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Dispersion modelling of emissions to air from EPR regulated processes at Johnson Matthey, Royston, to support the permit variation for the Apollo and replacement boiler projects

Final report

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Contents

Glossary

APIS	UK Air Pollution Information System; a source of information for air pollution and its effects on habitats and species
AQMA	Air Quality Management Area; places designated by local authorities where statutory air quality objectives are not likely to be achieved
AQMAU	Air Quality Modelling and Assessment Unit (Environment Agency)
Cl_2	chlorine
CO	carbon monoxide
DMF	dimethyl formamide
EAL	Environmental Assessment Level; air quality standards set by the Environment Agency for pollutants for which no statutory air quality objective exists
IPA	propan-2-ol (*iso*-propyl alcohol)
LAQM	Local Air Quality Management; local authorities' process for assessing air quality
HCl	hydrogen chloride
LNR	Local Nature Reserve
MEK	butan-2-one (methyl ethyl ketone)
MIBK	methyl-*iso*-butyl ketone
NH_3	ammonia
NH_4Cl	ammonium chloride
NMVOC	(Non Methane) Volatile Organic Compound
NNR	National Nature Reserve
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	nitrogen oxides (nitrogen dioxide plus nitric oxide)
N_2O	nitrous oxide
PC	Process Contribution
PEC	Predicted Environmental Concentration (PC plus background concentration)
PGMR	Platinum Group Metals Refining
PM_{10}	particulates of less than 10µm effective diameter
$PM_{2.5}$	particulates of less than 2.5µm effective diameter
Ramsar	International Convention on Wetlands of International Importance especially as Waterfowl Habitat
SAC	Special Area of Conservation
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
TPM	Total Particulate Matter

1. Summary

This assessment was carried out in support of Johnson Matthey PLC's permitting arrangements with the Environment Agency for their Royston site.

In order to investigate the impact on air quality of all relevant processes at the Royston site, to support the permit variation for the Apollo and replacement boiler projects, dispersion modelling of emissions to air was carried out using the ADMS 6 model (version 6.0.1.0). Johnson Matthey PLC provided all site, stack and emissions data.

The proposed variation will result in the addition of a new stack, and the replacement of the three existing boiler stacks with three new boiler stacks.

An assessment against air quality standards for the protection of human health was carried out for all offsite locations. For nearby designated conservation areas, assessment against critical levels for the protection of vegetation and ecosystems and critical loads for nitrogen and acid deposition was carried out.

1.1 Objectives and EALs for the protection of human health

The maximum offsite concentrations of carbon monoxide, acetic acid, ammonia, hydrogen chloride, ammonium chloride, nitrous oxide and ethanal are screened out as insignificant for all years.

PCs to NO_2 and particulate concentrations are not screened out, but the PECs for both pollutants are below the air quality objectives.

Predicted concentrations of NMVOCs are compared against EALs for DMF, which has the most stringent standard. Annual average NMVOC concentrations are not screened out, but they are well below the long-term EAL for DMF. Hourly average offsite concentrations are screened out as insignificant for all years.

Chlorine concentrations are not screened out, but they are below the short-term EAL. There is no long-term EAL for chlorine.

1.2 Critical levels for the Protection of Vegetation and Ecosystems

The daily average NO_x PCs are not screened out for any of the designated conservation areas, but the annual average PCs are screened out for the six LWSs. The annual and daily average PECs are below the respective critical levels.

At all designated conservation areas except Therfield Heath, the annual average NH_3 concentrations are screened out as insignificant. At Therfield Heath, the more stringent critical level was used and the PCs are not screened out for two out of the five years of meteorological data considered. The background concentration, 1.6 $\mu g/m^3$, exceeds the critical level of 1 $\mu g/m^3$.

1.3 Critical loads for the Protection of Vegetation and Ecosystems

The maximum PCs to nitrogen and acid deposition are screened out at relevant habitats at all designated conservation areas.

2. Introduction

Cambridge Environmental Research Consultants Ltd (CERC) was commissioned by Johnson Matthey PLC to carry out a dispersion modelling assessment in support of Johnson Matthey's permitting arrangements with the Environment Agency.

In order to investigate the impact on air quality of all relevant processes at the Royston site, to support the permit variation for the Apollo (Phase 1 and Phase 2) and replacement boiler projects, dispersion modelling of emissions to air was carried out using the ADMS 6 model (version 6.0.1.0).

Section 3 presents the air quality standards with which the modelled results are to be compared. Details of the assessment area, including a description of the site, are given in Section 4, along with background and monitored concentrations for the area. Section 5 describes the site layout and emissions. The meteorological data input to the modelling are described in Section 6.

Section 7 presents predicted concentrations for comparison with objectives and EALs for the protection of human health. Predicted concentrations for comparison with critical levels for the Protection of Vegetation and Ecosystems are provided in Section 8, and Section 9 presents the results of the deposition modelling.

A discussion of all of the modelling results is provided in Section 10. Finally, a description of the ADMS model used in the assessment is given in Appendix A.

3. Air quality standards

3.1 Air quality standards for the protection of human health

UK air quality objectives for nitrogen dioxide (NO_2), particulate matter (PM_{10} and $PM_{2.5}$) and carbon monoxide (CO), set for the protection of human health, are summarised in Table 3.1. The objectives are taken from *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland*, July 2007, and are the subject of Statutory Instrument 2000 No. 928, *The Air Quality (England) Regulations 2000*, which came into force on 6th April 2000. The objective values are set at a European level, and take into account the effects of each pollutant on the health of those who are most sensitive to air quality.

Table 3.1: UK Air Quality Objectives for the Protection of Human Health

Substance	Limit value (µg/m^3)	Reference period and allowed exceedences
NO_2	200	hourly mean not to be exceeded more than 18 times a year (modelled as 99.79th percentile)
	40	annual mean
PM_{10}	50	daily mean not to be exceeded more than 35 times a year (modelled as 90.41st percentile)
	40	annual mean
$PM_{2.5}$	20	annual mean
CO	10,000	maximum daily running 8-hour mean

A number of the air quality objectives are specified in terms of the number of times during a year that a concentration measured over a short period of time (for example, 15 minutes, 1 hour or 24 hours, as appropriate) is permitted to exceed a specified value. For example, the concentration of NO_2 measured as the average value recorded over a one-hour period is permitted to exceed the concentration of 200 µg/m^3 up to 18 times per year. Any more exceedences than this during a one-year period would represent a breach of the objective.

It is convenient to model objectives of this form in terms of the equivalent percentile concentration value. A percentile is the concentration below which lie a specified percentage of concentration measurements. For example, consider the 98th percentile of one-hour concentrations over a year. Taking all of the 8760 one-hour concentration values that occur in a year, the 98th percentile value is the concentration below which 98% of those concentrations lie. Or, in other words, it is the concentration exceeded by 2% (100 – 98) of those hours, that is, 175 hours per year. Taking the NO_2 objective considered above, allowing 18 exceedences per year is equivalent to not exceeding for 8742 hours or for 99.79% of the year. This is therefore equivalent to the 99.79th percentile value.

For some pollutants considered in this assessment, there are no air quality objectives, so Environmental Assessment Levels (EALs)[1] for the protection of human health were used, as presented in Table 3.2. Note that the table includes an additional short-term EAL for CO, which was considered, as well as the air quality objective presented in Table 3.1.

There are no published EALs for ammonium chloride (NH_4Cl) or nitrous oxide (N_2O).

- For NH_4Cl, the hierarchy set out in Environment Agency guidance on the derivation of new EALs to air [2] was followed. The long-term DNEL (Derived No Effect Level) for inhalation, for the General Population, was selected as a suitable long-term EAL.[3] No short-term hazard was identified.

- For N_2O, NOAEC values were found but it was not clear how uncertainty factors could be applied. Therefore, EALs were derived from the long-term Workplace Exposure Limit (WEL), using safety factors recommended in the withdrawn Environment Agency H1 guidance.

Table 3.2: Environmental Assessment Levels (EALs) (μg/m³)

	Long-term	**Short-term (hourly)**
Acetic acid	250	3,700
NH_3	180	2,500
N_2O [4]	1,830	54,900
NH_4Cl [5]	9,400	-
CO	-	30,000
Cl_2	-	290
HCl	-	750
Ethanal	370	9,200

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[1] https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit

[2] https://consult.environment-agency.gov.uk/environment-and-business/new-air-environmental-assessment-levels/supporting_documents/2012%20consultation%20on%20derivation%20of%20new%20Environmental%20Assessment%20Levels%20to%20air.pdf

[3] https://echa.europa.eu/brief-profile/-/briefprofile/100.031.976

[4] EALs derived from WELs using withdrawn Environment Agency H1 guidance.

[5] DNEL

As there are no standards for VOCs as a group, the EALs for the emitted VOCs were considered, as presented in Table 3.3; the most stringent EALs, those for DMF, were used for comparison with predicted concentrations of all VOCs combined. Note that ethanal was considered separately.

Table 3.3: Environmental Assessment Levels (EALs) (μg/m^3) for individual VOCs

	Long-term	Short-term (hourly)
Acetone	18,100	362,000
Acetonitrile	680	10,200
Butan-2-one (methyl ethyl ketone, MEK)	6,000	89,900
Dimethylformamide (DMF)	300	6,100
n-Hexane (used for petroleum products)	720	21,600
Pentan-2-one or methyl propyl ketone (used for methyl iso-butyl ketone, MIBK)	7,160	89,500
2-Propanol (isopropyl alcohol, IPA)	9,990	125,000

3.2 Critical levels for the Protection of Vegetation and Ecosystems

The critical levels for the Protection of Vegetation and Ecosystems, as set out in the Environment Agency's guidance for environmental permits[1], are summarised in Table 3.4.

The guidance recommends the assessment of:

- Special Protection Areas (SPAs)[6], Special Areas of Conservation (SACs)[7] and Ramsar[8] sites within 10 km of the installation; and
- Sites of Special Scientific Interest (SSSI)[9], National Nature Reserves (NNR)[9], Local Nature Reserves (LNR)[10], local wildlife sites (LWS) and ancient woodland within 2 km of the installation.

Table 3.4: Critical levels for the Protection of Vegetation and Ecosystems

	Critical level ($\mu g/m^3$)	**Comment**
NH_3	1	annual mean (for sensitive lichen & bryophytes communities and ecosystems where lichens & bryophytes are an important part of the ecosystem's integrity)
	3	annual mean (for all higher plants - all other ecosystems)
NO_x	30	annual mean
	75	daily mean

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[6] Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora

[7] Council Directive 79/409/EEC on the conservation of wild birds

[8] International Convention on Wetlands of International Importance especially as Waterfowl Habitat

[9] Declared by the statutory country conservation agencies, which have a duty under the Wildlife and Countryside Act 1981

[10] Declared under the National Parks and Access to the Countryside Act 1949 by local authorities after consultation with the relevant statutory nature conservation agency

4. Assessment area

4.1 Site location and surrounding area

The Johnson Matthey site is located on the north west edge of Royston, within the A505 Royston bypass. In the vicinity of the site, there are residential and other areas where the public may be exposed to the impact of emissions from the site. The location of the site is shown in Figure 4.1.

There are no SPAs, SACs or Ramsar sites within 10 km of the Johnson Matthey site. There are two SSSIs within 2 km of the site: Therfield Heath, to the south west of Royston; and Holland Hall (Melbourn) railway cutting, 1 km north east of Royston. Therfield Heath is also a Local Nature Reserve (LNR). The Environment Agency also requested that impacts be assessed at six Local Wildlife Sites (LWS):

1. Royston Chalk Pit;
2. Therfield, South of Tumulus;
3. Green Lane South of Royston;
4. Icknield Way, A505 North of Gallows Hill;
5. Therfield Green Lane; and
6. Shaftesbury Green.

The two SSSIs and six LWSs are shown on Figure 4.1.

The dispersion modelling has concentrated on an output grid of 3 km by 3 km, approximately centred on the site, with concentration values calculated at points 30 m apart within this grid.

A surface roughness length is used in the model to characterise the surrounding area in terms of the effects it will have on wind speed and turbulence, which are key components of the modelling. A value of 0.5 metres was used in this assessment, which represents open suburbia, and is therefore appropriate for the surrounding land use. A different surface roughness value was used for the Andrewsfield meteorological site, as described in Section 6.

In urban and suburban areas, a significant amount of heat is emitted by buildings and traffic, which warms the air within and above the area. This is known as the urban heat island and its effect is to prevent the atmosphere from becoming very stable. In general, the larger the urban area, the more heat is generated and the stronger the effect becomes. In the ADMS model, the stability of the atmosphere is represented by the Monin-Obukhov parameter, which has the dimension of length. The effect of the urban heat island is that, in stable conditions, the Monin-Obukhov length will never fall below some minimum value; the larger the urban area, the larger the minimum value. A value of 10 metres was used in this modelling, which is suitable for a small town. The model default value of 1 m was used for the Met Office Andrewsfield site.

4.2 Terrain data

The site is situated at a height of approximately 55 m above sea level, on a shallow slope rising from about 25 m in the north to 135 m in the south. The effects of the local terrain on dispersion may be significant and so were included in the modelling. Figure 4.2 shows a diagram of the local terrain. Note that the height scale shown on this plot is exaggerated.

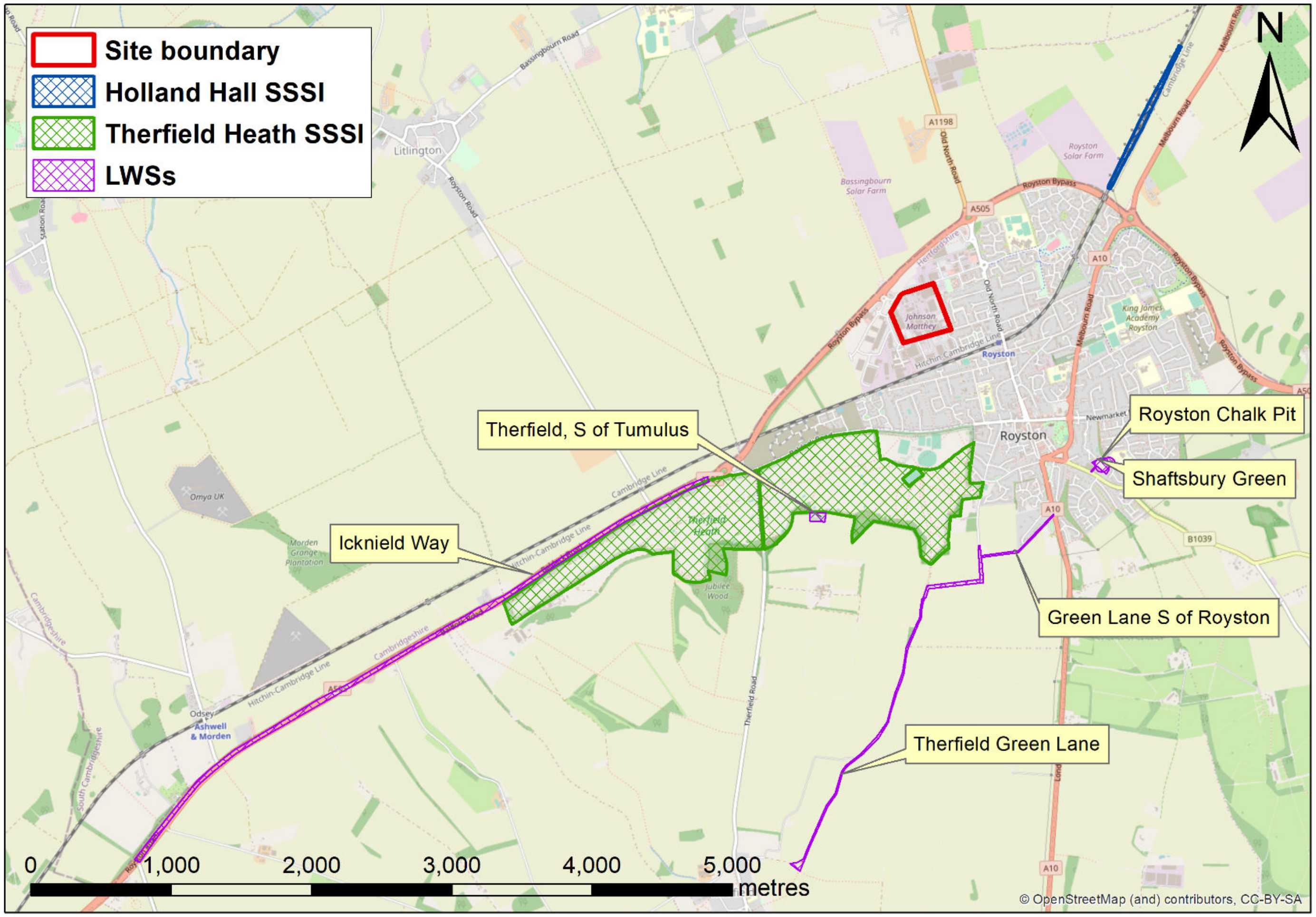

Figure 4.1: Site location

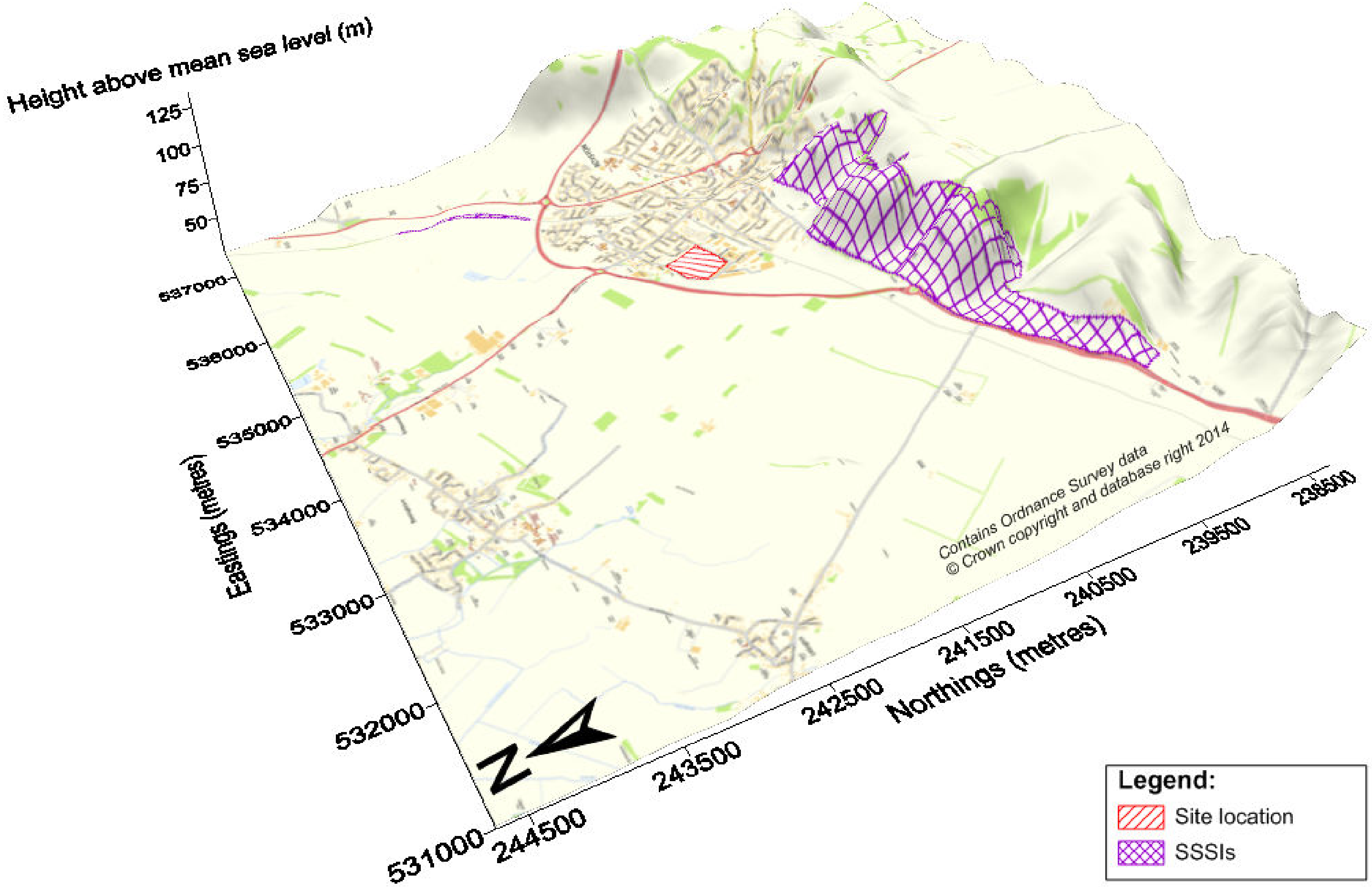

Figure 4.2: Local terrain (note: height scale exaggerated)

4.3 Local air quality

4.3.1 AQMAs and monitoring data

There are no Air Quality Management Areas (AQMAs) close to the Johnson Matthey site; the nearest AQMAs are approximately 20 km away, in Hitchin, and are therefore unlikely to be affected by emissions from the Johnson Matthey site.

