Grangemouth Emission Study

Results Report

FALKIRK COUNCIL

SWECO

Change list

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Table of contents

1 Introduction

Sweco UK Ltd (Sweco) have been appointed by Falkirk Council to provide consultancy support on behalf of the council and SEPA. 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 follows on from the Grangemouth Emissions Study completed in 2020 and published in 2021 and 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 study also considers the cumulative impact with road traffic emissions. Unfortunately no new road traffic data were available and therefore as worst case the study has used the same road traffic emissions data as the 2021 study as worst case.

The investigation reported here uses updated emissions information for the Grangemouth industrial facilities. The results of the dispersion modelling have also been used to inform decision-making processes regarding the future of the Grangemouth AQMA. This is fully detailed in the Grangemouth AQMA Detailed Assessment published August 2024.

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.

An investigation of emissions in Grangemouth was undertaken in 2020 and published in 20201 representing Phase 1 of a study into local emissions. This report detailed industrial and traffic emissions. It found that there were traffic emission hotspots at Glensburgh Road, Bo'ness Road and Beancross Road and that predicted concentrations of air pollutants due to the industrial emissions were below the relevant air quality objectives. The industrial modelling undertaken was conservative in that no time-varying factors were applied, therefore all sources were treated as operating for 8,760 hours of the year.

[1] Sweco (2021) Grangemouth Emissions Study. [Online] https://www.falkirk.gov.uk/services/environment/environmental-policy/air-quality/docs/air-quality/12%20Grangemouth%20Emissions%20Study%202020.pdf?v=202103021416, accessed November 2023

The current Phase 2 study is intended to update the work undertaken at Phase 1 through the use of updated industrial emission factors including some areas not included in previous dispersion models. Emissions from road traffic have been added to the industrial emissions to provide as complete a picture as possible. However no new traffic data was provided so the traffic emissions used are those from 2018. The emission rates used in the Phase 1 study were higher and so this is considered to represent a worst-case illustration of traffic related emissions.

This modelling study considers all of the principle air pollutants arising from the facility including:

- SO_2
- Oxides of nitrogen (NO_X)
- Nitrogen dioxide (NO_2)
- Particulate matter (PM_{10} and $PM_{2.5}$)
- Carbon MoNO_Xide (CO)
- Non-methane volatile organic compounds (NMVOC); and
- Methane (CH_4).

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.

2 Legislation, Policy and Guidance

2.1 Legislation

This section details legislation that is relevant to this study.

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.

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 update to the Air Quality Strategy within 12 months of the legislation coming into force.

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.

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.

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 Air Quality (Scotland) Amendment Regulations 2016

The Air Quality (Scotland) Amendment Regulations 2016 adds to the 2000 regulations the objective value of 10 µg/m³ for the concentration of $PM_{2.5}$ in ambient air.

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

TABLE 2.1 RELEVANT AIR QUALITY OBJECTIVES (HUMAN HEALTH)

Pollutant	Air Quality Standard Measured as ($\mu g/m^3$ unless stated)	
NO_2	40	Annual mean, for the protection of human health
	200	1-hour mean, not to be exceeded on more than 18 occasions per year
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
PM_{10}	18	Annual mean, for the protection of human health
	50	24-hour mean, not to be exceeded on more than 7 occasions per year
$PM_{2.5}$	10	Annual mean, for the protection of human health
CO	10 mg/m^3	8-hour rolling mean for the protection of human health
NMVOC (limit for benzene used as a proxy)	5	Annual mean, for the protection of human health

There is no health-based exposure value for the general public for concentrations of CH_4 in ambient air. The Methane Incident Management note2 states that CH_4 is potentially explosive at concentrations of between 5% and 15% in ambient air.

2.2 Policy

The policy documents detailed in the following sections are considered relevant to this study.

Grangemouth Air Quality Action Plan 2007

The Grangemouth Air Quality Action Plan 2007 was produced in response to the continued monitored exceedances of the SO_2 15-minute and 1-hour means following declaration of the AQMA. Whilst the monitoring continued to show exceedances, historic modelling undertaken in support of various reviews was not able to reproduce the exceedances due to inadequate input datasets. Modelling for the Action Plan included more detailed data and time varying data. With model uncertainty included as a factor the modelling showed exceedances but not more than the permitted number of occasions. Four actions were required as part of the Action Plan:

- Falkirk Council to provide SEPA with access to detailed monitoring data;

[2] Public Health England (2015) Methane Incident Management. [Online] https://www.gov.uk/government/publications/methane-properties-uses-and-incident-management, accessed December 2023

- Set up a working group with Falkirk Council and SEPA that can call on local industrial representatives with a view to improving local air quality;
- Introduce an SMS message alert system for specific individuals with control of emission generating activities, to be activated when monitored concentrations exceed set trigger levels; and
- Falkirk Council to introduce additional monitoring.

Cleaner Air for Scotland 2: Towards a Better Place for Everyone

The Scottish Government Cleaner Air for Scotland 2 represents the strategy for achieving cleaner air in Scotland and is related back to the Placemaking Principle common within the Scottish planning system and referred to directly in the National Planning Framework 4. The strategy refers to the responsibilities of SEPA and its regulatory powers in controlling emissions through the granting and enforcement of permits for polluting operations as part of the Pollution Prevention and Control regulations. The UK National Air Pollution Control Programme3 refers directly to Cleaner Air for Scotland 2 as the source of control measures for industrial emissions in Scotland.

2.3 Guidance

The guidance documents in the following sections have been used in the preparation of this modelling study.

Scottish Government Policy Guidance PG(S)(16)4

The policy guidance PG(S)(16) is issued by the Scottish Government under Part IV of the Environment Act 1995 as a summary of legislation and policy for air quality in Scotland and the roles of the factors affecting air quality that are specific to the Scottish Government policy aims;

Defra and the Devolved Authorities, Local Air Quality Management Technical Guidance TG(22)[5]

The technical guidance (LAQM.TG(22)) provides details on the handling of air quality monitoring data and handling of background air quality data. The guidance provides information on a number of technical requirements for both local authorities and air quality assessors;

[3] Department for Environment Food and Rural Affairs and the Devolved Administrations (2023) Revised UK Natinoal Air Pollution Control Programme (NAPCP). [Online] https://www.gov.uk/government/publications/air-quality-revised-uk-national-air-pollution-control-programme, accessed November 2023

[4] Scottish Government (2016) Local Air Quality Management Policy Guidance PG (S) 16. [Online] https://www.gov.scot/publications/local-air-quality-management-policy-guidance/, accessed November 2023

[5] Department for Environment Food and Rural Affairs and the Devolved Administrations (2022) Local Air Quality Management Technical Guidance TG(22). [Online] https://laqm.defra.gov.uk/air-quality/featured/uk-regions-exc-london-technical-guidance/, accessed November 2023

3 Baseline Air Quality

3.1 Local Air Quality Management

The Council undertakes its Local air quality management duties under Part IV of the Environment Act 1995. Monitoring for an array of pollutants is undertaken through the use of continuous automatic monitors and passive diffusion tubes. A summary of the methods is shown in Table 3.1.

TABLE 3.1 SUMMARY OF 2022 MONITORING LOCATIONS

Pollutant	Monitoring Method, with number of locations in 2022					
	UV Fluorescence	Chemiluminescence	FIDAS	Beta Attenuation	Pumped Absorption	Diffusion Tube
SO_2	6	-	-	-	-	-
NO_2	-	7	-	-		61
PM_{10}	-	-	6	1	-	-
$PM_{2.5}$	-	-	6	1	-	-
Benzene	-	-	-	-	1	16

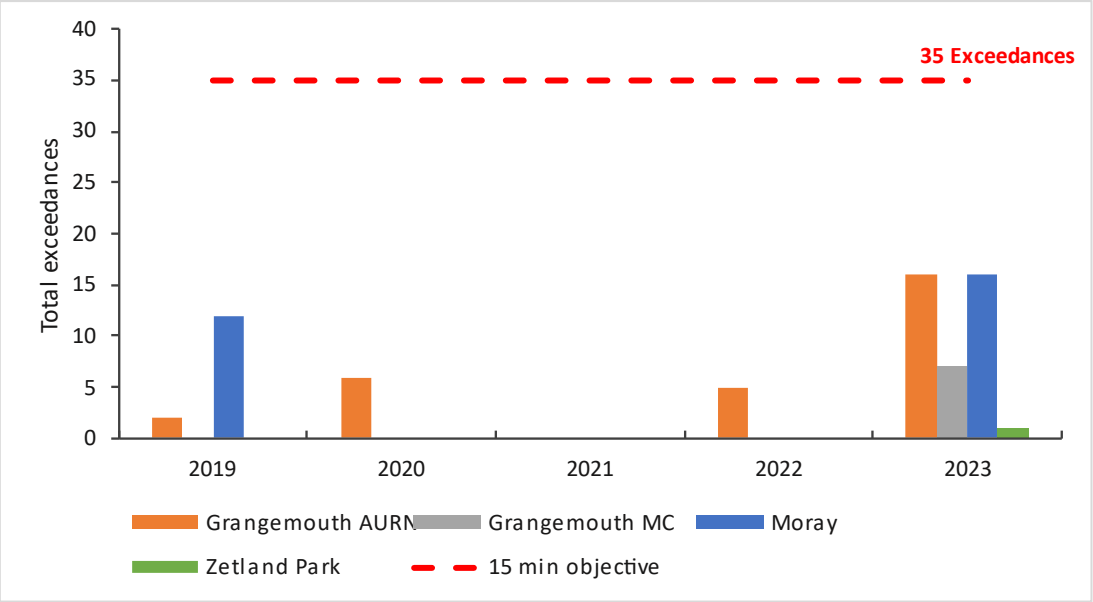
The Phase 1 report detailed Local Air Quality Management (LAQM) data up to 2018 as the focus of the study was emissions data provided for 2018. This study examines the LAQM data from 2019 onwards to 2023 given the emissions data provided is for 2023.

SO_2

Monitoring for SO_2 is undertaken at four locations relevant to this study, all of which are automatic monitors. Monitoring is undertaken against each of the three objectives for SO_2.

A summary of the exceedances of the 15-minute objective of 266 µg/m³ for SO_2 is shown in Figure 3.1 This shows an inconsistent pattern for exceedances, except for 2020 and 2021 where exceedances were zero or minimal due to the effects of the Scottish Government Covid-19 restrictions. The data shows a renewed increase in the number of exceedances recorded compared to the data presented in the Phase 1 study, however these can generally be attributed to specific flaring events or equipment maintenance issues. In all years where exceedances of the 266 µg/m³ did occur this was on less than the allowable maximum of 35 occasions in a calendar year. Tabular data is shown in Appendix A.

FIGURE 3.1 GRAPHICAL SUMMARY OF EXCEEDANCES OF THE 15-MINUTE OBJECTIVE FOR SO_2

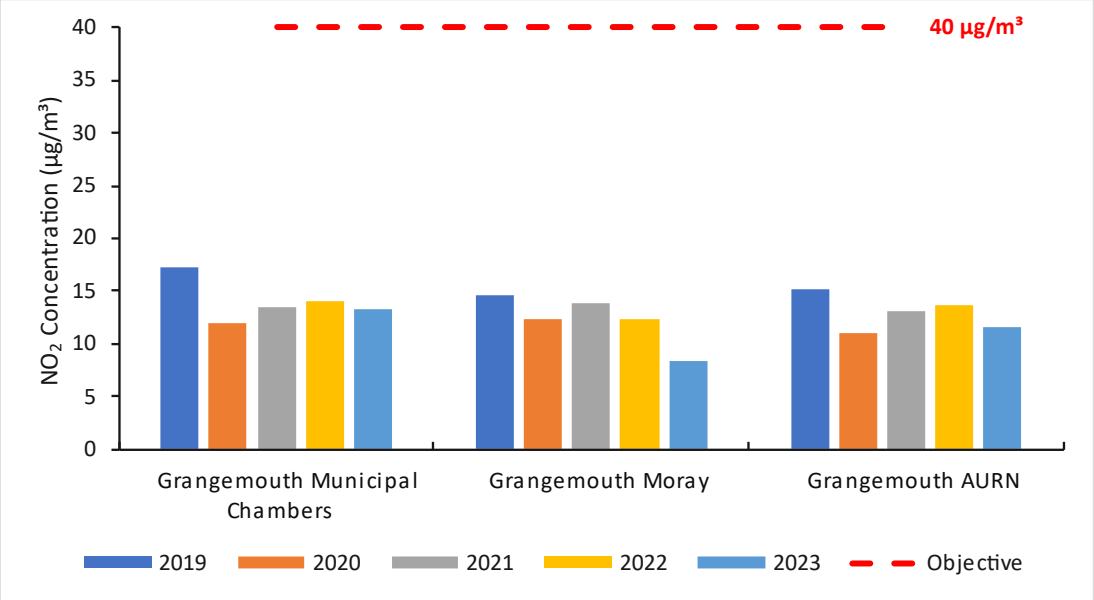


There have been only two recorded exceedances of the 1-hour objective for SO_2 of 350 µg/m³ which is less than the 24 permitted occasions, and no exceedances of the 24-hour objective of 125 µg/m³ for the period 2019-2023 inclusive. This is shown in Appendix A.

NO_2

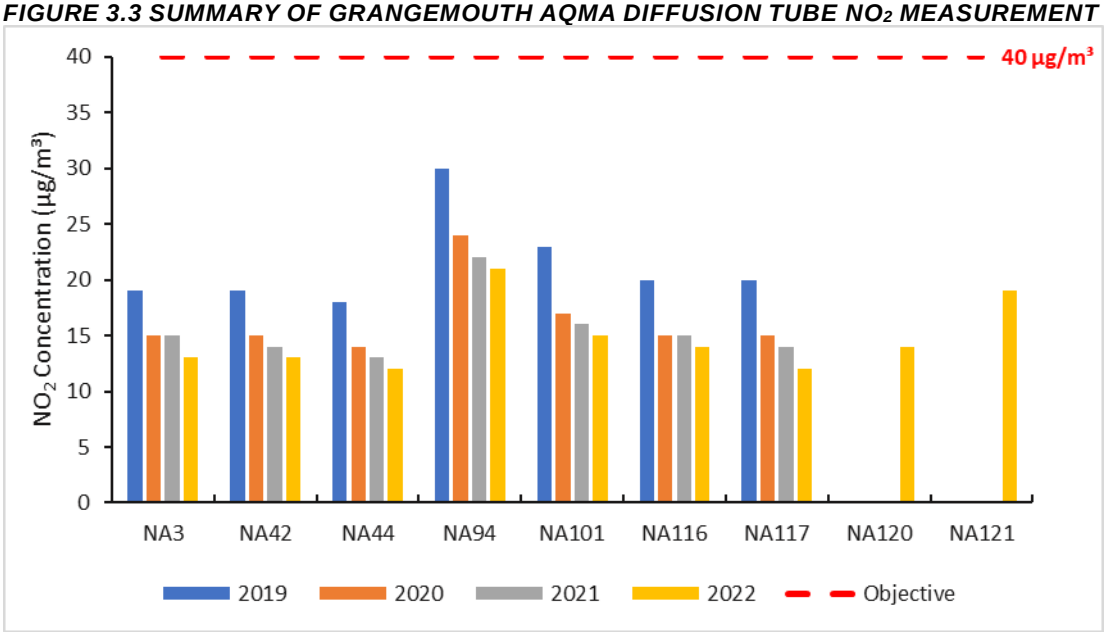
The results for the automatic monitoring of NO_2 concentrations shows a generally consistent reduction following on from the data presented at Phase 1. There have been no instances where the annual mean objective of 40 µg/m³ has been exceeded and no instances where the 1-hour objective of 200 µg/m³ has been exceeded. What is evident from this data is that whilst 2020 and 2021 are generally considered to be anomalous years due to the lack of activity as a result of the Covid-19 restrictions, the data for the years following this shows the lower concentrations to have been maintained. This evidence points to a permanent change in activity related to concentrations of NO_2. The data are summarised in Figure 3.2 and detailed in Appendix A Table 7.4.

FIGURE 3.2 SUMMARY OF GRANGEMOUTH AUTOMATIC NO_2 MONITORING



The measured diffusion tube data summarised in Figure 3.3 show that the annual mean objective for NO_2 of 40 µg/m³ was not exceeded at any location within or adjacent to the AQMA within the period studied. For those tubes where there were sufficient measurements, all locations showed a trend for an improvement in measured concentrations of NO_2.

FIGURE 3.3 SUMMARY OF GRANGEMOUTH AQMA DIFFUSION TUBE NO_2 MEASUREMENT

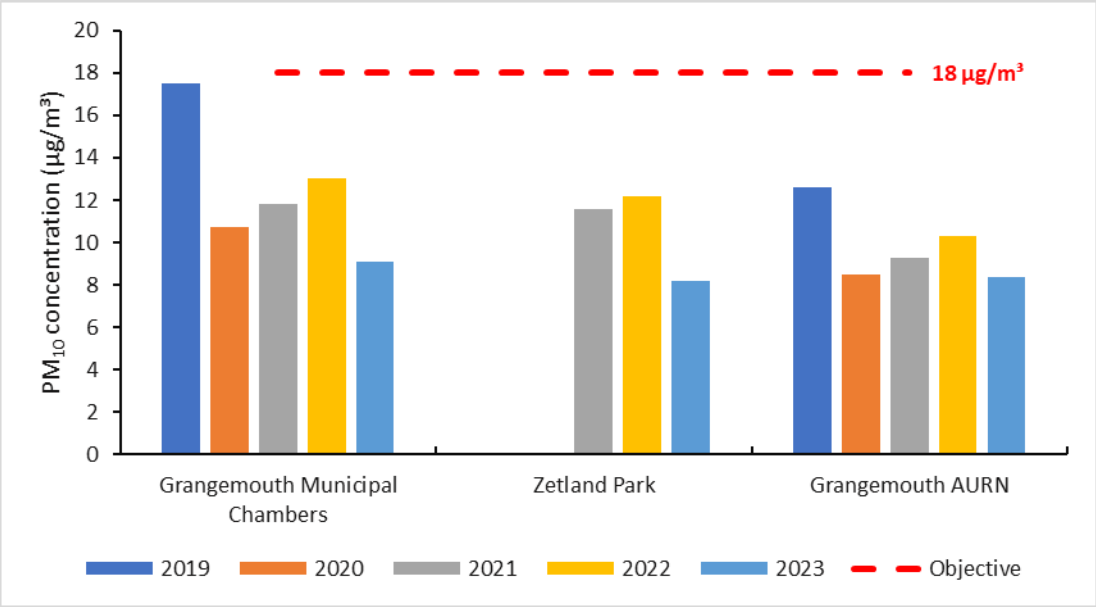


PM_{10}

In common with the Phase 1 study for data up to 2018, all monitored PM_{10} annual concentrations from 2019 onwards are below the objective value of 18 µg/m³ as shown in Figure 3.4. Monitored concentrations of PM_{10} at the Grangemouth AURN and Grangemouth Municipal Chambers locations generally appeared to have been little affected by the

Covid-19 restrictions. Both sites show a steady improvement in concentrations over the period studied despite a peak in 2022. Full data is presented in Appendix A

FIGURE 3.4 SUMMARY OF ANNUAL CONTINUOUS AUTOMATIC PM_{10} MEASUREMENT



The monitoring data shows that there were some exceedances of the 50 µg/m³ 24-hour objective for PM_{10} in 2022, but these were on less than the 18 occasions allowable under the objective. All of these occurred over a two-day period in March 2022 and therefore it may be possible to link them to a specific event. In 2023 there were no exceedances of the 50 µg/m³ 24-hour objective for PM_{10}.

$PM_{2.5}$

Automatic monitoring of $PM_{2.5}$ is summarised in Figure 3.5 (FIDAS results have not been adjusted6):

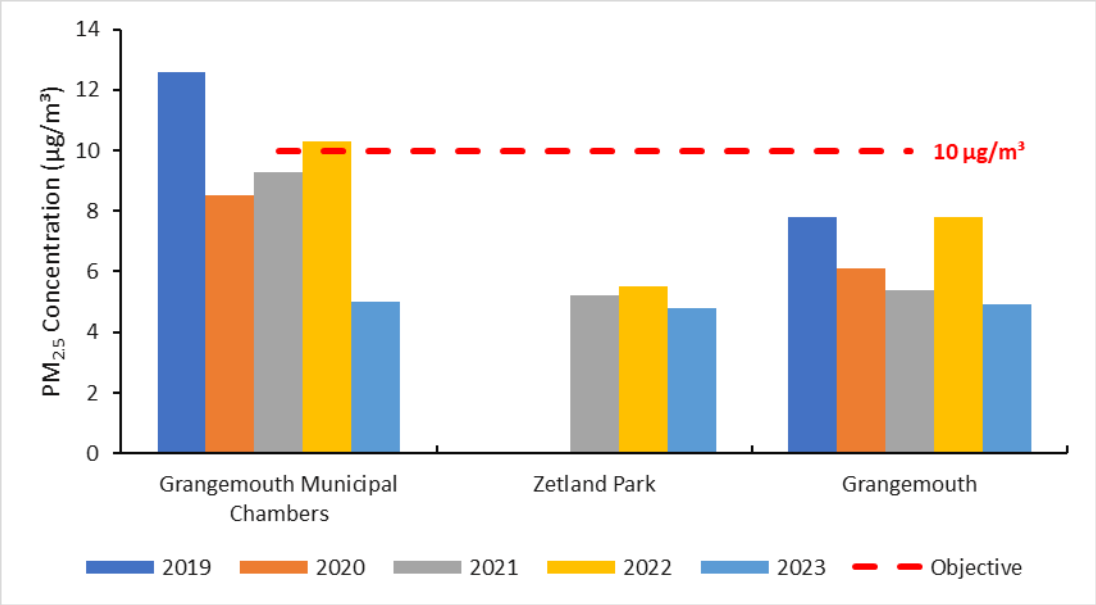
The monitoring data in Figure 3.5 shows the annual average monitoring results for $PM_{2.5}$. There have been no exceedances of the objective of 10 µg/m³ for $PM_{2.5}$ since 2019. In common with the monitoring results for NO_2 and PM_{10} the data show a gradual improvement in concentrations at Grangemouth Municipal Chambers and Grangemouth AURN automatic monitors despite the peak in 2022.

At Zetland Park an overall improvement in concentrations is shown but this masks some variation in both directions. However this should be taken with caution as only three years of data are available.

Full data are presented in Appendix A.

[6] Ricardo Energy & Environment (2023) Equivalence Study to Investigate Particulate Matter Monitoring in Scotland Using the Fidas 200. [Online] https://www.scottishairquality.scot/technical-reports/equivalence-study-investigate-particulate-matter-monitoring-scotland-using-fidas, accessed July 2024

FIGURE 3.5 SUMMARY OF ANNUAL CONTINUOUS AUTOMATIC $PM_{2.5}$ MEASUREMENT



3.2 Background Concentrations

Background concentrations of the relevant pollutants have been obtained from the Scottish Government Air Quality In Scotland website for NO_2, NO_X and PM_{10}, and from the Defra Background Air Quality Archive for $PM_{2.5}$ from a base year of 2018. Modelled background concentration maps for SO_2 and CO are no longer maintained by Defra and are published for a base year of 2001 only. Adjustment factors are available for CO up to the year 2025, however no adjustment should be applied to the SO_2 background.

Where applicable sector removal for industrial or traffic emissions was undertaken on the datasets used in the dispersion models. The road contributions from the traffic modelling undertaken for the 2021 report were added to the Predicted Environmental Concentration and the appropriate background concentrations to provide an indication of overall air quality in Grangemouth.

In general, background concentrations are lower than those used in the 2021 stud given the passage of time from the 2018 data used for that assessment and the 2023 data used for this assessment. The exception are the background concentrations for SO_2 which are based on the 2001 concentrations. This dataset has not since been updated by Defra and was not adjusted for this assessment in order to provide worst-case predictions.

SO_2

Background concentrations of SO_2 are the unadjusted values from 2001, following the guidance published by Defra7. The data show areas where the background maps reflect the position of facilities that are no longer present, eg. 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:

[7] 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. Background concentrations of SO_2 for 2001 are shown in Figure 3.6.

NO_2

Modelled Concentrations of NO_2 for 2023 range between 6.7 µg/m³ and 15.8 µg/m³ within the Grangemouth AQMA. This is a maximum of 40% of the objective value of 40 µg/m³ Background concentrations of NO_2 for 2023 are shown in Figure 3.7.

NO_X

Background concentrations of NO_X for 2023 range between 9.4 µg/m³ and 23.8 µg/m³ within the Grangemouth AQMA. The highest background concentrations are up to 80% of the limit value of 30 µg/m³ for the protection of vegetation and are at background squares where designated nature conservation sites are located. Background concentrations of NO_X for 2023 are shown in Figure 3.8.

PM_{10}

Background concentrations of PM_{10} for 2023 range between 8.3 µg/m³ and 11.9 µg/m³, which is up to 66% of the objective value of 18 µg/m³. Background concentrations of PM_{10} for 2023 are shown in Figure 3.9.

$PM_{2.5}$

Modelled 2023 background concentrations of $PM_{2.5}$ range between 5.0 µg/m³ and 7.0 µg/m³ which is up to 70% of the objective value of 10 µg/m³. Background concentrations of $PM_{2.5}$ for 2023 are shown in Figure 3.10.

