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Air quality assessment for two boilers at H Westons & Sons Ltd, Much Marcle

Draft report

Prepared for
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CERC

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Contents

1 Summary

CERC was commissioned by Wiser Environment Ltd to carry out an air quality assessment to support a permit application for the operation of two boilers at the H Weston & Sons Ltd cider manufacturing site in Much Marcle, Ledbury.

The dispersion of emissions of nitrogen oxides (NO_x), particulate matter (PM), sulphur dioxide (SO_2), carbon monoxide (CO) and Volatile Organic Compounds (VOCs) from the two boilers was carried out using the ADMS 6 model (version 6.0.2.7). Hourly sequential Numerical Weather Prediction meteorological data were obtained for Much Marcle, for the years 2021 to 2025 inclusive. The modelling used stack data provided by the client and took into account the effect of site buildings on the dispersion of pollutants.

Ground level concentrations of NO_x, NO_2, PM, SO_2, CO and VOCs were calculated for comparison with the air quality objectives for human health and critical levels for the protection of vegetation and ecosystems, where relevant. Nitrogen and acid deposition rates were calculated for comparison with critical loads for the protection of vegetation and ecosystems.

1.1 Human health

The maximum offsite annual average NO_2 Process Contributions (PCs) are not screened out, though the Predicted Environmental Concentrations (PECs, including local background concentrations) are well below the objective values for all five years of meteorological data. The annual average PCs are screened out at all sensitive receptor locations. The maximum hourly average NO_2 PCs are screened out at all locations, including onsite, where there may be public exposure.

The maximum predicted 15-minute, hourly, and daily average SO_2 concentrations are not screened out at relevant locations, though the PECs are well below the objective values for all five years of meteorological data. The SO_2 PCs for all averaging periods are screened out at most residential receptors, except at two residential properties on How Caple, approximately 200 m from the stacks, where the 15-minute average PEC is 11% of the objective.

All predicted 8-hourly rolling and hourly average concentrations of CO, at relevant offsite and onsite locations, are screened out as they are less than 10% of the objective and EAL for the protection of human health.

All predicted offsite annual and maximum daily average concentrations of particulate matter are screened out as they are less than the relevant long-term and short-term screening criteria for the $PM_{2.5}$ and PM_{10} objectives for the protection of human health.

Although the maximum offsite annual average VOC PCs are not screened out, the PECs are well below the objective values for all five years of meteorological data. The PCs are screened out at all sensitive receptor locations. The maximum daily average VOC PCs are screened out at all locations, including onsite, where there may be public exposure.

1.2 Vegetation and ecosystems

The annual and daily average PCs of NO_x and the annual average PCs of SO_2 are screened out as insignificant against the relevant critical levels for all years of meteorological data at all sensitive habitat sites.

The contribution to nitrogen and acid deposition is screened out as insignificant against the relevant critical loads for all years of meteorological data, at all sites.

2 Introduction

CERC was commissioned by Wiser Environment Ltd to carry out an air quality assessment to support a permit application for the operation of two boilers at the H Weston & Sons Ltd cider manufacturing site in Much Marcle, Ledbury.

The assessment was carried out using the ADMS 6 dispersion model. The model inputs and the results of the dispersion modelling are described in this report.

Section 3 presents the air quality objectives 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 concentrations for the area. Section 5 describes the site layout and emissions. The meteorological data input to the modelling are described in Section 6.

Sections 7 to 9 set out the results of the dispersion modelling:

- Section 7 sets out the results of the assessment against objectives for the protection of human health;
- Section 8 sets out the results of the assessment against critical levels for the protection of vegetation and ecosystems; and
- Section 9 sets out the results of the assessment against critical loads for the protection of vegetation and ecosystems.

A discussion of the implications of the 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 objectives

3.1 Air quality standards for the protection of human health

UK air quality objectives for nitrogen dioxide (NO_2), particulate matter (PM), carbon monoxide (CO) and sulphur dioxide (SO_2), set for the protection of human health, are summarised in Table 3.1. The objectives are taken from *The Air Quality Standards Regulations 2010* and the UK *Air Quality Strategy*. The objective values take into account the effects of each pollutant on the health of those who are most sensitive to air quality.