NO_2 concentrations in Royston are monitored by North Hertfordshire District Council using diffusion tubes at two roadside locations. Annual average concentrations for the years 2020 to 2022 were taken from North Hertfordshire District Council's air quality report[11] and are presented in Table 4.1. Monitored concentrations are well below the air quality objective of 40 µg/m^3 for annual average NO_2 concentrations.

Table 4.1: NO_2 diffusion tube monitoring in Royston (µg/m^3)

Monitor ref	Location (from JM site)	Grid ref (m)	Type	2020	2021	2022
NH06	Melbourn Road opposite Town Hall (1 km south east)	535906, 240794	Roadside	21.7	20.5	27.4
NH115	Old North Road (300 m east)	535373, 241466	Roadside	21.5	17.5	19.2

4.3.2 Mapped background data

Background concentrations of carbon monoxide (CO) for the year 2010 and nitrogen dioxide (NO_2) and particulates (PM_{10} and $PM_{2.5}$) for the year 2022 were obtained from the UK AIR Air Information Resource background mapping [12].

These values are provided on a 1 km grid basis; Table 4.2 presents annual average concentrations for the grid square containing the Johnson Matthey site.

Table 4.2: Background concentrations from Defra background maps (µg/m^3)

Location (x,y) of grid square centre	NO_2	PM_{10}	$PM_{2.5}$	CO
534500, 241500	12.2	15.6	8.9	226

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[11] https://www.north-herts.gov.uk/home/environmental-health/pollution/air-quality/air-quality-reports

[12] https://uk-air.defra.gov.uk/data/gis-mapping/

Mapped background data for NH_3 and NO_x at the location of each SSSI and LWS, taken from the Air Pollution Information System (APIS) website,[13] are shown in Table 4.3. These values represent three year averages, over the period 2019 to 2021, at 1 km grid resolution.

Table 4.3: Background concentrations for SSSI / LWS from APIS website (µg/m³)

Sensitive site	Designation	Location (x,y)	NH_3	NO_x
Therfield Heath	SSSI	534500, 240500	1.6	10.8
Holland Hall	SSSI	536500, 242500	1.6	11.0
Royston Chalk Pit	LWS	536500, 240500	1.5	11.2
Therfield, South of Tumulus	LWS	534500, 240500	1.6	10.8
Green Lane South of Royston	LWS	535500, 239500	1.5	10.0
Icknield Way, A505 North of Gallows Hill	LWS	531500, 239500	1.6	11.2
Therfield Green Lane	LWS	534500, 238500	1.5	9.7
Shaftesbury Green	LWS	536500, 240500	1.5	11.2

4.3.3 Other background data

NH_3 and HCl are measured as part of Defra's National Ammonia Monitoring Network [14] and Acid Gases and Aerosol Network[15], respectively. For both networks, the nearest monitoring location to the Johnson Matthey site is Rothamsted, 35 km south west of Royston. Annual average concentrations of both pollutants for the most recent year of measurement in each case are presented in Table 4.4.

Table 4.4: Monitored HCl and NH_3 concentrations at Rothamsted (µg/m³)

Pollutant	Concentration	Year
HCl	0.28	2015
NH_3	0.78	2023

No background data were available for the other modelled pollutants.

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[13] http://www.apis.ac.uk/srcl

[14] https://uk-air.defra.gov.uk/networks/network-info?view=nh3

[15] https://uk-air.defra.gov.uk/networks/network-info?view=aganet

5. Site layout and source data

5.1 Modelled sources

A total of 27 stacks was considered. Table 5.1 sets out the stack information for all modelled sources, based on data provided by Johnson Matthey. Note that two phases of the Project Apollo were assessed.

The locations of the modelled stacks and site buildings are shown in Figure 5.1.

As efflux temperatures are measured at the sampling point rather than stack exit, efflux temperatures stated as being over 60°C [16] were reduced, assuming that the temperature will be reduced by 50% of the stack temperature in excess of an ambient temperature of 20°C. The efflux velocity was recalculated accordingly.

Typical and peak pollutant emission rates provided by Johnson Matthey are presented in Table 5.2 and Table 5.3. Due to the batch nature of many processes and the consequent variability in emissions, the calculation of 'typical' and 'peak' values is complex. Typical emission rates were used in the assessment against long-term air quality standards and peak emission rates were used in the assessment against short-term air quality standards.

Typical emissions were calculated based upon one of three input data sources.

1. For existing stacks with periodic monitoring data, mass emissions (g/s) were calculated from the most recent monitored data.
2. For stack A197, the annual mass emission limit was used to calculate mass emissions (g/s).
3. For new emission point (A286) and the boiler replacement stacks, emissions were derived from design information.

Peak emissions were derived from the stack emission limits and the most recent stack flow monitoring data or, where no emission limit exists, the highest hourly emissions recorded over the last three years.

Table 5.4 provides details of the breakdown of non-methane VOC (NMVOC) emissions, as estimated by Johnson Matthey. Predicted concentrations were compared against EALs for dimethyl formamide (DMF), the VOC with the most stringent standard. DMF is a minor component of the VOC emissions from just one stack, therefore a comparison against the EALs for this pollutant is a worst case assessment.

Note that ethanal (emitted by Project Apollo, stack A286 only) was considered separately.

Emission rates provided for total particulate matter (TPM) were used as conservative values for both PM_{10} and $PM_{2.5}$.

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[16] A230, A231, A8a, A8b and A3

Table 5.1: Stack parameters

Process	Stack	Height (m)	Diameter (m)	Exit velocity (m/s)	Actual volumetric flow rate (m^3/s)	Normal volumetric flow rate at STP (Nm^3/s)	Temperature (°C)	Location (m)	
								x	y
Fastcat	A207	21.5	0.9	20.4	12.99	11.59	31.5	534899	241580
CSF1	A230	21.5	0.9	11.7	8.91	5.58	90.2	534883	241575
CSF2	A231	25	1.32	7.4	11.09	7.98	62.4	534879	241546
Procat 1	A182	6.5	0.34 [17]	0.1 [18]	0.28	0.27	16.9	534757	241519
AgT	A57	12.5	0.5	8.6	1.69	1.58	20.2	534788	241602
AgT	A228	12	0.5	3.3	0.65	0.61	17.7	534741	241600
AgT	A109	8.6	0.4	7.8	0.98	0.92	19.2	534782	241620
F/C Inorganics	A11	17.6	0.78	9.4	4.44	4.23	15.1	534751	241525
F/C Inorganics	A4	30	0.8	8.5	4.28	3.98	22.0	534719	241507
HCP	A197	12	0.15	20.3	0.36	0.0001	15.0	534739	241400
PGMR	A28	44.7	0.8	16.9	8.50	7.77	25.5	534811	241438
PGMR	A30	44.7	0.8	16.0	8.04	7.47	21.3	534813	241439
PGMR	A31	44.7	0.8	16.2	8.16	7.55	22.5	534812	241441
PGMR	A35	8.01	0.3	3.0	0.21	0.19	23.0	534800	241473
PGMR	A80	6.1	0.2	7.2	0.23	0.22	13.0	534778	241447
Noble Metals	A225	9.5	0.25	2.1	0.10	0.09	27.3	534715	241392.5
Noble Metals	A226	10	0.5	9.7	1.90	1.74	25.0	534714	241393
CHP	A8a	15	0.6	8.3	2.64	2.67	61.6	534699	241613
CHP	A8b	15	0.6	8.5	2.82	3.17	81.5	534700	241610
VRP	A27	18.9	0.56	4.0	0.99	0.90	27.2	534745	241558
CA TC	A3	21	0.9	14.8	10.09	8.35	43.0	534923.5	241397
PU12	A97	24	0.25	5.7	0.28	0.26	29.5	534745	241441.5
PU12	A98	24	0.2	11.0	0.35	0.32	18.3	534742.5	241440.5
Project Apollo - Phase 1	A286	25	1.25	5.7	6.94	4.95	110.0	534870.5	241562
Project Apollo - Phase 2	A286	25	1.25	6.8	8.33	5.94	110.0	534870.5	241562
Boiler Replacement	A13	9.9	0.35	12.7	1.22	0.71	194.0	534868	241366
Boiler Replacement	A15	9.9	0.35	12.7	1.22	0.71	194.0	534870	241362
Boiler Replacement	A16	9.9	0.35	12.7	1.22	0.71	194.0	534871	241358

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[17] Effective diameter calculated for square duct 0.3 m diameter

[18] Horizontal release so minimum vertical exit velocity assumed

Table 5.2: Typical emission rates (g/s)

Stack	HCl	Cl_2	NO_x	CO	TPM	NH_3	NH_4Cl	NMVOC	Ethanal	Acetic acid	N_2O
A207	-	-	0.0713	0.0048	-	0.0214	-	-	-	-	-
A230	-	-	0.0605	0.0173	-	0.0061	-	-	-	-	-
A231	-	-	0.0273	0.0336	-	0.0145	-	-	-	-	-
A182	-	-	-	-	0.0030	-	-	-	-	-	-
A57	-	-	-	-	-	-	-	0.1988	-	-	-
A228	-	-	-	-	-	-	-	0.0028	-	-	-
A109	-	-	-	-	-	-	-	0.0047	-	-	-
A11	-	-	0.2220	-	-	-	-	-	-	0.0060	0.0016
A4	0.0213	0.0015	0.0032	-	0.0043	0.0007	-	-	-	-	-
A197	-	-	-	-	-	-	-	0.0686	-	-	-
A28	0.0264	0.0013	-	-	-	-	0.0014	-	-	-	-
A30	0.0240	0.0045	-	-	-	-	0.0006	-	-	-	-
A31	0.0594	0.0004	-	-	-	-	0.0007	-	-	-	-
A35	0.0001	0.0004	-	-	-	-	-	-	-	-	-
A80	0.0013	-	-	-	-	-	-	0.0118	-	-	-
A225	0.0002	0.00003	-	-	-	-	-	-	-	-	-
A226	0.0162	-	0.0008	-	-	-	-	-	-	-	-
A8a	-	-	0.2058	0.4050	-	-	-	-	-	-	-
A8b	-	-	0.0944	0.6776	-	-	-	-	-	-	-
A27	0.0004	-	-	-	-	0.0090	-	0.0051	-	-	-
A3	-	-	0.0133	-	-	-	-	-	-	-	-
A97	0.00004	0.00009	-	-	-	-	-	-	-	-	-
A98	-	-	-	-	-	0.00003	-	-	-	-	-
A286 Phase 1	-	-	0.1485	0.2475	-	-	-	-	0.0990	-	-
A286 Phase 2	-	-	0.1782	0.2970	-	-	-	-	0.1188	-	-
A13	-	-	0.0444	-	-	-	-	-	-	-	-
A15	-	-	0.0444	-	-	-	-	-	-	-	-
A16	-	-	0.0444	-	-	-	-	-	-	-	-

Table 5.3: Peak emission rates (g/s)

Stack	HCl	Cl_2	NO_x	CO	TPM	NH_3	NH_4Cl	NMVOC	Ethanal	Acetic acid	N_2O
A207	-	-	0.5793	1.1585	-	0.1738	-	-	-	-	-
A230	-	-	0.2788	0.5576	-	0.0836	-	-	-	-	-
A231	-	-	0.3990	0.7980	-	0.1197	-	-	-	-	-
A182	-	-	-	-	0.0053	-	-	-	-	-	-
A57	-	-	-	-	-	-	-	0.2069	-	-	-
A228	-	-	-	-	-	-	-	0.0456	-	-	-
A109	-	-	-	-	-	-	-	0.0102	-	-	-
A11	-	-	0.8463	-	-	-	-	-	-	0.2116	0.8463
A4	0.0398	0.0398	0.7958	-	0.0796	0.0597	-	-	-	-	-
A197	-	-	-	-	-	-	-	0.1586	-	-	-
A28	0.0777	0.5442	-	-	-	-	0.0777	-	-	-	-
A30	0.0747	0.5232	-	-	-	-	0.0747	-	-	-	-
A31	0.0755	0.5288	-	-	-	-	0.0755	-	-	-	-
A35	0.0019	0.0010	-	-	-	-	-	-	-	-	-
A80	0.0022	-	-	-	-	-	-	0.0163	-	-	-
A225	0.0009	0.0009	-	-	-	-	-	-	-	-	-
A226	0.0174	-	0.2615	-	-	-	-	-	-	-	-
A8a	-	-	0.5342	0.6143	-	-	-	-	-	-	-
A8b	-	-	0.6345	0.8537	-	-	-	-	-	-	-
A27	0.0090	-	-	-	-	0.0090	-	0.0897	-	-	-
A3	-	-	0.0300	-	-	-	-	-	-	-	-
A97	0.0008	0.0008	-	-	-	-	-	-	-	-	-
A98	-	-	0.0649	-	-	0.0004	-	-	-	-	-
A286 Phase 1	-	-	0.1485	0.2475	-	-	-	-	0.0990	-	-
A286 Phase 2	-	-	0.1782	0.2970	-	-	-	-	0.1188	-	-
A13	-	-	0.1070	-	-	-	-	-	-	-	-
A15	-	-	0.1070	-	-	-	-	-	-	-	-
A16	-	-	0.1070	-	-	-	-	-	-	-	-

Table 5.4: Breakdown of NMVOC emissions

Stack	Total NMVOC emissions (g/s)		Details of NMVOC components (% breakdown, where available)							
	Typical	Peak	Acetone	Acetonitrile	MEK	DMF	Petroleum products	MIBK	IPA	Other (components with no EALs)
A57	0.1988	0.2069	-	-	-	-	Exxsol D40 Exxsol D80 Surfynol 440	-	80%	Carbitol acetate Butyl cellosolve acetate Butyl carbitol acetate Priolene 6910 Pine Oil Proglyde DMM glycol diether
A228	0.0028	0.0456	-	-	-	-	10% White spirit	-	90%	-
A109	0.0047	0.0102	-	-	-	-	10% White spirit	-	90%	-
A197	0.0686	0.1586	Yes	Yes	60%	Yes	Petroleum ether	-	Yes	Methylated spirits
A80	0.0118	0.0163	-	-	-	-	50% Shellsol D70	-	-	30% Tributyl phosphate 20% Nitta N-iso tridecyl N-iso tridecanamide
A27	0.0051	0.0897	-	-	-	-	-	100%	-	-

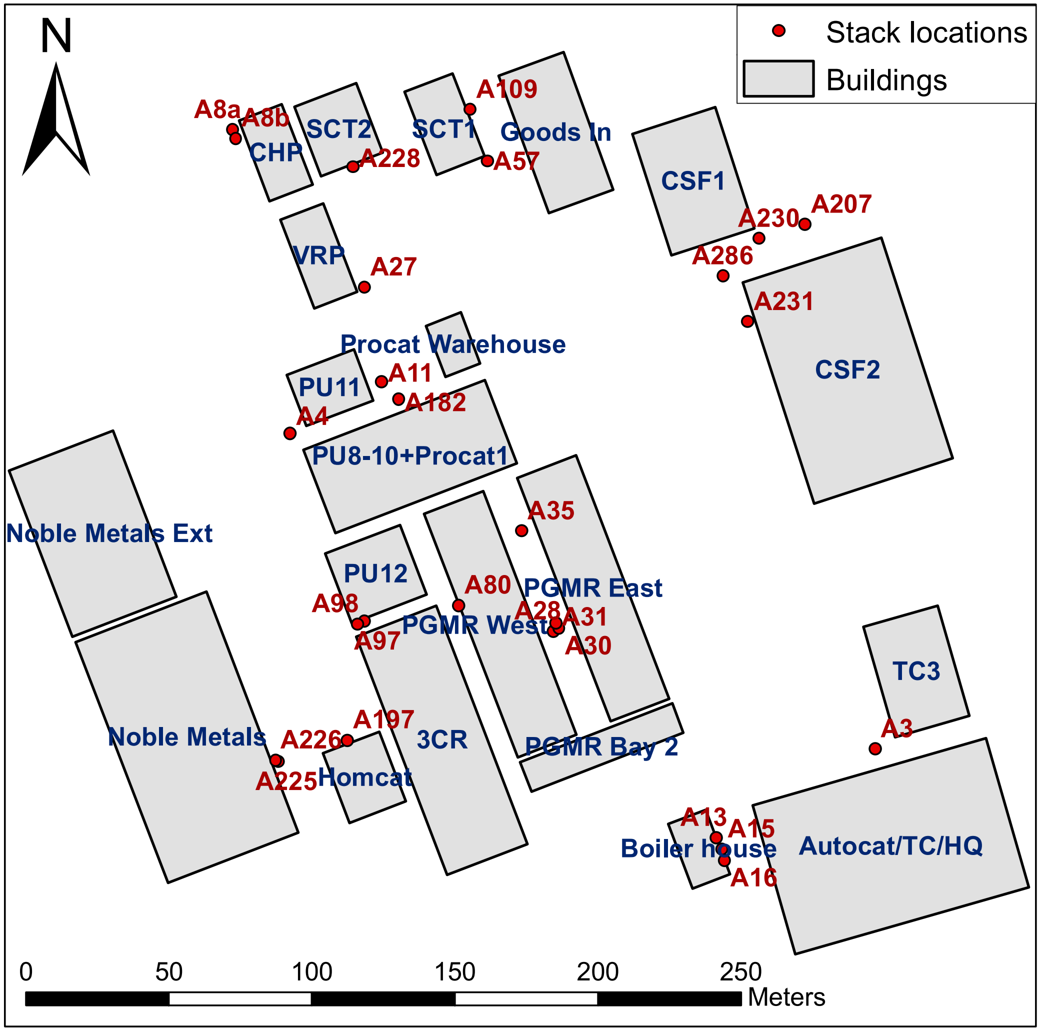

Figure 5.1: Modelled buildings and sources

5.2 Modelled buildings

Table 5.5 summarises the dimensions of the site buildings shown in Figure 5.1, as provided by Johnson Matthey.