FIGURE 3.6 2001 BACKGROUND SO_2 CONCENTRATIONS

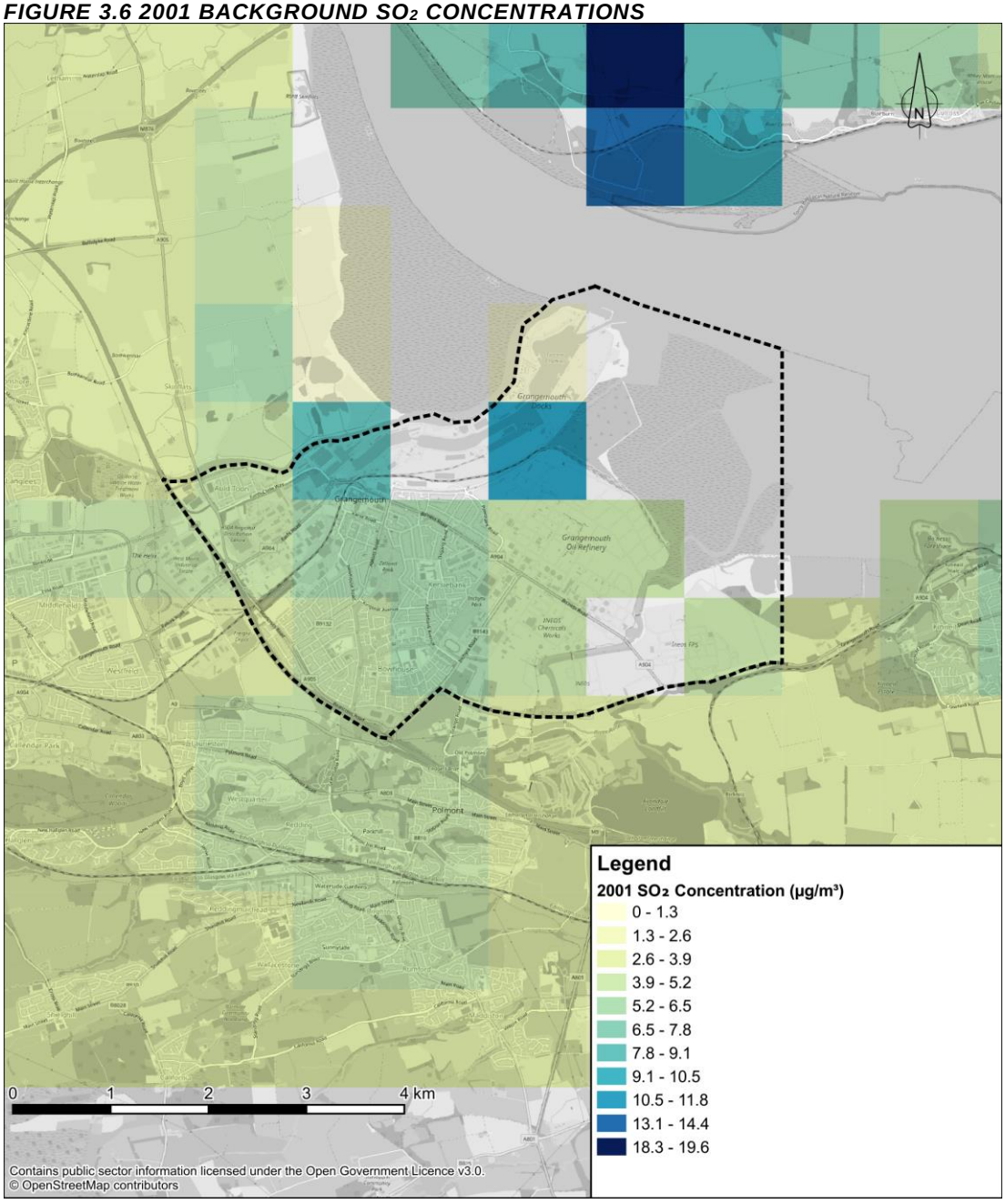


FIGURE 3.7 2023 BACKGROUND NO_2 CONCENTRATIONS

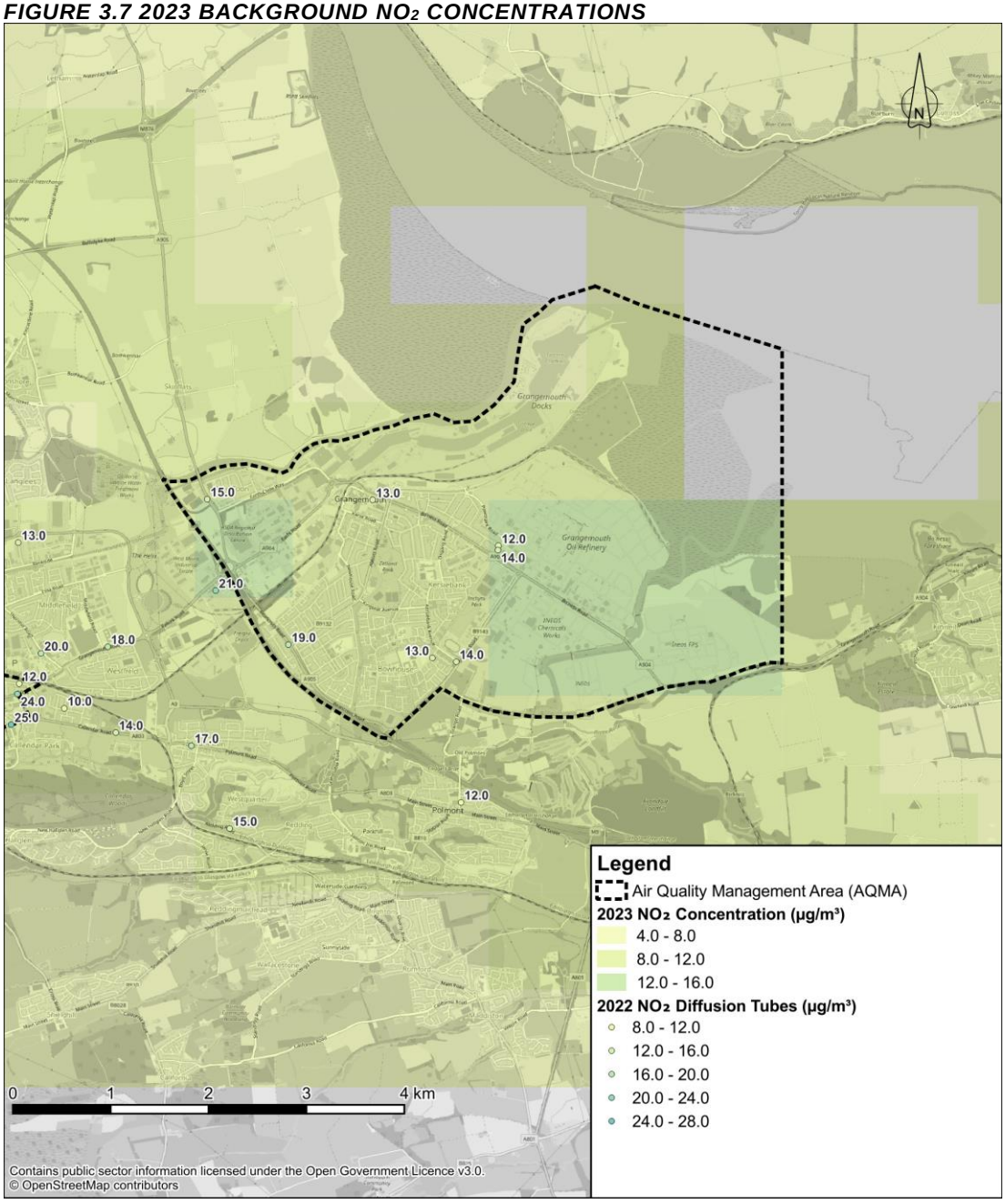


FIGURE 3.8 2023 BACKGROUND NO_X CONCENTRATIONS

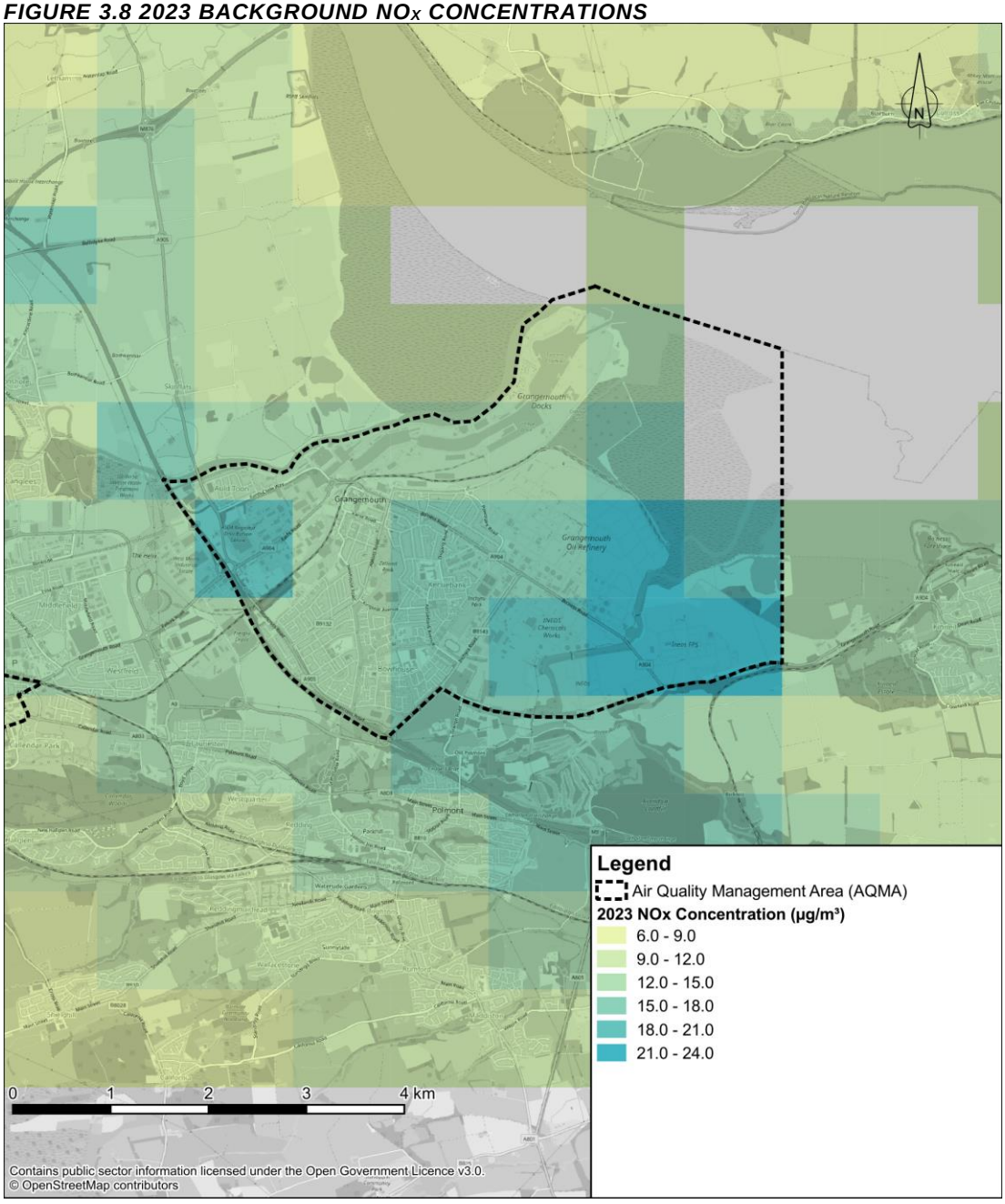


FIGURE 3.9 2023 BACKGROUND PM_{10} CONCENTRATIONS

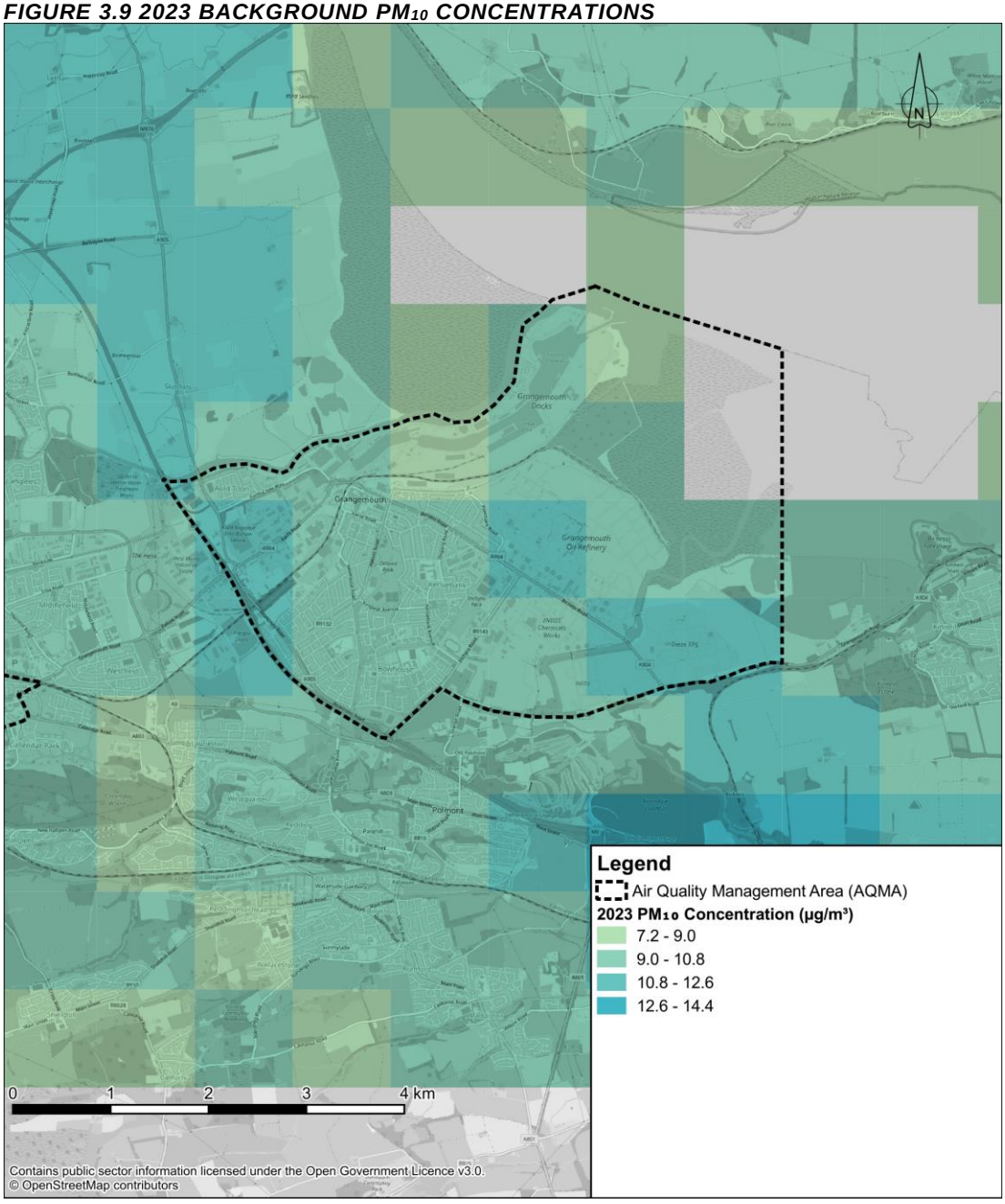
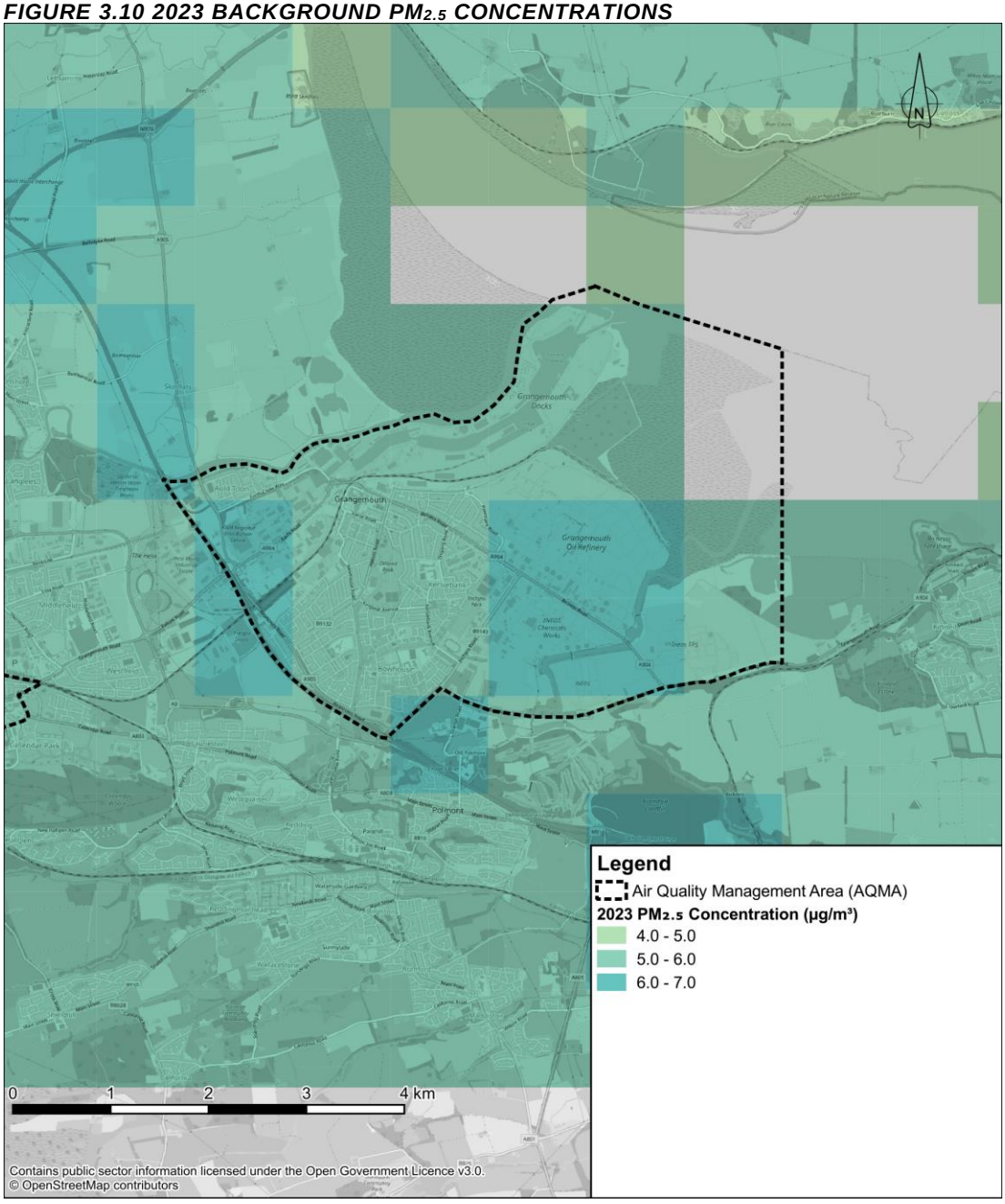


FIGURE 3.10 2023 BACKGROUND $PM_{2.5}$ CONCENTRATIONS



3.3 National Atmospheric Emission Inventory

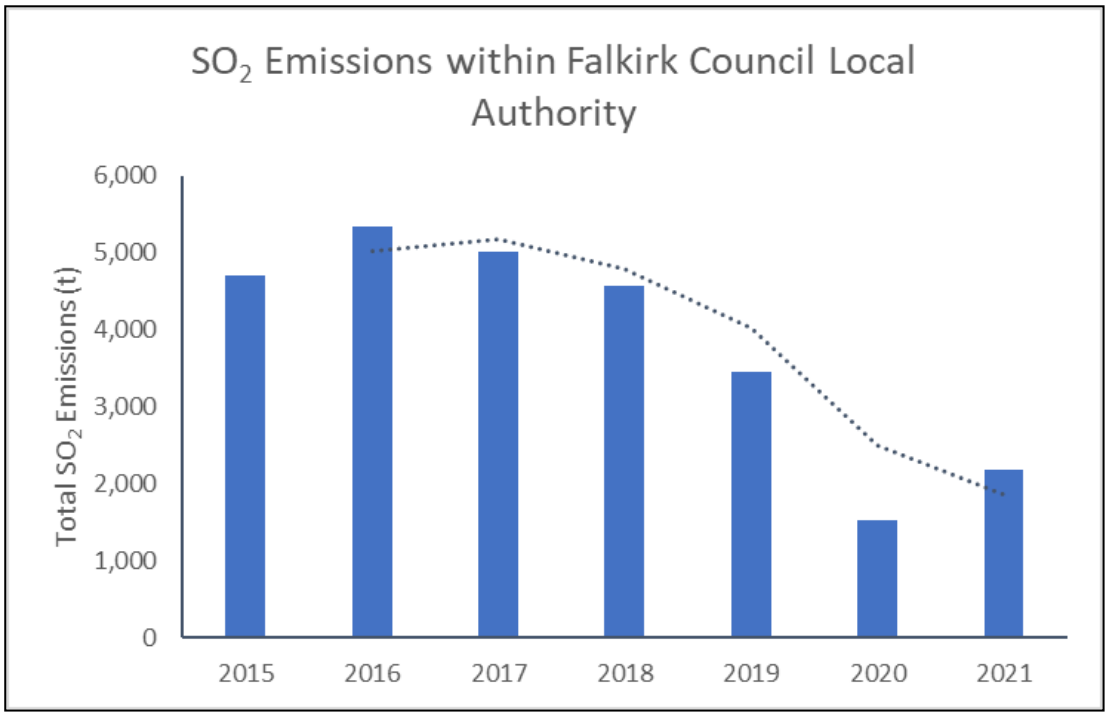
The UK National Atmospheric Emission Inventory (NAEI) aggregates information submitted to the Environment Agency, the Scottish Environment Protection Agency (SEPA) and Natural Resources Wales to provide a national summary of emissions to air of various pollutants. With reference to the Grangemouth AQMA emissions of SO_2 up to 2021 (the latest year available) for the Falkirk Council local authority area are presented in Table 3.2 and

Figure 3.11. At this time the Scottish Pollutant Release Inventory (SPRI) cannot be used for such information as it is incomplete following the cyber attack inflicted upon SEPA in 2019 therefore the data presented is from the NAEI only.

TABLE 3.2 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 3.11 FALKIRK COUNCIL AREA ANNUAL SO_2 EMISSIONS WITH MOVING AVERAGE



The mass emissions data in Table 3.2 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 3.1 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

4.1 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 2021 road traffic emission dispersion model used CERC ADMS-Roads Extra v5.0.

The two separate pieces of software have additional capabilities with respect to each other for the sources being modelled. ADMS contains features for industrial emissions modelling that are not present in ADMS-Roads and vice versa for the modelling of road sources. The two pieces of software are also not updated in tandem, therefore more accurate results can be obtained by using ADMS and ADMS-Roads to predict concentrations from the relevant sources and then combining the resultant outputs.

The ADMS suite of software are gaussian plume dispersion modelling systems that are 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.

4.2 Industrial Emissions Data Request

A generic data request was issued to all of the companies operating at the Grangemouth industrial area from which the following source groups were identified:

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

The approach of obtaining information directly from the operators was taken as information associated with environmental permits and annual reporting do not contain sufficient detail to facilitate effective dispersion modelling. The availability of SEPA records was also still affected by the malicious cyber-attack that disabled SEPA systems and resulted in the loss of significant quantities documentation.

Following receipt of the data request returns consultation was undertaken with the companies to ensure that emissions from their operations were represented as accurately as possible within the dispersion model.

Emission information was supplied covering the Normal Operation of a large number of industrial sources from all source groups, with peak flaring information provided for Ineos KG and Ineos FPS. To account for emissions during flaring three emissions profiles were developed:

- **Normal Operation Scenario**
  Annual 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 IneosFPS 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 IneosFPS Train 3 flares.

To understand how these emissions may affect ground concentrations, the model assumes these emissions are running continuously. In reality the flaring happens sporadically throughout the year. However, as meteorological conditions will have an impact on the plume dispersion over short time periods (i.e. sub-hourly, hourly, daily), it is important to assess these emissions under all meteorological conditions.

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

In the absence of time varying emissions data, the Peak Operation scenarios allow for all flares to be operating simultaneously which is unlikely to occur in reality, thereby representing a conservative assessment of ground level concentrations.

The flare emissions profiles for the Peak Operation scenarios are provided in Appendix A, with all other sources having the same emissions profile as the Normal Operating scenario.

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.

4.3 Road Emission Sources

No new traffic data was provided for this study, therefore traffic data used in the 2021 assessment are presented in Table 4.1 and the modelled road network shown in Figure 4.1.

Traffic data for a single scenario were used model the emissions from road sources. Automatic Traffic Counter (ATC) flows for 2018 were provided by Falkirk Council which were converted by the council into Annual Average Daily Traffic (AADT) flows suitable for air quality modelling. The model did not include any time varying emission factors as time variable traffic flows were not available. This means that complex, short-term traffic flows were not represented in the dispersion model.

TABLE 4.1 TRAFFIC DATA USED WITHIN THE ASSESSMENT OF ROAD TRAFFIC EMISSIONS

Road	AADT Baseline	Source	% Motorcycle	% Car	% LGV	%HGV	% Bus
A905 Skinflats	13,738	DfT 10965	0.8	82.2	0.6	16.3	0.1
A905 Glenburgh	12,565	Glensburgh Road ATC	2.4	82.1	1.1	12.3	2.1
A904 Earls Road	10,141	Earls Road ATC	1.1	77.4	0.8	17.5	3.2
Station Road	10,174	DfT 80189	0.4	72.4	1.8	25.3	0.1
A904 Bo'Ness Road	10,176	DfT 10964	0.4	72.4	1.8	25.3	0.1
Inchyra Road	18,302	Inchyra Road ATC	1.9	82.3	0.7	14	1.1
Beancross Road	13,097	Beancross Road ATC	0	85.1	0.8	13	1.1
A904 Falkirk Road	26,703	DfT 74405	0.2	78.3	1	16.9	3.6
Wholeflats Road	13,990	Wholeflats Road ATC	8.7	83	0.6	6.9	0.7
A903 Polmont	7,898	DfT 78580	0.2	85.1	1.8	12.8	0.1
M9	Between 38,423-67,336	DfT various	0.2	75.6	0.3	18.7	5.3
A904 Bo'Ness Road	10,114	DfT 40965	0.5	70.8	0.3	24.1	4.3
A904 Falkirk Road	17,416	DfT 80353	0.6	83.6	2.1	13.5	0.2

FIGURE 4.1 MODELLED ROAD NETWORK

4.4 Terrain and Surface Roughness

For the industrial point source modelling, 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 4.2.

For the industrial emission source model, 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 4.3 and was sampled at the same varying resolution as for the terrain data.

The 2021 roads emission model used a uniform surface roughness of 1 m as this was judged to best represent conditions within 200 m of the modelled road network.

FIGURE 4.2 POINT SOURCE MODEL VARIABLE TERRAIN

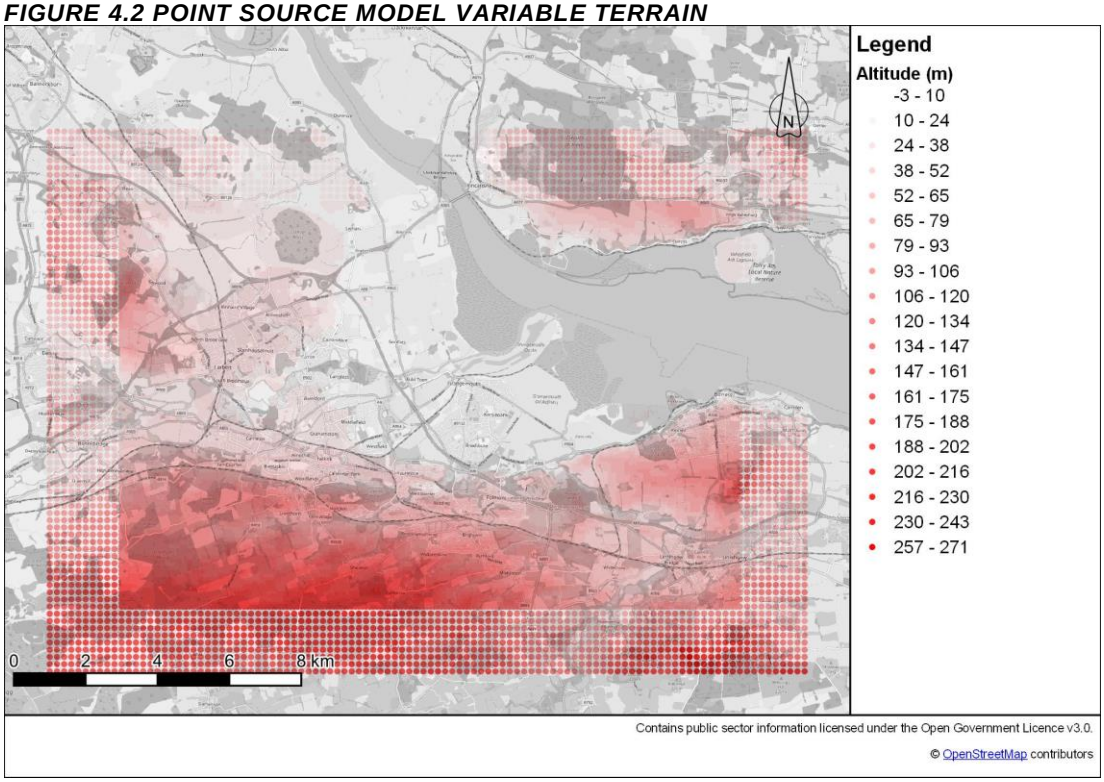
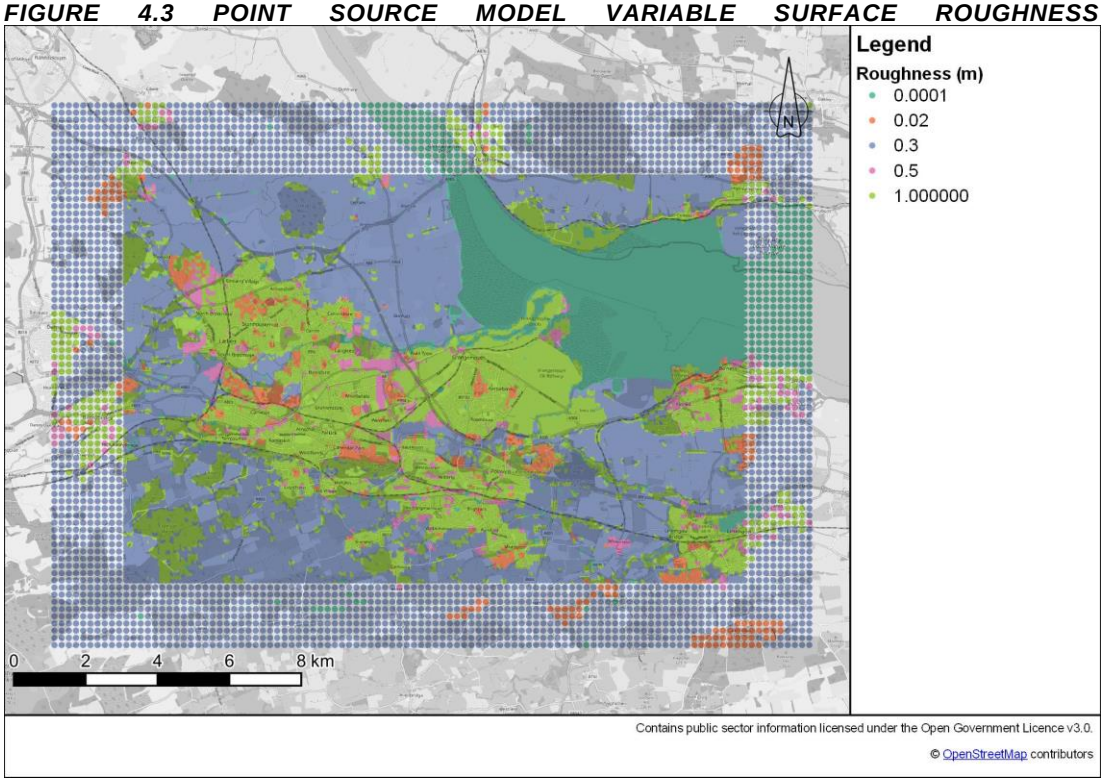


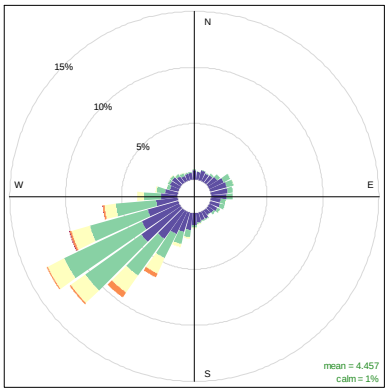
FIGURE 4.3 POINT SOURCE MODEL VARIABLE SURFACE ROUGHNESS



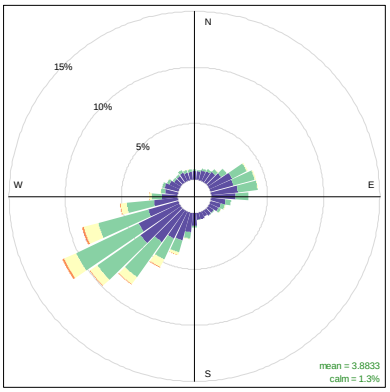
4.5 Meteorological datasets

Meteorological datasets from Edinburgh Gogarbank have been used for this study in common with previous studies of Grangemouth emissions. 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. Annual wind roses are shown in Figure 4.4 and more detailed monthly wind roses are shown in Appendix C.

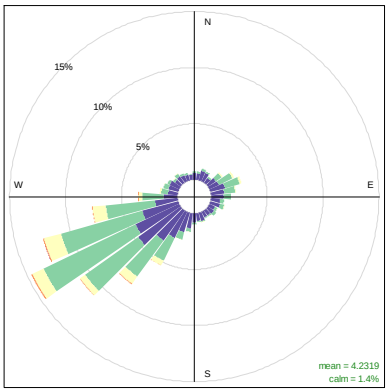
FIGURE 4.4 ANNUAL WIND ROSES FOR EDINBURGH GOGARBANK



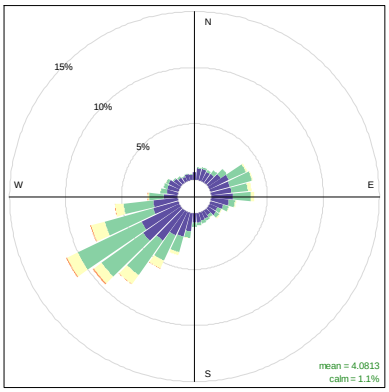
2015 Wind Rose



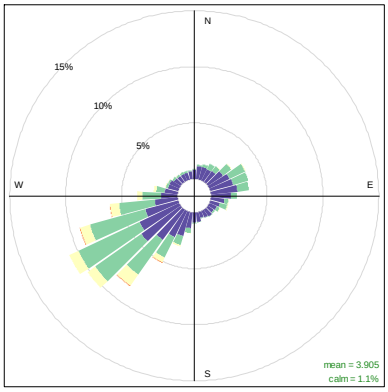
2016 Wind Rose



2017 Wind Rose



2018 Wind Rose



2019 Wind Rose

4.6 NO_X Conversion

For point source industrial emissions, the conversion of NO_X to NO_2 was undertaken using guidance provided by the UK Environment Agency Air Quality Modelling and Assessment Unit for a worst-case scenario:

- 35% of NO_X converted to NO_2 for comparison against the short-term (1-hour) objective; and
- 70% of NO_X converted to NO_2 for comparison against the long-term (annual mean) objective.

Predictions from the 2021 dispersion modelling for NO_X concentrations from road traffic emissions were converted to NO_2 concentrations through the use of the Defra NO_X to NO_2 Calculator v7.1.

4.7 Modelling Outputs

Modelling outputs have been selected according to the requirements of the legislation and objectives described in Table 2.1. Additional percentiles have been selected in order to obtain values for peak measurements against short-term objectives from the model results. The selected outputs are shown in Table 4.2.

TABLE 4.2 ADMS MODEL OUTPUTS

Pollutant	Averaging Period	Percentiles	Exceedance Threshold
SO_2	15-minute	100, 99.9	266 µg/m³
	1-hour	100, 99.73	350 µg/m³
	24-hour	100, 99.18	125 µg/m³
NO_X	1-hour	99.79	-
PM_{10}	1-hour	-	-
	24-hour	100, 98.08	50 µg/m³
$PM_{2.5}$	1-hour	-	-
CO	Max daily 8-hour rolling mean	100	10 mg/m³
	8-hour rolling mean	100	10 mg/m³
VOC	1-hour	100	-
	24-hour	100	-
CH_4	1-hour	100	-
	24-hour	100	-

4.8 Receptors

Discrete Human Receptors

The discrete human receptors used for this investigation were those presented in the 2021 Grangemouth Emissions Study undertaken by Sweco. The receptors were chosen on the façade of buildings relevant to the traffic modelling undertaken for the 2021 study, however given their geographical distribution within and outwith the Grangemouth AQMA they are considered representative for this study. Human receptor location are shown in Table 4.3 and Figure 4.5.

Automatic monitoring locations were also used for this study and these are shown in Table 4.4

TABLE 4.3 DISCRETE HUMAN RECEPTORS

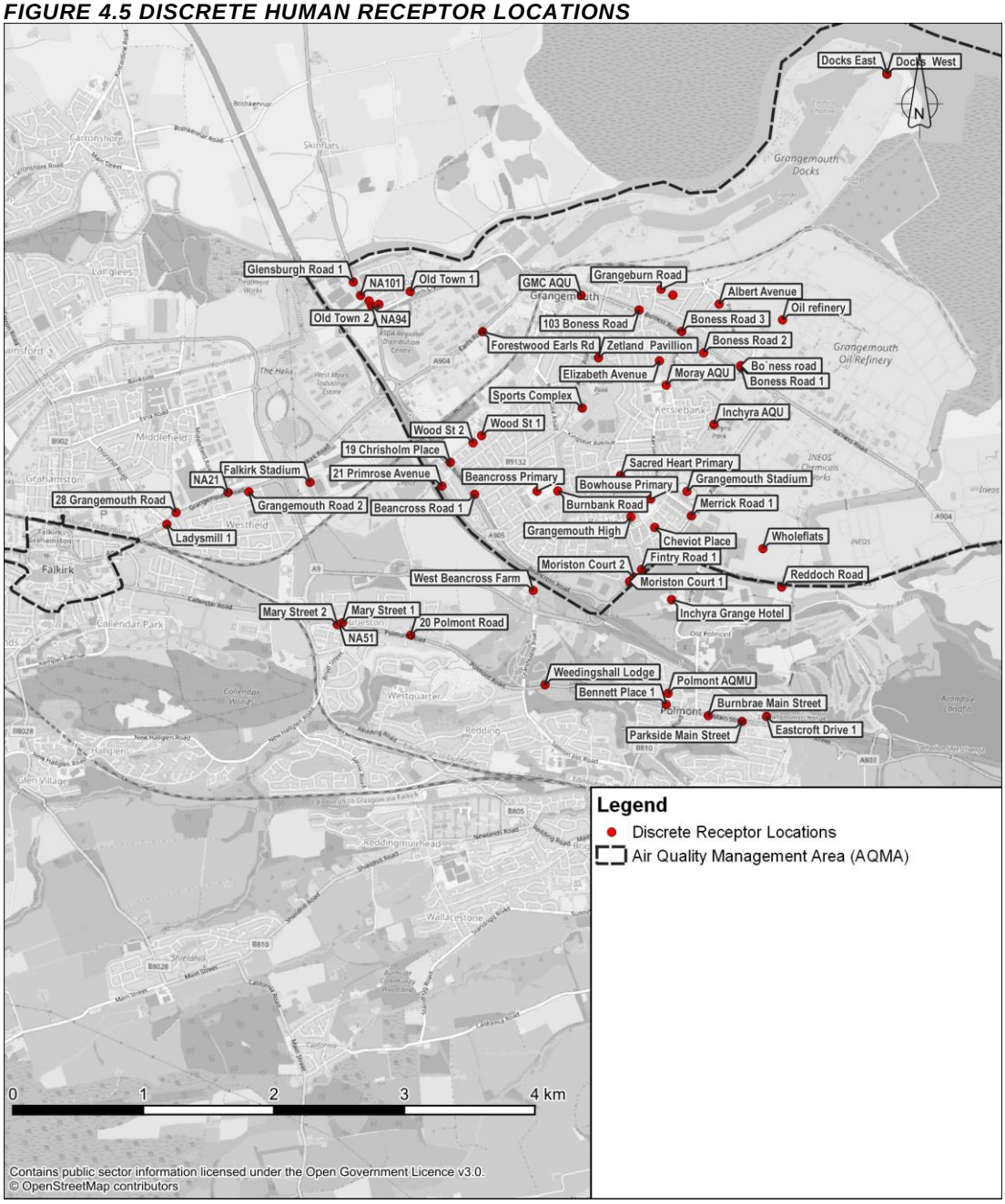
Receptor	X	Y	Height (m)	Description
Glensburgh Road 1	291071.6	682110.5	1.5	Residential
Glensburgh Road 2	291192.4	681964.7	1.5	Residential
21 Primrose Avenue	291750.7	680549.5	1.5	Residential
19 Chrisholm Place	291814.9	680731.1	1.5	Residential
Beancross Road 1	292001.1	680485.2	1.5	Residential
Moriston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

Receptor	X	Y	Height (m)	Description
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 4.4 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

FIGURE 4.5 DISCRETE HUMAN RECEPTOR LOCATIONS



Modelling Domain

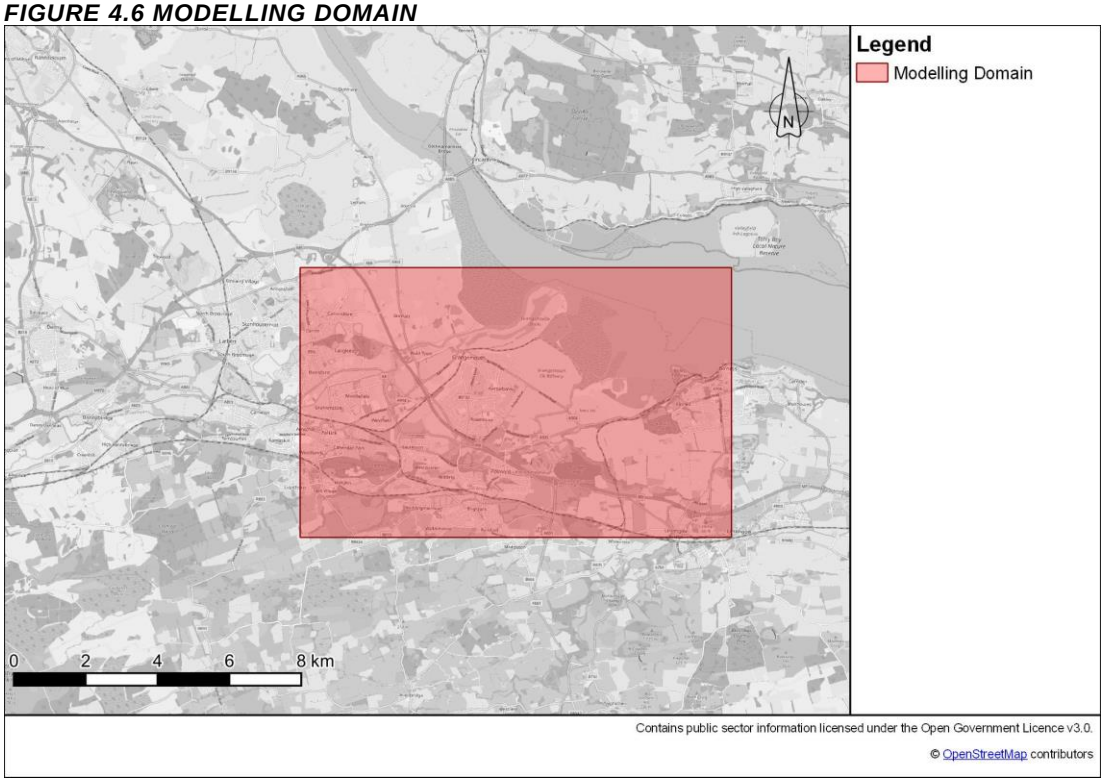
The modelling domain was set up in the ADMS software with the parameters shown in Table 4.5 and

Figure 4.6. The modelling domain was enlarged from the 2021 Grangemouth Emissions Study undertaken by Sweco to encompass the whole of the Grangemouth AQMA and include the Falkirk AQMA.

TABLE 4.5 MODELLING DOMAIN PARAMETERS

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

FIGURE 4.6 MODELLING DOMAIN



5 Model Results and Analysis

5.1 SO_2

This section details the results of the dispersion modelling for SO_2. All the results presented at the Process Contribution due to the inappropriate nature of the Defra SO_2 backgrounds.

Discrete Human Receptors:15-minute Mean SO_2

Normal Operation Scenario

The predicted 15-minute mean SO_2 concentrations at discrete human receptors are presented in this section. The focus of the analysis is on the ten (10no) receptors with the highest modelled concentrations and associated exceedances of the 15-minute mean concentration standard (266 µg/m^3) across each of the five years of modelled hourly meteorological data.

The modelled worst-case results from all five years of meteorological data against the 15-minute objective for SO_2 are shown in Table 5.1 under normal operating emission conditions.

The results of modelling relating to the 99.9th percentile demonstrate that the 15-minute mean objective is not breached at any of the sensitive discrete receptors in any of the five modelled years, with the highest 99.9th percentile concentrations remaining below the standard (266 µg/m^3). This is visualised in Figure 5.1, with all modelled exceedances of the objective (i.e. over 35 exceedances of 266 µg/m^3) being confined to within the Grangemouth industrial operational area.

The modelled worst-case results from all five years of meteorological data, represented by the maximum (100th percentile) 15-minute mean concentrations, are provided in Table 5.1 and depicted in Figure 5.2. The corresponding number of exceedances of the standard in each modelled year are presented in Figure 5.3. These results demonstrate that a limited number of receptors adjacent to the Grangemouth industrial area are predicted to experience a small number of exceedances of the 15-minute standard (maximum of nine exceedances at the Inchyra Air Quality Unit), but well below the 35 allowable exceedances per annum.

