Air Quality Modelling Study

Grangemouth Emissions Study

Falkirk Council

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SWECO

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1 Introduction

Sweco UK Ltd (Sweco) have been appointed by Falkirk Council to provide consultancy support on behalf of them and SEPA. The purpose of this report is to provide the Council with a report suitable for submission under the LAQM Review and Assessment process for the following modelling studies:

- Grangemouth traffic emissions modelling assessment and source apportionment analysis
- Review of pollutant emissions within Grangemouth AQMA including dispersion modelling of all industrial emissions

1.1 Background

Grangemouth is a town within the Falkirk local authority area. Falkirk Council declared an AQMA in Grangemouth for the SO_2 15minute mean in 2005 for an area encompassing Grangemouth petrochemical complex and the adjacent area.

Previous assessment work in the AQMA has focussed on the short term SO_2 objectives in isolation. This package of work will consider the following pollutant emissions, Oxides of Nitrogen (NOx/NO_2), Particulates (PM_{10} and $PM_{2.5}$), Sulphur Dioxide (SO_2) and Carbon Monoxide (CO), where data are available. The study area considered within the assessment is presented in Figure 1.1.

Falkirk Council originally wanted the modelling study to provide an overall picture of emissions during 2017. However, on completion of the road traffic modelling study and while compiling the emissions inventory for the industrial emissions we reviewed the 2018 emissions data. These data indicated that the emissions for several sites had reduced from 2017. For some sites this was due to a change in operation under revised permits and / or a reduction in permitted emissions in order that they meet new BAT standards. Therefore, the Council and SEPA agreed that an updated 2018 emission inventory be built for both the industrial emissions and road traffic study be updated to 2018 too. This will be discussed in more detail in the subsequent chapters of this report.

The modelling studies have predicted air pollutant concentrations within Grangemouth and undertaken detailed source apportionment modelling for all sources. This will determine which sources have the greatest influence on air quality concentrations within Grangemouth.

Since previous air quality modelling of sources within Grangemouth, there has been considerable changes to sources and their emissions.

To our knowledge, this assessment is the first assessment where both the road traffic sources and industrial sources within Grangemouth have been modelled together for the assessment of pollutant other than just the short term SO_2 objectives. By combining both the industrial and traffic emissions in a complete assessment, this will provide Falkirk Council with an overall understanding of pollutant concentrations across Grangemouth and inform future management of the AQMA.

2 Legislation and Policy

2.1 Legislation

Air quality is an issue of potential significance at international, national and local levels. While there are undoubtedly important ramifications for global and national air quality from a wide range of developments, as recognised by numerous international conventions and European Directives, the primary focus of this assessment is the suitability of the application site for residential development and the potential impact of the proposed development on the local air quality.

2.1.1 Environment Act 1995

Part IV of the Environment Act 1995 places a duty on the Secretary of State for the Environment to develop, implement and maintain an Air Quality Strategy with the aim of reducing atmospheric emissions and improving air quality. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (the UK) provides the framework for ensuring the air quality limit values are complied with based on a combination of international, national and local measures to reduce emissions and improve air quality. This includes the statutory duty, also under Part IV of the Environment Act 1995, where local authorities must review and assess air quality in their areas on an annual basis. This review and assessment process in known as Local Air Quality Management (LAQM).

The focus on local air quality is reflected in the air quality objectives (AQOs) set out in the Air Quality Strategy for the UK. The strategy presents measures to control and improve the quality of air in the UK and reflects the increasing understanding of the potential health risks associated with poor air quality and the benefits that can be gained from its improvements.

The UK objectives are at least as stringent as the European Limit Values for the various pollutants. The Limit Values carry legal standing and have been written into UK law through the various Air Quality Standards Regulations. It is worth noting that the Scottish Government has adopted a fine particulate matter (PM_{10}) annual mean objective that is more stringent than the UK or EU standard. The Scottish PM_{10} standard is written into regulation and therefore carries equivalent weight to the Limit Value based standards. In addition, on the 1st of April 2016, the Scottish Government adopted the World Health Organisation (WHO) Guideline Value for ultra-fine particulate matter ($PM_{2.5}$) of 10 µg/m^3 as an annual mean objective via the Air Quality (Scotland) Amendment Regulations 2016.

The LAQM framework requires that local authorities who identify exceedances of air quality objectives within their geographical area must designate Air Quality Management Areas (AQMAs) and produce an Air Quality Action Plan setting out measures they intend to take to work towards the objectives.

Table 2.1:Air Quality Standards (AQS) for the protection of human health

Pollutant	**Air Quality Standards (µg/m^3)**	**Measured as**
Nitrogen Dioxide	**40**	**Annual Mean**
	200	**One hour mean, not to be exceeded more than 18 times per year (equivalent to the 99.79th percentile of hourly means**

Particulate Matter (PM_{10})	**18**	**Annual Mean**
	50	**24 hour mean, not to be exceeded more than 7 times a year (equivalent to the 98.08th percentile of 24-hour means)**
Particulate Matter ($PM_{2.5}$)	**10**	**Annual Mean**
Sulphur dioxide (SO_2)	**125 µg/m^3 not to be exceeded more than 3 times a year**	**24 hour mean (99th percentile of 24-hour means)**
	350 µg/m^3 not to be exceeded more than 24 times a year	**1 hour mean (99.7th percentile of 24-hour means)**
	266 µg/m^3 not to be exceeded more than 35 times a year	**15 minute mean (99.9th percentile of 24-hour means)**
Carbon monoxide (CO)	**10 mg/m^3**	**Running 8 hour mean**

2.2 Sensitive locations

The locations where objectives apply are defined in the Air Quality Strategy (AQS) as locations outside buildings or other natural or man-made structures above or below ground where members of the public are regularly present and might reasonably be expected to be exposed over the relevant averaging period of the objectives. Typically, these include residential properties, hospitals and schools for the longer averaging periods (i.e. annual mean) pollutant objectives. Table 2.2 provides a summary of where the AQS objectives should and should not apply.

Table 2.2: Examples of where the Air Quality Objectives should and should not apply

Averaging Period	Objectives should apply at …	Objectives should not generally apply at …
Annual mean	**All locations where members of the public might be regularly exposed. Building façades of residential properties, schools, hospitals, care homes etc.**	**Building facades of offices or other places of work where members of the public do not have regular access. Hotels, unless people live there as their permanent residence. Gardens of residential properties. Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.**

Averaging Period	Objectives should apply at …	Objectives should not generally apply at …
8-hour and 24-hour Means	**All locations where the annual mean objective would apply, together with hotels and gardens of residential properties.**	**Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.**
1-hour Mean	**All locations where the annual mean, 24-hour mean and 8-hour mean apply plus: kerbside sites of busy shopping streets; parts of car parks, bus and railway stations, etc. which are not fully enclosed, where members of the public might reasonably be expected to spend one hour or more; Any outdoor locations where members of the public might reasonably be expected to spend one hour or longer.**	**Kerbside sites where the public would not be expected to have regular access.**
15-min mean	**All locations where members of the public might reasonably be exposed for a period of 15 minutes or longer.**	

3 Policy and Guidance

3.1 Local Air Quality Management Policy Guidance

This policy guidance [1] provides guidance to help local authorities with their local air quality management duties in line with the Environment Act 1995. The guidance outlines the background and legislative framework to which the local authorities must work to; the principles behind reviews and assessments of air quality and the recommended steps; how local authorities should handle the designation of AQMAs; the development of local air quality strategies and the general principles behind air quality and land use planning.

3.2 Clean Air Strategy, 2019

Published by Defra This Clean Air Strategy sets out the case for action and demonstrates the commitments to improve our air quality. It highlights that some objective levels are even more ambitious than EU requirements to protect human health and exposure to pollutants. The Clean Air Strategy outlines that air quality is the responsibility of the devolved administrations.

3.3 Cleaner Air for Scotland, 2015

Cleaner Air for Scotland is a cross-government strategy which details how the Scottish Government and any partner organisations propose to reduce air pollution and fulfil Scotland's legal requirements. It provides a national framework which allows the public to better understand how the Scottish Government and associated organisations will achieve these goals. The strategy outlines a range of policies and initiatives which include a National Modelling Framework; a National Low Emission Framework; the adoption of World Health Organisation guideline values for particulate matter in Scottish Legislation, and proposals to raise awareness on national air quality.

3.4 National Air Pollution Control Programme, 2019

The National Air Pollution Control Programme (NAPCP) sets out how the UK can meet the legally binding 2020 and 2030 emission reduction commitments (ERCs). These commitments apply for 5 pollutants:

- nitrogen oxides
- ammonia
- non-methane volatile organic compounds
- particulate matter
- sulphur dioxide

3.5 Grangemouth Air Quality Action Plan, 2007

In 2005 Falkirk Council declared an Air Quality Management Area (AQMA) in response to measured exceedances of the 15-minute SO_2 objective in the areas surrounding the large industrial complex in Grangemouth. Following the declaration of the AQMA, A Further Assessment of SO_2 concentrations in the AQMA was undertaken in 2006-2007. The aim of the Further Assessment was to consider emissions in more detail such that the specific source or sources contributing to the measured exceedances could be identified such that the Action Plan

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[1] Part IV of the Environment Act 1995: Local Air Quality Management Policy Guidance PG(S) (16) March 2016

could be targeted. The Further Assessment included a more detailed inventory of emissions from the principal emission sources.

Based upon the findings of the Further Assessment, Falkirk Council published an Air Quality Action Plan (AQAP) in 2007.

4 Baseline Air Quality

4.1 Monitoring data

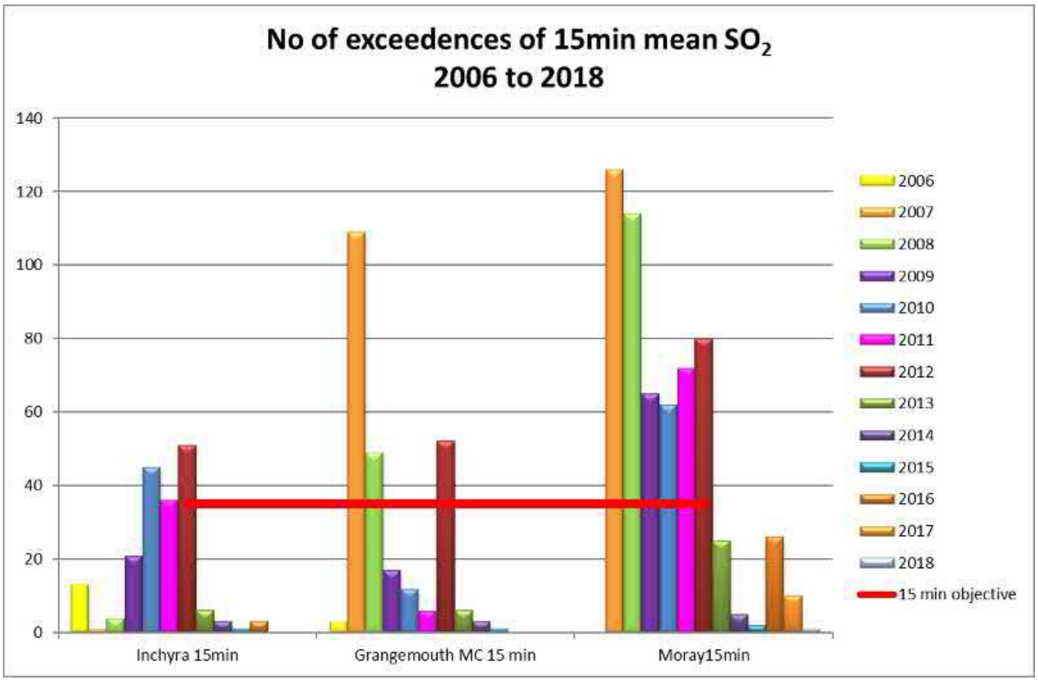
The assessment considers emissions data in 2018 therefore we have used 2018 measurement data to represent the baseline air quality within the modelling assessments.

Falkirk Council undertake monitoring of NO_2, PM_{10}, $PM_{2.5}$ and SO_2 at automatic monitoring sites in Grangemouth. Falkirk Council measures NO_2 using diffusion tubes at several locations in Grangemouth and the surrounding area. Falkirk Council do not undertake any CO monitoring.

4.2 SO_2

The Grangemouth AQMA was declared in 2005 for exceedances of the 15minute mean SO_2 objective. Since the AQMA was decaled the numbers of exceedances have dropped significantly from over 400 at their peak in 2003 to only 1 exceedance at Grangemouth Moray in 2018. A summary of the numbers of exceedances since the AQMA has been in place is shown in Chart 4-1.

Chart 4-1 Numbers of exceedances of 15 min mean SO2 2006 to 2018



The results for 2018 for comparison with all of the SO_2 short term air quality objectives has been provided in Table 4.1.

Table 4.1: SO_2 NUMBER OF EXCEEDANCES 2018

Site ID	Site	X	Y	In AQMA	15 minute objective (266 µg/m^3)	1 hour objective (350 µg/m^3)	24 hour objective (125 µg/m^3)
A8	Grangemouth AURN	293830	681022	Y	0	0	0
A9	Grangemouth Moray	293469	681321	Y	1	0	0
A10	Grangemouth Municipal Chambers	292816	682009	Y	0	0	0
A11	Zetland	292969	681106	Y	0	0	0

4.3 NO_2

Falkirk Council currently measures NO_2 at three automatic monitoring stations and at 5 further locations using diffusion tubes. There are currently no measured exceedances of the annual mean NO_2 objective at any of the sites in Grangemouth. The highest concentration measured in Grangemouth is 31 µg/m^3 measured at site NA94 which is located on the A905.

Due to the extent of the modelling study and for model verification of the road transport component additional monitoring locations out with Grangemouth have also been included these are locations NA21, NA51, NA94 and NA101.

The automatic sites at Grangemouth were deemed unsuitable for model verification as the automatic sites are not roadside locations and therefore not influenced by the road traffic emissions. While the Grangemouth MC is within 20m of Bo’ness Road it is also located within the Councils public carpark. This has meant the site was not suitable for verification as NOx measured at this location would not represent the Road NOx from Bo’ness Road in isolation.

The air quality concentrations measured at Grangemouth over the last 5 years are presented in Table 4.2. The monitoring sites within the study area are presented in Figure 4.1 for automatic sites and Figure 4.2 for diffusion tube monitoring locations.

Table 4.2: NO_2 monitoring results 2014 – 2018 (µg/m^3)

Site ID	Site	X	Y	In AQMA	2014	2015	2016	2017	2018
Automatic Monitoring									
A8	Grangemouth AURN	293830	681022	Y	16	14	16	14	14

Site ID	Site	X	Y	In AQMA	2014	2015	2016	2017	2018
A9	Grangemouth Moray	293469	681321	Y	15	15	18	17	17
A10	Grangemouth Municipal Chambers	292816	682009	Y	19	18	21	17	18
Diffusion Tube Monitoring									
NA3	Tinto Drive, Grangemouth	293427	680386	N	19	20	19	18	18
NA21	Grangemouth Rd, Falkirk College	290112	680500	N	28	28	28	28	28
NA42	Municipal Chambers, Grangemouth	292817	682000	N	19	20	20	17	19
NA51	Mary St, Laurieston	290965	679490	N	25	19	25	22	24
NA57	Inchyra Rd, Grangemouth	294028	680829	N	26	20	23	19	21
NA94	A905 (Glensburgh Rd), Grangemouth	291213	681927	N	31	24	21	30	31
NA101	Glensburgh Rd (2), Grangemouth	291127	682007	N	25	22	21	24	23

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

The Council currently monitors PM_{10} at two locations and $PM_{2.5}$ at only the Grangemouth Inchyra AURN site. Measured concentrations are significantly below the air quality objectives for both PM_{10} and $PM_{2.5}$. Measured concentrations for both PM_{10} and $PM_{2.5}$ for the last 5 years have been provided in Table 4.3 and Table 4.4, respectively.

Table 4.3: PM_{10} Monitoring Results 2014 – 2018 (µg/m^3)

Site ID	Site	X	Y	In AQMA	2014	2015	2016	2017	2018
Automatic Monitoring									
A8	Grangemouth AURN	293830	681022	Y	12	12	11	9	12
A10	Grangemouth Municipal Chambers	292816	682009	Y	15	13	13	12	12

*rounded to nearest whole number

Table 4.4: $PM_{2.5}$ Monitoring Results 2014 – 2018 (µg/m3)

Site ID	Site	X	Y	In AQMA	2014	2015	2016	2017	2018
Automatic Monitoring									
A8	Grangemouth AURN	293830	681022	Y	8	9	6	6	7
*rounded to nearest whole number									

4.5 Background Maps

The Scottish air quality background map[2] were used to assess current background concentrations of NOx, NO_2 and PM_{10} in the study area. The background map for $PM_{2.5}$ was downloaded from the Defra background maps [3]. Historic (2001) background annual mean CO and SO_2 concentrations were downloaded from the available background information from Defra[4]. This resource provides estimated annual mean background concentrations of key pollutants at a resolution of 1x1km for the UK. Mapped background concentrations from the grid squares within the study area for 2018 are provided in Table 4.5, these have been adjusted to remove the road traffic component and the industrial emissions component that are being explicitly modelled.