ADMS 6 offers a facility to allow the model to select the most significant building for impacts on dispersion from each stack, for each hour of meteorological data. This facility was used to generate the final results.

Table 5.5: Site buildings

Name	Coordinates of building centre		Height (m)	Length (m)	Width (m)	Angle of length from north (°)
	x	y				
3CR	534772	241400	18	89	30	159
Autocat/TC/HQ	534929	241363	13.2	54	85	164
Boiler house	534862	241362	6.8	24	14	159
CHP	534714	241605	9.2	30	16	159
CSF1	534860	241595	17.5	44.5	30.5	162
CSF2	534914	241529	18.6	81	51	162
Goods In	534812	241612	10	51	24	160
Homcat	534745	241387	9.5	26	21	159
Noble Metals	534683	241401	8.1	90	49	159
Noble Metals Extension	534650	241472	10.4	62	39	159
PGMR Bay 2	534828	241397.5	18.9	57	11	69
PGMR East	534825	241453	9.8	91	22	159
PGMR West	53472.5	241440.5	9.8	91	21	159
Procat Warehouse	534776	241538	9.1	19	13	159
PU11	534733	241523	10.2	25	19	69
PU12	534749	241458	24.5	28	26	69
PU8-10 & Procat1	534761	241499	7	68	31	69
SCT1	534773	241615	6	31	18	159
SCT2	534736	241613	11	26	23	159
TC3	534938	241424	17	40	27	164
VRP	534729	241569	15.7	33	16	159

6. Meteorological data

Modelling was carried out using hourly sequential meteorological data obtained from Andrewsfield meteorological station for the years 2016 to 2020 inclusive. Andrewsfield is located about 40 km to the south east of the Royston site.

A surface roughness length of 0.2 metres was used to characterise the Andrewsfield meteorological station. The value is representative of agricultural areas, considered appropriate for the surrounding land use.

The hours of meteorological data used in the analysis exclude hours of calm, hours of variable wind direction and unavailable data, for example due to issues with the instrumentation. A summary of the data used is given in Table 6.1. The ADMS meteorological pre-processor, written by the Met Office, uses the meteorological data to calculate the parameters required by the model.

Figure 6.1 shows wind roses for Andrewsfield, giving the frequency of occurrence of wind from different directions for a number of wind speed ranges, for the five years 2016 to 2020.

Table 6.1: Summary of meteorological data used

	Percentage used	Parameter	Minimum	Maximum	Mean
2016	93.8	Temperature (°C)	-3.7	32.0	10.5
		Wind speed (m/s)	0	19.5	4.1
		Cloud cover (oktas)	0	8	4.5
		Relative humidity (%)	25.6	100	82.3
		Annual rainfall (mm)	512		
2017	95.3	Temperature (°C)	-5.0	29.6	10.7
		Wind speed (m/s)	0	19.5	4.2
		Cloud cover (oktas)	0	8	4.8
		Relative humidity (%)	25.4	100	82.4
		Annual rainfall (mm)	541		
2018	91.6	Temperature (°C)	-6.2	32.2	11.0
		Wind speed (m/s)	0	19.5	4.0
		Cloud cover (oktas)	0	8	4.6
		Relative humidity (%)	25.3	100	80.8
		Annual rainfall (mm)	508		
2019	93.3	Temperature (°C)	-6.2	34.5	10.6
		Wind speed (m/s)	0	17.5	4.1
		Cloud cover (oktas)	0	8	4.5
		Relative humidity (%)	27	100	82.0
		Annual rainfall (mm)	573		
2020	95.2	Temperature (°C)	-2.4	33.7	11.1
		Wind speed (m/s)	0	17.5	4.5
		Cloud cover (oktas)	0	8	4.3
		Relative humidity (%)	23	100	79.9
		Annual rainfall (mm)	636		

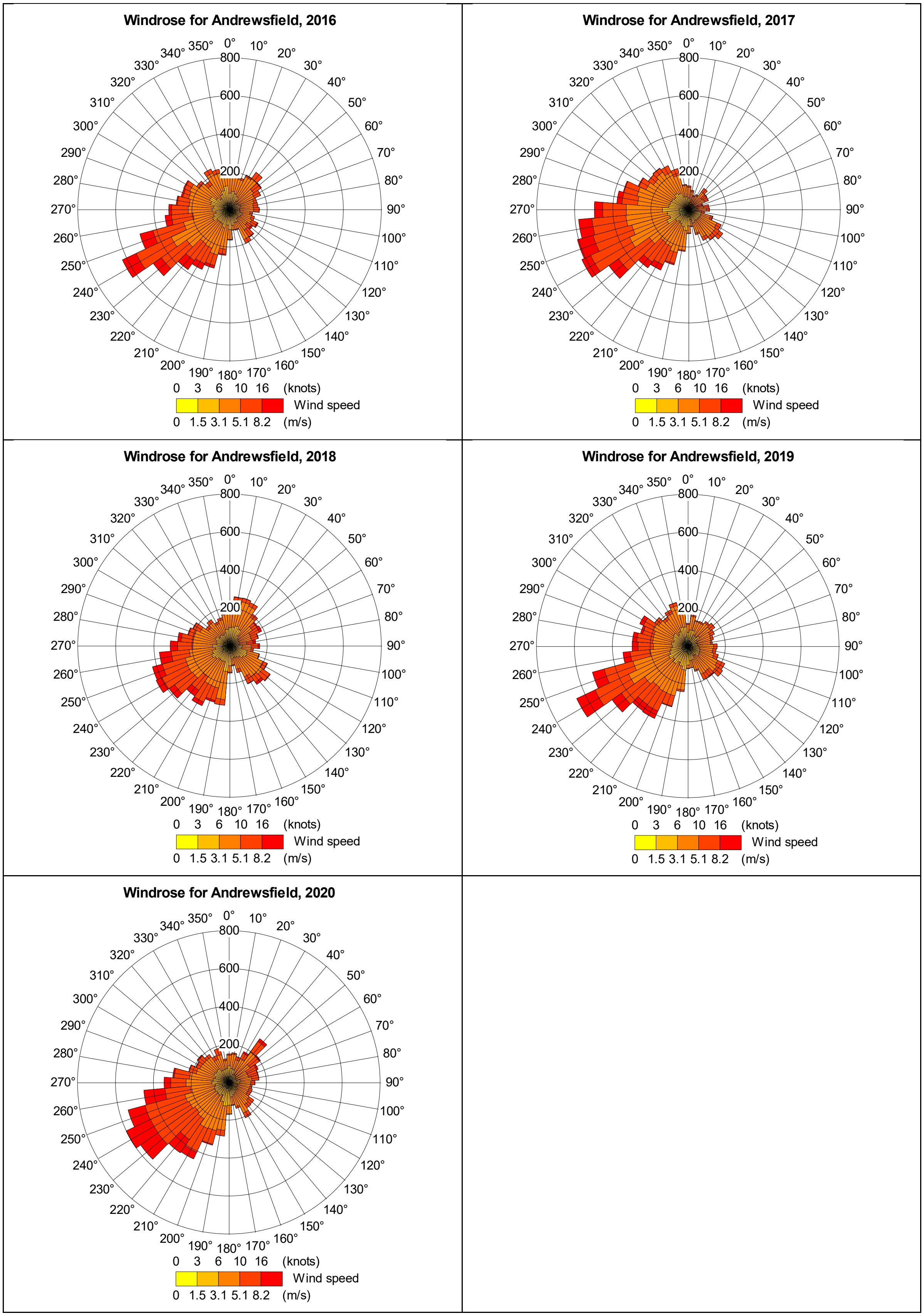

Figure 6.1: Wind roses for Andrewsfield, 2016-2020

7. Consideration of objectives and EALs for the protection of human health

Modelling was carried out to predict the Process Contribution (PC) to ground level concentrations of each relevant pollutant from the Johnson Matthey Royston site. The significance of the total pollutant release was assessed by comparing the PC to the relevant air quality objective or EAL. For long-term standards, the Environment Agency considers the release to be insignificant if the PC is less than 1% of the air quality standard.[1] For short-term standards, including percentiles, the Agency considers the release to be insignificant if the PC is less than 10% of the air quality standard.[1] Where a release is insignificant, the pollutant is screened out and no further assessment of levels of that pollutant undertaken.

Where a release is significant, the Predicted Environmental Concentration (PEC) for that substance is calculated. For long-term standards, the PEC is calculated by adding the PC to the estimated background concentration of the pollutant. For short-term standards, including percentiles, the PEC is calculated by adding the PC to twice the estimated background concentration of the pollutant.

For the assessment of human health effects, all maximum concentrations represent the maximum offsite concentrations; that is, concentrations within the site boundary were excluded.

7.1 Predicted concentrations of nitrogen dioxide

Nitrogen oxides (NO_x) comprise nitric oxide (NO) and nitrogen dioxide (NO_2). Only NO_2 is considered in statutory air quality objectives for the protection of human health; the NO_x critical levels for the Protection of Vegetation and Ecosystems are considered in Section 8.1.

The PC to NO_2 concentrations depends on the concentrations of NO_x due to other sources in the area and the chemical reactions taking place between NO and NO_2.

For direct comparison against the objectives for NO_2, an empirical relationship defined by the Environment Agency was therefore used to calculate the NO_2 PEC. This method assumes that a fixed proportion of the PC of NO_x is NO_2 (70% for the annual average and 35% for the 99.79th percentile of hourly averages). The NO_2 PEC is calculated by adding the annual average NO_2 background concentration to the annual average concentration, and twice the annual average background concentration of NO_2 to the 99.79th percentile of hourly average concentrations.

7.1.1 Apollo Phase 1

Table 7.1 shows the maximum predicted offsite concentrations of NO_2 with Apollo Phase 1, calculated using meteorological data for the five years 2016 to 2020.

The maximum annual average offsite NO_2 PC is 4.1 $\mu g/m^3$, 10% of the air quality objective of 40 $\mu g/m^3$, calculated using meteorological data for the year 2020. Including the background concentration of 12.2 $\mu g/m^3$, maximum predicted offsite PECs are below the air quality objective.

Figure 7.1 shows a contour plot of annual average NO_2 PC concentrations, based on meteorological data for the year 2020, the year giving the highest predicted annual average concentrations.

The maximum offsite 99.79th percentile of hourly average NO_2 PC concentration is 86 $\mu g/m^3$, 43% of the air quality objective of 200 $\mu g/m^3$, calculated using meteorological data for the year 2018. Including the background concentration of 24.4 $\mu g/m^3$, maximum predicted offsite PECs are below the air quality objective.

Figure 7.2 shows a contour plot of the 99.79th percentile of hourly average NO_2 PC concentrations, based on meteorological data for the year 2018, the year giving the highest predicted hourly average concentrations.

Table 7.1: Maximum predicted offsite concentrations of NO_2 (µg/m³), Apollo Phase 1

Year	Standard	Measured as	Objective value	PC (NO_x)	PC (NO_2)[19]	PC % of objective	Background NO_2[20]	PEC (NO_2)	PEC % of objective	Location x	Location y
2016	Short-term AQO	99.79th percentile of hourly averages	200	243	85	43	24.4	109	55	534680	241320
	Long-term AQO	Annual average	40	5.5	3.9	10	12.2	16	40	534770	241650
2017	Short-term AQO	99.79th percentile of hourly averages	200	241	84	42	24.4	108	54	534650	241650
	Long-term AQO	Annual average	40	5.7	4.0	10	12.2	16	40	534770	241650
2018	Short-term AQO	99.79th percentile of hourly averages	200	247	86	43	24.4	110	55	534680	241320
	Long-term AQO	Annual average	40	4.9	3.4	9	12.2	16	39	534770	241650
2019	Short-term AQO	99.79th percentile of hourly averages	200	236	83	42	24.4	107	54	534650	241650
	Long-term AQO	Annual average	40	5.7	4.0	10	12.2	16	40	534770	241650
2020	Short-term AQO	99.79th percentile of hourly averages	200	241	84	42	24.4	108	54	534650	241650
	Long-term AQO	Annual average	40	5.8	4.1	10	12.2	16	41	534770	241650

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[19] 35% of short-term NO_x PC and 70% of long term NO_x PC

[20] Adding double the annual average background concentration to the 99.79th percentile of hourly averages

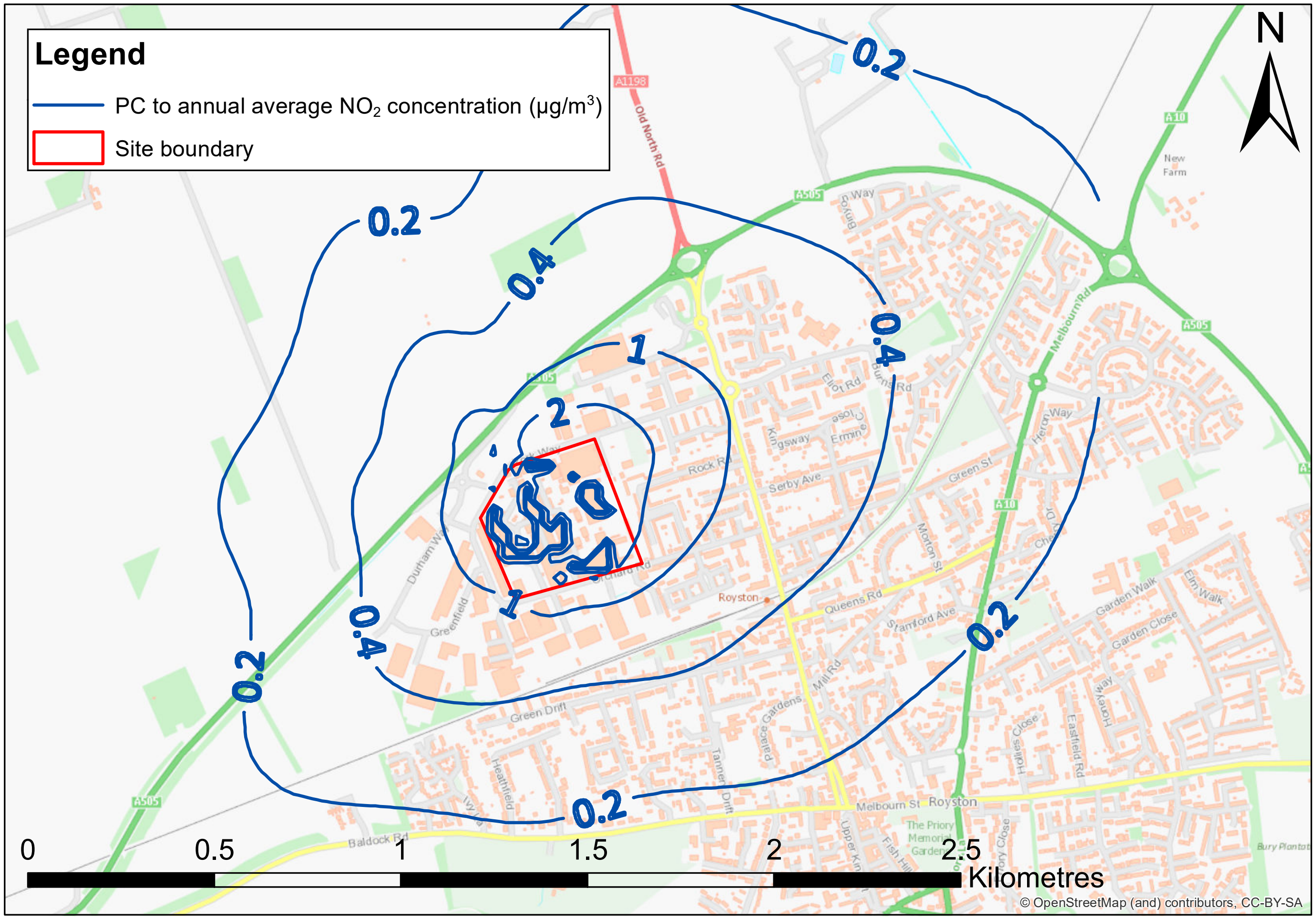

Figure 7.1: Contour plot of the PC to annual average NO_2 concentration, Apollo Phase 1, using meteorological data for the year 2020