Table 3.1: Air Quality Objectives

	Value ($\mu g/m^3$)	**Description of standard**
NO_2	200	1-hour mean not to be exceeded more than 18 times a year (modelled as 99.79th percentile)
	40	annual mean
CO	10,000	maximum daily running 8-hour mean
Benzene	5	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
SO_2	350	1-hour mean not to be exceeded more than 24 times a year (modelled as 99.73rd percentile)
	125	24-hour mean not to be exceeded more than 3 times a year (modelled as 99.18th percentile)
	266	15-minute mean not to be exceeded more than 35 times a year (modelled as 99.9th percentile)

The short-term standards considered are specified in terms of the number of times during a year that a concentration measured over a short period of time 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 $\mu g/m^3$ 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, taking the NO_2 objective, 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.

Where air quality objectives do not exist, long-term and short-term Environmental Assessment Levels (EALs)[1] for the protection of human health are used, as presented in Table 3.2. There are short-term EALs for benzene and carbon monoxide, in addition to the air quality objectives for these pollutants.

Table 3.2: Environmental Assessment Levels (EALs)

	Value (µg/m³)	Averaging time
Carbon monoxide	30,000	hourly average
Benzene	30	daily average

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 3.3.

The guidance recommends the assessment of:

- Special Protection Areas (SPAs)[2], Special Areas of Conservation (SACs)[3] and Ramsar[4] sites within 10 km of the installation; and
- Sites of Special Scientific Interests (SSSIs)[5], National Nature Reserves (NNRs)[5], Local Nature Reserves (LNRs)[6], Local Wildlife Sites (LWSs) and Ancient Woodland (AW) within 2 km of the installation.

Table 3.3: Critical levels for the Protection of Vegetation and Ecosystems

	Critical level (µg/m³)	Averaging time
SO_2	10	annual mean (for sensitive lichens)
	20	annual mean (for forests and natural and semi-natural vegetation – all other ecosystems)
NO_x	30	annual mean
	75	daily mean

[1] https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit
[2] Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora
[3] Council Directive 79/409/EEC on the conservation of wild birds
[4] International Convention on Wetlands of International Importance especially as Waterfowl Habitat
[5] Declared by the statutory country conservation agencies, which have a duty under the Wildlife and Countryside Act 1981
[6] 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

H Weston & Sons cider manufacturing plant is situated in a rural area approximately 1 km west of the village of Much Marcle, as shown in Figure 4.1.

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 stack emissions modelling. A surface roughness value of 0.5 m was used for the modelled area, representing the mixture of trees and agricultural land use around the site, as well as onsite infrastructure, including buildings and tanks. A value of 0.3 m was used for the meteorological data; see Section 6 for further information regarding the meteorological data.

In the ADMS model, the stability of the atmosphere is represented by the Monin-Obukhov parameter, which has the dimension of length. In stable conditions, a minimum value can be set in the model to represent the urban heat island effect, which prevents the atmosphere from getting very stable. A minimum value of 1 m was used for the modelled and meteorological areas, representative of a rural area.

