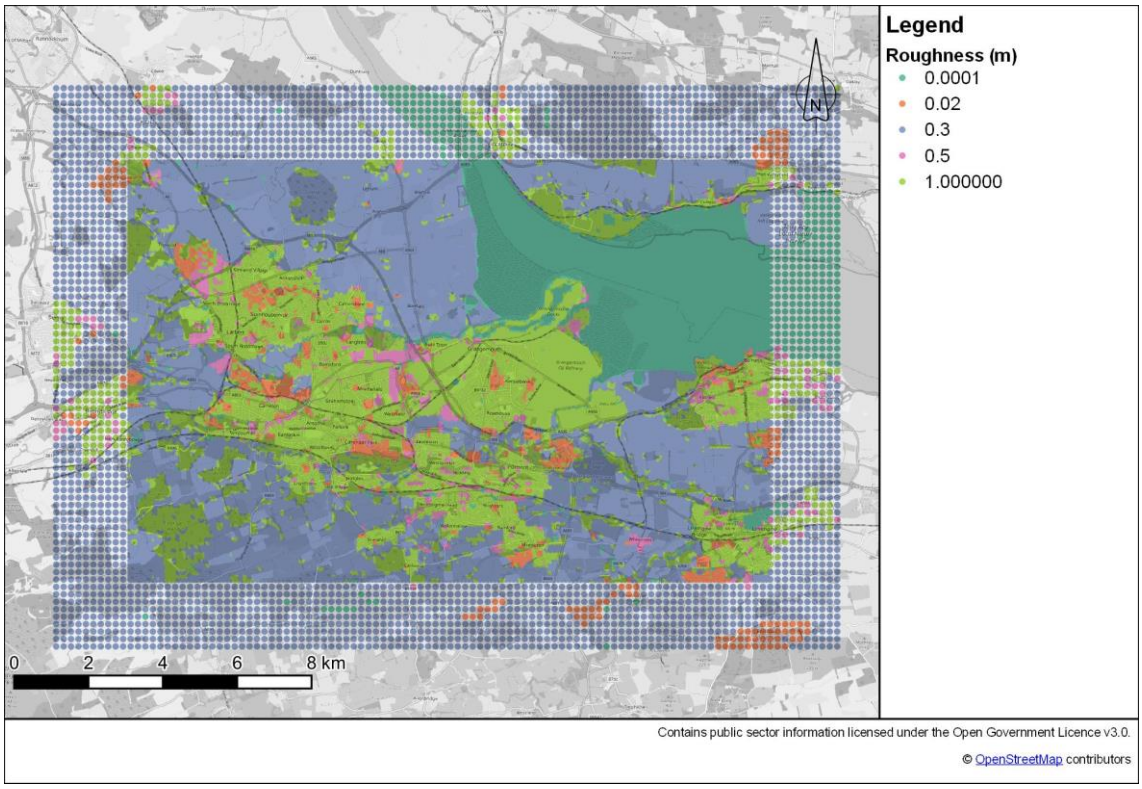


Figure 4.2 Variable Surface Roughness

4.5 Meteorological datasets

Meteorological datasets from Edinburgh Gogarbank have been used for this study in common with previous studies of Grangemouth emissions. To ensure the study considers all possible metrological conditions, datasets from the years from 2015 to 2019 have been used in order to identify the worst-case potential predicted concentrations based on meteorological variation. This will provide reassurance of future compliance too.

Annual wind roses are shown in Figure 4.3 and more detailed monthly wind roses are shown in Appendix D. The wind roses for each of the five years of data shown in Figure 4.3 shows the prevailing winds originating from the south-west. This can also be seen in the monthly wind roses in Appendix D with the majority of months showing prevailing winds from the south-west.

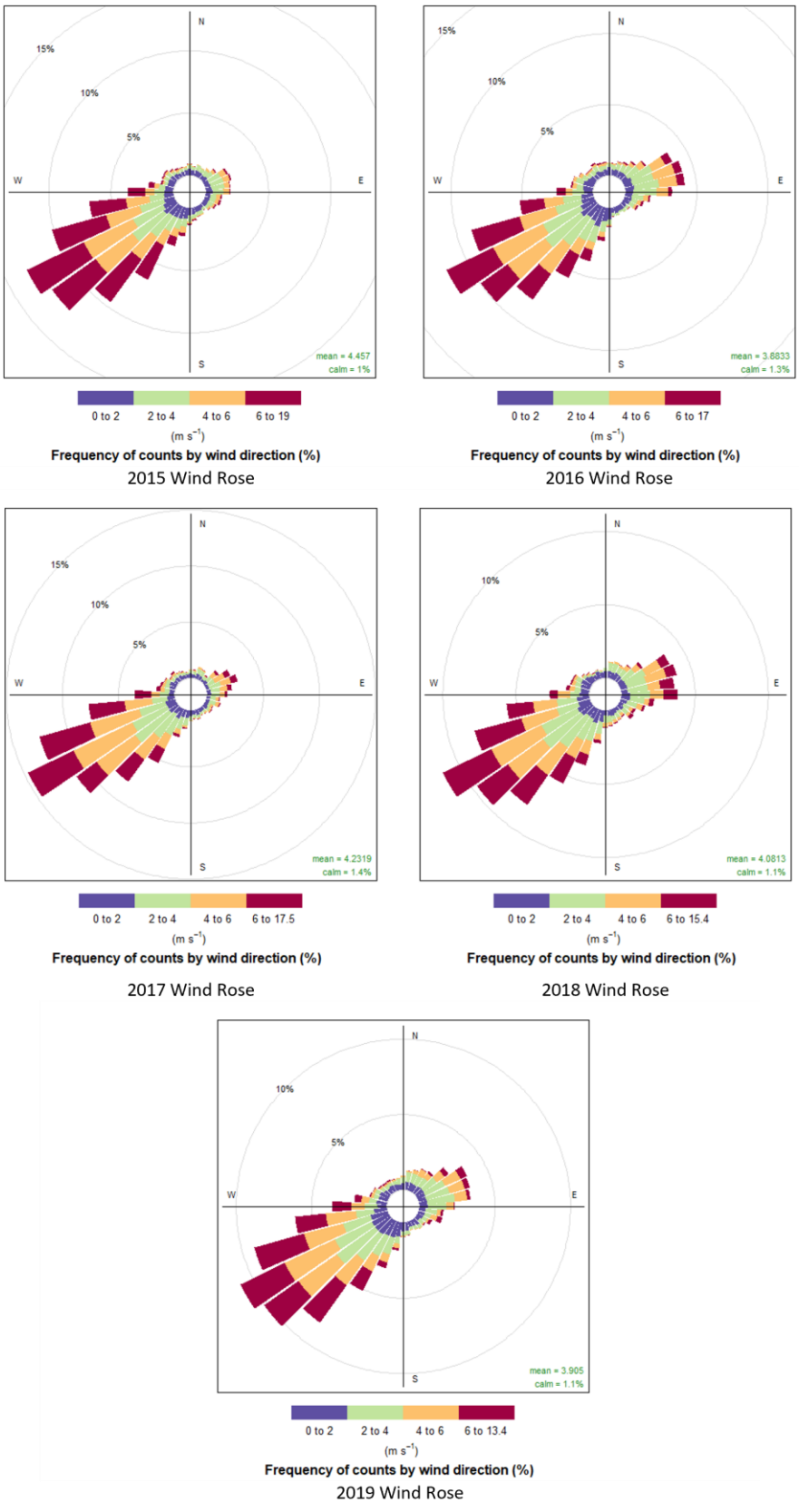


Figure 4.3 Annual Wind Roses for Edinburgh Gogarbank

4.6 Modelling Outputs

The AQMA has been declared for breach of the SO_2 15min mean. However in order to determine if the AQMA can be revoked or requires amended all short term SO_2 objectives have been considered in the Detailed Assessment. A summary of these is provided in Table 2.1.

The dispersion model can also provide an output as a percentile. Additional percentiles have been selected in order to represent peak concentrations in line with their respective short term mean objective.

. The selected outputs are shown in Table 4.1.

Table 4.1 ADMS Model Outputs

Pollutant	Averaging Period	Percentiles	SO_2 objective mean concentration (Number of permitted exceedances per annum)
SO_2	15-minute	100, 99.9	266 µg/m³ (35)
	1-hour	100, 99.73	350 µg/m³ (7)
	24-hour	100, 99.18	125 µg/m³ (3)

4.7 Source Apportionment

A study of the source apportionment was undertaken using the *Output per source* function in the ADMS software outputs to allow the pollutant contribution from different sources to be identified. This allows the contribution of all sources at every location to be expressed as a percentage of the total.

4.8 Receptors

4.8.1 Discrete Human Receptors

The discrete human receptors used for this study were those presented in the 2021 Grangemouth Emissions Study undertaken by Sweco. Their geographical distribution both within and out with the Grangemouth AQMA are considered representative for this study. Human receptor locations are shown in Table 4.2.

No designated nature conservation sites were included in this study as AQMA are declared for exceedances of human health-based objectives. In this case the AQMA is declared for exceedances of the 15-minute SO_2 objective which is not relevant to designated nature conservation sites.

Automatic monitoring locations were also used for this study and these are shown in Table 4.3 and Figure 3.1.

Table 4.2 Discrete Human Receptors

Receptor	X	Y	Height (m)	Description
Glensburgh Road 1	291071.6	682110.5	1.5	Residential
Glensburgh Road 2	291192.4	681964.7	1.5	Residential
21 Primrose Avenue	291750.7	680549.5	1.5	Residential
19 Chisholm Place	291814.9	680731.1	1.5	Residential
Beancross Road 1	292001.1	680485.2	1.5	Residential
Moriston Court 1	293188.4	679818.1	1.5	Residential
Moriston Court 2	293222.1	679852.5	1.5	Residential

Receptor	X	Y	Height (m)	Description
Fintry Road 1	293279.7	679910.8	1.5	Residential
Grangemouth Road 1	297363.1	680356.8	1.5	Residential
Bo'ness Road 1	294042.3	681455.6	1.5	Residential
Bo'ness Road 2	293755	681567.9	1.5	Residential
Bo'ness Road 3	293587.6	681732.1	1.5	Residential
103Bo'ness Road	293260.9	681895.7	1.5	Residential
Forestwood Earls Rd	292062.4	681729.9	1.5	Residential
Eastcroft Drive 1	294237.7	678785.9	1.5	Residential
Parkside Main Street	294049.8	678746.9	1.5	Residential
Burnbrae Main Street	293791.5	678792	1.5	Residential
Bennett Place 1	293468.7	678877.1	1.5	Residential
Weedingshall Lodge	292540.2	679028.3	1.5	Residential
20 Polmont Road	291512	679408.5	1.5	Residential
Mary Street 1	290988.2	679503	1.5	Residential
Mary Street 2	290949.7	679489.5	1.5	Residential
Grangemouth Road 2	290271.8	680504.3	1.5	Residential
28 Grangemouth Road	289714.1	680346.3	1.5	Residential
Ladysmill 1	289642.9	680256.1	1.5	Residential
Inchyra Grange Hotel	293510	679680	1.5	-
West Beancross Farm	292450	679750	1.5	Residential
Docks West	295160	683700	1.5	-
Docks East	295160	683710	1.5	-
Wholeflats	294210	680070	1.5	-
Oil refinery	294360	681820	1.5	-
Grangemouth Stadium	293628	680508	1.5	-
Sports Complex	292826	681146	1.5	-
Beancross Primary	292480	680510	1.5	School
Bowhouse Primary	293350	680450	1.5	School
Sacred Heart Primary	293120	680630	1.5	School
Zetland Pavilion	292950	681530	1.5	-
Roxburgh St	293520	682010	1.5	Residential
Bo'ness road	294040	681470	1.5	Residential
Albert Avenue	293874	681941	1.5	Residential
Grangemouth High	293198	680312	1.5	School
Grangeburn Road	293430	682055	1.5	Residential

Receptor	X	Y	Height (m)	Description
Elizabeth Avenue	293417	681507	1.5	Residential
Cheviot Place	293381	680232	1.5	Residential
Burnbank Road	292638	680511	1.5	Residential
The Inches	286165	684008	1.5	-
Merrick Road 1	293662.69	680321.31	1.5	Residential
Reddoch Road	294353.5	679776	1.5	Residential
Falkirk Stadium	290739.59	680577.81	1.5	-
Old Town 1	291507.6	682037.6	1.5	Residential
Old Town 2	291267.9	681939.1	1.5	Residential
Wood St 1	292055	680935.6	1.5	Residential
Wood St 2	291989.2	680880	1.5	Residential

Table 4.3 Automatic Monitor Receptors

Receptor	X	Y	Height (m)	Description
Inchyra AQU	293835	681020	1.5	Monitoring site
Moray AQU	293469	681321	1.5	Monitoring site
GMC AQU	292818	682008	1.5	Monitoring site

4.8.2 Modelling Domain

The modelling domain was set up in the ADMS software with the parameters shown in Table 4.4. The modelling domain was set large enough to encompass the whole of the Grangemouth AQMA and include the Falkirk AQMA. This ensures that the study area is wide enough to determine whether the AQMA needs amended or can be revoked.

Table 4.4 Modelling Domain Parameters

Parameter	Minimum (m)	Maximum (m)	Number of points
X	288000	300000	601
Y	677000	684500	376
Z	1.5	-	1

4.9 Limitations

The following modelling limitations apply to this modelling study:

- Emission rates included in the model are based on the information supplied by the operators at the Grangemouth facilities. These are annual emissions only.
- Time-varying emission data were not provided for any sources therefore there may be periods during normal operation when emissions are greater or less than these emissions.

- Building downwash can be a key consideration in modelling point sources. However as it's not possible to include all buildings and structures explicitly, the study has used a higher surface roughness to represent an urban environment within the Industrial area and a variable surface roughness across the wider study area. This is in line with previous Falkirk Council studies and sensitivity tests that have been undertaken in the past.

5 Modelling Results

This section details the results of the dispersion modelling for SO_2.

The Process Contribution (PC) is the contribution due to the emissions sources in isolation.

The Predicted Environmental Concentration (PEC) is inclusive of the five-year SO_2 annual average concentration of 1.4 ug/m^3. For the purposes of comparison with short-term objectives the short-term background is 2x the long-term background resulting in a background of 2.8 µg/m^3. The background has been treated according to the guidance in Box 7-16 of LAQM.TG (22).

5.1 Discrete Human Receptors

The results for the modelling of SO_2 dispersion at discrete human receptors are presented in this section. The 10 receptors with the highest number of exceedances for each of the five years modelled are provided.

5.1.1 15-minute mean Objective

5.1.1.1 Normal Operation

The model considered 5 years of met conditions with the Normal Operation scenario in order to consider the worst-case impacts under this scenario.

The modelling results are presented in Table 5.1 to Table 5.3 and Figure 5.1 to Figure 5.3 below,

The modelling results presented in Table 2.1 indicate that there are no 99th percentile values greater than 266 µg/m^3 , therefore indicating that there would not be a breach of the 15-minute mean objective at any location under Normal Operation. The modelled results for the comparison with the 99th percentile are also provided in Figure 5.1

The modelling results presented in Table 5,2 indicate that there is the potential for an exceedance of the !5minute mean objective, 266 µg.m^3 objective an at Wholeflats, the oil refinery, Bo'ness Road and the Inchyra AQU. Whilst the Wholeflats receptor is modelled as representative of human exposure, the site is currently unoccupied and the oil refinery receptor is located within the Grangemouth industrial facilities.

.Provided in Figure 5.2 is a contour plot for the number of exceedances of the 15-minute mean objective, with the number of exceedances at each receptor also shown in Figure 5.3.

The number of potential exceedances of the 15-minute mean objective at each of the specified receptors is presented in Table 5.3 and Figure 5.3.

Overall the modelling results for the Normal Operation scenario indicate that under certain meteorological conditions there could be potential exceedances of the 15-mean objective. However, the number would be much lower than the permitted 35 exceedances per annum. Therefore under this operating scenario there is no risk of a breach of the 15-min mean objective.

5.1.1.2 Peak A and Peak B Operation

The number of predicted exceedances of the 15-minute mean objective under the Peak Operation scenarios are shown in Table 5.4 and Figure 5.4, and Table 5.7 and Figure 5.7. These exceedances are concentrated around the area of the Grangemouth industrial facilities. As shown in Table 5.6 and Figure 5.6, and Table 5.9 and Figure 5.9 there are a number of locations where a exceedance of the 15-minute mean is predicted, however there are no breaches of the objective. Many are located around the Grangemouth Industrial facilities. There are predicted exceedances of the 15-minute mean objective at all of the top ten highest

receptor locations provided in Table 5.5 and Table 5.8, with the worst-case predictions for the 100th percentile provided on Figure 5.5 and Figure 5.8.

However it is worth noting that under these emissions profiles the model assumes constant flaring where in reality flaring episodes are sporadic, and their duration is unpredictable. Therefore, while exceedances are predicted these are based on 8760 hours of flaring. In reality the numbers of hours when flaring occurs will be significantly lower thus resulting in fewer exceedances. These results do indicate that under certain meteorological conditions flaring will result in an exceedance.

Table 5.1 Top 10 SO_2 Predictions – Normal Operation, 15-minute, 99.9th percentile

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor
1	108.0	110.8	Bo'ness Road 1	97.0	99.9	Bo'ness Road 1	95.7	98.5	Oil refinery	96.7	99.5	Wholeflats	102.0	104.8	Oil refinery
2	106.7	109.5	Oil refinery	94.1	96.9	Bo`ness road	86.8	89.6	Reddoch Road	87.2	90.0	Bo'ness Road 1	93.5	96.3	Bo`ness road
3	104.7	107.5	Bo`ness road	89.7	92.5	Oil refinery	85.9	88.7	Inchyra AQU	87.2	90.0	Oil refinery	87.6	90.4	Bo'ness Road 1
4	90.2	93.0	Inchyra AQU	82.5	85.4	Inchyra AQU	80.8	83.6	Bo'ness Road 1	86.2	89.0	Inchyra AQU	81.8	84.6	Inchyra AQU
5	86.6	89.4	Bo'ness Road 2	76.5	79.3	Moray AQU	79.8	82.6	Bo`ness road	85.8	88.7	Bo`ness road	80.9	83.7	Reddoch Road
6	75.8	78.6	Moray AQU	73.7	76.6	Bo'ness Road 2	73.9	76.7	Wholeflats	77.0	79.8	Sacred Heart Primary	70.6	73.5	Albert Avenue
7	74.9	77.7	Sports Complex	69.0	71.8	Docks West	65.7	68.5	Docks West	72.4	75.2	Docks East	68.1	71.0	Bo'ness Road 2
8	72.8	75.6	Wholeflats	67.6	70.4	Docks East	65.1	67.9	Albert Avenue	70.9	73.8	Docks West	65.0	67.8	Moray AQU
9	72.4	75.2	Docks East	63.5	66.3	Elizabeth Avenue	61.4	64.3	Bo'ness Road 2	70.2	73.0	Bo'ness Road 2	65.0	67.8	Grangemouth Stadium
10	72.3	75.1	Elizabeth Avenue	63.3	66.2	Reddoch Road	60.3	63.1	Grangemouth Road 1	65.4	68.2	Grangemouth Stadium	63.0	65.8	Wholeflats

Figure 5.1 Predictions for SO2, 15-minute, 99.9th Percentile, Normal Operation

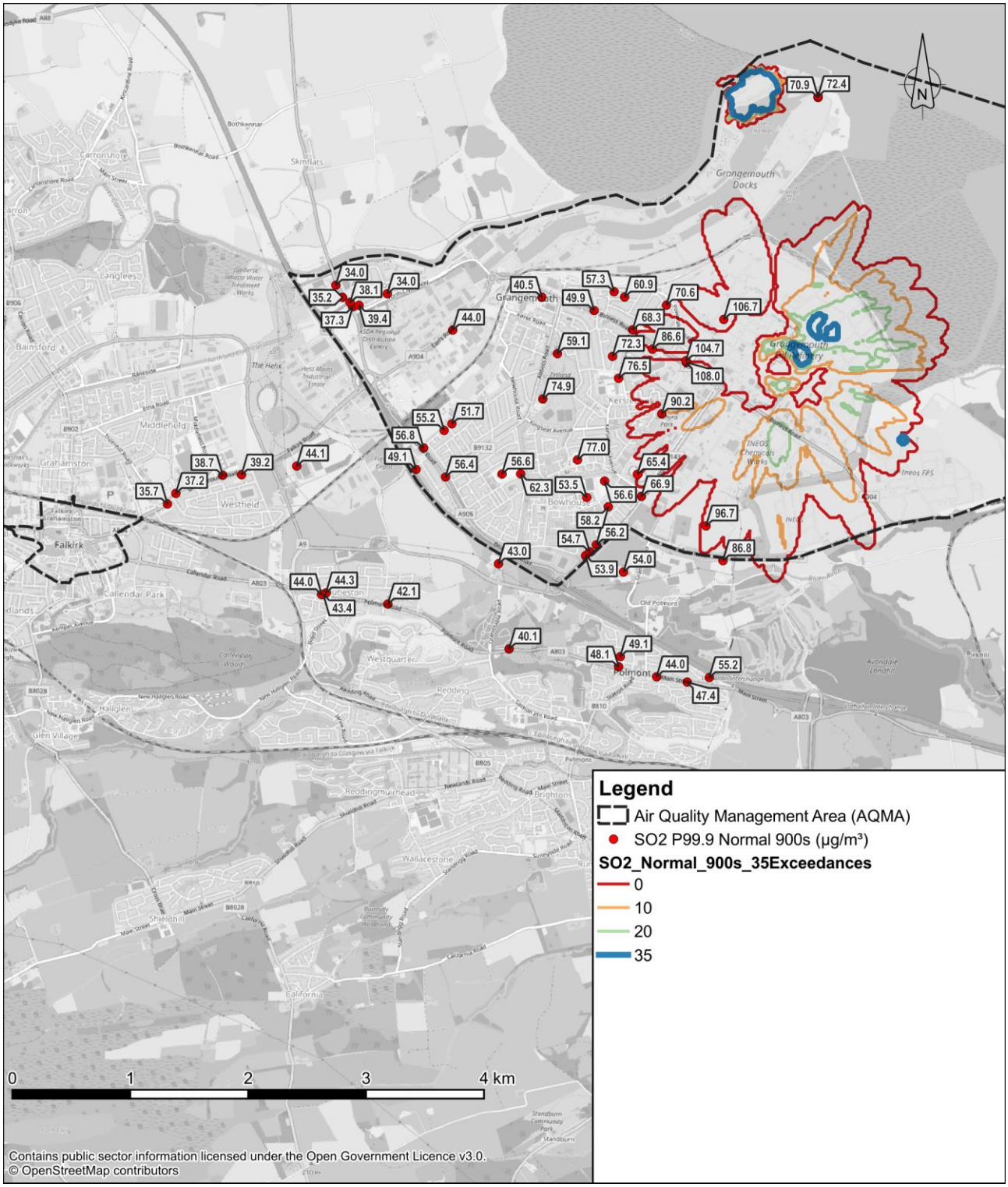


Table 5.2 Top 10 SO_2 Predictions – Normal Operation, 15-minute, 100th percentile.

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor
1	240.7	243.5	Elizabeth Avenue	268.9	271.7	Inchyra AQU	312.5	315.3	Oil refinery	266.4	269.2	Wholeflats	292.6	295.4	Inchyra AQU
2	235.6	238.4	Bo'ness Road 3	251.4	254.2	Grangemouth Stadium	286.8	289.7	Inchyra AQU	249.6	252.4	Bo`ness road	284.2	287.0	Wholeflats
3	229.4	232.2	Albert Avenue	247.9	250.7	Albert Avenue	250.3	253.1	Bo'ness Road 3	245.2	248.0	Bo'ness Road 1	274.5	277.3	Bo'ness Road 1
4	228.5	231.3	Inchyra AQU	233.6	236.5	Merrick Road 1	236.7	239.5	Bo'ness Road 2	233.7	236.5	Bowhouse Primary	257.1	259.9	Bo'ness Road 2
5	223.9	226.7	Bo'ness Road 1	233.0	235.9	Cheviot Place	235.6	238.5	Reddoch Road	224.5	227.4	Bo'ness Road 2	256.2	259.0	Bo`ness road
6	217.7	220.5	Bo`ness road	226.5	229.3	Bo'ness Road 1	208.6	211.4	Albert Avenue	208.7	211.5	Grangemouth High	254.9	257.7	Bo'ness Road 3
7	216.5	219.3	Sacred Heart Primary	225.4	228.2	Bo`ness road	200.2	203.0	Wholeflats	203.6	206.4	Reddoch Road	220.3	223.2	Moray AQU
8	214.2	217.0	Moray AQU	216.2	219.0	Sacred Heart Primary	193.8	196.6	103 Bo'ness Road	198.9	201.7	Grangemouth Stadium	218.3	221.2	Roxburgh St
9	203.8	206.6	Grangemouth Stadium	195.9	198.7	Elizabeth Avenue	181.0	183.8	Sacred Heart Primary	197.9	200.7	Inchyra Grange Hotel	209.1	211.9	Albert Avenue
10	201.9	204.7	Bo'ness Road 2	195.0	197.8	Reddoch Road	168.9	171.7	Bo`ness road	197.1	200.0	Oil refinery	208.4	211.2	103 Bo'ness Road

Figure 5.2 Predictions for SO2, 15-minute, 100th Percentile, Normal Operation

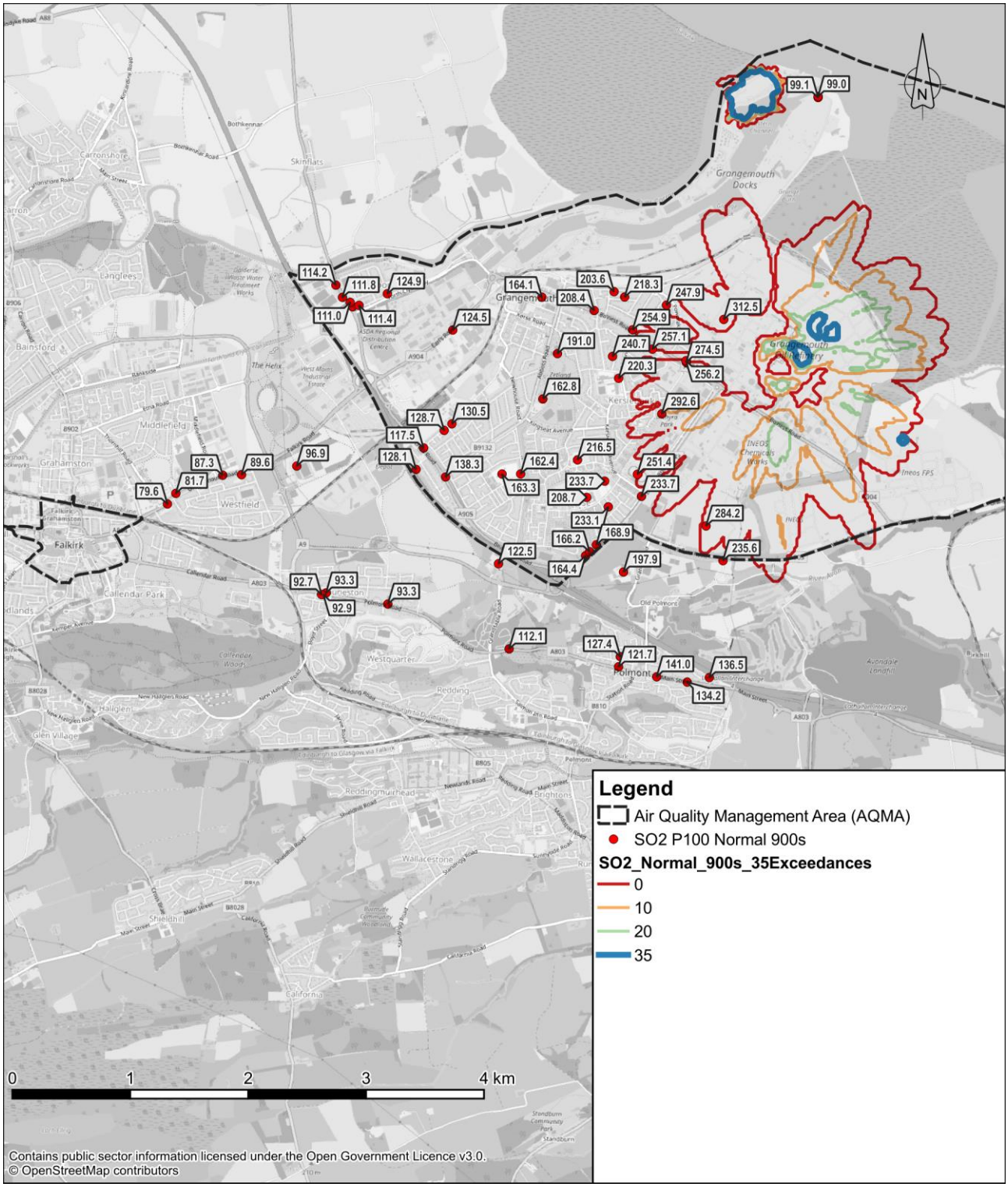


Table 5.3 Top 10 SO_2 Exceedances – Normal Operation, 15-minute

Rank	2015		2016		2017		2018		2019	
	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor
1	0	NA21	4	Inchyra AQU	9	Inchyra AQU	5	Wholeflats	8	Inchyra AQU
2	0	NA51	0	NA21	4	Oil refinery	0	NA21	4	Bo'ness Road 1
3	0	NA94	0	NA51	0	NA21	0	NA51	4	Wholeflats
4	0	NA101	0	NA94	0	NA51	0	NA94	0	NA21
5	0	Glensburgh Road 1	0	NA101	0	NA94	0	NA101	0	NA51
6	0	Glensburgh Road 2	0	Glensburgh Road 1	0	NA101	0	Glensburgh Road 1	0	NA94
7	0	21 Primrose Avenue	0	Glensburgh Road 2	0	Glensburgh Road 1	0	Glensburgh Road 2	0	NA101
8	0	19 Chisholm Place	0	21 Primrose Avenue	0	Glensburgh Road 2	0	21 Primrose Avenue	0	Glensburgh Road 1
9	0	Beancross Road 1	0	19 Chisholm Place	0	21 Primrose Avenue	0	19 Chisholm Place	0	Glensburgh Road 2
10	0	Moriston Court 1	0	Beancross Road 1	0	19 Chisholm Place	0	Beancross Road 1	0	21 Primrose Avenue

Figure 5.3 Predictions for SO2, 15-minute Exceedances, Normal Operation

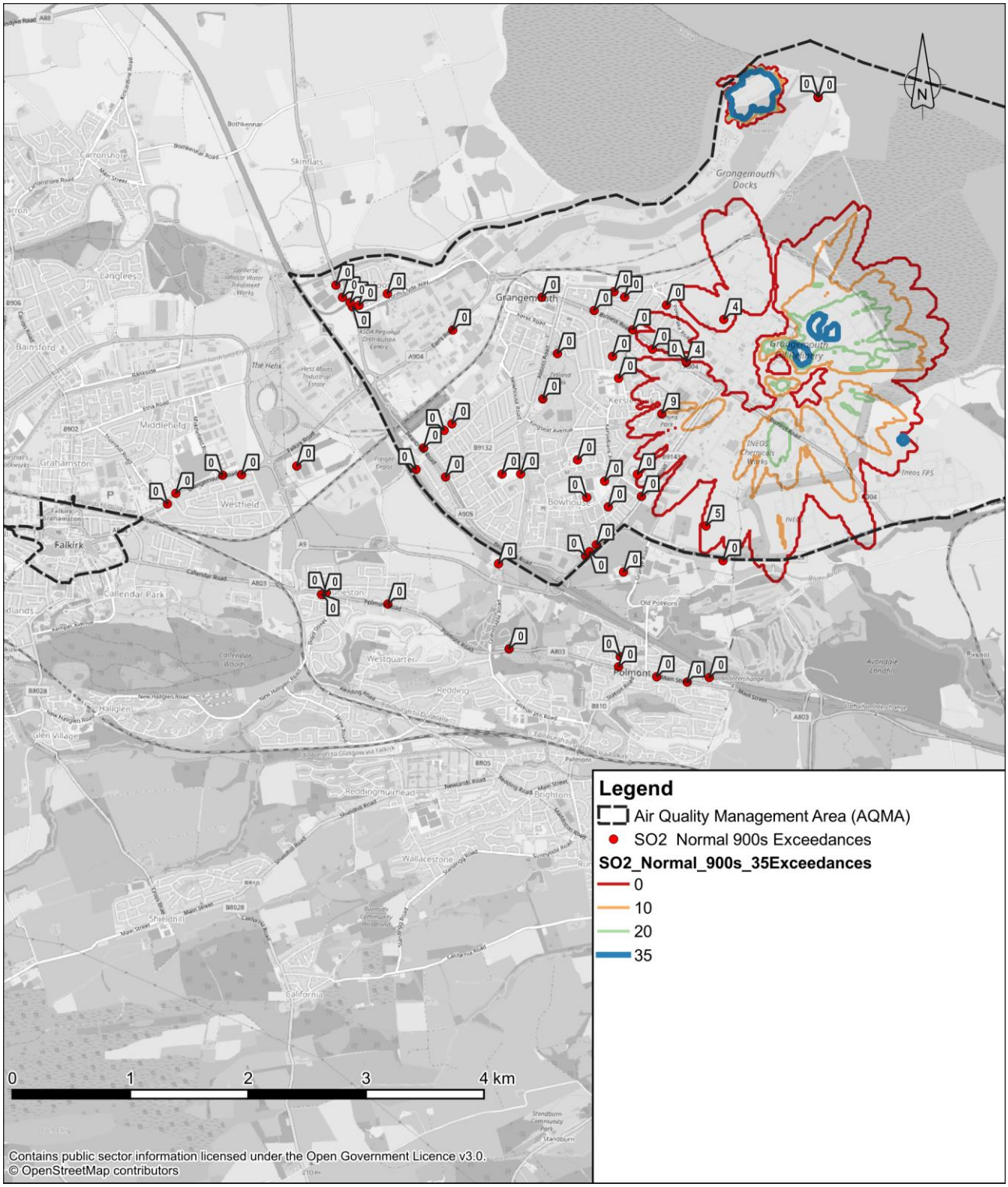


Table 5.4 Top 10 SO_2 Predictions – Peak A Operation, 15-minute, 99.9th percentile.