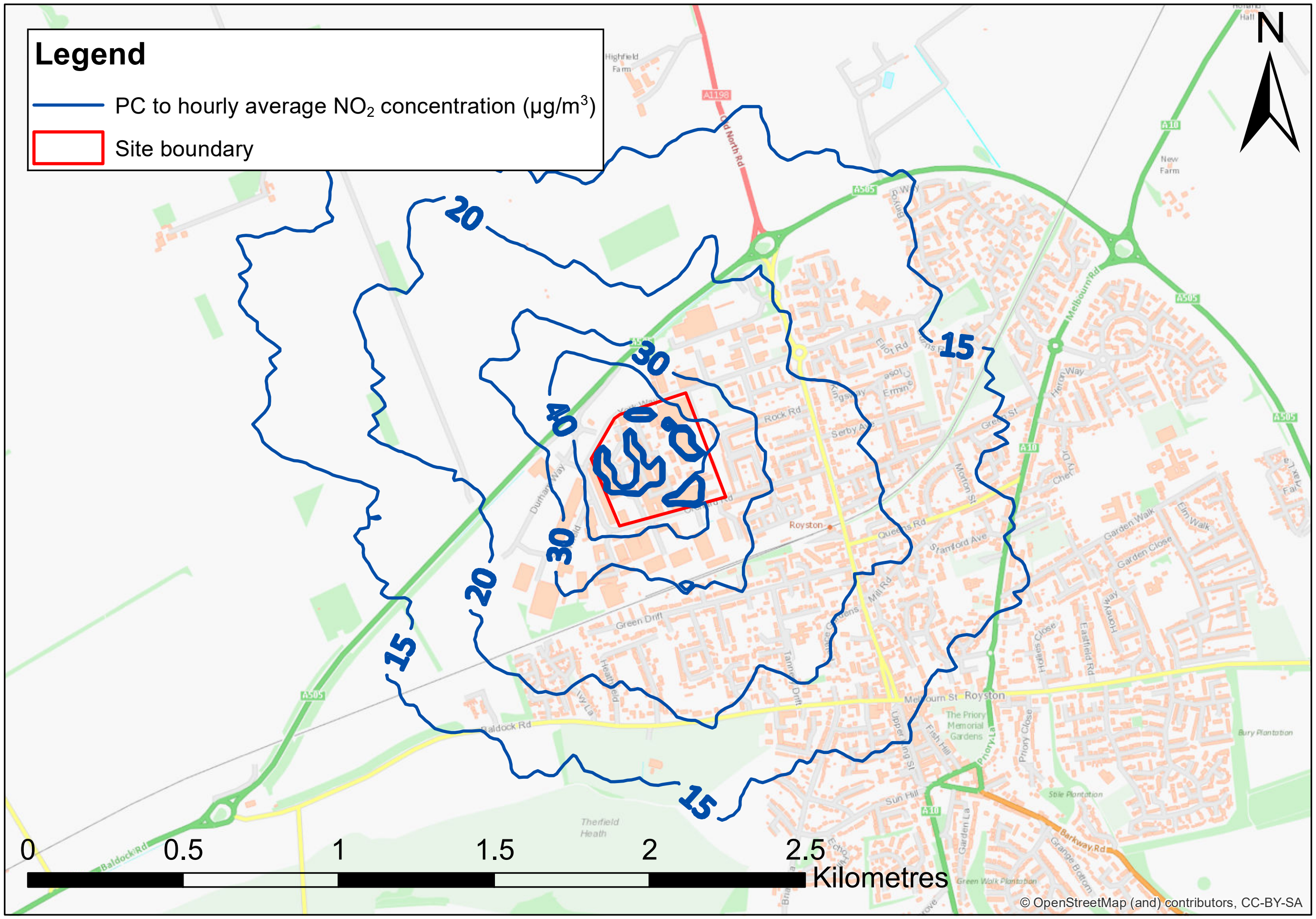

Figure 7.2: Contour plot of the PC to 99.79th percentile of hourly average NO_2 concentration, Apollo Phase 1, using meteorological data for the year 2018

7.1.2 Apollo Phase 2

Table 7.4 shows the maximum predicted offsite concentrations of NO_2 with Apollo Phase 2, calculated using meteorological data for the five years 2016 to 2020.

The results are almost identical to those for Phase 1; the maximum values are the same.

Table 7.2: Maximum predicted offsite concentrations of NO_2 ($\mu g/m^3$), Apollo Phase 2

Year	Standard	Measured as	Objective value	PC (NO_x)	PC (NO_2)[21]	PC % of objective	Background NO_2[22]	PEC (NO_2)	PEC % of objective	Location	
										x	y
2016	Short-term AQO	99.79th percentile of hourly averages	200	243	85	43	24.4	109	55	534680	241320
	Long-term AQO	Annual average	40	5.5	3.9	10	12.2	16	40	534770	241650
2017	Short-term AQO	99.79th percentile of hourly averages	200	242	85	43	24.4	109	55	534650	241650
	Long-term AQO	Annual average	40	5.7	4.0	10	12.2	16	40	534770	241650
2018	Short-term AQO	99.79th percentile of hourly averages	200	247	86	43	24.4	110	55	534680	241320
	Long-term AQO	Annual average	40	4.9	3.4	9	12.2	16	39	534770	241650
2019	Short-term AQO	99.79th percentile of hourly averages	200	236	83	42	24.4	107	54	534650	241650
	Long-term AQO	Annual average	40	5.7	4.0	10	12.2	16	40	534770	241650
2020	Short-term AQO	99.79th percentile of hourly averages	200	241	84	42	24.4	108	54	534650	241650
	Long-term AQO	Annual average	40	5.8	4.1	10	12.2	16	41	534770	241650

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[21] 35% of short-term NO_x PC and 70% of long term NO_x PC

[22] Adding double the annual average background concentration to the 99.79th percentile of hourly averages

7.2 Predicted concentrations of carbon monoxide

7.2.1 Apollo Phase 1

Table 7.3 shows the maximum predicted PC to ground level concentrations of CO for Apollo Phase 1, using meteorological data for the five years 2016 to 2020. The maximum offsite concentrations are screened out as insignificant for all years.

Table 7.3: Maximum predicted offsite CO concentrations (µg/m^3), Apollo Phase 1

Year	Standard	Measured as	Objective value	PC	PC % of objective	Significant release?	Location	
							x	y
2016	Short-term AQO	Maximum 8 hour rolling average	10,000	212	2	No	534650	241650
	Short-term EAL	Maximum hourly average	30,000	281	1	No	534770	241650
2017	Short-term AQO	Maximum 8 hour rolling average	10,000	219	2	No	534650	241650
	Short-term EAL	Maximum hourly average	30,000	288	1	No	534770	241650
2018	Short-term AQO	Maximum 8 hour rolling average	10,000	232	2	No	534620	241650
	Short-term EAL	Maximum hourly average	30,000	273	1	No	534980	241560
2019	Short-term AQO	Maximum 8 hour rolling average	10,000	223	2	No	534650	241650
	Short-term EAL	Maximum hourly average	30,000	333	1	No	534680	241650
2020	Short-term AQO	Maximum 8 hour rolling average	10,000	224	2	No	534650	241650
	Short-term EAL	Maximum hourly average	30,000	267	1	No	534620	241650

7.2.2 Apollo Phase 2

Table 7.6 shows the maximum predicted PC to ground level concentrations of CO for Apollo Phase 2, using meteorological data for the five years 2016 to 2020. The results are almost identical to those for Phase 1; the maximum offsite concentrations are screened out as insignificant for all years.

Table 7.4: Maximum predicted offsite CO concentrations (µg/m^3), Apollo Phase 2

Year	Standard	Measured as	Objective value	PC	PC % of objective	Significant release?	Location	
							x	y
2016	Short-term AQO	Maximum 8 hour rolling average	10,000	213	2	No	534650	241650
	Short-term EAL	Maximum hourly average	30,000	281	1	No	534770	241650
2017	Short-term AQO	Maximum 8 hour rolling average	10,000	219	2	No	534650	241650
	Short-term EAL	Maximum hourly average	30,000	288	1	No	534770	241650
2018	Short-term AQO	Maximum 8 hour rolling average	10,000	232	2	No	534620	241650
	Short-term EAL	Maximum hourly average	30,000	275	1	No	534980	241560
2019	Short-term AQO	Maximum 8 hour rolling average	10,000	224	2	No	534650	241650
	Short-term EAL	Maximum hourly average	30,000	334	1	No	534680	241650
2020	Short-term AQO	Maximum 8 hour rolling average	10,000	225	2	No	534650	241650
	Short-term EAL	Maximum hourly average	30,000	267	1	No	534620	241650

7.3 Predicted concentrations of particulates

For a worst case assessment of PM_{10} and $PM_{2.5}$ impacts, 100% of the emissions of total particulate matter (TPM) was assumed to be PM_{10} and $PM_{2.5}$ in each case.

Table 7.5 and Table 7.6 show the maximum predicted PCs to ground level concentrations of PM_{10} and $PM_{2.5}$, respectively, using meteorological data for the five years 2016 to 2020.

The maximum annual average offsite PM PC is 0.7 $\mu g/m^3$, calculated using meteorological data for the year 2018. This is 1.8% of the PM_{10} air quality objective of 40 $\mu g/m^3$, and 4% of the $PM_{2.5}$ air quality objective of 20 $\mu g/m^3$. Including the respective background concentrations, maximum predicted offsite PECs of both PM_{10} and $PM_{2.5}$ are below the air quality objective.

Figure 7.3 shows a contour plot of annual average PM PC concentrations, based on meteorological data for the year 2018, the year giving the highest predicted annual average concentrations.

The maximum offsite 90.41st percentile of 24-hour average PM_{10} PC concentration is 5.9 $\mu g/m^3$, 11.8% of the air quality objective of 50 $\mu g/m^3$, calculated using meteorological data for the year 2018. Including the background concentration of 15.6 $\mu g/m^3$, maximum predicted offsite PECs are below the air quality objective. The maximum offsite 90.41st percentile of 24-hour average PM_{10} PC concentrations for the other four years of meteorological data are screened out.

Figure 7.4 shows a contour plot of the 90.41st percentile of 24-hour average PM_{10} PC concentrations, based on meteorological data for the year 2018, the year giving the highest predicted hourly average concentrations.

Table 7.5: Maximum predicted offsite PM_{10} concentrations (µg/m^3)

Year	Standard	Measured as	Objective value	PC	PC % of objective	Significant release?	Background	PEC	PEC % of objective	Location	
										x	y
2016	Short-term PM_{10} AQO	90.41st percentile of 24-hour averages	50	3.7	7.4	No	-	-	-	534680	241620
	Long-term PM_{10} AQO	Annual average	40	0.5	1.3	Yes	15.6	16.1	40	534680	241620
2017	Short-term PM_{10} AQO	90.41st percentile of 24-hour averages	50	4.2	8.4	No	-	-	-	534920	241320
	Long-term PM_{10} AQO	Annual average	40	0.6	1.5	Yes	15.6	16.2	40	534920	241320
2018	Short-term PM_{10} AQO	90.41st percentile of 24-hour averages	50	5.9	11.8	Yes	15.6	21.5	43	534680	241620
	Long-term PM_{10} AQO	Annual average	40	0.7	1.8	Yes	15.6	16.3	41	534680	241620
2019	Short-term PM_{10} AQO	90.41st percentile of 24-hour averages	50	4.8	9.6	No	-	-	-	534680	241620
	Long-term PM_{10} AQO	Annual average	40	0.6	1.5	Yes	15.6	16.2	41	534680	241620
2020	Short-term PM_{10} AQO	90.41st percentile of 24-hour averages	50	3.9	7.8	No	-	-	-	534680	241620
	Long-term PM_{10} AQO	Annual average	40	0.5	1.3	Yes	15.6	16.1	40	534680	241620

Table 7.6: Maximum predicted offsite $PM_{2.5}$ concentrations (µg/m^3)

Year	Standard	Measured as	Objective value	PC	PC % of objective	Significant release?	Background	PEC	PEC % of objective	Location	
										x	y
2016	Long-term $PM_{2.5}$ AQO	Annual average	20	0.5	3	Yes	8.9	9.4	47	534680	241620
2017				0.6	3			9.5	48	534920	241320
2018				0.7	4			9.6	48	534680	241620
2019				0.6	3			9.5	48	534680	241620
2020				0.5	3			9.4	47	534680	241620

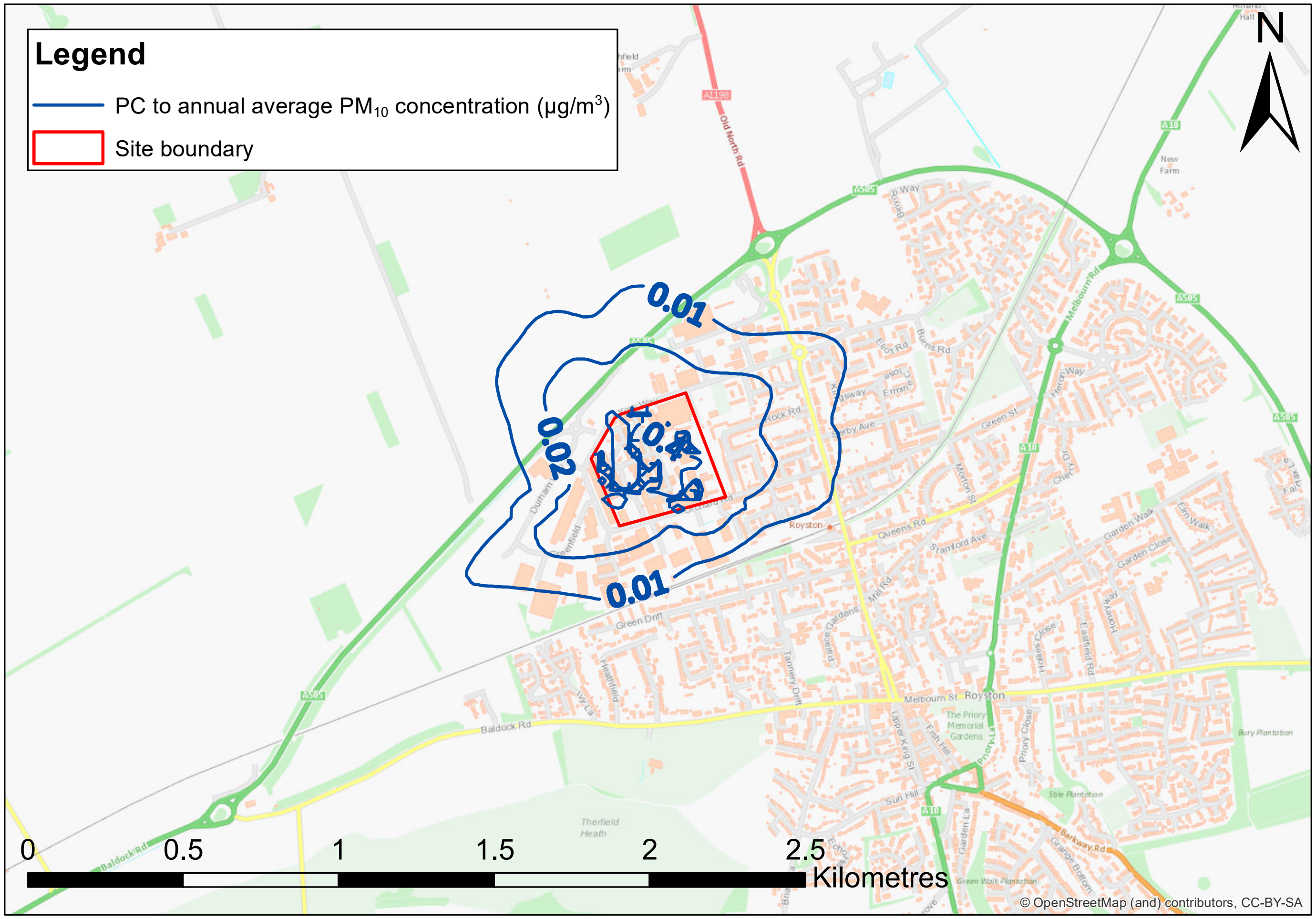

Figure 7.3: Contour plot of the PC to annual average PM concentration, using meteorological data for the year 2018

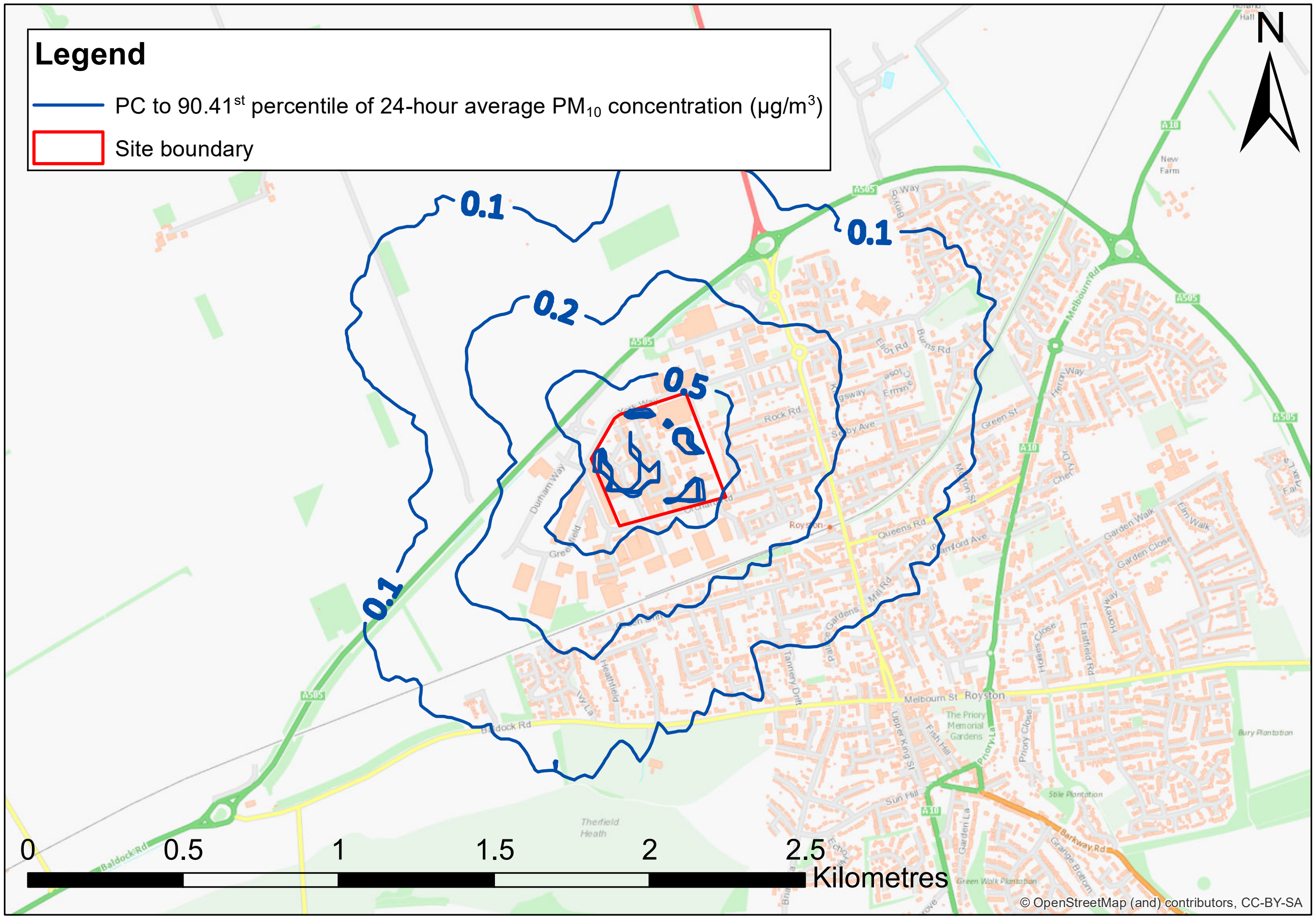

Figure 7.4: Contour plot of the PC to 90.41st percentile of 24-hour average PM_{10} concentration, using meteorological data for the year 2018

7.4 Predicted concentrations of acetic acid

Table 7.7 shows the maximum predicted PC to ground level concentrations of acetic acid, using meteorological data for the five years 2016 to 2020. The maximum offsite concentrations are screened out as insignificant for all years.