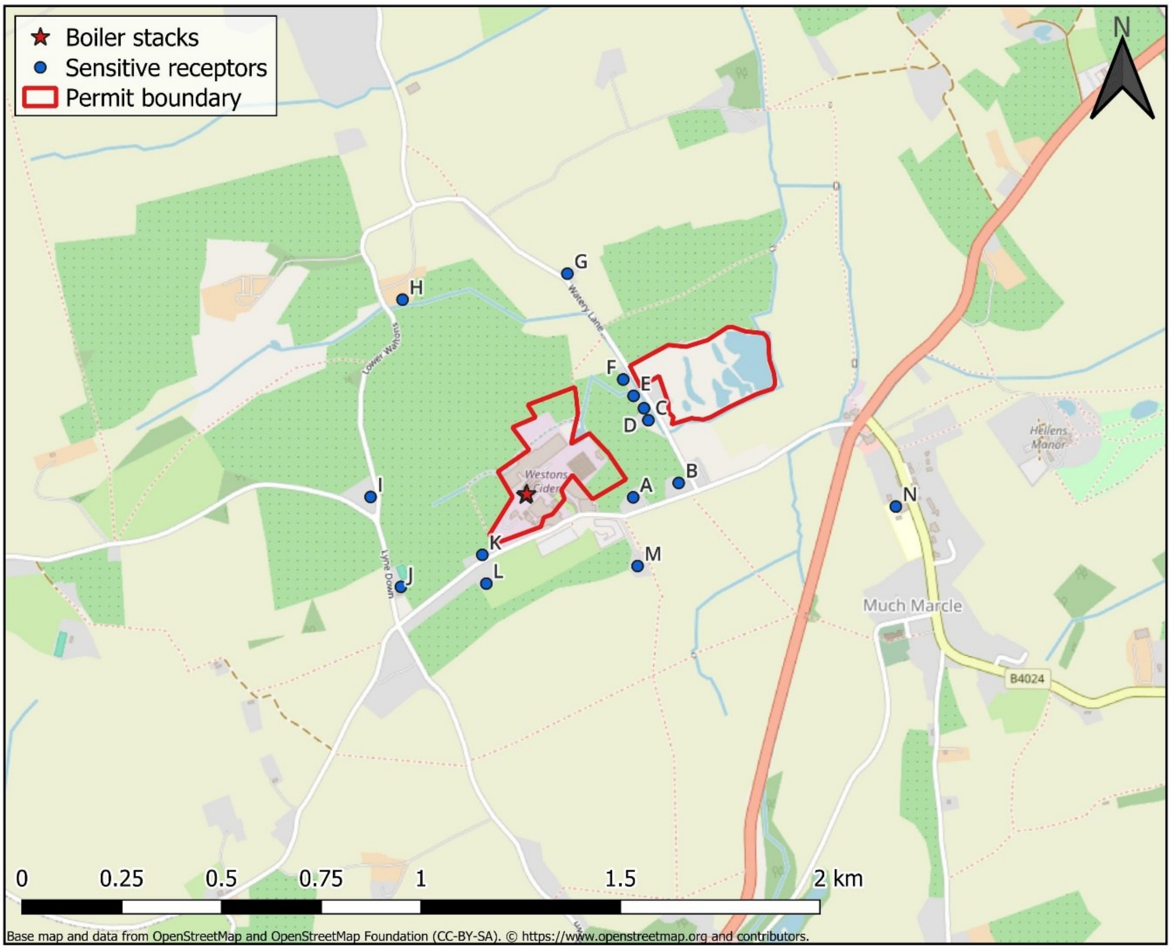

Figure 4.1: Site location and nearby sensitive human receptor locations

4.2 Terrain data

The site is situated at a height of approximately 75 m above sea level, on a gentle slope rising up to about 220 m on Marcle Ridge to the west. The effects of the local terrain on dispersion may be significant and so were included in the modelling.

Figure 4.2 shows a contour map of the local terrain.