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor
1	238.9	241.7	Oil refinery	217.6	220.4	Bo'ness Road 1	222.8	225.6	Oil refinery	211.1	214.0	Wholeflats	217.9	220.8	Oil refinery
2	232.6	235.4	Bo'ness Road 1	211.2	214.0	Bo`ness road	191.3	194.2	Inchyra AQU	189.3	192.1	Bo`ness road	197.4	200.2	Bo`ness road
3	221.1	223.9	Bo`ness road	195.0	197.8	Oil refinery	189.2	192.0	Reddoch Road	188.2	191.0	Bo'ness Road 1	194.8	197.6	Bo'ness Road 1
4	191.4	194.2	Inchyra AQU	183.9	186.7	Inchyra AQU	178.3	181.1	Bo'ness Road 1	179.2	182.0	Inchyra AQU	178.9	181.7	Inchyra AQU
5	190.6	193.5	Bo'ness Road 2	167.7	170.5	Moray AQU	170.3	173.1	Bo`ness road	178.1	180.9	Oil refinery	176.0	178.8	Reddoch Road
6	165.0	167.9	Moray AQU	147.6	150.4	Bo'ness Road 2	161.8	164.6	Wholeflats	162.9	165.7	Sacred Heart Primary	153.4	156.2	Bo'ness Road 2
7	160.2	163.0	Wholeflats	140.4	143.2	Elizabeth Avenue	147.2	150.0	Albert Avenue	150.6	153.4	Bo'ness Road 2	151.4	154.2	Albert Avenue
8	156.4	159.2	Sports Complex	138.6	141.4	Reddoch Road	133.9	136.7	Bo'ness Road 2	144.5	147.3	Merrick Road 1	140.0	142.8	Grangemouth Stadium
9	153.9	156.7	Grangemouth Road 1	131.0	133.8	Docks East	129.7	132.5	Grangemouth Road 1	140.5	143.3	Grangemouth Stadium	138.5	141.4	Moray AQU
10	152.4	155.3	Reddoch Road	130.5	133.3	Bo'ness Road 3	126.3	129.1	Moray AQU	140.3	143.1	Docks West	137.1	139.9	Wholeflats

Figure 5.4 Predictions for SO2, 15-minute, 99.9th Percentile, Peak A Operation

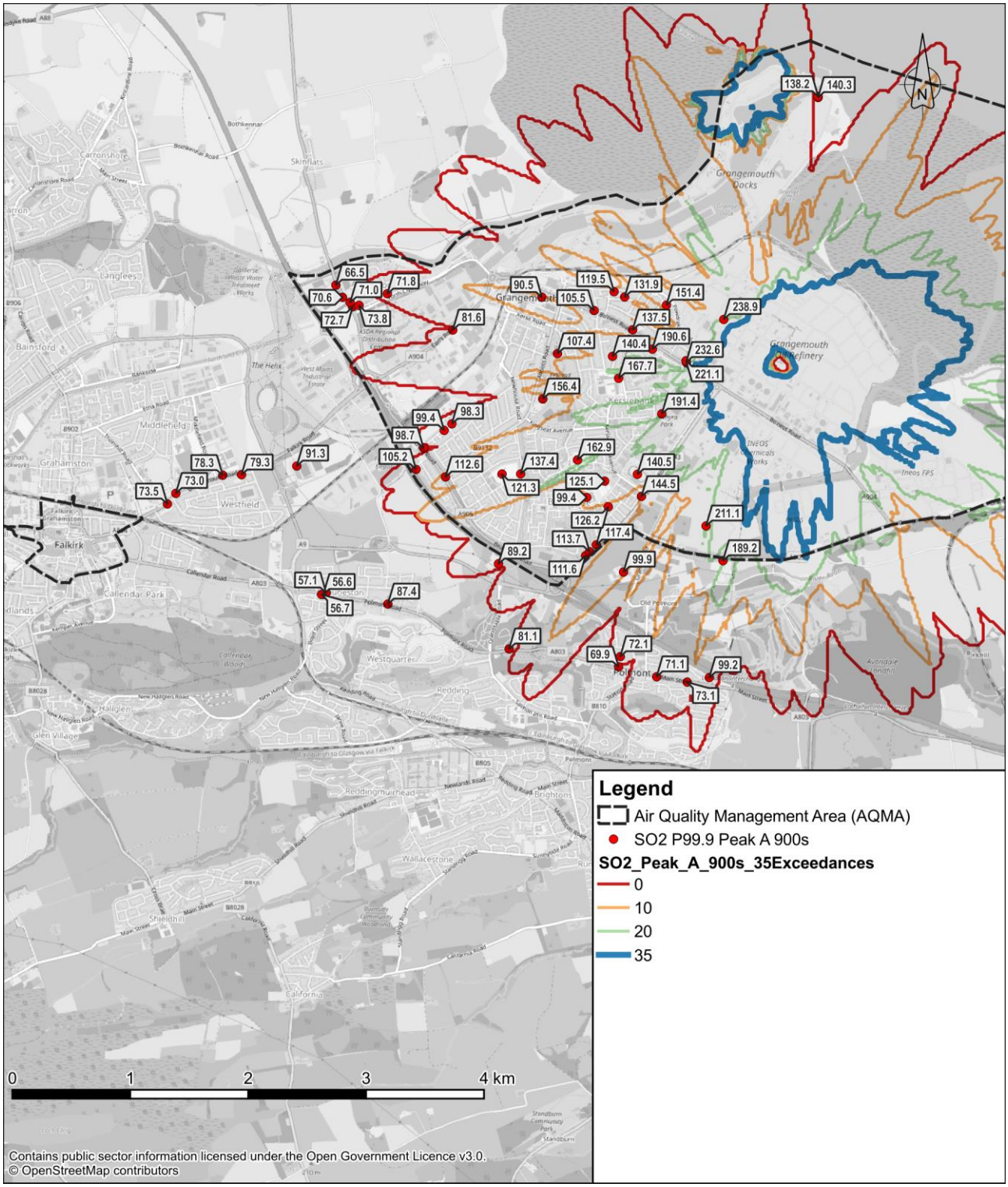


Table 5.5 Top 10 SO_2 Predictions – Peak A Operation, 15-minute, 100th Percentile.

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor
1	541.1	543.9	Bo'ness Road 3	600.2	603.0	Inchyra AQU	706.8	709.6	Oil refinery	594.8	597.6	Wholeflats	649.2	652.0	Inchyra AQU
2	539.5	542.3	Elizabeth Avenue	560.0	562.8	Grangemouth Stadium	654.3	657.1	Inchyra AQU	564.8	567.6	Bo`ness road	640.7	643.5	Wholeflats
3	520.9	523.7	Albert Avenue	551.6	554.4	Albert Avenue	561.1	563.9	Bo'ness Road 3	553.8	556.6	Bo'ness Road 1	628.0	630.8	Bo'ness Road 1
4	502.6	505.4	Inchyra AQU	542.7	545.5	Merrick Road 1	532.5	535.4	Reddoch Road	534.6	537.4	Bowhouse Primary	586.1	588.9	Bo`ness road
5	501.8	504.6	Bo'ness Road 1	529.8	532.6	Cheviot Place	532.1	534.9	Bo'ness Road 2	507.0	509.8	Bo'ness Road 2	577.2	580.0	Bo'ness Road 2
6	489.8	492.6	Sacred Heart Primary	510.9	513.8	Bo'ness Road 1	461.0	463.8	Albert Avenue	480.3	483.1	Grangemouth High	568.1	571.0	Bo'ness Road 3
7	489.4	492.2	Bo`ness road	508.4	511.2	Bo`ness road	438.8	441.6	Wholeflats	469.8	472.7	Reddoch Road	484.6	487.4	Moray AQU
8	484.4	487.2	Moray AQU	489.7	492.5	Sacred Heart Primary	425.1	427.9	103 Bo'ness Road	464.4	467.2	Grangemouth Stadium	477.1	480.0	Roxburgh St
9	451.5	454.4	Grangemouth Stadium	447.2	450.0	Reddoch Road	413.5	416.3	Sacred Heart Primary	445.2	448.0	Inchyra Grange Hotel	463.5	466.3	103 Bo'ness Road
10	445.0	447.9	Bo'ness Road 2	442.9	445.7	Elizabeth Avenue	364.0	366.8	Burnbank Road	442.5	445.3	Oil refinery	449.2	452.0	Sacred Heart Primary

Figure 5.5 Predictions for SO2, 15-minute, 100th Percentile, Peak A Operation

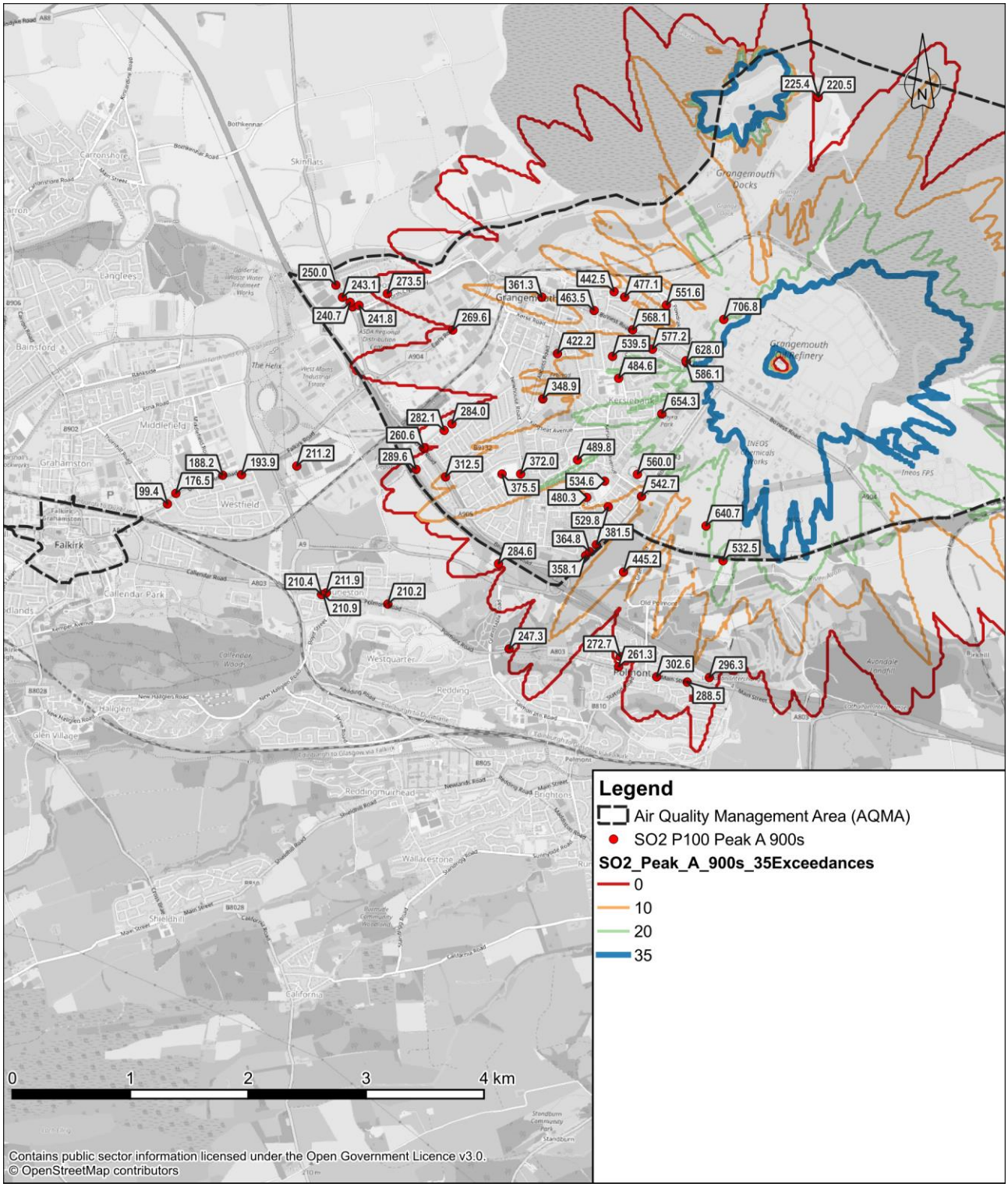


Table 5.6 Top 10 SO_2 Exceedances – Peak A Operation, 15-minute.

Rank	2015		2016		2017		2018		2019	
	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor
1	23	Inchyra AQU	21	Bo'ness Road 1	22	Oil refinery	15	Wholeflats	16	Inchyra AQU
2	18	Bo'ness Road 2	21	Bo`ness road	17	Inchyra AQU	15	Grangemouth Stadium	16	Sacred Heart Primary
3	18	Moray AQU	17	Inchyra AQU	17	Wholeflats	15	Beancross Primary	12	Bo'ness Road 1
4	18	Wholeflats	17	Beancross Primary	17	Sacred Heart Primary	15	Sacred Heart Primary	12	Bo'ness Road 2
5	14	Bo'ness Road 1	13	Beancross Road 1	17	Burnbank Road	15	Burnbank Road	12	GMC AQU
6	14	Grangemouth Stadium	13	Bo'ness Road 2	17	Reddoch Road	15	Reddoch Road	12	Wholeflats
7	14	Bowhouse Primary	13	Moray AQU	13	Beancross Primary	10	Inchyra Grange Hotel	12	Oil refinery
8	14	Bo`ness road	13	Wholeflats	9	Grangemouth Road 1	10	Bowhouse Primary	12	Grangemouth Stadium
9	14	Elizabeth Avenue	13	Oil refinery	9	Sports Complex	10	Albert Avenue	12	Bo`ness road
10	9	103 Bo'ness Road	13	Sacred Heart Primary	4	Bo'ness Road 1	10	Grangemouth High	12	Reddoch Road

Figure 5.6 Predictions for SO2, 15-minute Exceedances, Peak A Operation

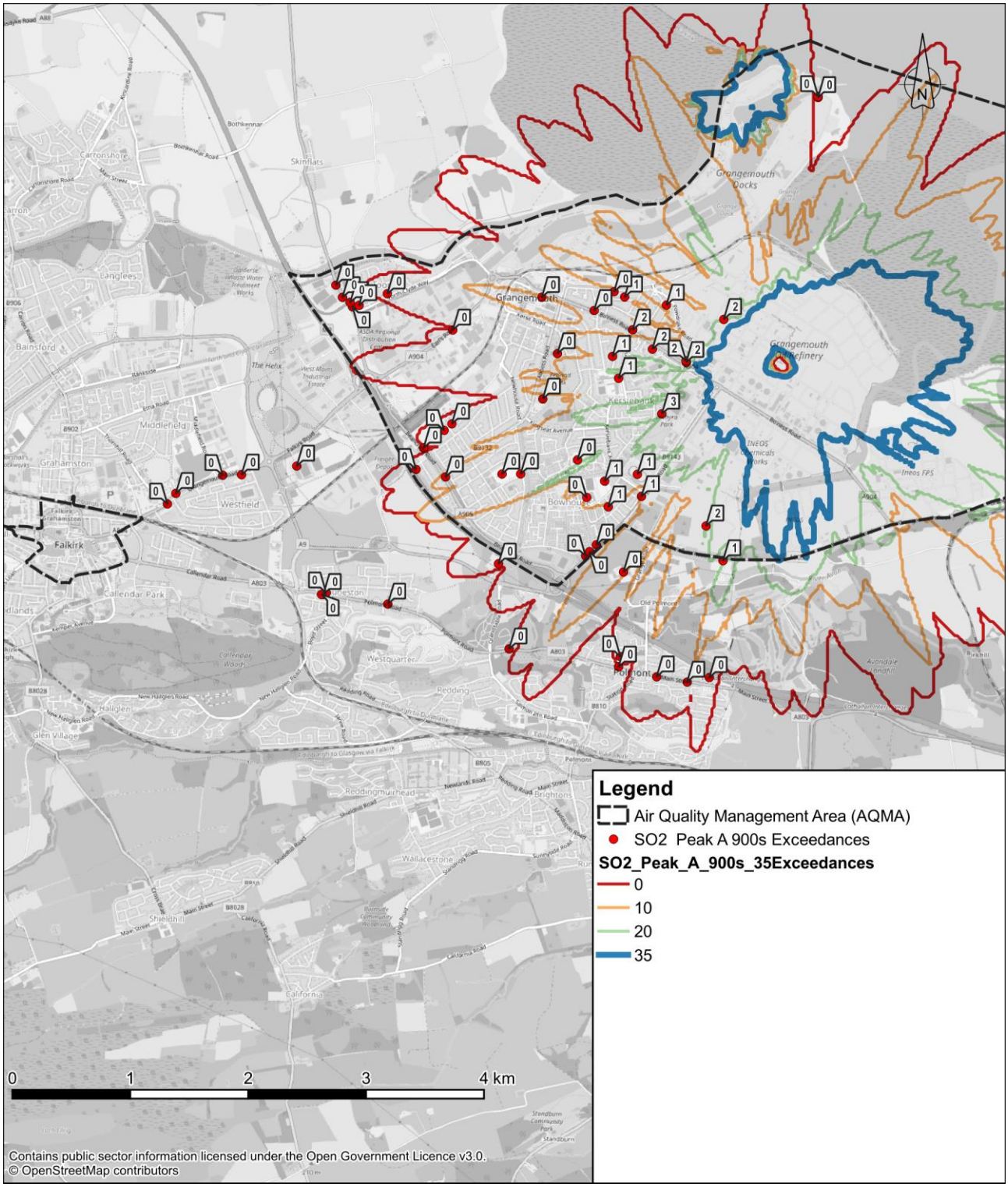


Table 5.7 Top 10 SO_2 Predictions – Peak B Operation, 15-minute, 99.9th percentile

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor
1	238.2	241.0	Oil refinery	217.3	220.1	Bo'ness Road 1	222.4	225.2	Oil refinery	211.1	214.0	Wholeflats	217.0	219.8	Oil refinery
2	232.5	235.3	Bo'ness Road 1	211.1	213.9	Bo`ness road	191.3	194.2	Inchyra AQU	188.5	191.3	Bo`ness road	197.3	200.1	Bo`ness road
3	221.0	223.8	Bo`ness road	194.6	197.4	Oil refinery	189.2	192.0	Reddoch Road	188.1	190.9	Bo'ness Road 1	194.7	197.5	Bo'ness Road 1
4	191.4	194.2	Inchyra AQU	183.9	186.7	Inchyra AQU	177.9	180.7	Bo'ness Road 1	179.2	182.0	Inchyra AQU	178.9	181.7	Inchyra AQU
5	189.5	192.3	Bo'ness Road 2	167.6	170.4	Moray AQU	170.2	173.0	Bo`ness road	177.6	180.4	Oil refinery	176.0	178.8	Reddoch Road
6	164.7	167.5	Moray AQU	147.5	150.3	Bo'ness Road 2	161.8	164.6	Wholeflats	162.9	165.7	Sacred Heart Primary	153.1	155.9	Bo'ness Road 2
7	160.2	163.0	Wholeflats	140.0	142.8	Elizabeth Avenue	146.2	149.0	Albert Avenue	150.4	153.2	Bo'ness Road 2	150.9	153.7	Albert Avenue
8	156.3	159.1	Sports Complex	138.6	141.4	Reddoch Road	133.6	136.4	Bo'ness Road 2	144.4	147.2	Merrick Road 1	139.9	142.7	Grangemouth Stadium
9	152.5	155.3	Reddoch Road	131.0	133.8	Docks East	127.0	129.8	Grangemouth Road 1	140.5	143.3	Grangemouth Stadium	138.5	141.3	Moray AQU
10	150.1	152.9	Grangemouth Road 1	130.3	133.1	Wholeflats	126.1	128.9	Moray AQU	140.3	143.1	Docks West	137.1	139.9	Wholeflats

Figure 5.7 Predictions for SO2, 15-minute, 99.9th Percentile, Peak B Operation

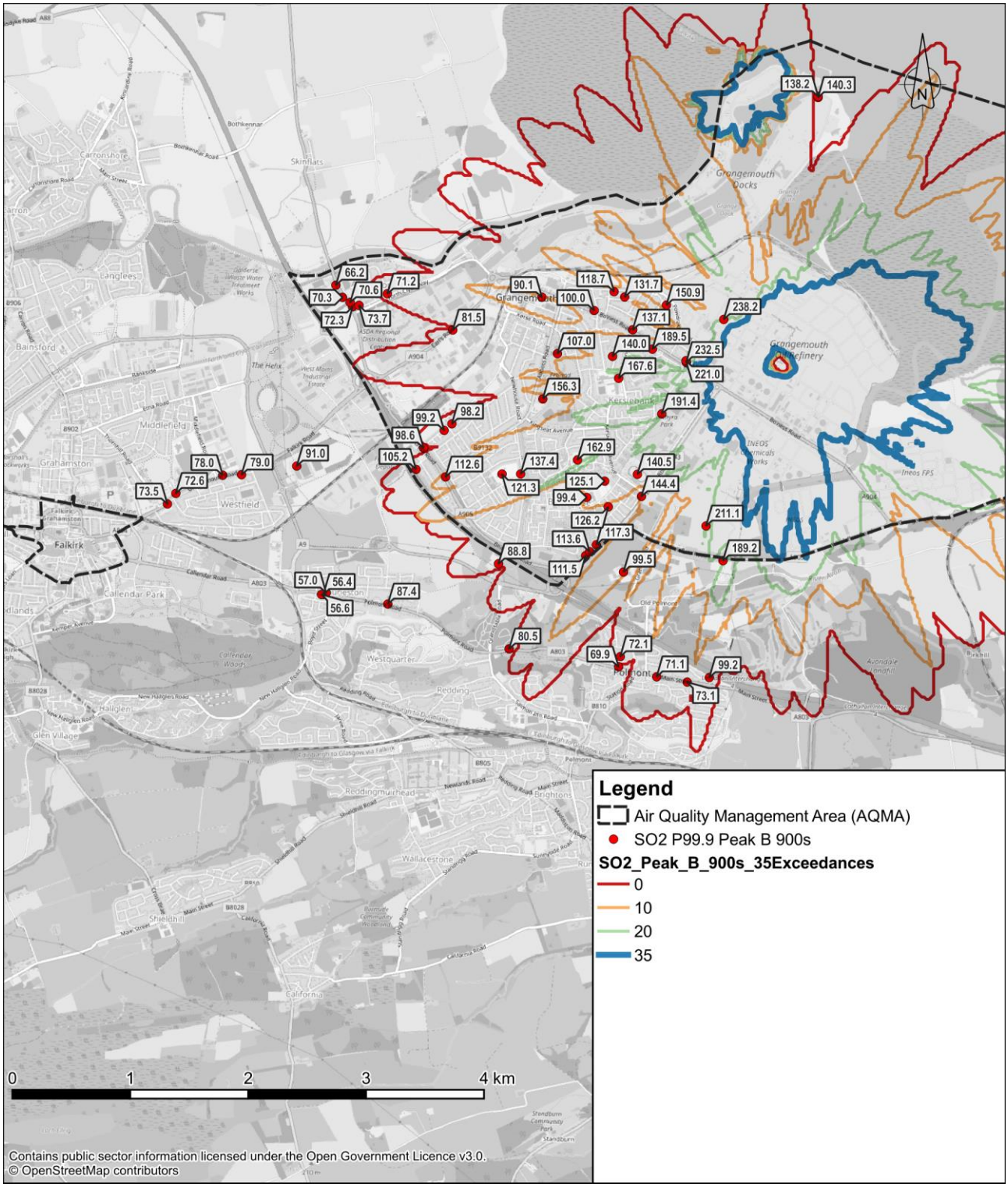


Table 5.8 Top 10 SO_2 Predictions – Peak B Operation, 15-minute, 100th Percentile.

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor
1	539.7	542.5	Bo'ness Road 3	600.2	603.0	Inchyra AQU	703.8	706.6	Oil refinery	594.8	597.6	Wholeflats	649.2	652.0	Inchyra AQU
2	539.0	541.8	Elizabeth Avenue	560.0	562.8	Grangemouth Stadium	654.3	657.1	Inchyra AQU	563.5	566.4	Bo`ness road	640.7	643.5	Wholeflats
3	517.2	520.0	Albert Avenue	548.2	551.0	Albert Avenue	559.6	562.4	Bo'ness Road 3	552.5	555.3	Bo'ness Road 1	628.0	630.8	Bo'ness Road 1
4	502.6	505.4	Inchyra AQU	542.7	545.5	Merrick Road 1	532.5	535.4	Reddoch Road	534.6	537.4	Bowhouse Primary	586.0	588.9	Bo`ness road
5	501.5	504.4	Bo'ness Road 1	529.8	532.6	Cheviot Place	529.9	532.7	Bo'ness Road 2	506.0	508.8	Bo'ness Road 2	574.8	577.6	Bo'ness Road 2
6	489.8	492.6	Sacred Heart Primary	510.2	513.0	Bo'ness Road 1	459.5	462.3	Albert Avenue	480.3	483.1	Grangemouth High	566.5	569.3	Bo'ness Road 3
7	489.1	491.9	Bo`ness road	507.7	510.5	Bo`ness road	438.8	441.6	Wholeflats	469.8	472.7	Reddoch Road	484.3	487.1	Moray AQU
8	483.1	485.9	Moray AQU	489.7	492.5	Sacred Heart Primary	423.9	426.7	103 Bo'ness Road	464.4	467.2	Grangemouth Stadium	474.9	477.7	Roxburgh St
9	451.5	454.3	Grangemouth Stadium	447.2	450.0	Reddoch Road	413.3	416.2	Sacred Heart Primary	445.2	448.0	Inchyra Grange Hotel	460.5	463.3	103 Bo'ness Road
10	444.9	447.7	Bo'ness Road 2	442.8	445.6	Elizabeth Avenue	364.0	366.8	Burnbank Road	439.7	442.5	Oil refinery	449.2	452.0	Sacred Heart Primary

Figure 5.8 Predictions for SO2, 15-minute, 100th Percentile, Peak B Operation

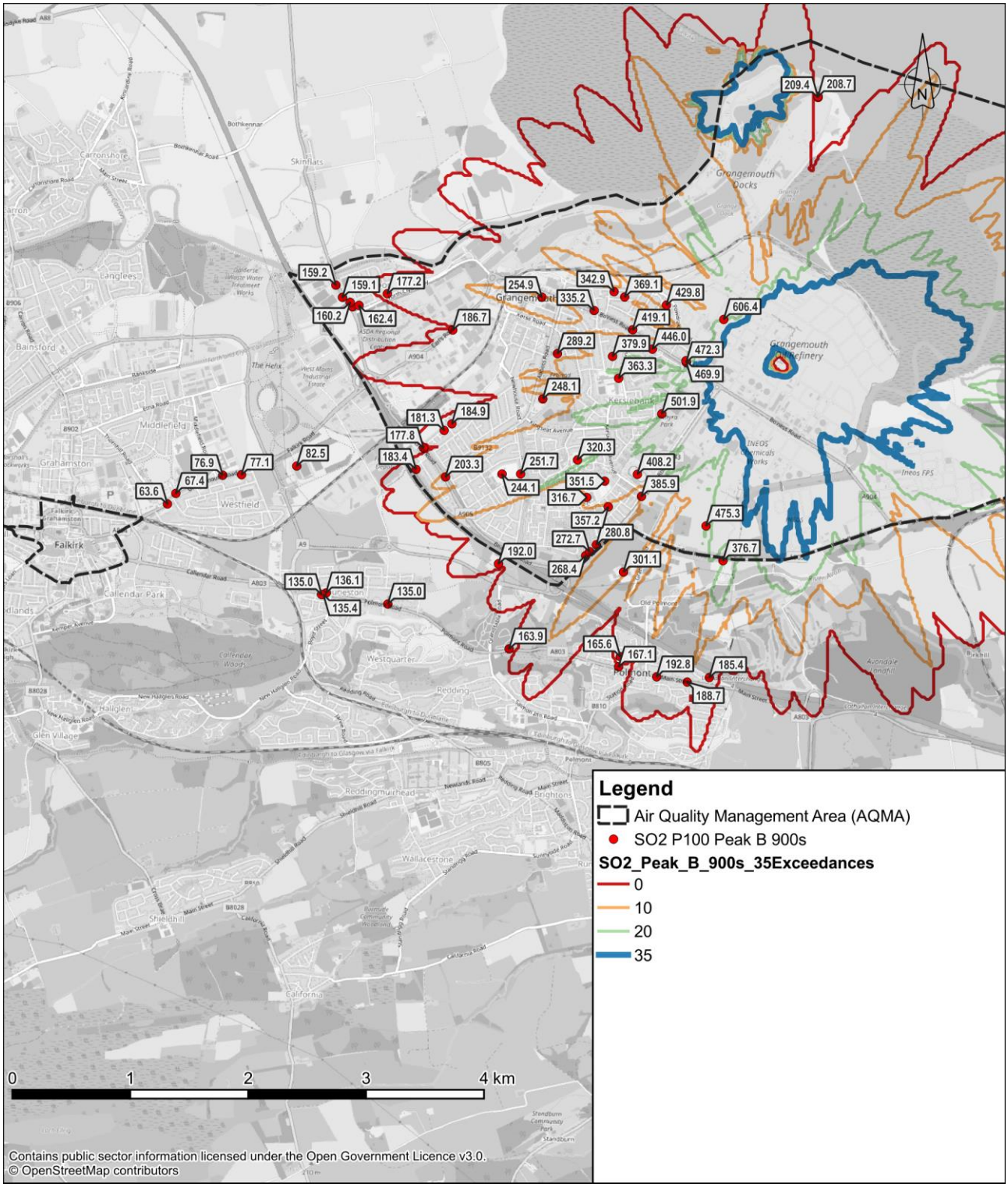
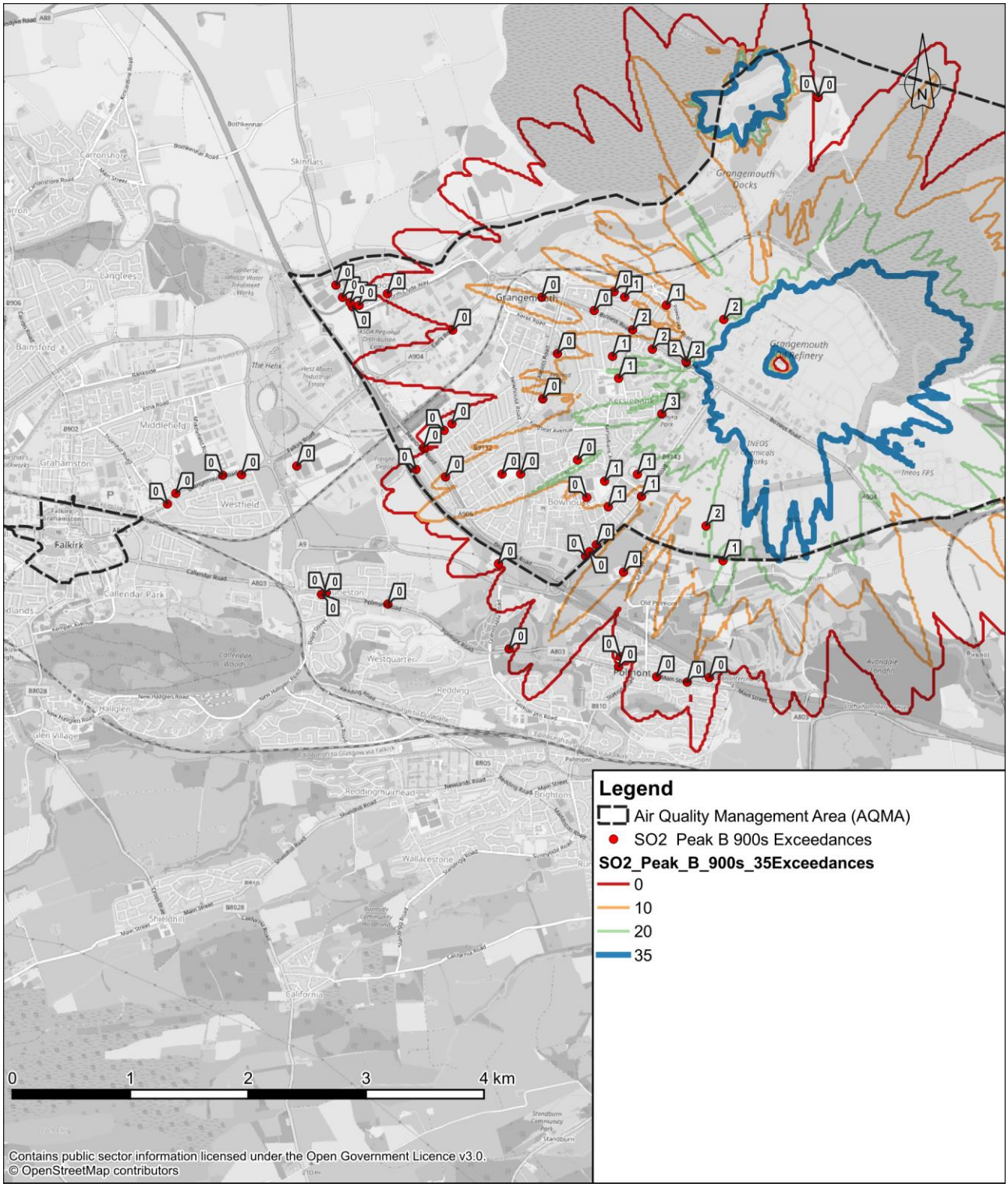


Table 5.9 Top 10 SO_2 Exceedances – Peak B Operation, 15-minute.