TABLE 5.1 TOP 10 15-MINUTE WORST-CASE SO_2 PREDICTIONS – NORMAL OPERATION

Rank	99.9th Percentile			100th Percentile			Exceedances	
	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)	Receptor
1	108.0	110.8	Bo'Ness Road 1	312.5	315.3	Oil refinery	9	Oil refinery
2	106.7	109.5	Oil refinery	292.6	295.4	Inchyra AQU	5	Reddoch Road
3	104.7	107.5	Bo'Ness Road	284.2	287.0	Wholeflats	4	Inchyra AQU
4	96.7	99.5	Wholeflats	274.5	277.3	Bo'Ness Road 1	4	Bo'ness Road 1
5	90.2	93.0	Inchyra AQU	257.1	259.9	Bo'Ness Road 2	0	Bo'ness road
6	86.8	89.6	Reddoch Road	256.2	259.0	Bo'Ness Road	0	Wholeflats
7	86.6	89.4	Bo'Ness Road 2	254.9	257.7	Bo'Ness Road 3	0	Docks West
8	77.0	79.8	Sacred Heart Primary	251.4	254.2	Grangemouth Stadium	0	Albert Avenue
9	76.5	79.3	Moray AQU	247.9	250.7	Albert Avenue	0	Bo'ness Road 2
10	74.9	77.7	Sports Complex	240.7	243.5	Elizabeth Avenue	0	Grangemouth Road 1

FIGURE 5.1 PREDICTIONS FOR SO_2, 15-MINUTE, 99.9TH PERCENTILE, NORMAL OPERATION

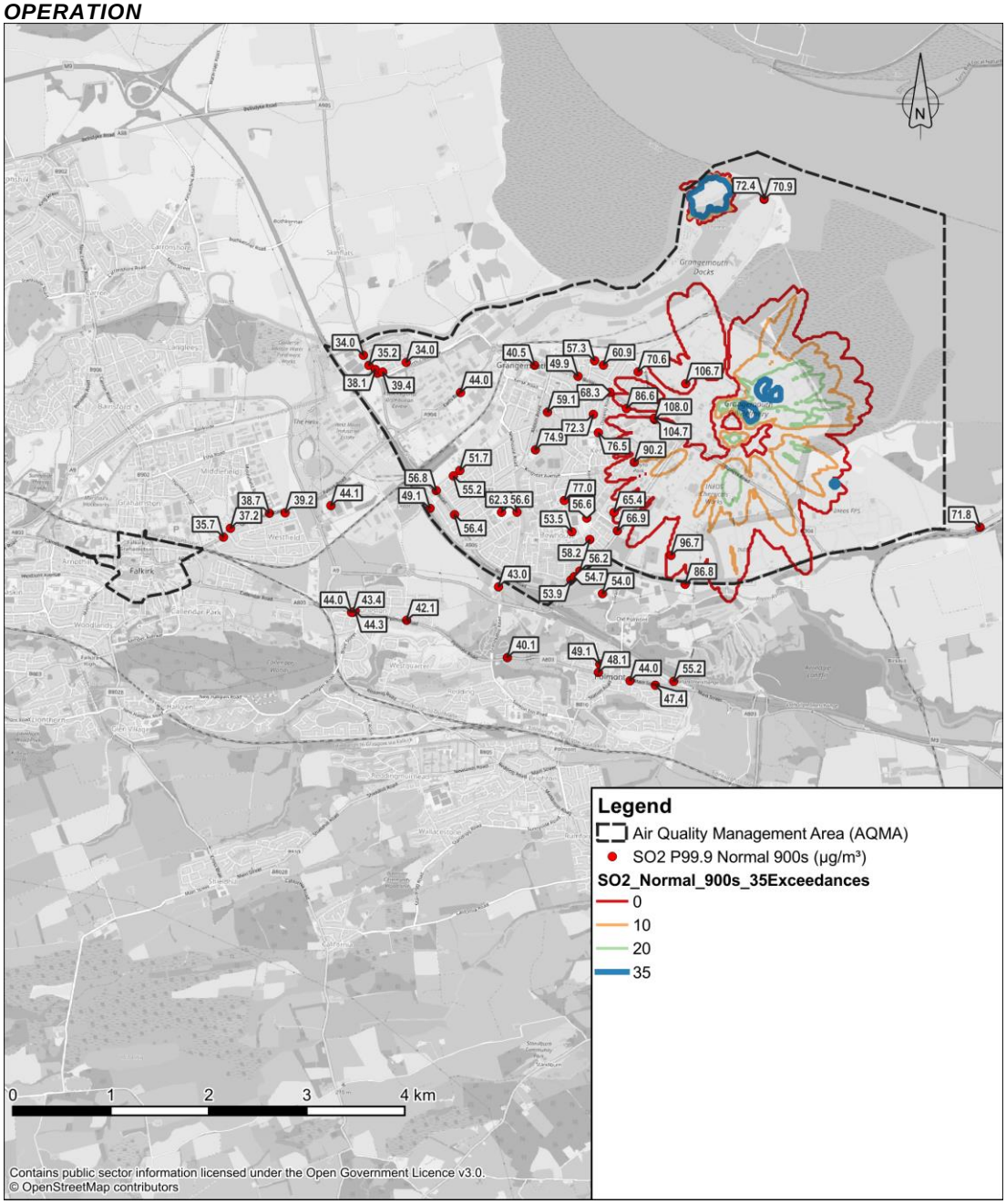


FIGURE 5.2 PREDICTIONS FOR SO_2, 15-MINUTE, 100TH PERCENTILE, NORMAL OPERATION

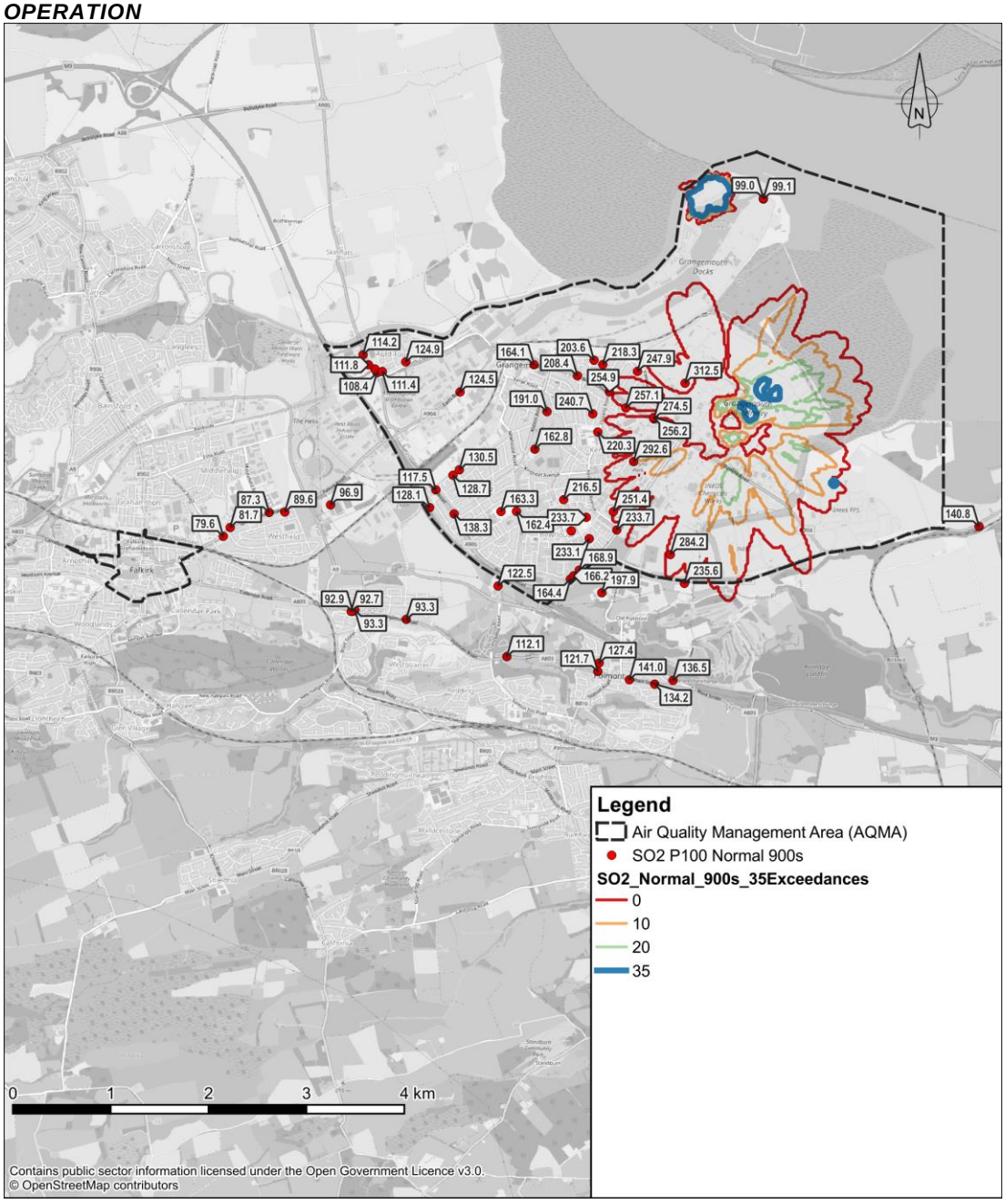


FIGURE 5.3 PREDICTIONS FOR SO_2, 15-MINUTE EXCEEDANCES, NORMAL OPERATION

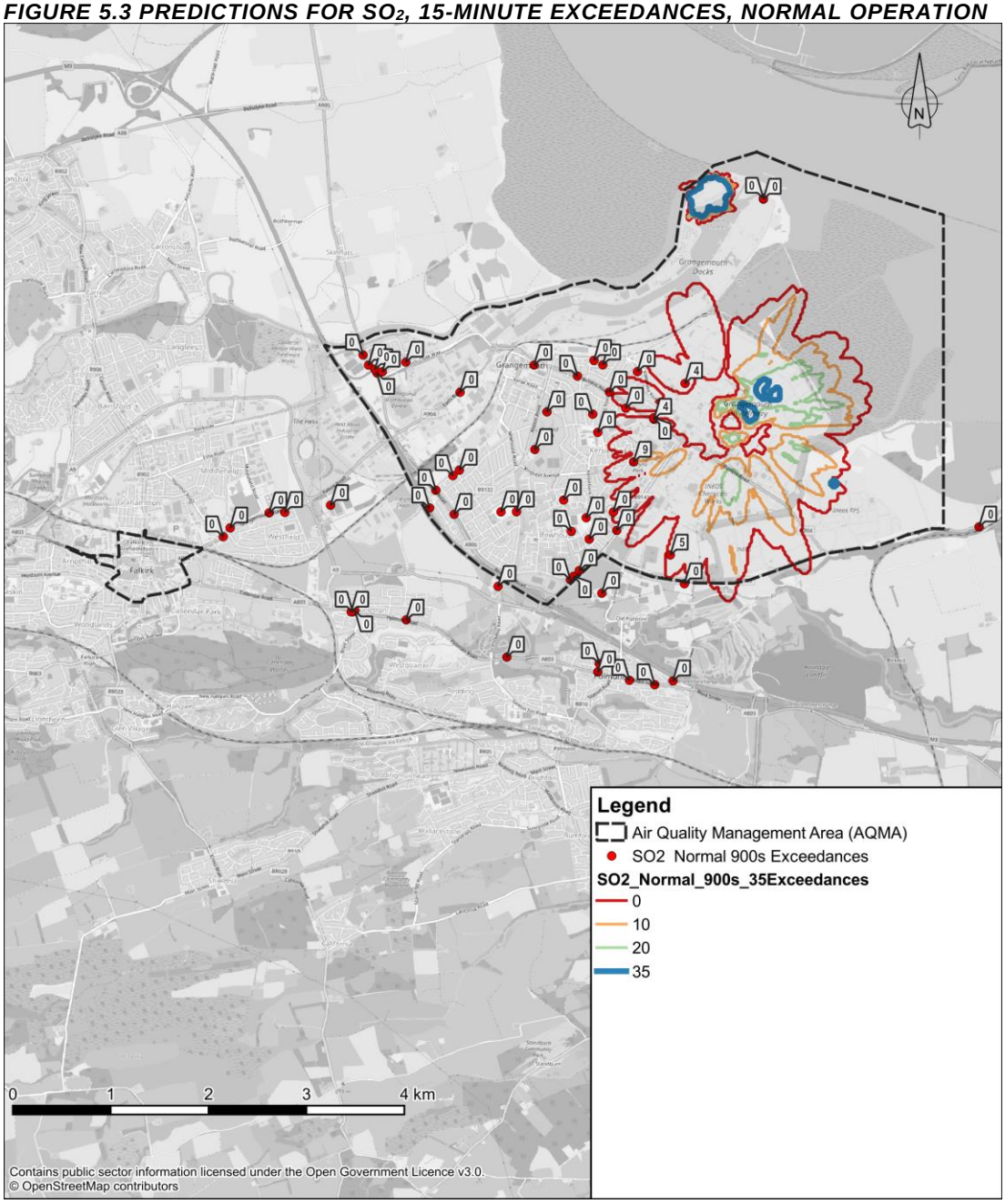


TABLE 5.2 TOP 10 15-MINUTE WORST-CASE SO_2 PREDICTIONS – PEAK A OPERATION

Rank	99.9th Percentile			100th Percentile			Exceedances	
	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)	Receptor
1	238.9	241.7	Oil refinery	706.8	709.6	Oil refinery	23.0	Inchyra AQU
2	232.6	235.4	Bo'Ness Road 1	654.3	657.1	Inchyra AQU	21.8	Oil refinery
3	221.1	223.9	Bo'Ness Road	640.7	643.5	Wholeflats	21.4	Bo'Ness Road 1
4	211.1	214.0	Wholeflats	628.0	630.8	Bo'Ness Road 1	21.4	Bo'Ness Road
5	191.4	194.2	Inchyra AQU	586.1	588.9	Bo'Ness Road	18.4	Bo'Ness Road 2
6	190.6	193.5	Bo'Ness Road 2	577.2	580.0	Bo'Ness Road 2	18.4	Moray AQU
7	189.2	192.0	Reddoch Road	568.1	571.0	Bo'Ness Road 3	18.4	Wholeflats
8	167.7	170.5	Moray AQU	560.0	562.8	Grangemouth Stadium	17.4	Sacred Heart Primary
9	162.9	165.7	Sacred Heart Primary	551.6	554.4	Albert Avenue	17.4	Burnbank Road
10	156.4	159.2	Sports Complex	542.7	545.5	Merrick Road 1	17.4	Reddoch Road

FIGURE 5.4 PREDICTIONS FOR SO_2, 15-MINUTE, 99.9TH PERCENTILE, PEAK A OPERATION

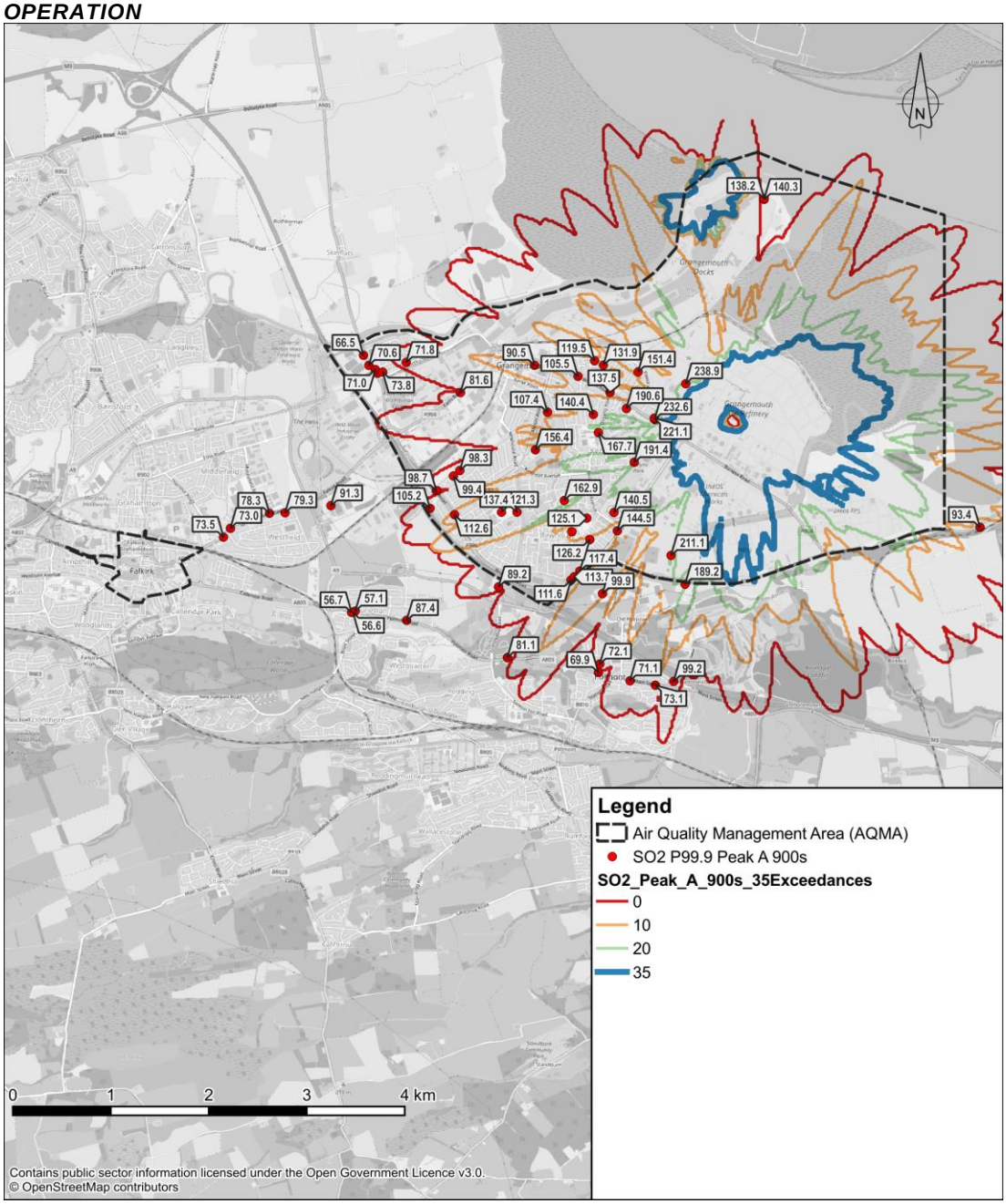


FIGURE 5.5 PREDICTIONS FOR SO_2, 15-MINUTE, 100TH PERCENTILE, PEAK A OPERATION

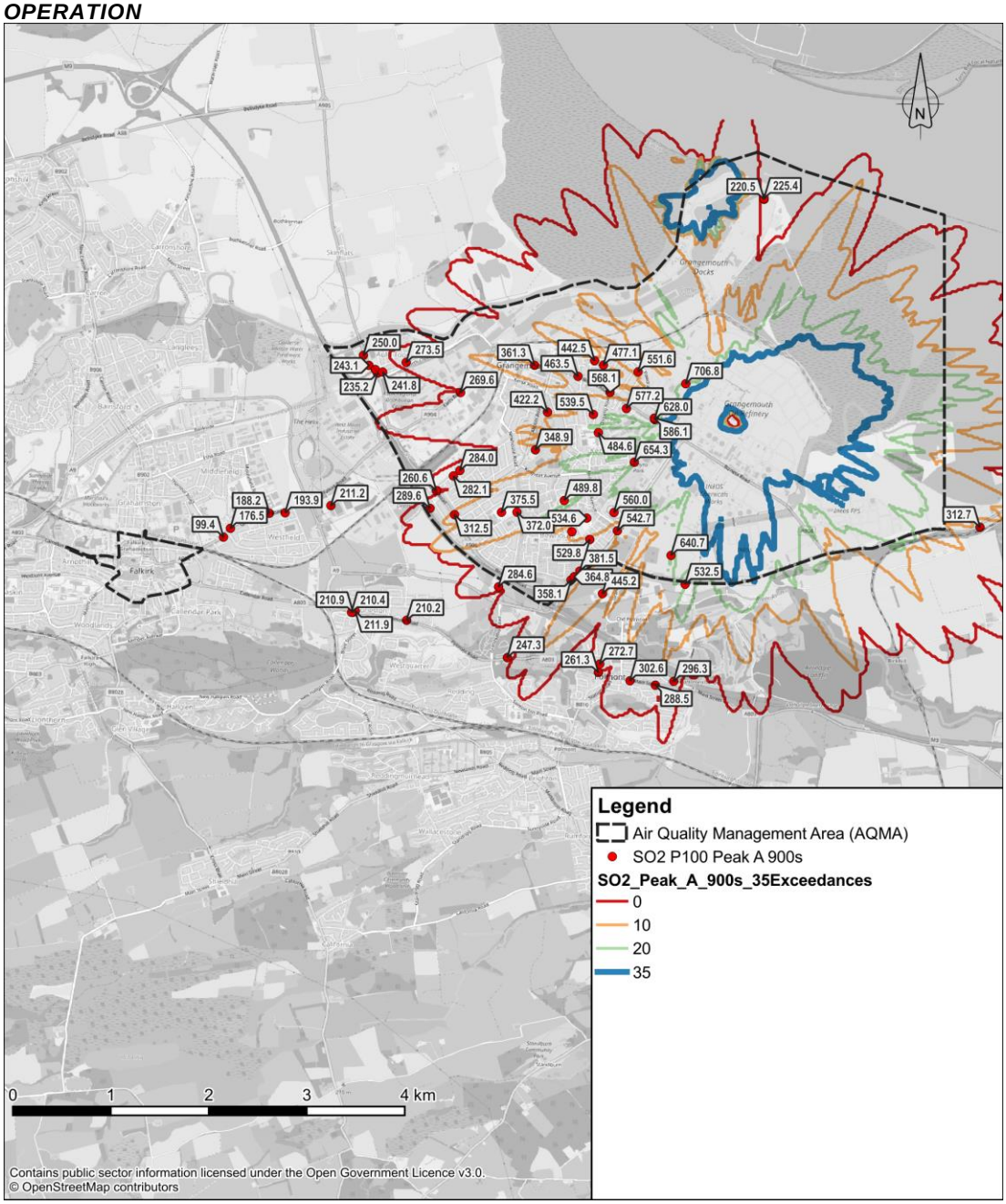


FIGURE 5.6 PREDICTIONS FOR SO_2, 15-MINUTE EXCEEDANCES, PEAK A OPERATION

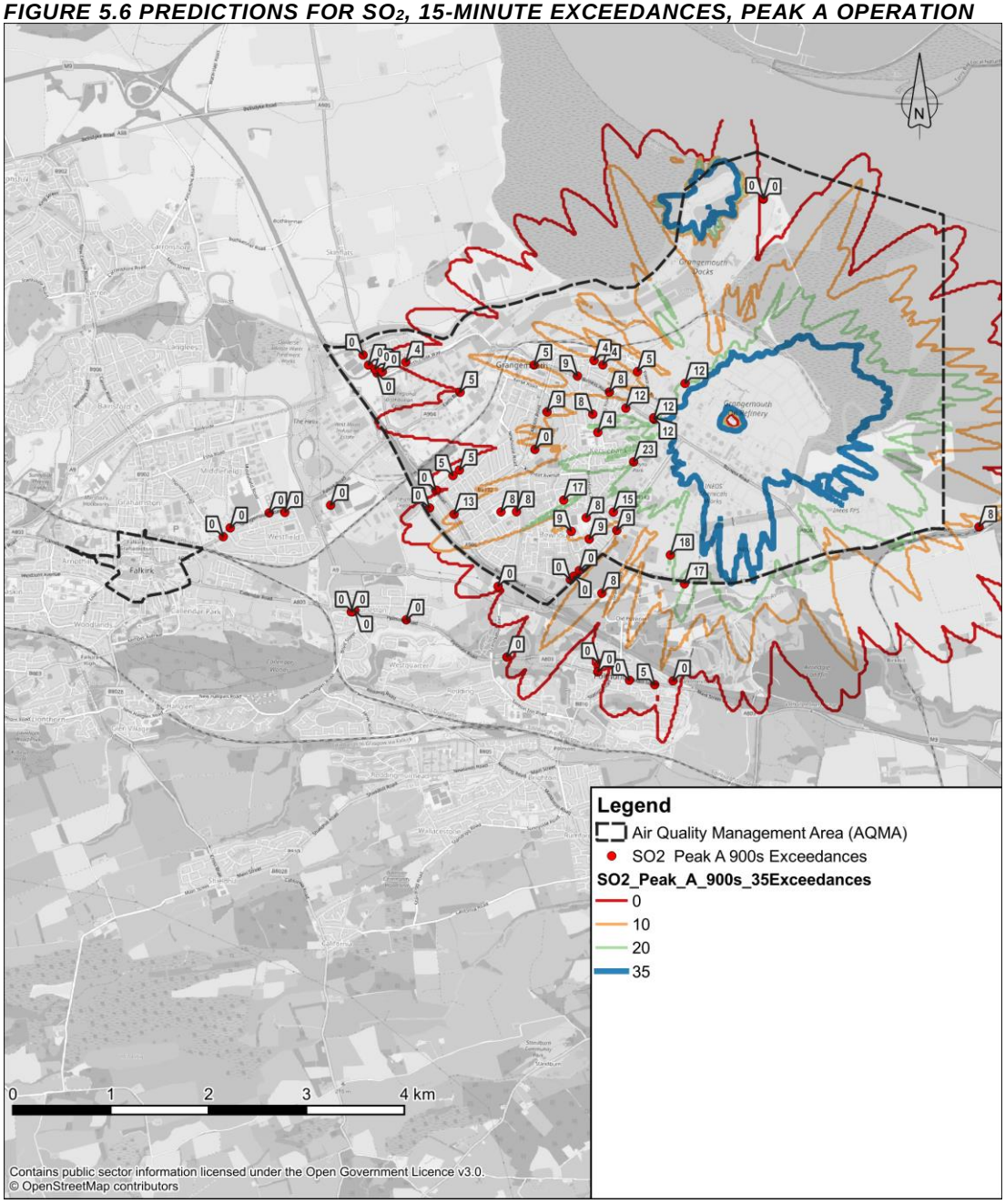


TABLE 5.3 TOP 10 15-MINUTE WORST-CASE SO_2 PREDICTIONS – PEAK B OPERATION

Rank	99.9th Percentile			100th Percentile			Exceedances	
	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	SO_2 PC (µg/m³)	SO_2 PEC (µg/m³)	Receptor	Exceedances	Receptor
1	238.2	241.0	Oil refinery	703.8	706.6	Oil refinery	23	Inchyra AQU
2	232.5	235.3	Bo'Ness Road 1	654.3	657.1	Inchyra AQU	21	Bo'Ness Road 1
3	221.0	223.8	Bo'Ness Road	640.7	643.5	Wholeflats	21	Bo'Ness Road
4	211.1	214.0	Wholeflats	628.0	630.8	Bo'Ness Road 1	18	Bo'Ness Road 2
5	191.4	194.2	Inchyra AQU	586.0	588.9	Bo'Ness Road	18	Moray AQU
6	189.5	192.3	Bo'Ness Road 2	574.8	577.6	Bo'Ness Road 2	18	Wholeflats
7	189.2	192.0	Reddoch Road	566.5	569.3	Bo'Ness Road 3	17	Oil refinery
8	167.6	170.4	Moray AQU	560.0	562.8	Grangemouth Stadium	17	Sacred Heart Primary
9	162.9	165.7	Sacred Heart Primary	548.2	551.0	Albert Avenue	17	Burnbank Road
10	156.3	159.1	Sports Complex	542.7	545.5	Merrick Road 1	17	Reddoch Road

FIGURE 5.7 PREDICTIONS FOR SO_2, 15-MINUTE, 99.9TH PERCENTILE, PEAK B OPERATION

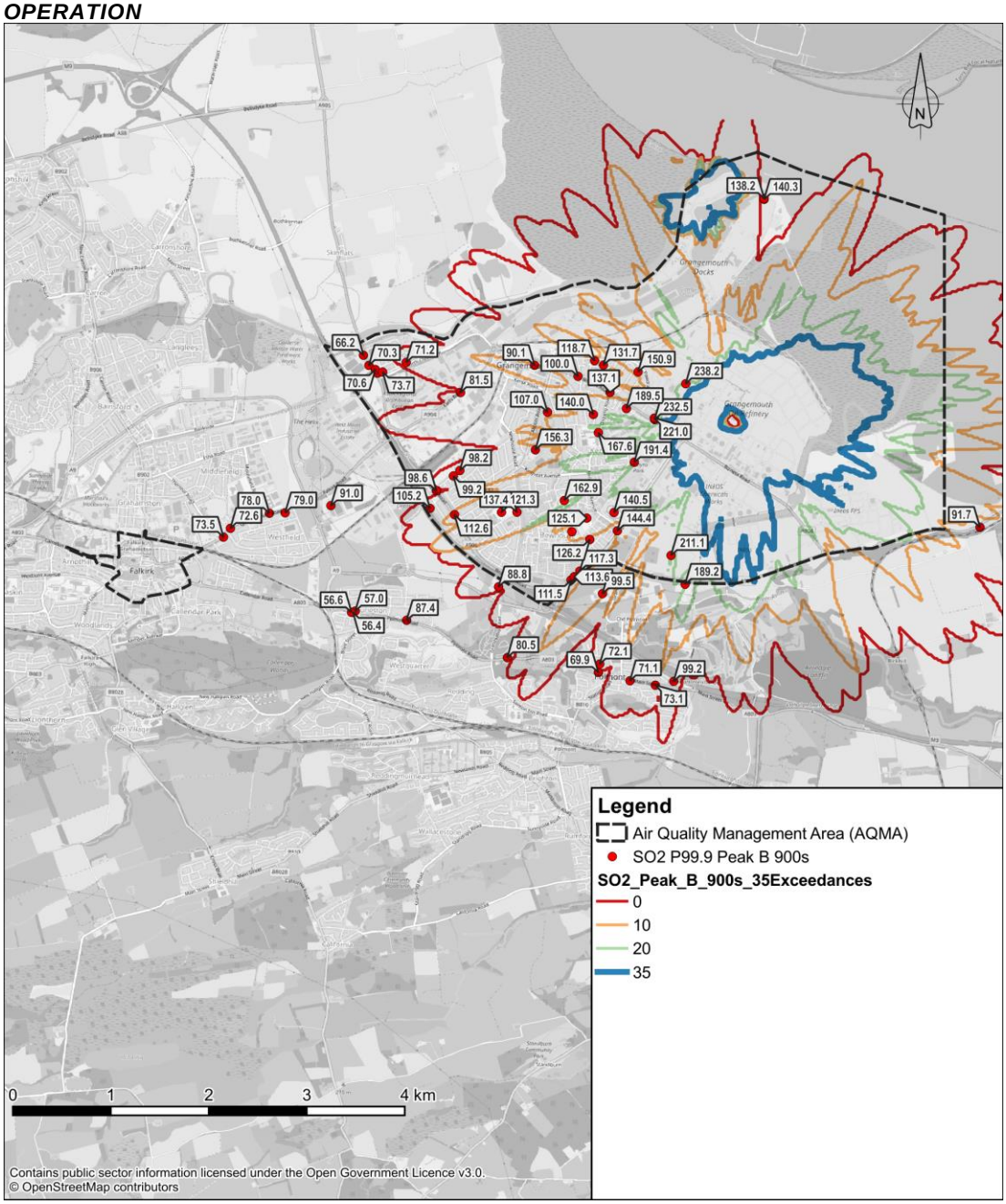


FIGURE 5.8 PREDICTIONS FOR SO_2, 15-MINUTE, 100TH PERCENTILE, PEAK B OPERATION

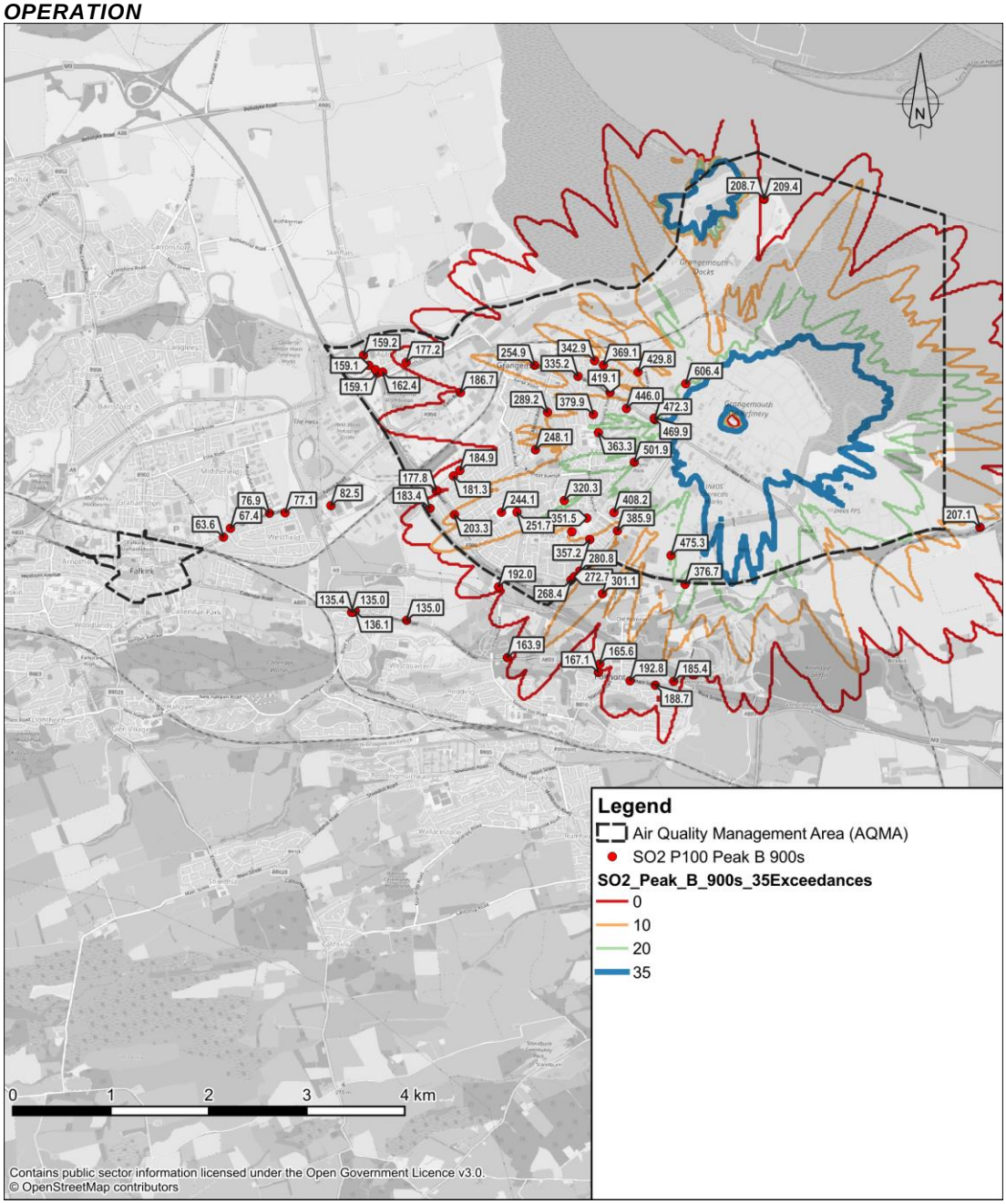
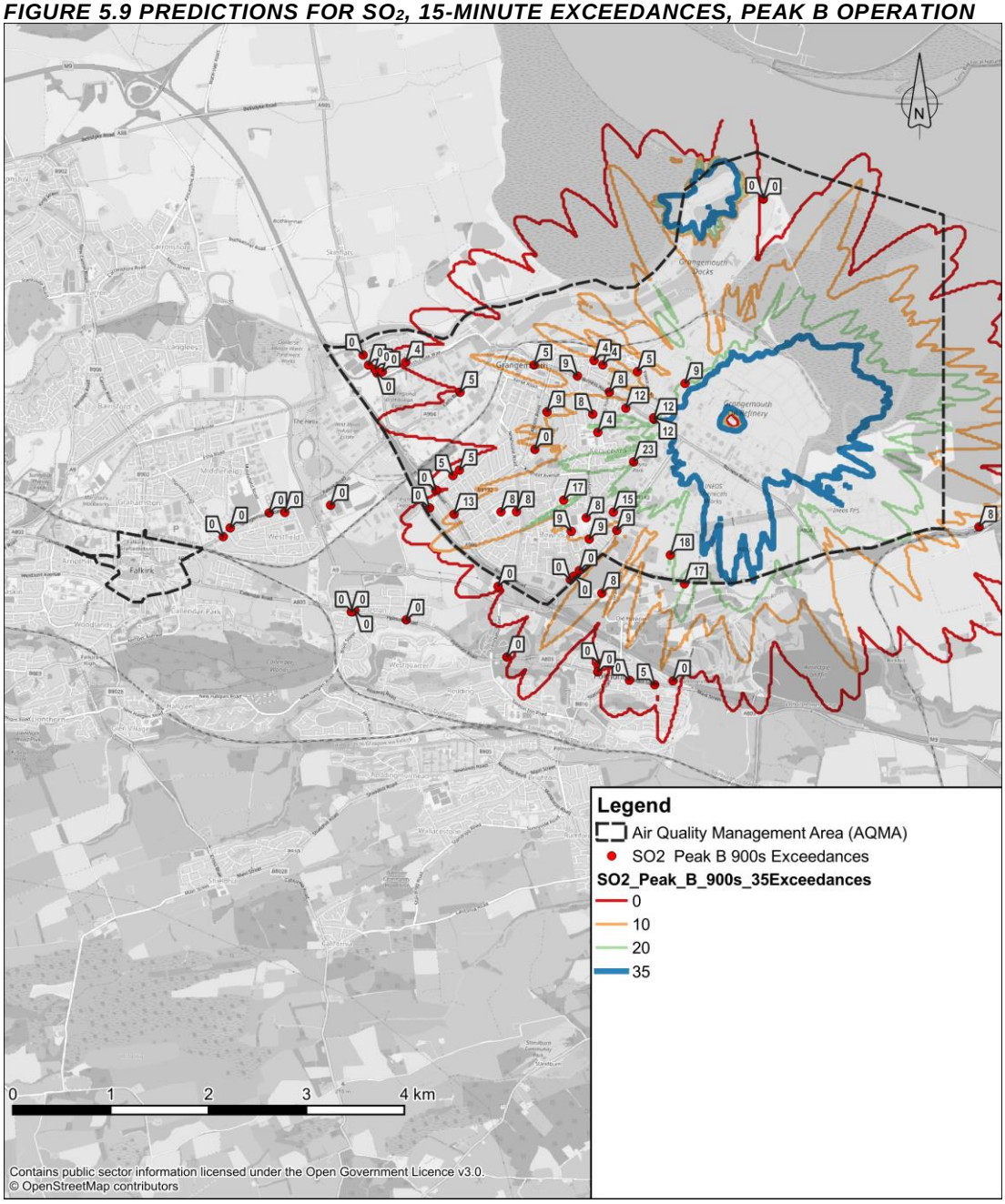


FIGURE 5.9 PREDICTIONS FOR SO_2, 15-MINUTE EXCEEDANCES, PEAK B OPERATION



Discrete Human Receptors:1-hour Objective

Normal Operation Scenario

The 1-hour mean objective of 350 µg/m³ is not predicted to be exceeded at any of the representative sensitive human receptors with the Grangemouth plant operating under normal conditions. A summary of the modelling results is provided in Table 5.4.

The spatial distribution of the predicted concentrations is also provided in Figure 5.10 and Figure 5.11.