[2] http://www.scottishairquality.scot/data/mapping?view=data

[3] 2017 Defra background maps, Available at: https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2017

[4] 2001 Defra background maps, Available at: https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2001

Table 4.5 Adjusted annual mean background concentrations 2018 (μg/m³)

2018 Grid Square	NOx	PM_{10}	$PM_{2.5}$	SO_2	CO
286500, 684500	15.4	12.2	6.8	6.8	2.4
288500, 677500	9.1	9.5	6.4	5.6	2.5
288500, 6835000	15.4	10.3	10.6	6.1	4.2
289500, 680500	17	10.2	6.1	6.1	3.9
290500, 679500	14.5	9.6	5.9	5.9	3.4
290500, 680500	15.1	11.2	6.4	6.4	3.8
291500, 679500	13.9	10.4	6.2	6.2	4.4
291500, 680500	17.4	11.8	6.6	6.7	3.6
291500, 681500	22.6	12.1	6.8	6.8	4.0
291500, 682500	16.9	11.5	6.4	6.4	5.0
292500, 679500	15.3	10.9	6.4	6.5	4.8
292500, 680500	17.8	10.6	6.4	6.4	4.9
292500, 681500	17.7	10.7	6.3	6.3	5.3
292500, 682500	15.1	10.9	6.4	6.4	8.7
293500, 678500	16.6	10.5	6.1	6.1	5.1
293500, 679500	21.7	11.6	6.6	6.7	4.5
293500, 680500	16.3	10.9	6.4	6.4	5.4
293500, 681500	19.4	10.5	6.4	6.5	5.7
293500, 682500	14.2	9.8	6	6.0	5.7
294500, 678500	19.2	11.2	6.3	6.4	3.8
294500, 679500	16.1	10.6	6.1	6.1	3.7
294500, 680500	17.5	10.8	6.4	6.4	4.1
294500, 681500	18.2	12.6	7.6	7.6	5.2

5 Methodology

5.1 Dispersion modelling methodology

Dispersion models, which are used to predict ground level pollutant concentrations.

The dispersion models used in this assessment were the most up-to-date version of the model, ADMS-Roads Extra (ADMS ROADS 5.0), was used for the assessment of road traffic emissions Modelling of industrial sources was undertaken in ADMS 5.2.

While ADMS ROADS EXTRA can model point sources simultaneously with road traffic sources it doesn't have some of the functionality of ADMS. Due to the complexity of the industrial points sources being modelled and the need to use additional input files the industrial emissions were modelled separately. Full details of this is discussed in the following sections.

5.1.1 Mapping

The mapping data used within the assessment is mastermap data provided by Falkirk Council. This enabled accurate OS x,y grid references to be obtained for the industrial installation locations and for receptor locations to be accurately identified. All maps within this report contain Ordnance Survey data © Crown copyright and database right 2019.

5.1.2 Meteorological data

Typically, when undertaking an assessment of industrial emissions to obtain the worst case impact you would assess 3 to 5 years of meteorological data. While we did undertake a meteorological sensitivity, the purpose of this assessment is to determine what the pollutant concentrations across Grangemouth were in based on 2018 emissions to provide a total pollutant concentration for all sources in 2018. Therefore only 2018 hourly sequential meteorological data measured at the Edinburgh Gogarbank site was used for the final model predictions.

Previous modelling has shown that the meteorological data has many hours which can be classified as calm and under these conditions ground level concentrations can be greater. Therefore, the Calms module within ADMS was utilised in the modelling of the industrial emissions.

The 2018 wind rose for Gogarbank is presented in Chart 5-1.

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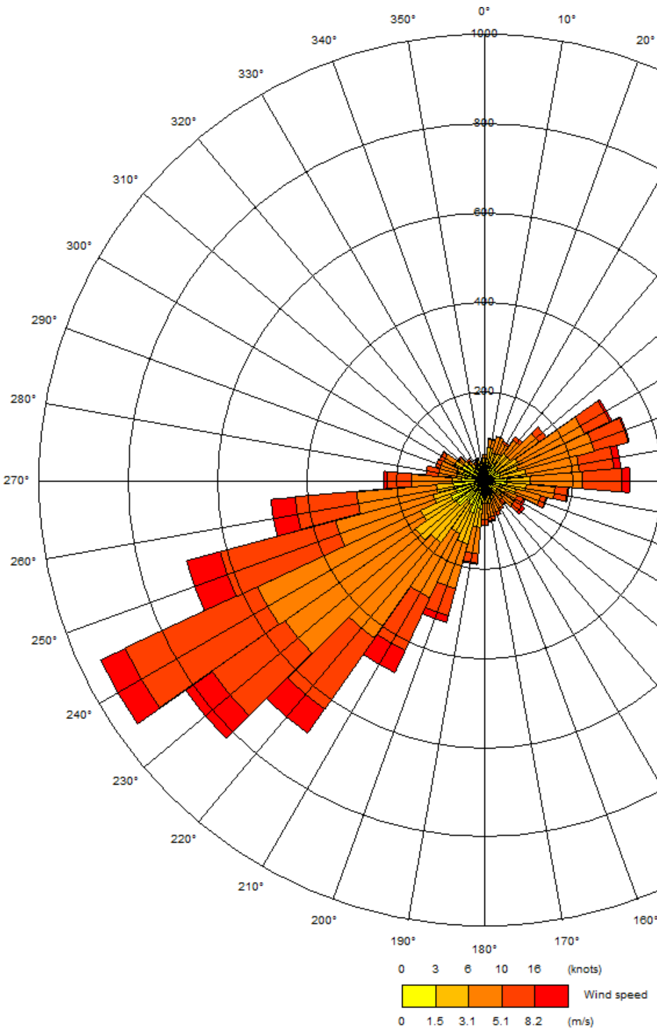
Chart 5-1 2018 Edinburgh Gogarbank meteorological data



5.1.3 Surface roughness and meteorological parameters

A surface roughness of 1m was used to represent the dispersion site within the road traffic model to represent the mixed suburban area. The minimum Monin-Obukhov length (m) was set to 30m, which is representative of mixed urban/industrial.

Due to the complexity of the industrial sites which includes large numbers of buildings and structures it's not possible to include all of these explicitly in the model but they will have an influence on the dispersion as shown in previous modelling assessment of the area. Therefore, a surface roughness of 1.5m was used to represent the dispersion site within the industrial model, due to the built-up nature of the industrial sites within Grangemouth This has been accepted method in previous modelling assessments of the AQMA.

The minimum Monin-Obukhov length (m) was set to 30m, which is representative of mixed urban/industrial.

At the meteorological site, a surface roughness of 0.02m was used to represent the Edinburgh Gogarbank metrological site. The minimum Monin-Obukhov length (m) was set to 10m.

5.1.4 Terrain

Previous studies have shown that gradient is a key consideration in the assessment of the industrial emissions within the Grangemouth AQMA, Therefore, a terrain file was included in the model.

5.1.5 Model domain and receptor locations

The model has been used to predict pollutant concentrations at a number of specified receptors and across a modelled grid. The modelled grid was set at a resolution of 30m.

The model has been used to predict annual mean concentrations of NO_2, PM_{10} and $PM_{2.5}$ at a selection of sensitive receptors within the study area. The receptors are located at the façade of buildings in the model domain where relevant exposure exists. While CO and SO_2 are assessed against the short term objectives it was felt that these receptors were still representative.

The receptors have been modelled at 1.5 m to represent human exposure at ground floor level. The receptors modelled and the model domain are presented in Table 5.1 and Figure 5.1.

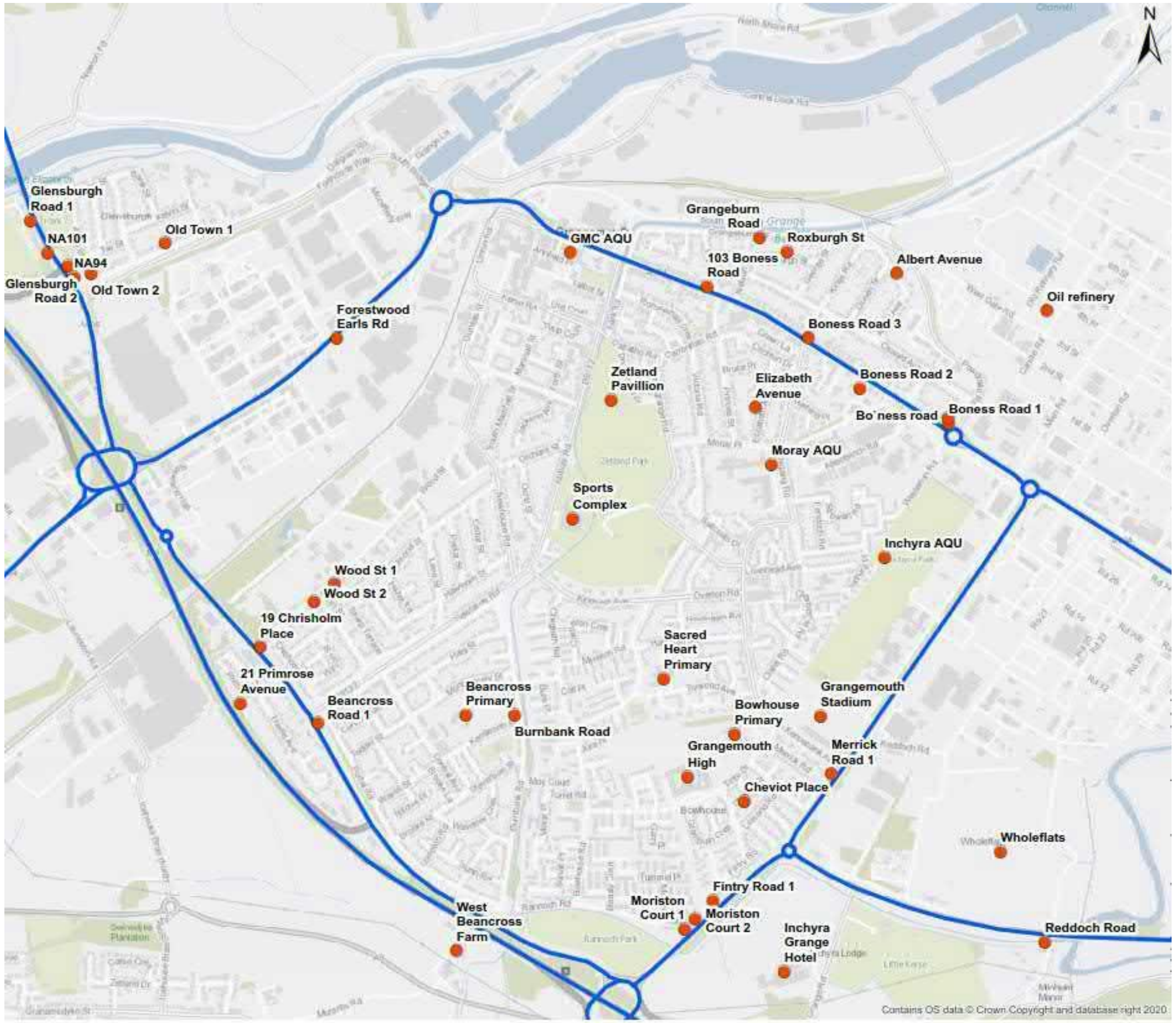
Table 5.1: Receptor Locations

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
Boness Road 1	294042.3	681455.6	1.5	Residential
Boness Road 2	293755	681567.9	1.5	Residential
Boness Road 3	293587.6	681732.1	1.5	Residential
103 Boness Road	293260.9	681895.7	1.5	Residential
Forestwood Earls Rd	292062.4	681729.9	1.5	Residential

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

Receptor	X	Y	Height (m)	Description
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	-
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

Figure 5.1: Receptor Locations Grangemouth



6 Road Traffic Assessment

6.1 Traffic data

Falkirk Council undertake automatic traffic counts (ATC) at a number of road side locations around the Council area on an annual basis. Traffic data were provided in the form of Annual Average Daily Traffic (AADT) flows, which were derived from their ATC count data provided by Falkirk Council representing 2018. Where ATC data were unavailable, traffic data were supplemented with Department for Transport (DfT) traffic data for 2018.

Each road link included in the model also included a detailed fleet split namely: motorcycles; cars, LGV; HGV and buses.

Full details of the traffic data used within the assessment is presented in Table 6.1.

Traffic patterns in urban locations are complex and it is not possible to fully represent the complexities in atmospheric dispersion models. As 24 hour time varying traffic flow data were not available a degree of uncertainty is introduced in the modelling as it uses simple metrics (AADT, average speed and vehicle split composition) to describe the complex traffic patterns. However, any uncertainty in the emissions is modelling assumptions is reduced in the model verification and adjustment process. This is described in detail in Appendix A.

Furthermore, speed data has been estimated from google maps traffic layer, adding uncertainty to the modelled vehicle speeds.

Table 6.1: Traffic Data used within Assessment

Road	AADT Baseline 2018	Source	%Mcycle	%Car	%LGV	% HGV	%Bus
A905 Skinflats	13738	DfT 10965	0.8	82.2	0.6	16.3	0.1
A905 Glenburgh	12565	Glensburgh Road ATC	2.4	82.1	1.1	12.3	2.1
A904 Earls Road	10141	Earls Road ATC	1.1	77.4	0.8	17.5	3.2
Station Road	10174	DfT 80189	0.4	72.4	1.8	25.3	0.1
A904 Boness Road	10,176	DfT 10964	0.4	72.4	1.8	25.3	0.1
Inchyra Road	18302	Inchyra Road ATC	1.9	82.3	0.7	14.0	1.1
Beancross Road	13097	Beancross Road ATC	0	85.1	0.8	13.0	1.1
A904 Falkirk Road	26703	DfT 74405	0.2	78.3	1.0	16.9	3.6
Wholeflats Road	13990	Wholeflats Road ATC	8.7	83.0	0.6	6.9	0.7
A803 Polmont	7898	DfT 78580	0.2	85.1	1.8	12.8	0.1
M9	Between 38423-67336	DfT various	0.2	75.6	0.3	18.7	5.3
A904 Boness Road	10114	DfT 40965	0.5	70.8	0.3	24.1	4.3
A904 Falkirk Road	17416	DfT 80353	0.6	83.6	2.1	13.5	0.2

6.2 Vehicle emission factors

The latest version of the Emissions Factors Toolkit (EFT V9.0 May 2019 release) was used in this assessment to calculate pollutant emission factors for each road link modelled. The emissions were calculated in the ADMS-Roads 5.0 model, which has EFT V9.0 built into the model.

Parameters such as traffic volume, speed and fleet composition were entered into ADMS, and an emissions factor in grams of pollutant/kilometre/second was generated for use in the dispersion model. In the latest version of the EFT, NOx and PM emission factors are taken from the European Environment Agency (EEA) COPERT 5 emission calculation tool. These emissions factors are widely used for calculating emissions from road traffic in Europe. Defra recognise these as the current official emission factors for road traffic sources when conducting local, regional and national scale dispersion modelling assessments.

The latest version of the EFT also includes addition of road abrasion emission factors for particulate matter; and changes to composition of the vehicle fleet in terms of the proportion of vehicle km travelled by each Euro standard, technology mix, vehicle size and vehicle category. Much of the supporting data in the EFT is provided by the Department for Transport (DfT), Highways Agency and Transport Scotland.

Vehicle emission projections are based largely on the assumption that emissions from the fleet will fall as newer vehicles are introduced at a renewal rate forecast by the DfT. Any inaccuracy in the projections or the COPERT 5 emissions factors contained in the EFT will be unavoidably carried forward into this modelling assessment.

6.3 Treatment of modelled NO_x road contribution

It is necessary to convert the modelled NO_x concentrations to NO_2 for comparison with the relevant objectives.

The Defra NO_x/NO_2 model was used to calculate NO_2 concentrations from the NO_x concentrations predicted by ADMS-Roads. The model requires input of the background NOx, the modelled road contribution and accounts for the proportion of NO_x released as primary NO_2. For Falkirk in 2018 with the “All Other urban UK Traffic” option in the model, the NO_x/NO_2 model estimates that 27.9% of NO_x is released as primary NO_2.

6.4 Validation of ADMS-Roads Extra

Validation of the model is the process by which the model outputs are tested against monitoring results at a range of locations and the model is judged to be suitable for use in specific applications; this is usually conducted by the model developer.

CERC have carried out extensive validation of ADMS applications by comparing modelled results with standard field, laboratory and numerical data sets, participating in EU workshops on short range dispersion models, comparing data between UK M4 and M25 motorway field monitoring data, carrying out inter-comparison studies alongside other modelling solutions such as DMRB and CALINE4, and carrying out comparison studies with monitoring data collected in cities throughout the UK using the extensive number of studies carried out on behalf of local authorities and Defra.

7 Industrial Emissions Assessment

At the time of commissioning this package of work 2017 emissions data were to be used for both studies. However, while the 2017 emissions inventory was being built and the models developed, new industrial emissions data were provided by SEPA for 2018. These data showed that emissions had reduced during 2018 due to new permits and BAT. Therefore, the Council and SEPA agreed that an updated 2018 emission inventory be built for both the industrial emissions and road traffic emissions.

An initial screening of the industrial facilities which operate and are permitted within the Grangemouth AQMA was undertaken in collaboration with the Council and SEPA to determine which sites should be taken forward into the study to identify a number of permitted sites. SEPA provided access to their reporting portal[5] which is used by each site to provide annual reporting requirements.

The next stage was to use the emissions inventory to build a dispersion model of all of the point sources identified for each site. For each point source we required all efflux parameters for each stack to allow them to be included in the model and operating in 2018.

While there were a number of point sources identified which did have the key pollutant emissions reported there were no efflux stack parameters reported and therefore these sources could not be modelled at this time.