Table 7.7: Maximum predicted offsite acetic acid concentrations (µg/m^3)

Year	Standard	Measured as	EAL value	PC	PC % of EAL	Significant release?	Location	
							x	y
2016	Short-term EAL	Maximum hourly average	3,700	72	1.9	No	534740	241650
	Long-term EAL	Annual average	250	0.04	< 0.1	No	534950	241620
2017	Short-term EAL	Maximum hourly average	3,700	54	1.5	No	534680	241620
	Long-term EAL	Annual average	250	0.05	< 0.1	No	534950	241620
2018	Short-term EAL	Maximum hourly average	3,700	63	1.7	No	534740	241650
	Long-term EAL	Annual average	250	0.03	< 0.1	No	534950	241620
2019	Short-term EAL	Maximum hourly average	3,700	55	1.5	No	534740	241650
	Long-term EAL	Annual average	250	0.04	< 0.1	No	534950	241620
2020	Short-term EAL	Maximum hourly average	3,700	60	1.6	No	534740	241650
	Long-term EAL	Annual average	250	0.04	< 0.1	No	534860	241680

7.5 Predicted concentrations of ammonia

Table 7.8 shows the maximum predicted PC to ground level concentrations of ammonia, using meteorological data for the five years 2016 to 2020. The maximum offsite concentrations are screened out as insignificant for all years.

Table 7.8: Maximum predicted offsite NH_3 concentrations ($\mu g/m^3$)

Year	**Standard**	**Measured as**	**EAL value**	**PC**	**PC % of EAL**	**Significant release?**	**Location**	
							x	**y**
2016	Short-term EAL	Maximum hourly average	2,500	31.8	1.3	No	534980	241560
	Long-term EAL	Annual average	180	0.2	0.1	No	535010	241650
2017	Short-term EAL	Maximum hourly average	2,500	37.5	1.5	No	534980	241560
	Long-term EAL	Annual average	180	0.3	0.2	No	535010	241620
2018	Short-term EAL	Maximum hourly average	2,500	32.7	1.3	No	534980	241560
	Long-term EAL	Annual average	180	0.2	0.1	No	534950	241680
2019	Short-term EAL	Maximum hourly average	2,500	36.9	1.5	No	534980	241560
	Long-term EAL	Annual average	180	0.2	0.1	No	535010	241650
2020	Short-term EAL	Maximum hourly average	2,500	26.9	1.1	No	534980	241560
	Long-term EAL	Annual average	180	0.3	0.2	No	534980	241650

7.6 Predicted concentrations of hydrogen chloride

Table 7.9 shows the maximum predicted PC to ground level concentrations of HCl, using meteorological data for the five years 2016 to 2020. The maximum offsite concentrations are screened out as insignificant for all years. Note that there is no long-term EAL for HCl.

Table 7.9: Maximum predicted offsite HCl concentrations (μg/m^3)

Year	Standard	Measured as	EAL value	PC	PC % of EAL	Significant release?	Location	
							x	y
2016	Short-term EAL	Maximum hourly average	750	35	5	No	534950	241320
2017				55	7	No	534950	241290
2018				37	5	No	534620	241440
2019				34	5	No	534980	241320
2020				39	5	No	534620	241440

7.7 Predicted concentrations of chlorine

Background concentrations of chlorine (Cl_2) are assumed to be zero, therefore the predicted PC is assumed to be equal to the PEC. Note that there is no long-term EAL for Cl_2.

Table 7.10 shows the maximum predicted offsite concentrations of Cl_2, calculated using meteorological data for the five years 2016 to 2020. The maximum hourly average offsite PC is 99 μg/m^3, 34% of the short term EAL of 290 μg/m^3, calculated using meteorological data for the year 2018.

Figure 7.5 shows a contour plot of the maximum hourly average chlorine concentrations, based on meteorological data for the year 2018.

Table 7.10: Maximum predicted offsite Cl_2 concentrations (μg/m^3)

Year	Standard	Measured as	EAL value	PC = PEC	PC % of EAL	Significant release?	Location	
							x	y
2016	Short-term EAL	Maximum hourly average	290	81	28	Yes	534860	241290
2017				93	32	Yes	534800	241290
2018				99	34	Yes	534800	241290
2019				80	28	Yes	534800	241290
2020				79	27	Yes	534980	241110

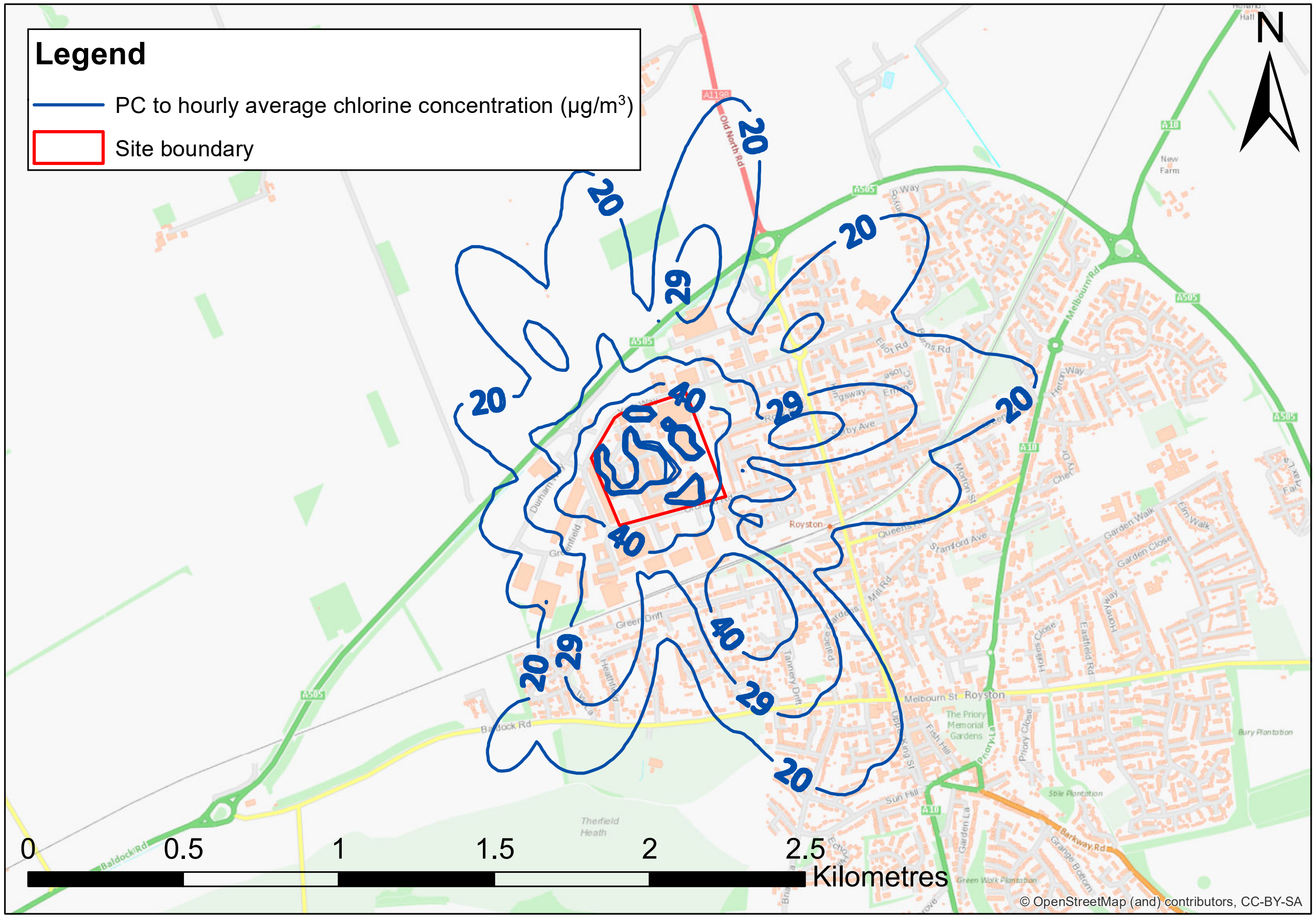

Figure 7.5: Contour plot of the PC to hourly average chlorine concentrations, using meteorological data for the year 2018

7.8 Predicted concentrations of NH4Cl

Background concentrations of ammonium chloride (NH_4Cl) are assumed to be zero, therefore the predicted PC is assumed to be equal to the PEC. Note that there is no short-term EAL for NH_4Cl.

Table 7.11 shows the maximum predicted offsite concentrations of NH_4Cl, calculated using meteorological data for the five years 2016 to 2020. The maximum offsite concentrations are screened out as insignificant for all years.

Table 7.11: Maximum predicted offsite NH_4Cl concentrations (µg/m^3)

Year	Standard	Measured as	EAL value	PC = PEC	PC % of EAL	Significant release?	Location	
							x	y
2016	Long-term EAL	Annual average	9,400	0.004	< 0.1	No	535040	241590
2017				0.004			535070	241590
2018				0.003			535040	241590
2019				0.004			535040	241590
2020				0.004			535040	241590

7.9 Predicted concentrations of NMVOCs

The predicted concentrations of NMVOCs are compared against EALs for DMF, the emitted VOC with the most stringent standard. Background concentrations of DMF are assumed to be zero, therefore the predicted PC concentrations presented in the tables are assumed to be equal to the PEC.

Table 7.12 shows the maximum predicted offsite concentrations of NMVOCs using meteorological data for the five years 2016 to 2020.

The maximum annual average offsite PC is 5.7 µg/m^3, 2% of the long-term EAL for DMF of 300 µg/m^3, calculated using meteorological data for the years 2019 and 2020. These maximum offsite concentrations are not considered significant in comparison against the EALs for any of the other VOCs.

Figure 7.6 shows a contour plot of the PC to annual average NMVOC concentration, based on meteorological data for the year 2019.

The maximum hourly average offsite NMVOC concentrations are screened out as insignificant for all years.

Table 7.12: Maximum predicted offsite NMVOC concentrations (µg/m^3) [compared against the EALs for DMF]

Year	Standard	Measured as	EAL value	PC =PEC	PC % of EAL	Significant release?	Location	
							x	y
2016	Short-term EAL	Maximum hourly average	6,100	270	4	No	534950	241320
	Long-term EAL	Annual average	300	5.3	2	Yes	534860	241680
2017	Short-term EAL	Maximum hourly average	6,100	424	7	No	534920	241320
	Long-term EAL	Annual average	300	5.3	2	Yes	534860	241680
2018	Short-term EAL	Maximum hourly average	6,100	282	5	No	534680	241320
	Long-term EAL	Annual average	300	4.8	2	Yes	534830	241680
2019	Short-term EAL	Maximum hourly average	6,100	263	4	No	534980	241320
	Long-term EAL	Annual average	300	5.7	2	Yes	534860	241680
2020	Short-term EAL	Maximum hourly average	6,100	286	5	No	534620	241440
	Long-term EAL	Annual average	300	5.7	2	Yes	534860	241680

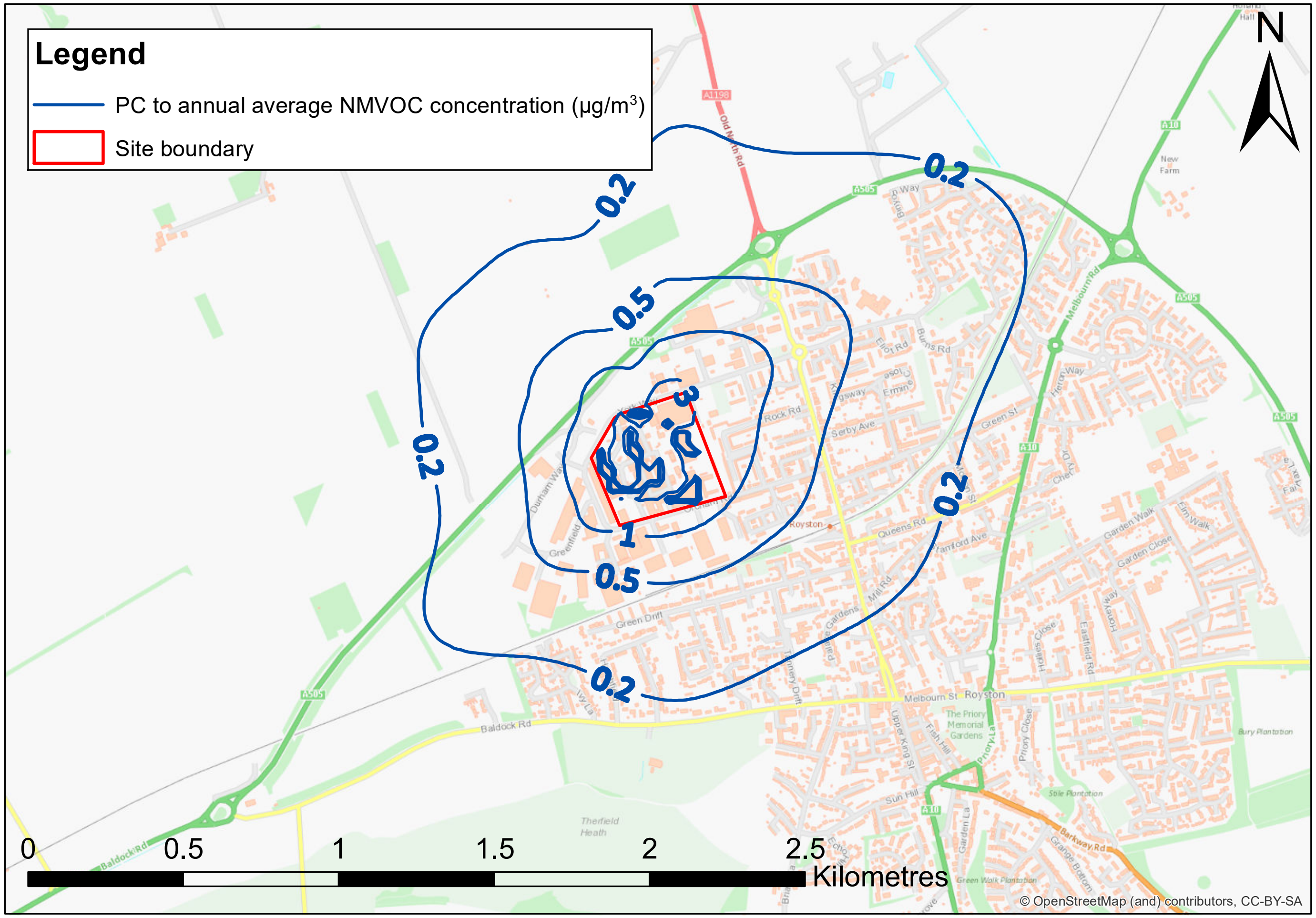

Figure 7.6: Contour plot of the PC to annual average NMVOC concentrations, using meteorological data for the year 2019

7.10 Predicted concentrations of nitrous oxide

Table 7.13 shows the maximum predicted PC to ground level concentrations of N_2O, using meteorological data for the five years 2016 to 2020. The maximum offsite concentrations are screened out as insignificant for all years.

Table 7.13: Maximum predicted offsite N_2O concentrations (µg/m^3)

Year	Standard	Measured as	EAL value	PC	PC % of EAL	Significant release?	Location	
							x	y
2016	Short-term EAL	Maximum hourly average	54,900	289	0.5	No	534740	241650
	Long-term EAL	Annual average	1,830	0.01	< 0.1	No	534950	241620
2017	Short-term EAL	Maximum hourly average	54,900	217	0.4	No	534680	241620
	Long-term EAL	Annual average	1,830	0.01	< 0.1	No	534950	241620
2018	Short-term EAL	Maximum hourly average	54,900	254	0.5	No	534740	241650
	Long-term EAL	Annual average	1,830	0.01	< 0.1	No	534950	241620
2019	Short-term EAL	Maximum hourly average	54,900	218	0.4	No	534740	241650
	Long-term EAL	Annual average	1,830	0.01	< 0.1	No	534950	241620
2020	Short-term EAL	Maximum hourly average	54,900	239	0.4	No	534740	241650
	Long-term EAL	Annual average	1,830	0.01	< 0.1	No	534860	241680

7.11 Predicted concentrations of ethanal

7.11.1 Apollo Phase 1

Table 7.14 shows the maximum predicted PC to ground level concentrations of ethanal for Apollo Phase 1, using meteorological data for the five years 2016 to 2020.

The maximum offsite concentrations for Apollo Phase 1 are screened out as insignificant for all years.

Table 7.14: Maximum predicted offsite ethanal concentrations (µg/m^3), Apollo Phase 1

Year	Standard	Measured as	EAL value	PC	PC % of EAL	Significant release?	Location	
							x	y
2016	Short-term EAL	Maximum hourly average	9,200	7.7	0.1	No	534980	241560
	Long-term EAL	Annual average	370	0.3	0.1	No	534980	241560
2017	Short-term EAL	Maximum hourly average	9,200	8.1	0.1	No	534980	241560
	Long-term EAL	Annual average	370	0.4	0.1	No	534980	241560
2018	Short-term EAL	Maximum hourly average	9,200	7.6	0.1	No	534980	241560
	Long-term EAL	Annual average	370	0.3	0.1	No	534980	241560
2019	Short-term EAL	Maximum hourly average	9,200	8.0	0.1	No	534980	241560
	Long-term EAL	Annual average	370	0.6	0.2	No	534680	241620
2020	Short-term EAL	Maximum hourly average	9,200	6.9	0.1	No	534800	241680
	Long-term EAL	Annual average	370	0.5	0.1	No	534680	241620

7.11.2 Apollo Phase 2

Table 7.14 shows the maximum predicted PC to ground level concentrations of ethanal for Apollo Phase 2, using meteorological data for the five years 2016 to 2020.