TABLE 5.4 TOP 10 1-HOUR WORST-CASE SO_2 PREDICTIONS – NORMAL OPERATION

Rank	99.73th Percentile		100th Percentile	
	SO_2 Concentration ($\mu g/m^3$)	Receptor	SO_2 Concentration ($\mu g/m^3$)	Receptor
1	82.5	Oil refinery	273.2	Oil refinery
2	70.2	Bo'Ness Road 1	229.8	Inchyra AQU
3	69.9	Bo'Ness Road	214.7	Bo'Ness Road 1
4	59.8	Inchyra AQU	213.0	Wholeflats
5	54.0	Bo'Ness Road 2	211.2	Bo'Ness Road
6	48.8	Wholeflats	204.0	Bo'Ness Road 2
7	48.8	Albert Avenue	197.7	Albert Avenue
8	48.3	Moray AQU	193.9	Bo'Ness Road 3
9	47.1	Elizabeth Avenue	186.1	Grangemouth Stadium
10	46.2	Bo'Ness Road 3	174.4	Elizabeth Avenue

FIGURE 5.10 PREDICTIONS FOR SO_2, 1-HOUR, 99.73TH PERCENTILE, NORMAL OPERATION

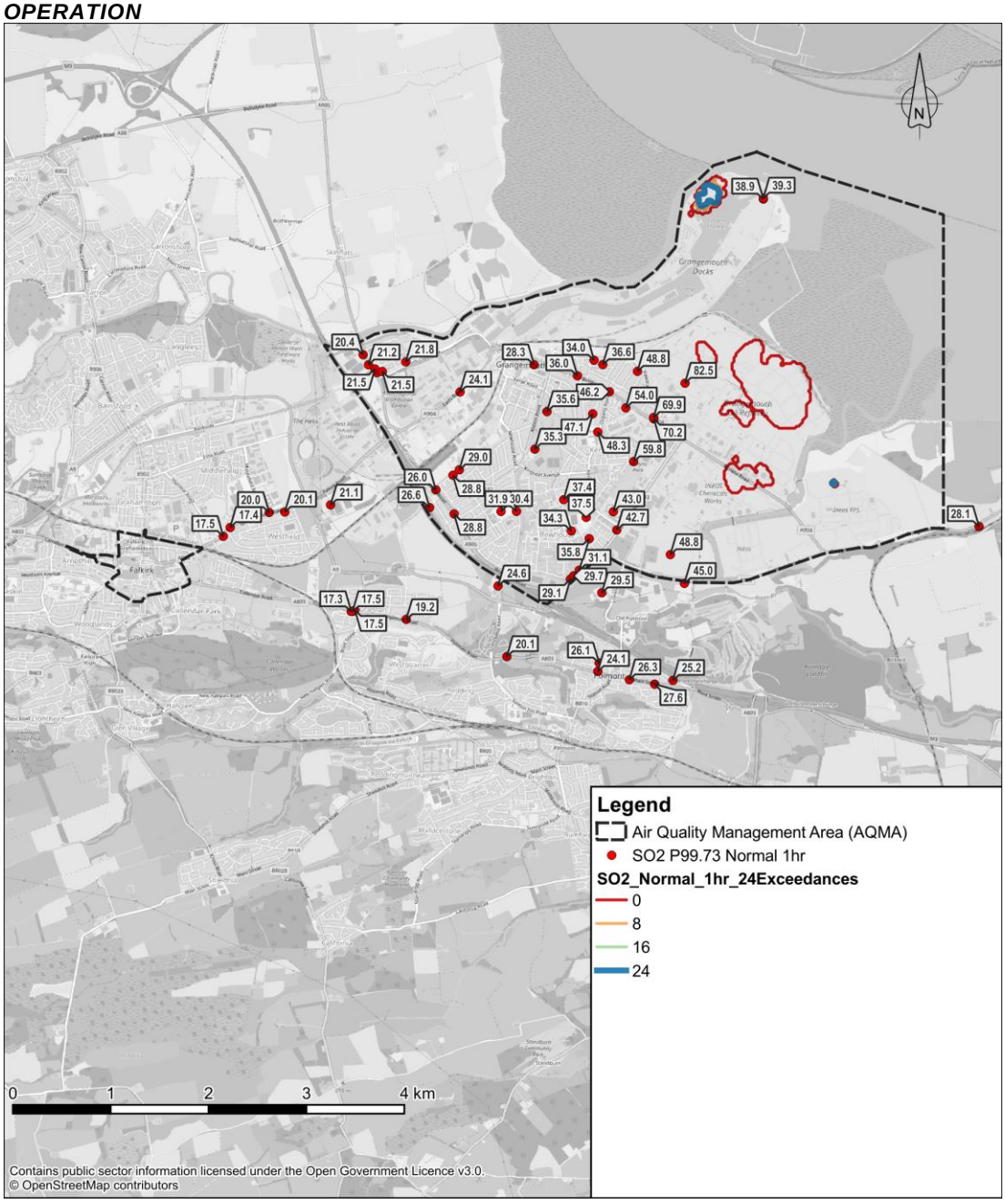
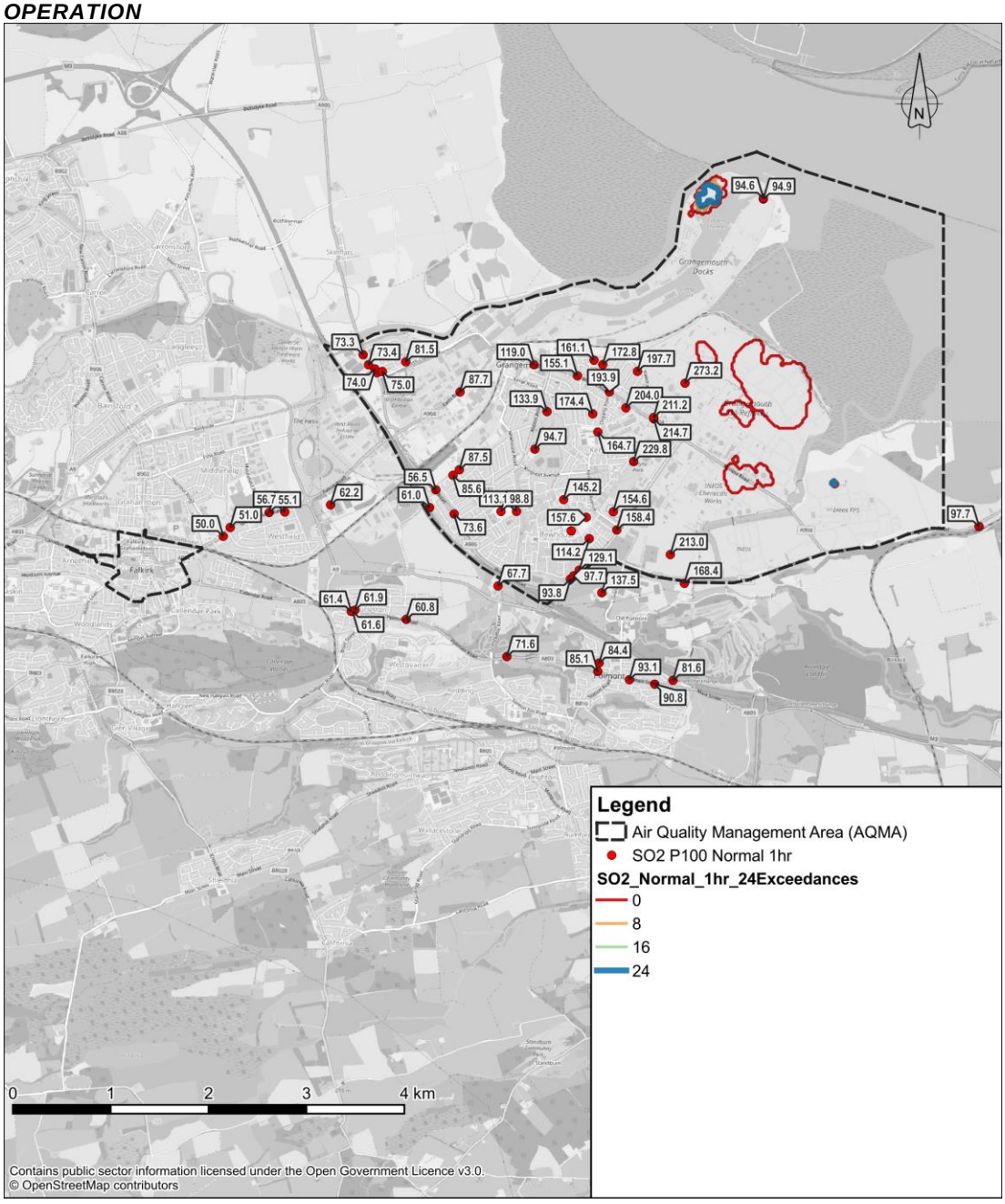


FIGURE 5.11 PREDICTIONS FOR SO_2, 1-HOUR, 100TH PERCENTILE, NORMAL OPERATION



Peak Operation

The results of the modelling indicate that exceedance of the 1-hour mean standard concentration is highly unlikely. The highest number of exceedances of the objective of 350 µg/m³ at Inchyra Park is less than the 24 allowable occurrences. This is shown in Table 5.5 and Table 5.6, and graphically in Figure 5.12, Figure 5.13, Figure 5.14 and Figure 5.15.

TABLE 5.5 TOP 10 1-HOUR WORST-CASE SO_2 PREDICTIONS – PEAK A OPERATION

Rank	99.73th Percentile		100th Percentile		Exceedances	
	SO_2 Concentration (µg/m³)	SO_2 Concentration (µg/m³)	Receptor	SO_2 Concentration (µg/m³)	Receptor	Receptor
1	181.6	Oil refinery	608.8	Oil refinery	3	Inchyra AQU
2	154.1	Bo'Ness Road	501.9	Inchyra AQU	2	Wholeflats
3	153.6	Bo'Ness Road 1	475.3	Wholeflats	2	Oil refinery
4	129.4	Inchyra AQU	472.6	Bo'Ness Road 1	2	Bo'Ness Road 2
5	114.4	Bo'Ness Road 2	471.3	Bo'Ness Road	2	Bo'Ness Road 1
6	106.2	Wholeflats	447.9	Bo'Ness Road 2	2	Bo'Ness Road 3
7	106.1	Albert Avenue	432.1	Albert Avenue	2	Bo'Ness Road
8	104.6	Moray AQU	420.7	Bo'Ness Road 3	1	Grangemouth Stadium
9	100.2	Bo'Ness Road 3	408.2	Grangemouth Stadium	1	Bowhouse Primary
10	98.6	Elizabeth Avenue	385.9	Merrick Road 1	1	Reddoch Road

FIGURE 5.12 PREDICTIONS FOR SO_2, 1-HOUR, 99.73TH PERCENTILE, PEAK A OPERATION

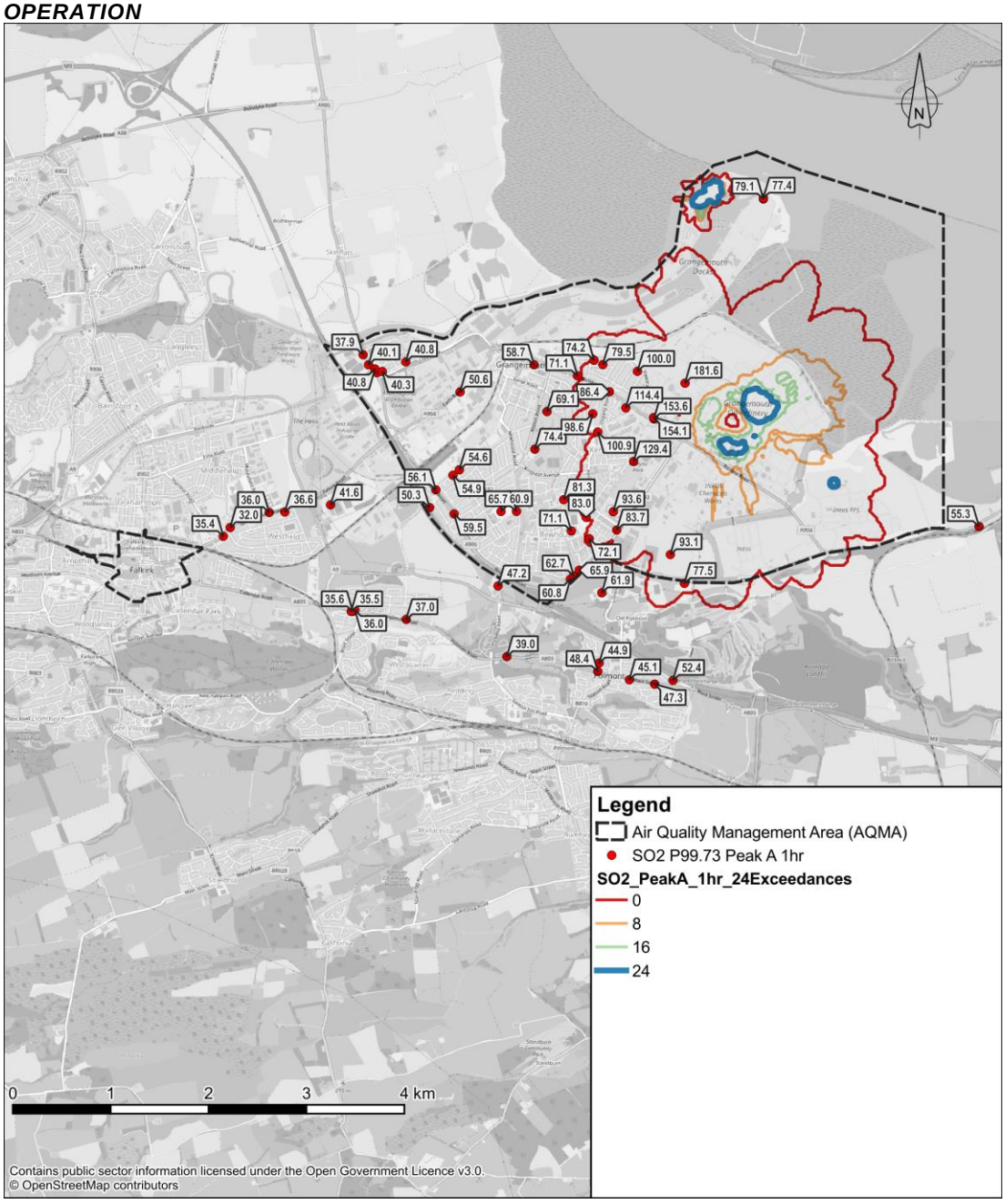


FIGURE 5.13 PREDICTIONS FOR SO_2, 1-HOUR, 100TH PERCENTILE, PEAK A OPERATION

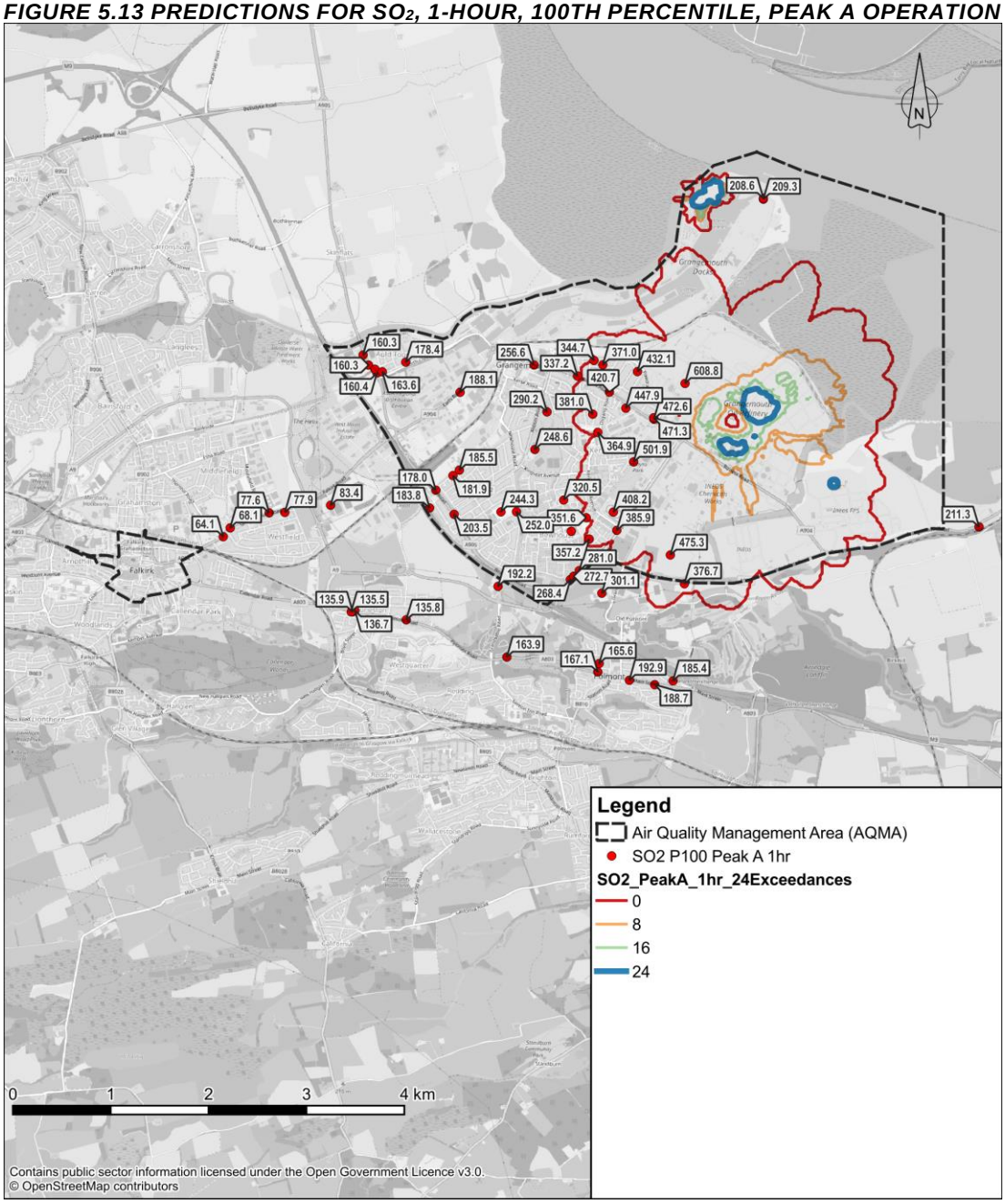


FIGURE 5.14 PREDICTIONS FOR SO_2, 1-HOUR, EXCEEDANCES, PEAK A OPERATION

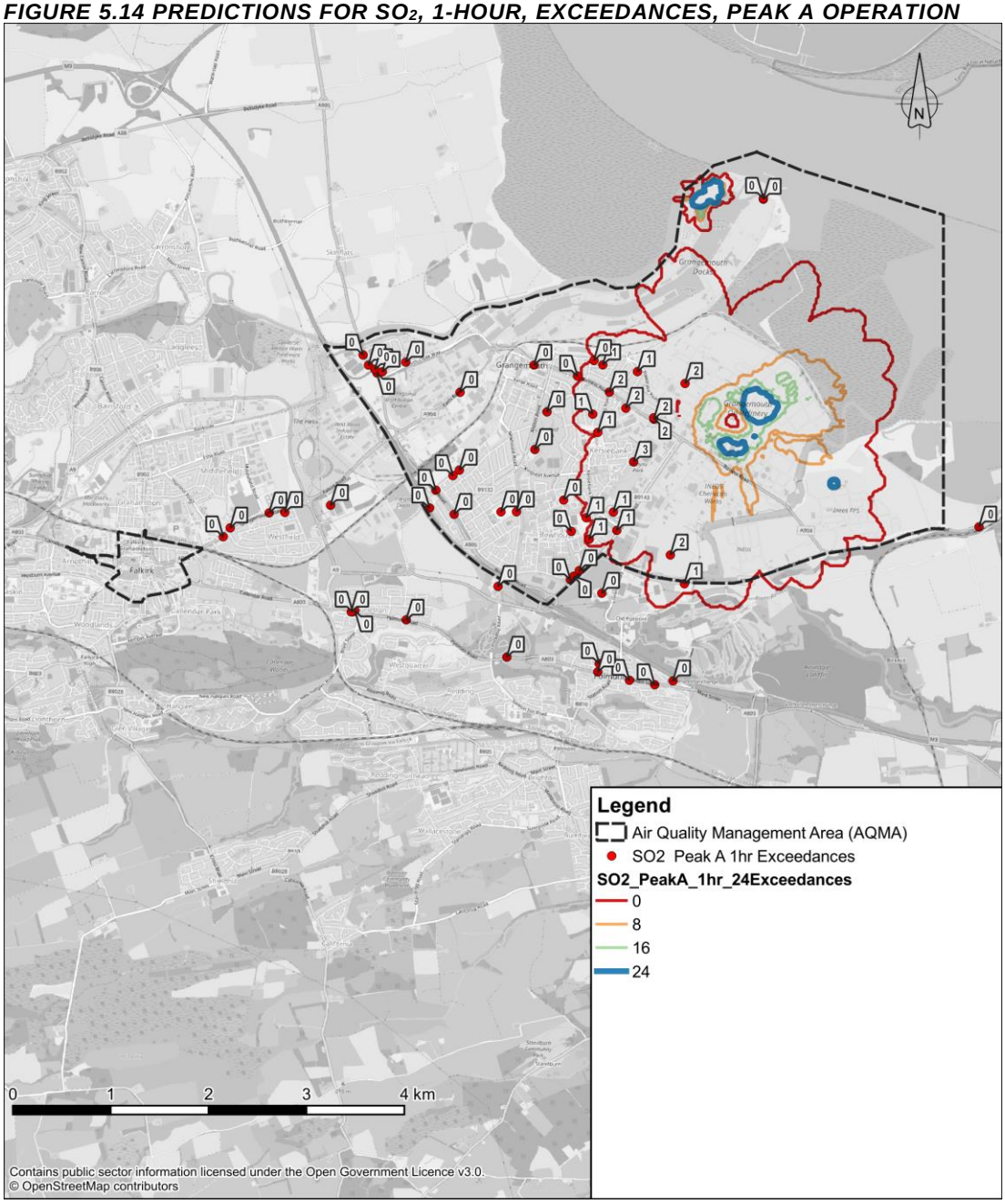


TABLE 5.6 TOP 10 1-HOUR WORST-CASE SO_2 PREDICTIONS – PEAK B OPERATION

Rank	99.73th Percentile		100th Percentile		Exceedances	
	SO_2 Concentration (µg/m³)	Receptor	SO_2 Concentration (µg/m³)	Receptor	Receptor	
1	181.3	Oil refinery	606.4	Oil refinery	3	Inchyra AQU
2	153.8	Bo'Ness Road	501.9	Inchyra AQU	2	Wholeflats
3	153.6	Bo'Ness Road 1	475.3	Wholeflats	2	Oil refinery
4	129.3	Inchyra AQU	472.3	Bo'Ness Road 1	2	Bo'Ness Road 2
5	114.0	Bo'Ness Road 2	469.9	Bo'Ness Road	2	Bo'Ness Road 1
6	106.2	Wholeflats	446.0	Bo'Ness Road 2	2	Bo'Ness Road 3
7	105.5	Albert Avenue	429.8	Albert Avenue	2	Bo'Ness Road
8	104.4	Moray AQU	419.1	Bo'Ness Road 3	1	Grangemouth Stadium
9	99.9	Bo'Ness Road 3	408.2	Grangemouth Stadium	1	Bowhouse Primary
10	98.5	Elizabeth Avenue	385.9	Merrick Road 1	1	Reddoch Road

FIGURE 5.15 PREDICTIONS FOR SO_2, 1-HOUR, 99.73TH PERCENTILE, PEAK B OPERATION

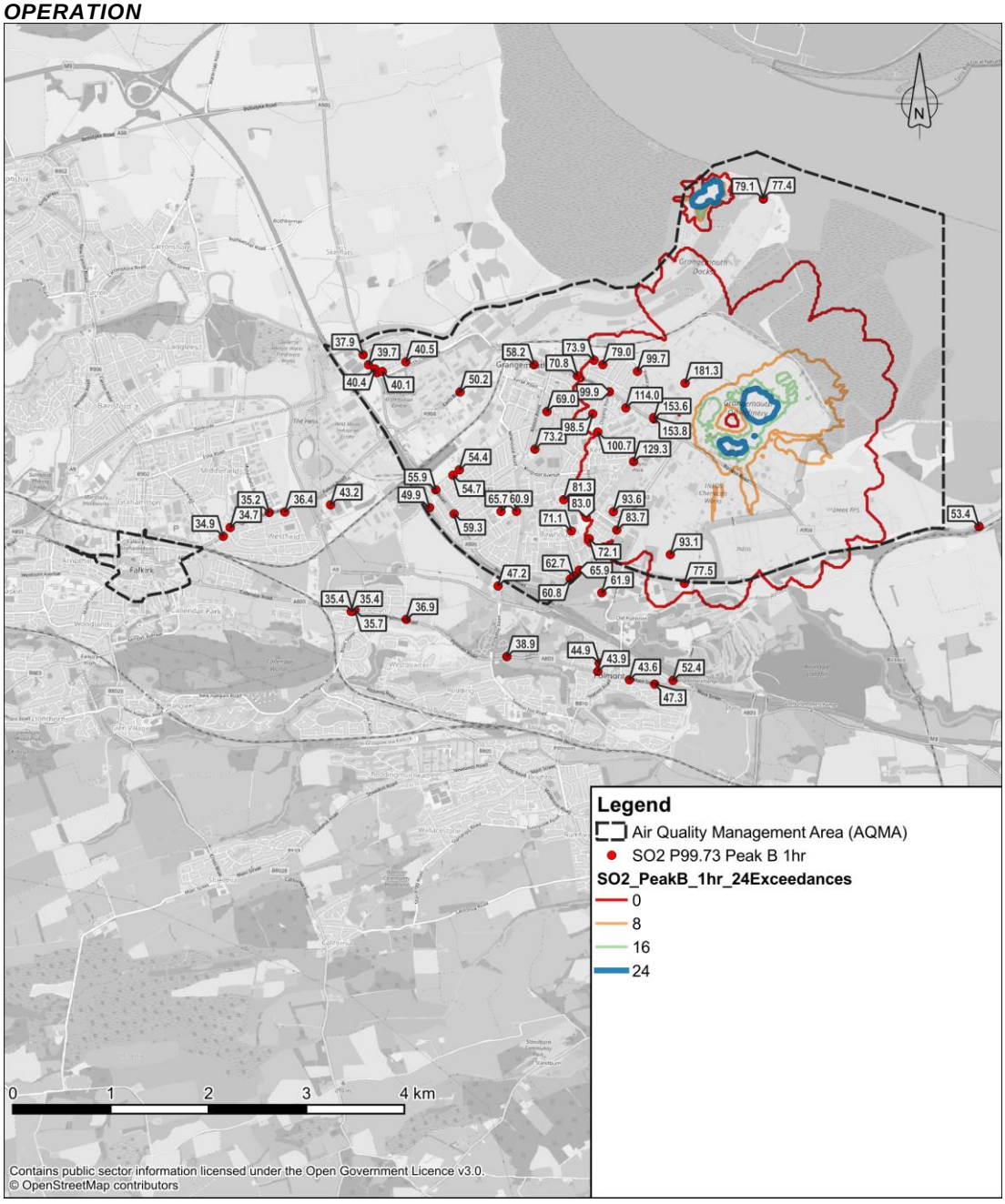


FIGURE 5.16 PREDICTIONS FOR SO_2, 1-HOUR, 100TH PERCENTILE, PEAK B OPERATION

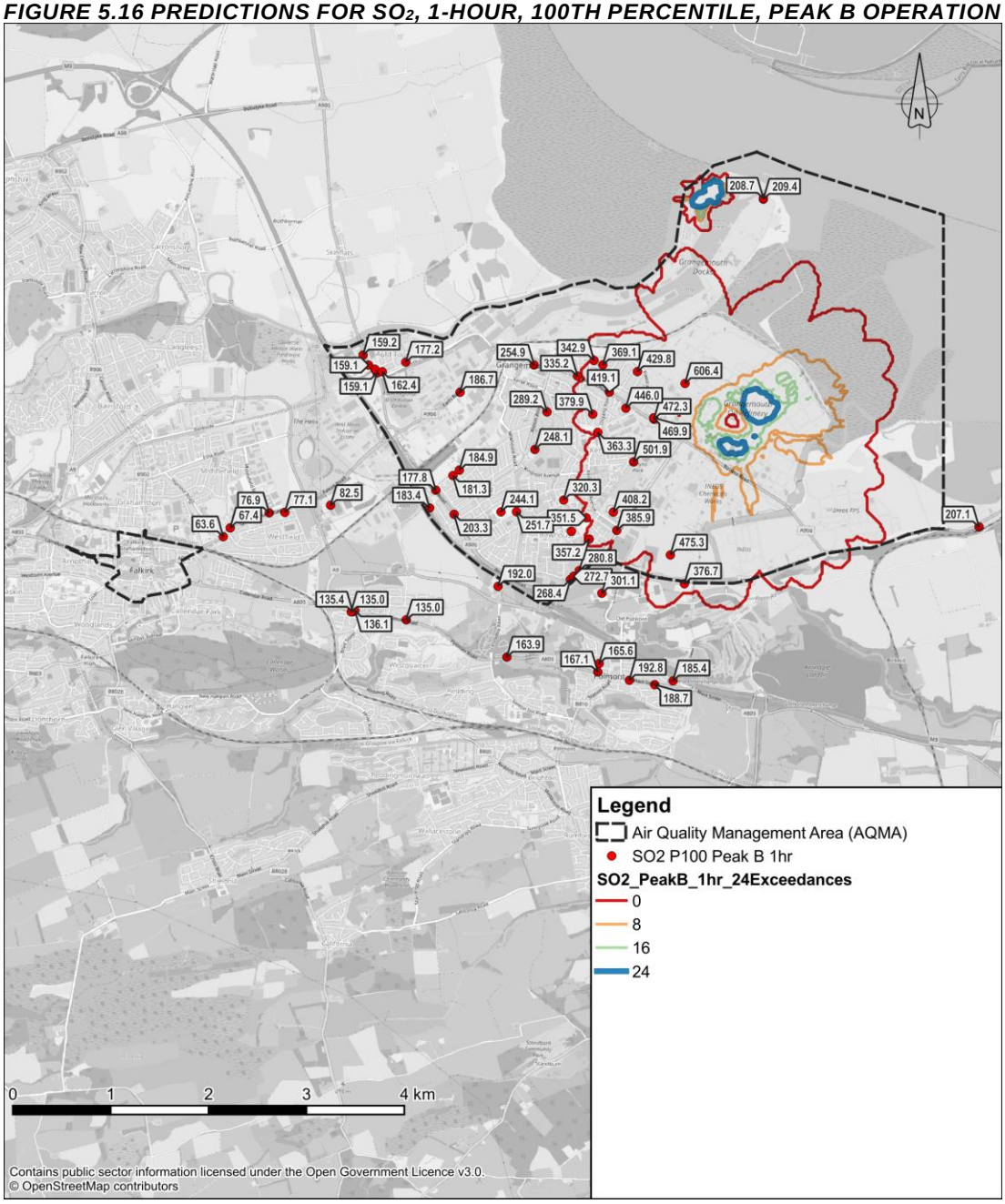
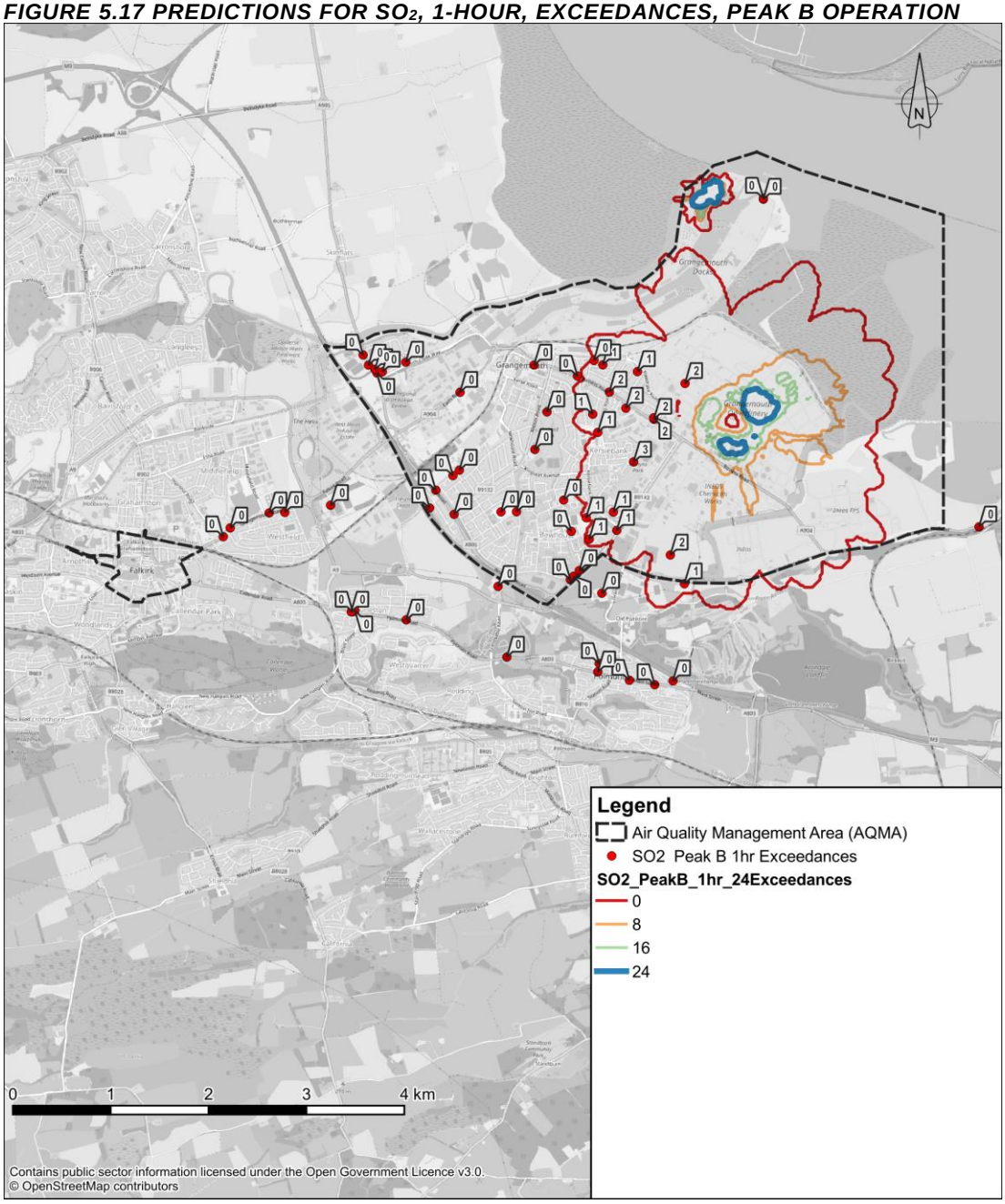


FIGURE 5.17 PREDICTIONS FOR SO_2, 1-HOUR, EXCEEDANCES, PEAK B OPERATION



The results of the modelling indicate that exceedance of the 1-hour mean standard concentration is highly unlikely. The highest number of exceedances of the objective of 350 µg/m³ at Inchyra Park is less than the 24 allowable occurrences. This is shown in Table 5.5, Table 5.6, Figure 5.14and Figure 5.17.

shows that the 350 µg/m³ objective is not predicted to be exceeded on more than the 24 allowable occasions under the peak operation scenario, however some predicted exceedances of the 350 µg/m³ are predicted to occur, also shown in Figure 5.12 and Figure 5.14. Table 5.5 shows the maximum predicted 1-hour concentrations which peak at over 200% of the objective with the dispersion model operating with the 2017 meteorological dataset, also shown in Table 5.6.

Discrete Human Receptors: 24-hour Objective

There are no predicted exceedances of the 24-hour mean objective under any scenario. The 100th percentile predictions are all substantially below the objective value of 125 µg/m³.