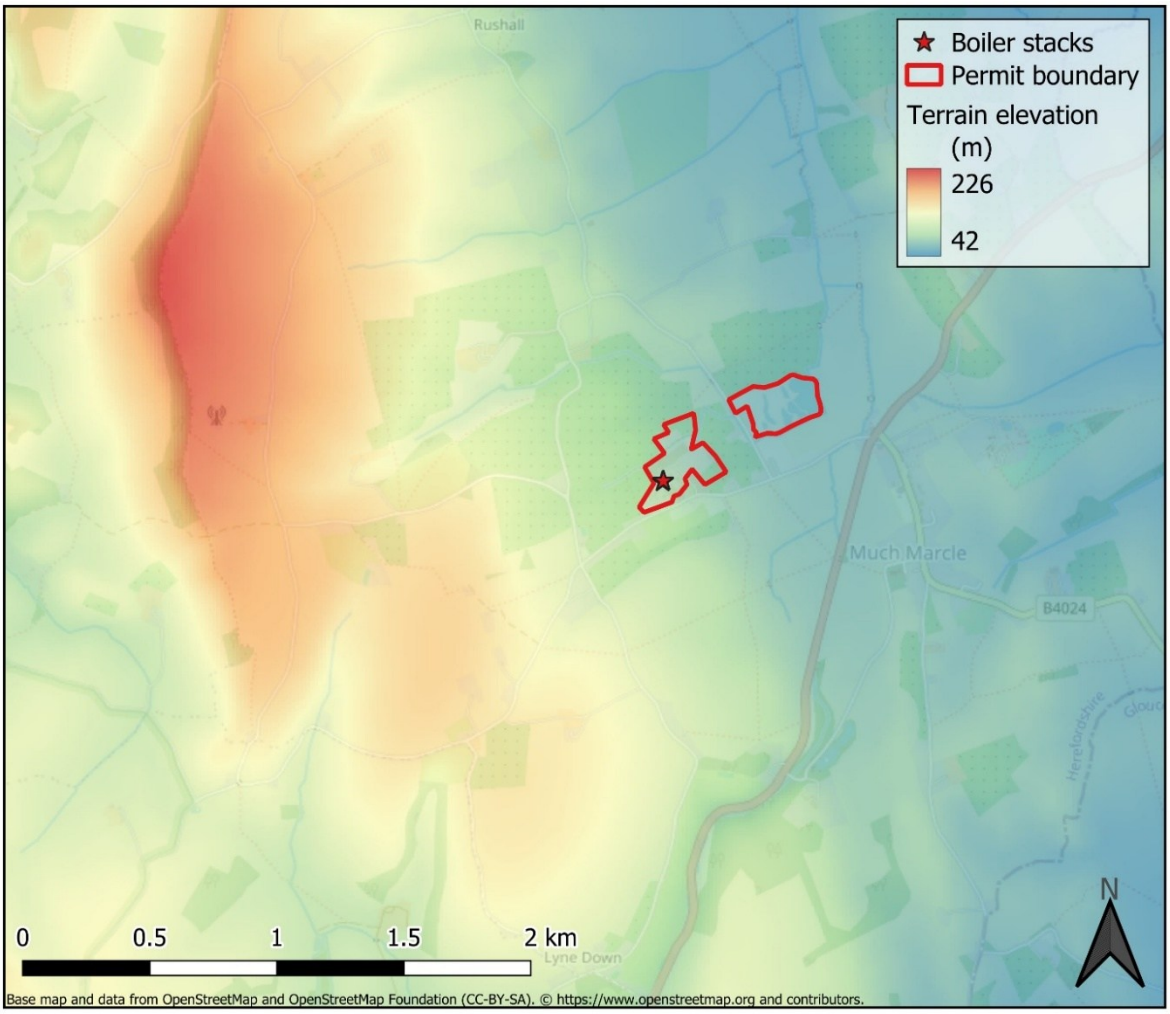

Figure 4.2: Local terrain elevation

4.3 Sensitive receptors for human health impact

Model output was generated at ground level on an output grid extending 2 km by 2 km, approximately centred on the site, with concentration values calculated at points 10 m apart on this grid, capturing the maximum predicted concentrations across the modelled area.

The site offers public tours of the facility, lasting approximately 1 hour, and also has an onsite restaurant and bar open to the public. Due to the reasonable public exposure, hourly and sub-hourly average concentrations are presented as the maximum over all onsite and offsite locations. Averaging periods of 8 hours or longer are presented exclusively over offsite locations, due to lack of onsite public exposure for these periods.

Model output was also generated at locations of specific sensitive human health receptors. The locations of these receptors with respect to the modelled stacks are described in Table 4.1 and shown in Figure 4.1. All sensitive receptors were modelled at ground level.