Rank	2015		2016		2017		2018		2019	
	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor
1	23	Inchyra AQU	21	Bo'ness Road 1	17	Inchyra AQU	15	Wholeflats	16	Inchyra AQU
2	18	Bo'ness Road 2	21	Bo`ness road	17	Wholeflats	15	Grangemouth Stadium	16	Sacred Heart Primary
3	18	Moray AQU	17	Inchyra AQU	17	Oil refinery	15	Beancross Primary	12	Bo'ness Road 1
4	18	Wholeflats	17	Beancross Primary	17	Sacred Heart Primary	15	Sacred Heart Primary	12	Bo'ness Road 2
5	14	Bo'ness Road 1	13	Beancross Road 1	17	Burnbank Road	15	Burnbank Road	12	GMC AQU
6	14	Grangemouth Stadium	13	Bo'ness Road 2	17	Reddoch Road	15	Reddoch Road	12	Wholeflats
7	14	Bowhouse Primary	13	Moray AQU	13	Beancross Primary	10	Inchyra Grange Hotel	12	Oil refinery
8	14	Bo`ness road	13	Wholeflats	9	Grangemouth Road 1	10	Bowhouse Primary	12	Grangemouth Stadium
9	14	Elizabeth Avenue	13	Sacred Heart Primary	9	Sports Complex	10	Albert Avenue	12	Bo`ness road
10	9	103 Bo'ness Road	13	Elizabeth Avenue	4	Bo'ness Road 1	10	Grangemouth High	12	Reddoch Road

Figure 5.9 Predictions for SO2, 15-minute Exceedances, Peak B Operation



5.2 Gridded Receptors

5.2.1 15-minute Objective

5.2.1.1 Normal Operation

Figure 5.10 and Figure 5.11 show the 99.9th and 100th percentiles for the Normal Operation scenario respectively. Both Figures show that SO_2 15-minute mean concentrations are predicted to be above the 15-minute objective in areas where people would not be expected to stay for 15 minutes or longer. The one notable exception to this is Inchyra Park. The area is predicted to experience concentrations that are in excess of the 15-minute objective but not in breach of the 35 permitted exceedances as shown on Figure 5.12.

5.2.1.2 Peak Operation

For the Peak Operation scenarios Figure 5.13 and Figure 5.14 show the 99th and 100th percentiles predictions of SO_2 for Peak A, and Figure 5.16 and Figure 5.17 for Peak B. The 100th percentile predictions show that a large part of Grangemouth town to be exposed to concentrations in excess of the 15-minute mean objective, with concentrations south of the M9 motorway and beyond, predicted as potentially at or above the 15-minute mean objective.

Figure 5.15 and Figure 5.18 confirm that no areas are predicted to experience a breach of the 35 permitted exceedances under the peak operation scenarios.

Figure 5.10 Gridded Predictions for SO2, 15-minute, 99.9th Percentile, Normal Operation

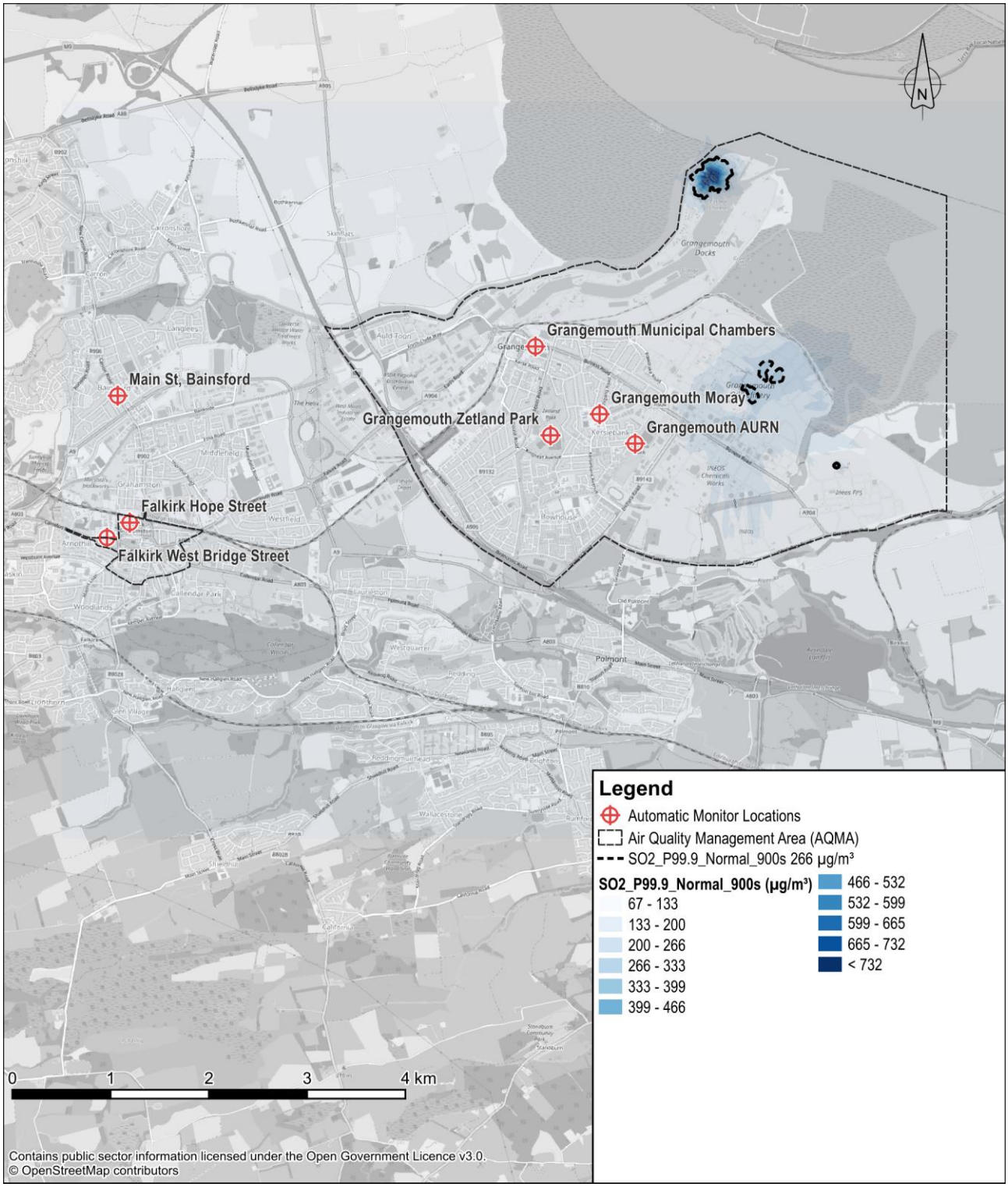


Figure 5.11 Gridded Predictions for SO2, 15-minute, 100th Percentile, Normal Operation

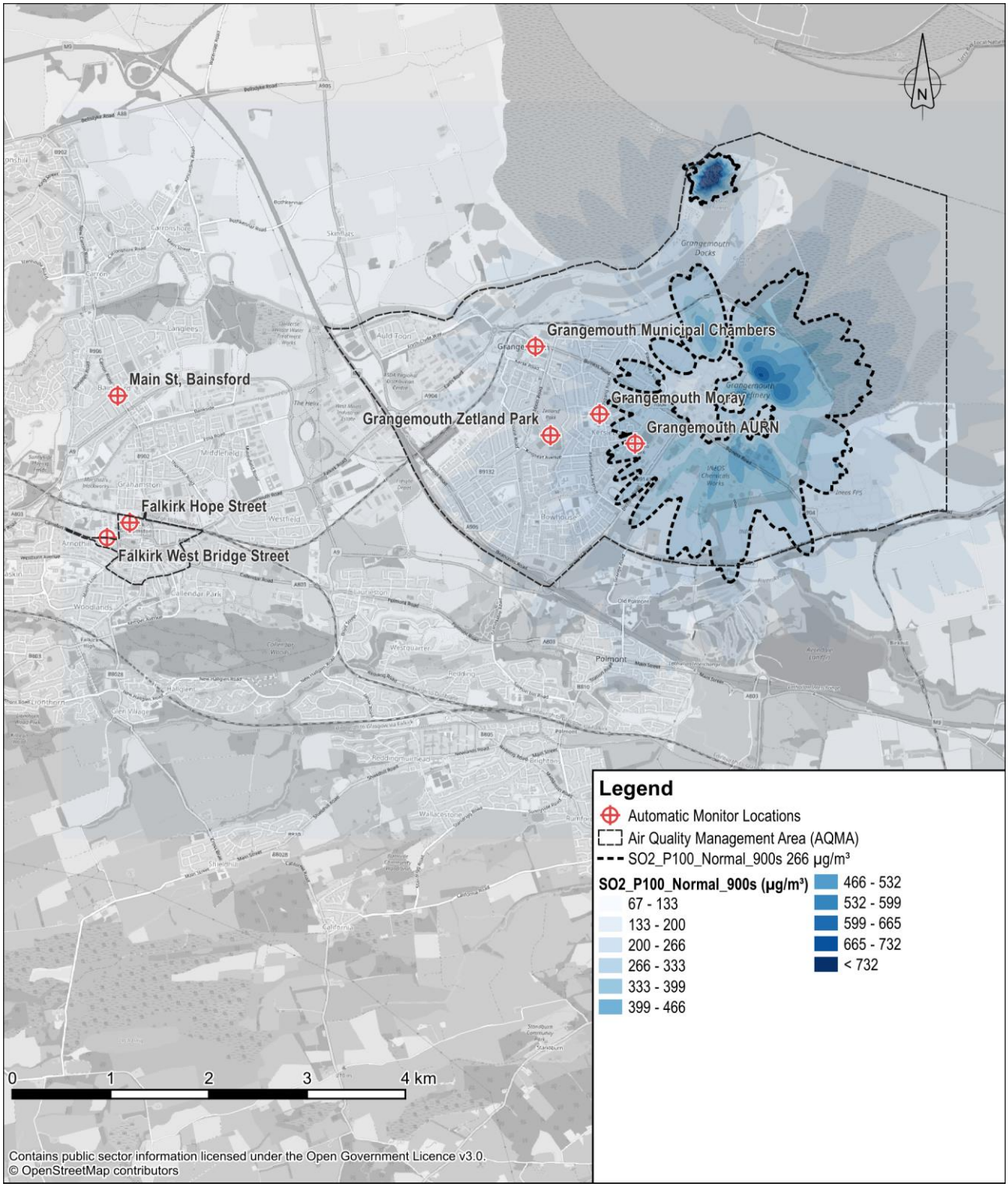


Figure 5.12 Gridded Predictions for SO2, 15-minute Exceedances, Normal Operation

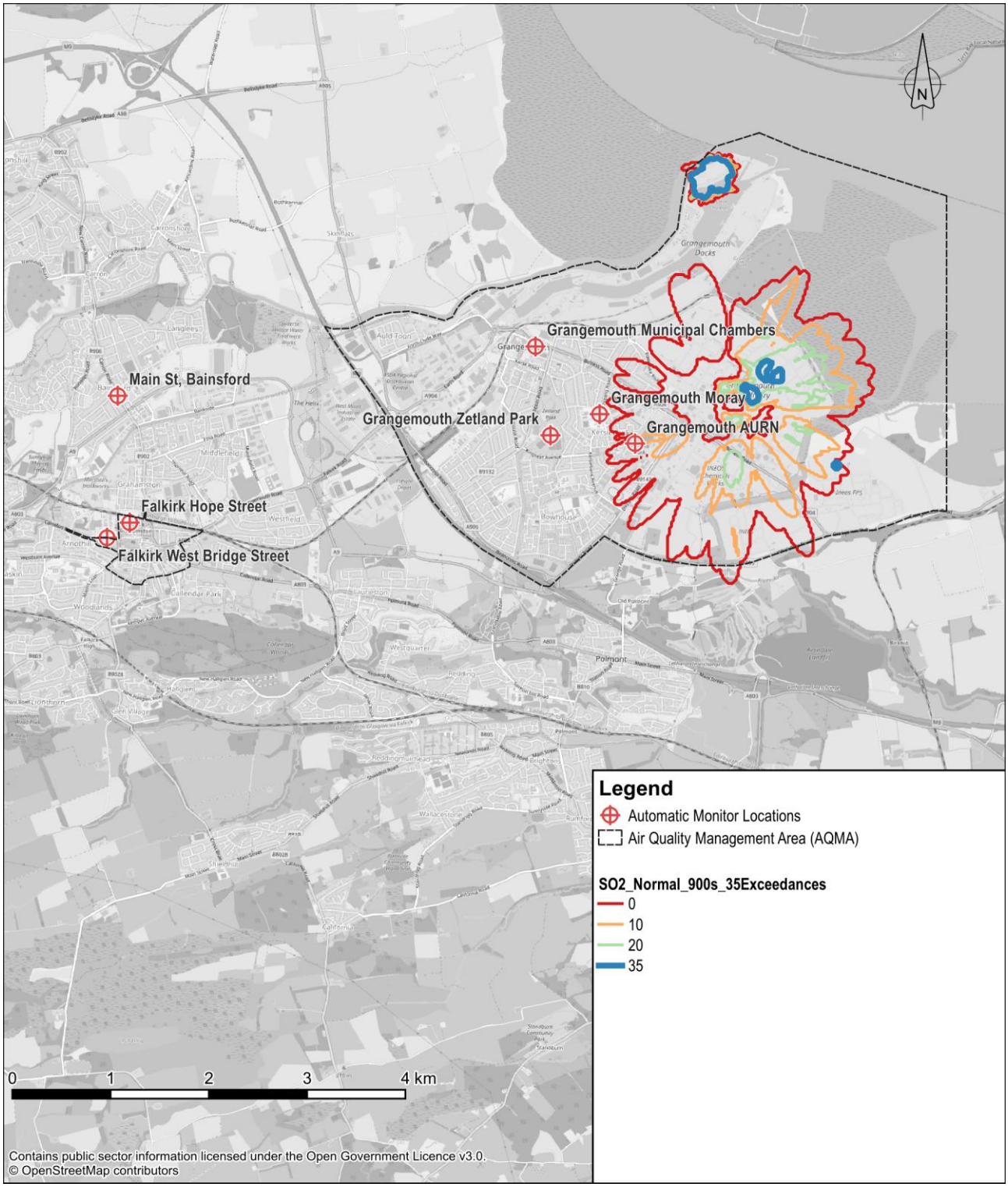


Figure 5.13 Gridded Predictions for SO2, 15-minute, 99.9th Percentile, Peak A Operation

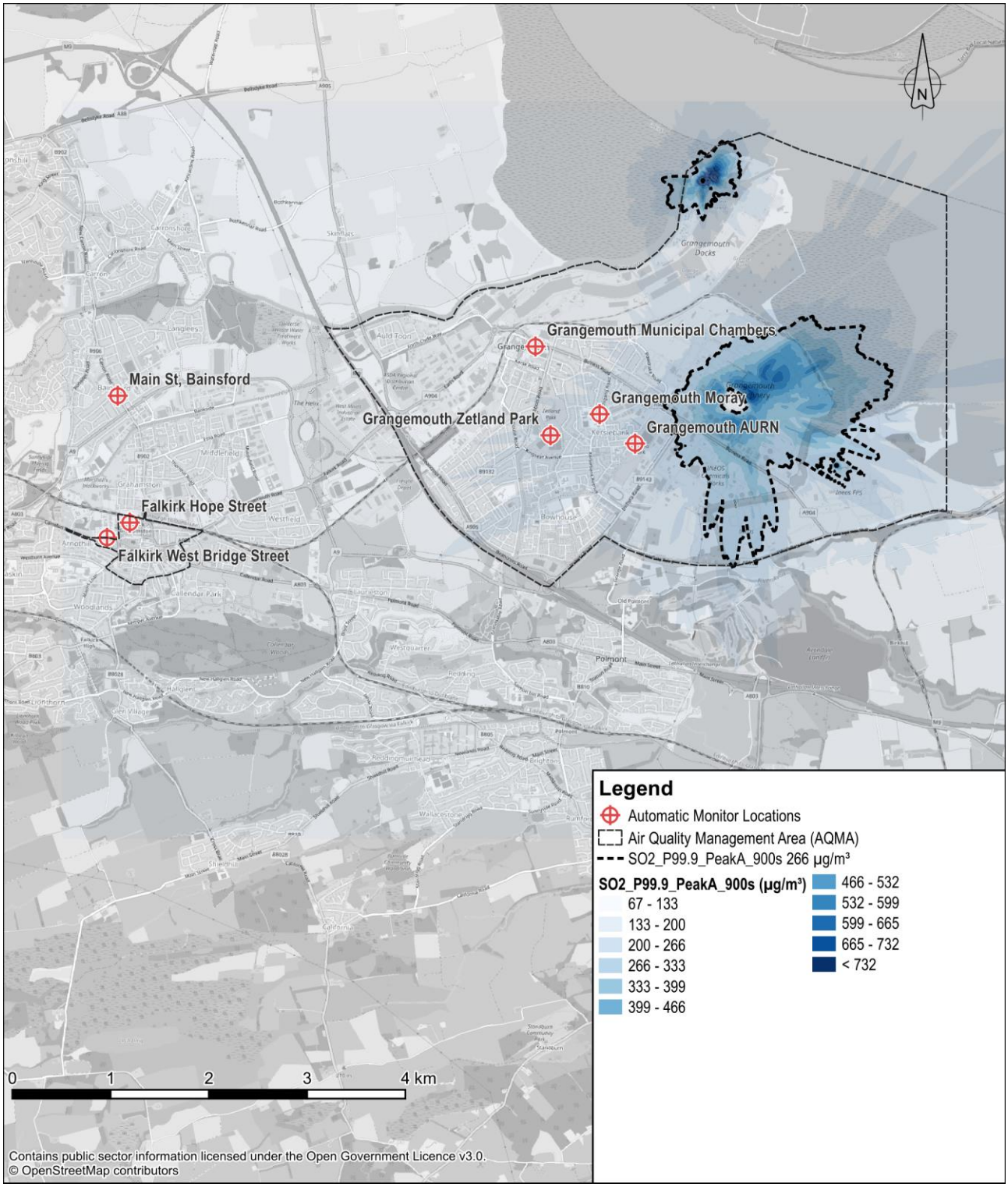


Figure 5.14 Gridded Predictions for SO2, 15-minute, 100th Percentile, Peak A Operation

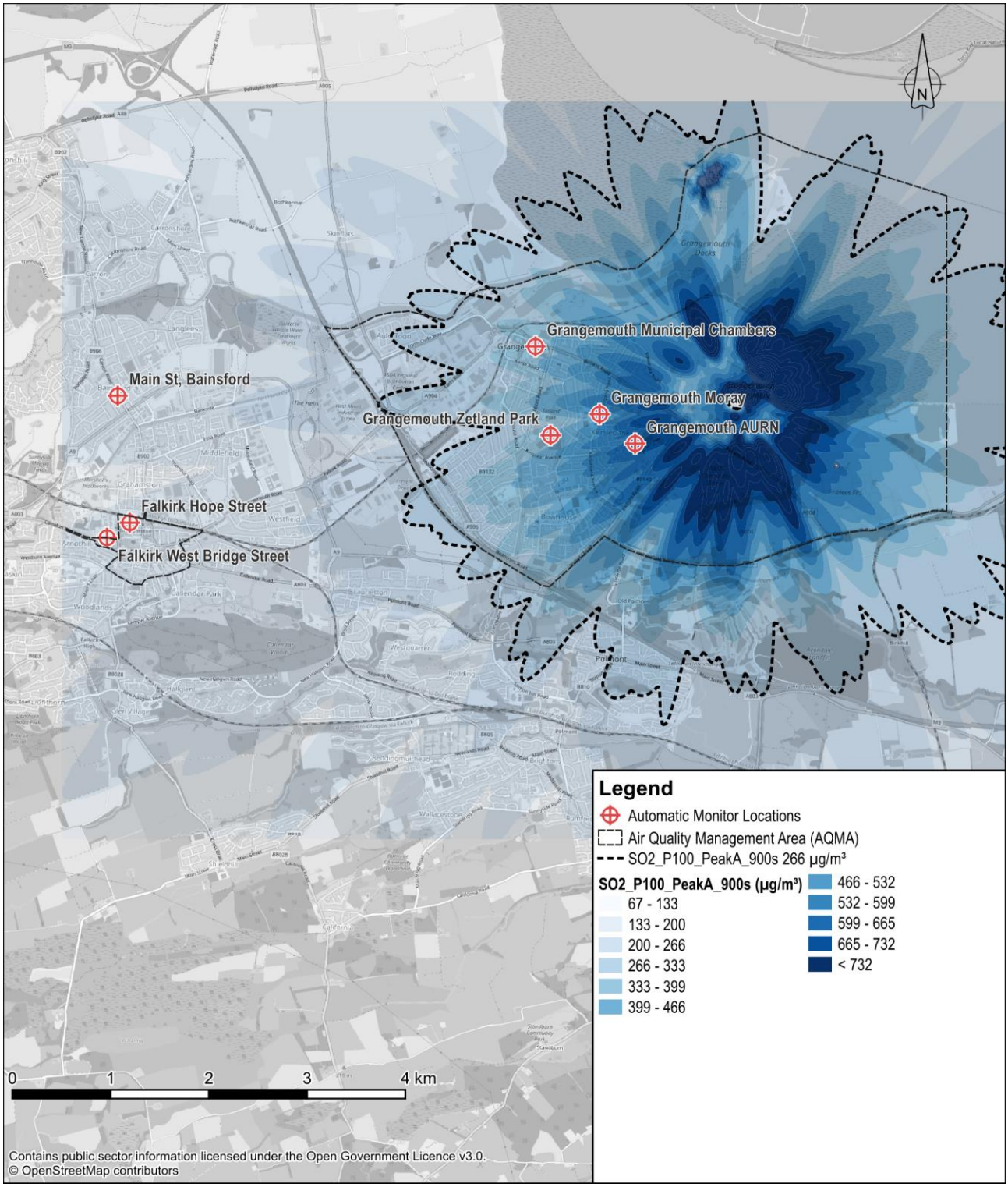


Figure 5.15 Gridded Predictions for SO2, 15-minute Exceedances, Peak A Operation

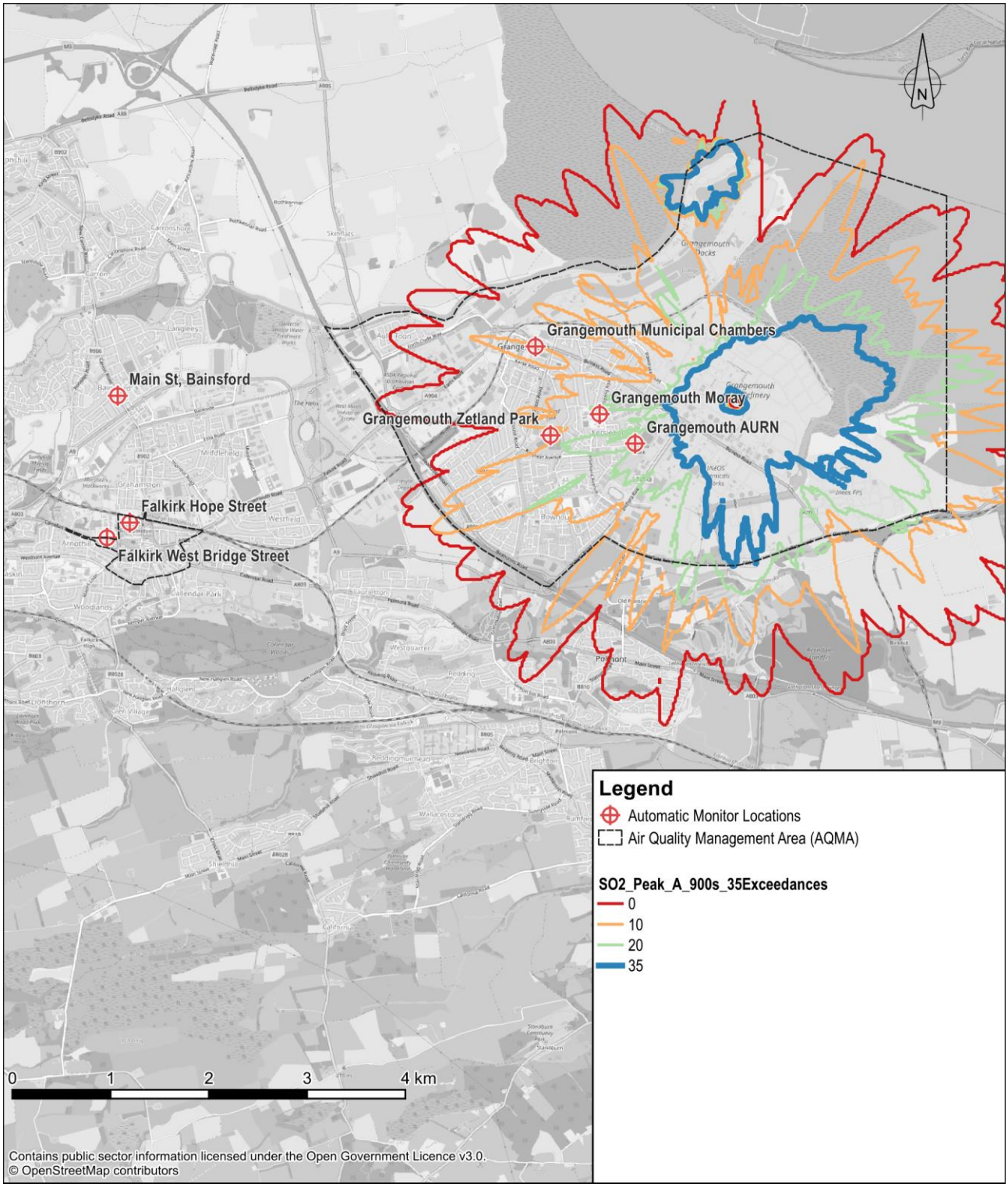


Figure 5.16 Gridded Predictions for SO2, 15-minute, 99.9th Percentile, Peak B Operation