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

- Table 5.7 Top 10 24-hour Worst case SO2 Predictions – Normal Operation
- Table 5.8 Top 10 24-hour Worst-case SO2 Predictions – Peak A Operation
- Table 5.9 Top 10 24-hour Worst-case SO2 Predictions – Peak B Operation

TABLE 5.7 TOP 10 24-HOUR WORST CASE SO_2 PREDICTIONS – NORMAL OPERATION

Rank	99.73th Percentile		100th Percentile	
	SO_2 Concentration (µg/m³)	Receptor	SO_2 Concentration (µg/m³)	Receptor
1	19.5	Bo'Ness Road 1	24.2	Oil refinery
2	19.2	Inchyra AQU	21.9	Bo'Ness Road
3	19.0	Moray AQU	21.7	Bo'Ness Road 2
4	18.9	Bo'Ness Road	21.5	Bo'Ness Road 1
5	17.6	Oil refinery	21.1	Moray AQU
6	17.1	Elizabeth Avenue	20.9	Inchyra AQU
7	16.2	Bo'Ness Road 2	20.0	Elizabeth Avenue
8	16.0	Sacred Heart Primary	19.5	Sacred Heart Primary
9	15.3	Sports Complex	19.2	Merrick Road 1
10	15.2	Albert Avenue	18.9	Bo'Ness Road 3

TABLE 5.8 TOP 10 24-HOUR WORST-CASE SO_2 PREDICTIONS – PEAK A OPERATION

Rank	99.73th Percentile		100th Percentile	
	SO_2 Concentration (µg/m³)	Receptor	SO_2 Concentration (µg/m³)	Receptor
1	43.0	Bo'Ness Road	47.5	Oil refinery
2	43.0	Bo'Ness Road 1	45.9	Bo'Ness Road 1
3	40.6	Moray AQU	45.8	Bo'Ness Road
4	40.4	Inchyra AQU	45.4	Moray AQU
5	36.8	Elizabeth Avenue	44.6	Bo'Ness Road 2
6	34.7	Oil refinery	43.0	Elizabeth Avenue
7	34.4	Bo'Ness Road 2	42.7	Inchyra AQU
8	33.9	Sacred Heart Primary	40.3	Sacred Heart Primary
9	31.8	Sports Complex	39.7	Merrick Road 1
10	31.7	Albert Avenue	39.0	Bo'Ness Road 3

TABLE 5.9 TOP 10 24-HOUR WORST-CASE *SO_2* PREDICTIONS – PEAK B OPERATION

Rank	99.73th Percentile		100th Percentile	
	SO_2 Concentration (µg/m³)	Receptor	SO_2 Concentration (µg/m³)	Receptor
1	42.7	Bo'Ness Road	47.3	Oil refinery
2	42.6	Bo'Ness Road 1	45.7	Bo'Ness Road 1
3	40.5	Moray AQU	45.6	Bo'Ness Road
4	40.3	Inchyra AQU	45.3	Moray AQU
5	36.7	Elizabeth Avenue	44.4	Bo'Ness Road 2
6	34.7	Oil refinery	42.9	Elizabeth Avenue
7	34.2	Bo'Ness Road 2	42.6	Inchyra AQU
8	33.8	Sacred Heart Primary	40.0	Sacred Heart Primary
9	31.6	Sports Complex	39.7	Merrick Road 1
10	31.5	Albert Avenue	38.9	Bo'Ness Road 3

Table 5.7, Table 5.8 and *Table 5.9* both show that there are no predicted exceedances of the 24-hour objective of 125 µg/m³ on more than the 7 permitted occasions under both the normal operation scenario and the peak operation scenario.

Gridded Receptors: 15-minute Objective

Figure 5.18 and Figure 5.19 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 5.20.

For the Peak Operation scenarios Figure 5.21 and Figure 5.22 show the 99th and 100th percentiles predictions of SO_2 for Peak A, and Figure 5.24 and Figure 5.25 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 5.23 and Figure 5.26 confirm that no areas are predicted to experience a breach of the 35 permitted exceedances under the peak operation scenarios.

FIGURE 5.18 GRIDDED PREDICTIONS FOR SO_2, 15-MINUTE, 99.9TH PERCENTILE, NORMAL OPERATION

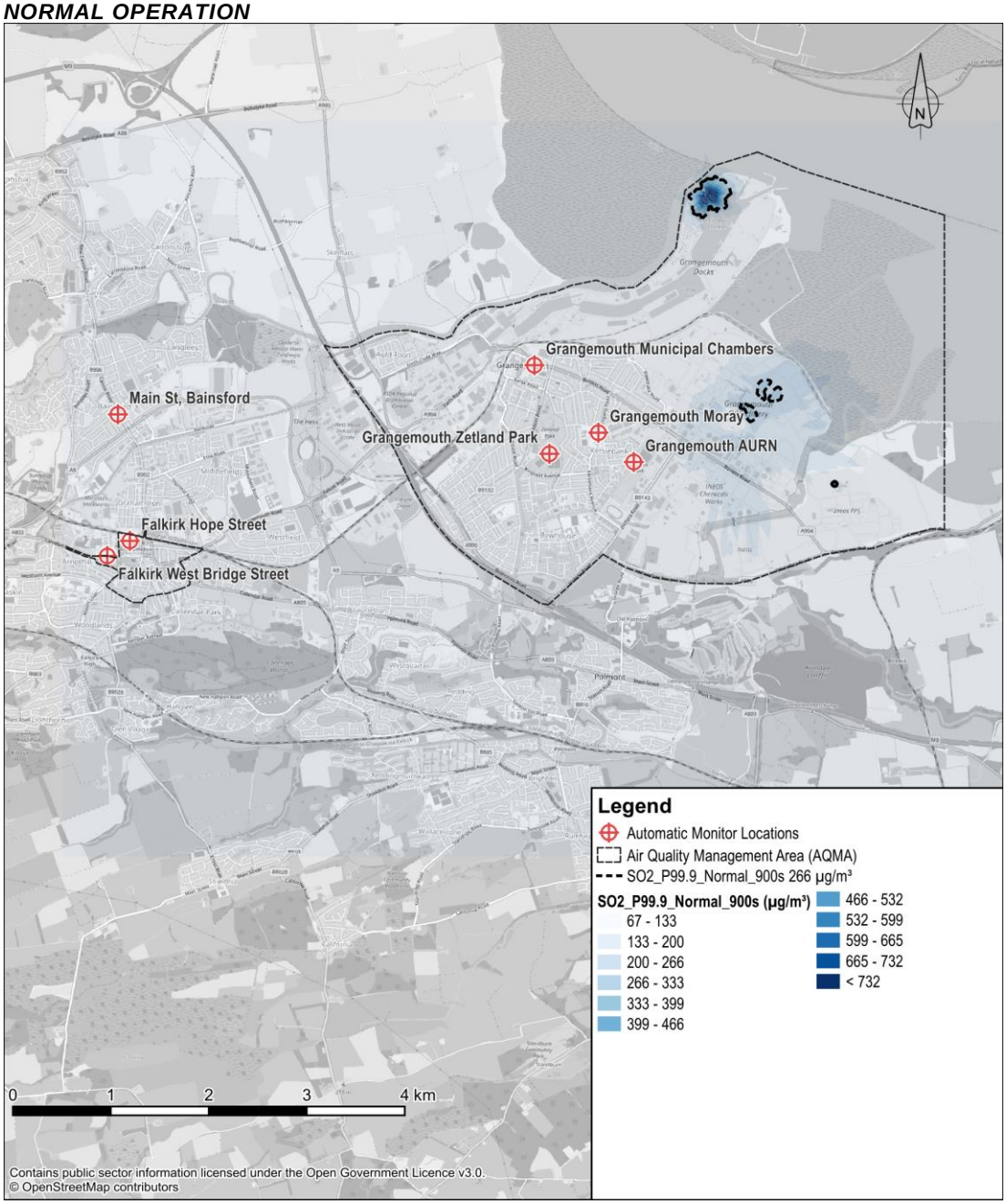


FIGURE 5.19 GRIDDED PREDICTIONS FOR SO_2, 15-MINUTE, 100TH PERCENTILE, NORMAL OPERATION

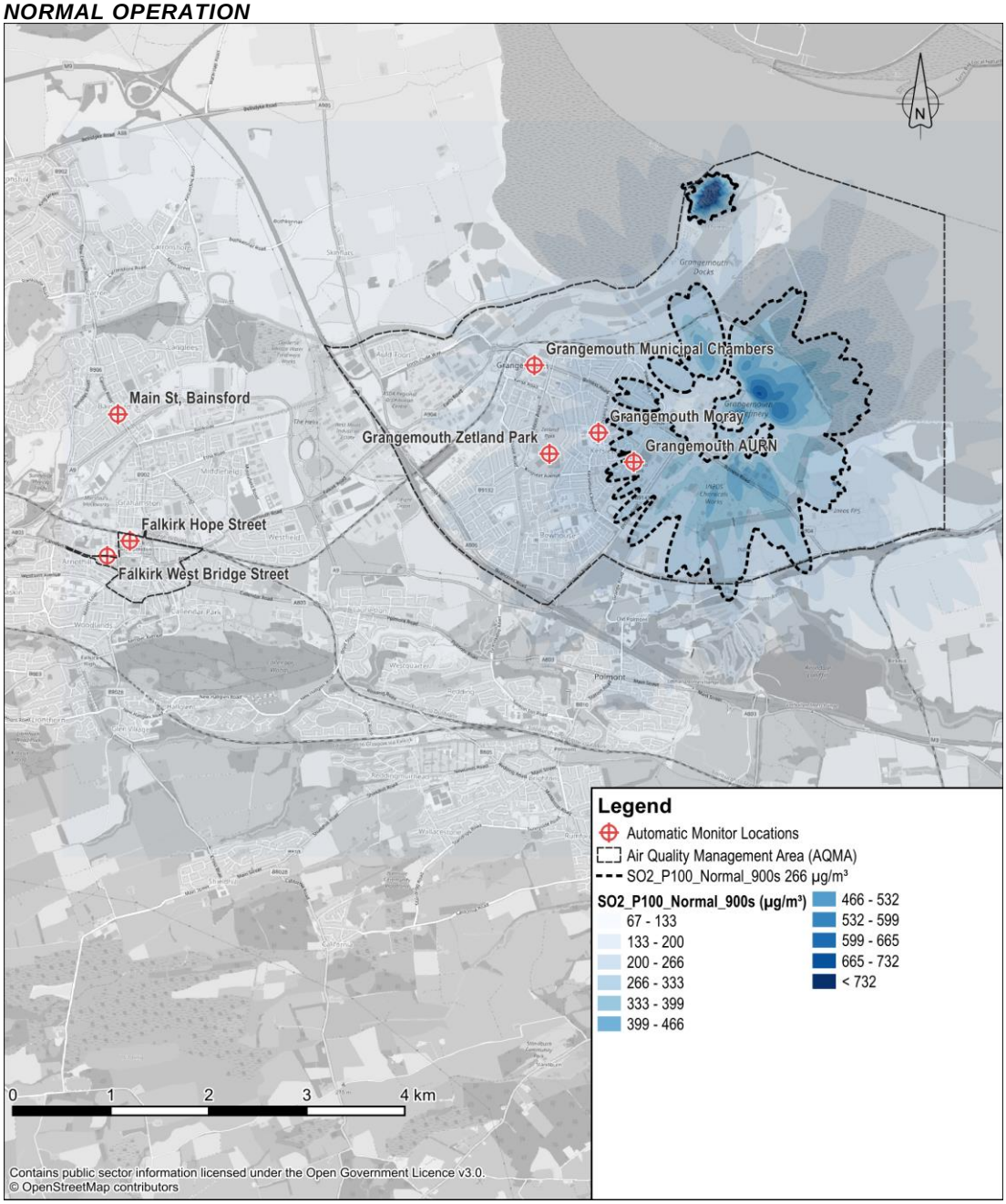


FIGURE 5.20 GRIDDED PREDICTIONS FOR SO_2, 15-MINUTE EXCEEDANCES, NORMAL OPERATION

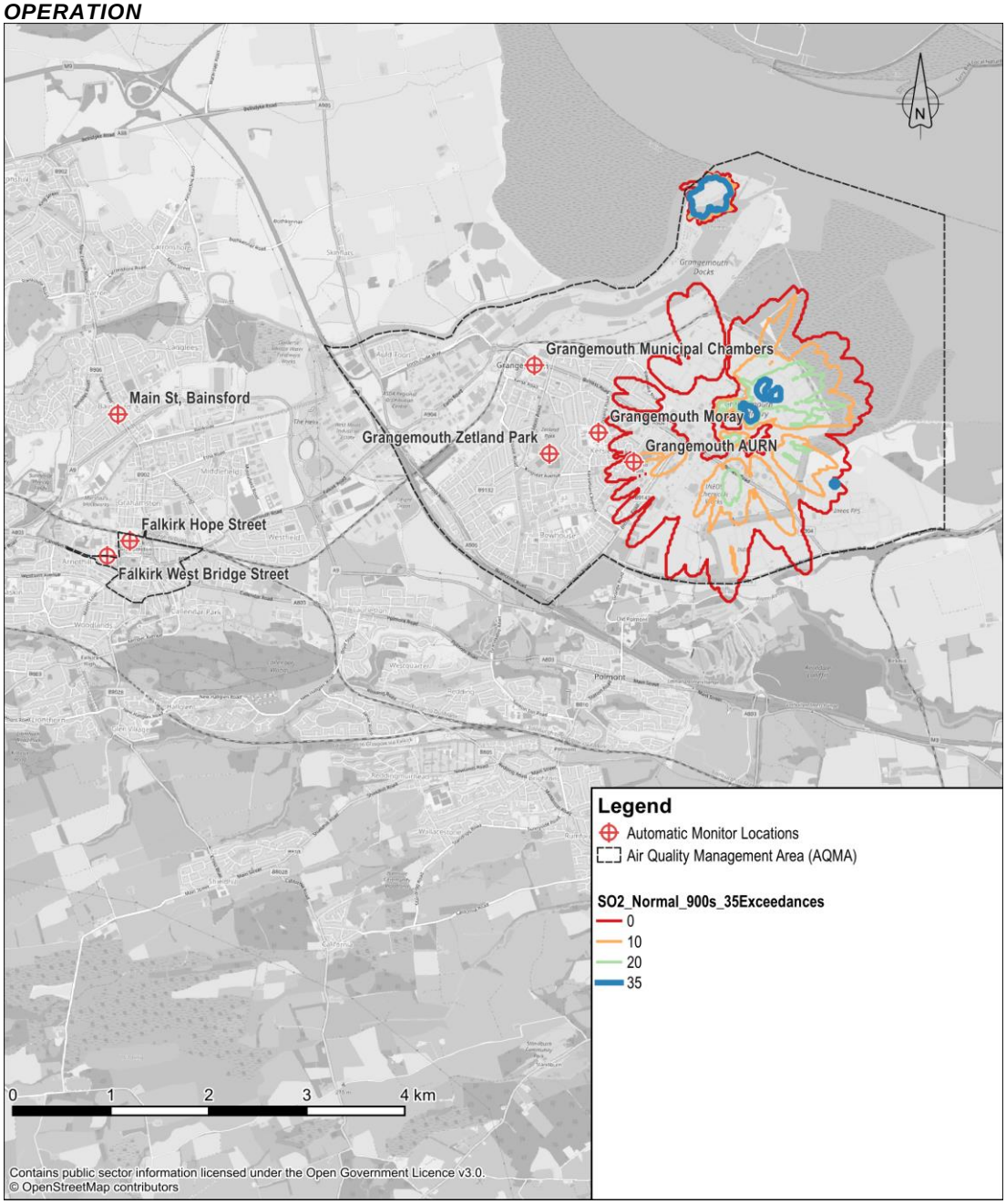


FIGURE 5.21 GRIDDED PREDICTIONS FOR SO_2, 15-MINUTE, 99.9TH PERCENTILE, PEAK A OPERATION

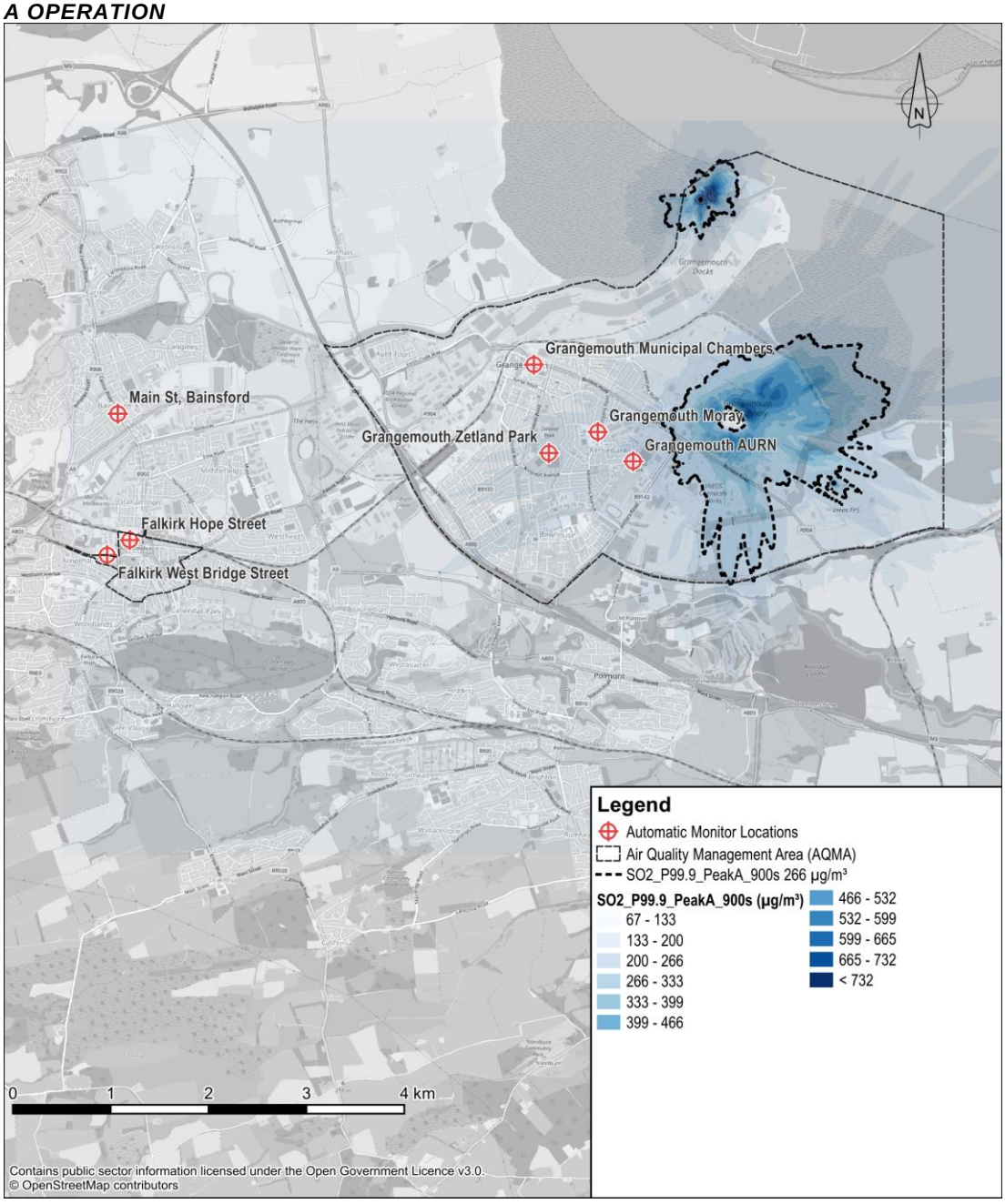


FIGURE 5.22 GRIDDED PREDICTIONS FOR SO_2, 15-MINUTE, 100TH PERCENTILE, PEAK A OPERATION

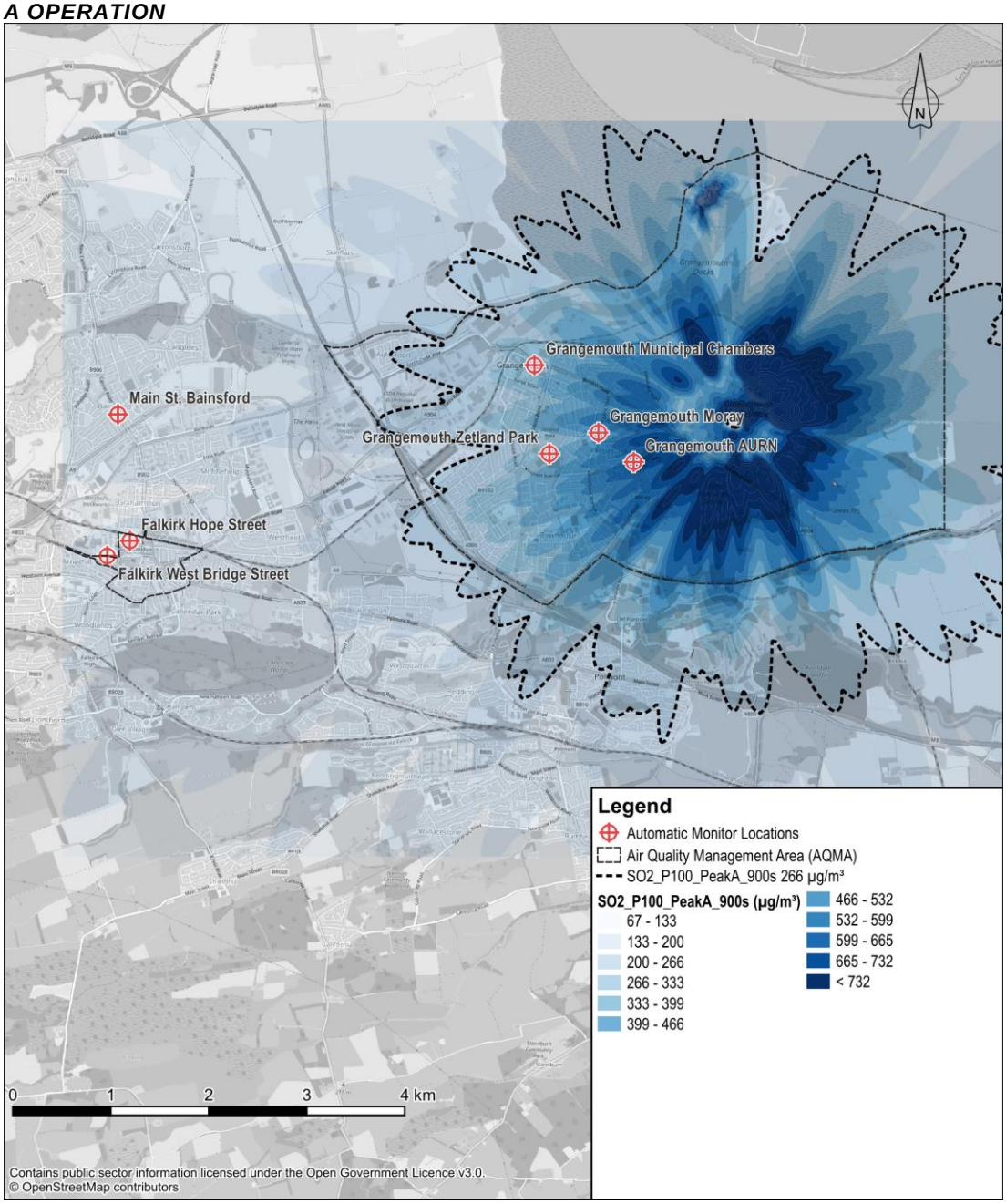


FIGURE 5.23 GRIDDED PREDICTIONS FOR SO_2, 15-MINUTE EXCEEDANCES, PEAK A OPERATION

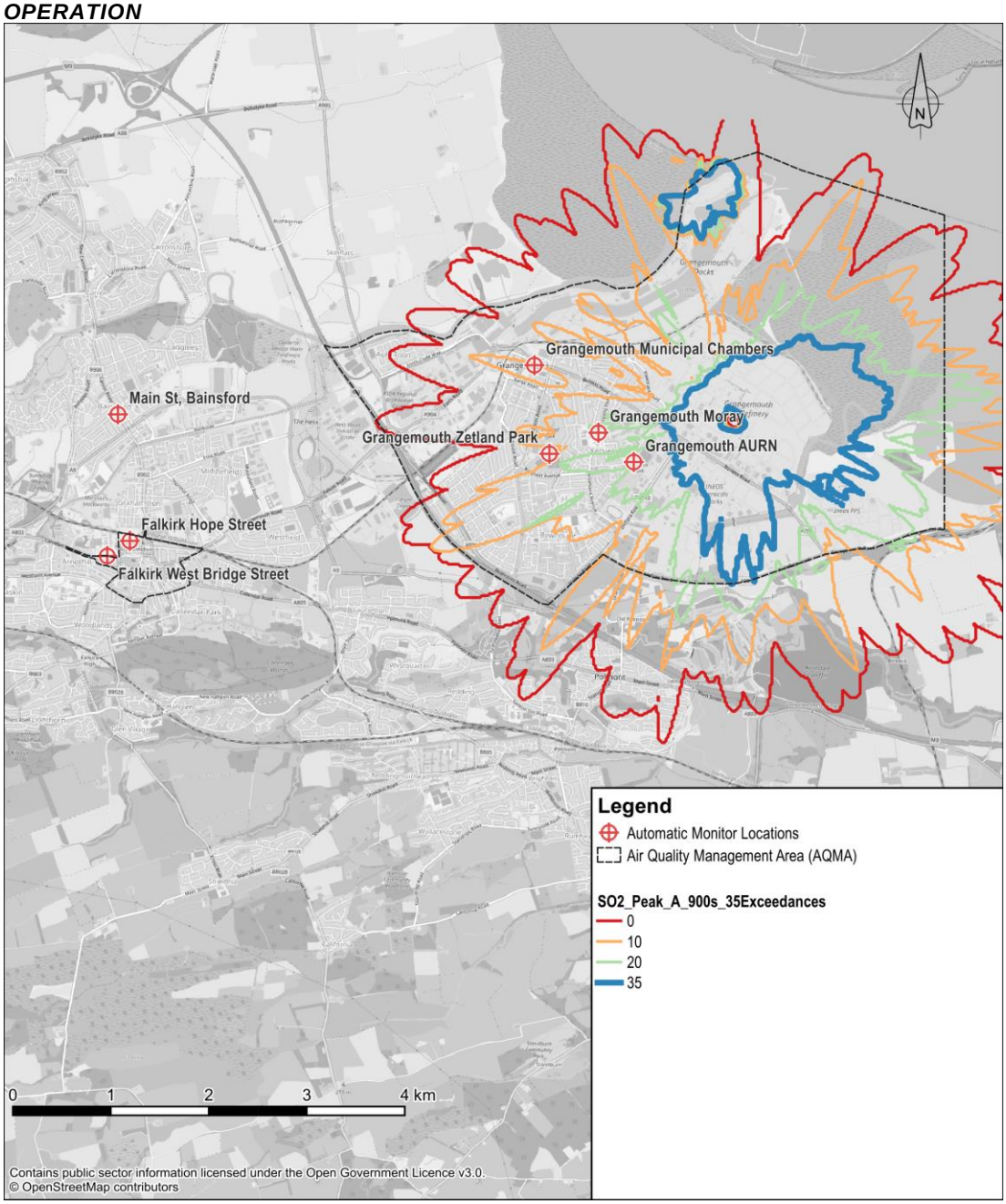


FIGURE 5.24 GRIDDED PREDICTIONS FOR SO_2, 15-MINUTE, 99.9TH PERCENTILE, PEAK B OPERATION

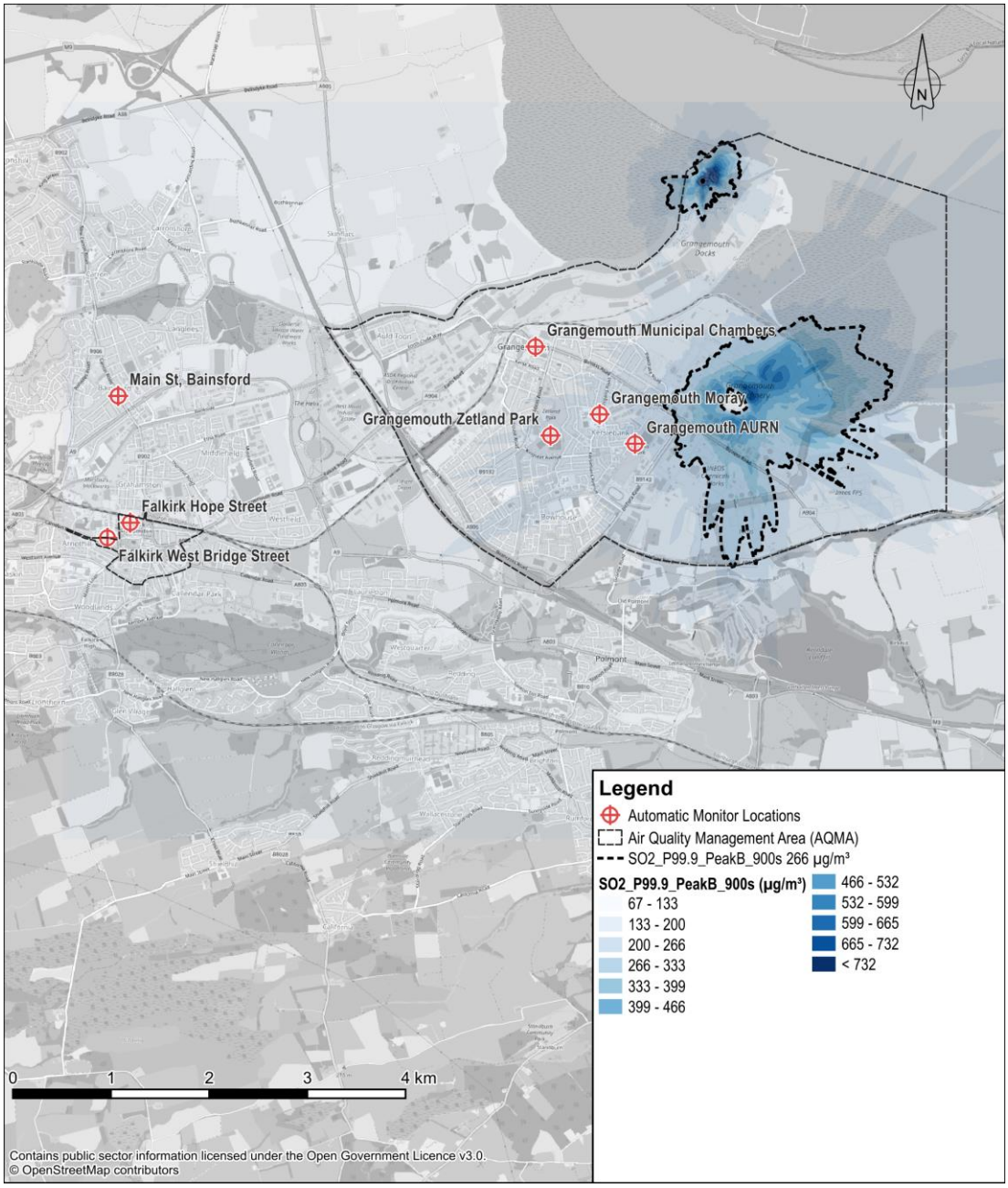


FIGURE 5.25 GRIDDED PREDICTIONS FOR SO_2, 15-MINUTE, 100TH PERCENTILE, PEAK B OPERATION

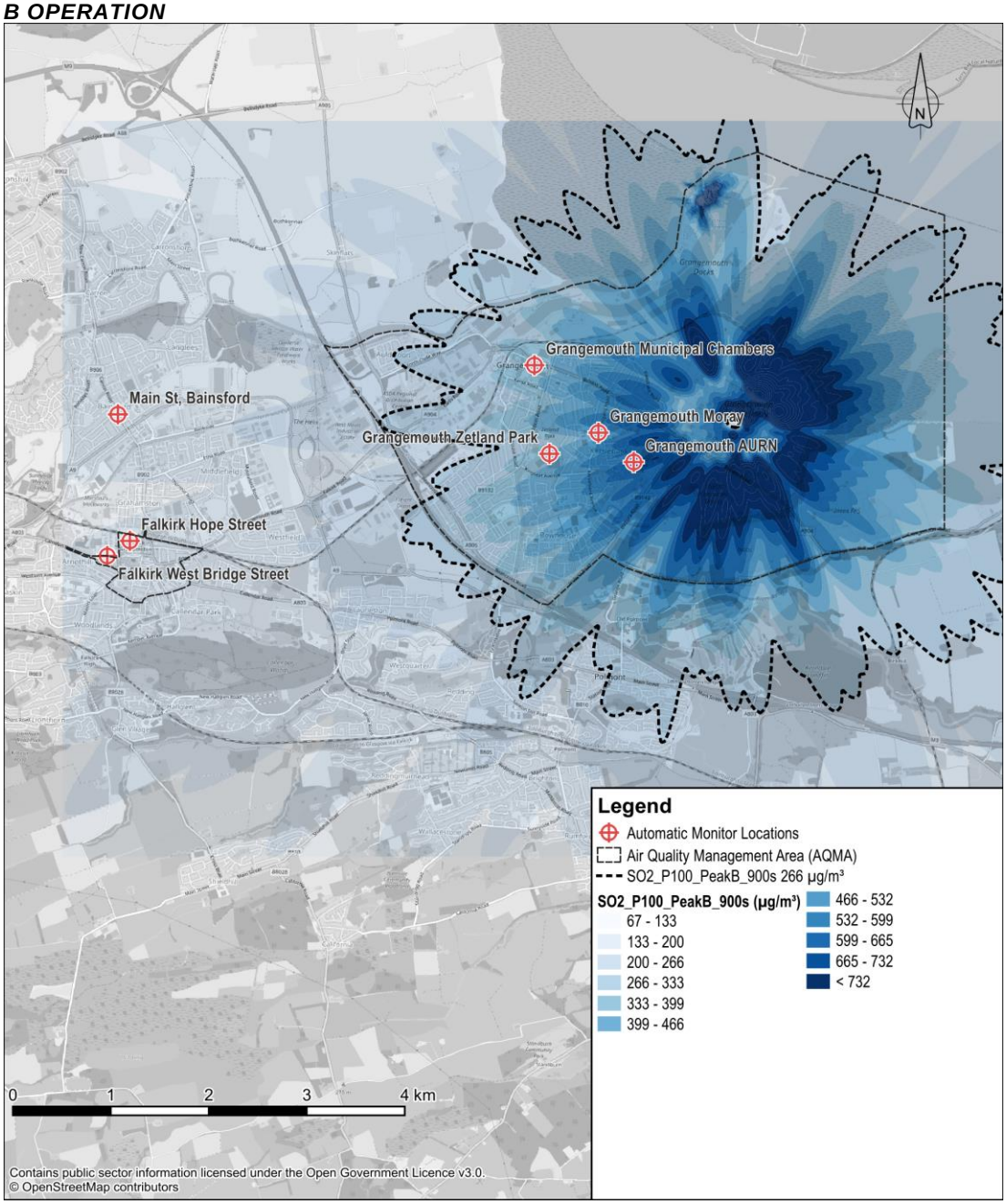
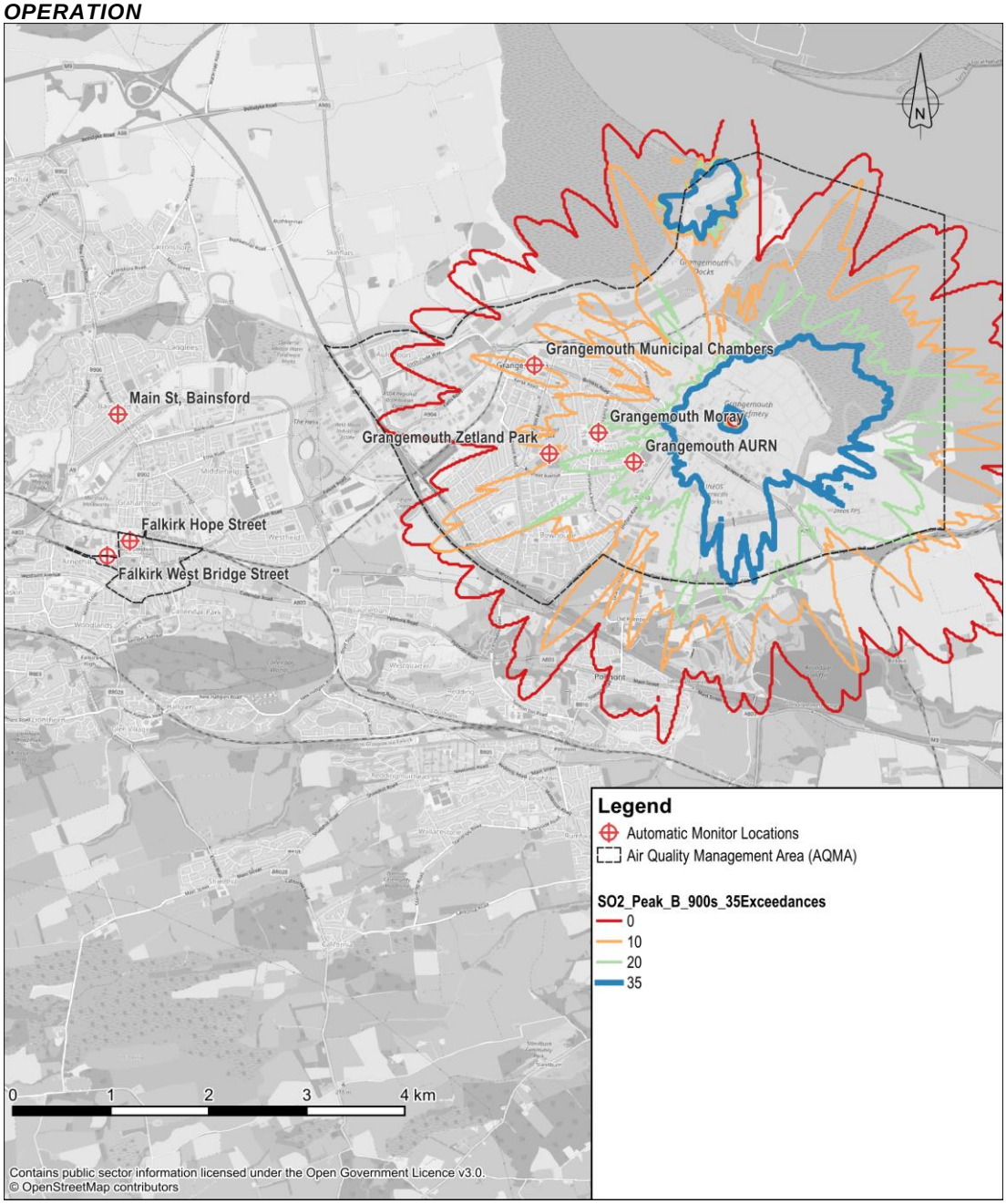


FIGURE 5.26 GRIDDED PREDICTIONS FOR SO_2, 15-MINUTE EXCEEDANCES, PEAK B OPERATION



Gridded Receptors: 1-hour Objective

Normal Operation Scenario

Against the 1-hour objective under the Normal Operation scenario, Figure 5.27 shows that the 1-hour objective of 350 µg/m^3 is unlikely to be exceeded where sensitive receptors are located .Figure 5.28 shows the 100th percentile peak concentrations limited to areas within the Grangemouth industrial facilities.