The maximum offsite concentrations for Apollo Phase 2 are screened out as insignificant for all years.

Table 7.15: Maximum predicted offsite ethanal concentrations (μg/m³), Apollo Phase 2

Year	**Standard**	**Measured as**	**EAL value**	**PC**	**PC % of EAL**	**Significant release?**	**Location**	
							x	**y**
2016	Short-term EAL	Maximum hourly average	9,200	8.7	0.1	No	534980	534980
	Long-term EAL	Annual average	370	0.3	0.1	No	535010	241650
2017	Short-term EAL	Maximum hourly average	9,200	9.0	0.1	No	534980	241560
	Long-term EAL	Annual average	370	0.5	0.1	No	534980	241560
2018	Short-term EAL	Maximum hourly average	9,200	8.1	0.1	No	534980	241560
	Long-term EAL	Annual average	370	0.3	0.1	No	534980	241560
2019	Short-term EAL	Maximum hourly average	9,200	8.9	0.1	No	534980	241560
	Long-term EAL	Annual average	370	0.3	0.1	No	535010	241650
2020	Short-term EAL	Maximum hourly average	9,200	7.6	0.1	No	534800	241680
	Long-term EAL	Annual average	370	0.4	0.1	No	534980	241560

8. Consideration of critical levels for the Protection of Vegetation and Ecosystems

Modelling was carried out to predict the Process Contribution (PC) to ground level concentrations of each relevant pollutant from the Johnson Matthey Royston site, at each of the designated conservation areas. Note that the maximum concentrations quoted for each pollutant are the maximum values occurring at locations relevant to the standard under consideration. This means that, for comparison against critical levels for the Protection of Vegetation and Ecosystems, only those values predicted within designated conservation areas were included.

The significance of the total pollutant release was assessed by comparing the PC to the relevant critical level. For long-term critical levels, the Environment Agency considers the release to be insignificant if the PC is less than 1% of the critical level.[1] Where a release is insignificant the pollutant is screened out and no further assessment undertaken.

Where a release is significant, the Predicted Environmental Concentration (PEC) for that substance is calculated. For long-term critical levels, the PEC is calculated by adding the PC to the estimated background concentration of the pollutant.

8.1 Predicted concentrations of nitrogen oxides

8.1.1 Apollo Phase 1

Table 8.1 and Table 8.2 show the maximum predicted daily average and annual average PCs to ground level concentrations of nitrogen oxides (NO_x) at each of the designated conservation areas, for Apollo Phase 1, using meteorological data for the five years 2016 to 2020.

As advised by the Environment Agency, the background concentration of NO_x has not been added to the daily average PC.

The daily average PCs are not screened out for any of the designated conservation areas, but the annual average PCs are screened out for the six LWSs. There are no exceedences of either of the critical levels.

Table 8.1: Predicted daily average NO_x concentrations ($\mu g/m^3$) at designated conservation areas, Apollo Phase 1

Site name	Critical level	Year	PC	PC / PEC % of critical level	Significant release?
Therfield Heath SSSI	75	2016	20	27	Yes
		2017	18	24	
		2018	19	25	
		2019	21	28	
		2020	19	25	
Holland Hall SSSI	75	2016	11	15	Yes
		2017	11	15	
		2018	9	12	
		2019	10	13	
		2020	8	11	
Therfield, South of Tumulus LWS	75	2016	8	11	Yes
		2017	6	8	No
		2018	9	12	Yes
		2019	10	13	
		2020	7	9	No
Royston Chalk Pit LWS	75	2016	8	11	Yes
		2017	8	11	
		2018	8	11	
		2019	13	17	
		2020	8	11	
Shaftsbury Green LWS	75	2016	9	12	Yes
		2017	8	11	
		2018	8	11	
		2019	13	17	
		2020	9	12	
Icknield Way, A505 North of Gallows Hill LWS	75	2016	8	11	Yes
		2017	10	13	
		2018	6	8	No
		2019	7	9	
		2020	6	8	
Green Lane South of Royston LWS	75	2016	12	16	Yes
		2017	9	12	
		2018	10	13	
		2019	12	16	
		2020	11	15	

Table 8.1: continued

Site name	Critical level	Year	PC	PC / PEC % of critical level	Significant release?
Therfield Green Lane LWS	75	2016	8	11	Yes
		2017	6	8	No
		2018	9	12	Yes
		2019	7	9	No
		2020	8	11	Yes

Table 8.2: Predicted annual average NO_x concentrations ($\mu g/m^3$) at designated conservation areas, Apollo Phase 1

Site name	Critical level	Year	PC	% PC of critical level	Significant release?	Background	PEC	% PEC of critical level
Therfield Heath SSSI	30	2016	0.33	1.1	Yes	10.8	11.1	37
		2017	0.25	0.8	No	-	-	-
		2018	0.40	1.3	Yes	10.8	11.2	37
		2019	0.27	0.9	No	-	-	-
		2020	0.25	0.8				
Holland Hall SSSI	30	2016	0.31	1.0	Yes	11.0	12.0	40
		2017	0.36	1.2	Yes	11.0	12.2	41
		2018	0.28	0.9	No	-	-	-
		2019	0.35	1.2	Yes	11.0	12.2	41
		2020	0.30	1.0	No	-	-	-
Therfield, South of Tumulus LWS	30	2016	0.13	0.4	No	-	-	-
		2017	0.06	0.2				
		2018	0.17	0.6				
		2019	0.11	0.4				
		2020	0.10	0.3				
Royston Chalk Pit LWS	30	2016	0.16	0.5	No	-	-	-
		2017	0.19	0.6				
		2018	0.13	0.4				
		2019	0.16	0.5				
		2020	0.14	0.5				

Table 8.2: continued

Site name	Critical level	Year	PC	% PC of critical level	Significant release?	Background	PEC	% PEC of critical level
Shaftsbury Green LWS	30	2016	0.16	0.5	No	-	-	-
		2017	0.19	0.6				
		2018	0.13	0.4				
		2019	0.16	0.5				
		2020	0.14	0.5				
Icknield Way, A505 North of Gallows Hill LWS	30	2016	0.13	0.4	No	-	-	-
		2017	0.07	0.2				
		2018	0.12	0.4				
		2019	0.12	0.4				
		2020	0.11	0.4				
Green Lane South of Royston LWS	30	2016	0.14	0.5	No	-	-	-
		2017	0.15	0.5				
		2018	0.12	0.4				
		2019	0.14	0.5				
		2020	0.11	0.4				
Therfield Green Lane LWS	30	2016	0.12	0.4	No	-	-	-
		2017	0.06	0.2				
		2018	0.12	0.4				
		2019	0.09	0.3				
		2020	0.08	0.3				

8.1.2 Apollo Phase 2

Table 8.3 and Table 8.4 show the maximum predicted daily average and annual average PCs to ground level concentrations of nitrogen oxides (NO_x) at each of the designated conservation areas, using meteorological data for the five years 2016 to 2020.

As advised by the Environment Agency, the background concentration of NO_x has not been added to the daily average PC.

The results are very similar to those for Phase 1.

Table 8.3: Predicted daily average NO_x concentrations ($\mu g/m^3$) at designated conservation areas, Apollo Phase 2

Site name	Critical level	Year	PC	PC / PEC % of critical level	Significant release?
Therfield Heath SSSI	75	2016	20	27	Yes
		2017	18	24	
		2018	19	25	
		2019	21	28	
		2020	19	25	
Holland Hall SSSI	75	2016	11	15	Yes
		2017	11	15	
		2018	9	12	
		2019	10	13	
		2020	8	11	
Therfield, South of Tumulus LWS	75	2016	8	11	Yes
		2017	6	8	No
		2018	9	12	Yes
		2019	10	13	
		2020	7	9	No
Royston Chalk Pit LWS	75	2016	8	11	Yes
		2017	8	11	
		2018	8	11	
		2019	13	17	
		2020	8	11	
Shaftsbury Green LWS	75	2016	9	12	Yes
		2017	8	11	
		2018	8	11	
		2019	13	17	
		2020	9	12	
Icknield Way, A505 North of Gallows Hill LWS	75	2016	8	11	Yes
		2017	10	13	
		2018	6	8	No
		2019	7	9	
		2020	6	8	
Green Lane South of Royston LWS	75	2016	12	16	Yes
		2017	9	12	
		2018	10	13	
		2019	12	16	
		2020	11	15	

Table 8.3: continued

Site name	Critical level	Year	PC	PC / PEC % of critical level	Significant release?
Therfield Green Lane LWS	75	2016	8	11	Yes
		2017	6	8	No
		2018	9	12	Yes
		2019	7	9	No
		2020	8	11	Yes

Table 8.4: Predicted annual average NO_x concentrations ($\mu g/m^3$) at designated conservation areas, Apollo Phase 2

Site name	Critical level	Year	PC	% PC of critical level	Significant release?	Background	PEC	% PEC of critical level
Therfield Heath SSSI	30	2016	0.33	1.1	Yes	10.8	11.1	37
		2017	0.26	0.9	No	-	-	-
		2018	0.41	1.4	Yes	10.8	11.2	37
		2019	0.28	0.9	No	-	-	-
		2020	0.25	0.8				
Holland Hall SSSI	30	2016	0.32	1.1	Yes	11.0	11.3	38
		2017	0.36	1.2			11.4	
		2018	0.29	1.0	No	-	-	-
		2019	0.36	1.2	Yes	11.0	11.4	38
		2020	0.31	1.0			11.3	
Therfield, South of Tumulus LWS	30	2016	0.13	0.4	No	-	-	-
		2017	0.06	0.2				
		2018	0.17	0.6				
		2019	0.11	0.4				
		2020	0.11	0.4				
Royston Chalk Pit LWS	30	2016	0.16	0.5	No	-	-	-
		2017	0.20	0.7				
		2018	0.13	0.4				
		2019	0.16	0.5				
		2020	0.14	0.5				

Table 8.4: continued

Site name	Critical level	Year	PC	% PC of critical level	Significant release?	Background	PEC	% PEC of critical level
Shaftsbury Green LWS	30	2016	0.16	0.5	No	-	-	-
		2017	0.20	0.7				
		2018	0.13	0.4				
		2019	0.16	0.5				
		2020	0.14	0.5				
Icknield Way, A505 North of Gallows Hill LWS	30	2016	0.13	0.4	No	-	-	-
		2017	0.07	0.2				
		2018	0.12	0.4				
		2019	0.12	0.4				
		2020	0.11	0.4				
Green Lane South of Royston LWS	30	2016	0.14	0.5	No	-	-	-
		2017	0.15	0.5				
		2018	0.12	0.4				
		2019	0.14	0.5				
		2020	0.11	0.4				
Therfield Green Lane LWS	30	2016	0.12	0.4	No	-	-	-
		2017	0.06	0.2				
		2018	0.12	0.4				
		2019	0.09	0.3				
		2020	0.08	0.3				

8.2 Predicted concentrations of ammonia

Table 8.5 shows the maximum predicted PC to annual average ammonia (NH_3) concentrations at each of the designated conservation areas, using meteorological data for the five years 2016 to 2020.

For all designated conservation areas except Therfield Heath, the annual average NH_3 concentrations are screened out as insignificant. At these areas, the less stringent critical level of 3 $\mu g/m^3$ is used.

At Therfield Heath, the woodland habitat may include sensitive lichen and bryophytes communities, so the more stringent critical level has been used and the PCs are not screened out for two out of the five years of meteorological data. The background concentration, 1.6 $\mu g/m^3$, exceeds the critical level of 1 $\mu g/m^3$.

Table 8.5: Predicted annual average NH_3 concentrations ($\mu g/m^3$) at designated conservation areas

Site name	Critical level	Year	PC	% PC of critical level	Significant release?	Background	PEC	% PEC of critical level
Therfield Heath SSSI	1	2016	0.014	1.4	Yes	1.6	1.6	160
		2017	0.010	1.0	No	-	-	-
		2018	0.017	1.7	Yes	1.6	1.6	160
		2019	0.011	1.1				
		2020	0.011	1.1				
Holland Hall SSSI	3	2016	0.015	0.5	No	-	-	-
		2017	0.017	0.6				
		2018	0.013	0.4				
		2019	0.016	0.5				
		2020	0.014	0.5				
Therfield, south of Tumulus LWS	3	2016	0.006	0.2	No	-	-	-
		2017	0.002	0.1				
		2018	0.008	0.3				
		2019	0.005	0.2				
		2020	0.005	0.2				
Royston Chalk Pit LWS	3	2016	0.007	0.2	No	-	-	-
		2017	0.008	0.3				
		2018	0.005	0.2				
		2019	0.007	0.2				
		2020	0.006	0.2				

Table 8.5: continued

Site name	Critical level	Year	PC	% PC of critical level	Significant release?	Background	PEC	% PEC of critical level
Shaftsbury Green LWS	3	2016	0.007	0.2	No	-	-	-
		2017	0.008	0.3				
		2018	0.005	0.2				
		2019	0.007	0.2				
		2020	0.006	0.2				
Icknield Way, A505 North of Gallows Hill LWS	3	2016	0.005	0.2	No	-	-	-
		2017	0.003	0.1				
		2018	0.005	0.2				
		2019	0.005	0.2				
		2020	0.005	0.2				
Green Lane South of Royston LWS	3	2016	0.006	0.2	No	-	-	-
		2017	0.006	0.2				
		2018	0.005	0.2				
		2019	0.006	0.2				
		2020	0.004	0.1				
Therfield Green Lane LWS	3	2016	0.005	0.2	No	-	-	-
		2017	0.003	0.1				
		2018	0.005	0.2				
		2019	0.004	0.1				
		2020	0.004	0.1				

9. Nitrogen and acid deposition

Material from a plume can be lost to the ground, at the surface of the ground (dry deposition), and through wash out with precipitation (wet deposition). Deposition of pollutants may lead to detrimental effects at sensitive habitats due to acidification and nitrogen eutrophication.

Modelling was carried out to predict the Process Contribution (PC) to the nitrogen and acid deposition rates from the Johnson Matthey Royston site over the designated conservation areas. The significance of the total pollutant release was assessed by comparing the PC to the relevant critical loads. For long-term impacts, as in the case of deposition, the Environment Agency considers the release to be insignificant if the PC is less than 1% of the critical load. Where a release is insignificant the impact is screened out and no further assessment undertaken.

9.1 Deposition of nitrogen

9.1.1 Critical loads and existing levels of nitrogen deposition

The Air Pollution Information System (APIS) website[13] gives critical load values for specific SSSIs. For sites such as LWSs, critical load values can be found by location.

Table 9.1 shows the habitat types, critical loads and total nitrogen deposition values at the two SSSIs and six LWSs identified in Section 4.1. A habitat type of ‘calcareous grassland’ has been assumed for Holland Hall SSSI and the six LWSs, and two habitat types, ‘broadleaved, mixed and yew woodland’ and ‘calcareous grassland’, have been assumed for Therfield Heath SSSI. The total nitrogen deposition values presented are specific to habitat types at each designated conservation area. The total nitrogen deposition values presented represent the average deposition over the years 2019 to 2021, due to existing local sources and background contributions.

In some cases, the existing total nitrogen deposition rate exceeds the relevant critical load range.

Table 9.1: Total nitrogen deposition (kg N ha^{-1} yr^{-1})

Site name	Habitat type	Relevant Nitrogen critical load class	Critical load	Total nitrogen deposition
Therfield Heath SSSI	Broadleaved, mixed and yew woodland	Fagus woodland	10 – 20	27.6 (max) 26.8 (min) 27.2 (avg)
	Calcareous grassland	Sub-Atlantic semi-dry calcareous grassland	15 - 25	15.7 (max) 15.2 (min) 15.5 (avg)
Holland Hall SSSI	Calcareous grassland	Sub-Atlantic semi-dry calcareous grassland	15 - 25	14.7 (max) 14.6 (min) 14.7 (avg)
Therfield, south of Tumulus LWS	Calcareous grassland	Sub-Atlantic semi-dry calcareous grassland	15 - 25	15.3
Royston Chalk Pit LWS				15.1
Shaftsbury Green LWS				15.1
Icknield Way, A505 north of Gallows Hill LWS				16.2 (max) 15.3 (min) 15.7 (avg)
Green Lane South of Royston LWS				15.5
Therfield Green Lane LWS				16.1 (max) 15.5 (min) 15.8 (avg)

9.1.2 Process contribution to nitrogen deposition, Apollo Phase 1

The deposition of nitrogen from concentrations of NO_2, NH_3 and NH_4Cl was considered.

The Environment Agency Air Quality Modelling and Assessment Unit (AQMAU)[23] recommend dry deposition velocities for grassland and forest. Dry deposition velocities of 0.0015 m/s for NO_x and 0.02 m/s for NH_3 were used for grassland; values of 0.003 m/s for NO_x and 0.03 m/s for NH_3 were used for forest. Wet deposition for these pollutants was not included, as advised by AQMAU.

Deposition of NH_4Cl was modelled assuming a particulate with density 1530 kg/m^3 and diameter 10 µm, which is likely to be a worst case (overestimating) assumption. Wet deposition of NH_4Cl was included based on the default ADMS parameters[24].

The maximum predicted annual PC to deposition rates of nitrogen at each designated conservation area, for Apollo Phase 1, is presented in Table 9.2, together with the PC as a percentage of the most stringent critical load applicable to each designated conservation area.

The maximum PCs to nitrogen deposition are screened out for grassland habitats at all designated conservation areas.

For the woodland habitat, the maximum PC to nitrogen deposition at Therfield Heath SSSI is greater than 1% of the lower value of the critical load range for two of the five years of meteorological data, so this impact was investigated further.

Figure 9.1 shows a contour plot of the PC to the nitrogen deposition rate at Therfield Heath SSSI, using meteorological data for the year 2018, using deposition velocities for the woodland habitat. The maximum value of 0.159 kgN ha^{-1} yr^{-1} occurs at the northern edge of the SSSI, coinciding with an area of grassland rather than woodland. The maximum value occurring at an area of woodland (indicated by solid green shading on the map) is less than 0.1 kgN ha^{-1} yr^{-1}, i.e. less than 1% of the lower value of the critical load range. Therefore, the PC to nitrogen deposition at Therfield Heath SSSI is screened out as insignificant, as it is less than 1% of the critical load range relevant to specific locations.

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[23] AQTAG 06, *Technical Guidance on detailed modelling approach for an appropriate assessment for emissions to air*, Environment Agency, March 2014

[24] Washout coefficient A = 0.0001, washout coefficient B = 0.64.