Table 4.1: Sensitive human receptor locations

Receptor ID	Name	Type	Distance from stacks	OSGB X,Y coordinates (m)
A	Applegarth	Residential	265 m east	365053, 233091
B	Upper Venning	Residential	380 m east	365167, 233127
C	Tavern Cottage	Residential	355 m north east	365091, 233284
D	Watery Lane 1	Residential	365 m north east	365080, 233314
E	Watery Lane 2	Residential	365 m north east	365054, 233345
F	Watery Lane 3	Residential	375 m north east	365028, 233386
G	Southbank	Residential	560 m north	364888, 233651
H	Lower Wolton	Residential	575 m north west	364475, 233586
I	Lower Woltons	Residential	385 m west	364395, 233092
J	Old Pike	Residential	385 m south west	364471, 232867
K	How Caple 1	Residential	185 m south west	364675, 232947
L	How Caple 2	Residential	240 m south west	364685, 232875
M	Cowlease	Residential	330 m south east	365064, 232919
N	Much Marcle Primary	School	925 m east	365711, 233068

4.4 Sensitive receptors for the protection of vegetation and ecosystems

There are no SPAs or Ramsar sites within 10 km of the site. There are no SSSIs, LNRs, NNRs or LWSs within 2 km of the site.

The River Wye SAC is approximately 5 km west of the site, at the nearest point, and stretches north to south. There are two areas of Ancient Woodland roughly 1.8 km west of the site. The areas of Ancient Woodland and the nearest parts of the SAC are shown on Figure 4.3.