FIGURE 5.27 GRIDDED PREDICTIONS FOR SO_2, 1-HOUR, 99.73TH PERCENTILE, NORMAL OPERATION

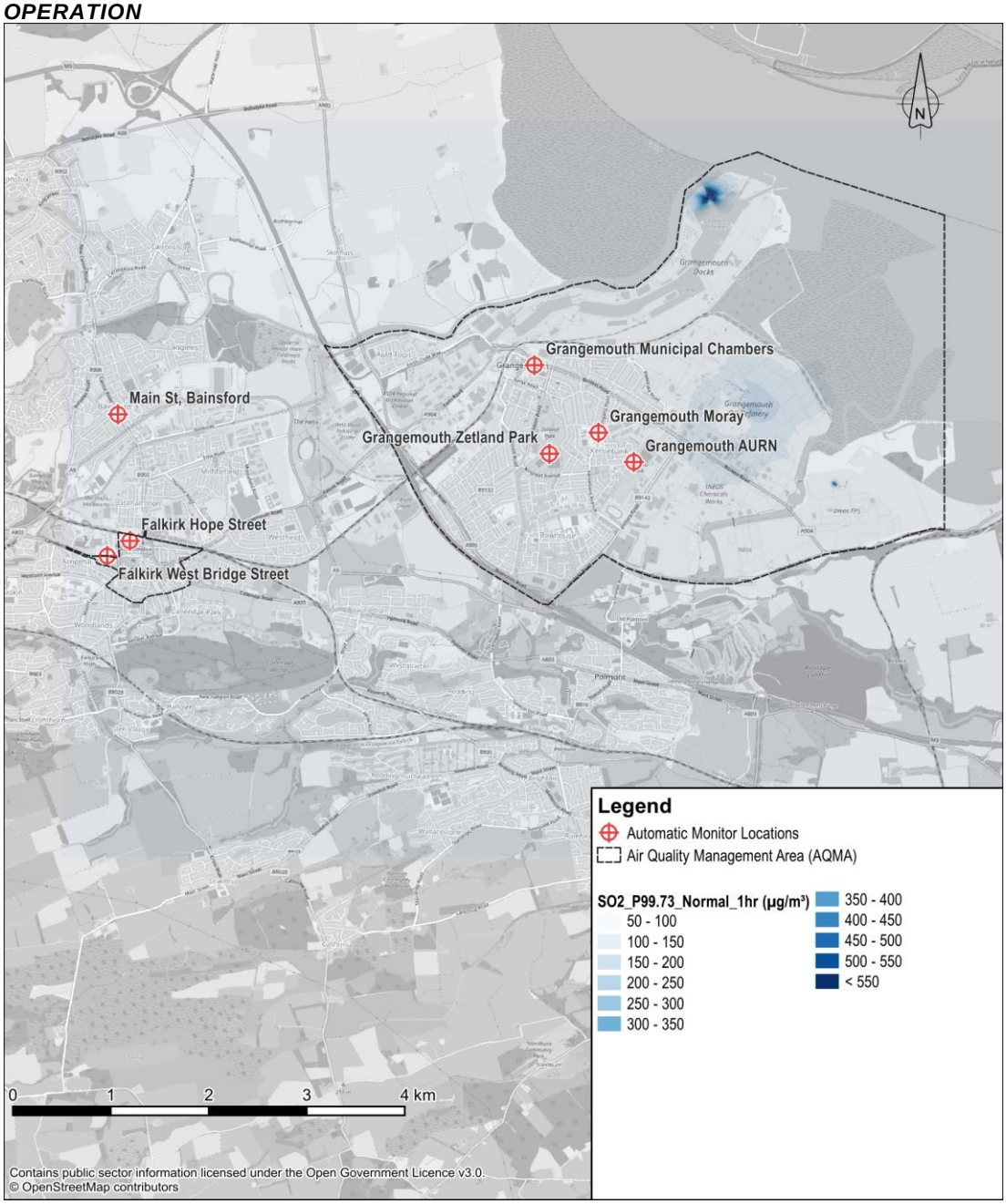
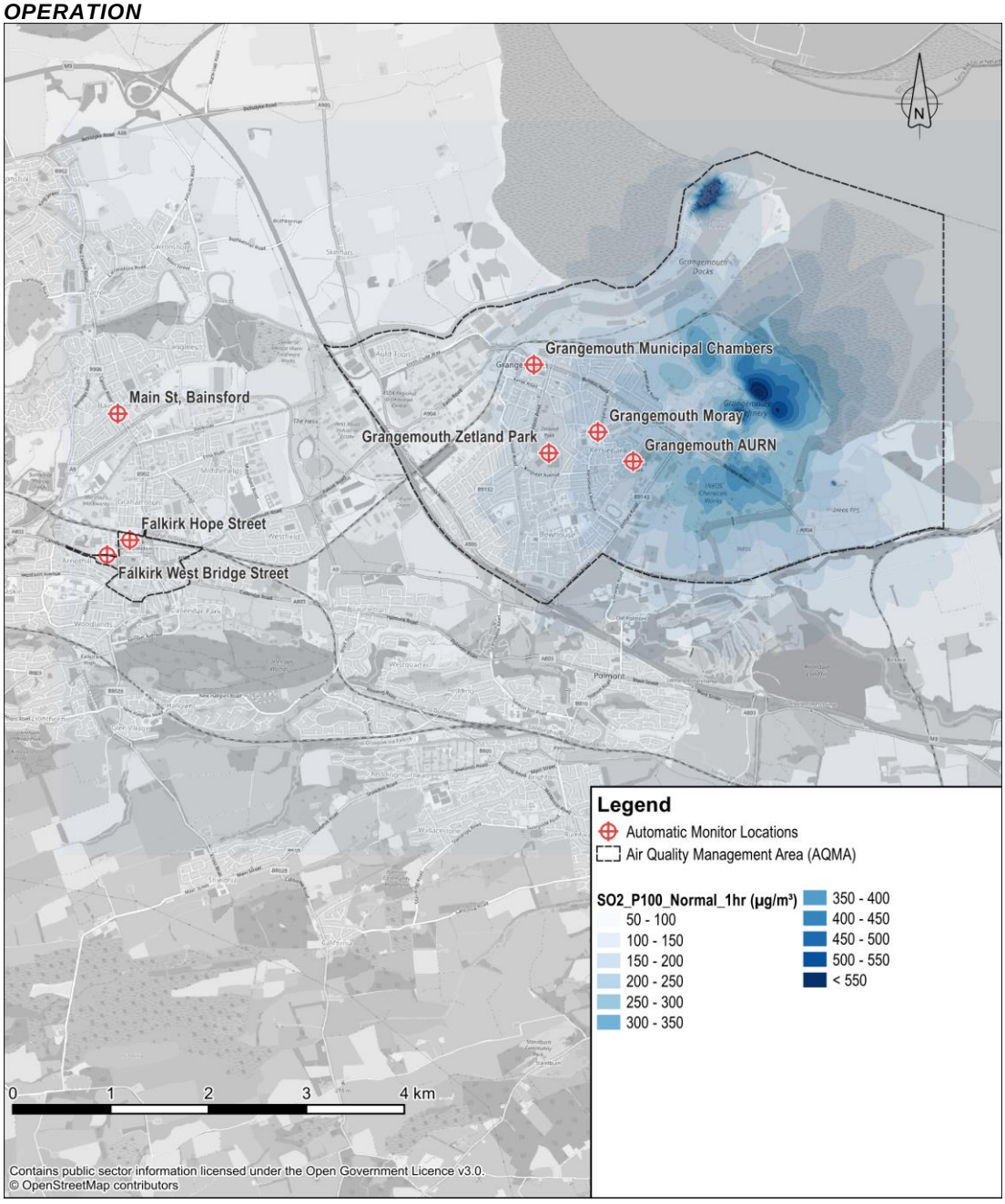


FIGURE 5.28 GRIDDED PREDICTIONS FOR SO_2, 1-HOUR, 100TH PERCENTILE, NORMAL OPERATION



Peak Operation Scenarios

Figure 5.29, Figure 5.30, Figure 5.31 and Figure 5.32, representing the Peak Operation scenarios show that there is the possibility for predicted exceedances of the 1-hour standard 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 do not exceed the 24 allowed exceedances as per the objective. It is necessary to reinforce that the Peak Operation scenarios involve simultaneous flaring, which is highly unlikely to occur.

FIGURE 5.29 GRIDDED PREDICTIONS FOR SO_2, 1-HOUR, 99.73TH PERCENTILE, PEAK A OPERATION

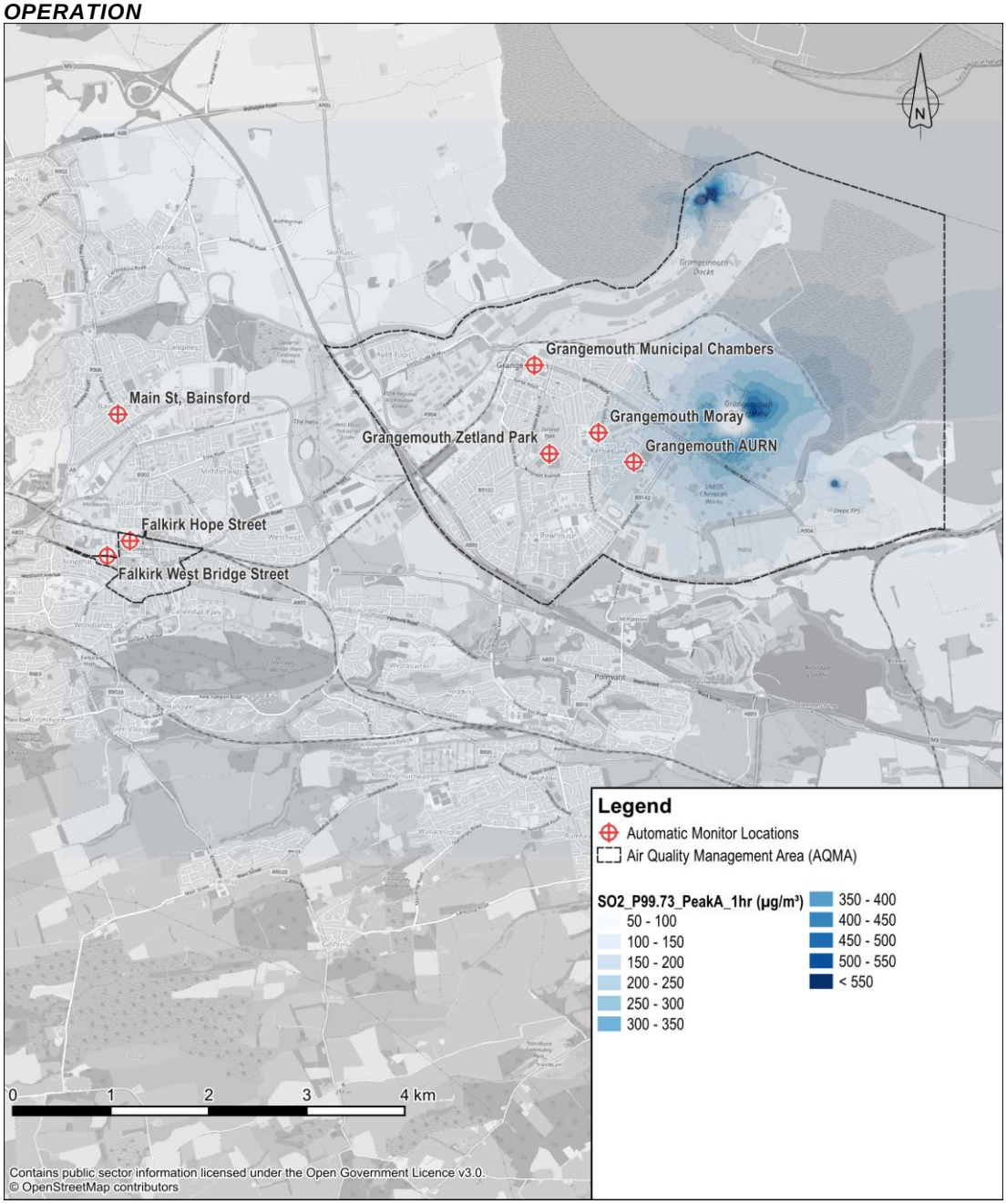


FIGURE 5.30 GRIDDED PREDICTIONS FOR SO_2, 1-HOUR, 100TH PERCENTILE, PEAK A OPERATION

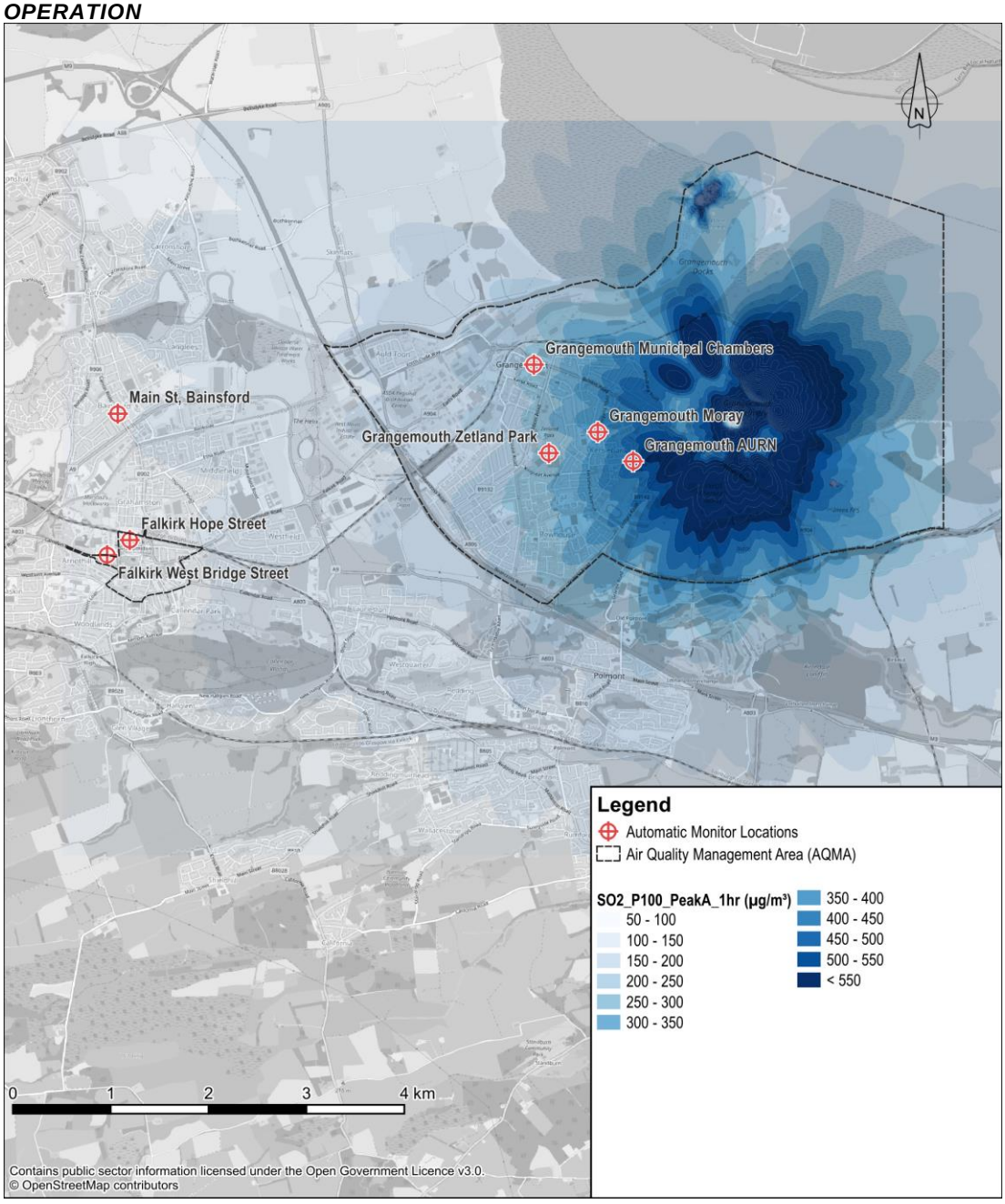


FIGURE 5.31 GRIDDED PREDICTIONS FOR SO_2, 1-HOUR, 99.73TH PERCENTILE, PEAK B OPERATION

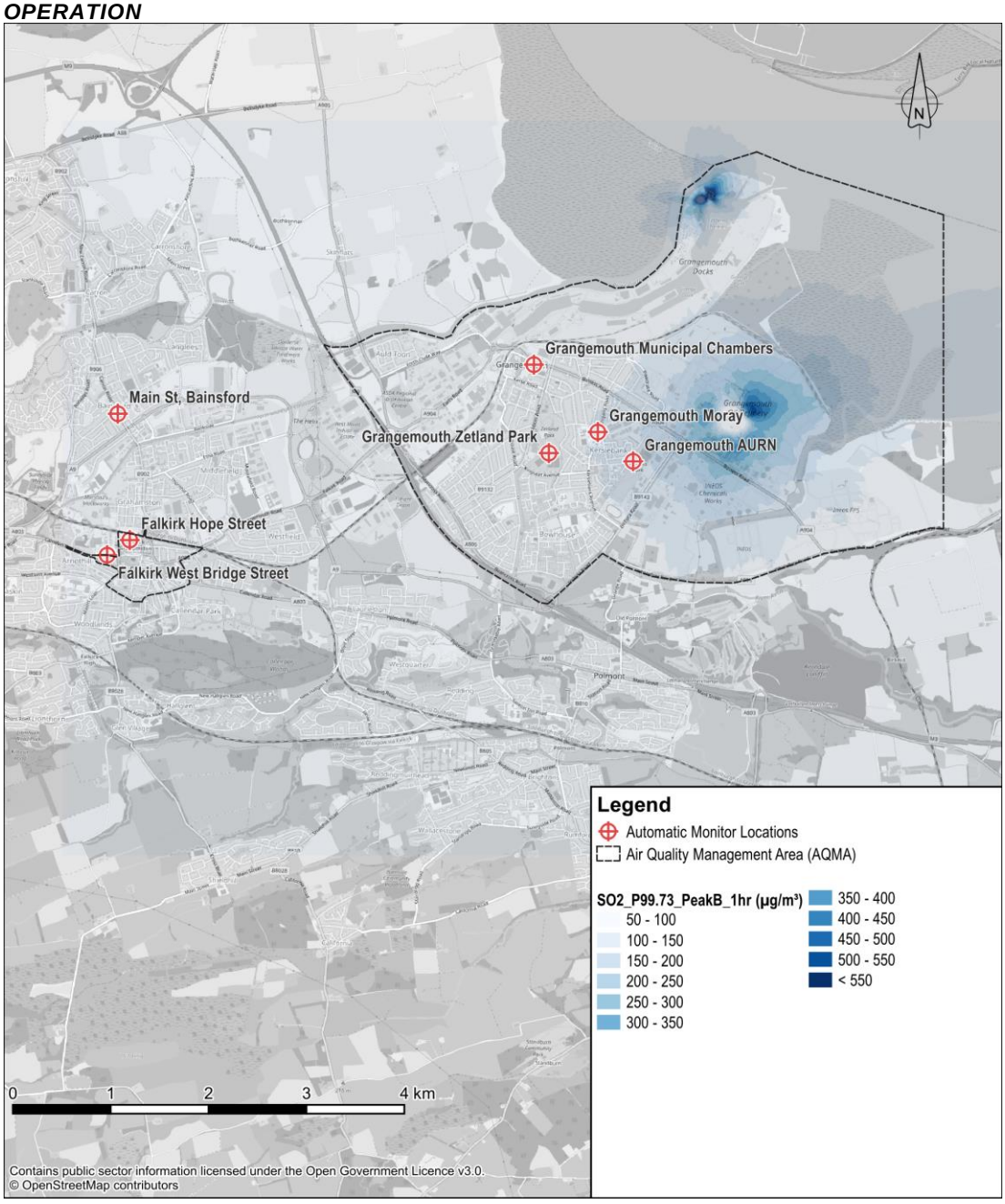
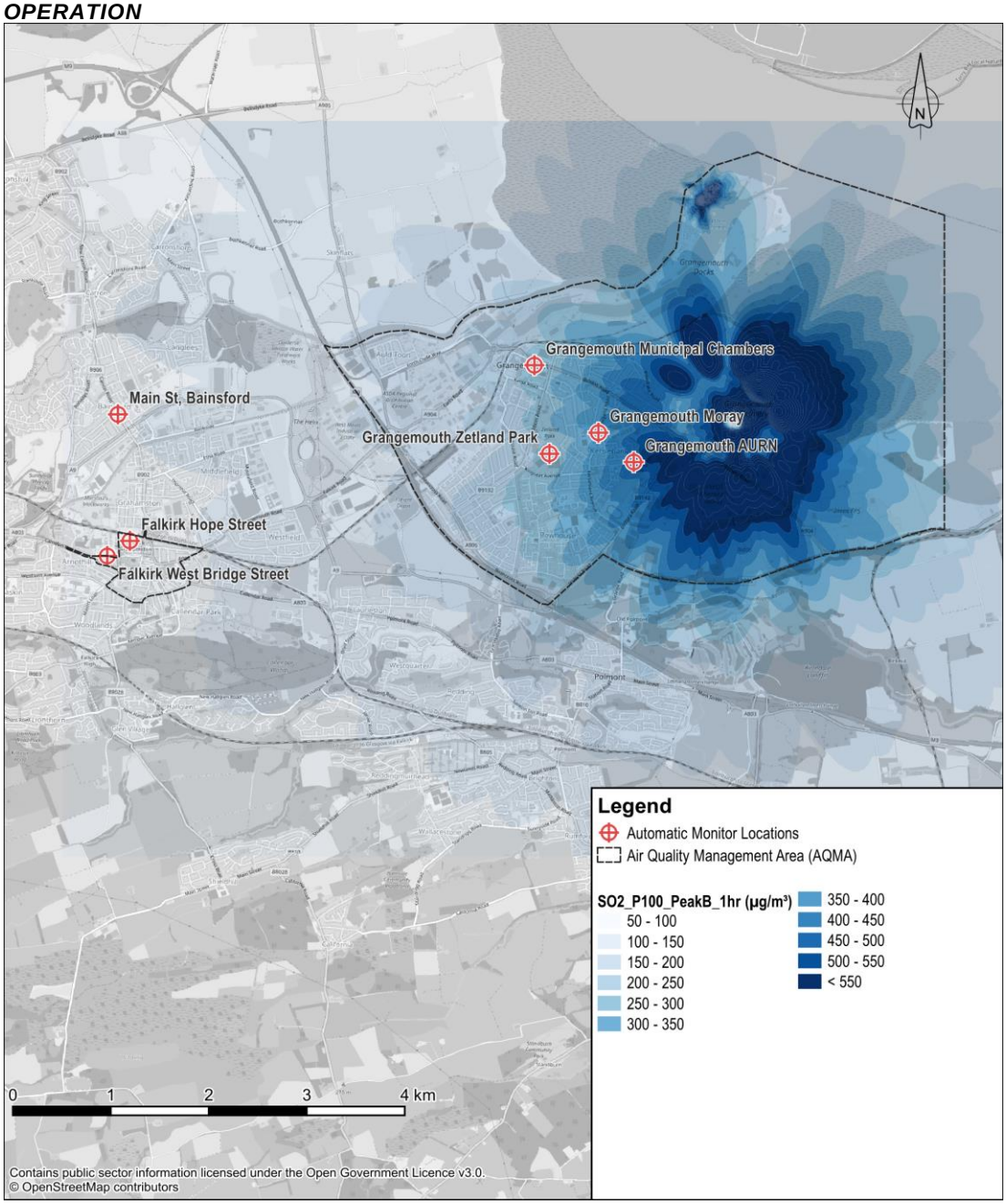


FIGURE 5.32 GRIDDED PREDICTIONS FOR SO_2, 1-HOUR, 100TH PERCENTILE, PEAK B OPERATION



Source Apportionment

An analysis of source apportionment for the peak occurring over Grangemouth Golf Course and Polmonthill Snowsports Centre using the point receptor at Reddoch Road as a proxy shows the dominant contribution to pollutant concentrations at this location to be from the Ineos FPS flare operations to the east and the PetroIneos SRU to the north. It can be seen that locations to the east of the Grangemouth Facilities are more affected by the operation of flares in the Peak Operation scenario. Emissions from the CHP plant also make up a greater proportion of SO_2 emissions under the Normal Operation scenario than under the Peak Operations scenario. This is shown in Figure 5.33 under the Normal Operation scenario and under the Peak Operation scenario in Figure 5.34. These are represented geographically in Figure 5.36, Figure 5.37 and Figure 5.38.