Based on the information within the SEPA reporting portal we were able to model sources for the following sites which were in operation during 2018:

- Ineos
- Veolia Calachem
- Engie
- Ineos Chemicals

7.1 Operator emissions

SEPA also provided Sweco with a copy of a modelling study undertaken by Golder Associates which had a full breakdown of all of the SO_2 emitting sources assessed as part of the Tail Gas treatment feasibility. These data were used to supplement the data available on the SEPA reporting portal, namely exit temperature and exact stack grid references. The pollutant sources and emissions reported for 2018 are presented in Table 7.1 for Ineos, Table 7.2 for Calachem and Table 7.3 for Engie.

7.1.1.1 Operating Scenarios

The emissions data available from the online web portal, is based upon annual emissions and emissions data gathered as part of stack testing reports. This will be worst case as under stack testing the emissions are at 100% load. It is unlikely that all sources for all sites would run at 100% load for 8760 hours per annum and simultaneously. SEPA were also consulted and advised that annual average hourly emissions rate should be used given the numbers of points sources for this study rather than obtaining time varying hourly emissions data.

[5] https://beta.sepa.org.uk/publicregister/

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Whilst using reported 2018 emissions instead of 2017 presents a more current and up to date reflection of emissions across Grangemouth, the uncertainty of the operating hours is a limitation of the study. Therefore, the assessment is worst case in this aspect.

Table 7.1: Stack Exit Parameters INEOS

Source	X	Y	Stack Height from Ground (m)	Stack Internal Diameter (m)	Exit Temperature (ºC)	Exit Vol Flow (m^3/s)	NO_x (g/s)	PM_{10} (g/s)	SO_2 (g/s)	CO (g/s)
Ineos Boiler 8	294561	681217	65	2.7	136	17.8	2.395	0.004	0.010	0.058
Ineos Boiler 9	294634	681158	91	3.08	162	16.8	4.110	0.013	0.055	0.015
Ineos Boiler 10	294634	681158	91	3.08	166	18.7	4.193	0.025	0.769	0.121
Ineos Boiler 14 east duct	294725	681117	91	2.4	195	29.0	6.397	0.142	3.346	0.015
Ineos Boiler 14 West duct	294725	681117	91	2.4	200	29.1	6.551	0.166	4.562	0.019
Ineos Boiler 15 East duct	294725	681117	91	2.4	195	34.7	10.438	0.136	2.977	0.009
Ineos Boiler 15 West duct	294725	681117	91	2.4	191	30.9	7.747	0.156	3.304	0.024
Inoes CHP, g/s and Vol.flow used and set as NTP	294449	681130	65	5.3	105	352.4	11.100	0.003	1.100	0.300
CDU3/DHT combined (BA-101 & BA-301)	294854	681832	79	3.7	263	28.4	11.859	0.539	25.273	0.761
CRU Main Heater & WHB common stack	294871	681660	95.7	2.7	339	21.0	2.709	0.011	2.457	0.126
CRU 1st Interheater Unit (B-109)	294917	681731	67.5	2.4	190	11.7	1.461	0.006	1.315	0.025
No.1 CDU B1 Heater	294547	681945	42.3	1.37	485	14.0	5.454	0.285	15.094	-
No.1 CDU B1A Heater	294547	681945	56.4	1.58	406	6.4	2.061	0.095	1.205	-
No.2 CDU/No.2 DHT (combined)	294628	681824	61	3.38	379	1.5	0.296	-	0.800	0.012

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Source	X	Y	Stack Height from Ground (m)	Stack Internal Diameter (m)	Exit Temperature (ºC)	Exit Vol Flow (m^3/s)	NO_x (g/s)	PM_{10} (g/s)	SO_2 (g/s)	CO (g/s)
Hydrofiner combined heater & stripper boilers	294506	681798	80	1.35	340	3.7	1.617	-	0.602	-
EPFCCU1= FCCU regenerator	294639	681981	70	1.32	220	33.0	14.751	1.643	44.319	0.132
EPHYDX1= S-601 No.2 VDU and HCU heaters (combined)	294619	681378	85	3.5	300	28.8	13.699	0.539	20.865	-
EPHCU2= Mild Vacuum Column Reboiler (Stack H-370)	294779	681373	70	1.5	390	5.7	1.871	0.063	0.698	-
EPHYD2= Hydrogen plan heater (Stack S-602)	294718	681450	84	4.19	230	29.6	10.147	0.317	3.678	-
EPSRU1= H-50704 Sulphur Recovery Unit 5	294795	681535	70	0.91	800	3.6	-	-	0.571	-
EPSRU3= H-60704 Sulphur Recovery Unit 6	294750	681610	70	0.91	800	3.6	-	-	4.630	-
KG4A= KG Furnace 36-F-1A	294924	680223	33.30	1.62	194	14.1	0.961	-	0.002	-
KG4B= KG Furnace 36-F-1B	294927	680209	33.30	1.62	207	14.5	0.894	-	0.002	-
KG4C= KG Furnace 36-F-1C	294929	680195	33.30	1.62	184	13.8	0.717	-	0.001	-
KG4D=KG Furnace 36-F-1D	294931	680180	33.30	1.62	191	14.0	0.961	-	0002	-
KG4E=KG Furnace 36-F-1E	294934	680166	33.30	1.62	205	13.7	1.126	-	0.002	-
KG4F= KG Furnace 36-F-1F	294936	680152	33.30	1.62	171	13.9	0.682	-	0.001	-
KG4G= KGXX Furnace 36-F-1G	294953	680053	33.30	1.62	154	12.3	0.815	-	0.001	-

Source	X	Y	Stack Height from Ground (m)	Stack Internal Diameter (m)	Exit Temperature (ºC)	Exit Vol Flow (m^3/s)	NO_x (g/s)	PM_{10} (g/s)	SO_2 (g/s)	CO (g/s)
KG4H= KGXX Furnace 36-F-1H	294955	680039	33.30	1.62	169	12.7	0.866	-	0.002	-
KG4J=KGXX Furnace 36-F-1J	294958	680025	33.30	1.62	163	12.5	1.012	-	0.002	-
KG6A=Steam Boiler 36-F-501A	294914	680265	30	1.73	114	16.4	2.531	0.004	0.002	-
KG6B=Steam Boiler 36-F-501B	294916	680251	30	1.73	114	16.4	2.427	0.004	-	-

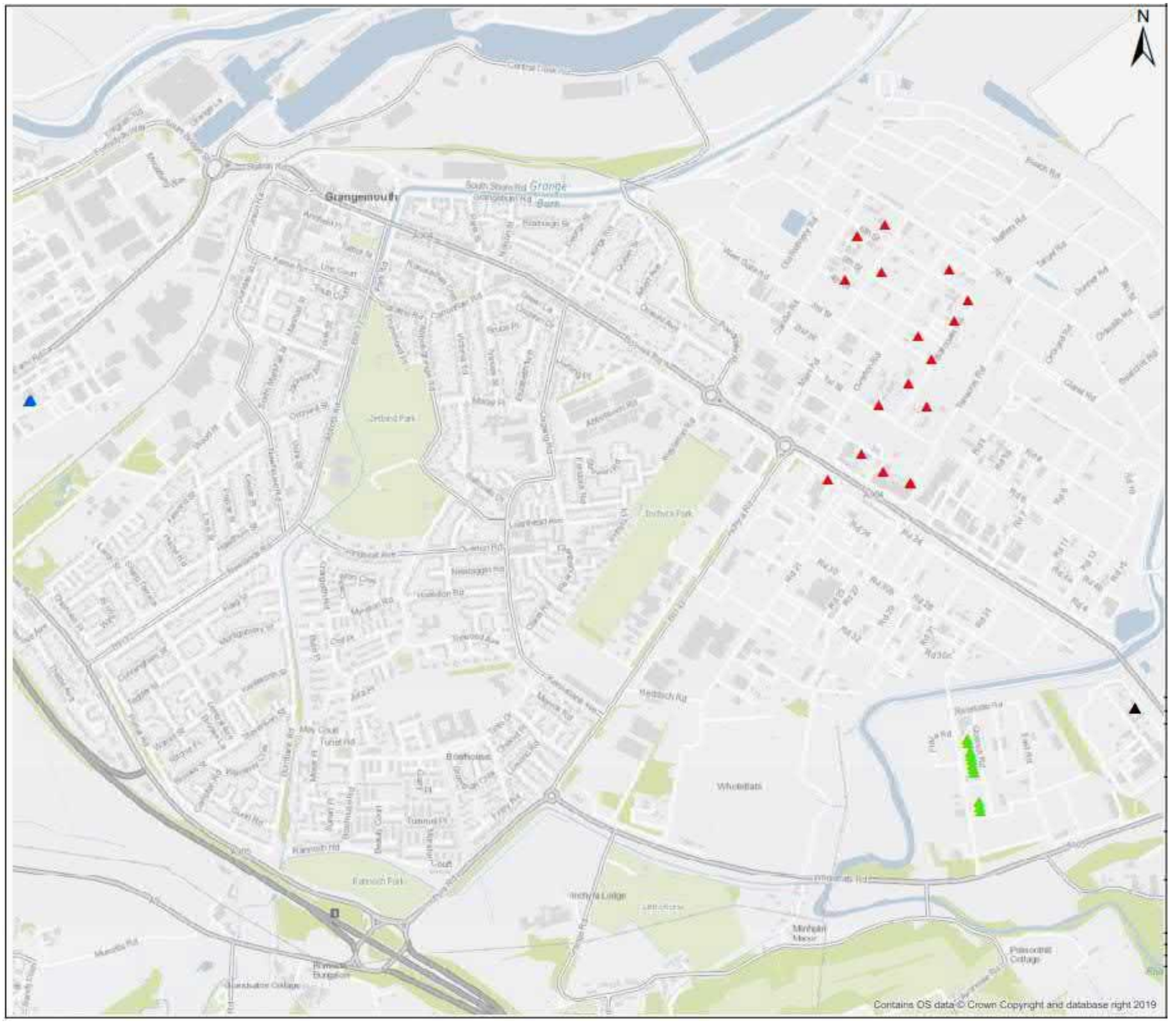
Table 7.2: Stack Exit Parameters Calachem

Source	X	Y	Stack Height from Ground (m)	Stack Internal Diameter (m)	Exit Temperature (ºC)	Exit Vol Flow (m^3/s)	NO_x (g/s)	PM_{10} (g/s)	SO_2 (g/s)	CO (g/s)
Calachem Boiler BB02	291780	681392	40	1.3	189	1.4	0.193	-	0.034	-
Calachem Boiler BB03	291780	681392	40	1.3	156	0.9	0.073	-	0.004	0.002
Calachem Boiler BB05	291786.9	681397	40	1.0	131	2.6	0.296	-	0.040	0.001

Table 7.3: Stack Exit Parameters ENGIE

Source	X	Y	Stack Height from Ground (m)	Stack Internal Diameter (m)	Exit Temperature (ºC)	Exit Vol Flow (m^3/s)	NO_x (g/s)	PM_{10} (g/s)	SO_2 (g/s)	CO (g/s)
Engie Cochrane Boiler	295473.7	680367.8	37.8	1.1	153	2.5	0.189	0.001	0.002	0.019
Engie Nebraska 1	295473.7	680367.8	37.8	1.1	153	4.9	0.654	0.009	0.016	0.017
Engie Nebraska 2	295473.7	680367.8	37.8	1.1	158	5.2	0.642	0.001	0.007	0.033

Figure 7.1 Stack Locations



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7.1.2 Building parameters

Nearby buildings (within five flue heights) can have a significant effect on the dispersion characteristics of a flue plume. The main effect can be to increase concentrations in the immediate vicinity of the building, while reducing concentrations further away. Due to the scale of the modelling assessment and the number of industrial sources modelled, buildings were not added to the model. This was dealt with the higher surface roughness discussed in chapter 5.

7.1.3 NOx to NO_2

As worst case and we have assumed that 100% of NOx has been converted to NO_2 for comparison with the annual mean NO_2 objective.

7.1.4 Addition of process contributions

To assess the impact of emissions on local air quality, modelled concentrations are required to be added to the background concentrations. For long term concentrations the background concentration (BG) is added to the modelled process contribution (PC) to provide the predicted environmental concentration (PEC).

For short term concentrations, double the background concentration (BG) is required to be added to the modelled process contribution (PC) to provide the predicted environmental concentration (PEC).

8 Road traffic emissions results

8.1 Model verification

Model verification is the comparison of modelled results with available local monitoring data. This identifies how well the model is performing. LAQM.TG (16) recommends making the adjustment to the road contribution of the pollutant only. The model is refined as part of the verification process to reduce uncertainties within the modelling.

For this assessment, diffusion tube monitoring sites located within the study area were used for model verification. The modelling results were verified against modelling locations NA21, NA51, NA57 and NA94 and NA101.

8.2 NO_2 verification

The modelled NOx concentrations were verified against monitoring locations NA21, NA51, NA57, NA94 and NA101. Following refinements of the model, the modelled road contribution required an adjustment factor of 1.6304 to bring the predicted Road NOx concentrations in line with the measured Road NOx concentrations at diffusion tube locations NA21, NA51, NA57, NA94 and NA101. The adjustment factor was applied to all modelled road NOx concentrations. Following adjustment, the road NOx was then input into the Defra NOx to NO_2 calculator. A summary of the model pre and post adjustment annual mean NO_2 concentrations are outlined in Table 8.1 below.

Model uncertainty can be estimated by calculating the root mean square error (RMSE). The RSME was 3.2 µg/m^3.

Verifying modelling data with diffusion tube data will always be subject to uncertainty due to the limitations in diffusion tube monitoring data, even automatic data has some uncertainties. The model results should be considered in this context. Further information on the verification process including the linear regression analysis are available in **Appendix A.**

Table 8.1: Modelled vs measured annual mean NO_2 concentrations 2018

Measuring Location	Measured (µg/m^3)	Modelled (µg/m^3)
	Pre-Adjustment	
NA21	28	19.8
NA51	24	19.8
NA57	21	20.7
NA94	31	22.9
NA101	23	16.7
	Post-Adjustment	
NA21	28	25.6
NA51	24	25.8

NA57	21	26.2
NA94	31	28.1
NA101	23	20.2

8.3 PM verification

There were no roadside monitoring sites which measured PM_{10} that could be used to verify the modelled Road PM_{10} concentrations. LAQM.TG (16) states that in the absence of any PM_{10} data for verification, it is appropriate to apply the road-NOx adjustment to the modelled road-PM_{10}. Therefore, an adjustment factor of 1.6304 was applied to all modelled PM_{10} and $PM_{2.5}$ concentrations.

8.4 Adjusted Modelling Results

Adjusted annual mean concentrations at the specified receptors from the road traffic modelling are discussed within this section. Full details of all predicted pollutant concentrations are provided in **Appendix B**.

The road traffic results are discussed separately from the industrial results before both are combined together.

8.4.1 NO_2 modelling results

No annual mean NO_2 concentrations in excess of the 40 µg/m^3 air quality objective were predicted across the study area.

The highest modelled concentration from the road traffic modelling was 26 µg/m^3 at Glensburgh Road.

Although all annual mean concentrations were below the objective, The study identified the following areas with the highest concentrations, although still well below the air quality objectives:

- Glensburgh Road
- Beancross Road
- Bo’ness Road

8.5 PM_{10} modelling results

No annual mean PM_{10} concentrations in excess of the 18 µg/m^3 air quality objective are predicted at any locations in the study area. The highest modelled concentration from the road traffic modelling was 15 µg/m^3 at Primrose Avenue, which borders the M9.

8.6 $PM_{2.5}$ modelling results

Scotland has an annual mean objective set for $PM_{2.5}$ of 10 µg/m^3. The highest modelled $PM_{2.5}$ concentration in 2018 was 8.4 µg/m^3 Bo’ness Road.

9 Industrial emissions/ combined modelling results

Modelling of the identified point sources was undertaken for 2018 based upon the annual reported emissions for 2018.

The concentrations predicted by the model is known as the process contribution (PC). However, to compare the predicted concentrations with their respective objective the background concentrations are added to provide the predicted environmental concentrations (PEC). As we have explicitly modelled a number of road sources as part of this package of work the Background concentrations are added in accordance with the steps outlined in Section 4.3.

9.1 NO_2

The model has predicted the NOx concentration at ground level across a number of specified receptors. This has been as worst case been assumed to be 100%NO2. This has been added to the ROAD NO2 and the adjusted background concentrations as presented in Table 4.5. The NO_2 annual mean concentrations at all specified receptor locations are below the annual mean objective of 40 µg/m^3.

The 99.8 percentile of 1-hour concentrations are also significantly below the 200 µg/m^3 1-hour objective at all receptors within the study area. The highest 1 hour concentration was at the Inchyra automatic monitoring site. Full details are presented in Appendix B.

9.2 PM

The dispersion model has predicted 24 hour mean and annual mean PM_{10} concentrations at all receptors. The predicted PM_{10} concentrations across all receptors are predicted to be below the both the annual mean and 24 hour mean objective levels.

$PM_{2.5}$ annual mean concentrations are below the Scottish annual mean objective for $PM_{2.5}$ of 10 µg/m^3. Full details are presented in Appendix B.

9.3 SO_2

9.3.1 15min objective

The dispersion model has predicted 15min mean concentrations across all receptors. The results have indicated that while no location breeched the 15 min objective of 35 exceedances per year the modelling did show that the objective would be exceeded at multiple locations. A summary of the locations where the maximum15 min mean was over 266 µg/m^3 is provided in Table 9.1.