Table 9.2: Maximum nitrogen deposition (kg N ha^{-1} yr^{-1}) at designated conservation areas, Apollo Phase 1

Site name	Critical load class	Critical load	Year	PC (from NO_2)	PC (from NH_3)	PC (from NH_4Cl)	PC (total)	PC as % of critical load	Significant release?
Therfield Heath SSSI	Fagus woodland	10 – 20	2016	0.058	0.065	0.0015	0.125	0.6 - 1.3	Yes
			2017	0.045	0.050	0.0015	0.096	0.5 - 1.0	No
			2018	0.072	0.086	0.0021	0.159	0.8 - 1.6	Yes
			2019	0.048	0.052	0.0013	0.101	0.5 - 1.0	No
			2020	0.044	0.052	0.0017	0.098	0.5 - 1.0	
	Calcareous grassland	15 – 25	2016	0.031	0.047	0.0015	0.079	0.4 – 0.7	No
			2017	0.024	0.035	0.0015	0.061		
			2018	0.038	0.061	0.0021	0.101		
			2019	0.025	0.037	0.0013	0.064		
			2020	0.024	0.037	0.0017	0.063		
Holland Hall SSSI	Calcareous grassland	15 – 25	2016	0.030	0.056	0.0022	0.088	0.5 – 0.6	No
			2017	0.033	0.062	0.0023	0.097		
			2018	0.026	0.047	0.0016	0.075		
			2019	0.033	0.060	0.0023	0.095		
			2020	0.029	0.055	0.0025	0.086		
Therfield, south of Tumulus LWS	Calcareous grassland	15 – 25	2016	0.012	0.018	0.0005	0.030	0.1 – 0.3	No
			2017	0.005	0.008	0.0003	0.014		
			2018	0.015	0.024	0.0007	0.040		
			2019	0.009	0.013	0.0004	0.023		
			2020	0.009	0.015	0.0006	0.025		

Table 9.2: continued

Site name	Critical load class	Critical load	Year	PC (from NO_2)	PC (from NH_3)	PC (from NH_4Cl)	PC (total)	PC as % of critical load	Significant release?
Royston Chalk Pit LWS	Calcareous grassland	15 – 25	2016	0.014	0.021	0.0007	0.036	0.2 – 0.3	No
			2017	0.018	0.026	0.0008	0.045		
			2018	0.011	0.017	0.0006	0.029		
			2019	0.015	0.022	0.0007	0.037		
			2020	0.012	0.018	0.0006	0.031		
Shaftsbury Green LWS	Calcareous grassland	15 – 25	2016	0.014	0.021	0.0007	0.036	0.2 – 0.3	No
			2017	0.018	0.026	0.0008	0.045		
			2018	0.011	0.017	0.0006	0.029		
			2019	0.015	0.022	0.0007	0.037		
			2020	0.012	0.018	0.0006	0.031		
Icknield Way, A505 north of Gallows Hill LWS	Calcareous grassland	15 – 25	2016	0.012	0.018	0.0005	0.030	0.1 – 0.2	No
			2017	0.006	0.009	0.0003	0.016		
			2018	0.011	0.016	0.0006	0.028		
			2019	0.011	0.015	0.0004	0.026		
			2020	0.011	0.016	0.0006	0.027		
Green Lane South of Royston LWS	Calcareous grassland	15 – 25	2016	0.013	0.019	0.0006	0.032	0.2 – 0.2	No
			2017	0.014	0.020	0.0007	0.035		
			2018	0.011	0.016	0.0005	0.028		
			2019	0.012	0.019	0.0006	0.032		
			2020	0.010	0.014	0.0005	0.024		

Table 9.2: continued

Site name	Critical load class	Critical load	Year	PC (from NO_2)	PC (from NH_3)	PC (from NH_4Cl)	PC (total)	PC as % of critical load	Significant release?
Therfield Green Lane LWS	Calcareous grassland	15 – 25	2016	0.010	0.015	0.0004	0.026	0.1 – 0.2	No
			2017	0.006	0.008	0.0003	0.014		
			2018	0.010	0.016	0.0005	0.027		
			2019	0.008	0.011	0.0003	0.019		
			2020	0.007	0.010	0.0003	0.018		

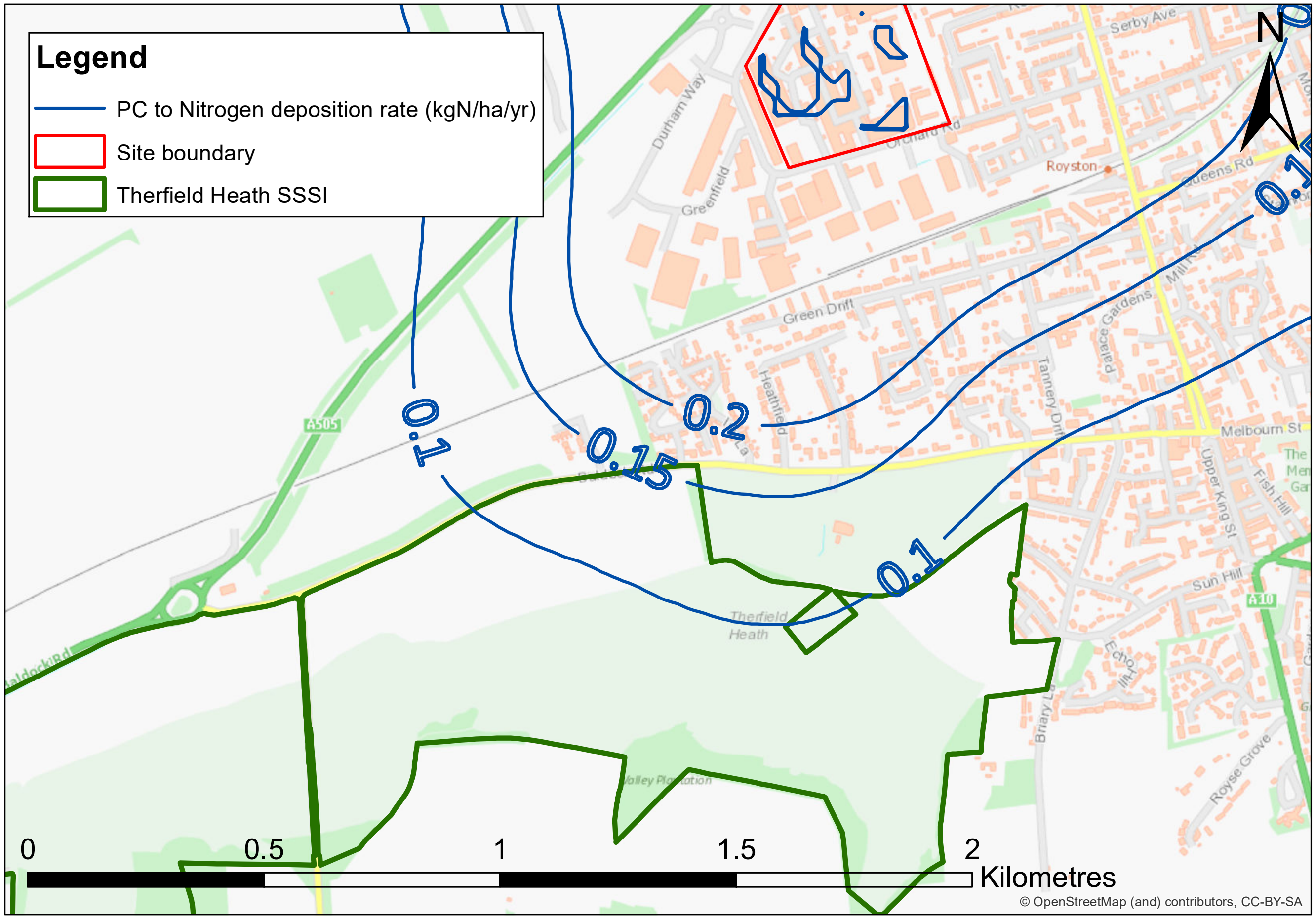

Figure 9.1: Contour plot of the PC to nitrogen deposition for woodland habitat at Therfield Heath SSSI, Apollo Phase 1, based on meteorological data for the year 2018

9.1.3 Process contribution to nitrogen deposition, Apollo Phase 2

The maximum predicted annual PC to deposition rates of nitrogen at each designated conservation area for Apollo Phase 2 is presented in Table 9.3, together with the PC as a percentage of the most stringent critical load applicable to each designated conservation area.

The results are very similar to those for Phase 1.

Table 9.3: Maximum nitrogen deposition (kg N ha^{-1} yr^{-1}) at designated conservation areas, Apollo Phase 2

Site name	Critical load class	Critical load	Year	PC (from NO_2)	PC (from NH_3)	PC (from NH_4Cl)	PC (total)	PC as % of critical load	Significant release?
Therfield Heath SSSI	Fagus woodland	10 – 20	2016	0.059	0.065	0.0015	0.125	1.3	Yes
			2017	0.046	0.050	0.0015	0.097	1.0	No
			2018	0.073	0.086	0.0021	0.160	1.6	Yes
			2019	0.048	0.052	0.0013	0.101	1.0	No
			2020	0.045	0.052	0.0017	0.099	1.0	
	Calcareous grassland	15 – 25	2016	0.031	0.047	0.0015	0.079	0.4 – 0.7	No
			2017	0.024	0.035	0.0015	0.061		
			2018	0.038	0.061	0.0021	0.102		
			2019	0.026	0.037	0.0013	0.064		
			2020	0.024	0.037	0.0017	0.063		
Holland Hall SSSI	Calcareous grassland	15 – 25	2016	0.030	0.056	0.0022	0.088	0.5 – 0.7	No
			2017	0.034	0.062	0.0023	0.098		
			2018	0.027	0.047	0.0016	0.075		
			2019	0.034	0.060	0.0023	0.096		
			2020	0.029	0.055	0.0025	0.087		
Therfield, south of Tumulus LWS	Calcareous grassland	15 – 25	2016	0.012	0.018	0.0005	0.030	0.1 – 0.3	No
			2017	0.005	0.008	0.0003	0.014		
			2018	0.015	0.024	0.0007	0.040		
			2019	0.010	0.013	0.0004	0.023		
			2020	0.010	0.015	0.0006	0.025		

Table 9.3: continued

Site name	Critical load class	Critical load	Year	PC (from NO_2)	PC (from NH_3)	PC (from NH_4Cl)	PC (total)	PC as % of critical load	Significant release?
Royston Chalk Pit LWS	Calcareous grassland	15 – 25	2016	0.015	0.021	0.0007	0.036	0.2 – 0.3	No
			2017	0.018	0.026	0.0008	0.045		
			2018	0.012	0.017	0.0006	0.029		
			2019	0.015	0.022	0.0007	0.037		
			2020	0.013	0.018	0.0006	0.031		
Shaftsbury Green LWS	Calcareous grassland	15 – 25	2016	0.015	0.021	0.0007	0.036	0.2 – 0.3	No
			2017	0.018	0.026	0.0008	0.045		
			2018	0.012	0.017	0.0006	0.029		
			2019	0.015	0.022	0.0007	0.037		
			2020	0.013	0.018	0.0006	0.031		
Icknield Way, A505 north of Gallows Hill LWS	Calcareous grassland	15 – 25	2016	0.012	0.018	0.0005	0.031	0.1 – 0.2	No
			2017	0.006	0.009	0.0003	0.016		
			2018	0.011	0.016	0.0006	0.028		
			2019	0.011	0.015	0.0004	0.026		
			2020	0.011	0.016	0.0006	0.028		
Green Lane South of Royston LWS	Calcareous grassland	15 – 25	2016	0.013	0.019	0.0006	0.032	0.1 – 0.2	No
			2017	0.014	0.020	0.0007	0.035		
			2018	0.011	0.016	0.0005	0.028		
			2019	0.013	0.019	0.0006	0.032		
			2020	0.010	0.014	0.0005	0.024		

Table 9.3: continued

Site name	Critical load class	Critical load	Year	PC (from NO_2)	PC (from NH_3)	PC (from NH_4Cl)	PC (total)	PC as % of critical load	Significant release?
Therfield Green Lane LWS	Calcareous grassland	15 – 25	2016	0.011	0.015	0.0004	0.026	0.1 – 0.2	No
			2017	0.006	0.008	0.0003	0.014		
			2018	0.011	0.016	0.0005	0.027		
			2019	0.008	0.011	0.0003	0.019		
			2020	0.007	0.010	0.0003	0.018		

9.2 Acid deposition

9.2.1 Critical loads and existing levels of acid deposition

The APIS website gives critical load values for specific SSSIs. For sites such as LWSs, critical load values can be found by location.

Table 9.4 shows the habitat types, critical loads and total acid deposition values at the two SSSIs and six LWSs identified in Section 4.1. The critical loads presented are specific to each designated conservation area.

The Critical Load Function is defined by three quantities to account for the contribution of different species to total acid deposition[13]. CLmaxS is the maximum critical load for acidity expressed in terms of sulphur, i.e. when nitrogen deposition is zero; this value also considers non marine chloride deposition[23]. Similarly, CLmaxN is the maximum critical load of acidity expressed in terms of nitrogen only, i.e. when sulphur and non-marine chloride deposition is zero. Finally, CLminN defines a nitrogen deposition level below which additional nitrogen will not acidify the system, due to long-term nitrogen losses in the soil, e.g. nitrogen uptake by vegetation.

The total acid deposition values presented represent the average deposition over the years 2019 to 2021, due to existing local sources and background contributions. The nitrogen (N) and sulphur (S) contributions are presented.

Table 9.4: Total acid deposition (keq ha^{-1} yr^{-1})

Site name	Habitat type	Relevant Acidity critical load class	Critical load (keq)	Total acid deposition N|S
Therfield Heath SSSI	Broadleaved, mixed and yew woodland	Unmanaged broadleafed/ coniferous woodland	MaxCLminN: 0.142 MaxCLmaxN: 10.918 MaxCLmaxS: 10.776 MinCLminN: 0.142 MinCLmaxN: 10.828 MinCLmaxS: 10.686	1.92|0.15
	Calcareous grassland	Calcareous grassland (using base cation)	MaxCLminN: 0.856 MaxCLmaxN: 4.856 MaxCLmaxS: 4 MinCLminN: 0.856 MinCLmaxN: 4.856 MinCLmaxS: 4	1.09|0.12
Holland Hall SSSI	Calcareous grassland	Calcareous grassland (using base cation)	MaxCLminN: 0.856 MaxCLmaxN: 4.856 MaxCLmaxS: 4 MinCLminN: 0.856 MinCLmaxN: 4.856 MinCLmaxS: 4	1.05|0.11

Table 9.4: Total acid deposition (keq ha^{-1} yr^{-1}): continued

Site name	Habitat type	Relevant Acidity critical load class	Critical load (keq)	Total acid deposition N|S
Royston Chalk Pit LWS	Calcareous grassland	Calcareous grassland (using base cation)	CLminN: 0.856 CLmaxN: 4.856 CLmaxS: 4	1.08|0.11
Shaftsbury Green LWS				1.08|0.11
Icknield Way, A505 North of Gallows Hill LWS				1.12|0.12
Green Lane South of Royston LWS				1.10|0.12
Therfield, South of Tumulus LWS				1.09|0.12
Therfield Green Lane LWS				1.12|0.12

9.2.2 Process contribution to acid deposition, Apollo Phase 1

The rate of acid deposition calculated in this assessment is based on the PC to acid deposition from nitrogen, presented in Section 9.1, plus the additional contribution from HCl.

Dry deposition velocities recommended by AQMAU were used for all pollutants. The dry deposition velocities used for NO_2 and NH_3, and the parameters assumed for NH_4Cl, are provided in Section 9.1.

For HCl, a dry deposition velocity of 0.025 m/s, for grassland, and a dry deposition velocity of 0.06 m/s, for forest, was assumed. Wet deposition was also included for HCl, calculated from rainfall in the meteorological data and assuming washout coefficients A=0.0003 and B=0.66, as suggested in the Power Technology report PT/04/BE965/R[25].

The APIS Critical Load Function Tool[26] was used to assess the combined impact of the nitrogen and HCl contributions to acid deposition at each of the designated conservation areas.

For each identified habitat, minCLmaxS, minCLmaxN and minCLminN were input to the tool, along with the maximum background deposition, presented in Table 9.4.

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[25] Power Technology report *Comparison of ADMS wet deposition against monitored data and assessment of the relevance of HCl deposition from power stations*, SJ Griffiths, September 2004

[26] http://www.apis.ac.uk/critical-load-function-tool

The maximum PCs to the nitrogen contribution were also input to the tool. The maximum PCs to the HCl contribution were included as the sulphur contribution, as specified in the AQTAG 06 habitats assessment guidance[27].

Table 9.5 presents the maximum predicted contributions from nitrogen and HCl to the acid deposition rates at each designated conservation area, for Apollo Phase 1.

Table 9.5: Contributions to acid deposition (keq ha^{-1} yr^{-1}) at designated conservation areas, Apollo Phase 1

Site name	Habitat type	Year	PC (N)	PC (HCl as H)
Therfield Heath SSSI	Broadleaved, mixed and yellow woodland	2016	0.009	0.011
		2017	0.007	0.011
		2018	0.011	0.016
		2019	0.007	0.010
		2020	0.007	0.010
	Calcareous grassland	2016	0.006	0.005
		2017	0.004	0.006
		2018	0.007	0.008
		2019	0.005	0.005
		2020	0.004	0.005
Holland Hall SSSI	Calcareous grassland	2016	0.006	0.006
		2017	0.007	0.006
		2018	0.005	0.005
		2019	0.007	0.006
		2020	0.006	0.006
Royston Chalk Pit LWS	Calcareous grassland	2016	0.003	0.003
		2017	0.003	0.003
		2018	0.002	0.002
		2019	0.003	0.003
		2020	0.002	0.002
Shaftsbury Green LWS	Calcareous grassland	2016	0.003	0.003
		2017	0.003	0.003
		2018	0.002	0.002
		2019	0.003	0.003
		2020	0.002	0.002

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[27] AQTAG 06, *Technical Guidance on detailed modelling approach for an appropriate assessment for emissions to air*, Environment Agency, March 2014

Table 9.5: continued

Site name	Habitat type	Year	PC (N)	PC (HCl as H)
Icknield Way, A505 North of Gallows Hill LWS	Calcareous grassland	2016	0.002	0.002
		2017	0.001	0.001
		2018	0.002	0.002
		2019	0.002	0.002
		2020	0.002	0.002
Green Lane South of Royston LWS	Calcareous grassland	2016	0.002	0.002
		2017	0.002	0.003
		2018	0.002	0.002
		2019	0.002	0.002
		2020	0.002	0.002
Therfield, South of Tumulus LWS	Calcareous grassland	2016	0.002	0.002
		2017	0.001	0.001
		2018	0.003	0.003
		2019	0.002	0.002
		2020	0.002	0.002
Therfield Green Lane LWS	Calcareous grassland	2016	0.002	0.002
		2017	0.001	0.001
		2018	0.002	0.002
		2019	0.001	0.001
		2020	0.001	0.001

Table 9.6 presents the PC as a percentage of the Critical Load Function, as output from the APIS Critical Load Function Tool, for each identified habitat at each designated conservation area, for Apollo Phase 1.