FIGURE 5.33 NORMAL OPERATION SOURCE APPORTIONMENT AT SELECTED RECEPTORS FOR THE 99.9TH PERCENTILE SO_2 CONCENTRATIONS

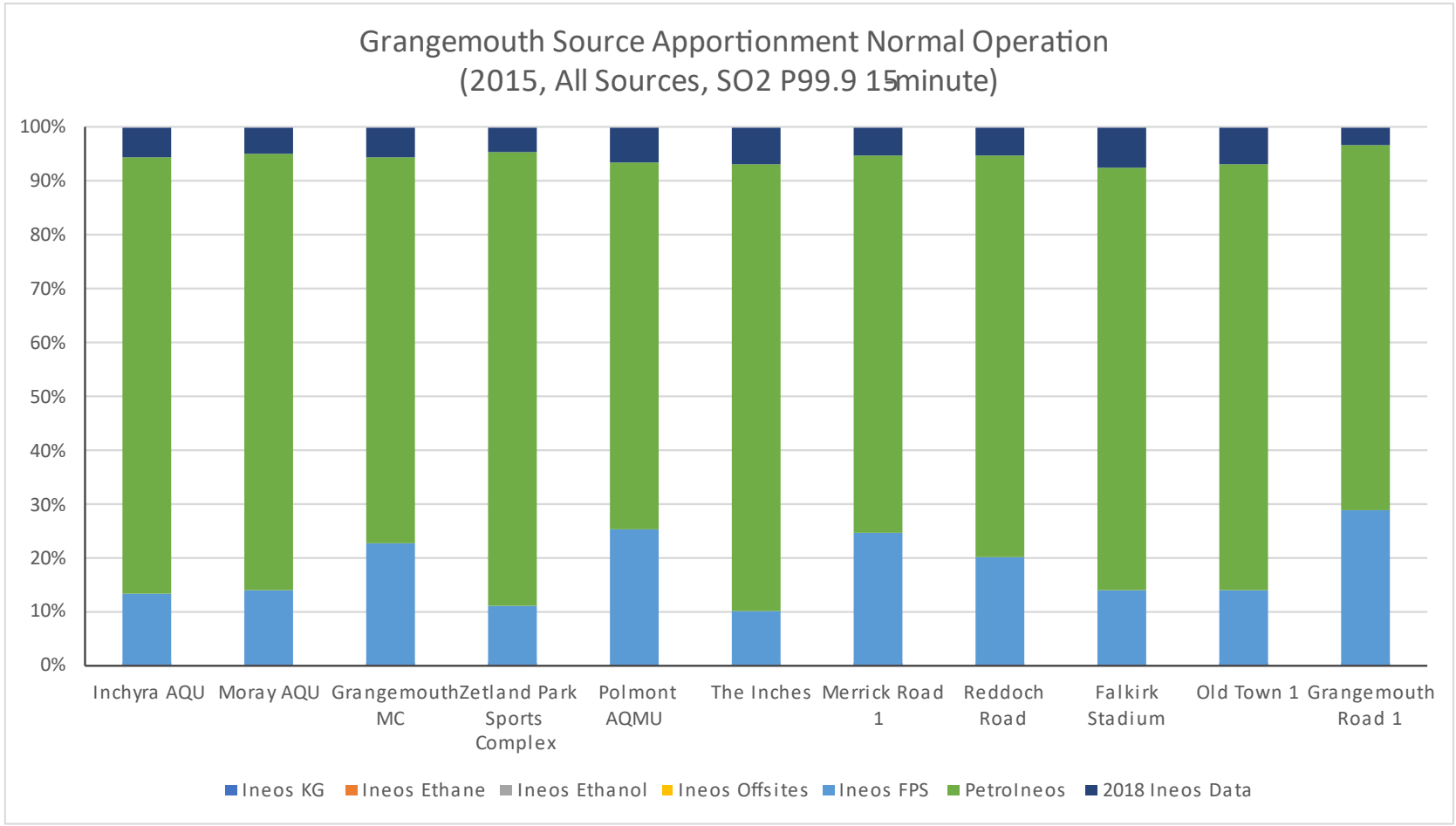


FIGURE 5.34 PEAK A OPERATION SOURCE APPORTIONMENT AT SELECTED RECEPTORS FOR THE 99.9TH PERCENTILE SO_2 CONCENTRATIONS

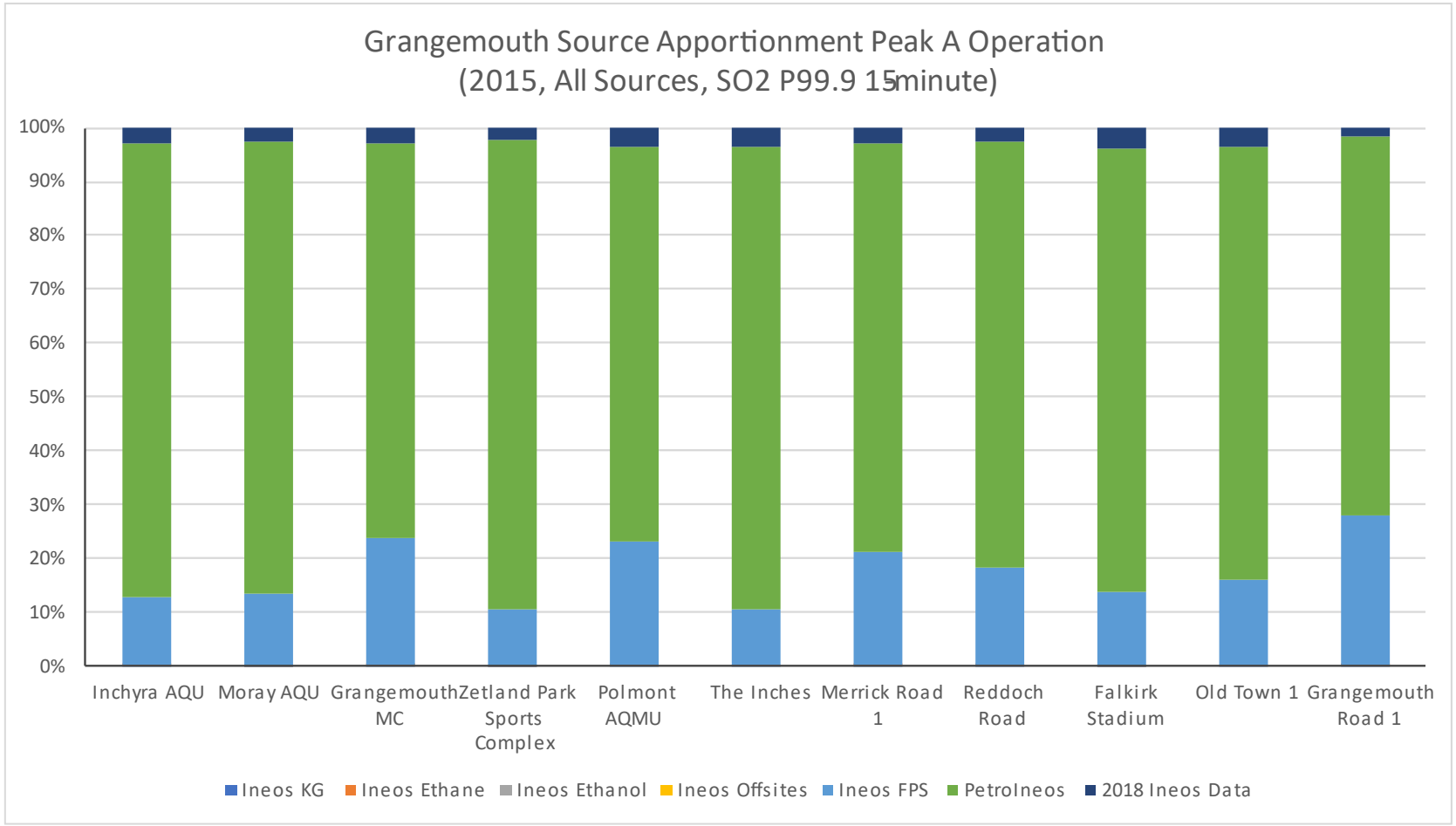


FIGURE 5.35 PEAK B OPERATION SOURCE APPORTIONMENT AT SELECTED RECEPTORS FOR THE 99.9TH PERCENTILE SO_2 CONCENTRATIONS

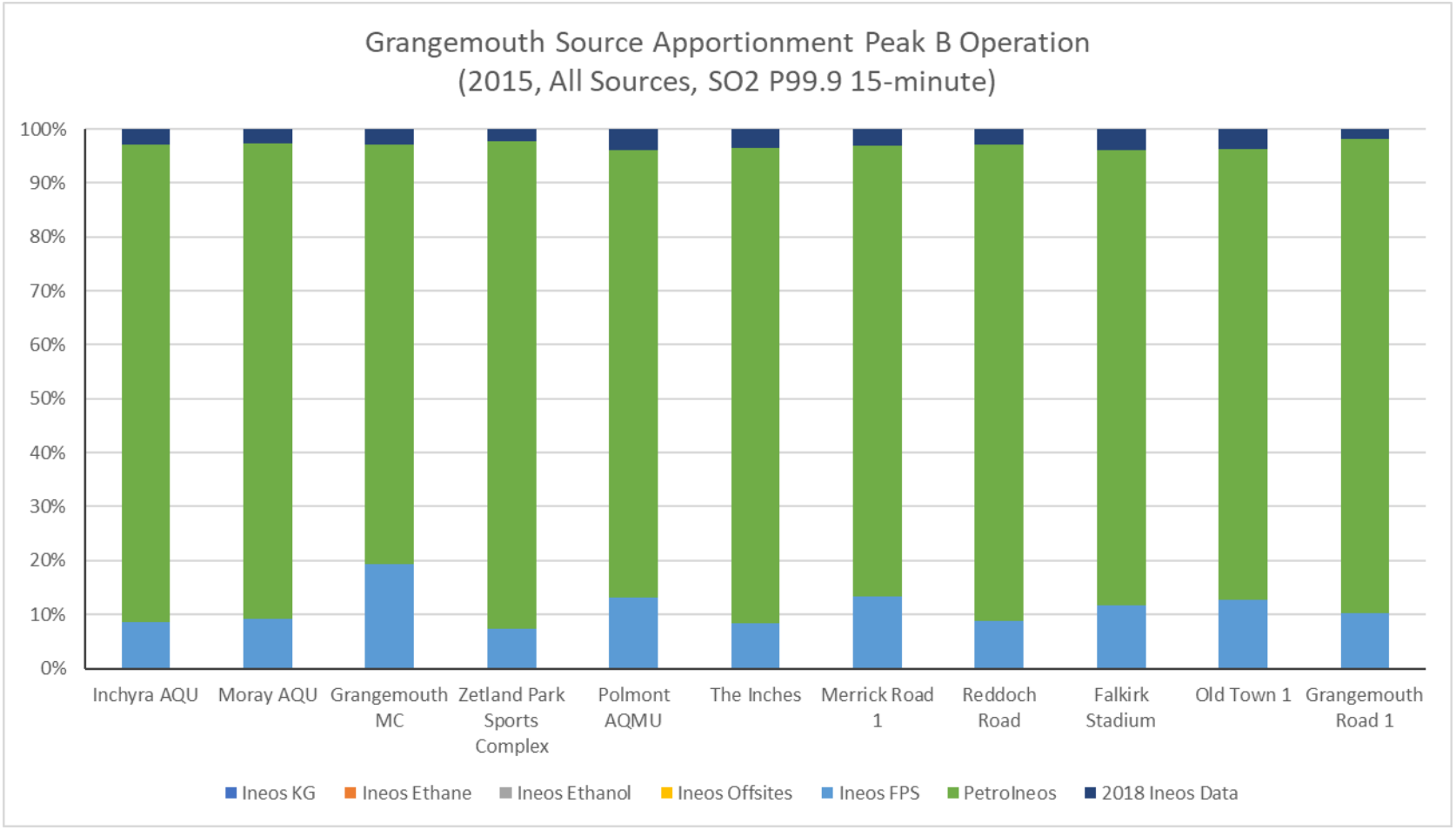


FIGURE 5.36 SPATIAL SOURCE APPORTIONMENT DISTRIBUTION, NORMAL OPERATION

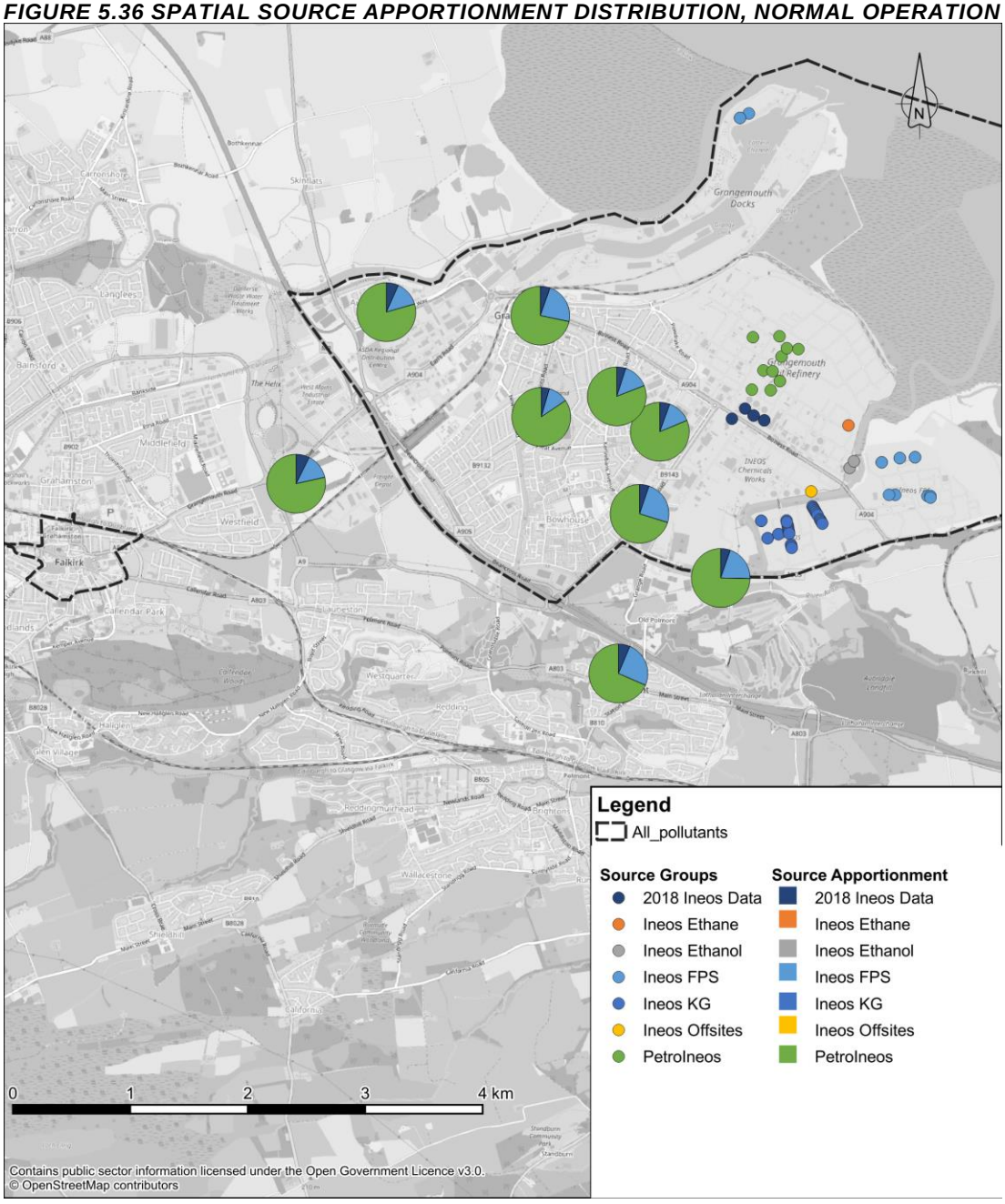


FIGURE 5.37 SPATIAL SOURCE APPORTIONMENT DISTRIBUTION, PEAK A OPERATION

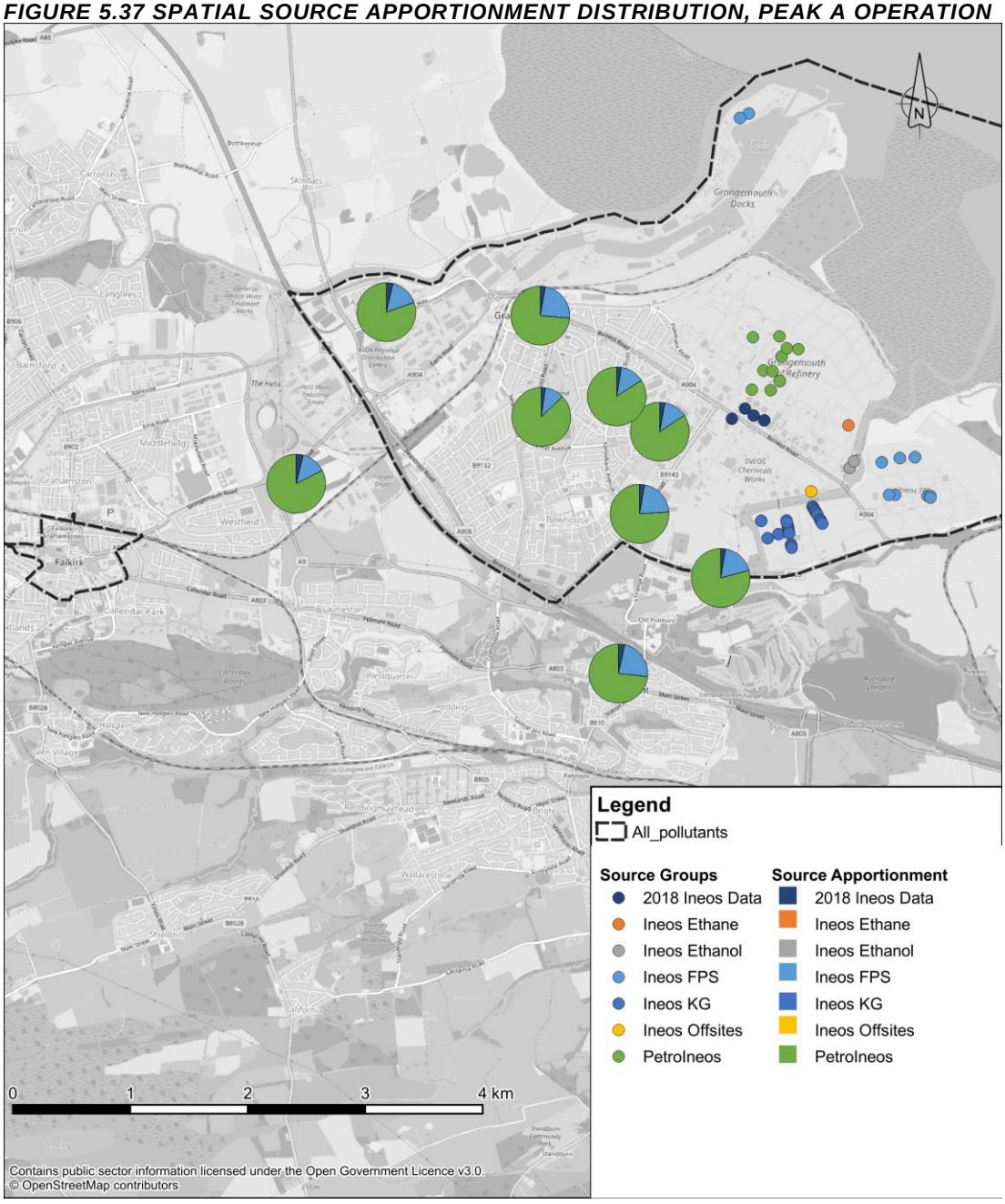
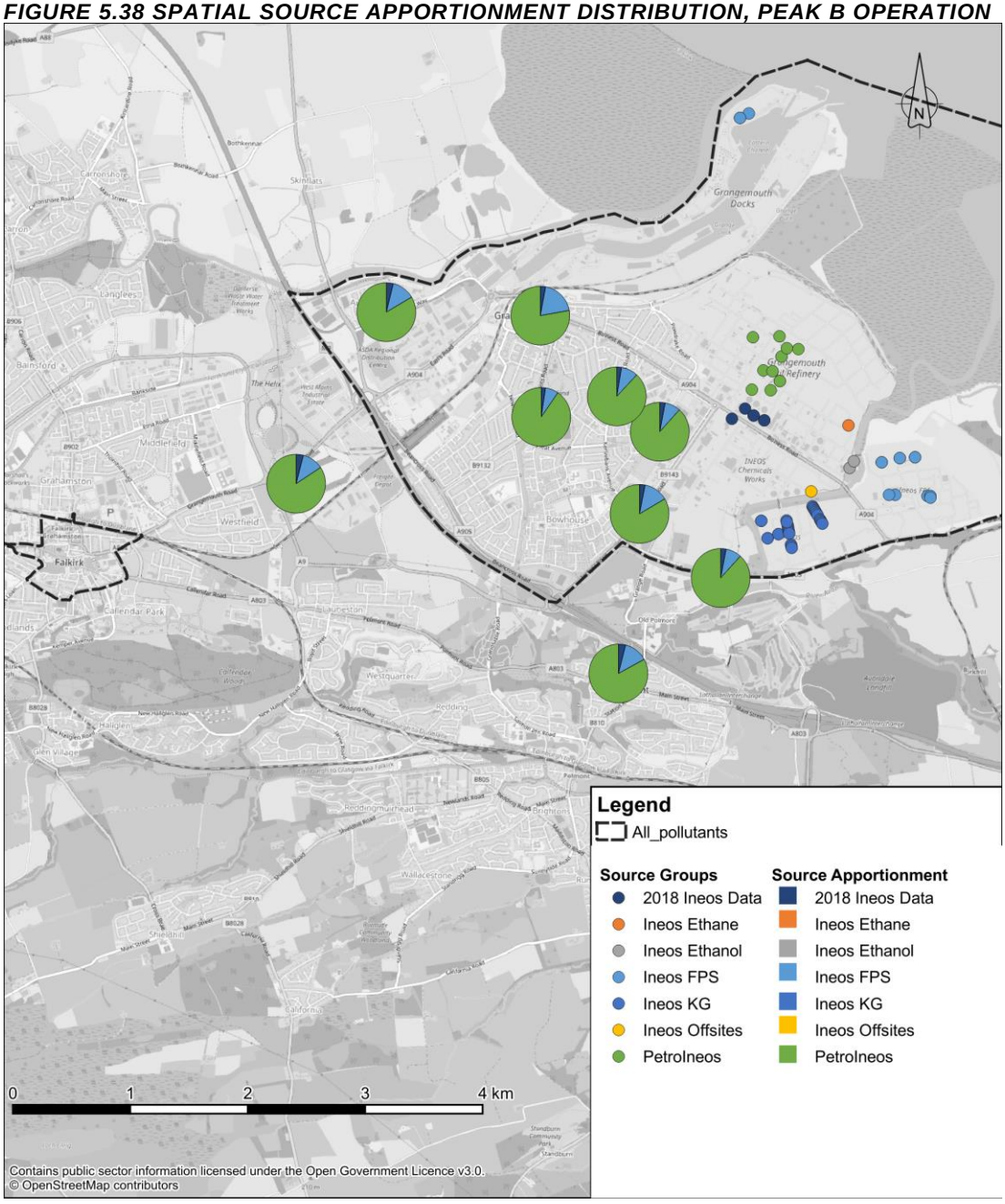


FIGURE 5.38 SPATIAL SOURCE APPORTIONMENT DISTRIBUTION, PEAK B OPERATION



5.2 NO_X and NO_2

Discrete Human Receptors

This section presents the results for the prediction for NO_X and NO_2. Both the Process Contribution and the Predicted Environmental Concentration are presented. Where predictions have been made against the 1-hour objective for NO_2 background concentrations have been multiplied by a factor of 2 according to the guidance in LAQM.TG(22)[5].

There are no exceedances of the NO_2 objective of 40 µg/m³ under any circumstances at the modelled receptors.The results for the predictions for NO_X and NO_2 are shown in the following tables:

- Table 5.10 Top 10 NOX PC Predictions, Annual Mean
- Table 5.11 Top 10 NO2 PC Predictions, Annual Mean
- Table 5.12 Top 10 NO2 PC Predictions, 1-hour Mean

TABLE 5.10 TOP 10 NO_X PC PREDICTIONS, ANNUAL MEAN

Rank	Normal Operation			Peak A Operation			Peak B Operation		
	NO_X PC (µg/m³)	NO_X PEC (µg/m³)	Receptor	NO_X PC (µg/m³)	NO_X PEC (µg/m³)	Receptor	NO_X PC (µg/m³)	NO_X PEC (µg/m³)	Receptor
1	7.7	16.2	Wholeflats	18.4	26.9	Wholeflats	18.4	26.9	Wholeflats
2	6.1	19.1	Inchyra AQU	11.9	22.5	Reddoch Road	11.9	22.5	Reddoch Road
3	6.0	16.6	Reddoch Road	9.9	18.6	Grangemouth Road 1	9.9	18.6	Grangemouth Road 1
4	6.0	15.5	Bo'Ness Road 1	8.8	20.6	Fintry Road 1	8.8	20.6	Fintry Road 1
5	5.9	15.4	Bo'Ness Road	8.5	20.3	Moriston Court 2	8.5	20.3	Moriston Court 2
6	5.5	18.5	Moray AQU	8.5	20.3	Inchyra Grange Hotel	8.5	20.3	Inchyra Grange Hotel
7	5.1	18.2	Bo'Ness Road 2	8.3	20.1	Moriston Court 1	8.3	20.1	Moriston Court 1
8	4.9	16.7	Inchyra Grange Hotel	7.6	17.7	Cheviot Place	7.6	17.7	Cheviot Place
9	4.8	17.8	Elizabeth Avenue	7.0	17.2	Merrick Road 1	7.0	17.2	Merrick Road 1
10	4.7	14.8	Grangemouth Stadium	6.8	18.7	West Beancross Farm	6.8	18.7	West Beancross Farm

TABLE 5.11 TOP 10 NO_2 PC PREDICTIONS, ANNUAL MEAN

Rank	Normal Operation			Peak A Operation			Peak B Operation		
	NO_2 PC (µg/m³)	NO_X PEC (µg/m³)	Receptor	NO_2 PC (µg/m³)	NO_X PEC (µg/m³)	Receptor	NO_2 PC (µg/m³)	NO_X PEC (µg/m³)	Receptor
1	5.4	12.1	Wholeflats	12.9	19.6	Wholeflats	12.9	19.6	Wholeflats
2	4.3	14.2	Inchyra AQU	8.3	16.6	Reddoch Road	8.3	16.6	Reddoch Road
3	4.2	12.5	Reddoch Road	6.9	13.8	Grangemouth Road 1	6.9	13.8	Grangemouth Road 1
4	4.2	11.6	Bo'Ness Road 1	6.2	15.3	Fintry Road 1	6.2	15.3	Fintry Road 1
5	4.2	11.6	Bo'Ness Road	6.0	15.1	Moriston Court 2	6.0	15.1	Moriston Court 2
6	3.9	13.8	Moray AQU	5.9	15.1	Inchyra Grange Hotel	5.9	15.1	Inchyra Grange Hotel
7	3.6	13.5	Bo'Ness Road 2	5.8	15.0	Moriston Court 1	5.8	15.0	Moriston Court 1
8	3.4	12.6	Inchyra Grange Hotel	5.3	13.2	Cheviot Place	5.3	13.2	Cheviot Place
9	3.4	13.3	Elizabeth Avenue	4.9	12.8	Merrick Road 1	4.9	12.8	Merrick Road 1
10	3.3	11.2	Grangemouth Stadium	4.7	13.9	West Beancross Farm	4.7	13.9	West Beancross Farm

TABLE 5.12 TOP 10 NO_2 PC PREDICTIONS, 1-HOUR MEAN

Rank	Normal Operation			Peak A Operation			Peak B Operation		
	NO_2 PC (µg/m³)	NO_X PEC (µg/m³)	Receptor	NO_2 PC (µg/m³)	NO_X PEC (µg/m³)	Receptor	NO_2 PC (µg/m³)	NO_X PEC (µg/m³)	Receptor
1	2.7	16.1	Wholeflats	6.4	19.9	Wholeflats	6.4	19.9	Wholeflats
2	2.1	22.0	Inchyra AQU	4.2	20.7	Reddoch Road	4.2	20.7	Reddoch Road
3	2.1	18.6	Reddoch Road	3.5	17.2	Grangemouth Road 1	3.5	17.2	Grangemouth Road 1
4	2.1	17.0	Bo'Ness Road 1	3.1	21.4	Fintry Road 1	3.1	21.4	Fintry Road 1
5	2.1	17.0	Bo'Ness Road	3.0	21.3	Moriston Court 2	3.0	21.3	Moriston Court 2
6	1.9	21.8	Moray AQU	3.0	21.3	Inchyra Grange Hotel	3.0	21.3	Inchyra Grange Hotel
7	1.8	21.7	Bo'Ness Road 2	2.9	21.2	Moriston Court 1	2.9	21.2	Moriston Court 1
8	1.7	20.0	Inchyra Grange Hotel	2.7	18.5	Cheviot Place	2.7	18.5	Cheviot Place
9	1.7	21.6	Elizabeth Avenue	2.5	18.3	Merrick Road 1	2.5	18.3	Merrick Road 1
10	1.7	17.4	Grangemouth Stadium	2.4	20.8	West Beancross Farm	2.4	20.8	West Beancross Farm

Under the Normal Operation scenario, Table 5.10 Table 5.11 and Table 5.12 show that there are no exceedances of the long-term objective for NO_X or NO_2 or short-term objective for NO_2. All of the highest predicted long-term PECs are less than 75% of the respective objective values and the short-term PEC for NO_2 approximately 25% of the objective value.

Under the Peak Operation scenario, Table 5.10 and Table 5.11 show that there are no exceedances of the long-term objective values for NO_X or NO_2. All of the highest PECs are less than 75% of their respective objective values.

Table 5.12 shows that there are no predicted exceedances of the 1-hour objective for NO_2. The highest PEC is 59% of the 1-hour objective of 200 µg/m³. Analysis of the source attribution shows the largest contribution to be from source EP-KG-3 under peak operation.

The worst case annual mean industrial PC concentrations from the Normal Operation scenario have been added to the outputs from the 2021 traffic modelling. This shows the highest predicted NO_2 concentrations below the objective value of 40 µg/m³. The top 10 receptor predictions are shown in Table 5.13.

TABLE 5.13 TOTAL ANNUAL MEAN NO_2 FROM TRAFFIC AND INDUSTRIAL SOURCES

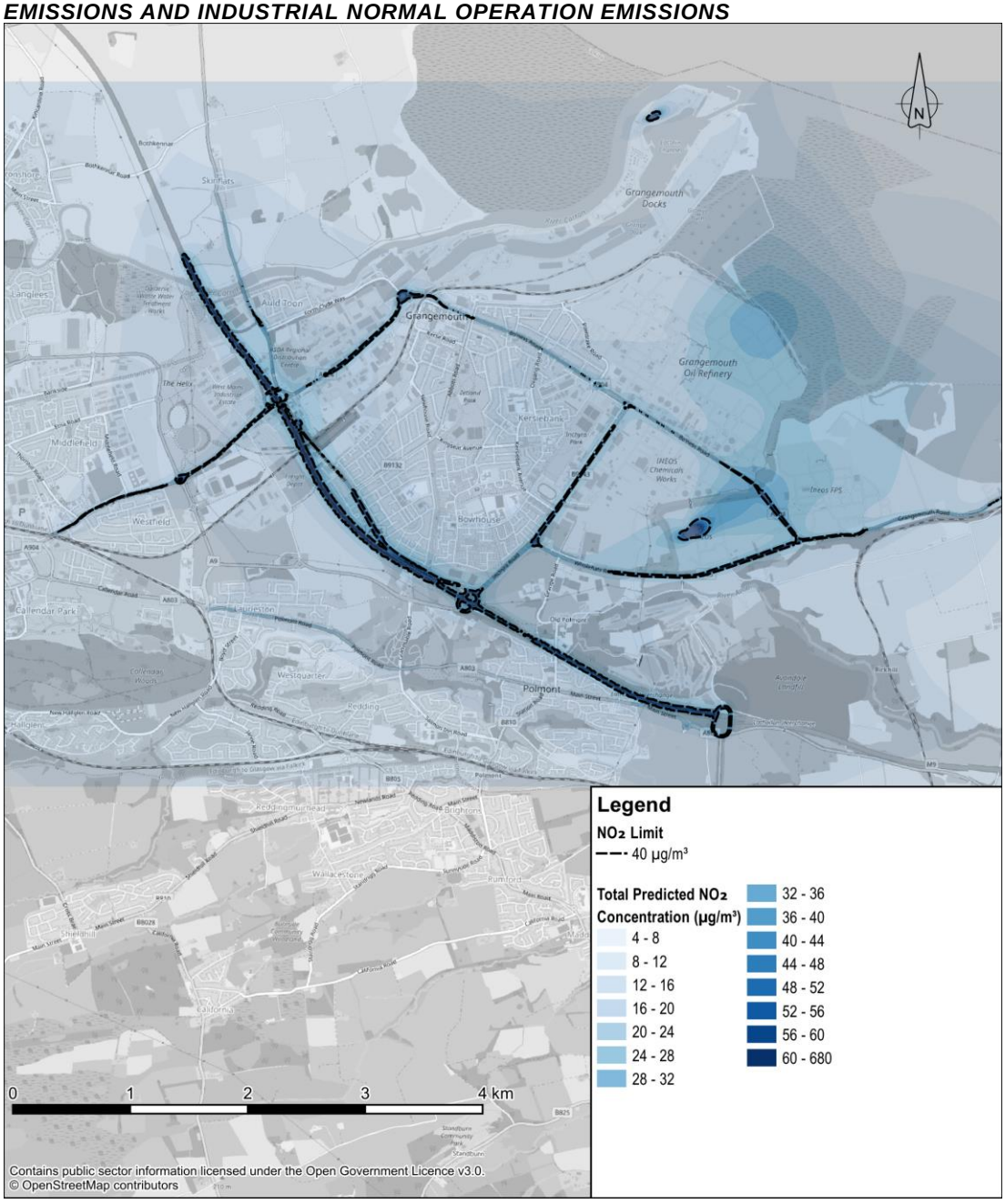
Rank	NO_2 concentration (µg/m³)	Receptor Name
1	28.1	Glensburgh Road 2
2	26.5	Beancross Road 1
3	25.0	103 Bo'ness Road
4	24.9	Bo'ness Road 3
5	24.8	Bo'ness Road 1
6	24.2	Ladysmill 1
7	24.1	Merrick Road 1
8	23.8	21 Primrose Avenue
9	23.7	19 Chrisholm Place
10	21.9	28 Grangemouth Road

Gridded Receptors

Gridded PC predictions from the industrial modelling have been added to the results of the 2021 traffic modelling to produce isopleths for NO_2. The road component of the NO_X predictions was processed in the NO_X to NO_2 Calculator v7.1 to maintain consistency with the 2021 processing of these results however the 2023 backgrounds were used in common with the treatment of results in this report.

The results show that concentrations of NO_2 in excess of the objective of 40 µg/m³ are confined to areas within the carriageways of the major roads and the immediate area around industrial sources. It is highly unlikely that such high concentrations of NO_2 will be present at human receptor locations. This is shown in Figure 5.39.

FIGURE 5.39 GRIDDED PREDICTIONS FOR NO_2, ANNUAL MEAN, WITH TRAFFIC EMISSIONS AND INDUSTRIAL NORMAL OPERATION EMISSIONS



Source Apportionment

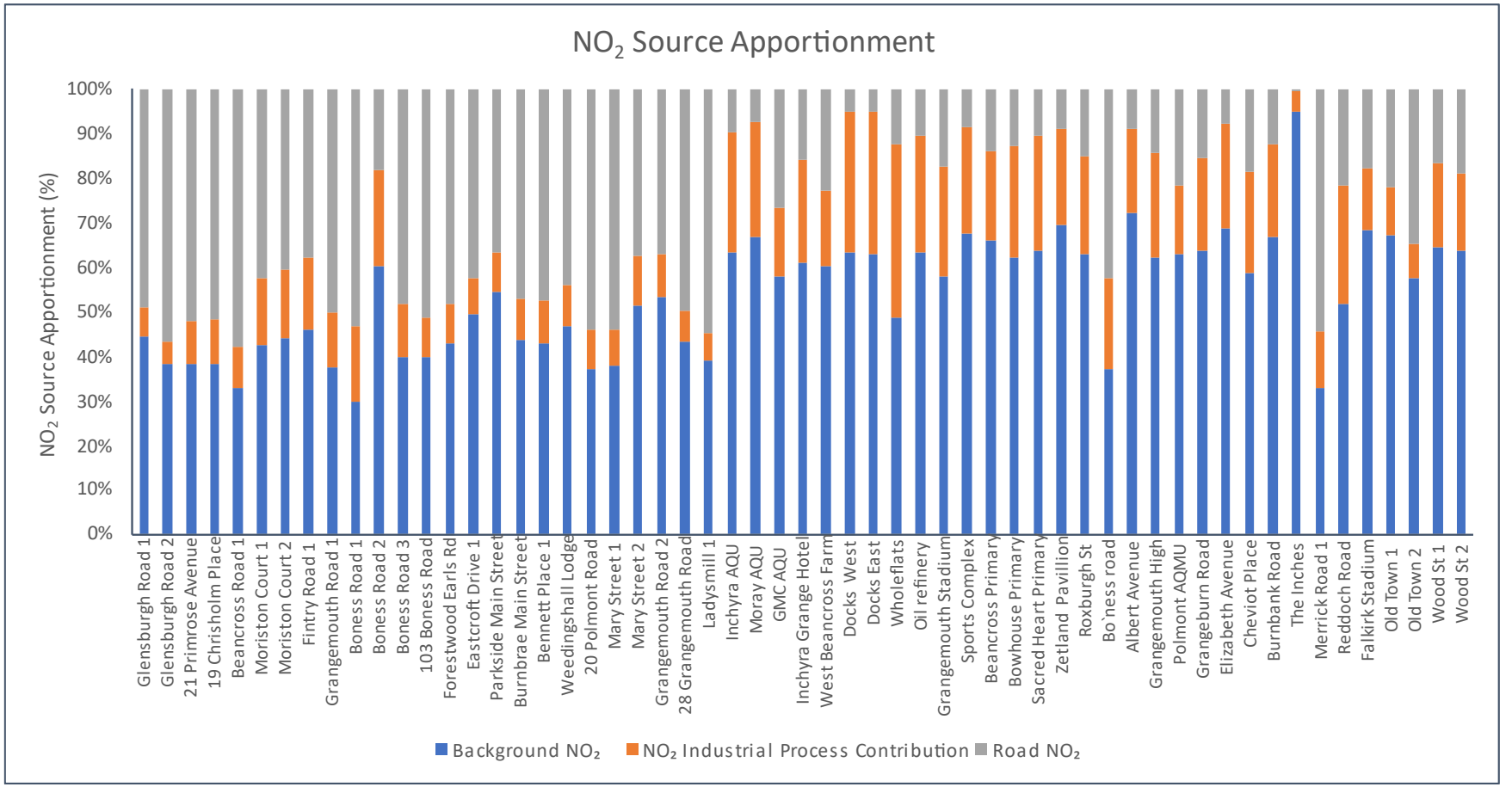
An analysis of the source apportionment for NO_2 at discrete receptor locations has been undertaken based on the industrial PC, NO_X to NO_2 calculator Road NO_2 component and the 2023 Scottish Government backgrounds.

The largest contributor to total predicted concentrations of NO_2 varies between the road component and background concentrations:

- The road component varies between 0.5% and 65.2% of total predicted concentrations
- The PC component varies between 3.0% and 35.1% of total predicted concentrations
- The background component varies between 30.0% and 96.5% of total predicted concentrations.

The source apportionment is shown graphically in Figure 5.40.

FIGURE 5.40 GRAPH SHOWING THE NO_2 SOURCE APPORTIONMENT PERCENTAGE AT DISCRETE HUMAN RECEPTOR LOCATIONS



5.3 Particulates (PM_{10} and $PM_{2.5}$)

Discrete Human Receptors

This section details the results of the receptor predictions for PM_{10} and $PM_{2.5}$. For PEC prediction against the short-term objective for PM_{10} the PC was added to unchanged background concentrations following the guidance in LAQM.TG(22)[5]. Results tables are provided for the Normal Operation scenario only as none of the Peak Operation sources in Appendix A Table 7.10 were provided with particulate emission factors.

The results are shown in the following tables:

- Table 5.14 Top 10 PM10 PC Predictions, Annual Mean
- Table 5.15 Top 10 PM10 PC Predictions, 24-hour Mean 98.08th Percentile
- Table 5.16 Top 10 PM2.5 PC Predictions, Annual Mean

TABLE 5.14 TOP 10 PM_{10} PC PREDICTIONS, ANNUAL MEAN

Rank	Normal Operation			Peak A Operation			Peak B Operation		
	PM_{10}PC (µg/m³)	NO_X PEC (µg/m³)	Receptor	PM_{10}PC (µg/m³)	NO_X PEC (µg/m³)	Receptor	PM_{10}PC (µg/m³)	NO_X PEC (µg/m³)	Receptor
1	2.9	13.1	Bo'Ness Road	2.9	13.1	Bo'Ness Road	2.9	13.1	Bo'Ness Road
2	2.9	13.1	Bo'Ness Road 1	2.9	13.1	Bo'Ness Road 1	2.9	13.1	Bo'Ness Road 1
3	2.5	11.6	Bo'Ness Road 2	2.5	11.6	Bo'Ness Road 2	2.5	11.6	Bo'Ness Road 2
4	2.2	12.5	Oil refinery	2.2	12.5	Oil refinery	2.2	12.5	Oil refinery
5	2.1	11.2	Moray AQU	2.1	11.2	Moray AQU	2.1	11.2	Moray AQU
6	2.1	11.2	Inchyra AQU	2.1	11.2	Inchyra AQU	2.1	11.2	Inchyra AQU
7	2.1	11.2	Elizabeth Avenue	2.1	11.2	Elizabeth Avenue	2.1	11.2	Elizabeth Avenue
8	2.0	11.1	Bo'Ness Road 3	2.0	11.1	Bo'Ness Road 3	2.0	11.1	Bo'Ness Road 3
9	1.7	10.8	Albert Avenue	1.7	10.8	Albert Avenue	1.7	10.8	Albert Avenue
10	1.6	11.2	Zetland Pavillion	1.6	11.2	Zetland Pavillion	1.6	11.2	Zetland Pavillion

TABLE 5.15 TOP 10 PM_{10} PC PREDICTIONS, 24-HOUR MEAN 98.08TH PERCENTILE

Rank	Normal Operation			Peak A Operation			Peak B Operation		
	PM_{10} PC (µg/m³)	NO_X PEC (µg/m³)	Receptor	PM_{10}PC (µg/m³)	NO_X PEC (µg/m³)	Receptor	PM_{10}PC (µg/m³)	NO_X PEC (µg/m³)	Receptor
1	14.8	25.1	Bo'Ness Road 1	14.8	25.1	Bo'Ness Road 1	14.8	25.1	Bo'Ness Road 1
2	14.6	24.9	Oil refinery	14.6	24.9	Oil refinery	14.6	24.9	Oil refinery
3	14.6	24.9	Bo'Ness Road	14.6	24.9	Bo'Ness Road	14.6	24.9	Bo'Ness Road
4	11.8	20.9	Bo'Ness Road 2	11.8	20.9	Bo'Ness Road 2	11.8	20.9	Bo'Ness Road 2
5	10.8	19.9	Bo'Ness Road 3	10.8	19.9	Bo'Ness Road 3	10.8	19.9	Bo'Ness Road 3
6	10.7	19.8	Moray AQU	10.7	19.8	Moray AQU	10.7	19.8	Moray AQU
7	10.3	19.4	Inchyra AQU	10.3	19.4	Inchyra AQU	10.3	19.4	Inchyra AQU
8	10.0	19.1	Elizabeth Avenue	10.0	19.1	Elizabeth Avenue	10.0	19.1	Elizabeth Avenue
9	9.0	18.1	Albert Avenue	9.0	18.1	Albert Avenue	9.0	18.1	Albert Avenue
10	7.7	17.2	Zetland Pavillion	7.7	17.2	Zetland Pavillion	7.7	17.2	Zetland Pavillion

TABLE 5.16 TOP 10 $PM_{2.5}$ PC PREDICTIONS, ANNUAL MEAN

Rank	Normal Operation			Peak A Operation			Peak B Operation		
	$PM_{2.5}$ PC (µg/m³)	NO_X PEC (µg/m³)	Receptor	$PM_{2.5}$PC (µg/m³)	NO_X PEC (µg/m³)	Receptor	$PM_{2.5}$PC (µg/m³)	NO_X PEC (µg/m³)	Receptor
1	2.9	8.3	Bo'Ness Road	2.9	8.3	Bo'Ness Road	2.9	8.3	Bo'Ness Road
2	2.9	8.3	Bo'Ness Road 1	2.9	8.3	Bo'Ness Road 1	2.9	8.3	Bo'Ness Road 1
3	2.6	8.1	Bo'Ness Road 2	2.6	8.1	Bo'Ness Road 2	2.6	8.1	Bo'Ness Road 2
4	2.2	7.7	Moray AQU	2.2	7.7	Moray AQU	2.2	7.7	Moray AQU
5	2.2	7.7	Elizabeth Avenue	2.2	7.7	Elizabeth Avenue	2.2	7.7	Elizabeth Avenue
6	2.2	7.6	Oil refinery	2.2	7.6	Oil refinery	2.2	7.6	Oil refinery
7	2.1	7.6	Bo'Ness Road 3	2.1	7.6	Bo'Ness Road 3	2.1	7.6	Bo'Ness Road 3
8	2.1	7.6	Inchyra AQU	2.1	7.6	Inchyra AQU	2.1	7.6	Inchyra AQU
9	1.7	7.2	Albert Avenue	1.7	7.2	Albert Avenue	1.7	7.2	Albert Avenue
10	1.7	7.1	Zetland Pavillion	1.7	7.1	Zetland Pavillion	1.7	7.1	Zetland Pavillion

Table 5.14, Table 5.15 and Table 5.16 show that there are no exceedances of the objectives for PM_{10} and $PM_{2.5}$. The highest long-term PC prediction for PM_{10} shown in Table 5.14 is 16% of the objective of 18 µg/m³. Similarly, the highest long-term PC prediction for $PM_{2.5}$ is 29% of the objective of 10 µg/m³. All PEC predictions against the long-term objectives for PM_{10} are less than 75% of the objective values, and the highest PEC for $PM_{2.5}$ is 83% of the objective value.

The highest 24-hour PC prediction for PM_{10} 2.6 µg/m³ which is 5.2% of the objective of 50 µg/m³.

The worst-case annual mean PC industrial predictions for PM_{10} and $PM_{2.5}$ have been added to the outputs from the 2021 traffic model. The highest worst-case predictions for total PM_{10} are below the objective value of 18 µg/m³ and the highest worst-case prediction for total $PM_{2.5}$ are below the objective value of 10 µg/m³. These are shown in Table 5.17 and Table 5.18.

TABLE 5.17 TOTAL ANNUAL MEAN PM_{10} FROM TRAFFIC AND INDUSTRIAL SOURCES

Rank	PM_{10} concentration (µg/m³)	Receptor Name
1	15.1	Bo'ness Road 1
2	15.1	21 Primrose Avenue
3	14.5	Bo'ness road
4	14.4	19 Chrisholm Place
5	14.3	Glensburgh Road 2
6	13.5	Moriston Court 1
7	13.4	Beancross Road 1
8	13.3	Bo'ness Road 3
9	13.3	Eastcroft Drive 1
10	13.3	Moriston Court 2

TABLE 5.18 TOTAL ANNUAL MEAN $PM_{2.5}$ FROM TRAFFIC AND INDUSTRIAL SOURCES

Rank	$PM_{2.5}$ concentration (µg/m³)	Receptor Name
1	9.5	Bo'ness Road 1
2	9.1	Bo'ness road
3	8.9	Bo'ness Road 3
4	8.7	21 Primrose Avenue
5	8.4	19 Chrisholm Place
6	8.4	Bo'ness Road 2
7	8.4	103 Bo'ness Road
8	8.3	Beancross Road 1
9	8.2	Glensburgh Road 2
10	8.1	Moriston Court 1

Gridded Receptors

As with the predictions for NO_2, the industrial PC predictions have been added to the outputs of the 2021 traffic modelling using 2023 background concentrations. Concentrations in excess of the respective objectives of 18 µg/m³ for PM_{10} and 10 µg/m³ for $PM_{2.5}$ are confined to carriageway areas and the immediate areas surrounding relevant industrial sources. It is highly unlikely that concentrations of PM_{10} and $PM_{2.5}$ in excess of the objectives will be present at human receptor locations. The gridded outputs for PM_{10} and $PM_{2.5}$ are shown in Figure 5.41 and Figure 5.42.