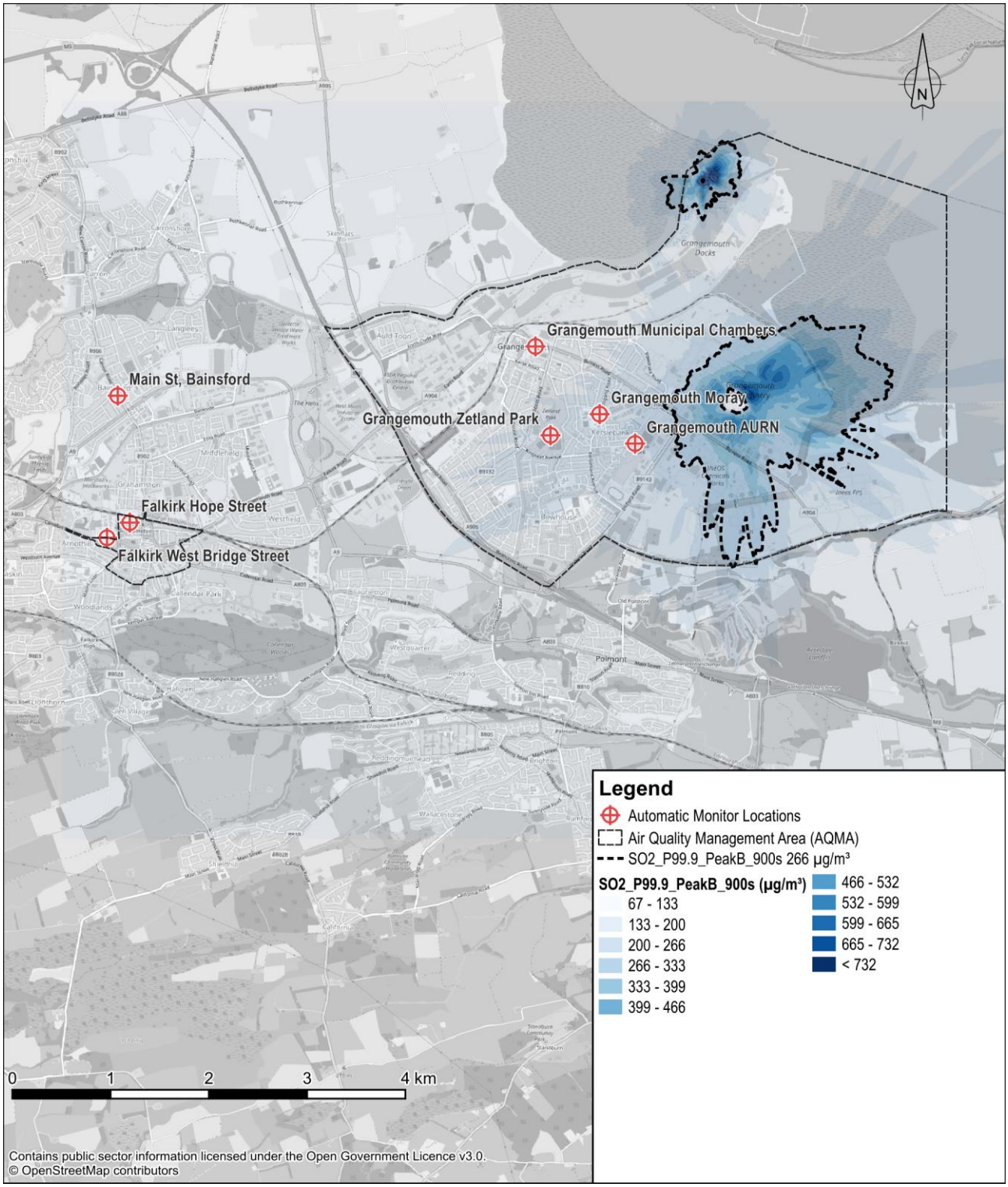


Figure 5.17 Gridded Predictions for SO2, 15-minute, 100th Percentile, Peak B Operation

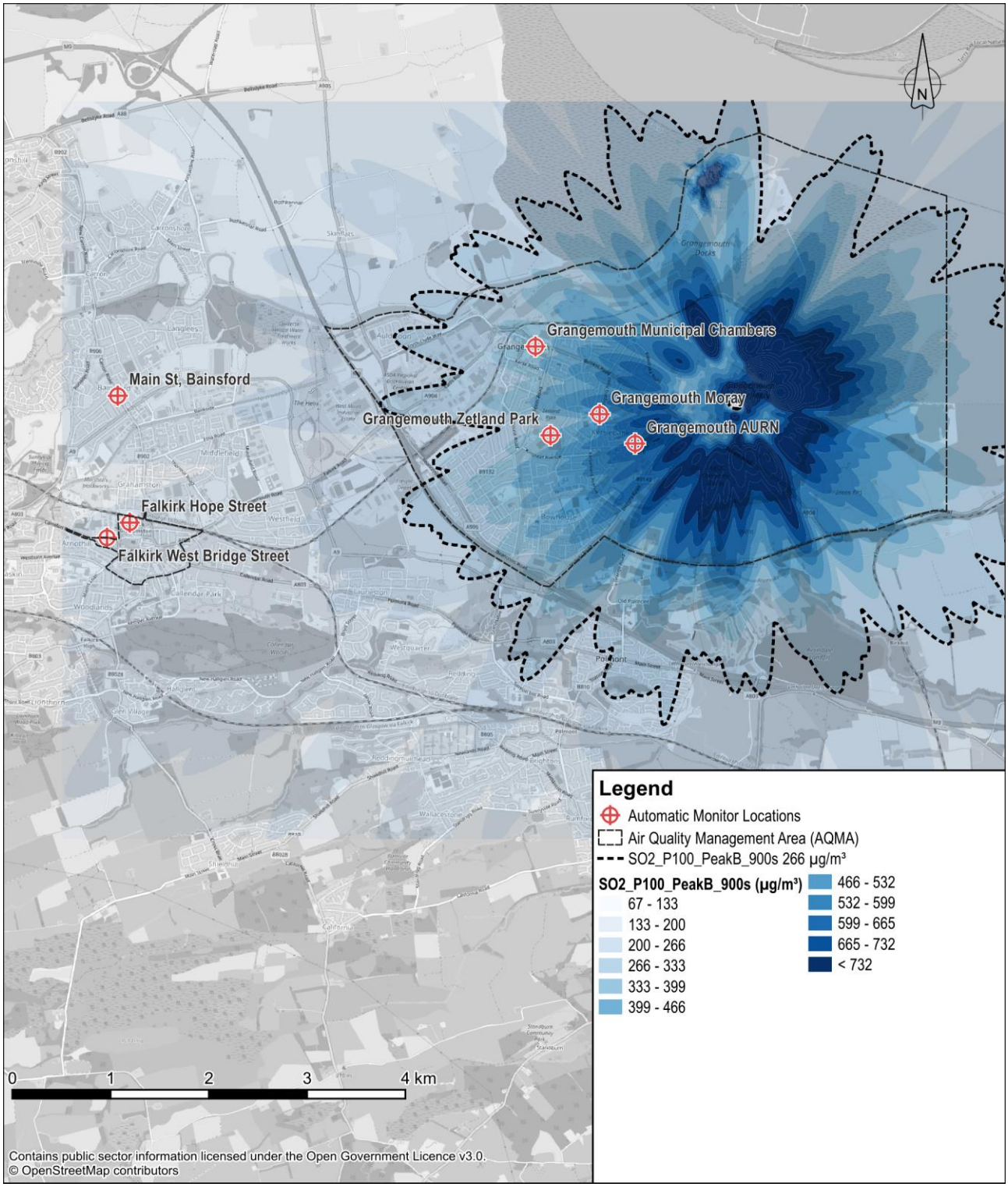
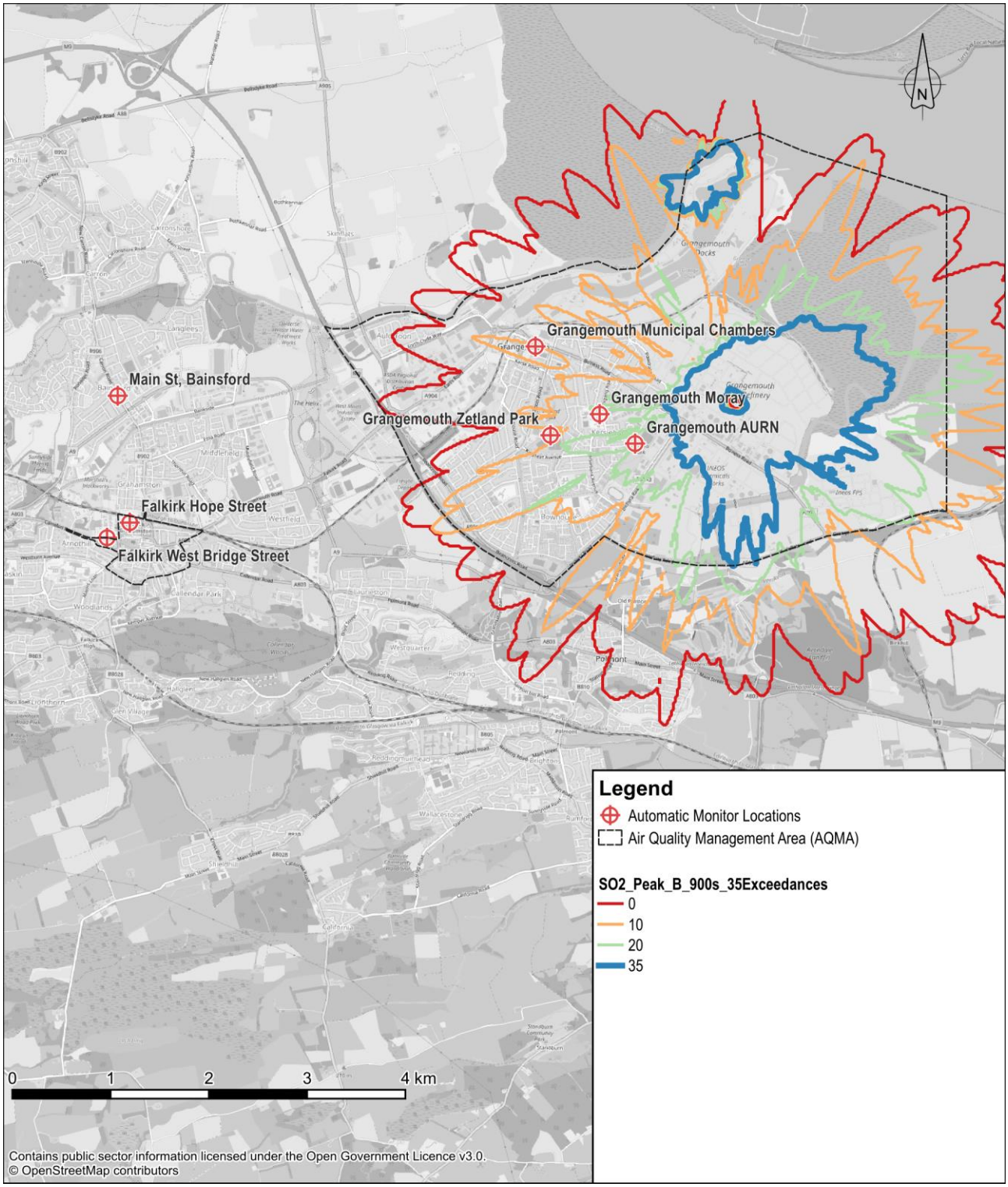


Figure 5.18 Gridded Predictions for SO2, 15-minute Exceedances, Peak B Operation



5.2.2 Source apportionment

An analysis of source apportionment for the automatic monitor locations at a selection of nearby representative receptor locations was undertaken. This used the worst case met year for the 99thpercentile, 2015 meteorological data. Full details of each point source within each group can be found in Appendix A.

An analysis of source apportionment for the automatic monitoring locations and a selection of nearby representative sensitive receptor locations was undertaken, based on the dispersion model outputs corresponding to the 99.9th percentile of 15-minue mean SO_2 concentrations. This analysis was completed for both the Normal Operation scenario and Peak Operation scenarios (A and B), with their respective apportionments presented on the following pages in graph form and subsequently overlain onto a base map at the corresponding geographical locations, as follows:

- Figure 5.10: Normal Operation Scenario source apportionment analysis (*graph*)
- Figure 5.11: Peak Operation Scenario A source apportionment analysis (*graph*)
- Figure 5.12: Peak Operation Scenario B source apportionment analysis (*graph*)
- Figure 5.13: Normal Operation Scenario source apportionment analysis (*base map*)
- Figure 5.14: Peak Operation Scenario A source apportionment analysis (*base map*)
- Figure 5.15: Peak Operation Scenario B source apportionment analysis (*base map*)

It is evident from the analysis that the dominant contributors of SO_2 emissions in each scenario at the assessed locations are the PetroIneos and Ineos FPS operations in the north and east of the Grangemouth industrial area, respectively.

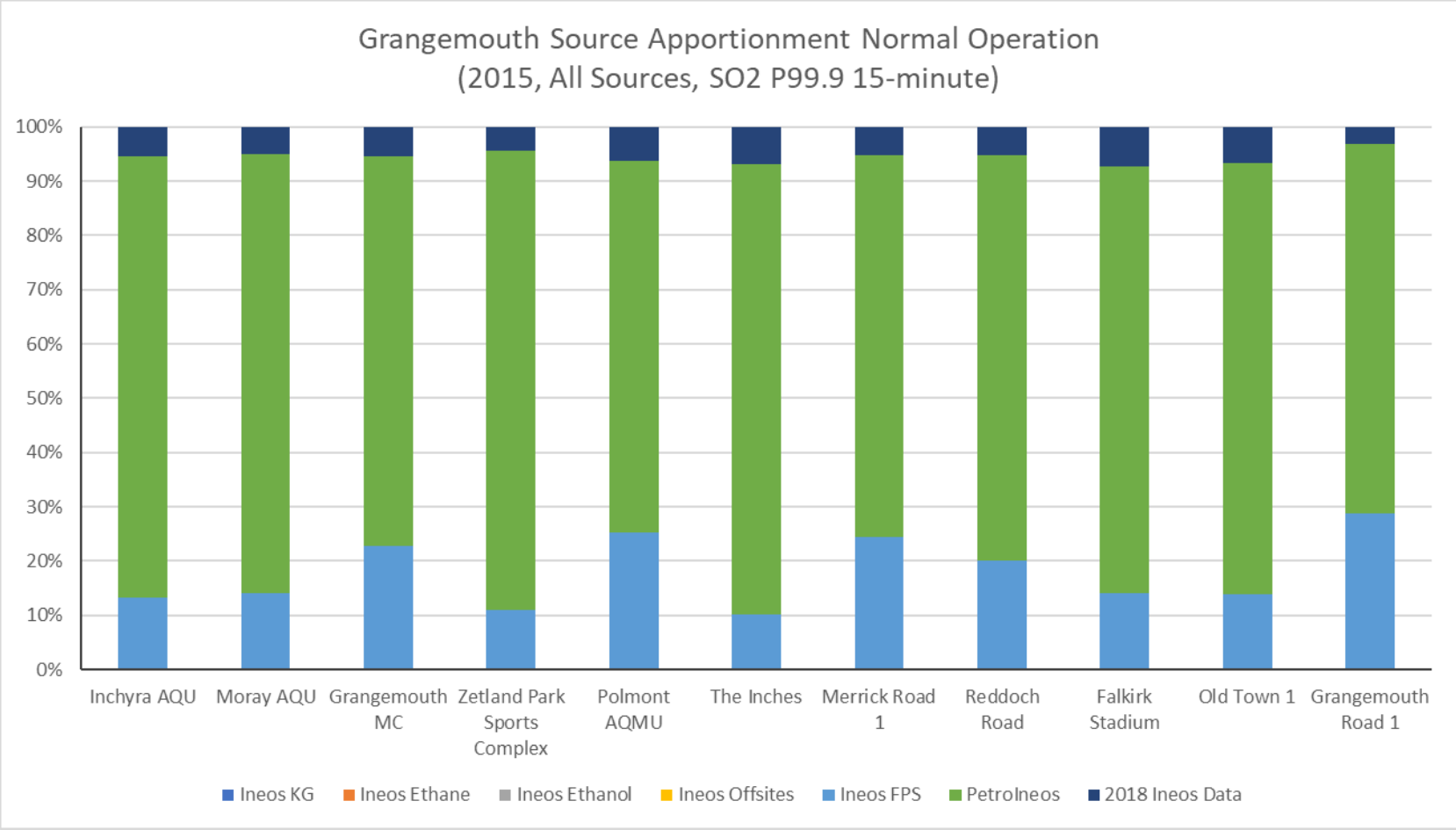


Figure 5.19 Normal Operation Source Apportionment at Selected Receptors for the 99.9th Percentile SO_2 Concentrations

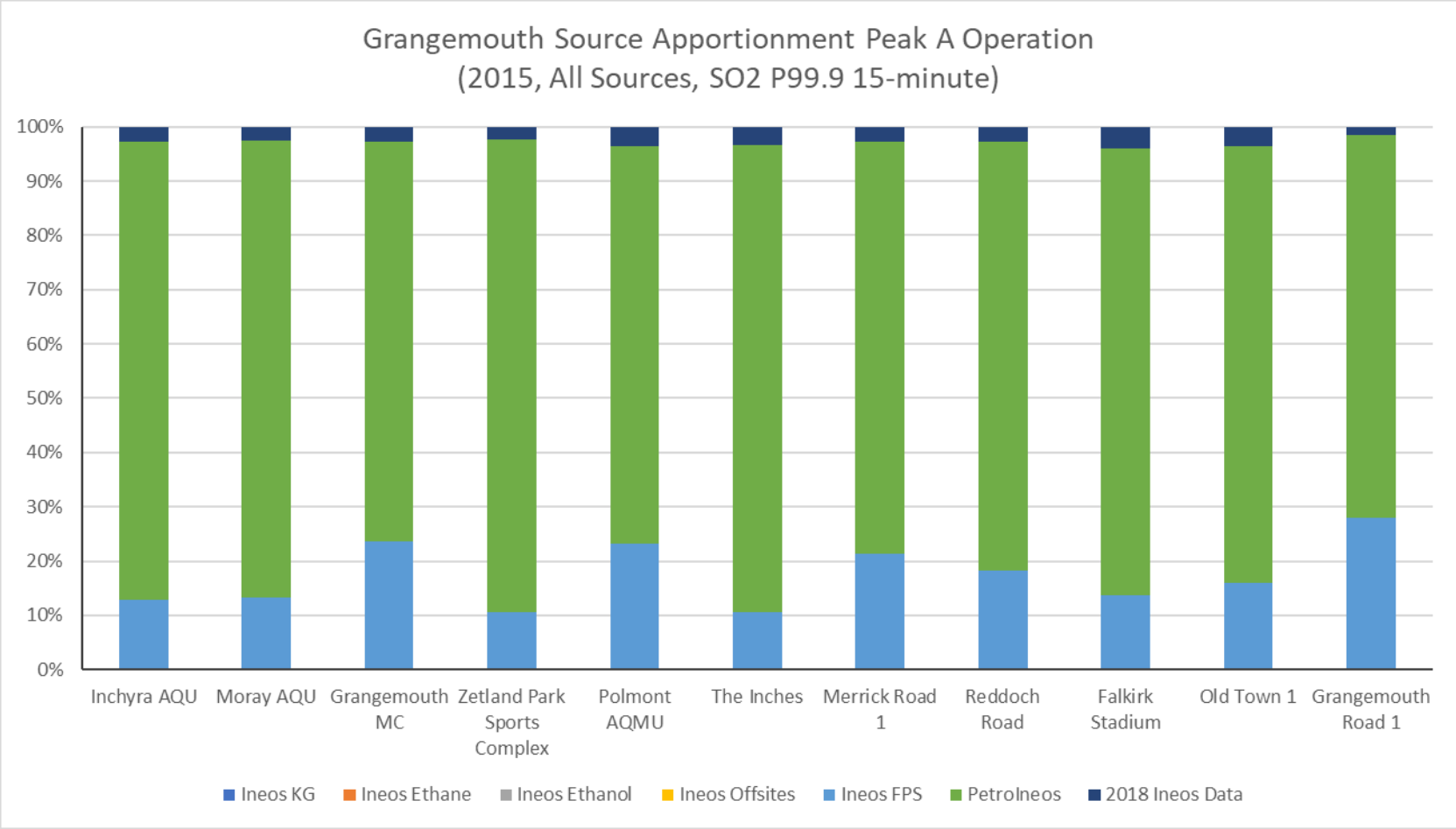


Figure 5.20 Peak A Operation Source Apportionment at Selected Receptors for the 99.9th Percentile SO2 Concentrations

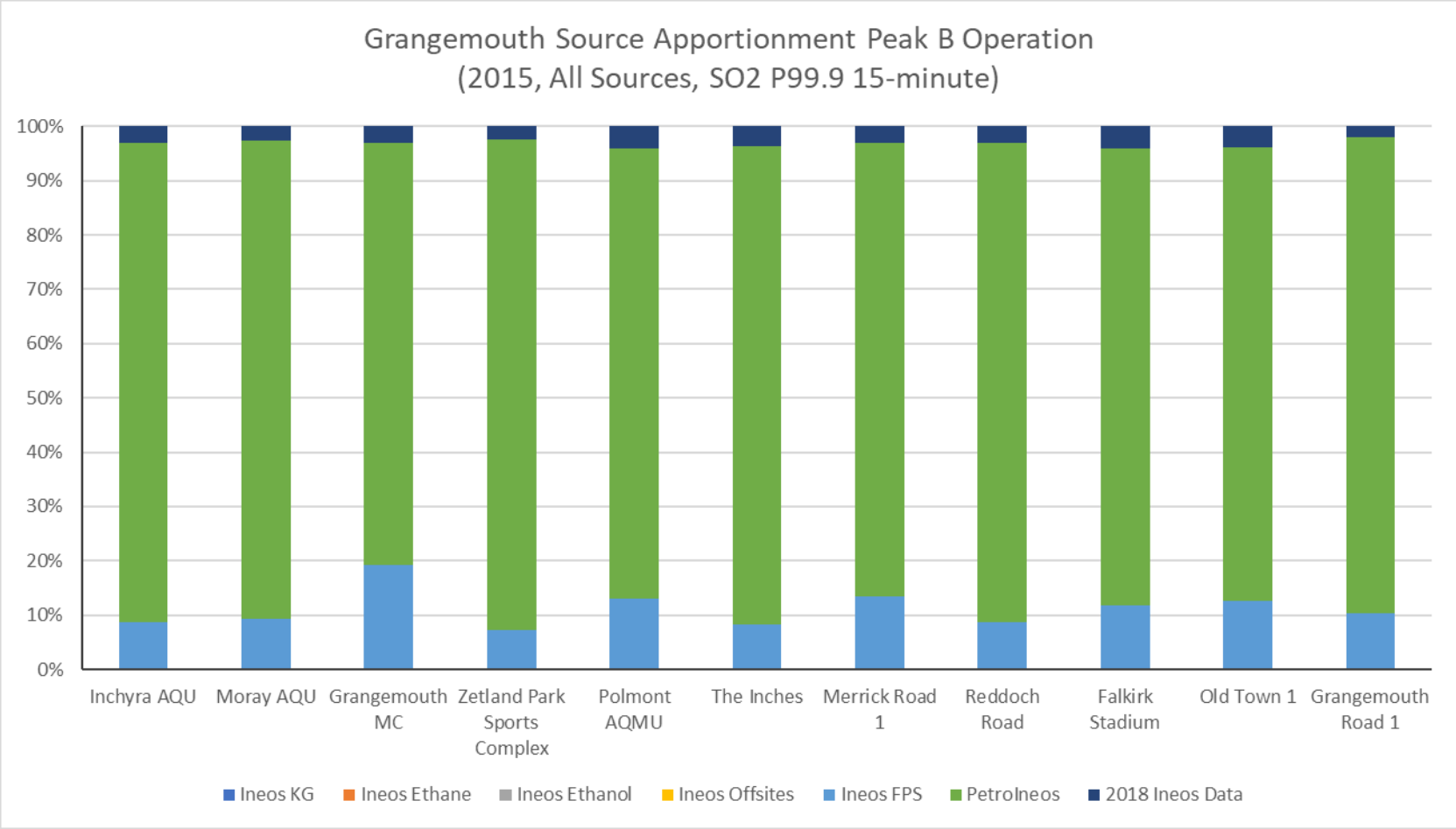


Figure 5.21 Peak B Operation Source Apportionment at Selected Receptors for the 99.9th Percentile SO2 Concentrations

Figure 5.22 Spatial Source Apportionment Distribution, Normal Operation

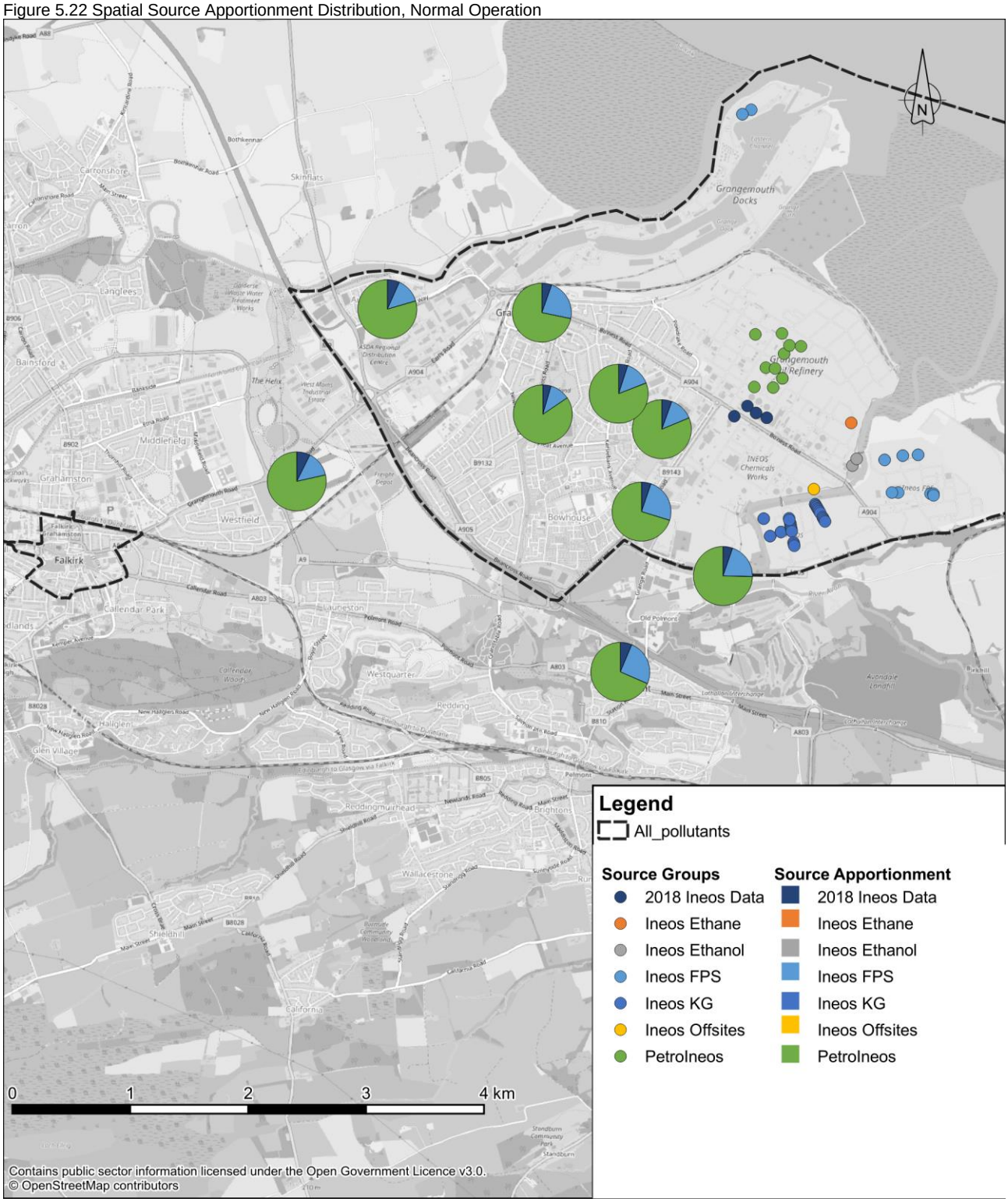


Figure 5.23 Spatial Source Apportionment Distribution, Peak A Operation

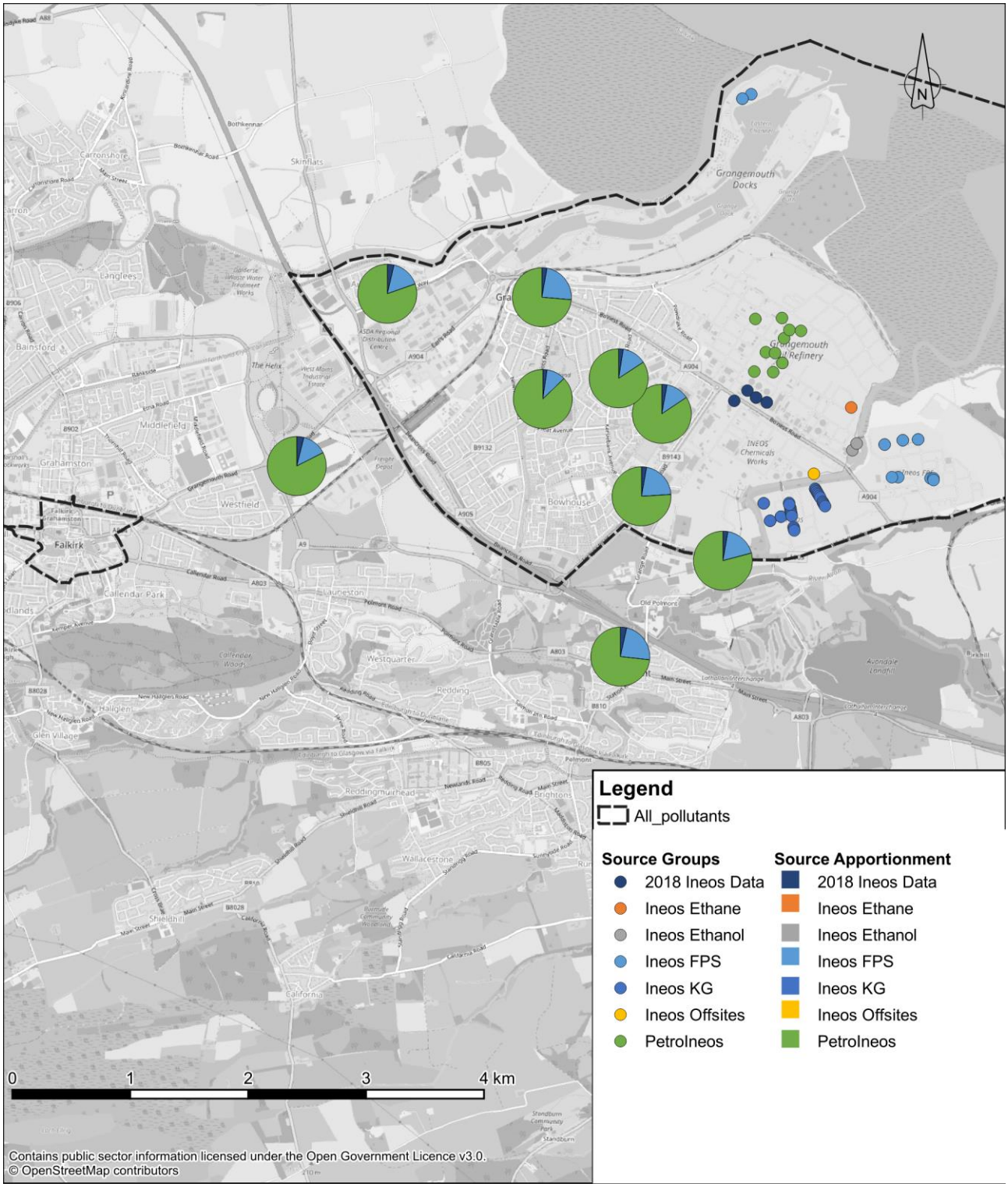
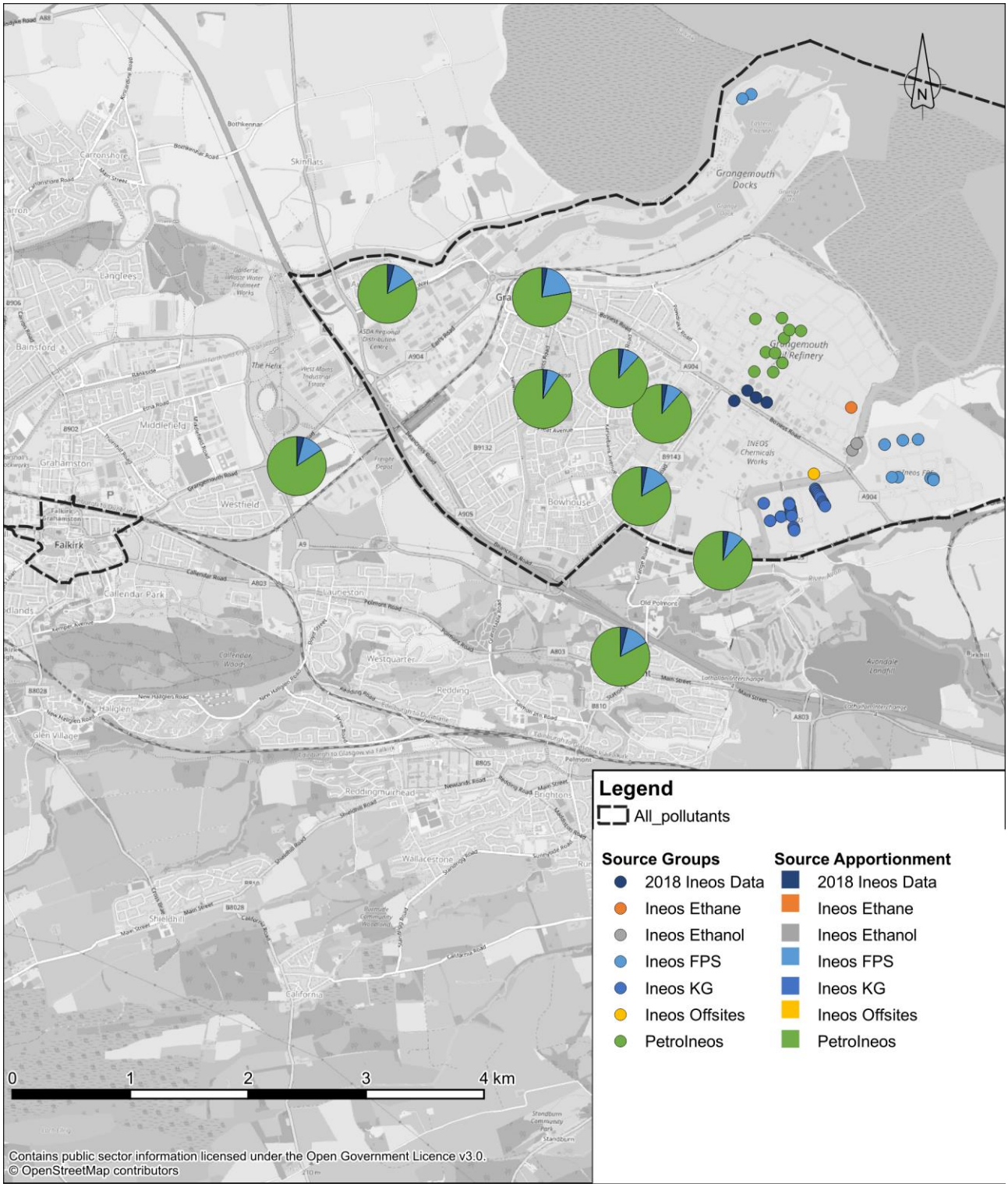


Figure 5.24 Spatial Source Apportionment Distribution, Peak B Operation



6 Conclusions

A Detailed Assessment in line with LAQM TG (22) has been completed to determine whether the Council can consider amending or revoking their AQMA for the 15 min mean SO_2 in Grangemouth.