Table 9.1 Results of 15 min SO_2 concentrations

Receptor Name	Max 15 min mean	99.9%ile 15 min mean	No of predicted exceedances
Bo`ness road	400	189	18
Inchyra AQU	398	201	9
Boness Road 1	392	183	18
Boness Road 2	391	201	28

Receptor Name	Max 15 min mean	99.9%ile 15 min mean	No of predicted exceedances
Elizabeth Avenue	370	201	14
Moray AQU	341	231	18
Reddoch Road	335	151	5
Wholeflats	332	154	5
Grangemouth Stadium	328	140	5
Boness Road 3	317	153	5
Docks West	303	128	5
Oil refinery	302	254	14
Docks East	302	128	5
Bowhouse Primary	284	129	5
Merrick Road 1	271	132	0

The results indicate that based on the emissions data included in the model that the AQMA should stay in place. While the results indicate that there wasn't a breach of the objective, the numbers of exceedances and the numbers of locations where there are exceedances is still significant.

The results indicate that locations on Bo'ness Road may be experiencing higher concentrations than those currently measured at Moray air quality monitoring unit.

The overestimation in numbers of exceedances may be due to the conservative approach in the assessment. Emissions data are based on stack testing which would be done at 100% load and all sources operating at this simultaneously. It also assumes that these emissions are continuous for the full year (8760 hours). Full details are presented in Appendix B.

9.3.2 1 hour mean SO_2

The dispersion model has predicted 1 hour mean concentrations across all receptors. The results have indicated that while these 3 locations have predicted an exceedance of the 1 hour mean, 350 µg/m^3 only 1 exceedance was predicted. Full details are presented in Appendix B.

Table 9.2: Results of 1 hour SO_2 concentrations

Receptor Name	Max 1 hour mean	99.73%ile 1 hour mean	No of predicted exceedances
Bo`ness road	375	146	1

Receptor Name	Max 1 hour mean	99.73%ile 1 hour mean	No of predicted exceedances
Boness Road 1	370	144	1
Inchyra AQU	363	120	1

9.3.3 24 hour mean

The model has predicted 24 hour mean concentrations across all specified receptors. The results indicate that there would be no exceedances of the 24 hour mean at any location. Full details are presented in **Appendix B.**

9.4 CO

The model has predicted 8 hour running mean for all receptors the results show that predicted concentrations are significantly below this air quality standard. Full details are presented in **Appendix B.**

10 Source Apportionment

The study has predicted air pollutant concentrations within Grangemouth for all sources included within the assessment. Source apportionment has been undertaken to determine which sources have the greatest contribution to annual mean concentrations of NOx and PM_{10} within Grangemouth. The source apportionment has considered the different vehicle classes for road traffic sources and the different industrial facilities included in the modelling.

10.1 Road traffic source apportionment

The road traffic source apportionment has considered the contribution from background concentrations, cars, LGV, HGV and buses which have contributed to the modelled concentrations within the assessment. The source apportionment has identified the variation in sources across the study area. The results for NOx and PM_{10} are presented below in Chart 10-1to Chart 10-3

10.1.1 NOx source apportionment

Background concentrations accounted for between 30%-40% of concentrations close to the main traffic routes within Grangemouth such as Glensburgh Road, Bo’ness Road and Beancross Road.

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Chart 10-1 NOx contribution by location

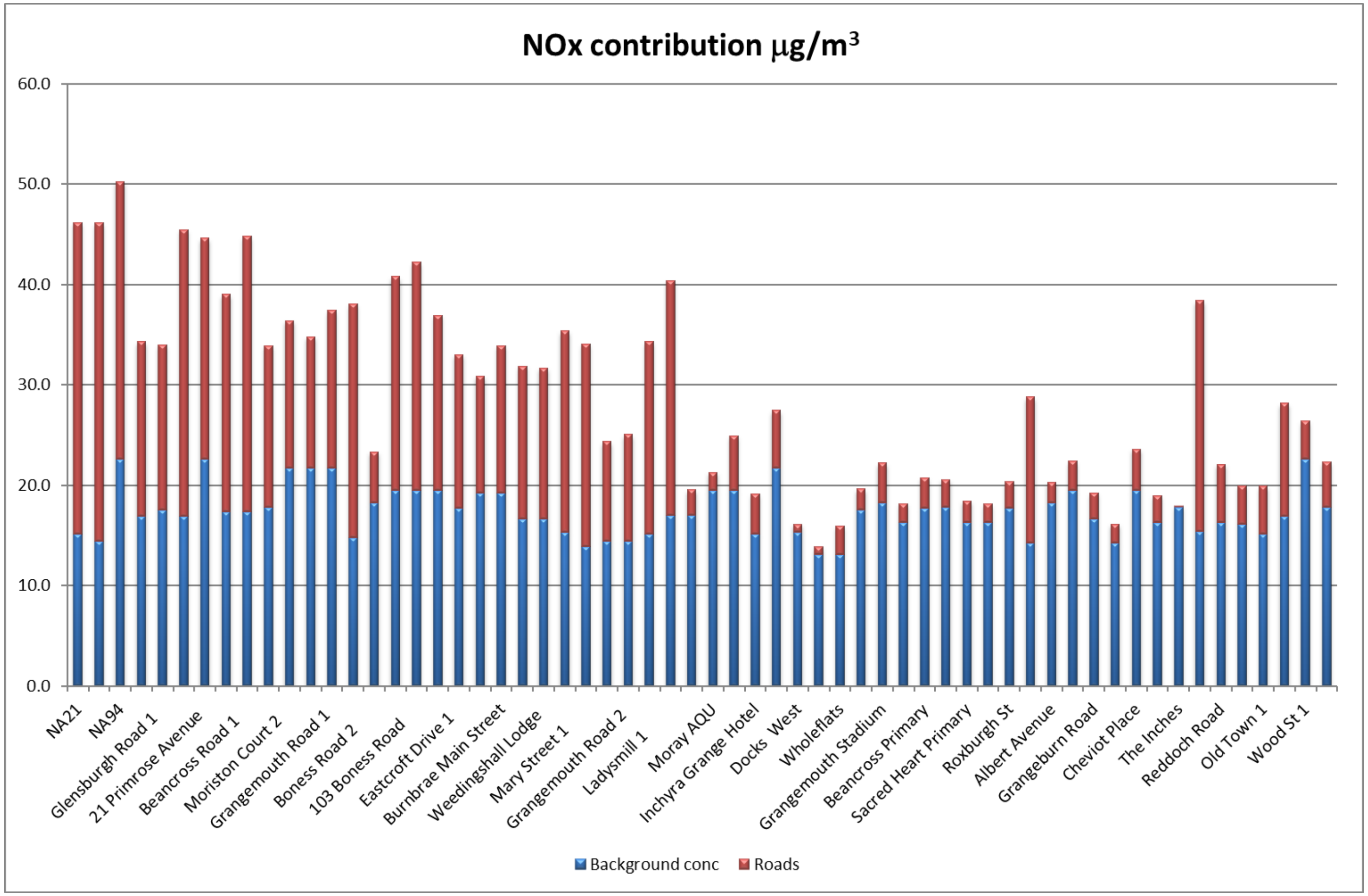

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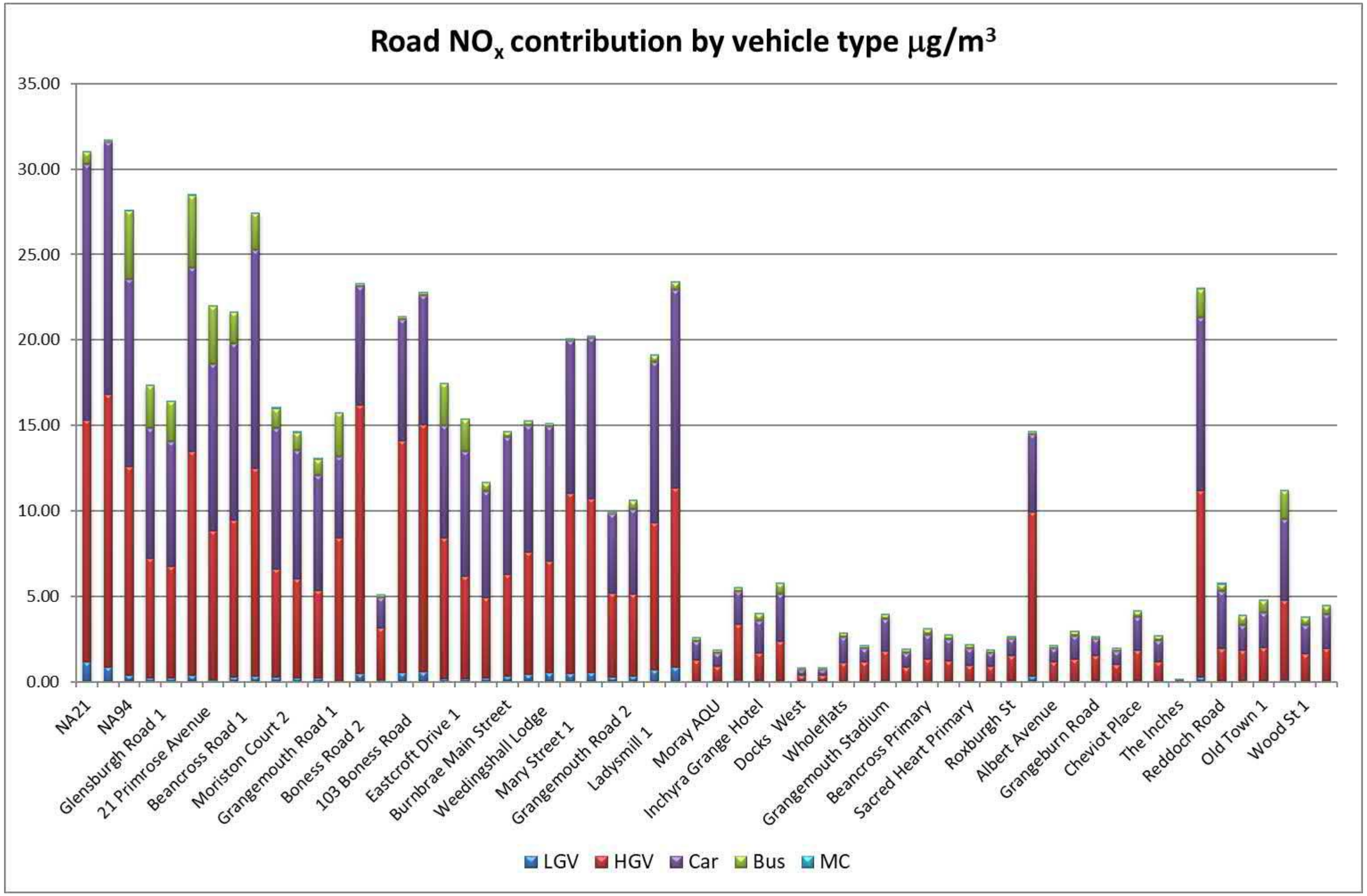
Chart 10-2 Road NOx analysis by vehicle type



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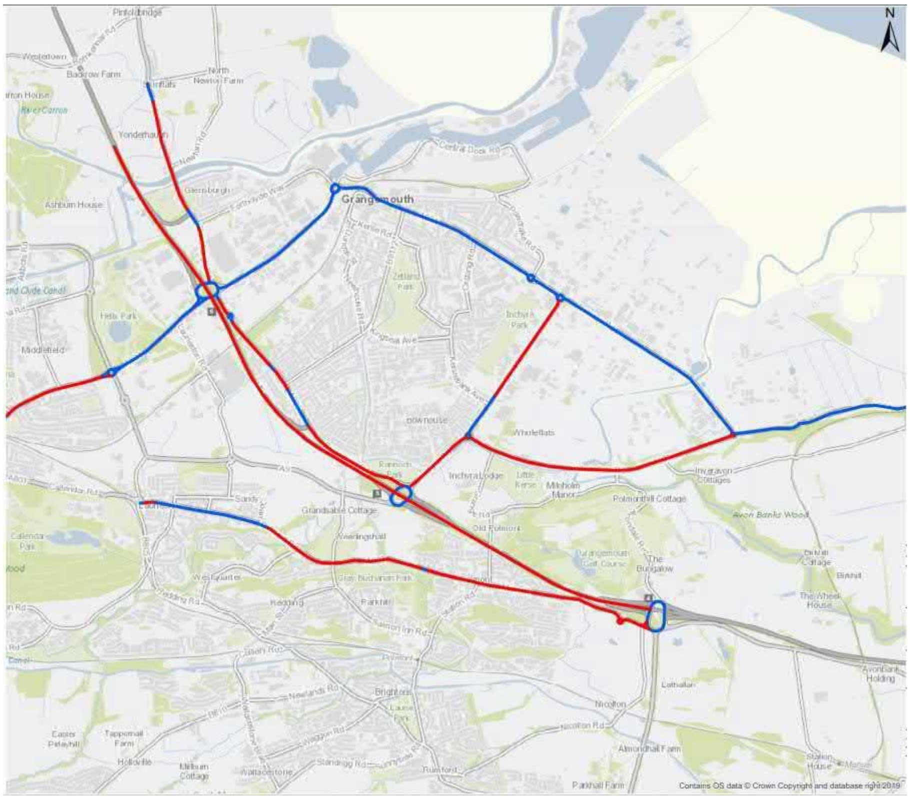
Further analysis of the Road NOx contribution is presented in Figure 10.1. This analysis has identified which vehicle type has the greatest NOx emissions for each road considered in the modelling study.

The road links, shown in blue have HGV vehicles as the highest contribution. These are mainly in line with HGV routes from the motorways to the port and the industrial area in Grangemouth.

The road links shown in red represent those links where emissions from Cars had the greatest emissions on NOx out of all of the vehicle types modelled.

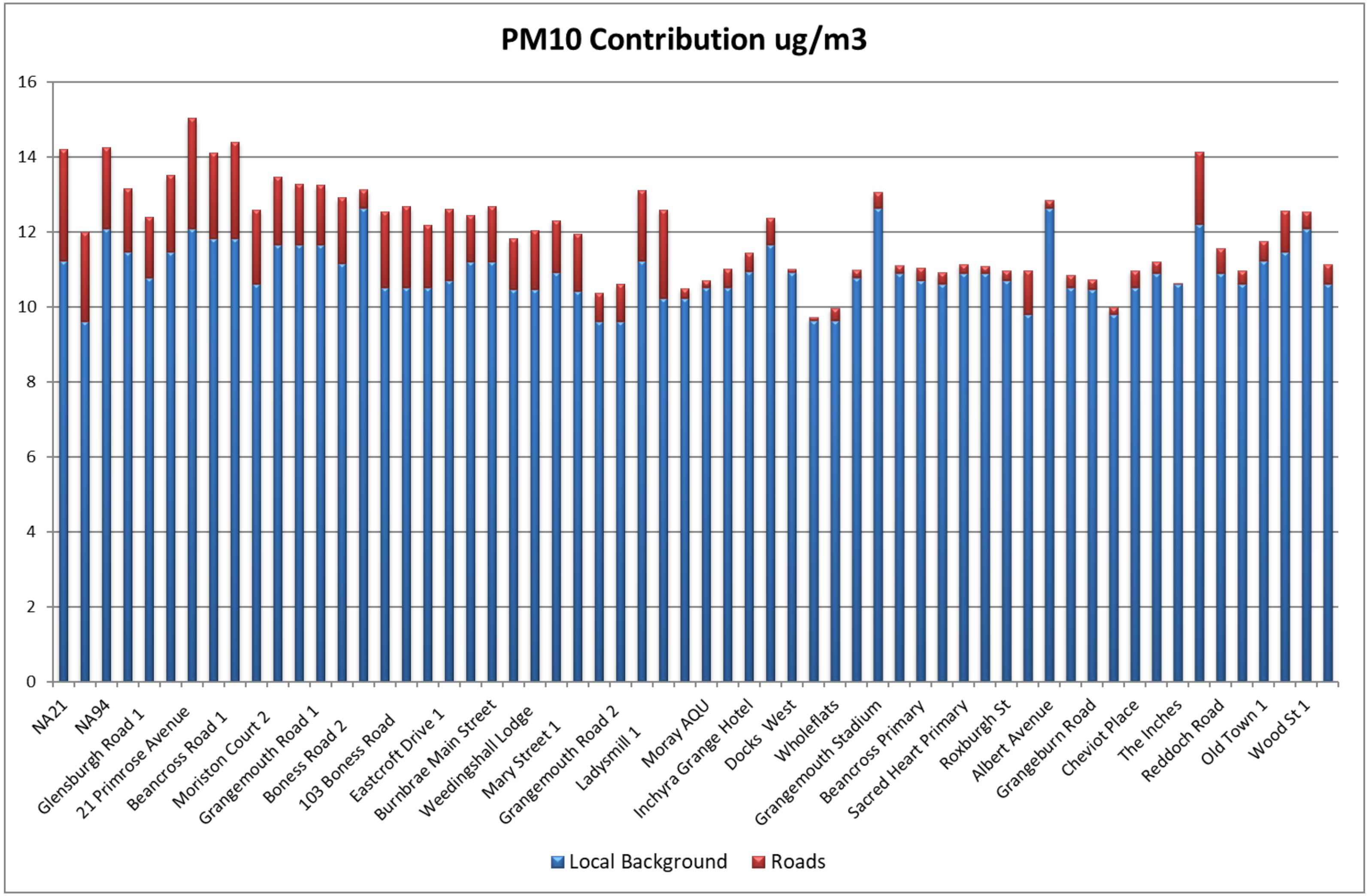
Figure 10.1: Road Link Source Apportionment Analysis



10.1.2 PM10 Source Apportionment

Overall background concentrations contribute a large proportion of PM_{10} concentrations. Background concentrations of PM_{10} account for more than 90% of PM_{10} concentrations. Therefore, road sources only account for a small proportion of PM_{10} concentrations.