FIGURE 5.41 GRIDDED PREDICTIONS FOR PM_{10}, ANNUAL MEAN, WITH TRAFFIC EMISSIONS AND INDUSTRIAL NORMAL OPERATION EMISSIONS

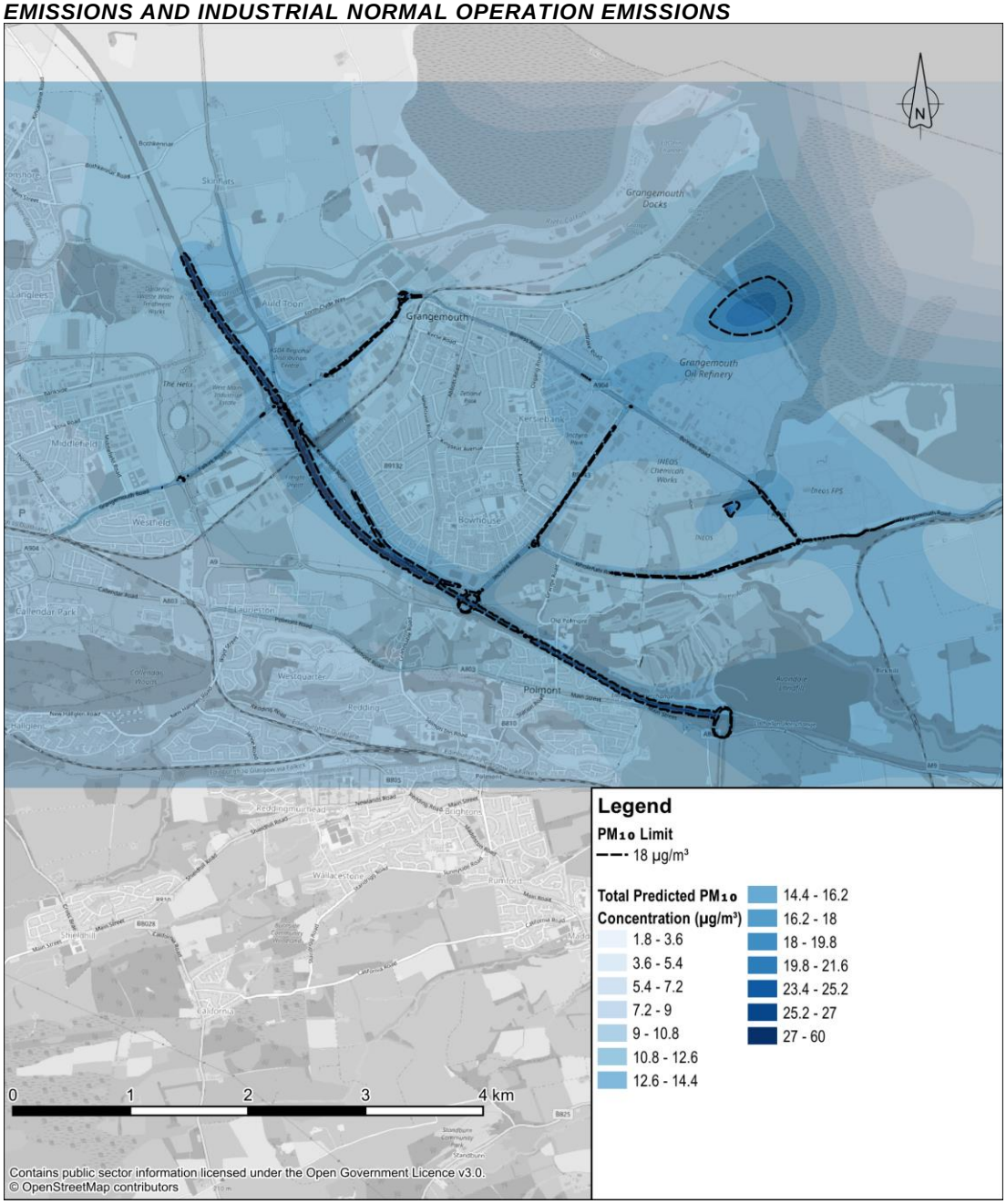
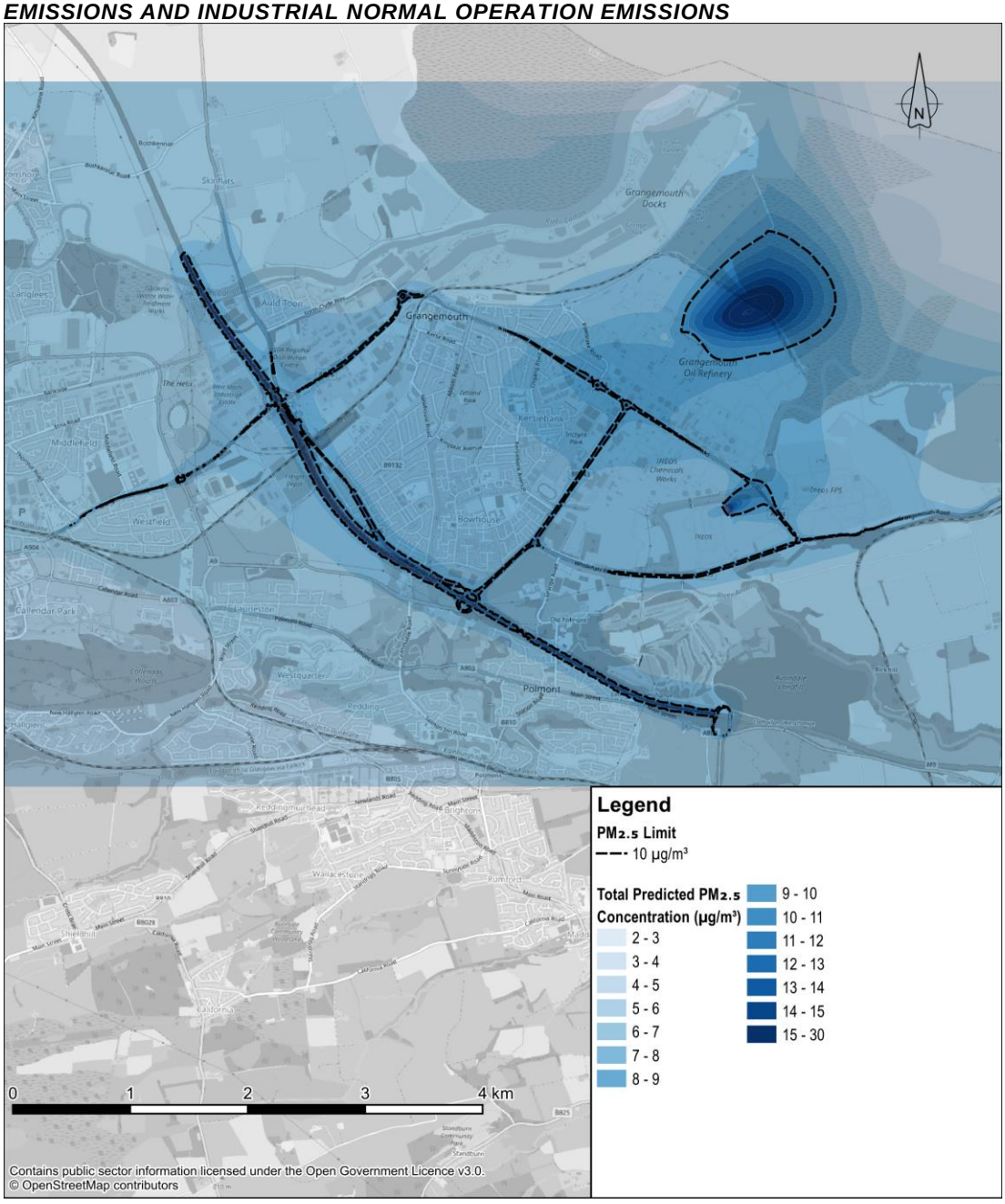


FIGURE 5.42 GRIDDED PREDICTIONS FOR $PM_{2.5}$, ANNUAL MEAN, WITH TRAFFIC EMISSIONS AND INDUSTRIAL NORMAL OPERATION EMISSIONS



Source Apportionment

An analysis of the source apportionment for PM_{10} and $PM_{2.5}$ at discrete receptor locations has been undertaken based on the industrial PC, road PM component and the 2023 Scottish Government backgrounds.

The largest contributor to total predicted concentrations of both PM_{10} and $PM_{2.5}$ is background concentrations by a large margin:

- The road component for PM_{10} varies between 0.1% and 23.6% of total predicted concentrations
- The PM_{10} PC component varies between 0.4% and 3.0% of total predicted concentrations
- The background PM_{10} component varies between 75.4% and 99.5% of total predicted concentrations
- The road component for $PM_{2.5}$ varies between 0.0% and 24.9% of total predicted concentrations
- The $PM_{2.5}$ PC component varies between 0.7% and 5.3% of total predicted concentrations
- The background $PM_{2.5}$ component varies between 73.3% and 99.2% of total predicted concentrations.

The source apportionments for PM_{10} and $PM_{2.5}$ are shown graphically in Figure 5.43 and Figure 5.44.

FIGURE 5.43 GRAPH SHOWING THE PM_{10} SOURCE APPORTIONMENT PERCENTAGE AT DISCRETE HUMAN RECEPTOR LOCATIONS

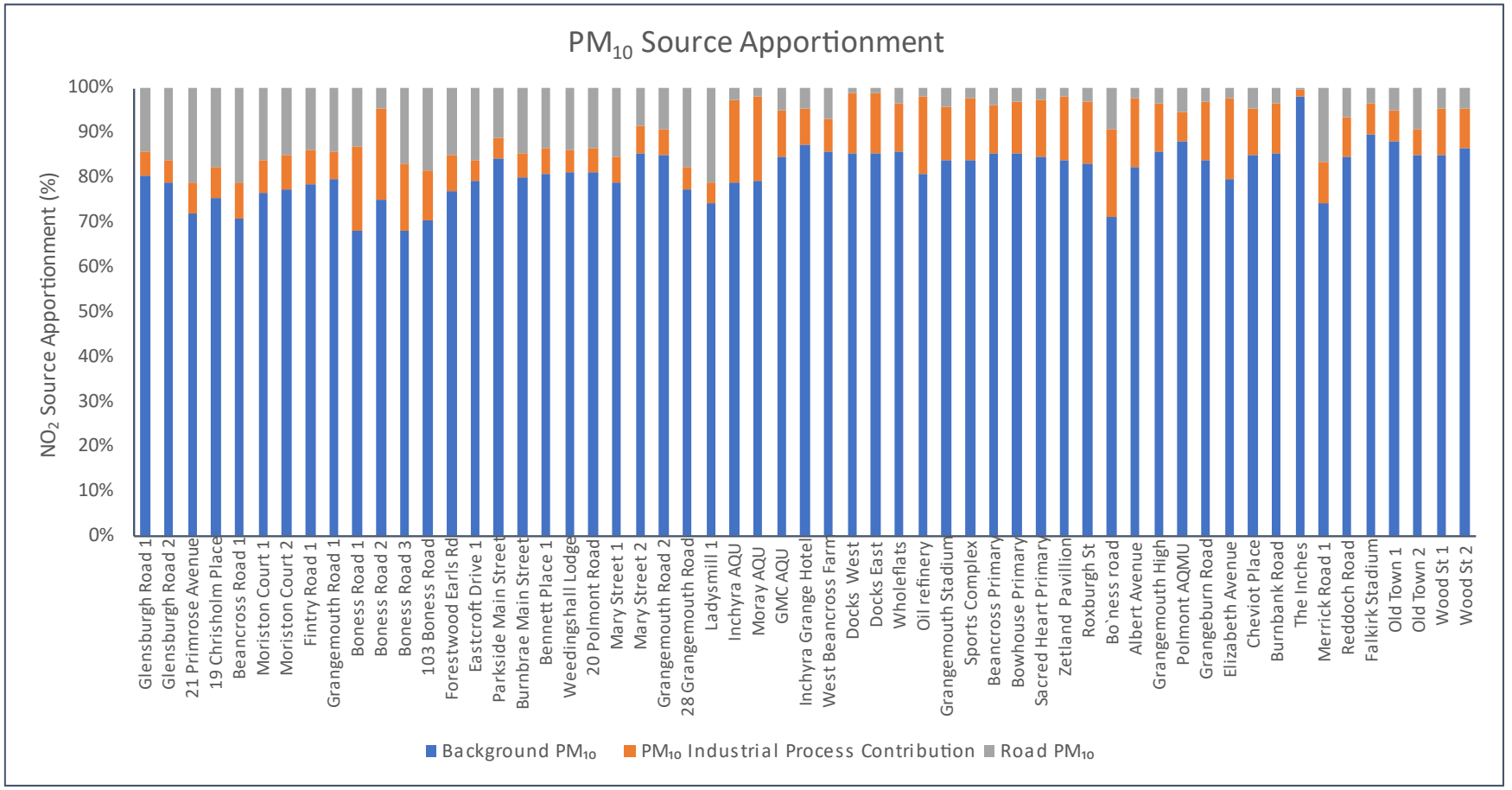
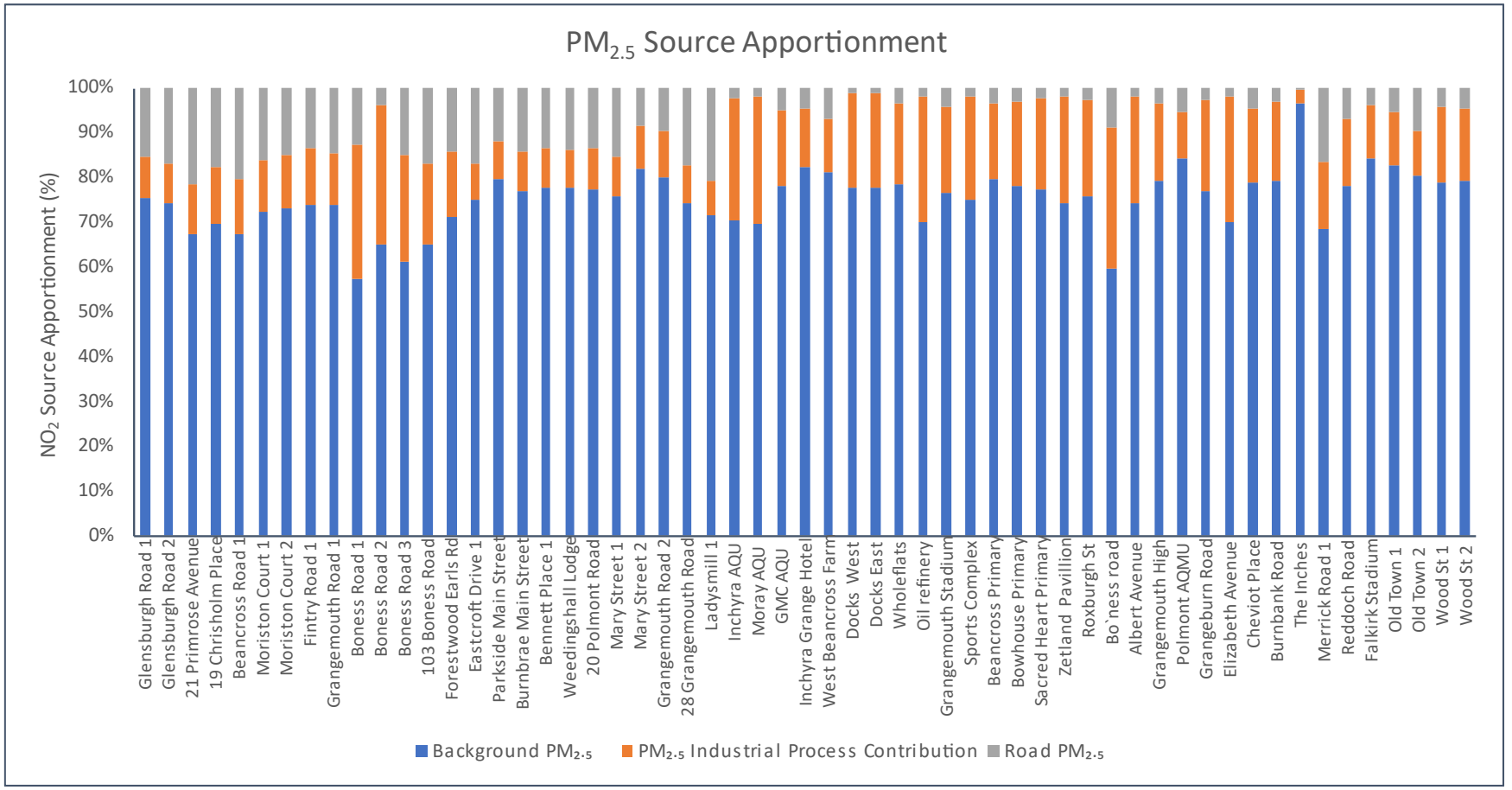


FIGURE 5.44 GRAPH SHOWING THE $PM_{2.5}$ SOURCE APPORTIONMENT PERCENTAGE AT DISCRETE HUMAN RECEPTOR LOCATIONS



5.4 CO, CH_4 and VOC

This section describes the results for the dispersion modelling for CO, CH_4 and VOCs. The dispersion modelling predictions for CO are compared to the 8-hour rolling mean, whereas the results for the predictions for CH_4 and VOCs are presented for information only. There is no ambient air quality objective for CH_4 and VOCs are a combination of a number of different compounds and hydrocarbons. Where the limit value for benzene might ordinarily be used as a proxy for the assessment of VOC predictions in the case of this study it is clear from the results that a large number of compounds are included in the parameters provided for VOC emissions such that this

TABLE 5.19 TOP 10 CO PREDICTIONS, ROLLING 8-HOUR MEAN

Rank	Normal Operation		Peak A Operation		Peak B Operation	
	CO Concentration (mg/m^3)	Receptor	CO Concentration (mg/m^3)	Receptor	CO Concentration (mg/m^3)	Receptor
1	4.8	Wholeflats	4.8	Wholeflats	4.8	Wholeflats
2	2.9	Merrick Road 1	2.9	Merrick Road 1	2.9	Merrick Road 1
3	2.6	Cheviot Place	2.6	Cheviot Place	2.6	Cheviot Place
4	2.6	Fintry Road 1	2.6	Fintry Road 1	2.6	Fintry Road 1
5	2.4	Moriston Court 2	2.4	Moriston Court 2	2.4	Moriston Court 2
6	2.3	Grangemouth Road 1	2.3	Grangemouth Road 1	2.3	Grangemouth Road 1
7	2.3	Moriston Court 1	2.3	Moriston Court 1	2.3	Moriston Court 1
8	2.1	Inchyra Grange Hotel	2.1	Inchyra Grange Hotel	2.1	Inchyra Grange Hotel
9	2.1	Grangemouth High	2.1	Grangemouth High	2.1	Grangemouth High
10	2.0	Grangemouth Stadium	2.0	Grangemouth Stadium	2.0	Grangemouth Stadium

TABLE 5.20 TOP 10 CH_4 PREDICTIONS, ANNUAL MEAN

Rank	Normal Operation		Peak A Operation		Peak B Operation	
	CH_4 Concentration (µg/m³)	Receptor	CH_4 Concentration (µg/m³)	Receptor	CH_4 Concentration (µg/m³)	Receptor
1	0.9	Wholeflats	1.5	Wholeflats	1.5	Wholeflats
2	0.6	Reddoch Road	0.9	Reddoch Road	0.9	Reddoch Road
3	0.5	Inchyra Grange Hotel	0.8	Grangemouth Road 1	0.8	Grangemouth Road 1
4	0.4	Fintry Road 1	0.7	Fintry Road 1	0.7	Fintry Road 1
5	0.4	Moriston Court 2	0.7	Moriston Court 2	0.7	Moriston Court 2
6	0.4	Moriston Court 1	0.6	Moriston Court 1	0.6	Moriston Court 1
7	0.4	Merrick Road 1	0.6	Inchyra Grange Hotel	0.6	Inchyra Grange Hotel
8	0.3	Cheviot Place	0.6	Cheviot Place	0.6	Cheviot Place
9	0.3	Grangemouth Stadium	0.6	Merrick Road 1	0.6	Merrick Road 1
10	0.3	Grangemouth High	0.5	Grangemouth High	0.5	Grangemouth High

TABLE 5.21 TOP 10 VOC PREDICTIONS, ANNUAL MEAN

Rank	Normal Operation		Peak A Operation		Peak B Operation	
	VOC Concentration (µg/m³)	Receptor	VOC Concentration (µg/m³)	Receptor	VOC Concentration (µg/m³)	Receptor
1	280.4	Wholeflats	287.5	Wholeflats	287.5	Wholeflats
2	213.0	Merrick Road 1	214.9	Merrick Road 1	214.9	Merrick Road 1
3	195.2	Reddoch Road	202.5	Reddoch Road	202.5	Reddoch Road
4	189.8	Cheviot Place	191.9	Cheviot Place	191.9	Cheviot Place
5	178.2	Fintry Road 1	181.6	Fintry Road 1	181.6	Fintry Road 1
6	166.9	Moriston Court 2	170.4	Moriston Court 2	170.4	Moriston Court 2
7	160.2	Moriston Court 1	163.7	Moriston Court 1	163.7	Moriston Court 1
8	157.0	Grangemouth Stadium	159.3	Grangemouth Stadium	159.3	Grangemouth Stadium
9	156.1	Bennett Place 1	158.6	Bennett Place 1	158.6	Bennett Place 1
10	156.0	Grangemouth High	157.6	Grangemouth High	157.6	Grangemouth High

The highest predicted PC concentrations of CO for the Normal Operation and Peak Operation scenarios, as shown in Table 5.19, are below the 8-hour rolling mean objective value of 10 mg/m³. The highest concentrations, up to 50% of the objective, are predicted consistently at the Wholeflats location where it is not expected that members of the public would normally be present. The next highest predicted predictions where members of the public may be present are up to 30% of the objective under both the Normal Operation and Peak Operation scenarios.

The top ten predictions for concentrations of CH_4 in ambient air are shown in Table 5.20. There is no health-based exposure value for the general public for concentrations of CH_4 in ambient air. The Methane Incident Management note[8] states that CH_4 is potentially explosive at concentrations of between 5% and 15% in ambient air. Predicted concentrations are substantially below this, the predicted peak being only 1.5 µg/m³ or 2.2 ppb.

Predictions for VOCs would normally be compared to the objective for benzene, however given that this is likely to be only a small part of the constituents for the VOC emissions such a comparison is not considered to be appropriate.

The highest predictions for VOC concentrations shown in Table 5.21 are located in the Wholeflats area. As previously described it is not expected that members of the public would normally be present in this area. The next highest predictions are located at Merrick Road.

[8] Public Health England (2015) Methane Incident Management. [Online] https://www.gov.uk/government/publications/methane-properties-uses-and-incident-management, accessed December 2023

6 Summary

6.1 SO_2

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. In reality 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 episodes are unknown.

As a worst case the Peak A and Peak B Operating Scenarios have been run as if all industrial emission sources run constantly. This allows the model to determine the potential highest concentrations across a range of meteorological conditions.

The results of the modelling have indicated that even under Normal operation there is the potential for exceedances, but the risk of a breach is highly unlikely.

However the maximum concentrations predicted at the remaining receptors are still considered to have a negative impact on human health under all modelled scenarios.

The Peak Operating scenario has shown no potential for a breach of the 15-minute objective within the study area however exceedances of the 15-minute mean do remain. This occurs at the following locations:

- 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.

It should be noted that this number of exceedances is for a whole year of operation. This indicates that when there is flaring under the right meteorological conditions elevated concentrations that are considered to have a negative impact on human health will occur.

The potential for predicted exceedances can also be seen in the monitoring data which pre- and post- Covid-19 show limited numbers of exceedances of the 15-minute and 1-hour objectives occurring at the locations of automatic monitors, provided in Figure 3.1 and Appendix A Table 7.1 and Table 7.2, though on less than the permitted number of occasions in a calendar year.

The 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 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. Modelling against the 15-minute objective during the Peak Operation scenario suggests the results may tie in with the possibility of exceedances being recorded by the monitoring stations during flaring events.

The modelling also shows that the dispersion pattern on site has changed, and the current monitoring locations are no longer in the worst-case locations. This is likely due to changes on site where a number of the previous SO_2 emitters within Petroineos are no longer in operation, ground flares have replaced many elevated flares. There is also the inclusion of emissions data from sources at the Ineos FPS location that have not been available to include in earlier iterations of the modelling of the AQMA.

The 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, four, under the Peak A and Peak B operation scenarios. This could indicate other areas of Grangemouth and the surrounding area may have experienced a breach of the 15-minute mean objective in 2023.

6.2 NO_X and NO_2

The modelling for the dispersion of NO_X and NO_2 shows that in general the predicted concentrations at human receptors were low for the annual mean objectives under both the Normal Operation scenario and Peak Operation scenario.

Under the Peak Operation scenario there were no predicted exceedances of the 1-hour objective of 200 µg/m³. Study of the source attribution showed that the principal contribution to predicted NO_X and NO_2 concentrations originated from the EP-KG-3 flare in the Ineos FPS plant. As with the short-term objectives for SO_2 under the Peak Operation scenario, the results should be interpreted with the assumption that the Peak Operation scenario assumes the simultaneous operation of all flares which is highly unlikely to occur though the high contribution from this single source suggests the elevated concentrations of NO_X and NO_2 will occur whenever this single source is in operation.

6.3 Particulates (PM_{10} and $PM_{2.5}$)

The data in Appendix A Table 7.9 and Table 7.10 show that roughly half of all the sources have specified emissions of particulates and these emissions are low compared to other pollutants. As such the results from the dispersion modelling show PC concentrations that are approximately 1% of the objective values for PM_{10} and up to 3% of the objective for $PM_{2.5}$. None of the flare sources under the Peak Operation scenario have any particulate emissions specified, therefore the operating scenario has no impact on the predicted concentrations for PM_{10} and $PM_{2.5}$.

The predictions for $PM_{2.5}$ are considered to be conservative. No specific emission information was provided for $PM_{2.5}$, therefore the values for PM_{10} emissions were applied to $PM_{2.5}$.

6.4 CO, CH_4 and VOC

Predicted concentrations for CO are below the 8-hour rolling mean of 10 mg/m³ under both the Normal Operation and Peak Operation scenarios.

There is no statutory human health-based limit or objective for comparison of the predicted concentrations of CH_4 therefore a health and safety approach was taken for interpretation of

the results based on the potential flammable/explosive concentration for CH_4 in ambient air. The proportion of CH_4 in ambient air that is considered flammable or explosive is between 5% and 15%. The predicted concentrations were substantially below these thresholds and therefore the concentrations of CH_4 are safe.

No information was provided on the constituents of the VOC emissions from the various emission sources, therefore is has not been possible to make a proxy comparison against a limit or objective for a specific pollutant. In order to determine the exact nature of VOC predictions for comparison against a human health-based limit or objective value it will be necessary in future studies to use information on the constituent parts of the VOC emissions being produced at the Grangemouth facilities.

7 Conclusions

This study has undertaken an updated dispersion modelling exercise of the emissions from the Grangemouth industrial facilities and combined this with the results of the 2021 traffic emission modelling reported in the 2021 Grangemouth Emissions Study[1].

Emissions from a increased number of industrial sources were provided compared to the 2021 study, however the data were subject to similar constraints, for example as being in operation for 8,760 hours per year when this may not be the case. Flaring was also estimated based on emissions being spread throughout the year for the Normal Operation scenario, and with peak operational emissions for all flares running throughout the year for the Peak Operation A and B scenarios. Whilst, for the Peak Operation Scenarios, this is appropriate for the identification of worst-case peak short-term periods, time varying emission or operation parameters would provide a more accurate picture.

The monitoring results analysed as part of this assessment fall somewhere in between the predictions made under Normal Operation scenario and the Peak Operation scenario, therefore the modelling results provide the best representation of reality possible given the data that has been supplied.

Together with the more detailed Revocation Report, this investigation provides an overview of all relevant pollutants in the Grangemouth area for which objectives are set for the protection of human health. In the case of the pollutant SO_2, despite improvements in the operating parameters and available scrubbing technology used at the Grangemouth facilities, local exceedances of both the 15-minute objective of 266 µg/m³ and the 1-hour objective of 350 µg/m³ cannot be ruled out. Whilst the number of times these objectives have been exceeded is less than the number permitted, the latest monitoring data for 2023 shows that the limit to the number of exceedances can easily be placed at risk.

The results of the modelling show that there is the potential for improved monitoring locations to be chosen for SO_2 due to the changes in operation at the Grangemouth facilities since the current monitoring locations were established. The monitoring locations should be based on the locations of worst-case exposure. If the predicted locations of worst-case exposure move geographically then it follows that the monitoring locations should also be moved to compensate.

For NO_2, PM_{10} and $PM_{2.5}$ the annual mean objectives are not at risk at human receptor locations within Grangemouth. The predictions show that any elevated concentrations at or above the objectives are confined to carriageway areas or areas immediately adjacent to industrial sources, where people would not be expected to be normally present. The same is true for the short-term objectives for NO_2 and PM_{10} as the long-term predictions do not reach the thresholds where exceedance of the short-term objectives may be considered possible.

Appendix A LAQM Monitoring

TABLE 7.1 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 AURN
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)

TABLE 7.2 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 7.3 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)

The Sen's Slope statistic is used to provide an indication of the direction and magnitude of the trend in concentrations. A negative statistic is indicative of an improvement in measured pollutant concentrations, and the value is the change with each time period step, in this case the yearly change. The statistics show a continued improvement in concentrations with those monitored at Grangemouth Moray improving by almost 1 µg/m³ per year for the period in this study.

TABLE 7.4 SUMMARY OF ANNUAL CONTINUOUS AUTOMATIC NO_2 MEASUREMENT

Year	Annual NO_2 Exceedances (Max. Concentration in µg/m³)			
	Grangemouth Municipal Chambers	Grangemouth Moray	Falkirk Hope Street	Grangemouth
2015	0 (18.5)	0 (14.9)	0 (20.8)	0 (14.7)
2016	0 (20.5)	0 (17.8)	0 (22.5)	0 (16)
2017	0 (16.6)	0 (16.7)	0 (18.8)	0 (14.3)
2018	0 (17.8)	0 (16.8)	0 (21)	0 (14.4)
2019	0 (17.2)	0 (14.7)	0 (20)	0 (15.2)
2020	0 (11.9)	0 (12.3)	0 (14.2)	0 (11.1)
2021	0 (13.4)	0 (13.8)	0 (15.5)	0 (13.1)
2022	0 (14.0)	0 (12.3)	0 (14.3)	0 (13.6)
2023	0 (13.3)	0 (8.3)	0 (16.2)	0 (11.6)
Sen's Slope Statistic	-0.875	-0.958	-0.914	-0.394

TABLE 7.5 SUMMARY OF GRANGEMOUTH AQMA DIFFUSION TUBE NO_2 MEASUREMENT

Tube ID	Measured NO_2 Concentration (µg/m³)								Sen's Slope
	2015	2016	2017	2018	2019	2020	2021	2022	
NA3	20	19	18	18	19	15	15	13	-1.000
NA42	20	20	17	19	19	15	14	13	-1.000
NA44	12	12	16	19	18	14	13	12	±0.000
NA94	24	21	30	31	30	24	22	21	-0.714
NA101	22	21	24	23	23	17	16	15	-1.000
NA116	-	-	-	-	20	15	15	14	-1.550
NA117	-	-	-	-	20	15	14	12	-2.133
NA120	-	-	-	-	-	-	-	14	-
NA121	-	-	-	-	-	-	-	19	-

TABLE 7.6 SUMMARY OF ANNUAL CONTINUOUS AUTOMATIC PM_{10} MEASUREMENT

Year	Annual PM_{10} Exceedances (Max. Concentration in µg/m³)			
	Grangemouth Municipal Chambers	Zetland Park	Falkirk Hope Street	Grangemouth
2015	0 (16.3)	-	-	0 (10.2)
2016	0 (16.3)	-	-	0 (10.7)
2017	0 (14.9)	-	-	0 (9.4)
2018	0 (15.9)	-	0 (14.4)	0 (11.8)
2019	0 (17.5)	-	0 (16.9)	0 (12.6)
2020	0 (10.7)	-	0 (12.1)	0 (8.5)
2021	0 (11.8)	0 (11.6)	0 (12.1)	0 (9.3)
2022	0 (13)	0 (12.2)	0 (12.4)	0 (10.3)
2023	0 (9.1)	0 (8.2)	0 (8.5)	0 (8.4)
Sen's Slope	-0.750	+1.700	-1.800	-0.196

TABLE 7.7 SUMMARY OF 24-HOUR CONTINUOUS AUTOMATIC PM_{10} MEASUREMENT

Year	24 hour PM_{10} Exceedances (Max. Concentration in µg/m³)			
	Grangemouth Municipal Chambers	Zetland Park	Falkirk Hope Street	Grangemouth
2015	3 (54.6)	-	-	0 (49.6)
2016	0 (47.1)	-	-	0 (37.4)
2017	1 (50.8)	-	-	1 (51.8)
2018	0 (45.7)	-	0 (31.9)	0 (41)
2019	2 (68)	-	3 (84.3)	2 (75.3)
2020	0 (34.1)	-	0 (46.1)	0 (24.6)
2021	0 (30.1)	0 (37.6)	0 (38.8)	0 (24.9)
2022	3 (67.1)	2 (62.1)	2 (57.8)	1 (50.6)
2023	0 (32.5)	0 (30.5)	0 (31.1)	0 (24.6)

TABLE 7.8 SUMMARY OF ANNUAL CONTINUOUS AUTOMATIC $PM_{2.5}$ MEASUREMENT

Year	Annual $PM_{2.5}$ Exceedances (Max. Concentration in µg/m³)			
	Grangemouth Municipal Chambers	Zetland Park	Falkirk Hope Street	Grangemouth
2015	1 (10.2)	-	-	0 (9.3)
2016	1 (10.7)	-	-	0 (6.4)
2017	0 (9.4)	-	-	0 (6.4)
2018	1 (11.8)	-	-	0 (7.2)
2019	1 (12.6)	-	-	0 (7.8)
2020	0 (8.5)	-	-	0 (6.1)
2021	0 (9.3)	0 (5.2)	0 (5.1)	0 (5.4)
2022	1 (10.3)	0 (5.5)	0 (5.3)	0 (7.8)
2023	0 (5.0)	0 (4.8)	0 (4.7)	0 (4.9)
Sen's Slope	-0.320	-0.200	-0.200	-0.250

Appendix B Emissions Parameters

TABLE 7.9 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	Annual Average 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	-	-

Source	Group	Description	X	Y	Stack height (m)	Stack internal diameter (m)	Annual Hours of operation	Temp. (°C)	Vol./Mass Flow	Flow/ Mass units	Annual Average Emissions (g/s)						
											NO_X	PM_{10}	$PM_{2.5}$	SO_2	CO	CH_4	Non Methane VOCs
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	-	-
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	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	-	-	-

Source	Group	Description	X	Y	Stack height (m)	Stack internal diameter (m)	Annual Hours of operation	Temp. (°C)	Vol./Mass Flow	Flow/ Mass units	Annual Average Emissions (g/s)						
											NO_x	PM_{10}	$PM_{2.5}$	SO_2	CO	CH_4	Non Methane VOCs
Tower No.7																	
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	-	-	-
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

Source	Group	Description	X	Y	Stack height (m)	Stack internal diameter (m)	Annual Hours of operation	Temp. (°C)	Vol./Mass Flow	Flow/ Mass units	Annual Average Emissions (g/s)						
											NO_x	PM_{10}	$PM_{2.5}$	SO_2	CO	CH_4	Non Methane VOCs
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	-	-
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	-	-

Source	Group	Description	X	Y	Stack height (m)	Stack internal diameter (m)	Annual Hours of operation	Temp. (°C)	Vol./Mass Flow	Flow/ Mass units	Annual Average Emissions (g/s)						
											NO_x	PM_{10}	$PM_{2.5}$	SO_2	CO	CH_4	Non Methane VOCs
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	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	-	-

Source	Group	Description	X	Y	Stack height (m)	Stack internal diameter (m)	Annual Hours of operation	Temp. (°C)	Vol./Mass Flow	Flow/ Mass units	Annual Average Emissions (g/s)						
											NO_x	PM_{10}	$PM_{2.5}$	SO_2	CO	CH_4	Non Methane VOCs
		(Stack H-370)															
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	-	-
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	294725	681117	91.0	2.4	5,689	195.0	243,312.0	Am³/hr	3.925	0.087	0.087	2.05E+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	Annual Average Emissions (g/s)						
											NO_x	PM_{10}	$PM_{2.5}$	SO_2	CO	CH_4	Non Methane VOCs
		combined in .AAI)															
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	-	-

TABLE 7.10 PEAK OPERATION PARAMETERS FOR SPECIFIED SOURCES

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

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-FLARE-3 Peak	PetroIneos	No.3 Flare SO_2 peak	294857	681451	96.4	4.8	8,760	600.0	676,732.032.0	Am^3/hr	1.078	-	-	57.870	-	-	-

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