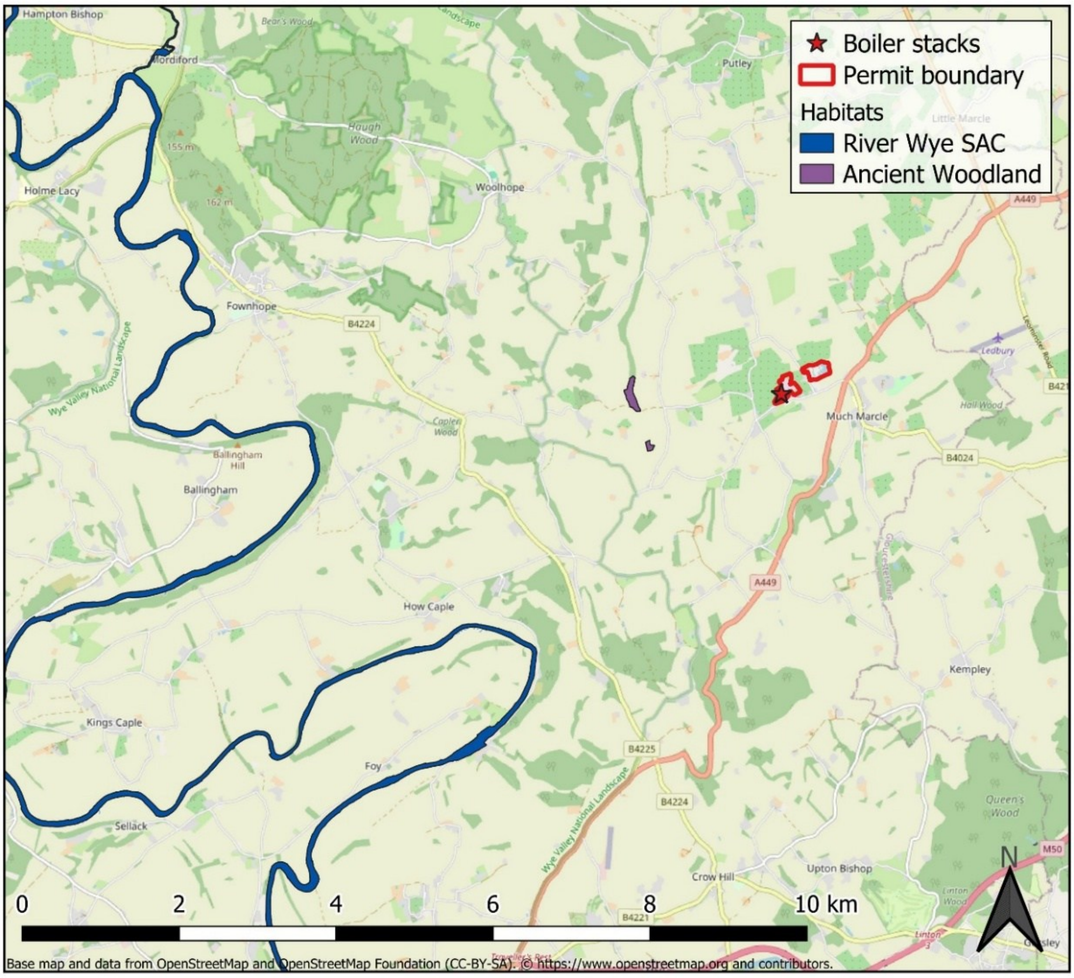

Figure 4.3: Locations of River Wye SAC and areas of Ancient Woodland

4.5 Local air quality

A good indication of the sensitivity of a particular area is whether it has been declared an Air Quality Management Area (AQMA). An AQMA is an area in which one or more air quality objectives are not likely to be achieved, for which the local authority is obliged to prepare a plan to improve air quality. Herefordshire Council has declared two AQMAs, in Leominster and Hereford, due to high levels of NO_2 from road traffic emissions. The nearest of these is the AQMA in Hereford, over 15 km north west of the site.

Air quality around the site is therefore expected to be good, and emissions from the site are unlikely to affect any AQMAs.

There are no nearby monitoring sites. The nearest monitors are diffusion tubes measuring NO_2, including an industrial site and suburban area on the outskirts of Hereford. These sites are detailed in Table 4.2, which also summarises the annual average NO_2 concentrations at the sites, taken from the Herefordshire Council Air Quality Annual Status Report 2025.[7] Concentrations are well below the annual average air quality objective for NO_2.

[7] https://www.herefordshire.gov.uk/community/environmental-health/environmental-control/air-quality-management-areas/

Table 4.2: Summary of nearby NO_2 diffusion tube monitoring site

ID	Site name	Site type	Location (x,y)	Concentration (µg/m³)				
				2020	2021	2022	2023	2024
85	Huntington Lane	Rural	348753, 241942	6.2	6.7	6.7	6.0	5.7
92	Rotherwas Industrial Estate	Urban background	352916, 237844	9.8	10.6	10.2	9.2	8.9

4.6 Background concentrations

Local background concentrations of carbon monoxide (CO) for the year 2010 and sulphur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (PM_{10} and $PM_{2.5}$) and benzene for the year 2024 were obtained from the UK AIR Air Information Resource background mapping[8]. These values are provided on a 1 km grid basis; Table 4.3 presents annual average concentrations for the grid square containing the cider manufacturing site (364500, 233500).

These values were used in calculations of the Predicted Environmental Concentration for comparison against objectives for human health.

Table 4.3: Annual average background concentrations (µg/m³)

Year	CO	NO_2	$PM_{2.5}$	PM_{10}	SO_2	Benzene
2010	200	-	-	-	-	-
2024	-	3.12	5.51	10.16	0.87	0.17

For the assessment of ecologically sensitive sites, background concentrations of SO_2 and nitrogen oxides (NO_x) were obtained for each area from the APIS[9] web site. Table 4.4 presents background concentrations for each of the sensitive ecological sites. These values represent three-year averages, over the period 2022 to 2024.

For designated sites that cover a large area, the provided concentration values represent the part of the site where the worst impacts are seen.

Table 4.4: APIS background concentrations (µg/m³)

Grid square	Ecologically sensitive site	NO_x	SO_2
361500, 229500	River Wye SAC	4.4	0.7
362500, 232500	Unnamed AW	4.2	0.7
363500, 232500	Foxhalls Wood AW	4.2	0.7

[8] https://uk-air.defra.gov.uk/data/gis-mapping/ (accessed 26/05/26)
[9] https://www.apis.ac.uk/app (accessed 06/07/26)

5 Modelled stack and emissions data

5.1 Modelled stacks

Emissions from the two boiler stacks were modelled assuming continuous emissions throughout the year, as they operate for approximately 8064 hours per year. Emission rates were calculated based on the appropriate Emission Limit Values (ELVs) provided by Wiser.