Chart 10-3 PM_{10} source apportionment



10.2 Industrial emissions source apportionment

The industrial source apportionment has considered the contribution from background concentrations and the Engie, Calachem and Ineos sites which have contributed to the modelled concentrations within the assessment. The source apportionment has identified the variation in sources across the study area. The results for NOx and PM_{10} are presented below.

10.2.1 NOx source apportionment

Background concentrations accounted for between 65%- 85% of concentrations across the study area.

Further analysis of the Industrial NOx contributions has identified that Ineos contributed the greatest to NOx concentrations across the study area.

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Chart 10-4 NOx contribution by location from industrial emissions

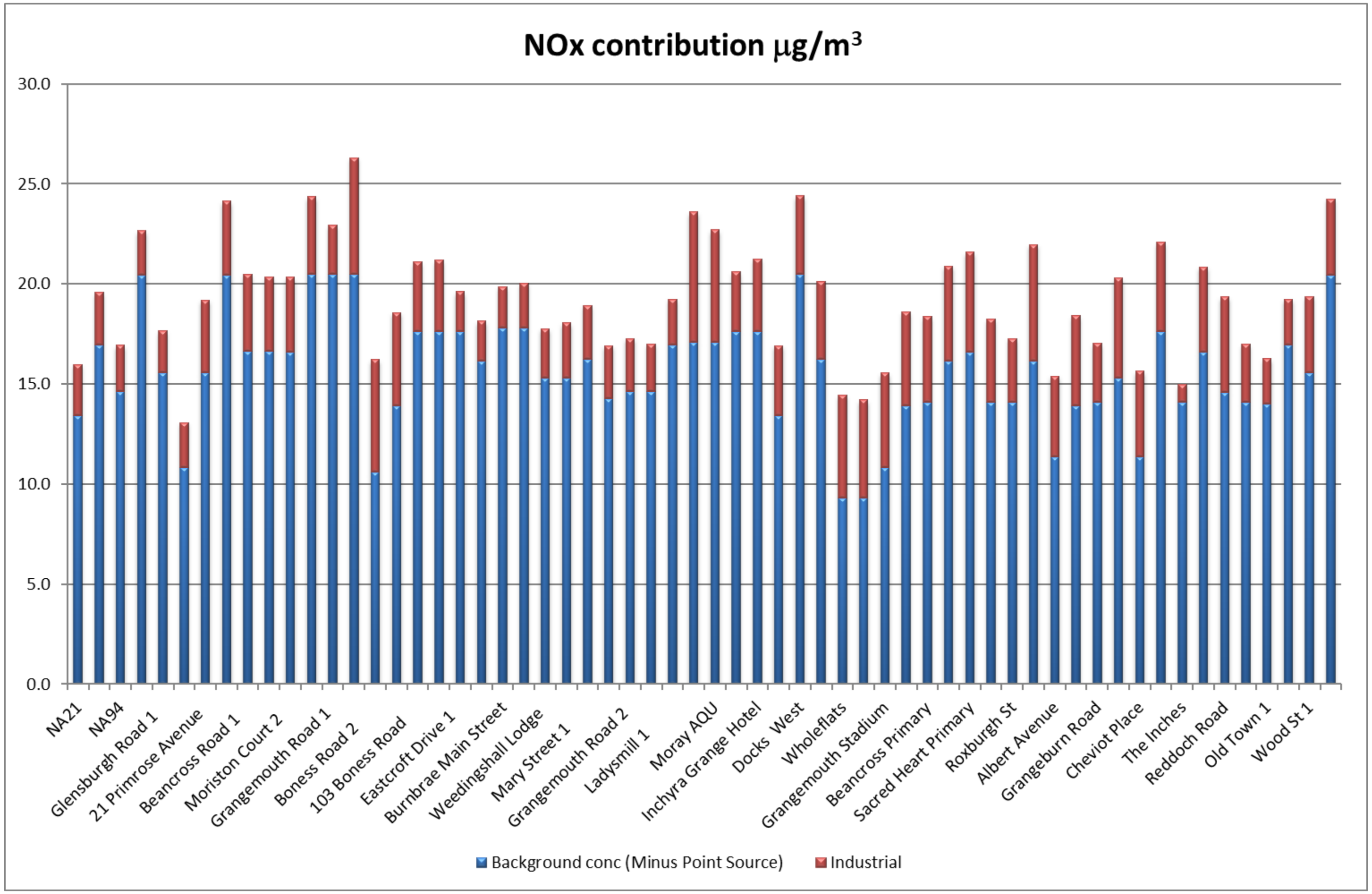
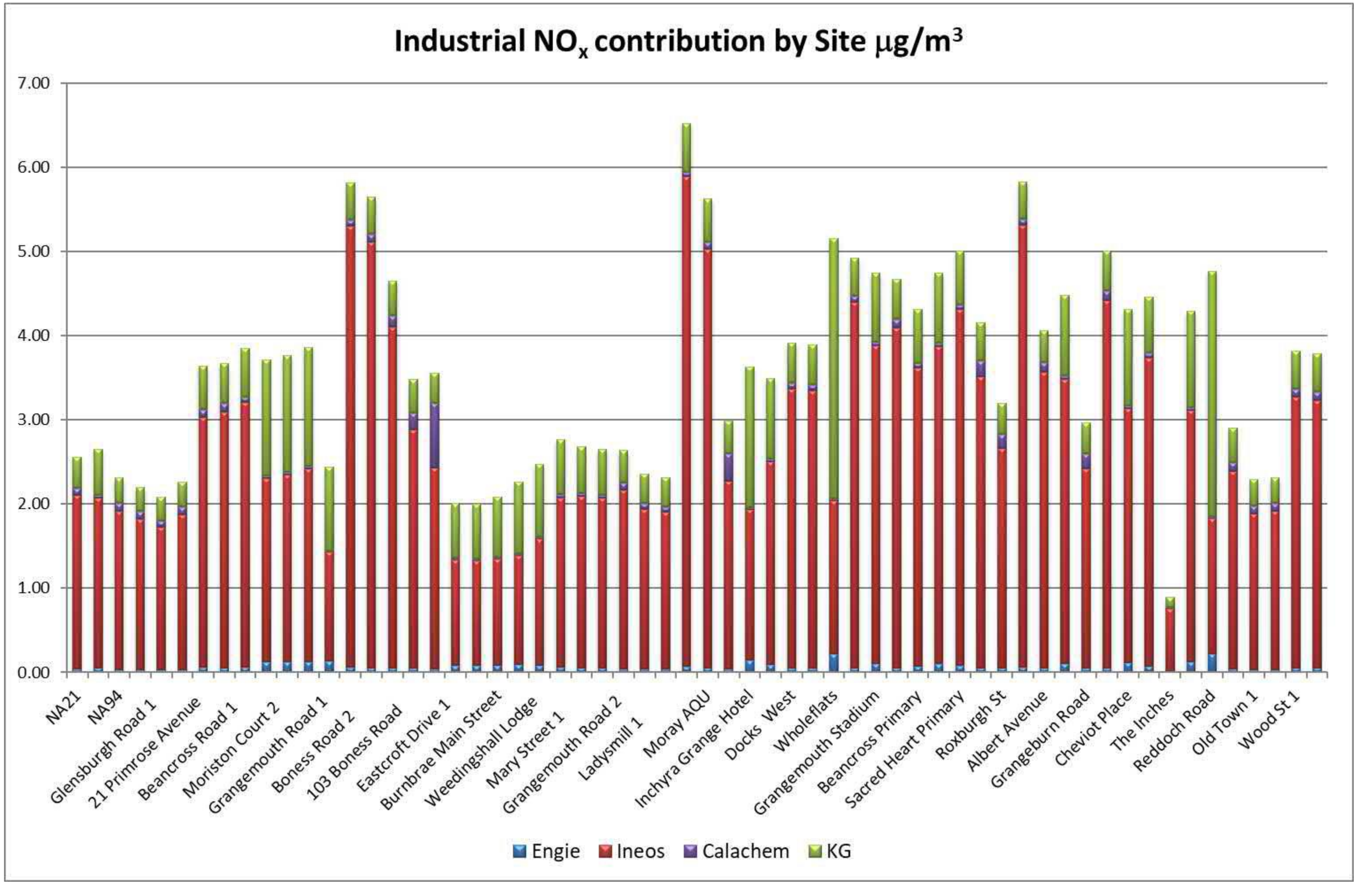


Chart 10-5 NOx contribution contribution by industrial operator



10.2.2 PM$_{10}$ source apportionment

Overall background concentrations contribute a large proportion of PM$_{10}$ concentrations. Background concentrations of PM$_{10}$ account for more than 95% of PM$_{10}$ concentrations. Therefore, industrial sources only account for a small proportion of PM$_{10}$ concentrations.

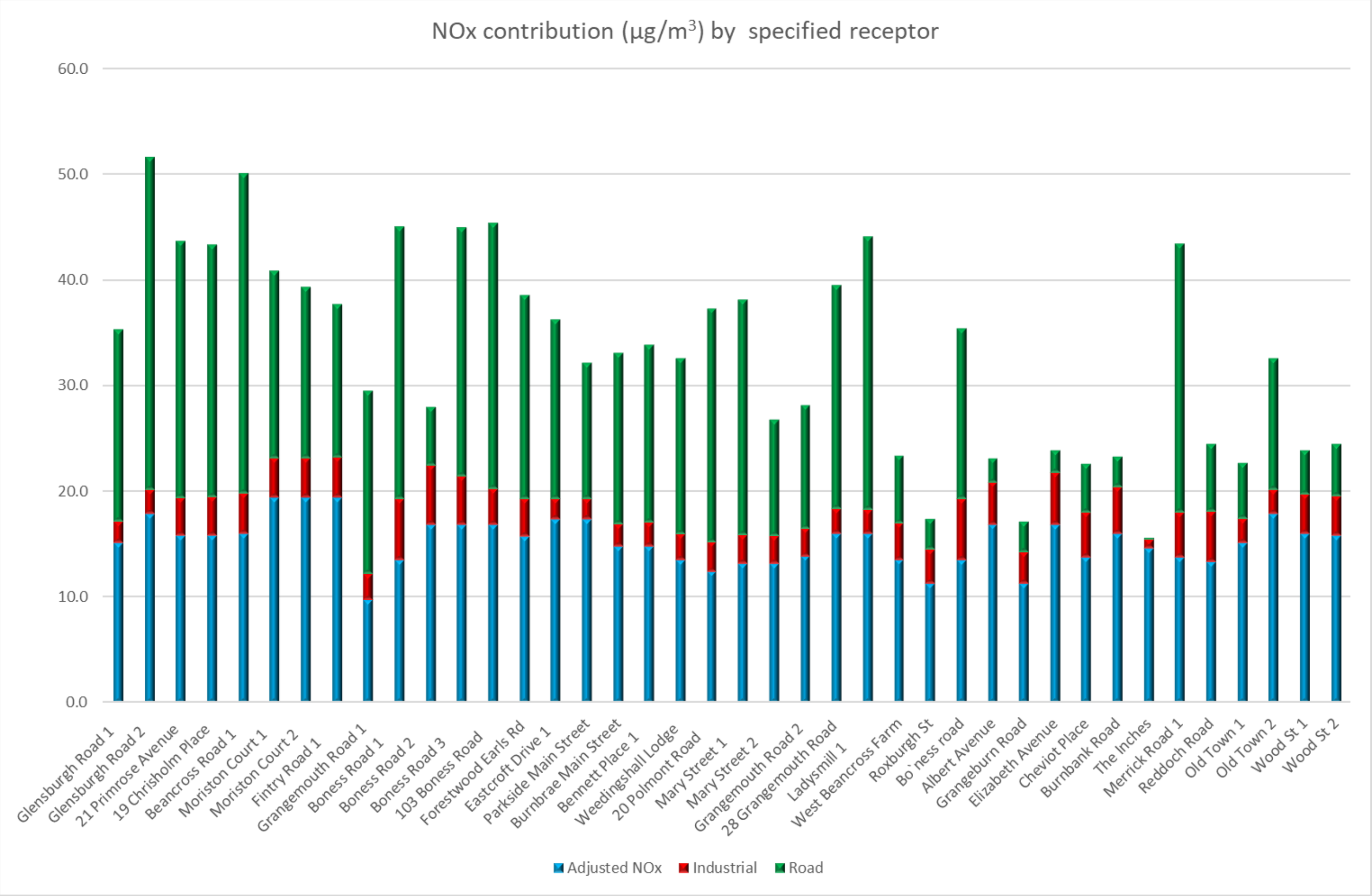
10.3 All sources source apportionment

The source apportionment analysis for all sources has reviewed the breakdown across all specified receptors for both NOx and PM$_{10}$ concentration. A summary of this is presented in Chart 10-6.

10.3.1 NOx

Further review of the source apportionment analysis for NOx concentrations from both the road and industrial sources identified that road sources contributed the highest proportion of NOx concentrations at all of the specified receptor locations. The maximum contribution of NOx was seen at Bo'ness Road with 5.8 µg/m^3 of NOx which was equivalent to 20% of the total NOx at this location. Industrial sources contributed less than 25% at all specified receptor locations.

Chart 10-6 NOx (µg/m³)contribution by source for each receptor



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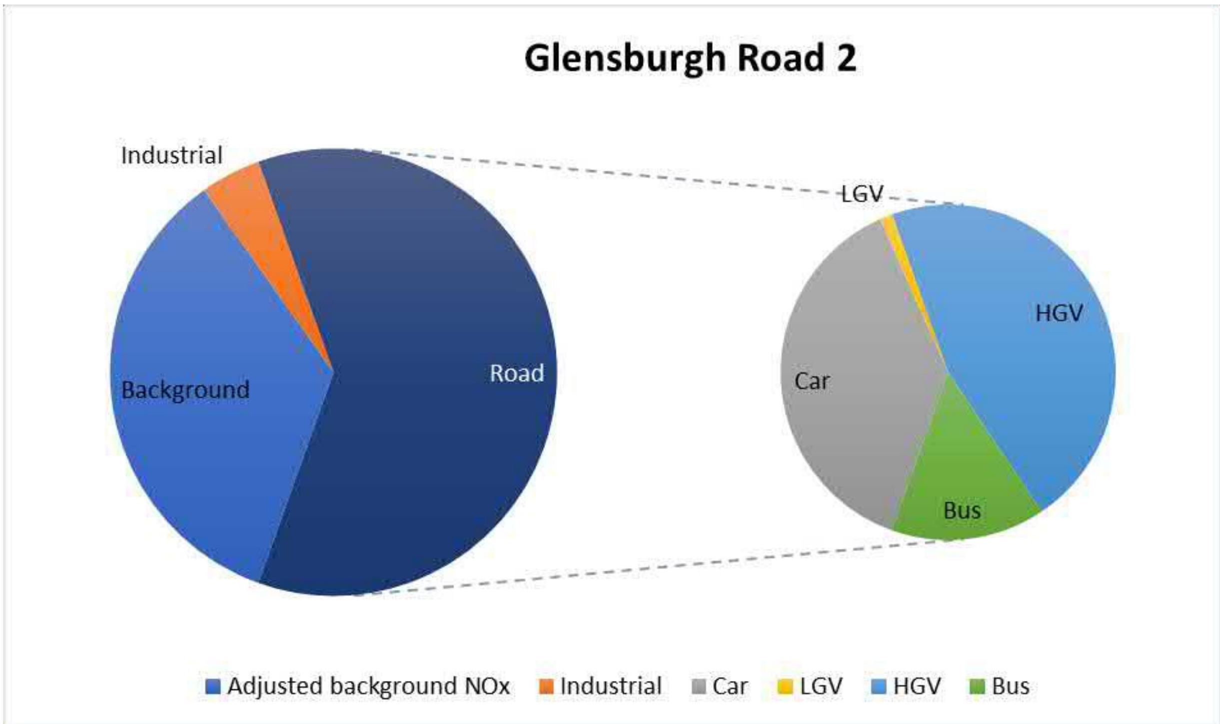
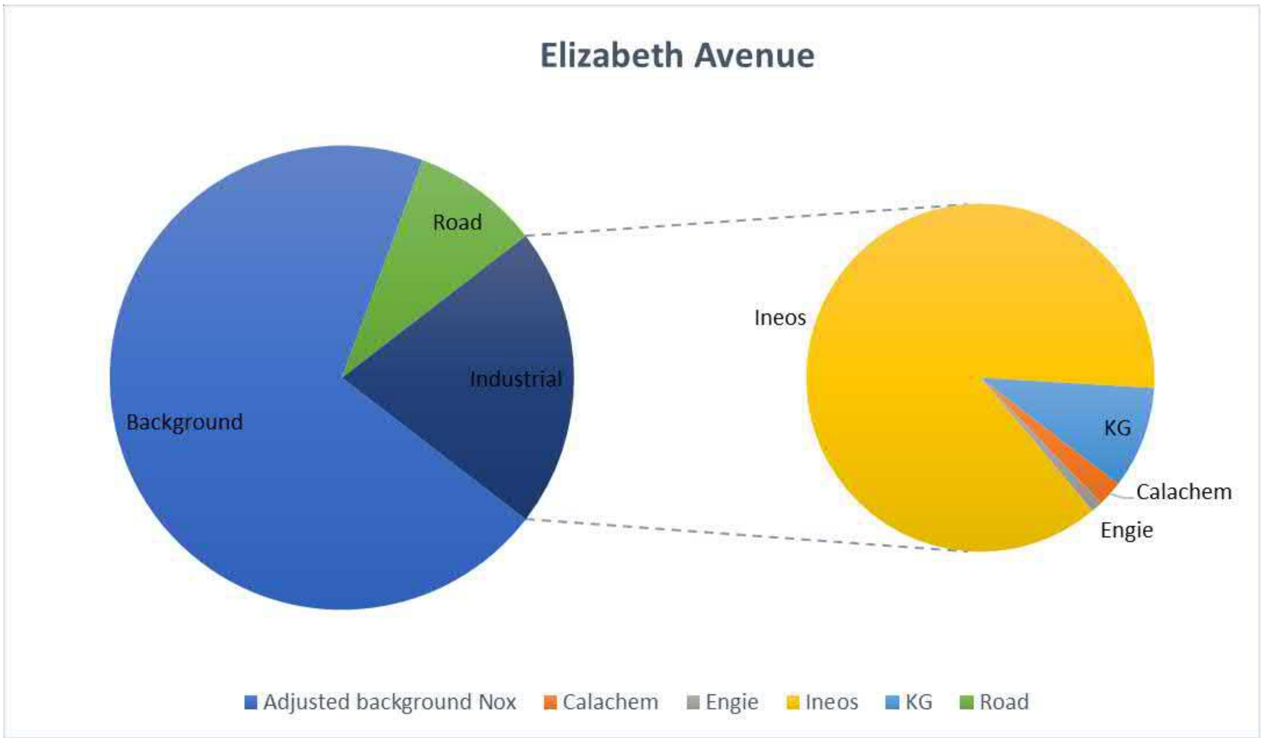
At receptor locations such as Wood Street and Elizabeth Avenue which are set back from the modelled roads, these locations were influenced more by background concentrations. Glensburgh Road 2 was identified as the receptor location where road traffic contributed most to NOx concentrations (61%). Contributions at Glensburgh Road 2 are presented in Chart 10-7

Chart 10-7 NOx specified receptor source apportionment at Glensburgh Road 2 specified receptor source apportionment



Elizabeth Avenue was identified as the location where industrial sources contributed greatest to total NOx concentrations (21%). Contributions at Elizabeth Avenue are presented Chart 10-8.