A review of all historic monitoring data and an air quality dispersion modelling study has been undertaken based on the latest emissions data provided by site operators with the Grangemouth AQMA. The focus of this study is to determine whether the AQMA boundary is now appropriate, can be revoked in full or if it should remain in place but amended.

Monitoring data has shown a steady decrease in the number of exceedances and there has been no breach of the 15-minute mean objective since 2015. However in 2023 the numbers of exceedances have risen; this has been due to some additional flaring and issues with the SRU within PetroIneos.

The modelling has considered three operating scenarios Normal Operation, Peak A and Peak B Operating Scenarios. It will be a combination of these emissions profiles that will operate throughout the year. However, due to the sporadic nature of flaring, and other episodes of maintenance or similar throughout the year the exact frequency and duration of these flaring episodes are unknown.

To consider the potential worst case 15 min mean as a result of the Peak A and B scenarios, these have been run in the air quality model as if all industrial emission sources operate continuously. This allows the model to determine the potential highest concentrations across a range of meteorological conditions during flaring episodes.

Notwithstanding the conservative assumptions applied to the modelling study, the results demonstrate that the 15-minute mean objective (35 exceedances of 266 µg/m^3 per annum) is not predicted to be breached under both Normal and Peak Operation scenarios at any of the modelled sensitive receptor locations.

Although the objective was not exceeded at any receptor, there were modelled exceedances of the 15-minute mean standard (266 µg/m^3) at the following locations under normal and/or peak operation.

- Bowhouse area
- Grangemouth High School
- Inchyra Park
- Sacred Heart RC Primary School
- Beancross Primary School
- Beancross Road
- Grangemouth Golf Course and the Polmonthill Snowsports Centre.

This indicates that when there is flaring under the right meteorological conditions elevated concentrations greater than the 15min mean will occur.

Predictions made as part of this modelling exercise should be interpreted alongside the limitations to this and previous studies. It has historically been difficult to predict the number of exceedances of the 15-minute mean objective to replicate exactly those measured at the monitoring locations. Without accurate time varying emissions data for all sources, a gaussian model will find it challenging to predict the exact number of exceedances for a 15-minute interval.

For example, monitoring for year 2023 has shown there to be up to 16 exceedances at Grangemouth Moray, which is greater than the number of exceedances predicted by the model under the Peak A and Peak B operation scenarios (4no. exceedances modelled). This could indicate other areas of Grangemouth and the surrounding area had the potential to experience elevated 15-minute mean concentrations in 2023.

However, the results of the modelling assessment broadly align with the results of the reported air quality monitoring over recent years, in that whilst there have been limited exceedances of the standard (266 µg/m^3), the objective (35 exceedances per annum) has not been breached at any sensitive location.

The modelling has demonstrated that the spatial dispersion of emissions from the Grangemouth industrial area has changed, and Grangemouth Moray may not be representative of the potential worst-case exposure locations. This is due to changes to facility operations, where a number of the previous SO_2 emitters within PetroIneos are no longer in operation, with ground flares replacing many of the elevated flares. This modelling study has also included emissions from sources at the Ineos FPS, which have not been available in previous model iterations of the AQMA. To address this, potential additional and/or relocated monitoring sites are recommended to capture potential worst-case exposure (see **Section 6.1**).

Overall, this Detailed Assessment has demonstrated that **the revocation of the Grangemouth AQMA over the residential and town centre areas of Grangemouth can be justified** on the basis that a breach of the 15-minute mean SO_2 objective is highly unlikely to occur, based on both monitored and modelled data. However, current monitoring should continue and be supplemented by monitoring at other relevant exposure locations, as outlined in **Section 6.1**.

6.1 Next Steps

The Proposal for the Revocation of the Grangemouth AQMA reports that all measures from the 2007 Air Quality Action Plan have been achieved and that there have been no breaches of the 15-minute mean objective since 2012. The data in Table 3.1 show that no breaches of the 35 permitted exceedances of the 15-minute standard concentration have occurred since at least 2015.

The revocation proposal provides a number of actions that are to be maintained, including the retention of all existing fixed, automatic monitoring stations. The information provided by this Detailed Assessment supports this, given that the dispersion model results demonstrate that exceedances of the 15-minute mean standard may still occur in Grangemouth, with a potential shift in the spatial dispersion of emissions over the local area owing to a change in the nature and location of SO_2 sources within the industrial area.

Based on the data provided in Section 5 and associated conclusions given in Section 6, supplementary automatic SO_2 monitoring is recommended at one of, or a combination of, the following sensitive exposure locations:

- Bowhouse Primary School and/or Grangemouth High School, Tinto Drive
- Sacred Heart R C Primary School, Torwood Avenue
- Merrick Road, Grangemouth
- Polmonthill Ski Centre / Grangemouth Golf Course.

Appendix A

Emission Parameters

Normal Operation Emission Parameters

Source	Group	Description	X	Y	Stack height (m)	Stack internal diameter (m)	Annual Hours of operation	Temp. (°C)	Vol./Mass Flow	Flow/ Mass units	Emissions (g/s)						
											NO_x	PM_{10}	$PM_{2.5}$	SO_2	CO	CH_4	Non-Methane VOCs
EP-KG-1	Ineos KG	KG Flare A Annual Average	294699	680262	91.5	1.0	8,760	699.9	13,396.3	Am³/hr	2.398	-	-	-	2.212	0.571	2.238
EP-KG-2	Ineos KG	KG Flare B Annual Average	294753	680114	91.5	1.0	8,760	699.9	13,396.3	Am³/hr	2.398	-	-	-	2.212	0.571	2.238
EP-KG-3	Ineos KG	KG Ground Flare Annual Average	294845	680149	25.8	13.6	8,760	699.9	13,396.3	Am³/hr	2.398	-	-	-	2.212	0.571	2.238
EP-KG-4A	Ineos KG	KG Furnace	294924	680224	33.3	1.6	3,624	162.5	101,931.9	Am³/hr	0.697	-	-	1.16E-03	0.008	-	-
EP-KG-4B	Ineos KG	KG Furnace	294926	680211	33.3	1.6	4,344	208.7	104,768.5	Am³/hr	0.800	-	-	1.34E-03	0.004	-	-
EP-KG-4C	Ineos KG	KG Furnace	294928	680197	33.3	1.6	3,648	193.0	99,749.9	Am³/hr	0.687	-	-	1.15E-03	0.032	-	-
EP-KG-4D	Ineos KG	KG Furnace	294931	680182	33.3	1.6	6,048	171.5	101,277.3	Am³/hr	0.664	-	-	1.11E-03	0.036	-	-
EP-KG-4E	Ineos KG	KG Furnace	294934	680169	33.3	1.6	8,760	174.1	104,332.1	Am³/hr	1.218	-	-	2.03E-03	0.011	-	-
EP-KG-4F	Ineos KG	KG Furnace	294936	680155	33.3	1.6	5,088	164.8	96,913.4	Am³/hr	0.592	-	-	9.88E-04	0.014	-	-
EP-KG-4G	Ineos KG	KG Furnace	294952	680060	46.3	1.6	8,760	170.0	93,204.0	Am³/hr	1.151	-	-	1.92E-03	0.005	-	-
EP-KG-4H	Ineos KG	KG Furnace	294955	680046	46.3	1.6	8,760	162.0	96,477.0	Am³/hr	0.969	-	-	1.62E-03	0.008	-	-
EP-KG-4J	Ineos KG	KG Furnace	294958	680032	46.3	1.6	8,760	150.5	95,167.8	Am³/hr	1.064	-	-	1.78E-03	0.007	-	-
EP-KG-6A	Ineos KG	Steam Boiler 36-F-501A	294914	680265	30	1.7	8,760	164.0	68,120.9	Am³/hr	1.898	0.006	0.006	9.81E-03	0.004	-	-

Source	Group	Description	X	Y	Stack height (m)	Stack internal diameter (m)	Annual Hours of operation	Temp. (°C)	Vol./Mass Flow	Flow/ Mass units	Emissions (g/s)						
											NO_X	PM_{10}	$PM_{2.5}$	SO_2	CO	CH_4	Non-Methane VOCs
EP-KG-6B	Ineos KG	Steam Boiler 36-F-501B	294916	680251	30	1.7	8,760	132.0	73,452.1	Am³/hr	2.023	0.018	0.018	1.63E-03	0.004	-	-
Cooling Tower No.1	Ineos KG	Cooling Tower No.1	295135	680385	21.2	10.6	8,760	34.3	1,951,142.5	Am³/hr	-	0.180	0.180	0.00E+00	-	-	-
Cooling Tower No.2	Ineos KG	Cooling Tower No.2	295142	680373	21.2	10.6	8,760	34.3	1,951,142.5	Am³/hr	-	0.180	0.180	0.00E+00	-	-	-
Cooling Tower No.3	Ineos KG	Cooling Tower No.3	295148	680362	21.2	10.6	8,760	34.3	1,951,142.5	Am³/hr	-	0.180	0.180	0.00E+00	-	-	-
Cooling Tower No.4	Ineos KG	Cooling Tower No.4	295156	680349	21.2	10.6	8,760	34.3	1,951,142.5	Am³/hr	-	0.180	0.180	0.00E+00	-	-	-
Cooling Tower No.5	Ineos KG	Cooling Tower No.5	295162	680338	21.2	10.6	8,760	34.3	1,951,142.5	Am³/hr	-	0.180	0.180	0.00E+00	-	-	-
Cooling Tower No.6	Ineos KG	Cooling Tower No.6	295170	680325	21.2	10.6	8,760	34.3	1,951,142.5	Am³/hr	-	0.180	0.180	0.00E+00	-	-	-
Cooling Tower No.7	Ineos KG	Cooling Tower No.7	295178	680311	21.2	10.6	8,760	34.3	1,951,142.5	Am³/hr	-	0.180	0.180	0.00E+00	-	-	-
Cooling Tower No.8	Ineos KG	Cooling Tower No.8	295199	680274	21.2	10.6	8,760	21.3	3,021,123.9	Am³/hr	-	0.180	0.180	0.00E+00	-	-	-
Cooling Tower No.9	Ineos KG	Cooling Tower No.9	295205	680263	21.2	10.6	8,760	21.3	3,021,123.9	Am³/hr	-	0.180	0.180	0.00E+00	-	-	-

Source	Group	Description	X	Y	Stack height (m)	Stack internal diameter (m)	Annual Hours of operation	Temp. (°C)	Vol./Mass Flow	Flow/ Mass units	Emissions (g/s)						
											NO_X	PM_{10}	$PM_{2.5}$	SO_2	CO	CH_4	Non-Methane VOCs
Cooling Tower No.10	Ineos KG	Cooling Tower No.10	295212	680250	21.2	10.6	8,760	21.3	3,021,123.9	Am³/hr	-	0.180	0.180	0.00E+00	-	-	-
Cooling Tower No.11	Ineos KG	Cooling Tower No.11	295219	680238	21.2	10.6	8,760	21.3	3,021,123.9	Am³/hr	-	0.180	0.180	0.00E+00	-	-	-
GM-71-S-601	Ineos Ethane	Elevated cryogenic flare	295441	681074	45.0	1.0	8,760	699.9	11.0	Nm³/hr	0.003	-	-	5.56E-06	2.653	-	0.001
D-S-1	Ineos Ethanol	Items connected to the North Side Flare	295451	680712	45.0	0.6	286.5	66.8	55,423.0	Am³/hr	0.009	-	-	-	1.257	0.968	2.195
D-S-2	Ineos Ethanol	Items connected to the North Side Flare	295487	680769	45.0	0.6	286.5	66.8	55,423.0	Am³/hr	0.009	-	-	0.00E+00	1.257	0.968	2.195
Z-S-1	Ineos Offsites	South Offsites Flare	295124	680512	45.7	0.5	8,760	298.0	5.7	Am³/hr	0.000	-	-	0.00E+00	0.000	0.025	555.556
A1	Ineos FPS	Gas turbines/auxiliary heaters	295839	680483	30.0	4.0	7,392	500.0	5,625.6	Am³/h	0.117	-	-	4.10E-01	317.560	-	-
A2 (Stack 2)	Ineos FPS	Trains 1&2 Crude oil pre-heater stacks	295786	680483	40.0	1.3	3,936	215.0	2,928.1	Am³/h	0.102	-	-	0.00E+00	0.000	-	-
A3 (Stack 3)	Ineos FPS	Train 3 LP Gas Turbine Stack	296113	680474	25.0	1.6	7,800	350.0	2,474.0	Am³/h	0.031	-	-	3.51E-02	5.852	-	-
A4 (Stack 4)	Ineos FPS	Train 3 MP/HP Gas Turbine Stack	296138	680474	35.0	1.9	8,496	330.0	4,986.6	Am³/h	0.085	-	-	1.24E-01	9.499	-	-
A5 (Stack 5)	Ineos FPS	Train 3 crude oil pre-heater stack	296139	680459	48.0	2.5	8,760	250.0	5,208.9	Am³/h	0.222	-	-	3.21E-01	0.000	-	-
A13-16 (Stack 10)	Ineos FPS	Train 3 Ground Flares	295878	680796	12.0	10.5	8,760	450.0	0.5	kg/s	0.000	-	-	2.90E-01	0.000	-	-

Source	Group	Description	X	Y	Stack height (m)	Stack internal diameter (m)	Annual Hours of operation	Temp. (°C)	Vol./Mass Flow	Flow/ Mass units	Emissions (g/s)						
											NO_X	PM_{10}	$PM_{2.5}$	SO_2	CO	CH_4	Non-Methane VOCs
A12 (Stack 11)	Ineos FPS	Trains 1&2 Elevated Flare	295724	680760	45.0	1.2	7,392	450.0	0.5	kg/s	0.000	-	-	2.90E-01	0.000	-	-
A17 (Stack 12)	Ineos FPS	Train 3 Elevated Flare	296008	680803	88.0	1.2	8,760	450.0	0.5	kg/s	0.000	-	-	2.90E-01	0.000	-	-
A18 (Stack 8)	Ineos FPS	Propane Heater Stack	294593	683728	9.2	0.7	8,760	450.0	0.1	Am³/h	0.003	-	-	2.90E-01	0.011	0.011	0.053
A19 (Stack 13)	Ineos FPS	RLPG Ground Flares	294518	683690	12.0	7.2	8,760	450.0	1,629.0	Am³/h	0.479	-	-	5.11E-03	1.675	-	7.978
EP CDU3 1	PetroIneos	CDU3/DHT combined (BA-101 & BA-301)	294854	681832	79.0	3.7	8,760	318.0	8.9	Am³/hr	4.365	4.300	4.300	1.71E+00	5.800	-	-
EP CRU 1	PetroIneos	CRU Main Heater & WHB common stack	294871	681660	95.7	2.7	8,760	291.0	9.9	Am³/hr	2.551	0.400	0.400	2.95E-01	7.600	-	-
EP CRU 2	PetroIneos	CRU 1st Interheater Unit (B-109)	294917	681731	67.5	2.4	8,760	198.0	5.8	Am³/hr	1.404	1.300	1.300	3.57E-01	-	-	-
EP-CDU2-1	PetroIneos	No.2 CDU/No.2 DHT (combined)	294628	681824	61.0	3.4	8,760	334.0	6.8	Am³/hr	2.964	2.300	2.300	5.58E-01	-	-	-
EP-HYDX-1/ EP-HCU-1	PetroIneos	S-601 No.2 VDU and HCU heaters (combined)	294619	681378	85.0	3.5	8,760	353.0	14.3	Am³/hr	8.875	1.000	1.000	1.30E+00	2.300	-	-
EP-HCU-2	PetroIneos	Mild Vacuum Column Reboiler (Stack H-370)	294779	681373	70.0	1.5	8,760	378.0	5.1	Am³/hr	0.563	0.300	0.300	1.33E-01	1.300	-	-
EP-HYD-2	PetroIneos	Hydrogen plant heater (Stack S-602)	294717	681542	84.0	4.2	8,760	0.0	6.1	Am³/hr	2.660	0.200	0.200	0.00E+00	0.600	-	-

Source	Group	Description	X	Y	Stack height (m)	Stack internal diameter (m)	Annual Hours of operation	Temp. (°C)	Vol./Mass Flow	Flow/ Mass units	Emissions (g/s)						
											NO_X	PM_{10}	$PM_{2.5}$	SO_2	CO	CH_4	Non-Methane VOCs
EP-SRU-1	PetroIneos	H-50704 Sulphur Recovery Unit 5	294795	681535	70.0	0.9	8,760	775.0	6,480.0	Am³/hr	-	-	-	1.22E-03	-	-	-
EP No.1 Flare	PetroIneos	No.1 Flare	295015	681723	94.5	3.7	8,760	600.0	5,554.8	Am³/hr	0.222	-	-	0.285	-	-	-
EP-FLARE-3	PetroIneos	No.3 Flare	294857	681451	96.0	4.8	8,760	600.0	6,732.0	Am³/hr	1.078	-	-	23.973	-	-	-
EP-PG-8	2018 Ineos Data	Boiler 8	294561	681217	65.0	2.7	7,921	136.0	118,344.0	Am³/hr	3.338	0.005	0.005	1.41E-02	0.159	-	-
EP-PG-1	2018 Ineos Data	Boiler 9 (combine with 10 in. AAI)	294634	681158	91.0	3.1	6,584	162.0	158,793.0	Am³/hr	5.016	0.016	0.016	6.78E-02	0.009	-	-
EP-PG-2	2018 Ineos Data	Boiler 10 (combine with 9 in. AAI)	294634	681158	91.0	3.1	7,942	166.0	164,719.0	Am³/hr	5.554	0.032	0.032	1.02E+00	0.012	-	-
EP-PG-6-East	2018 Ineos Data	Boiler 14 (common stack 14 &15 combined in. AAI)	294725	681117	91.0	2.4	5,689	195.0	243,312.0	Am³/hr	3.925	0.087	0.087	2.05E+00	-	-	-
EP-PG-6-West	2018 Ineos Data	Boiler 14 (common stack 14 &15 combined in. AAI)	294725	681117	91.0	2.4	5,689	200.0	243,704.0	Am³/hr	3.996	0.101	0.101	2.79E+00	-	-	-
CHP	2018 Ineos Data	CHP (Emission point A)	294449	681130	65.0	5.3	8,355	104.9	1,985,565.1	Am³/hr	8.930981466	0.002787449	0.002787449	0.946629597	0.220779427	-	-

Peak Operation Parameters for Flare Sources only

Source	Group	Description	X	Y	Stack height (m)	Stack internal diameter (m)	Annual Hours of operation	Temp. (°C)	Vol./Mass Flow	Flow/ Mass units	Emissions (g/s)						
											NO_x	PM_{10}	$PM_{2.5}$	SO_2	CO	CH_4	Non-Methane VOCs
EP-KG-1 Peak	Ineos KG	KG Flare A Worst Case for maximum 0.25 hour	294699	680262	91.5	1.0	0.25	699.9	1,253,503.1	Am³/hr	235.000	-	-	-	216.667	20.833	250.000
EP-KG-2 Peak	Ineos KG	KG Flare B Worst Case for maximum 0.25 hour	294753	680114	91.5	1.0	0.25	699.9	1,253,503.1	Am³/hr	235.000	-	-	-	216.667	20.833	250.000
EP-KG-3 Peak	Ineos KG	KG Ground Flare Worst Case for maximum 0.25 hour	294845	680149	25.9	13.6	0.25	699.9	628,139.8	Am³/hr	117.500	-	-	-	108.333	11.111	138.889
A13-16 (Stack 10) Peak	Ineos FPS	Train 3 Ground Flares Peak	295878	680796	12.0	10.5	8,760	450.0	0.5	kg/s	-	-	-	6.80E-01	-	-	-
A12 (Stack 11) Peak	Ineos FPS	Trains 1&2 Elevated Flare Peak	295724	680760	45.0	1.2	7,392	450.0	0.5	kg/s	-	-	-	6.80E-01	-	-	-
A17 (Stack 12) Peak	Ineos FPS	Train 3 Elevated Flare Peak	296008	680803	88.0	1.2	8,760	450.0	0.5	kg/s	-	-	-	6.80E-01	-	-	-
A19 (Stack 13) Peak	Ineos FPS	RLPG Ground Flares Peak	294518	683690	12.0	7.2	8,760	450.0	1,629.0	Am³/h	0.479	-	-	6.80E-01	1.675	-	7.978
EP-FLARE-3 Peak	PetroIneos	No.3 Flare SO_2 peak	294857	681451	96.4	4.8	8,760	600.0	676,732.032.0	Am³/hr	1.078	-	-	57.870	-	-	-

Appendix B

1-hour and 24-hour results

1-hour Mean Objective at Receptors

Normal Operation

The 1-hour mean objective of 350 µg/m³ is not predicted to be exceeded at any of the representative human receptors with the Grangemouth plant operating under normal conditions. A summary of the modelling results is provided in Table 6.1 and Table 6.3.

The spatial distribution of the predicted concentrations is also provided in Figure 6.1 and Figure 6.3.

Peak Operation

The results of the modelling indicate that there is the potential for exceedance of the 1-hour mean objective. However, it is not predicted to be exceeded on more than the 24 permitted occasions under this Peak Operation scenario.

Some 1-hour exceedances are predicted to occur in the Kersiebank area of Grangemouth as shown in Figure 6.5. Figure 6.4 shows the maximum predicted 1-hour mean concentrations which peak at over 200% of the objective with the dispersion model operating with the 2017 meteorological dataset.

Table 6.1 Top 10 SO_2 Predictions – Normal Operation, 1-hour, 99.73th percentile

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor
1	82.5	85.3	Oil refinery	70.2	73.0	Bo'ness Road 1	68.3	71.2	Oil refinery	66.7	69.5	Bo'ness Road 1	81.3	84.1	Oil refinery
2	69.5	72.3	Bo`ness road	69.9	72.7	Bo`ness road	59.9	62.7	Bo'ness Road 1	66.5	69.3	Bo`ness road	69.3	72.1	Bo'ness Road 1
3	69.4	72.2	Bo'ness Road 1	68.1	70.9	Oil refinery	58.7	61.5	Bo`ness road	62.3	65.1	Oil refinery	67.9	70.7	Bo`ness road
4	54.0	56.9	Bo'ness Road 2	59.7	62.5	Inchyra AQU	54.8	57.6	Inchyra AQU	58.0	60.8	Inchyra AQU	59.8	62.6	Inchyra AQU
5	53.1	56.0	Inchyra AQU	52.2	55.0	Bo'ness Road 2	48.8	51.7	Wholeflats	49.9	52.7	Bo'ness Road 2	49.9	52.7	Bo'ness Road 2
6	48.8	51.6	Albert Avenue	48.3	51.2	Moray AQU	47.7	50.5	Bo'ness Road 2	43.8	46.7	Albert Avenue	48.3	51.1	Albert Avenue
7	47.3	50.2	Moray AQU	44.3	47.1	Albert Avenue	45.0	47.8	Reddoch Road	43.2	46.0	Bo'ness Road 3	47.0	49.8	Moray AQU
8	47.1	49.9	Elizabeth Avenue	44.2	47.0	Elizabeth Avenue	42.5	45.3	Moray AQU	42.9	45.7	Moray AQU	43.5	46.3	Wholeflats
9	46.2	49.0	Bo'ness Road 3	42.4	45.2	Grangemouth Stadium	42.4	45.2	Albert Avenue	42.7	45.5	Merrick Road 1	43.0	45.8	Grangemouth Stadium
10	43.2	46.0	Wholeflats	41.1	44.0	Wholeflats	39.4	42.2	Grangemouth Stadium	41.7	44.5	Grangemouth Stadium	42.8	45.6	Elizabeth Avenue

Figure 6.1 Predictions for SO2, 1-hour, 99.73rd Percentile, Normal Operation

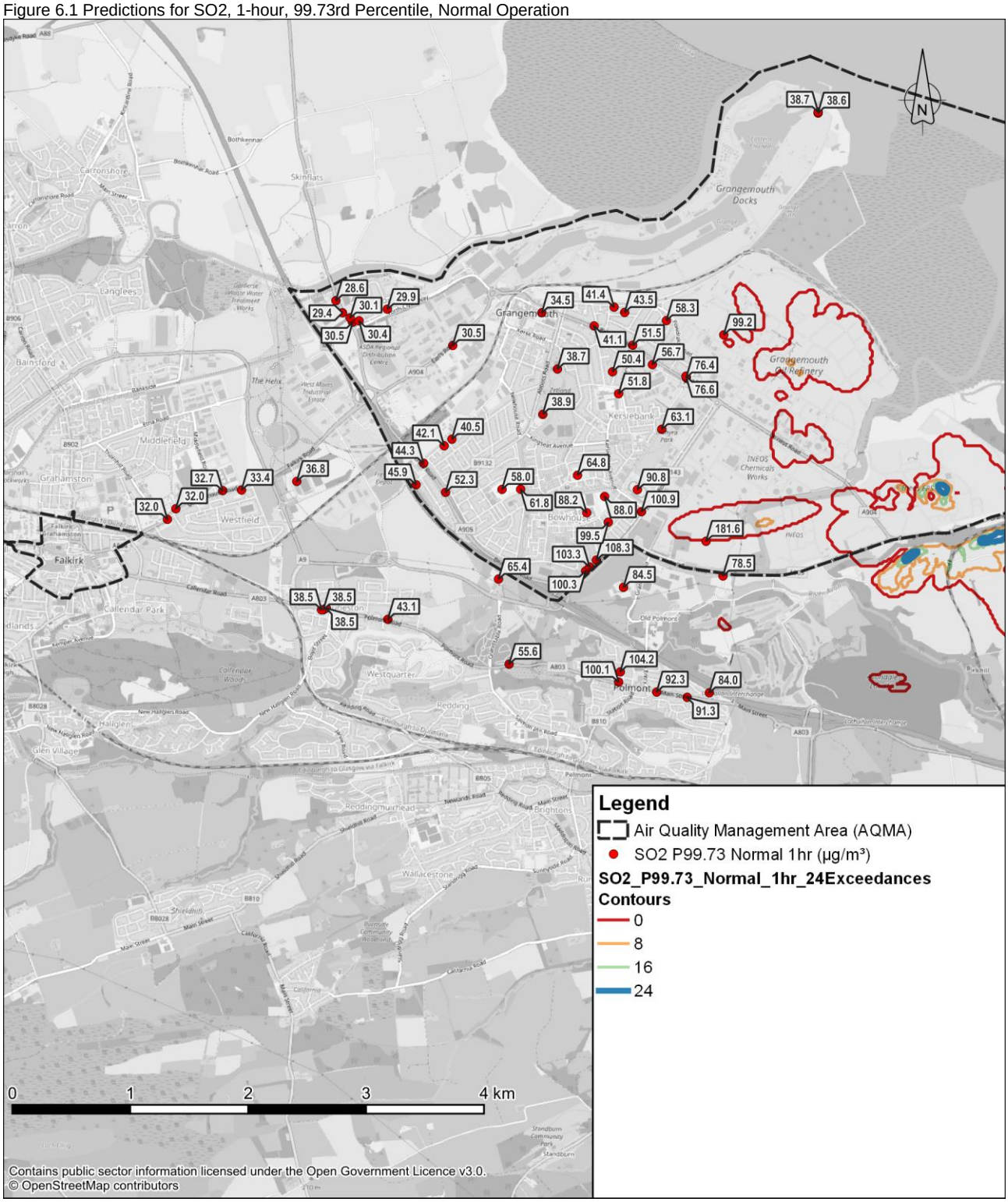


Table 6.2 Top 10 SO_2 Predictions – Normal Operation, 1-hour, 100th percentile.