According to the Critical Load Function Tool, the maximum PCs to acid deposition are screened out at all designated conservation areas.

Table 9.6: Results from APIS Critical Load Function Tool, Apollo Phase 1

Site name	Habitat type	Acidity critical load class	PC as % of CL function	Significant?
Therfield Heath SSSI	Broadleaved, mixed and yew woodland	Unmanaged broadleafed/ coniferous woodland	0.3	No
	Calcareous grassland	Calcareous grassland (using base cation)	0.4	No
Holland Hall SSSI	Calcareous grassland	Calcareous grassland (using base cation)	0.2	No
Royston Chalk Pit LWS	Calcareous grassland	Calcareous grassland (using base cation)	0.2	No
Shaftsbury Green LWS	Calcareous grassland	Calcareous grassland (using base cation)	0.2	No
Icknield Way, A505 North of Gallows Hill LWS	Calcareous grassland	Calcareous grassland (using base cation)	0	No
Green Lane South of Royston LWS	Calcareous grassland	Calcareous grassland (using base cation)	0.2	No
Therfield, South of Tumulus LWS	Calcareous grassland	Calcareous grassland (using base cation)	0.2	No
Therfield Green Lane LWS	Calcareous grassland	Calcareous grassland (using base cation)	0	No

9.2.3 Process contribution to acid deposition, Apollo Phase 2

The acid deposition results for Phase 2 were identical to those for Phase 1.

10. Discussion

In order to investigate the impact on air quality of all relevant processes at the Royston site, to support the permit variation for the Apollo and replacement boiler projects, dispersion modelling of emissions to air was carried out.

10.1 Objectives and EALs for the protection of human health

The maximum offsite concentrations of carbon monoxide, acetic acid, ammonia, hydrogen chloride, ammonium chloride, nitrous oxide and ethanal are screened out as insignificant for all years.

PCs to NO_2 and particulate concentrations are not screened out, but the PECs for both pollutants are below the air quality objectives.

Predicted concentrations of NMVOCs are compared against EALs for DMF, which has the most stringent standard. Annual average NMVOC concentrations are not screened out, but they are well below the long-term EAL for DMF. Hourly average offsite concentrations are screened out as insignificant for all years.

Chlorine concentrations are not screened out, but they are below the short-term EAL. There is no long-term EAL for chlorine.

10.2 Critical levels for the Protection of Vegetation and Ecosystems

The daily average NO_x PCs are not screened out for any of the designated conservation areas, but the annual average PCs are screened out for the six LWSs. The annual and daily average PECs are below the respective critical levels.

At all designated conservation areas except Therfield Heath, the annual average NH_3 concentrations are screened out as insignificant. At Therfield Heath, the more stringent critical level was used and the PCs are not screened out for two out of the five years of meteorological data considered. The background concentration, 1.6 $\mu g/m^3$, exceeds the critical level of 1 $\mu g/m^3$.

10.3 Critical loads for the Protection of Vegetation and Ecosystems

The maximum PCs to nitrogen and acid deposition are screened out at relevant habitats at all designated conservation areas.

APPENDIX A: Summary of ADMS 6

ADMS, the **A**tmospheric **D**ispersion **M**odelling **S**ystem[28], has been developed to make use of the most up-to-date understanding of the airflow and turbulence behaviour in the lower levels of the atmosphere in an easy-to-use computer modelling system for the dispersion of atmospheric emissions. This allows the impact of emissions from industrial and other facilities to be thoroughly investigated as part of an environmental assessment or for other regulatory purposes. The model is supported on Windows 11 and Windows 10 environments.

ADMS's original sponsors included the Environment Agency, the Health and Safety Executive (HSE) and successor power companies of the CEGB (Central Electricity Generating Board), whilst the Met Office and University of Surrey contributed to its development. The model is now used for regulatory and other purposes in many countries across the world.

The following is a summary of the capabilities and validation of ADMS 6. More details can be found on the CERC web site at www.cerc.co.uk.

The core model calculates the average concentration arising from an emission for a given meteorological condition (for example, wind speed and direction), taking account of plume rise and stack downwash where required. The emission may be released from a single source or from a number of sources. In addition, ADMS is able to:

- calculate long-term concentration statistics, typically for a period of one year, for direct comparison with air quality standards and objectives;
- take into account the often very significant effects that a nearby building can have on the dispersion of emissions;
- model the chemical conversions that occur in the atmosphere between nitric oxide (NO), nitrogen dioxide (NO_2) and ozone (O_3);
- include background concentrations in concentration statistics;
- allow for the effects of complex terrain and changes in surface roughness on wind speed and direction, and on the levels of turbulence in the atmosphere;
- determine the quantities of an emission deposited to the ground by both dry and wet deposition processes;
- include the decay of radioactive emissions and determine the gamma dose at a location received from passing material;
- report the extent to which a moist plume will be visible;
- model sources over the sea, such as oil platforms, using special calculations of surface roughness and heat fluxes;
- output temperature, relative and/or specific humidity, as well as exceedences of temperature and/or humidity thresholds and simultaneous exceedences of temperature and humidity threshold values;
- output concentrations in units of ou_e for odour studies;
- model the effect of a coastline by accounting for the development of an internal convective layer during sea breeze events;

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[28] Carruthers DJ, Holroyd RJ, Hunt JCR, Weng W-S, Robins AG, Apsley DD, Thompson DJ and Smith FB, **1994**: UK-ADMS: A new approach to modelling dispersion in the earth's atmospheric boundary layer. J. of Wind Engineering and Industrial Aerodynamics, vol. 52, pp. 139-153, DOI: 10.1016/0167-6105(94)90044-2.

- calculate concentrations and deposition fluxes due to an instantaneous or finite duration release (puffs);
- model short-term fluctuations in concentration due to atmospheric turbulence, particularly important for modelling odours and concentrations for averaging times less than one hour;
- model the effect of building density on near-surface wind and turbulence profiles (urban canopy); and
- model the effect of wind turbines on plume dispersion.

More details of some of these processes are given below, along with a summary of data comparisons that have been used to validate the model.

Dispersion Modelling

ADMS uses boundary layer similarity profiles in which the boundary layer structure is characterised by the height of the boundary layer and the Monin-Obukhov length, a length scale dependent on the friction velocity and the heat flux at the ground. This has significant advantages over earlier methods in which the dispersion parameters did not vary with height within the boundary layer.

In stable and neutral conditions, dispersion is represented by a Gaussian distribution. In convective conditions, the vertical distribution takes account of the skewed structure of the vertical component of turbulence. This is necessary to reflect the fact that, under convective conditions, rising air is typically of limited spatial extent but is balanced by descending air extending over a much larger area. This leads to higher ground-level concentrations than would be given by a simple Gaussian representation.

The formulation of ADMS means that, for a given meteorological condition, as well as determining average concentrations, the model is also able to provide statistical information on concentration fluctuations. This can be particularly important in applications, for example, determining whether or not a dispersing material exceeds flammability or odour detection thresholds.

Emissions

Buoyant emissions, and those with vertical momentum, rise in the atmosphere after emission. This movement, which is referred to as *plume rise*, also results in additional dilution and can result in the emission penetrating the top of the atmospheric boundary layer and being lost from the local area. These effects are included in the modelling using an integral solution of the conservation equations for the plume's mass, momentum and heat. The possibility of entrainment behind the stack, known as *downwash*, which can lower the effective height of the emission, is also included in the calculation.

ADMS can also model emissions represented as:

- lines – for linear sources;
- areas – to represent situations where a source can best be represented as uniformly spread over an area, such as evaporation from an open tank;
- volumes – to represent situations where a source can best be represented as uniformly spread throughout a volume, such as fugitive emissions from a factory complex; and
- jets – to represent situations where emissions are not emitted vertically upwards.

Presentation of Results

For most situations ADMS is used to model the fate of emissions for a large number of different meteorological conditions. Typically, meteorological data are input for every hour during a year or for a set of conditions representing all those occurring at a given location. ADMS uses these individual results to calculate statistics for the whole data set. These are usually average values, including rolling averages, percentiles and the number of hours for which specified concentration thresholds are exceeded. This allows concentrations to be calculated for direct comparison with air quality limits, guidelines and objectives, in whatever form they are specified.

Results can be presented as numerical values at specified locations. In addition, by calculating concentrations over a grid of locations, results can be presented graphically as concentration contours or isopleths. This can be done using an integrated Mapper, which can also be used to visualise, add and edit sources, buildings and output points. The model also links to other software packages, such as Surfer, ArcGIS and MapInfo GIS.

Complex Effects - Buildings

A building or similar large obstruction can affect dispersion in three ways:

1. It deflects the wind flow and therefore the route followed by dispersing material;
2. This deflection increases levels of turbulence, possibly enhancing dispersion; and
3. Material can become entrained in a highly turbulent, recirculating flow region or cavity on the downwind side of the building.

The third effect is of particular importance because it can bring relatively concentrated material down to ground-level near to a source. From experience, this occurs to a significant extent in more than 95% of studies for industrial facilities.

The buildings effects module in ADMS has been developed using extensive published data from scale-model studies in wind-tunnels, CFD modelling and field experiments on the dispersion of pollution from sources near large structures. It has the following stages:

(i) A complex of buildings is reduced to a single wind-aligned rectangular block with the height of the dominant building and representative streamwise and crosswind lengths.
(ii) The disturbed flow field consists of a recirculating flow region in the lee of the building with a diminishing turbulent wake downwind, as shown in Figure A1.
(iii) Concentrations of the entrained part of the plume are uniform within the well-mixed recirculating flow region and based upon the fraction of the release that is entrained.
(iv) Concentrations further downwind in the main wake are the sum of those from two plumes: a ground level plume from the recirculating flow region and an elevated plume from the non-entrained remainder. The turbulent wake reduces plume height and increases turbulent spread.
(v) If the source is directly upwind of the building, the plume will be split into up to three plumes going around and over the building. These plumes are then used in the calculation of the fraction entrained into the cavity and represent the elevated plume for the non-entrained contribution in the main wake

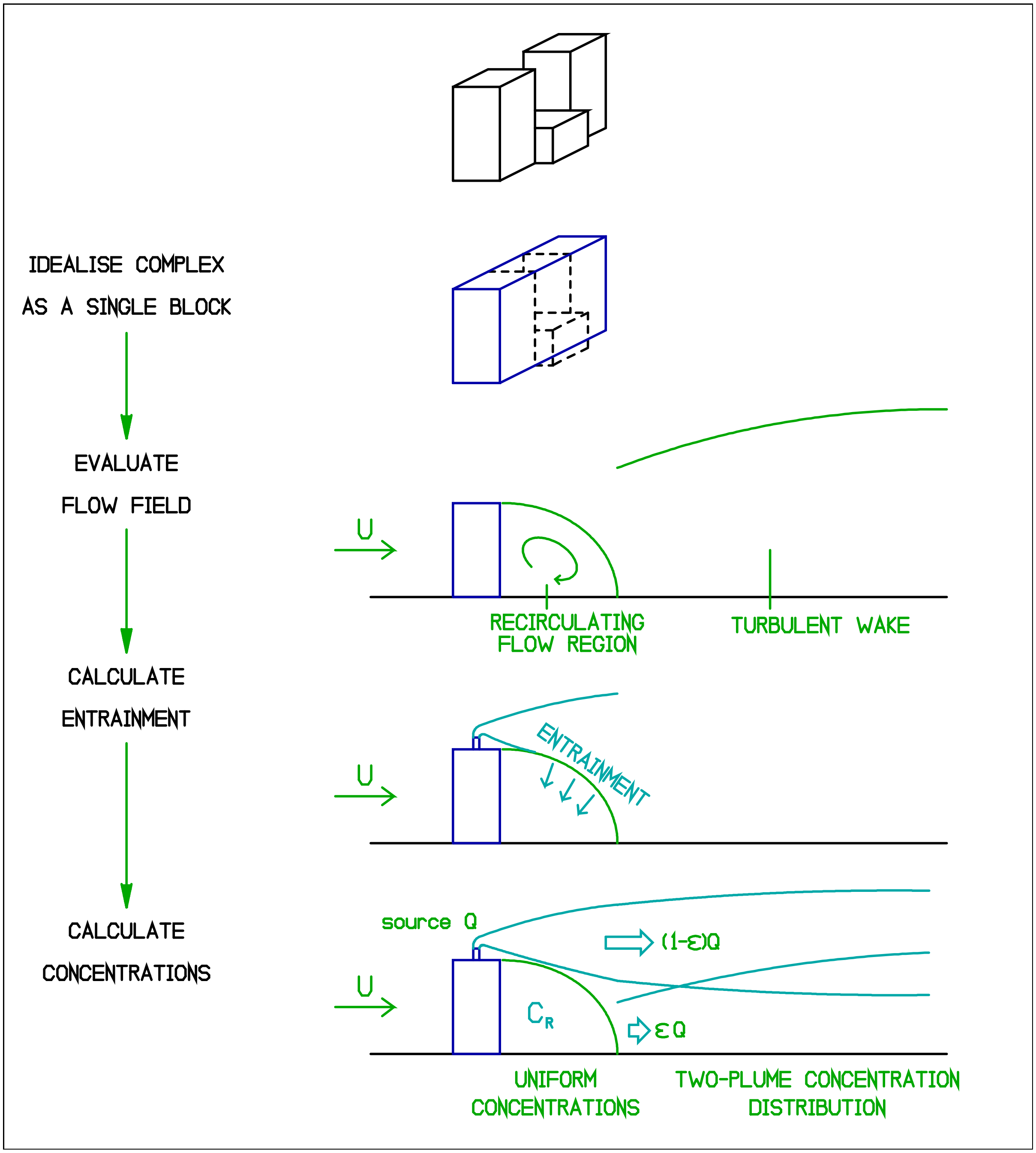

Figure A1: Stages in the modelling of building effects

Complex Effects – NO_x Chemistry

Nitrogen oxides (NO_x) emitted from combustion processes are typically only 5% to 10% nitrogen dioxide (NO_2), with the remainder as nitric oxide (NO). After emission, the NO combines with the ozone (O_3) present in the atmosphere to increase the proportion of NO_2. The key features of the two processes involved can be represented by:

(1) $NO + O_3 \rightarrow NO_2$; and
(2) $NO_2 + h\nu \rightarrow NO + O_3$,

where the role played by oxygen (O and O_2) has been omitted for clarity and $h\nu$ represents ultra violet radiation. Both of these reactions, which can proceed relatively rapidly, are modelled by ADMS, which only allows the second reaction to occur in daylight. A third reaction $2NO + O_2 \rightarrow 2NO_2$ is also included, though this will not have significant impact on NO and NO_2 concentrations unless the initial NO concentration is sufficiently high and the reaction takes place over a long period of time. Other reactions that involve O_3 and NO_2, such as those with Volatile Organic Compounds (VOCs), have not been included because their reaction times are significantly longer. They would not have any significant effect on concentrations arising from specific industrial emissions.

Complex Effects – Terrain and Roughness

Complex terrain can have a significant impact on wind-flow and consequently on the fate of dispersing material. Primarily, terrain can deflect the wind and therefore change the route taken by dispersing material. Terrain can also increase the levels of turbulence in the atmosphere, resulting in increased dilution of material. This is of particular significance during stable conditions, under which a sharp change with height can exist between flows deflected over hills and those deflected around hills or through valleys. The height of dispersing material is therefore important in determining the route it takes. In addition, areas of reverse flow, similar in form and effect to those occurring adjacent to buildings, can occur on the downwind side of a hill.

Changes in the surface roughness can also change the vertical structure of the boundary layer, affecting both the mean wind and levels of turbulence.

The ADMS Complex Terrain Module models these effects using the wind-flow model FLOWSTAR. This model uses linearised analytical solutions of the momentum and continuity equations, and includes the effects of stratification on the flow. The model is most accurate for hills of moderate slope and can typically be used for gradients up to about 1:2 but may not be reliable close to isolated slopes or escarpments with higher gradients or more generally if large parts of the modelling domain have slopes greater than 1:2. The terrain height is specified at up to 770,000 points that are interpolated by the model onto a regular grid of up to 512 by 512 points. The best results are achieved if the specified data points are regularly spaced. FLOWSTAR has been extensively tested with laboratory and field data.

Regions of reverse flow are treated by assuming that any emissions into the region are uniformly mixed within it. Material then disperses away from the region as if it were a virtual point source. Material emitted elsewhere is not able to enter reverse flow regions.

Deposition

Material in a plume that is close to the ground can be lost to the ground by dry deposition. This process is included in ADMS by using a gravitational settling velocity (which affects particles) and a deposition velocity based on aerodynamic, sub-layer and surface-layer resistance values (which affects gases and particles). The concentration profile within a dispersing plume is then adjusted to take account of the losses at the surface. Dry and wet deposition parameters can be varied spatially, to take into account changes in land use across the modelled area.

Wet deposition is included via a washout coefficient to control the quantity of material incorporated into rain. In addition, for SO_2 and HCl emitted from point sources, the 'Falling Drop' model is available, which includes the kinetics of the uptake of gases, as well as the thermodynamics and chemistry of the dissolution of gases in raindrops.

Radioactivity

For radioactive releases ADMS calculates the transformations within the plume of one isotope into another by radioactive decay. ADMS can also determine the gamma dose received at a location from a dispersing plume.

Visible Plumes

For moist emissions ADMS determines the section of the plume where the liquid water content is sufficient for the plume to be visible. This allows statistics of the frequency and lengths of visible plumes to be calculated.

Data Comparisons – Model Validation

The individual components of ADMS, for example the Buildings Module, have been developed using published scientific data and each component extensively tested to ensure that it provides reliable results. In addition, a very large number of studies have been performed on the accuracy of ADMS for point source emissions.

Among other validation studies, ADMS output has been compared with three flat terrain data sets known as Kincaid, Indianapolis and Prairie Grass, which are available from the US Modellers Data Archive. Each of these datasets has been generally accepted as containing enough measurements of sufficient quality for meaningful validation.

Further details of ADMS and model validation, including a full list of references, are available from the CERC web site at www.cerc.co.uk.