Chart 10-8 NOx specified receptor source apportionment at Elizabeth Avenue

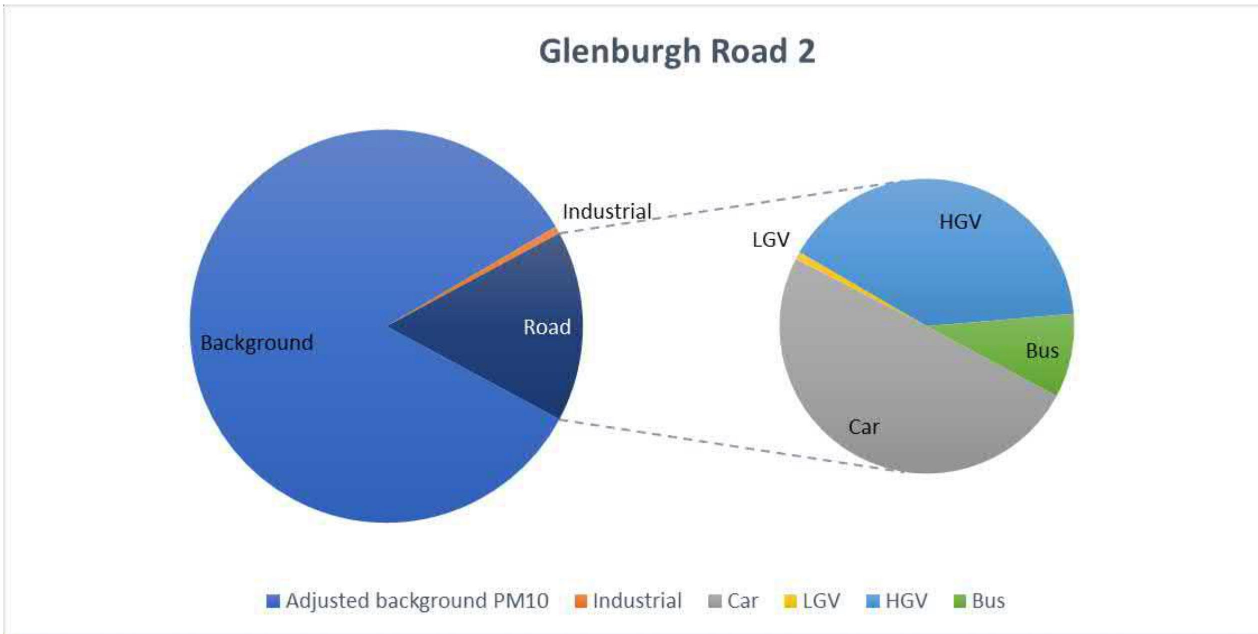


10.3.2 Combined Source Apportionment PM_{10}

A review of PM_{10} concentrations from both the road and industrial sources identified that background sources contributed the most to PM_{10} concentrations at the specified receptor locations (between 76%-96%).

Industrial sources contributed less than 3% at all specified receptor locations. Road sources contributed between 10%-20% at most receptor locations. Similar to NOx, the greatest contribution to PM_{10} from road traffic sources was at Glenburgh Road 2.

Chart 10-9 PM_{10} specified receptor source apportionment at Glensburgh Road 2



11 Conclusion

The assessment has considered both road sources and industrial sources within Grangemouth.

Previous assessment work in the AQMA has focussed on the short term SO_2 objectives in isolation. This package of work has considered a wider range of pollutants.

The study has predicted air pollutant concentrations within Grangemouth and detailed source apportionment modelling for all sources. This will determine which sources have the greatest influence on air quality concentrations within Grangemouth.

To our knowledge, this assessment is the first assessment where both the road traffic sources and industrial sources within Grangemouth have been modelled together. By combining both the industrial and traffic emissions in a complete assessment, this will give Falkirk Council an overall understanding of all emissions and traffic sources within the Grangemouth area and inform future management of the AQMA.

Road traffic Emissions

The road traffic assessment has used ATC traffic data to model pollutant concentrations in 2018. The road traffic model was verified using available monitoring data within the study area. Modelled concentrations were below the relevant air quality objectives for all pollutants modelled.

Hotspot areas were identified at Glensburgh Road, Bo'ness Road and Beancross Road, which are main routes within Grangemouth. **It is recommended that Falkirk Council undertake further monitoring within these locations to better understand pollutant concentrations.**

Industrial Emissions

The assessment of industrial sources has used annual emissions data for 2018 available on the SEPA web portal for permitted installations. These data showed that emissions had reduced during 2018 due to new permits which imposed new emission limit values.

Emissions data are conservative as test data has been used which is based on 100% load and assumes all sources operating 8760 hours.

The process contribution for each pollutant was added to the background concentrations to obtain the PEC. For NO_2 and PM_{10} the road traffic contribution was also added to predict a combined impact, with an adjusted background to account for the sources being explicitly modelled.

Modelled concentrations were below the relevant air quality objectives at all receptor locations for NO_2, PM_{10}, $PM_{2.5}$ and CO. The highest concentrations were predicted in the Inchyra area.

Source Apportionment

The source apportionment analysis has identified that across Grangemouth background NOx and PM_{10} sources contribute the greatest pollutant concentrations with road traffic emissions the next greatest contributor.

Further analysis of the road traffic emissions has identified that HGV and Car movements are responsible for the greatest source of NOx. However, this switched between the two dependant on the location of the road link. Typically, the routes from the motorway to the port and to the refinery have the highest contributions of NOX from HGV with the remaining links having car emissions as the predominant sources.

Analysis of the pollutant contributions from industrial sources has identified that Ineos contributed the greatest NOx concentrations across the study area.

12 Limitations and next steps

At the time of the study traffic count data were not available for every road in Grangemouth therefore the findings of the report are based only on the data included in the model. Therefore, the road traffic model could be improved by the addition of additional traffic flow data from new surveys around Grangemouth.

A number of point sources were identified in the screening process and compilation of the emissions inventory that unfortunately couldn't be included in the model. Typically, this was due to limitations in available data suitable for dispersion modelling in the SEPA reporting portal, as that level of detail isn't required for permit reporting purposes.

Emissions data which were based on stack testing reports or annual emissions reports, submitted to the SEPA reporting portal, assumed that these emissions data represented emissions for the entire year.

While the background data have been adjusted to remove all industrial NOx and PM_{10} emissions it is likely that this may be an over estimation of the contribution of the emissions being explicitly modelled. However, this is likely to have been balanced with the potential overestimation in the emissions which have been modelled.

The modelling could be improved by getting emissions data from each industrial operator to fill in the incomplete data gathered in the initial emissions inventory.

Appendix A – Model Verification

As stated in Section 8.1 above, the model was verified using annual mean NO_2 measurements from diffusion tube locations NA21, NA51, NA57, NA94 and NA101. The study area was extended to Polmont to assist with model verification. Details of the monitoring sites used for model verification are detailed below.

Site ID	Site	X	Y	In AQMA	2014	2015	2016	2017	2018
NA21	Grangemouth Rd, Falkirk College	290112	680500	N	28	28	28	28	28
NA51	Mary St, Laurieston	290965	679490	N	25	19	25	22	24
NA57	Inchyra Rd, Grangemouth	294028	680829	N	26	20	23	19	21
NA94	A905 (Glensburgh Rd), Grangemouth	291213	681927	N	31	24	21	30	31
NA101	Glensburgh Rd (2), Grangemouth	291127	682007	N	25	22	21	24	23

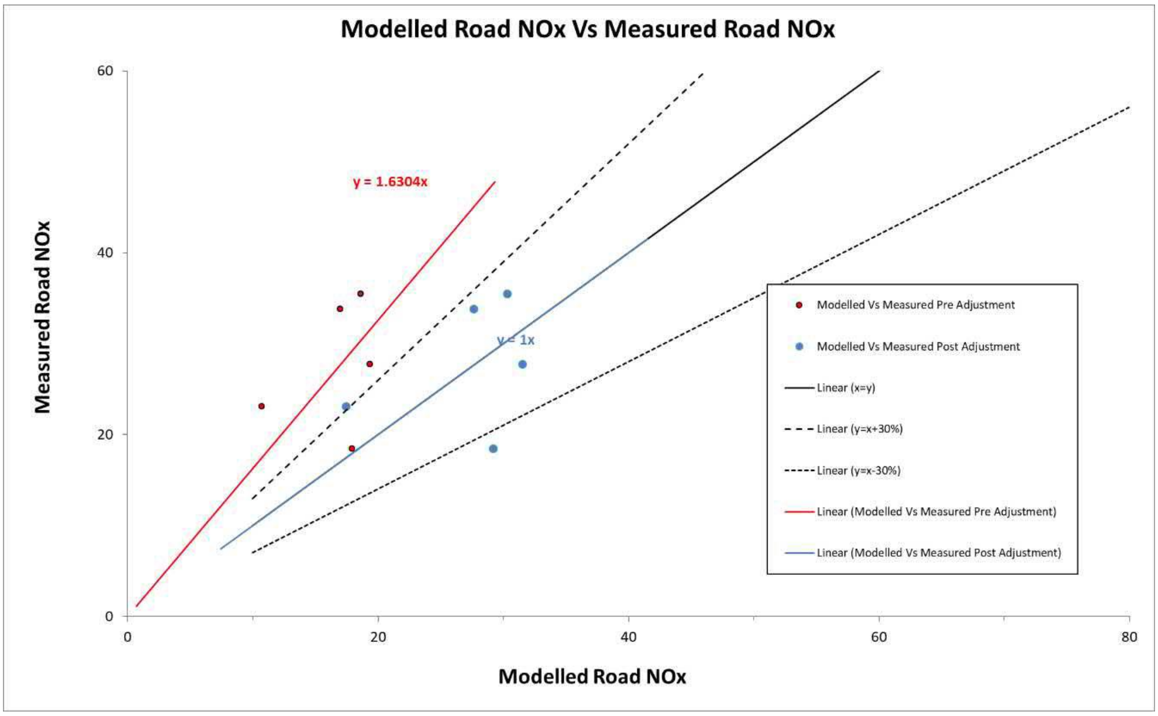
The initial comparison of the modelled vs measured Road NOx identified that the model was under-predicting the Road NOx contribution. Following initial review, some refinements were made to the model input to improve the overall model performance.

A linear regression plot comparing modelled and monitored Road NOx concentrations before and after adjustment is presented in Figure A.1.

A primary adjustment factor (PAdj) of 1.6304 was applied to all modelled Road NOx data prior to calculating an NO_2 annual mean.

There was no monitoring site measuring PM_{10} in close proximity to the modelled roads that were suitable to verify the modelled PM_{10} concentrations. LAQM.TG (16) states that in the absence of any PM_{10} data for verification, it is appropriate to apply the road-NOx adjustment to the modelled road-PM_{10}. Therefore, an adjustment factor of 1.6304 was applied to all modelled PM_{10} and $PM_{2.5}$ concentrations.

Figure A.1: Modelled vs Measured Road NOx



Appendix B – Combined Results

Table B.1 presented the results from the road traffic modelling for NO_2, PM_{10} and $PM_{2.5}$. Results from the Industrial sources are presented in Table B.2.

Table B.3 presents the combined results for the road traffic assessment and the industrial sources. These have been combined by using the annual mean road concentrations from the roads assessment and the process contribution from the industrial sources to provide a combined annual mean concentration. Roads and industrial sources were removed from the background concentrations to avoid double counting.

TABLE B.1: ROAD TRAFFIC MODELLING RESULTS

Receptor	Road Traffic NO_2 Annual mean µg/m^3	Road Traffic PM_{10} Annual mean µg/m^3	Road Traffic $PM_{2.5}$ Annual mean µg/m^3
Glensburgh Road 1	20.1	12.4	7.4
Glensburgh Road 2	25.7	13.5	7.6
21 Primrose Avenue	25.2	15.0	8.4
19 Chrisholm Place	22.5	14.1	7.9
Beancross Road 1	25.2	14.4	8.1
Moriston Court 1	19.9	12.6	7.5
Moriston Court 2	21.3	13.5	7.7
Fintry Road 1	20.5	13.3	7.6
Grangemouth Road 1	21.9	13.3	7.6
Boness Road 1	22.0	12.9	7.3
Boness Road 2	14.5	13.1	7.9
Boness Road 3	23.4	12.5	7.6
103 Boness Road	24.1	12.6	7.7
Forestwood Earls Rd	21.6	12.2	7.4

Receptor	Road Traffic NO_2 Annual mean µg/m^3	Road Traffic PM_{10} Annual mean µg/m^3	Road Traffic $PM_{2.5}$ Annual mean µg/m^3
Eastcroft Drive 1	19.4	12.6	7.4
Parkside Main Street	18.5	12.4	7.1
Burnbrae Main Street	20.0	12.7	7.2
Bennett Place 1	18.9	11.8	6.9
Weedingshall Lodge	18.7	12.0	7.0
20 Polmont Road	20.7	12.3	7.3
Mary Street 1	20.0	11.9	7.1
Mary Street 2	15.0	10.4	6.3
Grangemouth Road 2	15.5	10.6	6.5
28 Grangemouth Road	20.0	13.1	7.5
Ladysmill 1	23.1	12.6	7.4
Inchyra AQU	12.5	10.5	6.2
Moray AQU	13.4	10.7	6.6
GMC AQU	15.4	11.0	6.7
Inchyra Grange Hotel	12.3	11.4	6.7

Receptor	Road Traffic NO_2 Annual mean µg/m^3	Road Traffic PM_{10} Annual mean µg/m^3	Road Traffic $PM_{2.5}$ Annual mean µg/m^3
West Beancross Farm	16.7	12.4	7.0
Docks West	10.6	11.0	6.5
Docks East	9.4	9.7	5.9
Wholeflats	10.5	10.0	6.0
Oil refinery	12.5	11.0	6.5
Grangemouth Stadium	13.9	13.1	7.8
Sports Complex	11.7	11.1	6.5
Beancross Primary	13.1	11.0	6.5
Bowhouse Primary	13.0	10.9	6.5
Sacred Heart Primary	11.9	11.1	6.5
Zetland Pavillion	11.7	11.1	6.5
Roxburgh St	12.9	11.0	6.4
Bo`ness road	17.4	11.0	6.7
Albert Avenue	12.9	12.8	7.7
Grangemouth High	14.0	10.9	6.6

Receptor	Road Traffic NO_2 Annual mean µg/m^3	Road Traffic PM_{10} Annual mean µg/m^3	Road Traffic $PM_{2.5}$ Annual mean µg/m^3
Grangeburn Road	12.3	10.7	6.2
Elizabeth Avenue	10.6	10.0	6.1
Cheviot Place	14.7	11.0	6.7
Burnbank Road	12.2	11.2	6.6
The Inches	11.6	10.6	6.4
Merrick Road 1	22.1	14.1	8.0
Reddoch Road	13.9	11.6	6.8
Falkirk Stadium	12.8	11.0	6.3
Old Town 1	12.7	11.7	6.7
Old Town 2	17.0	12.6	7.0
Wood St 1	16.2	12.5	7.0
Wood St 2	14.0	11.1	6.7