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor
1	181.5	184.4	Inchyra AQU	197.7	200.5	Albert Avenue	273.2	276.0	Oil refinery	211.2	214.0	Bo`ness road	229.8	232.6	Inchyra AQU
2	174.8	177.7	Bo'ness Road 2	196.6	199.4	Inchyra AQU	212.2	215.0	Inchyra AQU	208.5	211.3	Bo'ness Road 1	214.7	217.5	Bo'ness Road 1
3	174.4	177.2	Elizabeth Avenue	192.2	195.0	Bo'ness Road 1	191.9	194.7	Bo'ness Road 3	204.8	207.6	Wholeflats	213.0	215.8	Wholeflats
4	168.8	171.6	Bo'ness Road 1	191.7	194.5	Bo`ness road	191.4	194.2	Bo'ness Road 2	186.7	189.6	Bo'ness Road 2	208.5	211.4	Bo`ness road
5	167.0	169.8	Bo`ness road	186.1	188.9	Grangemouth Stadium	187.2	190.0	Albert Avenue	163.1	165.9	Reddoch Road	204.0	206.8	Bo'ness Road 2
6	164.7	167.5	Moray AQU	170.3	173.1	Merrick Road 1	168.4	171.2	Reddoch Road	160.2	163.0	Oil refinery	193.9	196.7	Bo'ness Road 3
7	159.9	162.7	Albert Avenue	164.4	167.2	Wholeflats	167.9	170.7	Wholeflats	157.6	160.4	Bowhouse Primary	189.4	192.2	Albert Avenue
8	157.8	160.6	Bo'ness Road 3	162.1	164.9	Bo'ness Road 2	153.3	156.2	Bo`ness road	154.6	157.4	Grangemouth Stadium	172.8	175.6	Roxburgh St
9	156.6	159.4	Grangemouth Stadium	160.4	163.2	Cheviot Place	151.7	154.5	103 Bo'ness Road	149.0	151.9	Albert Avenue	161.1	163.9	Grangeburn Road
10	151.6	154.4	Oil refinery	159.3	162.1	Roxburgh St	146.0	148.8	Bo'ness Road 1	148.6	151.4	Elizabeth Avenue	158.9	161.7	Reddoch Road

Figure 6.2 Predictions for SO2, 1-hour, 100th Percentile, Normal Operation

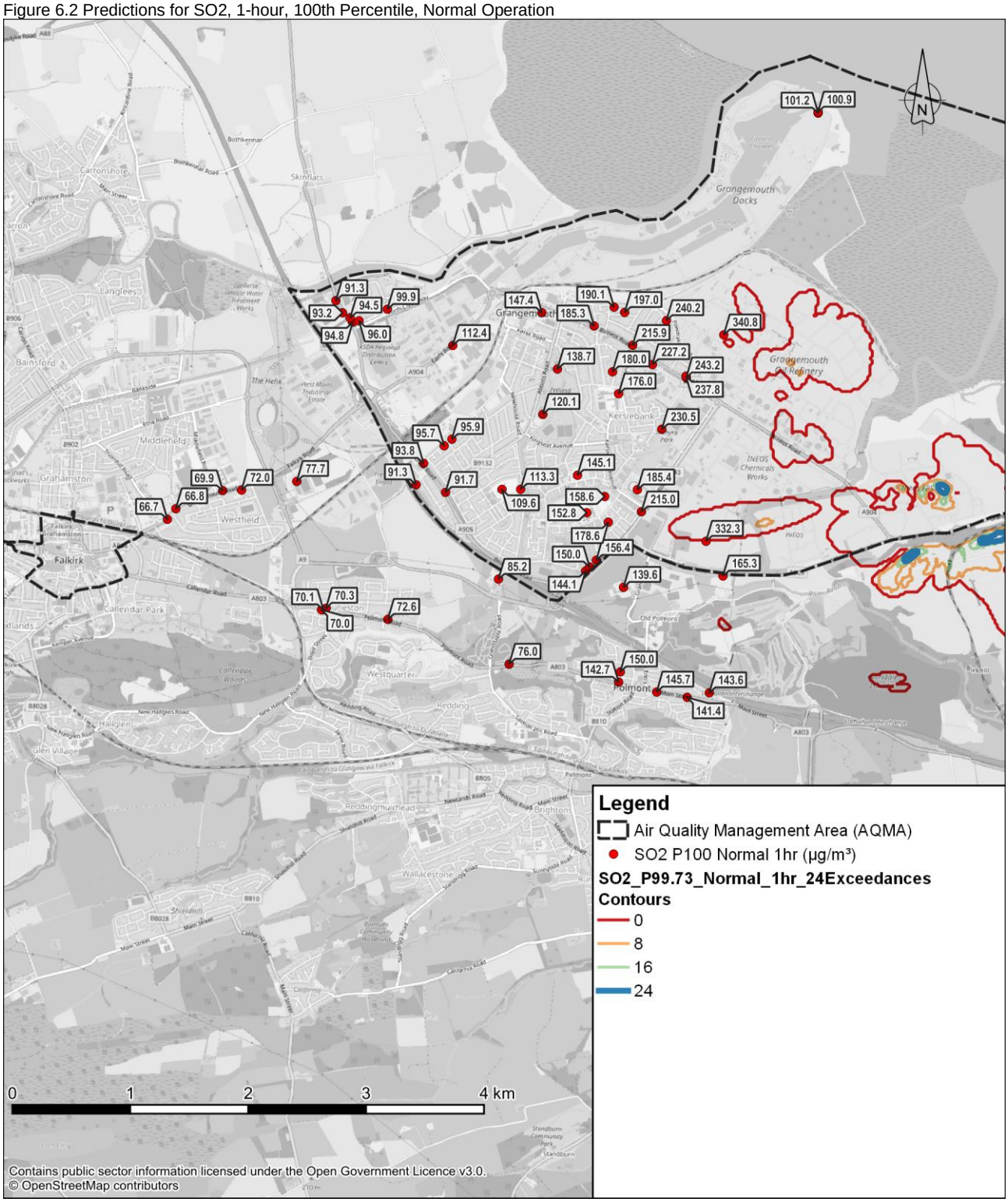


Table 6.3 Top 10 SO_2 Predictions – Peak A Operation, 1-hour, 99.73rd percentile

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor
1	181.6	184.4	Oil refinery	153.6	156.4	Bo'ness Road 1	138.2	141.0	Oil refinery	149.6	152.4	Bo'ness Road 1	174.4	177.2	Oil refinery
2	154.1	156.9	Bo`ness road	153.6	156.4	Bo`ness road	131.1	134.0	Bo'ness Road 1	147.2	150.0	Bo`ness road	151.7	154.6	Bo'ness Road 1
3	151.7	154.5	Bo'ness Road 1	140.8	143.6	Oil refinery	127.2	130.0	Bo`ness road	126.6	129.5	Oil refinery	151.7	154.5	Bo`ness road
4	117.8	120.6	Inchyra AQU	128.4	131.3	Inchyra AQU	116.5	119.4	Inchyra AQU	121.6	124.4	Inchyra AQU	129.4	132.2	Inchyra AQU
5	114.4	117.2	Bo'ness Road 2	112.9	115.8	Bo'ness Road 2	106.2	109.0	Wholeflats	108.1	110.9	Bo'ness Road 2	108.7	111.5	Bo'ness Road 2
6	106.1	108.9	Albert Avenue	103.0	105.8	Moray AQU	100.2	103.0	Bo'ness Road 2	94.4	97.2	Albert Avenue	100.9	103.7	Moray AQU
7	104.6	107.4	Moray AQU	97.3	100.1	Elizabeth Avenue	97.7	100.5	Reddoch Road	93.5	96.3	Docks East	100.0	102.8	Albert Avenue
8	100.2	103.0	Bo'ness Road 3	93.8	96.7	Albert Avenue	92.5	95.3	Moray AQU	91.9	94.7	Moray AQU	93.6	96.4	Grangemouth Stadium
9	98.6	101.4	Elizabeth Avenue	93.5	96.3	Grangemouth Stadium	91.5	94.3	Albert Avenue	91.8	94.6	Merrick Road 1	92.1	94.9	Wholeflats
10	93.1	95.9	Wholeflats	88.1	90.9	Wholeflats	84.6	87.4	Grangemouth Stadium	90.1	92.9	Bo'ness Road 3	90.9	93.7	Elizabeth Avenue

Figure 6.3 Predictions for SO2, 1-hour, 99.73rd Percentile, Peak A Operation

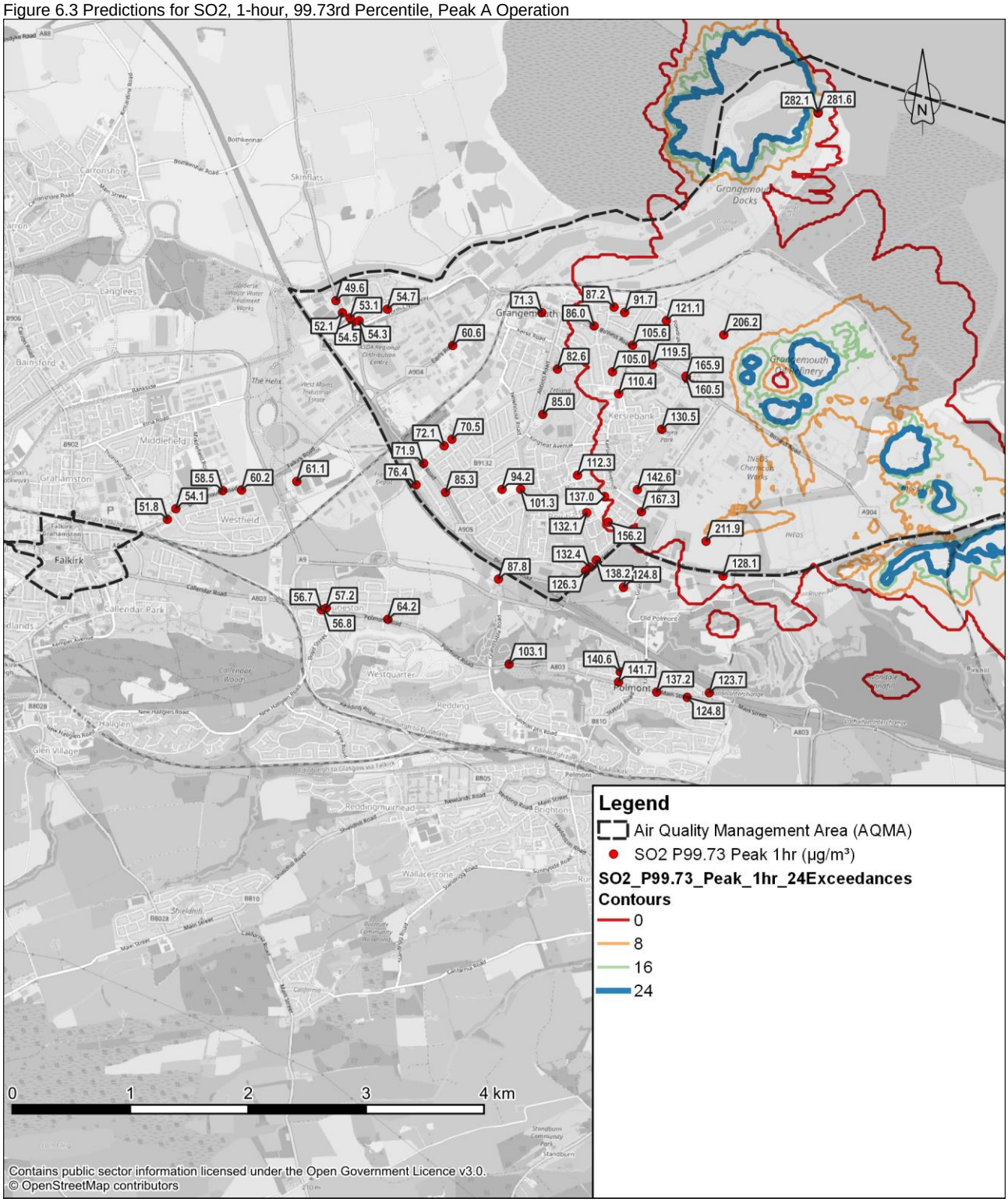


Table 6.4 Top 10 SO_2 Predictions – Peak A Operation, 1-hour, 100th percentile.

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor
1	394.9	397.7	Inchyra AQU	432.1	434.9	Albert Avenue	608.8	611.7	Oil refinery	471.3	474.1	Bo`ness road	501.9	504.7	Inchyra AQU
2	381.0	383.8	Elizabeth Avenue	430.2	433.0	Inchyra AQU	470.5	473.4	Inchyra AQU	465.1	467.9	Bo'ness Road 1	475.3	478.1	Wholeflats
3	376.5	379.3	Bo'ness Road 2	427.1	429.9	Bo'ness Road 1	422.1	424.9	Bo'ness Road 2	452.9	455.8	Wholeflats	472.6	475.5	Bo'ness Road 1
4	364.9	367.7	Bo'ness Road 1	425.8	428.6	Bo`ness road	420.5	423.3	Bo'ness Road 3	414.6	417.4	Bo'ness Road 2	458.3	461.1	Bo`ness road
5	364.9	367.7	Moray AQU	408.2	411.0	Grangemouth Stadium	411.8	414.6	Albert Avenue	372.0	374.8	Reddoch Road	447.9	450.8	Bo'ness Road 2
6	361.1	363.9	Bo`ness road	385.9	388.7	Merrick Road 1	376.7	379.5	Reddoch Road	351.6	354.4	Bowhouse Primary	420.7	423.5	Bo'ness Road 3
7	349.8	352.6	Albert Avenue	370.3	373.1	Wholeflats	370.7	373.5	Wholeflats	351.6	354.4	Grangemouth Stadium	399.9	402.7	Albert Avenue
8	346.3	349.1	Bo'ness Road 3	357.2	360.0	Cheviot Place	328.8	331.6	103 Bo'ness Road	345.7	348.5	Oil refinery	371.0	373.8	Roxburgh St
9	341.1	343.9	Grangemouth Stadium	356.5	359.3	Bo'ness Road 2	325.4	328.2	Bo`ness road	327.1	329.9	Elizabeth Avenue	365.2	368.1	Reddoch Road
10	338.6	341.5	Wholeflats	350.2	353.0	Roxburgh St	314.7	317.5	Elizabeth Avenue	316.8	319.6	Grangemouth High	344.7	347.6	Grangeburn Road

Figure 6.4 Predictions for SO2, 1-hour, 100th Percentile, Peak A Operation

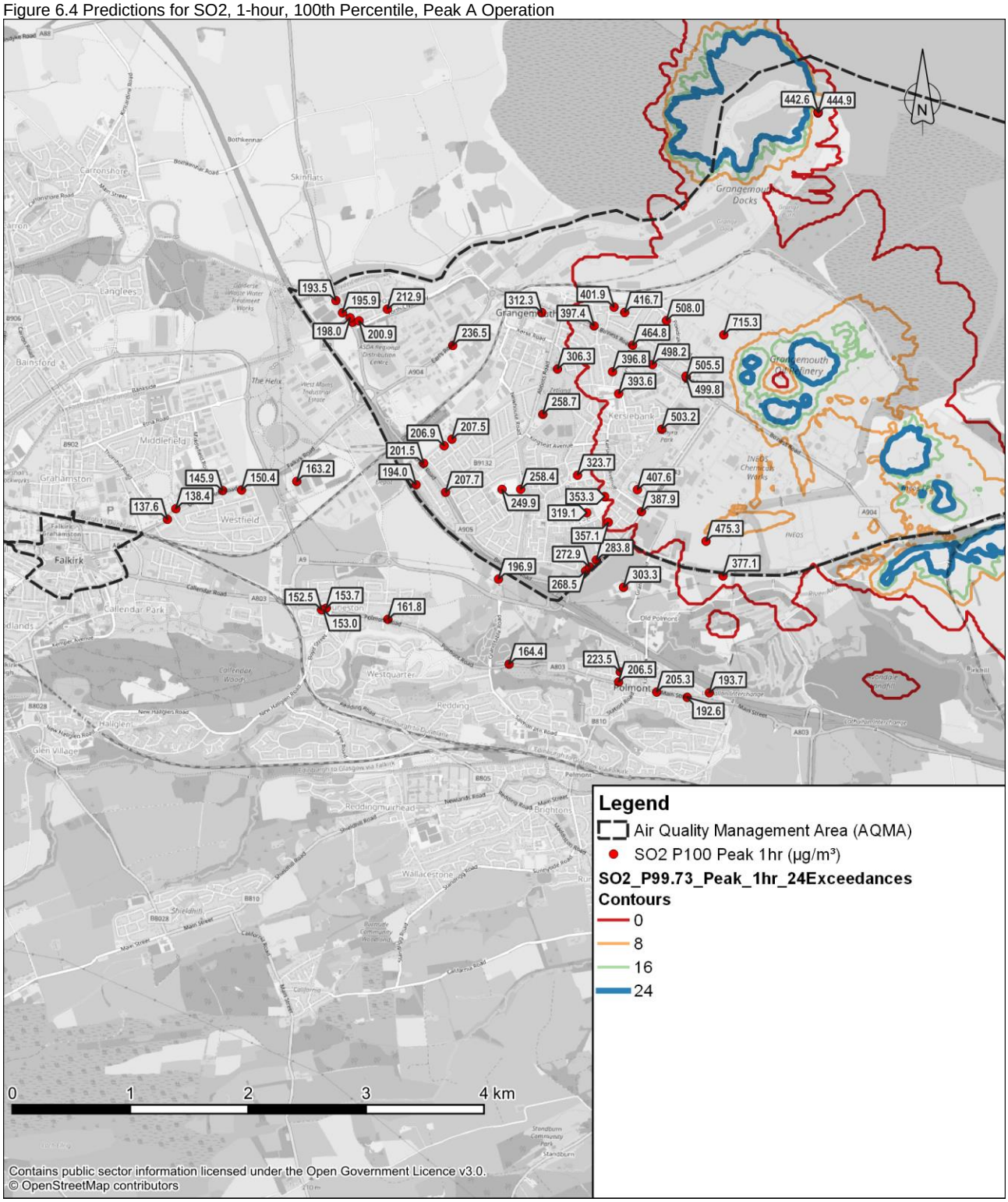


Table 6.5 Top 10 SO_2 Exceedances – Peak A Operation, 1-hour.

Rank	2015		2016		2017		2018		2019	
	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor
1	2	Inchyra AQU	2	Bo'ness Road 2	3	Inchyra AQU	1	Bo'ness Road 1	3	Inchyra AQU
2	1	Bo'ness Road 1	1	Bo'ness Road 1	2	Wholeflats	1	Bo'ness Road 2	2	Bo'ness Road 1
3	1	Bo'ness Road 2	1	Inchyra AQU	2	Oil refinery	1	Wholeflats	2	Bo'ness Road 3
4	1	Moray AQU	1	Wholeflats	1	Bo'ness Road 2	1	Grangemouth Stadium	2	Bo`ness road
5	1	Bo`ness road	1	Grangemouth Stadium	1	Bo'ness Road 3	1	Bowhouse Primary	1	Bo'ness Road 2
6	1	Elizabeth Avenue	1	Roxburgh St	1	Albert Avenue	1	Bo`ness road	1	Wholeflats
7	0	NA21	1	Bo`ness road	1	Reddoch Road	1	Reddoch Road	1	Roxburgh St
8	0	NA51	1	Albert Avenue	0	NA21	0	NA21	1	Albert Avenue
9	0	NA94	1	Cheviot Place	0	NA51	0	NA51	1	Reddoch Road
10	0	NA101	1	Merrick Road 1	0	NA94	0	NA94	0	NA21

Figure 6.5 Predictions for SO2, 1-hour Exceedances, Peak A Operation

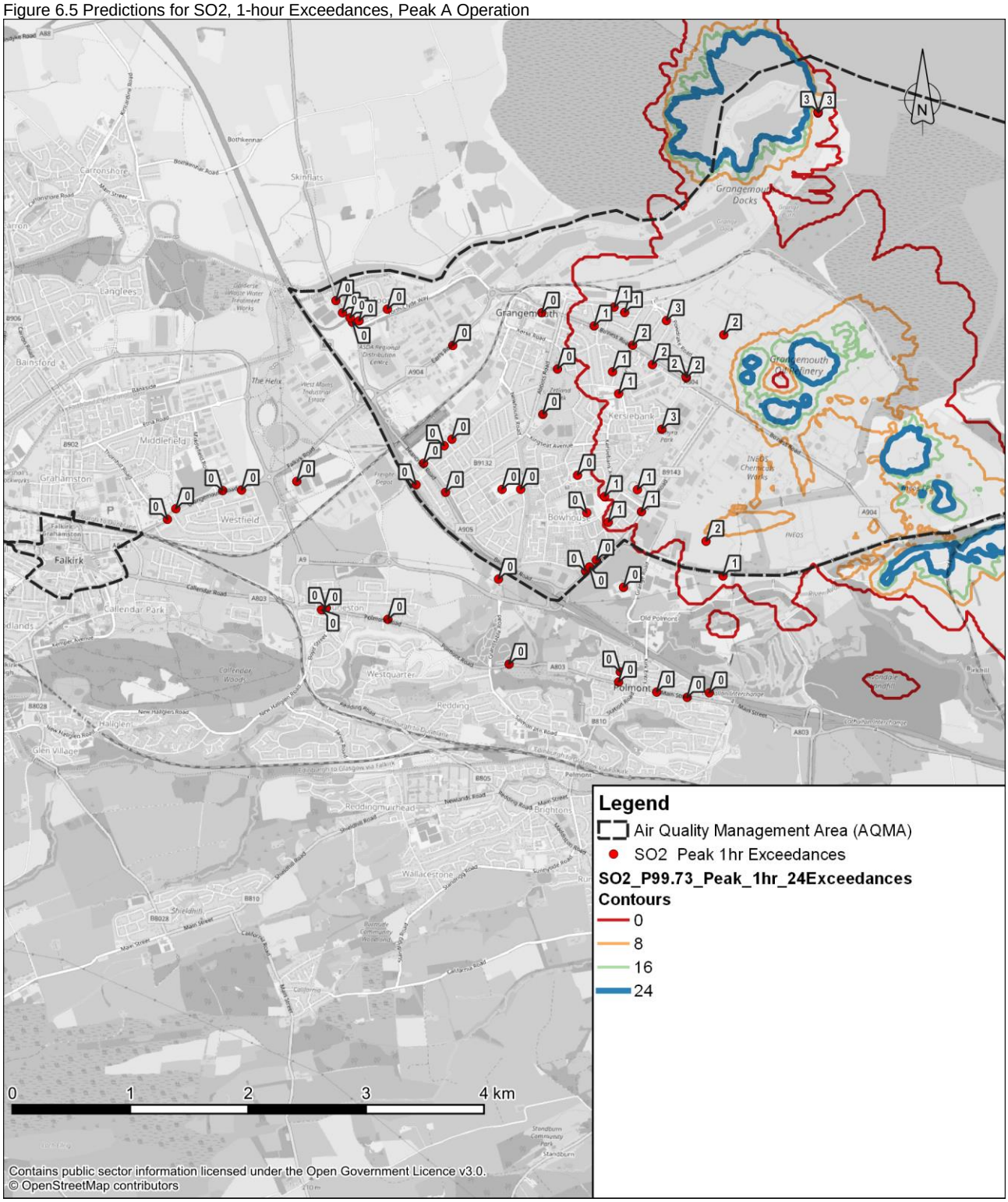


Table 6.6 Top 10 SO_2 Predictions – Peak B Operation, 1-hour, 99.73rd percentile

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor
1	181.6	184.4	Oil refinery	153.6	156.4	Bo'ness Road 1	138.2	141.0	Oil refinery	149.6	152.4	Bo'ness Road 1	174.4	177.2	Oil refinery
2	154.1	156.9	Bo`ness road	153.6	156.4	Bo`ness road	131.1	134.0	Bo'ness Road 1	147.2	150.0	Bo`ness road	151.7	154.6	Bo'ness Road 1
3	151.7	154.5	Bo'ness Road 1	140.8	143.6	Oil refinery	127.2	130.0	Bo`ness road	126.6	129.5	Oil refinery	151.7	154.5	Bo`ness road
4	117.8	120.6	Inchyra AQU	128.4	131.3	Inchyra AQU	116.5	119.4	Inchyra AQU	121.6	124.4	Inchyra AQU	129.4	132.2	Inchyra AQU
5	114.4	117.2	Bo'ness Road 2	112.9	115.8	Bo'ness Road 2	106.2	109.0	Wholeflats	108.1	110.9	Bo'ness Road 2	108.7	111.5	Bo'ness Road 2
6	106.1	108.9	Albert Avenue	103.0	105.8	Moray AQU	100.2	103.0	Bo'ness Road 2	94.4	97.2	Albert Avenue	100.9	103.7	Moray AQU
7	104.6	107.4	Moray AQU	97.3	100.1	Elizabeth Avenue	97.7	100.5	Reddoch Road	93.5	96.3	Docks East	100.0	102.8	Albert Avenue
8	100.2	103.0	Bo'ness Road 3	93.8	96.7	Albert Avenue	92.5	95.3	Moray AQU	91.9	94.7	Moray AQU	93.6	96.4	Grangemouth Stadium
9	98.6	101.4	Elizabeth Avenue	93.5	96.3	Grangemouth Stadium	91.5	94.3	Albert Avenue	91.8	94.6	Merrick Road 1	92.1	94.9	Wholeflats
10	93.1	95.9	Wholeflats	88.1	90.9	Wholeflats	84.6	87.4	Grangemouth Stadium	90.1	92.9	Bo'ness Road 3	90.9	93.7	Elizabeth Avenue

Figure 6.6 Predictions for SO2, 1-hour, 99.73rd Percentile, Peak B Operation

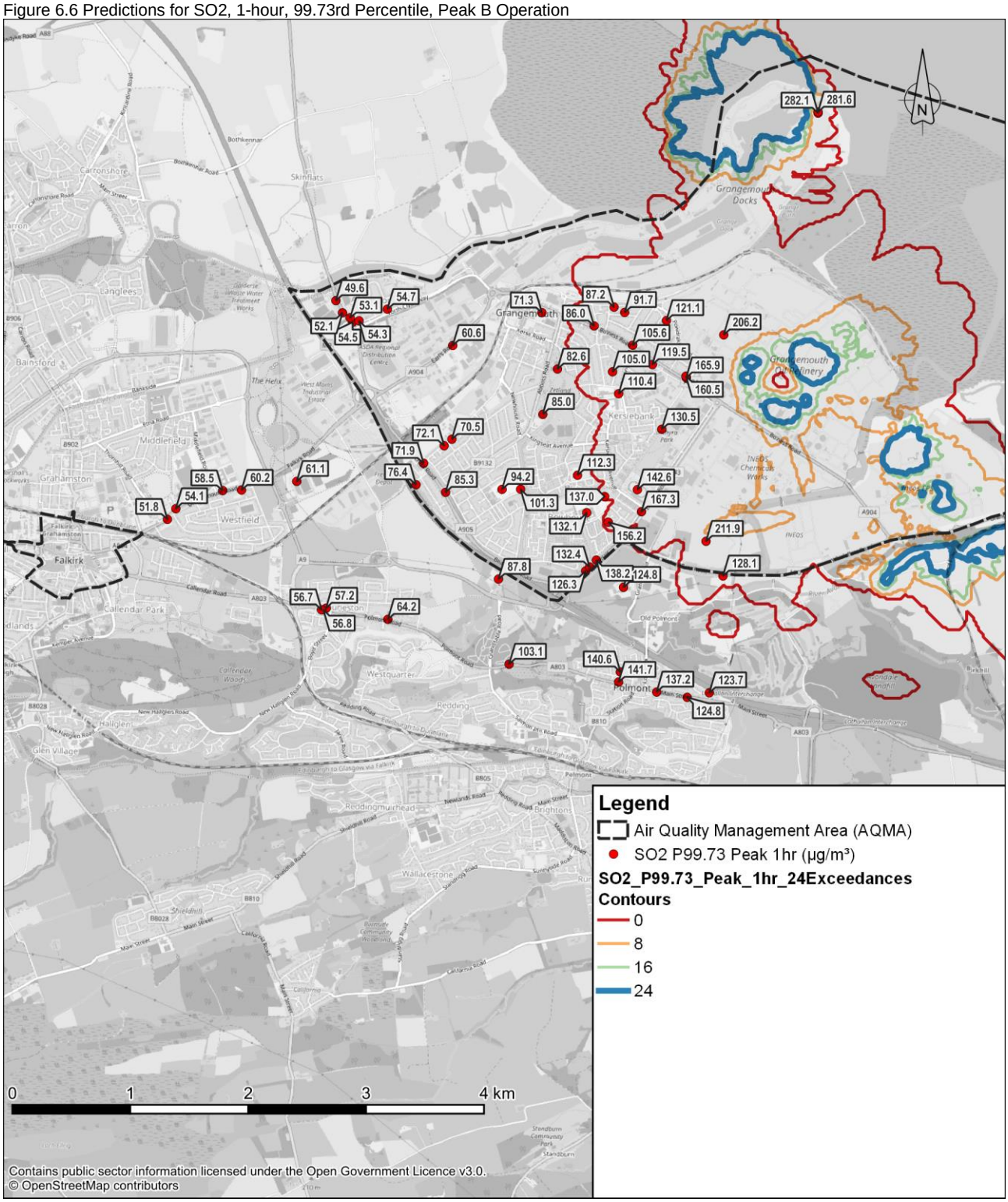


Table 6.7 Top 10 SO_2 Predictions – Peak B Operation, 1-hour, 100th percentile

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor
1	394.9	397.7	Inchyra AQU	432.1	434.9	Albert Avenue	608.8	611.7	Oil refinery	471.3	474.1	Bo`ness road	501.9	504.7	Inchyra AQU
2	381.0	383.8	Elizabeth Avenue	430.2	433.0	Inchyra AQU	470.5	473.4	Inchyra AQU	465.1	467.9	Bo'ness Road 1	475.3	478.1	Wholeflats
3	376.5	379.3	Bo'ness Road 2	427.1	429.9	Bo'ness Road 1	422.1	424.9	Bo'ness Road 2	452.9	455.8	Wholeflats	472.6	475.5	Bo'ness Road 1
4	364.9	367.7	Bo'ness Road 1	425.8	428.6	Bo`ness road	420.5	423.3	Bo'ness Road 3	414.6	417.4	Bo'ness Road 2	458.3	461.1	Bo`ness road
5	364.9	367.7	Moray AQU	408.2	411.0	Grangemouth Stadium	411.8	414.6	Albert Avenue	372.0	374.8	Reddoch Road	447.9	450.8	Bo'ness Road 2
6	361.1	363.9	Bo`ness road	385.9	388.7	Merrick Road 1	376.7	379.5	Reddoch Road	351.6	354.4	Bowhouse Primary	420.7	423.5	Bo'ness Road 3
7	349.8	352.6	Albert Avenue	370.3	373.1	Wholeflats	370.7	373.5	Wholeflats	351.6	354.4	Grangemouth Stadium	399.9	402.7	Albert Avenue
8	346.3	349.1	Bo'ness Road 3	357.2	360.0	Cheviot Place	328.8	331.6	103 Bo'ness Road	345.7	348.5	Oil refinery	371.0	373.8	Roxburgh St
9	341.1	343.9	Grangemouth Stadium	356.5	359.3	Bo'ness Road 2	325.4	328.2	Bo`ness road	327.1	329.9	Elizabeth Avenue	365.2	368.1	Reddoch Road
10	338.6	341.5	Wholeflats	350.2	353.0	Roxburgh St	314.7	317.5	Elizabeth Avenue	316.8	319.6	Grangemouth High	344.7	347.6	Grangeburn Road