Table 5.1 shows the modelled boiler stack parameters. Table 5.2 shows the modelled emission rates.

The two boilers run on furnace fuel oil. Boiler 1 has a thermal input rating of 1.73 MW and Boiler 2 has a rating of 2.33 MW.

Table 5.1: Boiler stack parameters

Parameter	**Boiler 1 Small boiler**	**Boiler 2 Big boiler**
Stack location (X,Y)	364785, 233098	364787, 233101
Stack height (m)	10	10
Diameter (m)	0.35	0.35
Temperature (°C)	156	155
Normalised volume flow rate[10] (Nm^3/hr)	1153	1193
Actual volume flow rate (Am^3/hr)	3298	3181
Exit velocity (m/s)	9.5	9.2

Table 5.2: Boiler emission rates

	NO_x	**PM**	**SO_2**	**CO**	**VOCs**
ELV[10] (mg/Nm^3)	150	5	350	100	50
Emission rates for Boiler 1 (g/s)	0.048	0.002	0.112	0.032	0.016
Emission rates for Boiler 2 (g/s)	0.050	0.002	0.116	0.033	0.017

[10] At 273 K, 101.3 kPa, 3% oxygen, dry

5.2 Modelled buildings

Buildings that are relatively close to the modelled stacks and higher than one third of the stack height can have an effect on dispersion, by disturbing wind flows and increasing turbulence. Increased concentrations can occur when pollutants are entrained into the region adjacent to a building, and downwind concentrations can also be affected.

The parameters of the buildings included in the modelling are given in Table 5.3. Buildings data were provided by Wiser.

Table 5.3: Modelled building data

Name	Coordinates of building centre		Height (m)	Length (m)	Width (m)	Angle of length to north (°)
	X	Y				
Boiler house	364789	233097	7.0	9	8	40.3
Six ways	364815	233120	7.0	60	20	40.3
Vat house	364812	233062	15.8	30	35	45.9
Canning line	364749	233137	10.6	30	37	52.0
Bottling line	364793	233175	8.8	66	31	53.0
Main warehouse	364839	233207	12.1	46	35	52.0

The modelled buildings and stacks are shown on Figure 5.1.