TABLE B.2: INDUSTRIAL SOURCE MODELLING RESULTS

Receptor	Industrial NO_2 Annual mean µg/m^3	Industrial NO_2 1 hour 99.79%ile µg/m^3	Industrial PM_{10} Annual mean µg/m^3	Industrial PM_{10} 98.08%ile 24 hour mean µg/m^3
Glensburgh Road 1	14.0	45.6	11.4	22.9
Glensburgh Road 2	19.0	47.0	12.2	23.0
21 Primrose Avenue	16.1	51.9	11.8	23.2
19 Chrisholm Place	16.1	52.0	11.8	23.1
Beancross Road 1	16.4	53.5	10.6	23.2
Moriston Court 1	19.1	54.7	11.6	23.0
Moriston Court 2	19.2	54.4	11.6	23.0
Fintry Road 1	19.3	53.8	11.6	23.0
Grangemouth Road 1	13.1	49.8	10.8	22.8
Boness Road 1	18.4	60.4	11.3	24.2
Boness Road 2	19.3	57.9	10.5	24.3
Boness Road 3	18.3	54.7	10.4	24.1
103 Boness Road	17.1	51.4	10.4	23.8
Forestwood Earls Rd	15.9	50.5	10.6	23.2

Receptor	Industrial NO_2 Annual mean µg/m^3	Industrial NO_2 1 hour 99.79%ile µg/m^3	Industrial PM_{10} Annual mean µg/m^3	Industrial PM_{10} 98.08%ile 24 hour mean µg/m^3
Eastcroft Drive 1	15.4	62.9	11.1	22.8
Parkside Main Street	15.4	58.4	11.1	22.8
Burnbrae Main Street	13.7	55.3	10.3	22.7
Bennett Place 1	13.9	53.5	10.3	22.8
Weedingshall Lodge	14.8	49.5	10.9	22.8
20 Polmont Road	13.6	46.0	10.4	22.9
Mary Street 1	13.6	45.4	9.6	22.9
Mary Street 2	13.6	45.3	9.6	22.9
Grangemouth Road 2	15.1	46.1	11.3	22.9
28 Grangemouth Road	14.7	44.3	10.3	22.9
Ladysmill 1	14.7	43.9	10.3	22.9
Inchyra AQU	20.2	65.2	10.4	23.8
Moray AQU	19.3	59.5	10.5	24.0
GMC AQU	13.8	48.0	10.8	23.2
Inchyra Grange Hotel	19.0	56.5	11.6	22.9

Receptor	Industrial NO_2 Annual mean µg/m^3	Industrial NO_2 1 hour 99.79%ile µg/m^3	Industrial PM_{10} Annual mean µg/m^3	Industrial PM_{10} 98.08%ile 24 hour mean µg/m^3
West Beancross Farm	15.8	53.1	10.9	23.0
Docks West	12.9	57.7	9.4	23.3
Docks East	12.9	57.8	9.4	23.3
Wholeflats	17.1	65.3	10.2	23.0
Oil refinery	17.5	72.9	11.3	24.1
Grangemouth Stadium	16.1	61.7	10.8	23.3
Sports Complex	17.0	60.4	10.7	23.5
Beancross Primary	16.9	54.1	10.6	23.3
Bowhouse Primary	16.1	60.9	10.8	23.2
Sacred Heart Primary	16.4	60.7	10.8	23.5
Zetland Pavillion	16.5	57.6	10.7	23.6
Roxburgh St	13.0	52.7	9.6	23.6
Bo`ness road	18.4	60.2	11.3	24.2
Albert Avenue	17.7	57.9	10.4	24.6
Grangemouth High	15.9	58.9	10.8	23.2

Receptor	Industrial NO_2 Annual mean µg/m^3	Industrial NO_2 1 hour 99.79%ile µg/m^3	Industrial PM_{10} Annual mean µg/m^3	Industrial PM_{10} 98.08%ile 24 hour mean µg/m^3
Grangeburn Road	12.7	51.9	9.6	23.3
Elizabeth Avenue	18.6	58.9	10.4	23.9
Cheviot Place	15.7	57.0	10.7	23.1
Burnbank Road	17.0	56.5	10.7	23.4
The Inches	11.5	37.7	12.2	22.7
Merrick Road 1	15.7	56.2	10.7	23.2
Reddoch Road	16.2	66.3	10.4	23.0
Falkirk Stadium	15.4	47.6	11.3	23.0
Old Town 1	14.2	47.3	11.4	23.0
Old Town 2	19.0	47.7	12.2	23.0
Wood St 1	16.4	54.3	10.6	23.2
Wood St 2	16.2	54.6	11.8	23.2

TABLE B.3: COMBINED ANNUAL MEAN RESULTS

Receptor	Height (m)	Combined NO_2 Annual mean µg/m^3	Combined PM_{10} Annual mean µg/m^3
Glensburgh Road 1	1.5	22.0	13.0
Glensburgh Road 2	1.5	28.2	14.0
21 Primrose Avenue	1.5	26.7	14.6
19 Chrisholm Place	1.5	26.5	14.0
Beancross Road 1	1.5	29.5	13.0
Moriston Court 1	1.5	23.9	13.4
Moriston Court 2	1.5	25.6	13.3
Fintry Road 1	1.5	24.8	13.1
Grangemouth Road 1	1.5	24.9	12.4
Boness Road 1	1.5	25.4	13.0
Boness Road 2	1.5	17.2	10.9
Boness Road 3	1.5	27.9	12.3
103 Boness Road	1.5	27.4	12.4
Forestwood Earls Rd	1.5	25.0	12.2

Receptor	Height (m)	Combined NO_2 Annual mean µg/m^3	Combined PM_{10} Annual mean µg/m^3
Eastcroft Drive 1	1.5	21.6	12.9
Parkside Main Street	1.5	21.0	12.3
Burnbrae Main Street	1.5	22.5	11.8
Bennett Place 1	1.5	21.3	11.6
Weedingshall Lodge	1.5	21.3	12.3
20 Polmont Road	1.5	23.4	11.7
Mary Street 1	1.5	22.6	11.0
Mary Street 2	1.5	17.9	10.3
Grangemouth Road 2	1.5	18.3	12.1
28 Grangemouth Road	1.5	22.6	12.0
Ladysmill 1	1.5	26.2	12.5
Inchyra AQU	1.5	19.7	10.6
Moray AQU	1.5	18.9	10.5
GMC AQU	1.5	18.2	11.2
Inchyra Grange Hotel	1.5	14.6	11.9

Receptor	Height (m)	Combined NO_2 Annual mean µg/m^3	Combined PM_{10} Annual mean µg/m^3
West Beancross Farm	1.5	20.7	11.5
Docks West	1.5	14.5	9.5
Docks East	1.5	11.4	9.5
Wholeflats	1.5	13.9	10.5
Oil refinery	1.5	14.2	11.5
Grangemouth Stadium	1.5	15.7	11.1
Sports Complex	1.5	16.0	10.8
Beancross Primary	1.5	17.6	10.9
Bowhouse Primary	1.5	18.1	11.0
Sacred Heart Primary	1.5	16.5	11.0
Zetland Pavillion	1.5	15.5	10.8
Roxburgh St	1.5	16.3	9.9
Bo`ness road	1.5	22.2	12.5
Albert Avenue	1.5	14.0	10.5
Grangemouth High	1.5	18.4	11.0

Receptor	Height (m)	Combined NO_2 Annual mean µg/m^3	Combined PM_{10} Annual mean µg/m^3
Grangeburn Road	1.5	15.4	9.8
Elizabeth Avenue	1.5	14.7	10.8
Cheviot Place	1.5	18.8	11.0
Burnbank Road	1.5	16.2	10.5
The Inches	1.5	12.8	14.0
Merrick Road 1	1.5	27.1	11.3
Reddoch Road	1.5	18.2	10.8
Falkirk Stadium	1.5	15.1	11.6
Old Town 1	1.5	15.2	12.4
Old Town 2	1.5	19.5	12.4
Wood St 1	1.5	17.8	11.0
Wood St 2	1.5	18.0	11.7

Appendix C – A3 FIGURES

Legend

ADMS Road Sources

0 05 1 Kilometers

P01	07/07/2020	For Information	RMT	RMcL
Rev.	Rev. Date	Drawing Suitability	Drawn	Appr'd

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Client

Falkirk Council

Project

Grangemouth Emissions Study

Drawing Title

Figure 1.1

Scale @ A3	1:31,156	DO NOT SCALE
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BIM No.		

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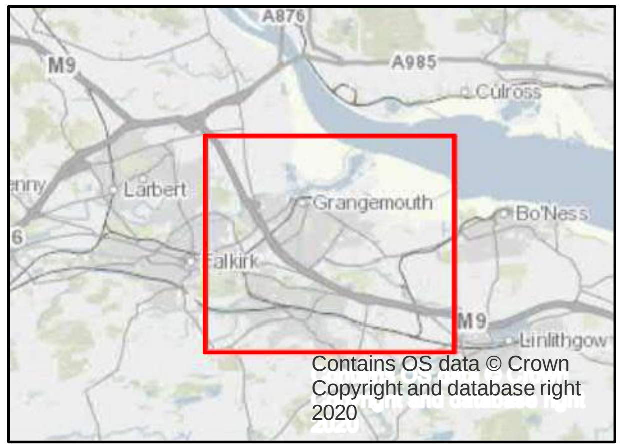
Legend

- Automatic Monitoring Sites
- ADMS Road Source

0 0.5 1 Kilometers



P01	18/02/2021	For Information	EMP	JS
Rev.	Rev. Date	Drawing Suitability	Drawn	Appr'd

SWECO

Sweco, City Park Bldg Alexandra Parade, Suite 3/5, City Park, 368 Alexandra Parade, Glasgow G31 3AU Tel: +44 (0) 141 414 1700

Client

Project

Grangemouth Emissions Study

Drawing Title

Figure 4.1

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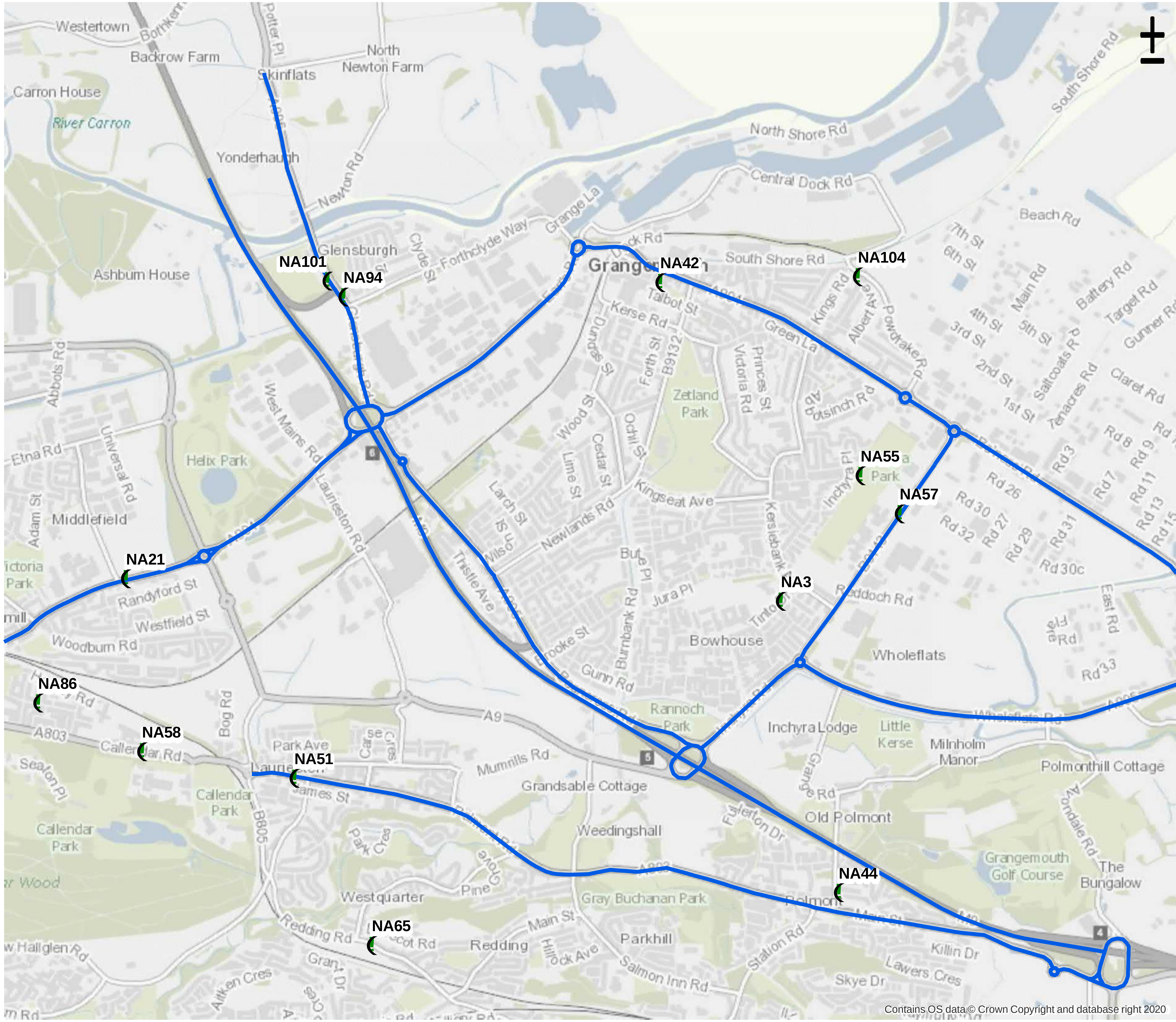
BIM No.	NA		

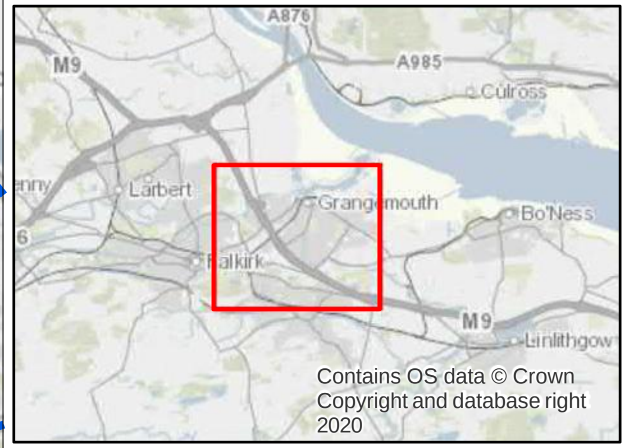


Legend

Non Automatic Monitoring

ADMS Road Source

0 0.5 1 Kilometers



P01	19/02/2021	For Information	EMP	JS
Rev.	Rev. Date	Drawing Suitability	Drawn	Appr'd

SWECO

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Grangemouth Emissions Study

Drawing Title

Figure 4.2

Scale @ A3	1:18,534	DO NOT SCALE	
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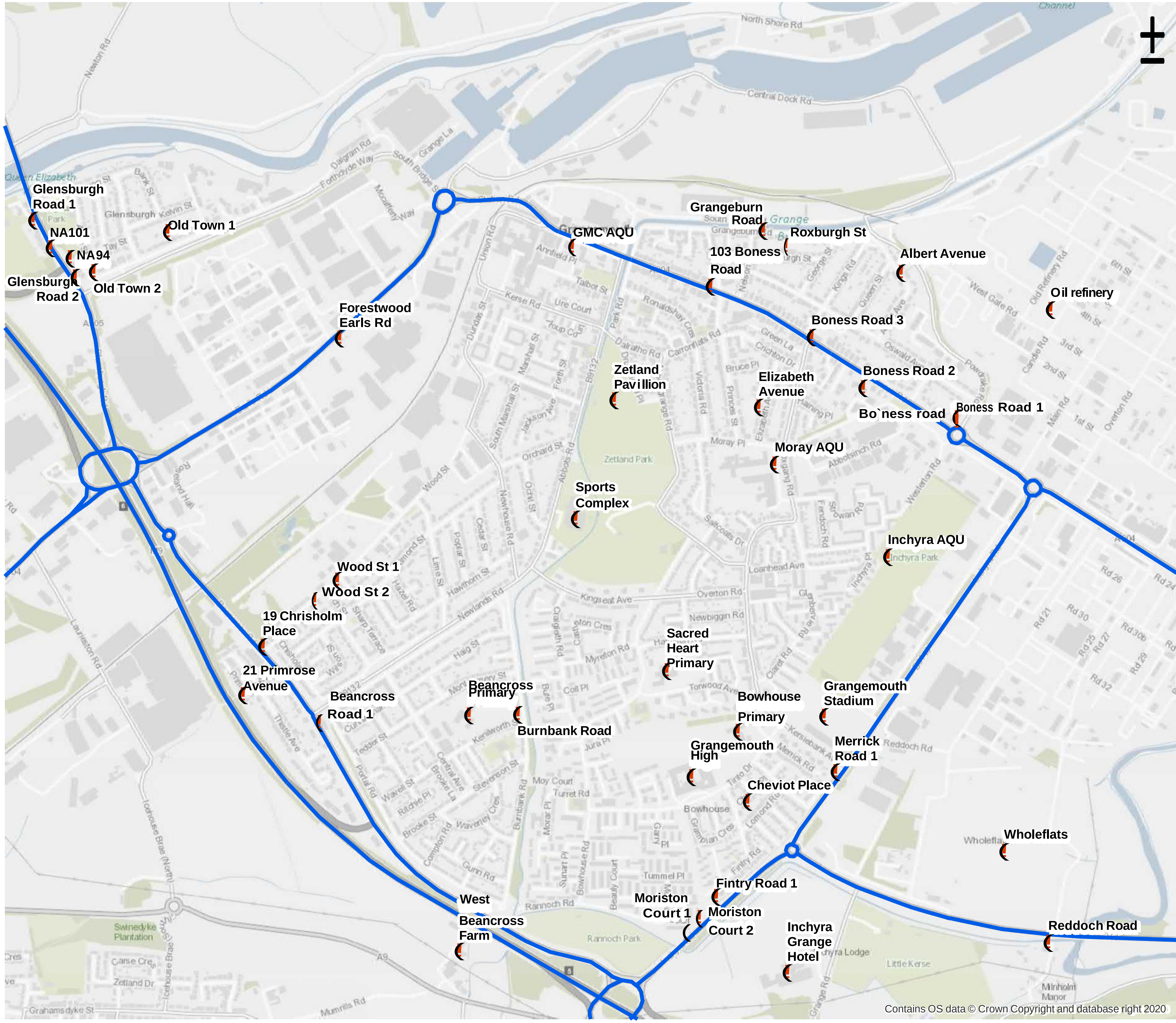
BIM No.	NA		