Figure 6.7 Predictions for SO2, 1-hour, 100th Percentile, Peak B Operation

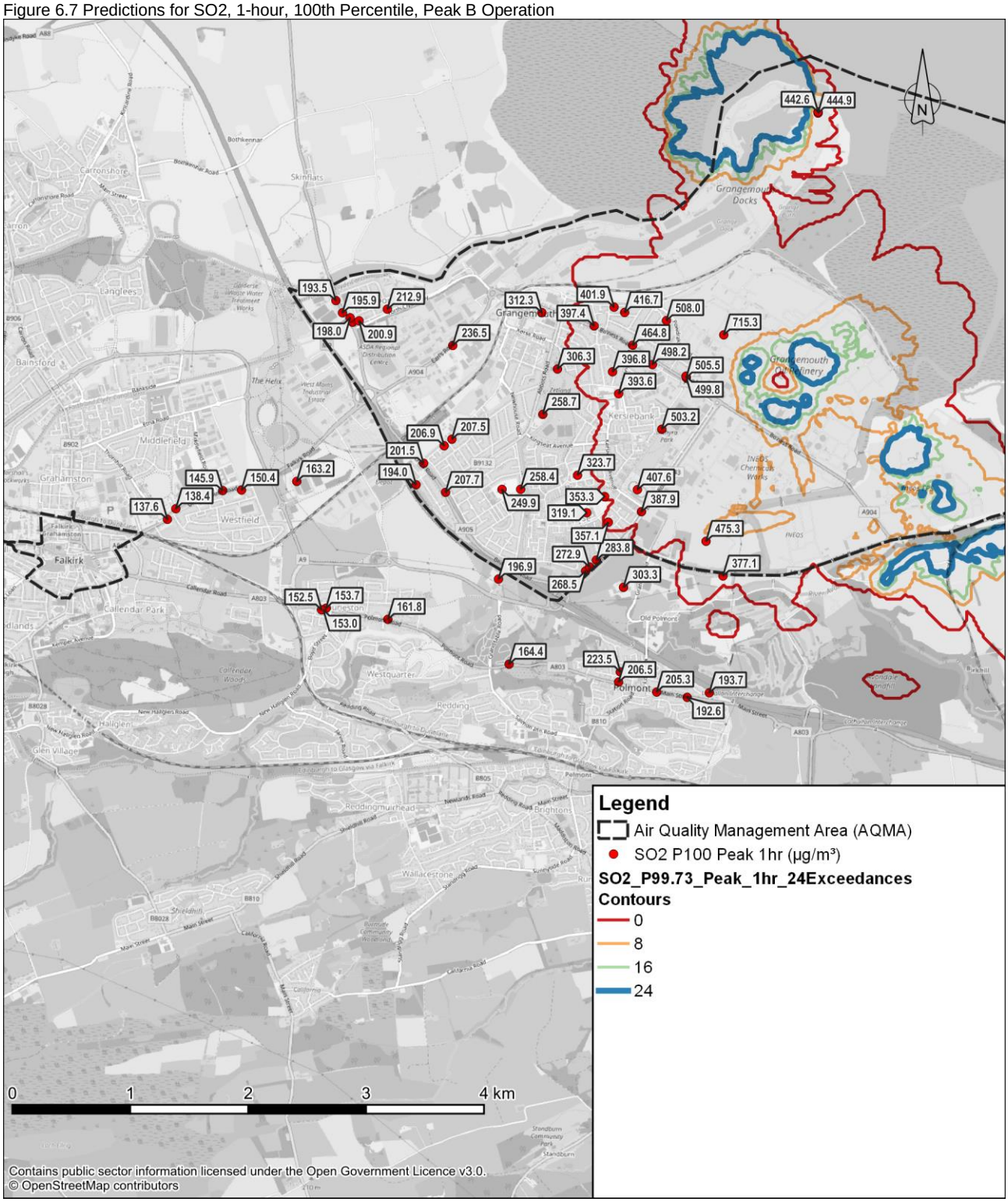
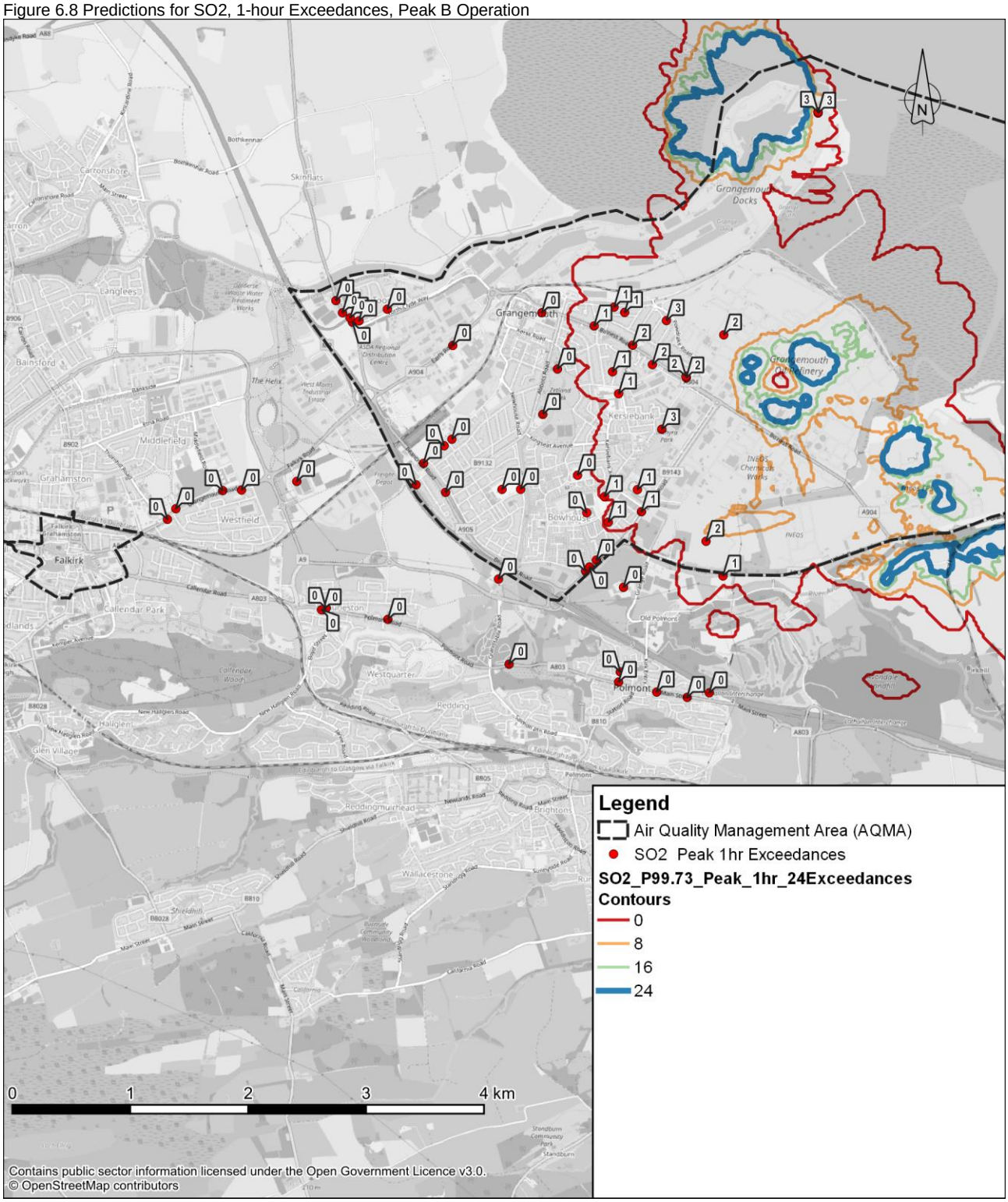


Table 6.8 Top 10 SO_2 Exceedances – Peak B Operation, 1-hour.

Rank	2015		2016		2017		2018		2019	
	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor	No. Exceedances	Receptor
1	2	Inchyra AQU	2	Bo'ness Road 2	3	Inchyra AQU	1	Bo'ness Road 1	3	Inchyra AQU
2	1	Bo'ness Road 1	1	Bo'ness Road 1	2	Wholeflats	1	Bo'ness Road 2	2	Bo'ness Road 1
3	1	Bo'ness Road 2	1	Inchyra AQU	2	Oil refinery	1	Wholeflats	2	Bo'ness Road 3
4	1	Moray AQU	1	Wholeflats	1	Bo'ness Road 2	1	Grangemouth Stadium	2	Bo`ness road
5	1	Bo`ness road	1	Grangemouth Stadium	1	Bo'ness Road 3	1	Bowhouse Primary	1	Bo'ness Road 2
6	1	Elizabeth Avenue	1	Roxburgh St	1	Albert Avenue	1	Bo`ness road	1	Wholeflats
7	0	NA21	1	Bo`ness road	1	Reddoch Road	1	Reddoch Road	1	Roxburgh St
8	0	NA51	1	Albert Avenue	0	NA21	0	NA21	1	Albert Avenue
9	0	NA94	1	Cheviot Place	0	NA51	0	NA51	1	Reddoch Road
10	0	NA101	1	Merrick Road 1	0	NA94	0	NA94	0	NA21

Figure 6.8 Predictions for SO2, 1-hour Exceedances, Peak B Operation



1-hour Mean Objective Gridded Results

Normal Operation

Against the 1-hour objective under the Normal Operation scenario, Figure 6.9 and Figure 6.10 show that the 1-hour objective of 350 µg/m³ is unlikely to be exceeded where the human population is located. Figure 6.10 shows the 100th percentile peak concentrations limited to areas within the Grangemouth industrial facilities.

Peak Operation

Figure 6.11, Figure 6.12, Figure 6.13 and Figure 6.14, representing the Peak Operation scenarios show that there is the possibility for predicted exceedances of the 1-hour objective of 350 µg/m³ over inhabited areas in the east of Grangemouth as far as Zetland Park and the Grangemouth Municipal Chambers, however the predicted exceedances are on less than the permitted 24 occasions per year, and it is emphasised that the Peak Operation scenario involves simultaneous flaring, which is highly unlikely to occur.

Figure 6.9 Gridded Predictions for SO2, 1-hour, 99.73rd Percentile, Normal Operation

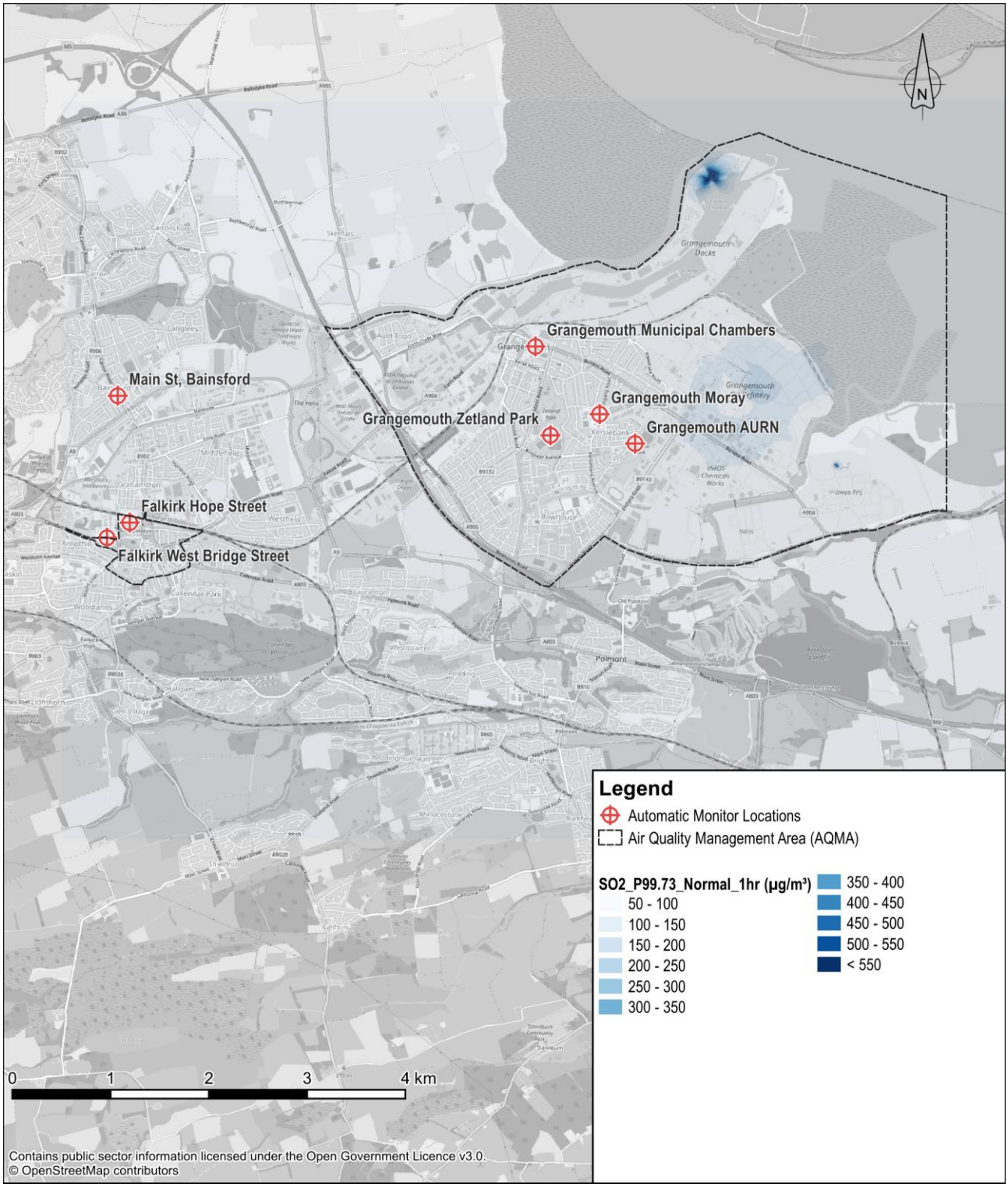


Figure 6.10 Gridded Predictions for SO2, 1-hour, 100th Percentile, Normal Operation

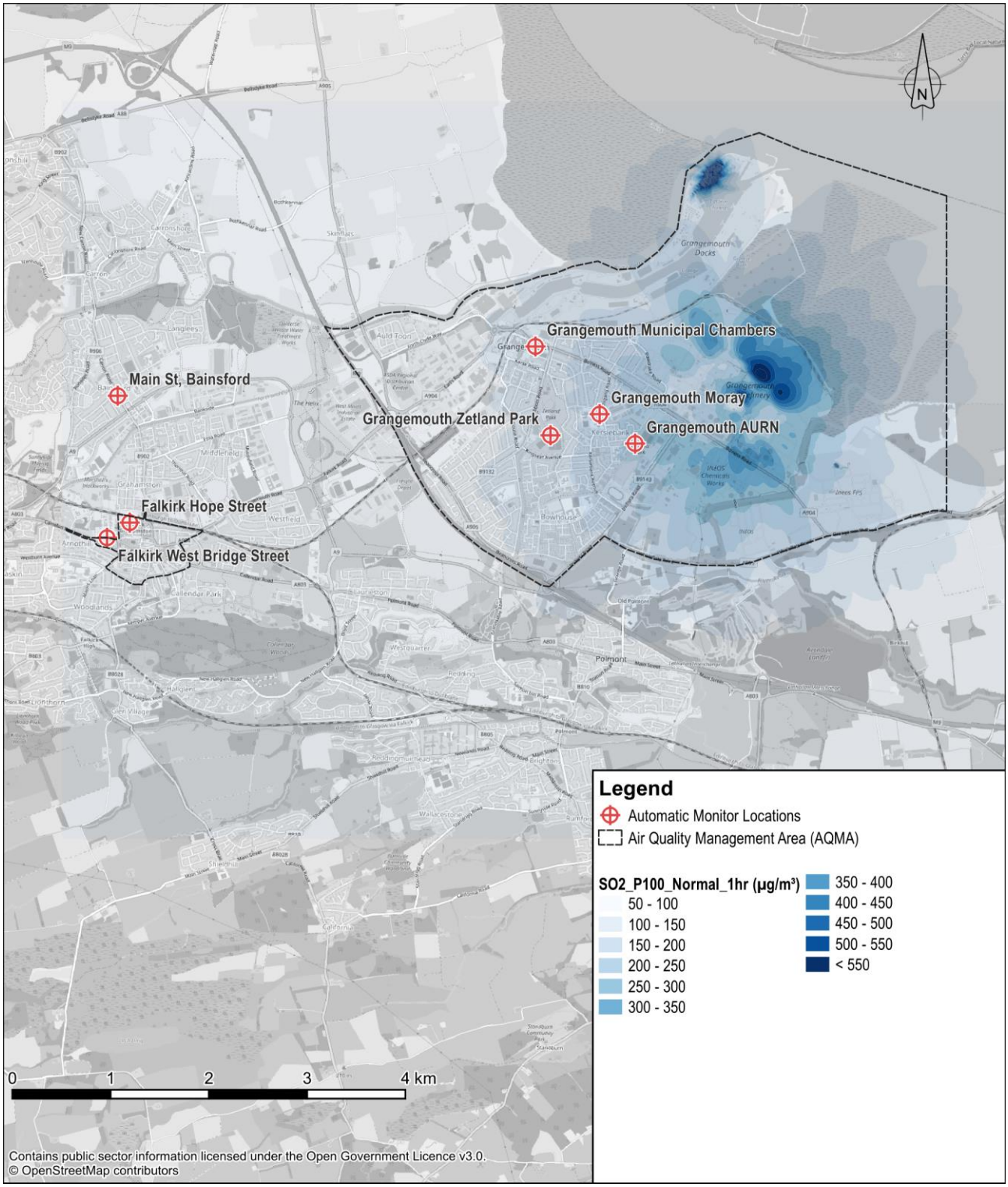


Figure 6.11 Gridded Predictions for SO2, 1-hour, 99.73rd Percentile, Peak A Operation

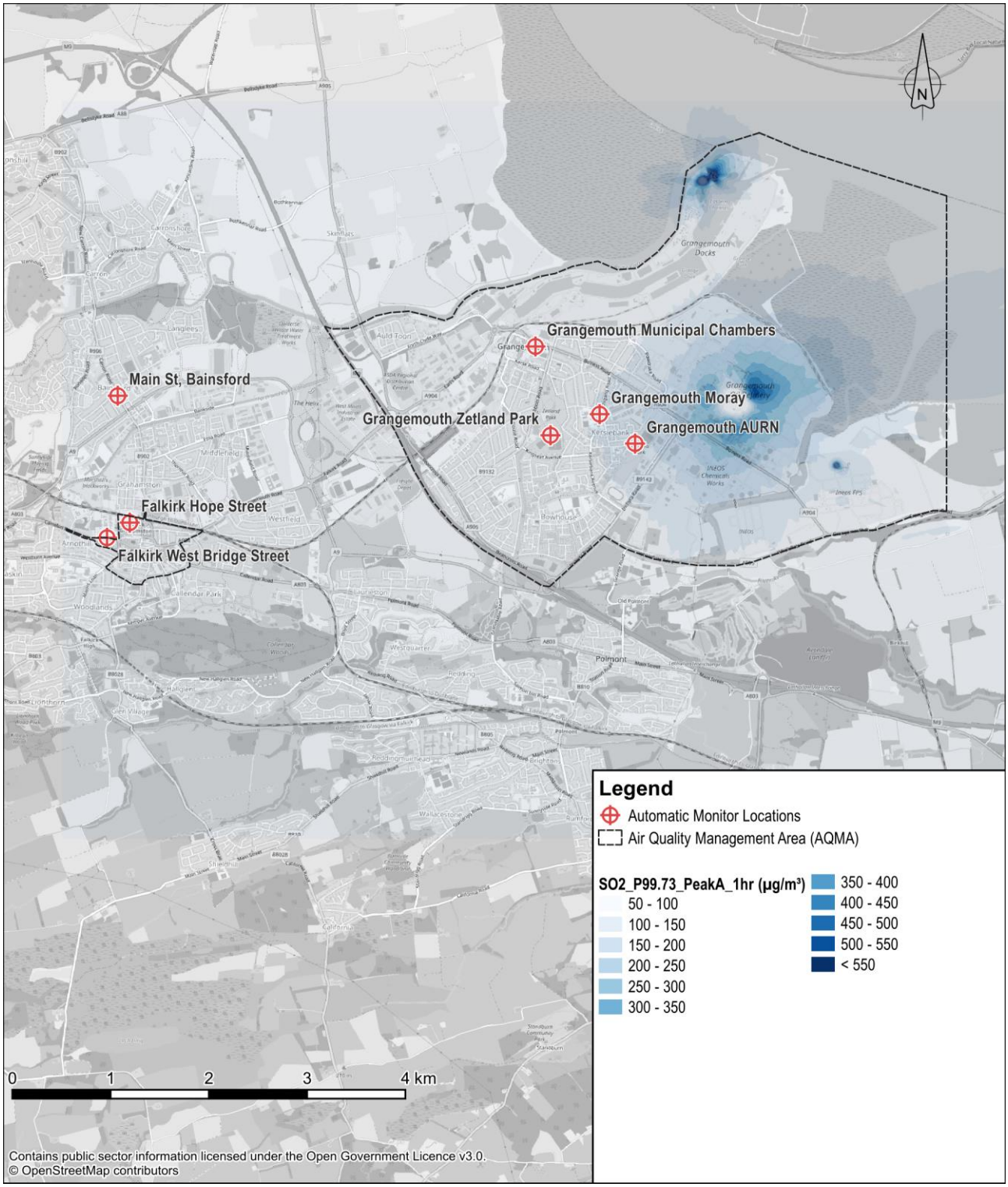


Figure 6.12 Gridded Predictions for SO2, 1-hour, 100th Percentile, Peak A Operation

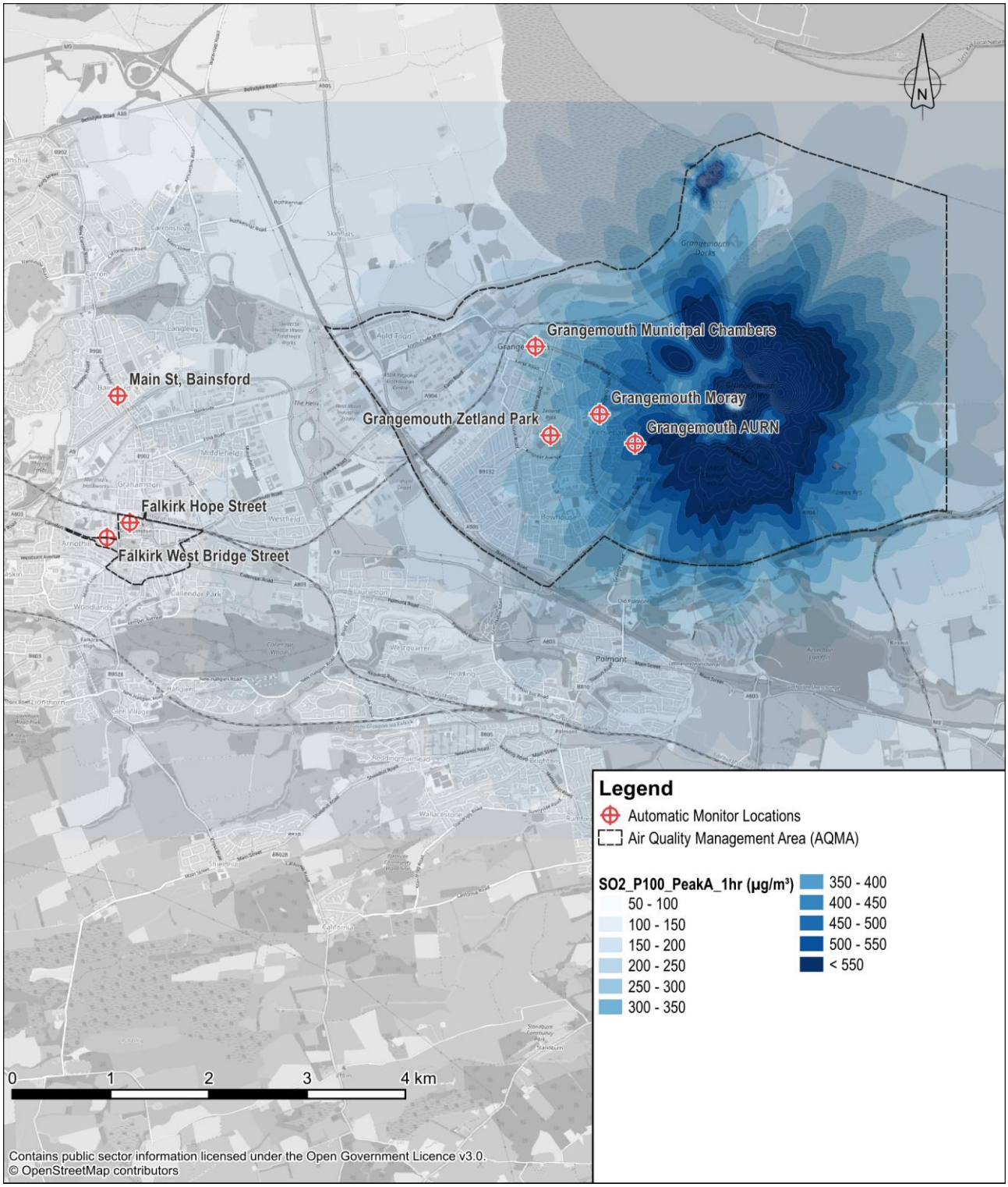


Figure 6.13 Gridded Predictions for SO2, 1-hour, 99.73rd Percentile, Peak B Operation

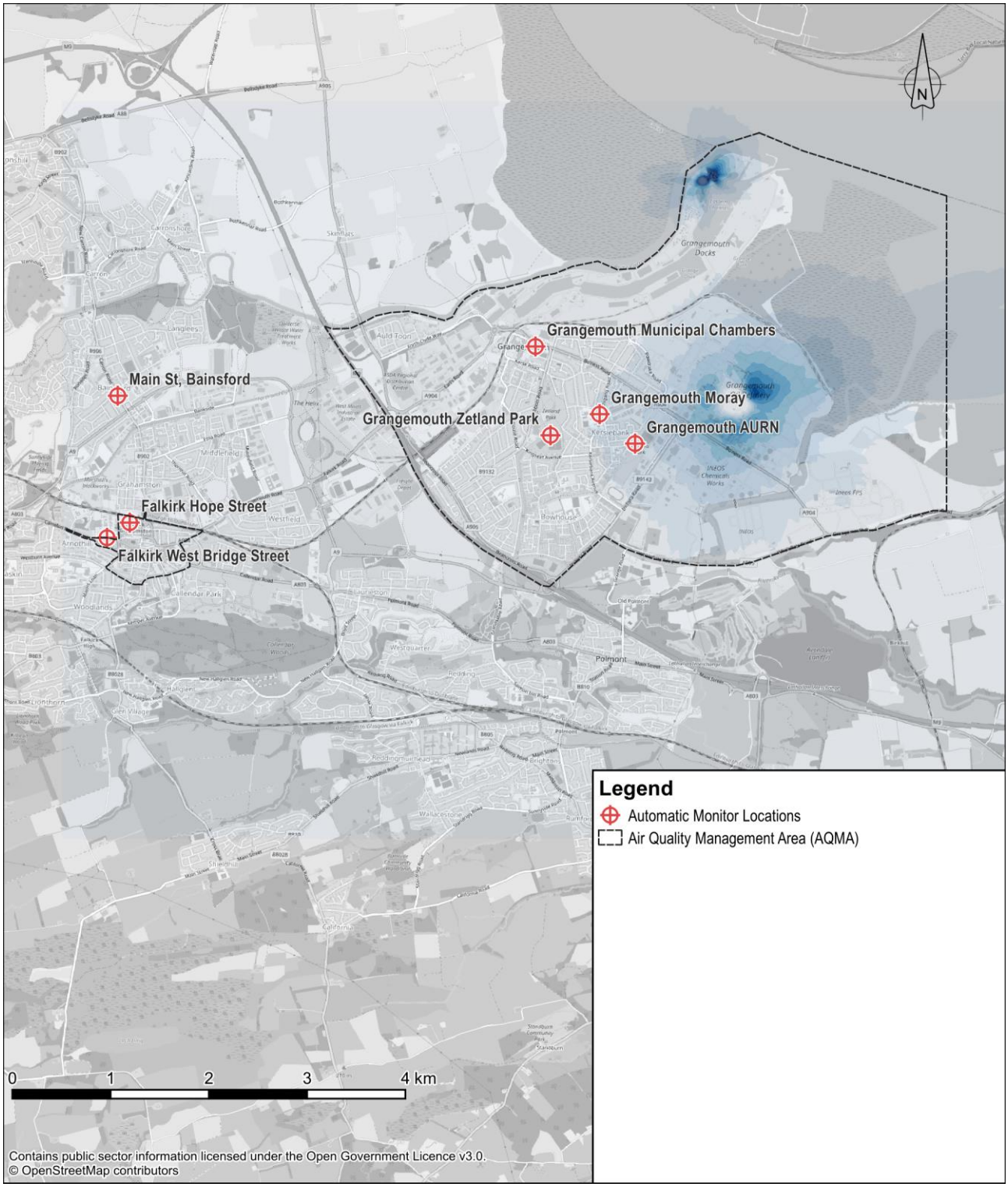
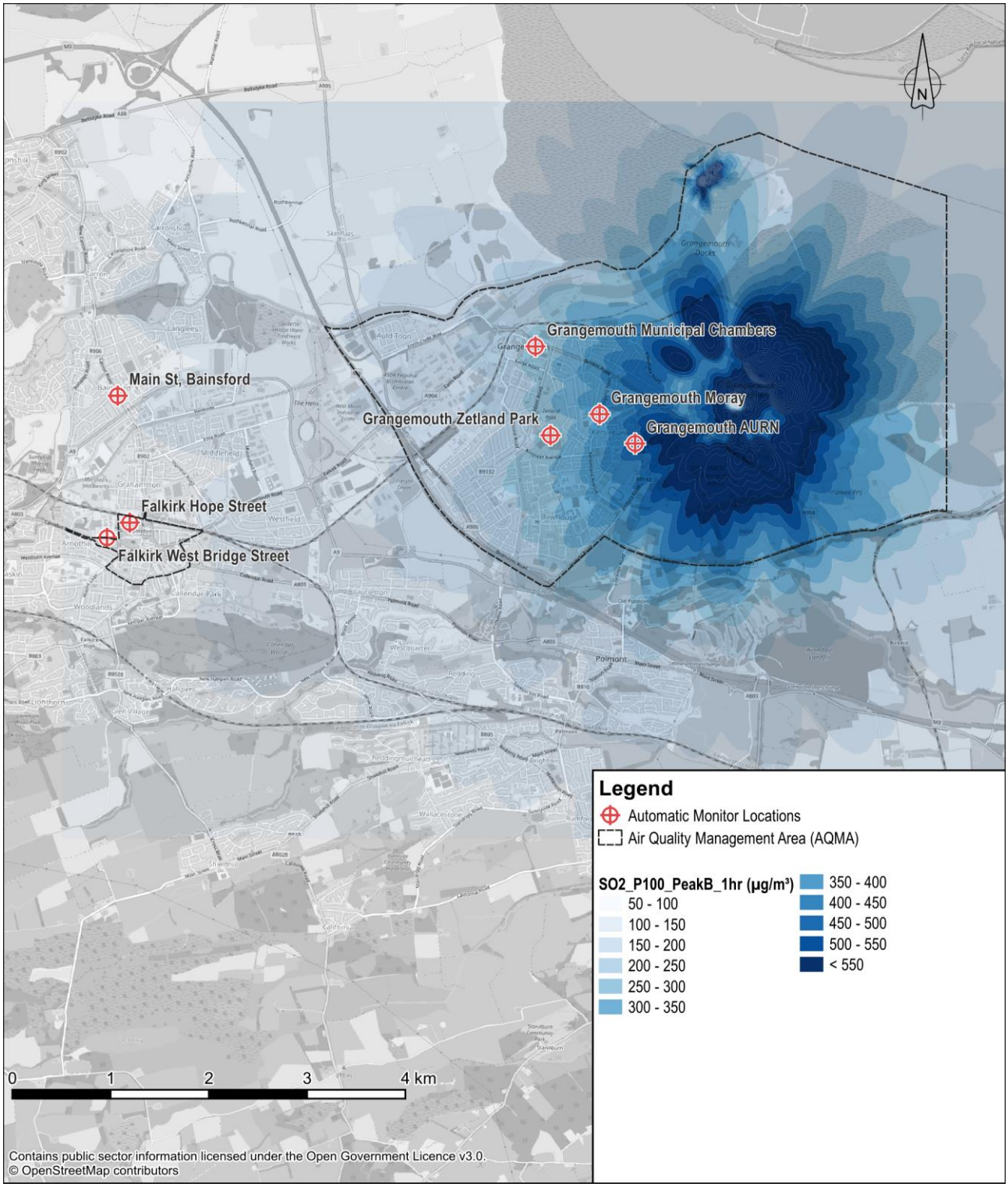


Figure 6.14 Gridded Predictions for SO2, 1-hour, 100th Percentile, Peak B Operation



24-hour Objective

There are no predicted exceedances of the 24-hour mean objective under any scenario.