Legend

ADMS Receptors

ADMS Road Source

0 0.5 1 K

P01	18/02/2021	For Information	EMP	JS
Rev.	Rev. Date	Drawing Suitability	Drawn	Appr'd

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Figure 5.1

Scale @ A3	1:11,824	DO NOT SCALE	
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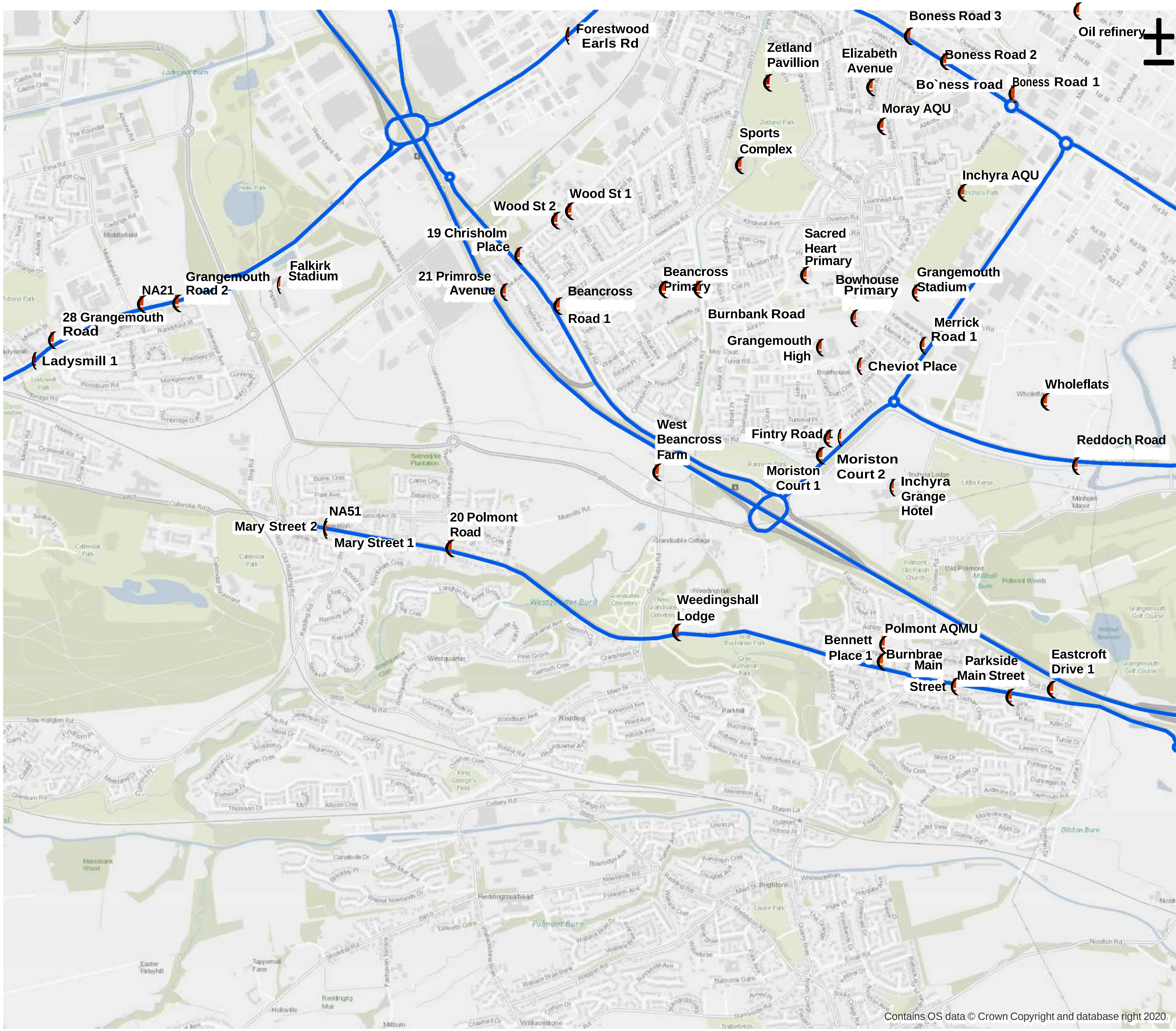
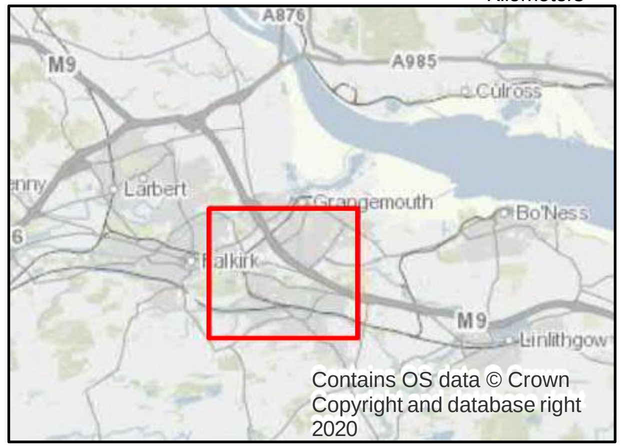
BIM No.	NA		





P01	18/02/2021	For Information	EMP	JS
Rev.	Rev. Date	Drawing Suitability	Drawn	Appr'd

SWECO

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368 Alexandra Parade, Glasgow G31 3AU Tel: +44 (0) 141 414 1700

Client

Project

Grangemouth Emissions Study

Drawing Title

Figure 5.2

Scale @ A3	1:16,604	DO NOT SCALE	
Project No.	121384	Status	S2
BIM No.	NA		

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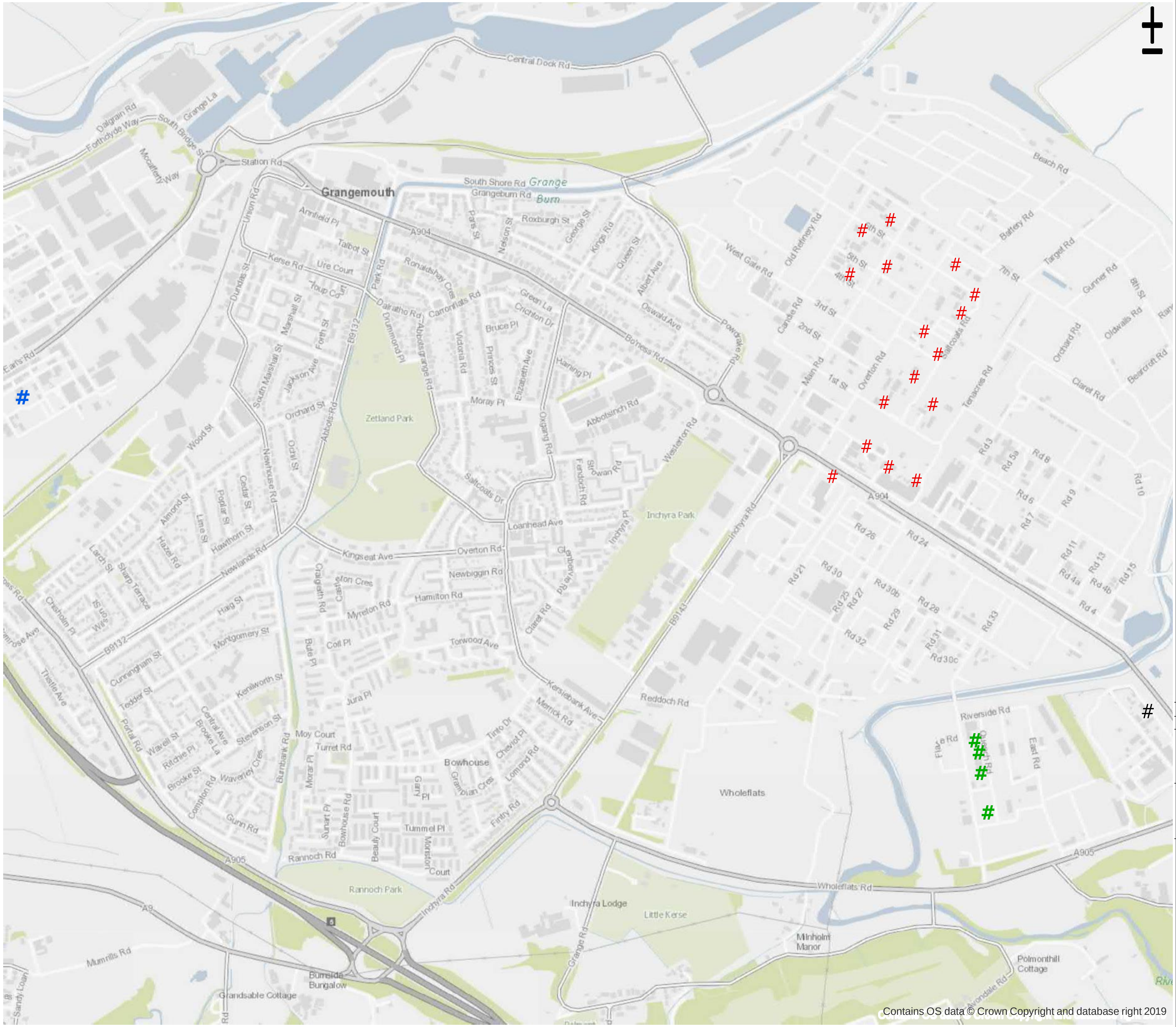

Legend

- # Ineos Sources
- # Ineos Chemical Sources
- # Engie Sources
- # Calachem Sources

0 0.5 1 Kilo

P01	08/07/2020	For Information	RMT	RMcL
Rev.	Rev. Date	Drawing Suitability	Drawn	Appr'd

SWECO

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Client

Falkirk Council

Project

Grangemouth Emissions Study

Drawing Title

Figure 7.1

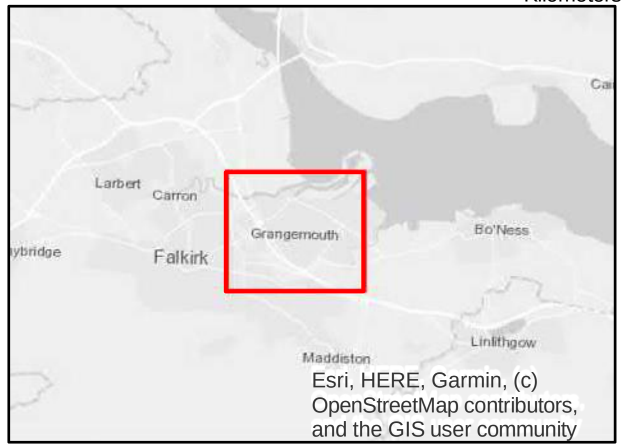
Scale @ A3	1:12,114	DO NOT SCALE	
Project No.	121384	Status	
BIM No.			

Legend

NO_2 Annual Mean Concentration

- 13 - 15
- 16 - 20
- 21 - 30
- 31 - 36
- 37 - 40
- 41 - 60
- 61 - 85
- ADMS Road Source

0 0.5 1 Kilometers



Rev.	Rev. Date	Drawing Suitability	Drawn	Appr'd
P01	18/02/2021	For Information	EMP	JS

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Project

Grangemouth Emissions Study

Drawing Title

Figure 9.1

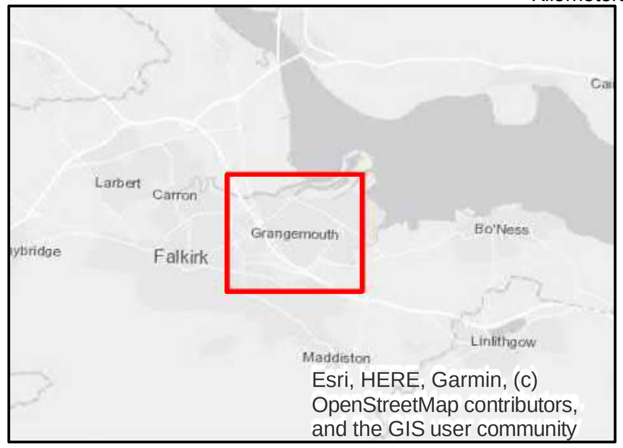
Scale @ A3	1:15,358	DO NOT SCALE	
Project No.	121384	Status	S2
BIM No.	NA		

Legend

PM10 Annual Mean Concentration

- 11 - 12
- 13-14
- 14 - 15
- 16 - 18
- 19 - 20
- 21 - 30
- ADMS Road Source

0 0.5 1 Kilometers



P01	18/02/2021	For Information	EMP	JS
Rev.	Rev. Date	Drawing Suitability	Drawn	Appr'd

SWECO

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Client

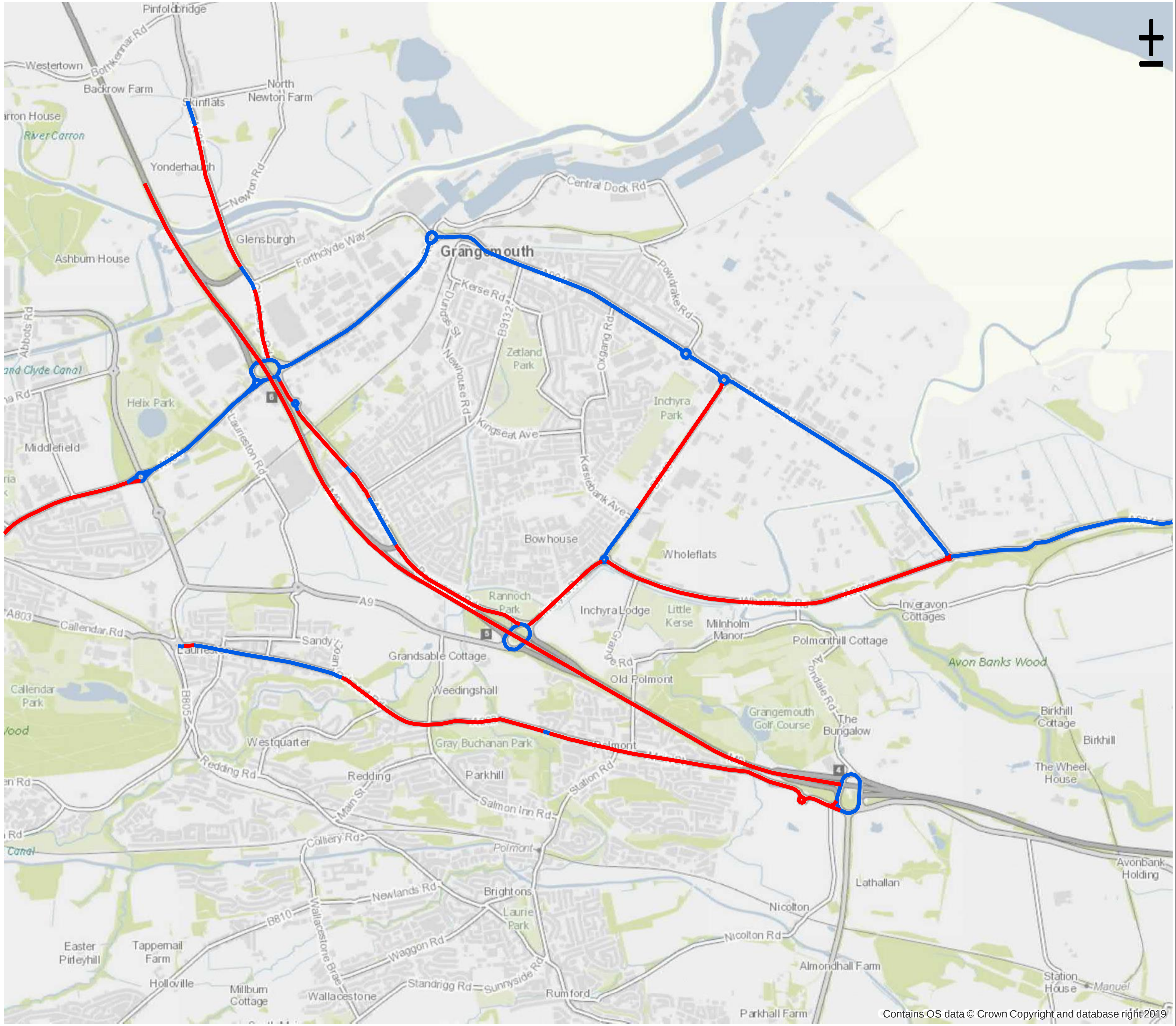
Project

Grangemouth Emissions Study

Drawing Title

Figure 9.2

Scale @ A3	1:15,129	DO NOT SCALE	
Project No.	121384	Status	S2
BIM No.	NA		



Legend

Highest NOx emissions

- Cars
- HGVs

0 0.5 1 Kilometers

P01	08/07/2020	For Information	RMT	RMcL
Rev.	Rev. Date	Drawing Suitability	Drawn	Appr'd

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Client

Falkirk Council

Project

Grangemouth Emissions Study

Drawing Title

Figure 10.1

Scale @ A3	1:24,000	DO NOT SCALE	
Project No.	121384	Status	
BIM No.			