The following tables present the results of modelling compared against the 24 hour mean objective:

- Table 6.9 Top 10 SO_2 Predictions – Normal Operation, 24-hour, 99.18th percentile;
- Table 6.10 Top 10 SO_2 Predictions – Normal Operation, 24-hour, 100th percentile;
- Table 6.11 Top 10 SO_2 Predictions – Peak A Operation, 24-hour, 99.18th ;
- Table 6.12 Top 10 SO_2 Predictions – Peak A Operation, 24-hour, 100th ;
- Table 6.13 Top 10 SO_2 Predictions – Peak B Operation, 24-hour, 99.18th percentile; and
- Table 6.14 Top 10 SO_2 Predictions – Peak B Operation, 24-hour, 100th percentile.

Table 6.9 Top 10 SO_2 Predictions – Normal Operation, 24-hour, 99.18th percentile

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor
1	16.3	19.1	Inchyra AQU	19.5	22.3	Bo'ness Road 1	19.2	22.0	Inchyra AQU	19.0	21.8	Moray AQU	17.9	20.7	Bo'ness Road 1
2	14.8	17.6	Bo`ness road	18.9	21.8	Bo`ness road	15.7	18.5	Sacred Heart Primary	18.2	21.0	Inchyra AQU	17.6	20.4	Oil refinery
3	14.4	17.3	Bo'ness Road 1	18.9	21.7	Inchyra AQU	14.9	17.7	Oil refinery	17.1	19.9	Elizabeth Avenue	17.5	20.3	Bo`ness road
4	13.3	16.1	Bo'ness Road 2	16.2	19.1	Moray AQU	14.6	17.4	Bo`ness road	16.7	19.6	Bo`ness road	17.0	19.8	Inchyra AQU
5	13.1	15.9	Moray AQU	15.3	18.1	Bo'ness Road 2	14.3	17.1	Bo'ness Road 1	16.7	19.5	Bo'ness Road 1	15.5	18.3	Moray AQU
6	12.3	15.1	Elizabeth Avenue	14.7	17.6	Sacred Heart Primary	14.3	17.1	Wholeflats	16.2	19.0	Bo'ness Road 2	15.2	18.1	Albert Avenue
7	12.3	15.1	Oil refinery	14.6	17.4	Elizabeth Avenue	13.9	16.7	Albert Avenue	16.0	18.8	Sacred Heart Primary	15.0	17.8	Grangemouth Stadium
8	12.0	14.8	Albert Avenue	14.1	16.9	Bowhouse Primary	13.3	16.1	Burnbank Road	15.3	18.1	Sports Complex	14.9	17.7	Bo'ness Road 3
9	11.6	14.5	Sacred Heart Primary	13.8	16.6	Grangemouth Stadium	13.2	16.0	Moray AQU	15.0	17.8	Oil refinery	14.9	17.7	Sacred Heart Primary
10	11.4	14.2	Bo'ness Road 3	13.6	16.4	Bo'ness Road 3	13.0	15.8	Bo'ness Road 2	14.2	17.1	Zetland Pavilion	14.7	17.5	Bo'ness Road 2

Table 6.10 Top 10 SO_2 Predictions – Normal Operation, 24-hour, 100th percentile

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor
1	18.7	21.5	Inchyra AQU	21.9	24.7	Bo`ness road	24.2	27.1	Oil refinery	20.7	23.5	Inchyra AQU	24.2	27.0	Oil refinery
2	17.4	20.2	Oil refinery	21.5	24.3	Bo'ness Road 1	21.4	24.2	Bo'ness Road 1	20.2	23.0	Moray AQU	21.9	24.7	Bo`ness road
3	16.7	19.5	Bo'ness Road 2	21.1	24.0	Moray AQU	21.2	24.0	Bo`ness road	20.0	22.8	Elizabeth Avenue	21.7	24.5	Bo'ness Road 2
4	16.7	19.5	Bo'ness Road 1	20.5	23.3	Inchyra AQU	20.9	23.7	Inchyra AQU	19.5	22.4	Bo'ness Road 2	21.2	24.1	Bo'ness Road 1
5	16.5	19.3	Wholeflats	19.9	22.7	Elizabeth Avenue	18.2	21.0	Elizabeth Avenue	18.8	21.7	Bo`ness road	19.5	22.3	Sacred Heart Primary
6	16.5	19.3	Bo`ness road	18.7	21.5	Bo'ness Road 2	17.9	20.7	Moray AQU	18.4	21.2	Bo'ness Road 1	19.2	22.0	Merrick Road 1
7	15.9	18.7	Bo'ness Road 3	18.0	20.8	Sacred Heart Primary	17.7	20.5	Albert Avenue	18.0	20.9	Sacred Heart Primary	19.1	21.9	Inchyra AQU
8	15.6	18.4	Sacred Heart Primary	17.0	19.8	Bo'ness Road 3	17.2	20.0	Bo'ness Road 2	17.5	20.3	Zetland Pavilion	18.9	21.7	Bo'ness Road 3
9	15.4	18.2	Bowhouse Primary	16.6	19.4	Zetland Pavilion	16.8	19.6	Wholeflats	17.0	19.8	Oil refinery	18.0	20.9	Grangemouth Stadium
10	15.4	18.2	Moray AQU	16.4	19.2	Burnbank Road	16.7	19.6	Sacred Heart Primary	16.5	19.3	Reddoch Road	17.5	20.3	Albert Avenue

Table 6.11 Top 10 SO_2 Predictions – Peak A Operation, 24-hour, 99.18th percentile.

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor
1	34.4	37.2	Inchyra AQU	43.0	45.8	Bo`ness road	40.4	43.2	Inchyra AQU	40.6	43.4	Moray AQU	37.2	40.0	Bo'ness Road 1
2	30.0	32.8	Bo`ness road	43.0	45.8	Bo'ness Road 1	32.8	35.6	Oil refinery	38.3	41.1	Inchyra AQU	35.5	38.3	Bo`ness road
3	29.6	32.4	Bo'ness Road 1	39.6	42.4	Inchyra AQU	31.5	34.3	Sacred Heart Primary	36.8	39.7	Elizabeth Avenue	35.3	38.1	Inchyra AQU
4	27.7	30.5	Bo'ness Road 2	33.7	36.5	Moray AQU	29.4	32.2	Wholeflats	34.4	37.2	Bo'ness Road 2	34.7	37.6	Oil refinery
5	27.0	29.8	Moray AQU	31.0	33.8	Bo'ness Road 2	28.4	31.3	Bo`ness road	34.0	36.8	Bo'ness Road 1	33.0	35.8	Moray AQU
6	24.9	27.7	Oil refinery	29.6	32.4	Elizabeth Avenue	28.4	31.3	Albert Avenue	33.9	36.7	Sacred Heart Primary	31.7	34.5	Albert Avenue
7	23.7	26.6	Elizabeth Avenue	29.2	32.0	Sacred Heart Primary	27.9	30.7	Bo'ness Road 1	33.1	35.9	Bo`ness road	30.8	33.6	Sacred Heart Primary
8	23.7	26.6	Bo'ness Road 3	28.5	31.3	Bowhouse Primary	27.6	30.4	Moray AQU	31.8	34.6	Sports Complex	30.1	32.9	Bo'ness Road 3
9	23.4	26.2	Sacred Heart Primary	27.8	30.6	Grangemouth Stadium	26.6	29.4	Reddoch Road	29.9	32.7	Oil refinery	29.1	31.9	Bowhouse Primary
10	22.7	25.5	Bowhouse Primary	27.4	30.2	Sports Complex	26.5	29.3	Burnbank Road	29.3	32.1	Zetland Pavilion	28.9	31.7	Grangemouth Stadium

Table 6.12 Top 10 SO_2 Predictions – Peak A Operation, 24-hour, 100th percentile.

Rank	Year 1			Year 2			Year 3			Year 4			Year 5		
	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor	SO_2 PC (µg/m^3)	SO_2 PEC (µg/m^3)	Receptor
1	37.9	40.8	Inchyra AQU	45.8	48.7	Bo`ness road	47.5	50.4	Oil refinery	43.6	46.5	Moray AQU	45.8	48.6	Oil refinery
2	33.8	36.6	Oil refinery	45.4	48.2	Moray AQU	45.9	48.7	Bo'ness Road 1	43.0	45.8	Bo'ness Road 2	45.6	48.4	Bo`ness road
3	33.8	36.6	Wholeflats	44.9	47.7	Bo'ness Road 1	45.4	48.2	Bo`ness road	43.0	45.8	Elizabeth Avenue	44.6	47.4	Bo'ness Road 2
4	33.6	36.4	Bo'ness Road 2	42.6	45.5	Elizabeth Avenue	42.4	45.2	Inchyra AQU	42.7	45.6	Inchyra AQU	44.1	46.9	Bo'ness Road 1
5	32.4	35.2	Bowhouse Primary	42.4	45.2	Inchyra AQU	38.9	41.7	Elizabeth Avenue	42.5	45.3	Bo`ness road	40.3	43.1	Sacred Heart Primary
6	32.2	35.0	Bo'ness Road 3	38.9	41.8	Bo'ness Road 2	37.7	40.5	Moray AQU	41.3	44.2	Bo'ness Road 1	39.7	42.6	Merrick Road 1
7	31.8	34.6	Sacred Heart Primary	37.2	40.0	Sacred Heart Primary	36.1	38.9	Albert Avenue	38.3	41.1	Sacred Heart Primary	39.0	41.8	Bo'ness Road 3
8	30.3	33.2	Bo'ness Road 1	35.4	38.3	Bo'ness Road 3	35.1	37.9	Bo'ness Road 2	36.9	39.7	Zetland Pavilion	38.4	41.2	Inchyra AQU
9	30.1	32.9	Bo`ness road	34.7	37.5	Zetland Pavilion	34.6	37.4	Wholeflats	34.5	37.3	Reddoch Road	36.8	39.6	Grangemouth Stadium
10	29.6	32.4	Moray AQU	34.5	37.3	Bowhouse Primary	34.0	36.8	Reddoch Road	33.7	36.5	Sports Complex	35.9	38.7	Albert Avenue

Table 6.13 Top 10 SO_2 Predictions – Peak B Operation, 24-hour, 99.18th percentile

Year 1			Year 2			Year 3			Year 4			Year 5		
SO_2 PC (µg/m³)	**SO_2 PEC (µg/m³)**	**Receptor**	**SO_2 PC (µg/m³)**	**SO_2 PEC (µg/m³)**	**Receptor**	**SO_2 PC (µg/m³)**	**SO_2 PEC (µg/m³)**	**Receptor**	**SO_2 PC (µg/m³)**	**SO_2 PEC (µg/m³)**	**Receptor**	**SO_2 PC (µg/m³)**	**SO_2 PEC (µg/m³)**	**Receptor**
33.8	36.7	Inchyra AQU	42.7	45.5	Bo`ness road	40.3	43.1	Inchyra AQU	40.5	43.3	Moray AQU	37.1	39.9	Bo'ness Road 1
29.7	32.5	Bo`ness road	42.6	45.5	Bo'ness Road 1	32.4	35.2	Oil refinery	38.2	41.0	Inchyra AQU	35.3	38.1	Bo`ness road
29.4	32.2	Bo'ness Road 1	39.5	42.3	Inchyra AQU	31.3	34.1	Sacred Heart Primary	36.7	39.6	Elizabeth Avenue	35.2	38.0	Inchyra AQU
27.5	30.3	Bo'ness Road 2	33.6	36.4	Moray AQU	29.2	32.1	Wholeflats	34.2	37.1	Bo'ness Road 2	34.7	37.5	Oil refinery
26.6	29.4	Moray AQU	30.7	33.5	Bo'ness Road 2	28.3	31.1	Bo`ness road	33.9	36.7	Bo'ness Road 1	32.9	35.7	Moray AQU
24.7	27.5	Oil refinery	29.4	32.2	Elizabeth Avenue	28.3	31.1	Albert Avenue	33.8	36.7	Sacred Heart Primary	31.5	34.3	Albert Avenue
23.6	26.4	Bo'ness Road 3	29.1	32.0	Sacred Heart Primary	27.7	30.6	Bo'ness Road 1	33.0	35.8	Bo`ness road	30.8	33.6	Sacred Heart Primary
23.5	26.3	Elizabeth Avenue	28.2	31.0	Bowhouse Primary	27.5	30.3	Moray AQU	31.6	34.5	Sports Complex	29.8	32.6	Bo'ness Road 3
23.3	26.1	Sacred Heart Primary	27.2	30.1	Grangemouth Stadium	26.3	29.1	Burnbank Road	29.7	32.5	Oil refinery	29.0	31.8	Bowhouse Primary
22.4	25.3	Bowhouse Primary	27.2	30.0	Sports Complex	26.3	29.1	Reddoch Road	29.2	32.0	Zetland Pavilion	28.8	31.6	Grangemouth Stadium

Table 6.14 Top 10 SO_2 Predictions – Peak B Operation, 24-hour, 100th percentile

Year 1			Year 2			Year 3			Year 4			Year 5		
SO_2 PC (µg/m³)	**SO_2 PEC (µg/m³)**	**Receptor**	**SO_2 PC (µg/m³)**	**SO_2 PEC (µg/m³)**	**Receptor**	**SO_2 PC (µg/m³)**	**SO_2 PEC (µg/m³)**	**Receptor**	**SO_2 PC (µg/m³)**	**SO_2 PEC (µg/m³)**	**Receptor**	**SO_2 PC (µg/m³)**	**SO_2 PEC (µg/m³)**	**Receptor**
37.9	40.7	Inchyra AQU	45.6	48.5	Bo`ness road	47.3	50.1	Oil refinery	43.5	46.3	Moray AQU	45.6	48.4	Oil refinery
33.7	36.6	Oil refinery	45.3	48.1	Moray AQU	45.7	48.5	Bo'ness Road 1	42.9	45.7	Bo'ness Road 2	45.4	48.2	Bo`ness road
33.5	36.4	Wholeflats	44.7	47.5	Bo'ness Road 1	45.2	48.0	Bo`ness road	42.9	45.7	Elizabeth Avenue	44.4	47.3	Bo'ness Road 2
33.4	36.2	Bo'ness Road 2	42.6	45.4	Elizabeth Avenue	42.3	45.1	Inchyra AQU	42.6	45.4	Inchyra AQU	43.9	46.7	Bo'ness Road 1
32.2	35.1	Bowhouse Primary	42.3	45.1	Inchyra AQU	38.7	41.6	Elizabeth Avenue	42.3	45.1	Bo`ness road	40.0	42.8	Sacred Heart Primary
32.0	34.8	Bo'ness Road 3	38.8	41.6	Bo'ness Road 2	37.5	40.4	Moray AQU	41.2	44.0	Bo'ness Road 1	39.7	42.6	Merrick Road 1
31.7	34.6	Sacred Heart Primary	37.0	39.9	Sacred Heart Primary	36.0	38.8	Albert Avenue	38.2	41.0	Sacred Heart Primary	38.9	41.7	Bo'ness Road 3
30.2	33.1	Bo'ness Road 1	35.2	38.0	Bo'ness Road 3	35.0	37.8	Bo'ness Road 2	36.8	39.6	Zetland Pavilion	38.1	41.0	Inchyra AQU
29.9	32.8	Bo`ness road	34.6	37.5	Zetland Pavilion	34.3	37.1	Wholeflats	33.6	36.4	Sports Complex	36.7	39.5	Grangemouth Stadium
29.4	32.2	Moray AQU	34.5	37.3	Bowhouse Primary	33.9	36.7	Reddoch Road	33.6	36.4	Reddoch Road	35.7	38.5	Albert Avenue

Appendix C

Data Request

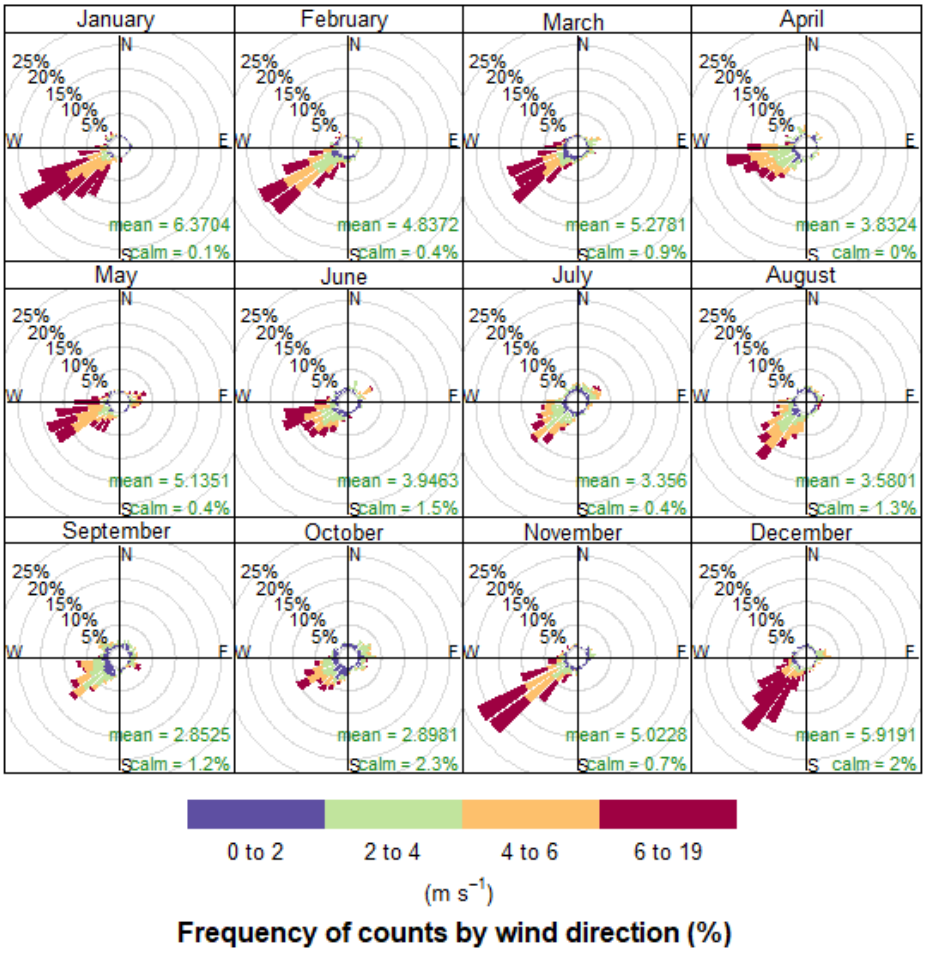
Emmission Point Source Name		Flue/Stack Exit paramaters									Annual average pollutant emission rates (g/s). Please update if different units provided. Notate with N/A where not applicable							Stack Location estimated (6 digit OS grid ref if possible, to nearest meter)	
Source ID	Description	Stack height above ground (m)	Stack internal diameter (m)	Combined Flue/Stack? *is this source combined with any other sources in a singular stack with combined flues. Please provide full details	Annual Hours of operation / Frequency	Actual Exit temperature (°C) or K please specify	Exit Velocity (m/s)	Oxygen content (%O2)	Water Content (%H2O)	Volumetric flow rate *state if actual or ref conditions (m^3/h or Nm^3/h)	NOx	PM_{10}	$PM_{2.5}$	SO_2	CO	Methane	Non-Methane VOCs	X	Y
1A	*eg. Main stack*	25	0.5	No	24 hours / 7 days per week	421	5	5	0			N/A				N/A			

Example text to be removed before completion

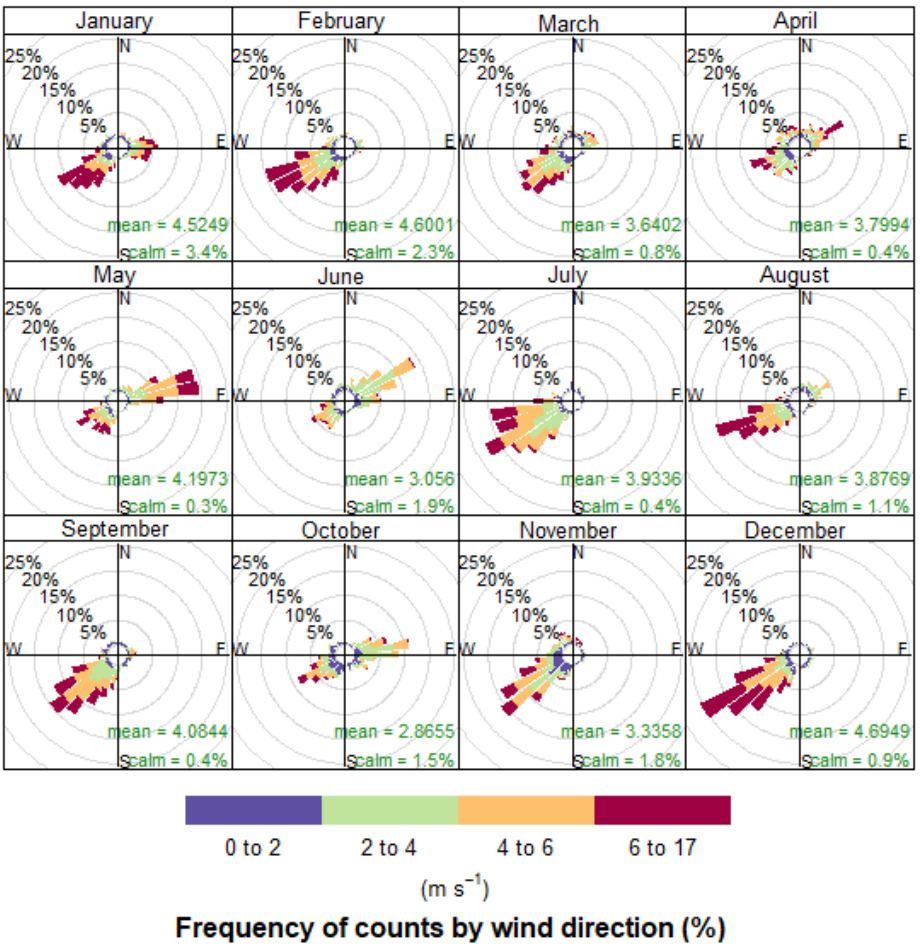
Figure 6.15 Example of the data request sheet sent to Grangemouth industrial plant operators

Appendix D

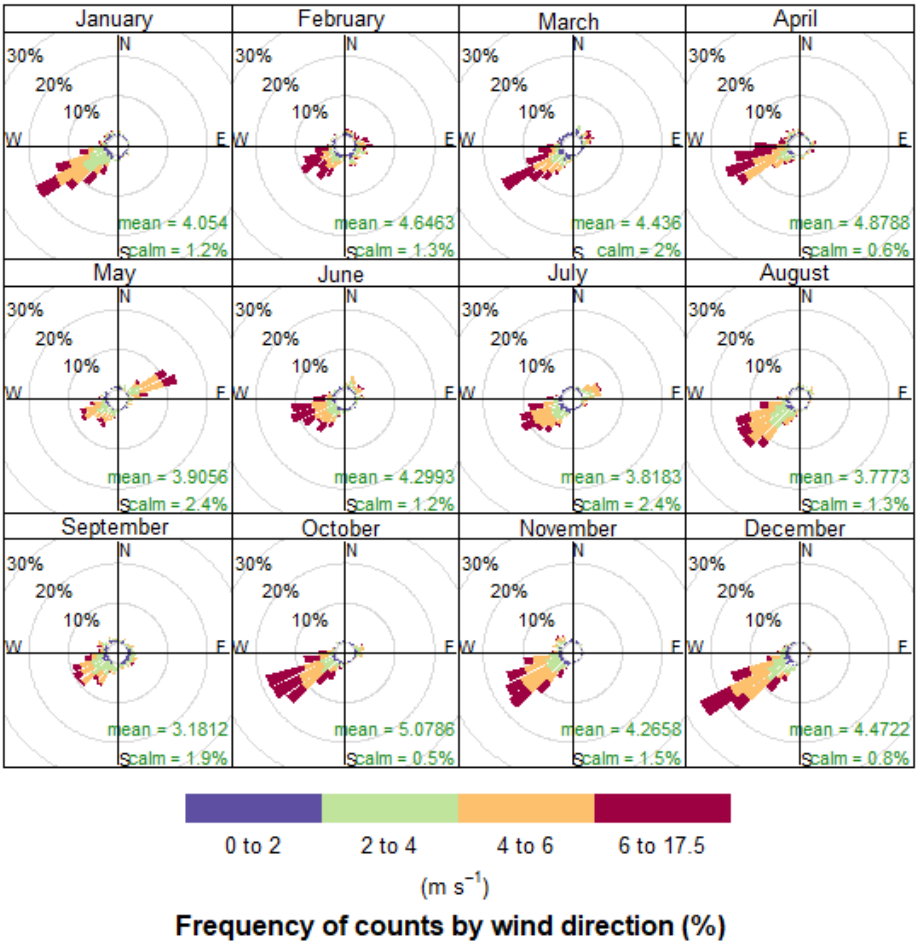
Edinburgh Gogarbank Monthly Wind Roses



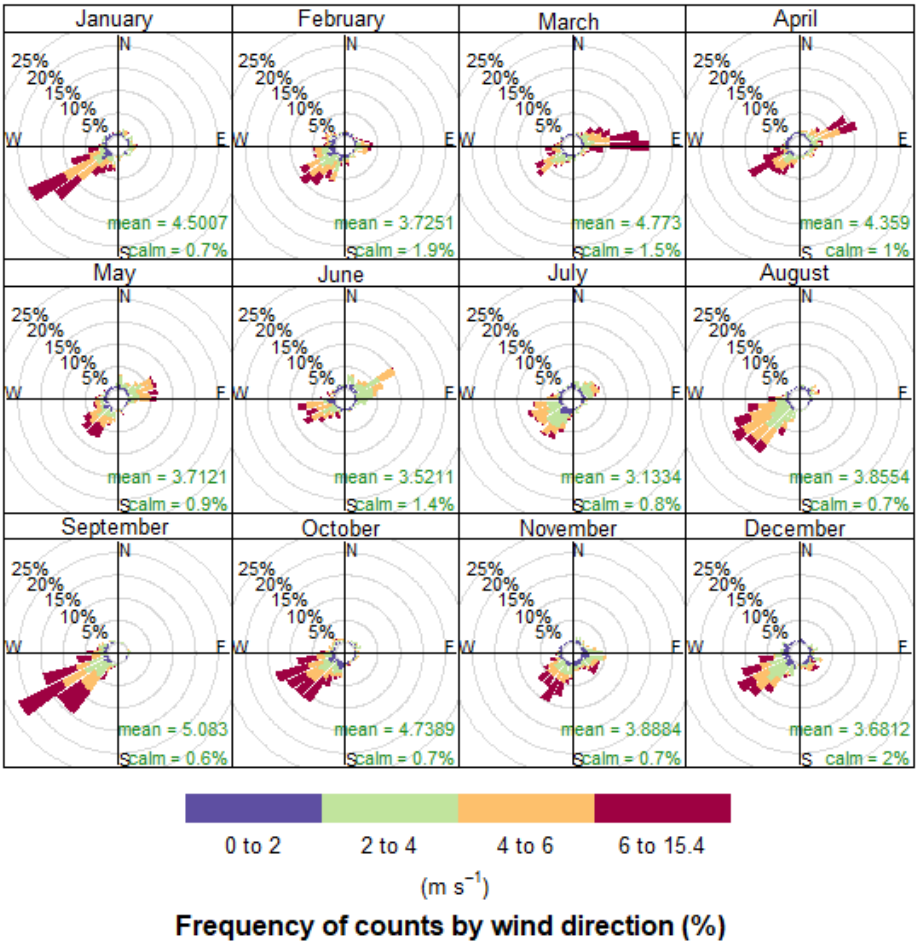
2015 Monthly Wind Roses



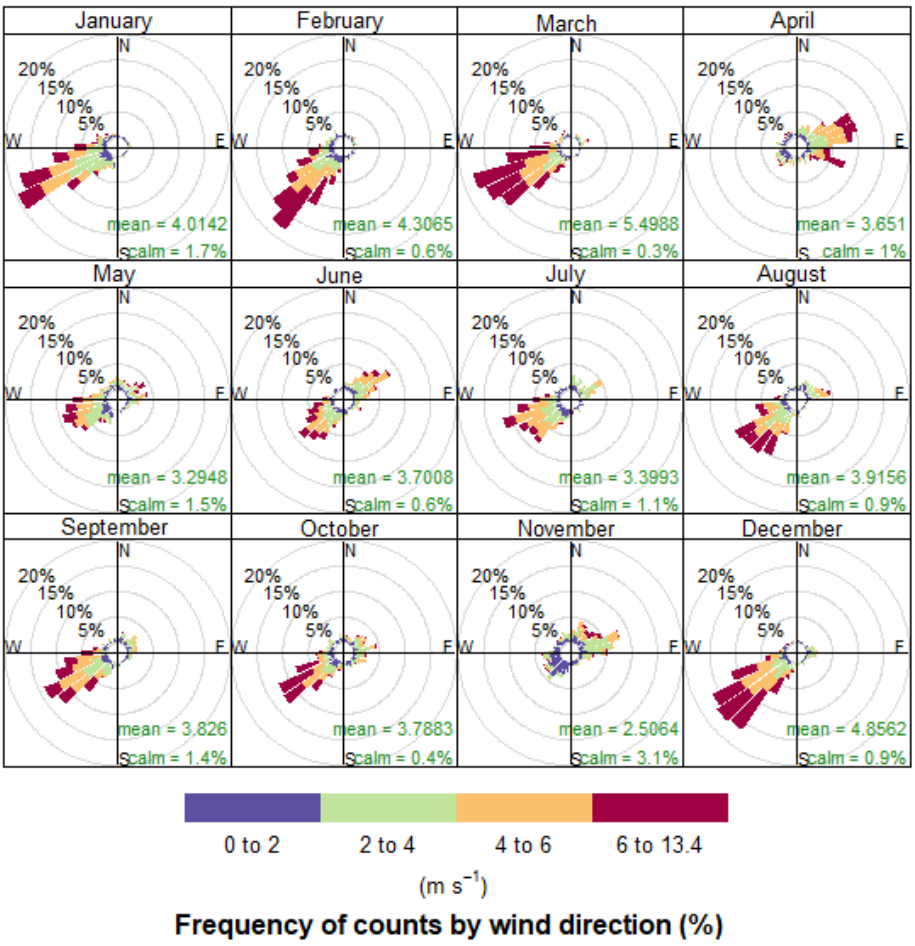
2016 Monthly Wind Roses



2017 Monthly Wind Roses



2018 Monthly Wind Roses



2019 Monthly Wind Roses

Together with our clients and the collective knowledge of our 18,500 architects, engineers and other specialists, we co-create solutions that address urbanisation, capture the power of digitalisation, and make our societies more sustainable.

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