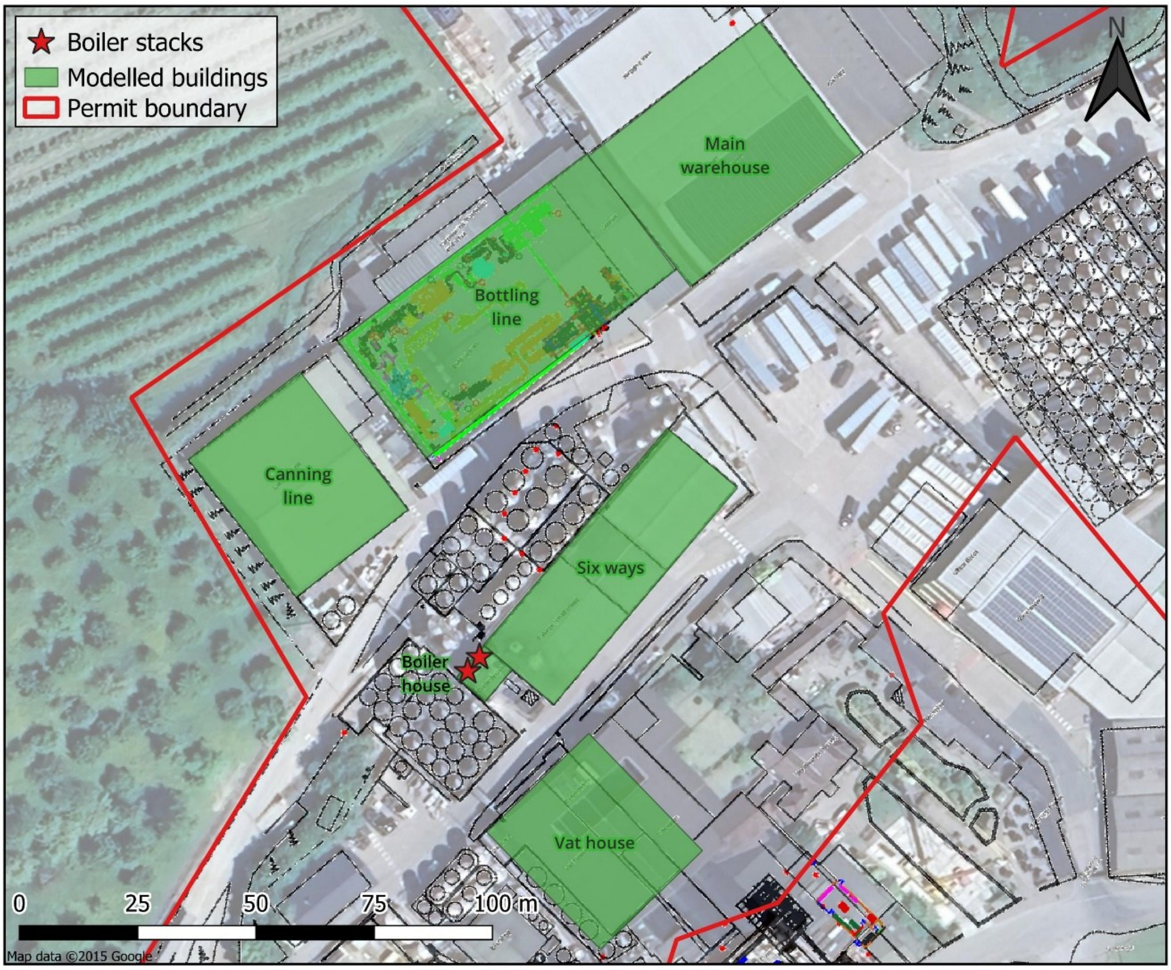

Figure 5.1: Site layout showing relative locations of modelled sources and buildings

6 Meteorological data

Modelling was carried out using hourly sequential Numerical Weather Prediction (NWP) meteorological data, for the five years 2021 to 2025. NWP data were generated at the location 52.00° N, 2.51° W. These data are considered to give the best possible representation of the meteorological conditions at the modelled location.

A surface roughness length of 0.3 metres was used to characterise the domain of the NWP data. The value is representative of mixed agricultural and wooded areas, appropriate for the surrounding land use.

The hours of meteorological data used in the analysis exclude hours of calm conditions and unavailable data. A summary of the data used is given below in Table 6.1. The ADMS meteorological pre-processor, written by the UK Met Office, uses the meteorological data to calculate the parameters required by the model.

Table 6.1: Summary of meteorological data used

Year	Percentage used	Parameter	Minimum	Maximum	Mean
2021	98.2	Temperature (°C)	-7.3	30.4	9.9
		Wind speed (m/s)	0	19.9	4.8
		Cloud cover (oktas)	0	8	4.5
		Precipitation (mm/hr)	0	6.4	0.05
2022	98.4	Temperature (°C)	-5.9	39.6	10.9
		Wind speed (m/s)	0	19.1	4.9
		Cloud cover (oktas)	0	8	4.2
		Precipitation (mm/hr)	0	6.5	0.04
2023	98.9	Temperature (°C)	-5.4	31.5	10.6
		Wind speed (m/s)	0	17.1	4.9
		Cloud cover (oktas)	0	8	4.5
		Precipitation (mm/hr)	0	7.2	0.05
2024	98.3	Temperature (°C)	-6.1	30.1	10.4
		Wind speed (m/s)	0	18.3	4.9
		Cloud cover (oktas)	0	8	4.9
		Precipitation (mm/hr)	0	17.6	0.06
2025	98.7	Temperature (°C)	-5.8	35	10.8
		Wind speed (m/s)	0.1	16.2	4.9
		Cloud cover (oktas)	0	8	4.2
		Precipitation (mm/hr)	0	9.1	0.05

Figure 6.1 shows wind roses for the NWP data, giving the frequency of occurrence of wind from different directions for a number of wind speed ranges.

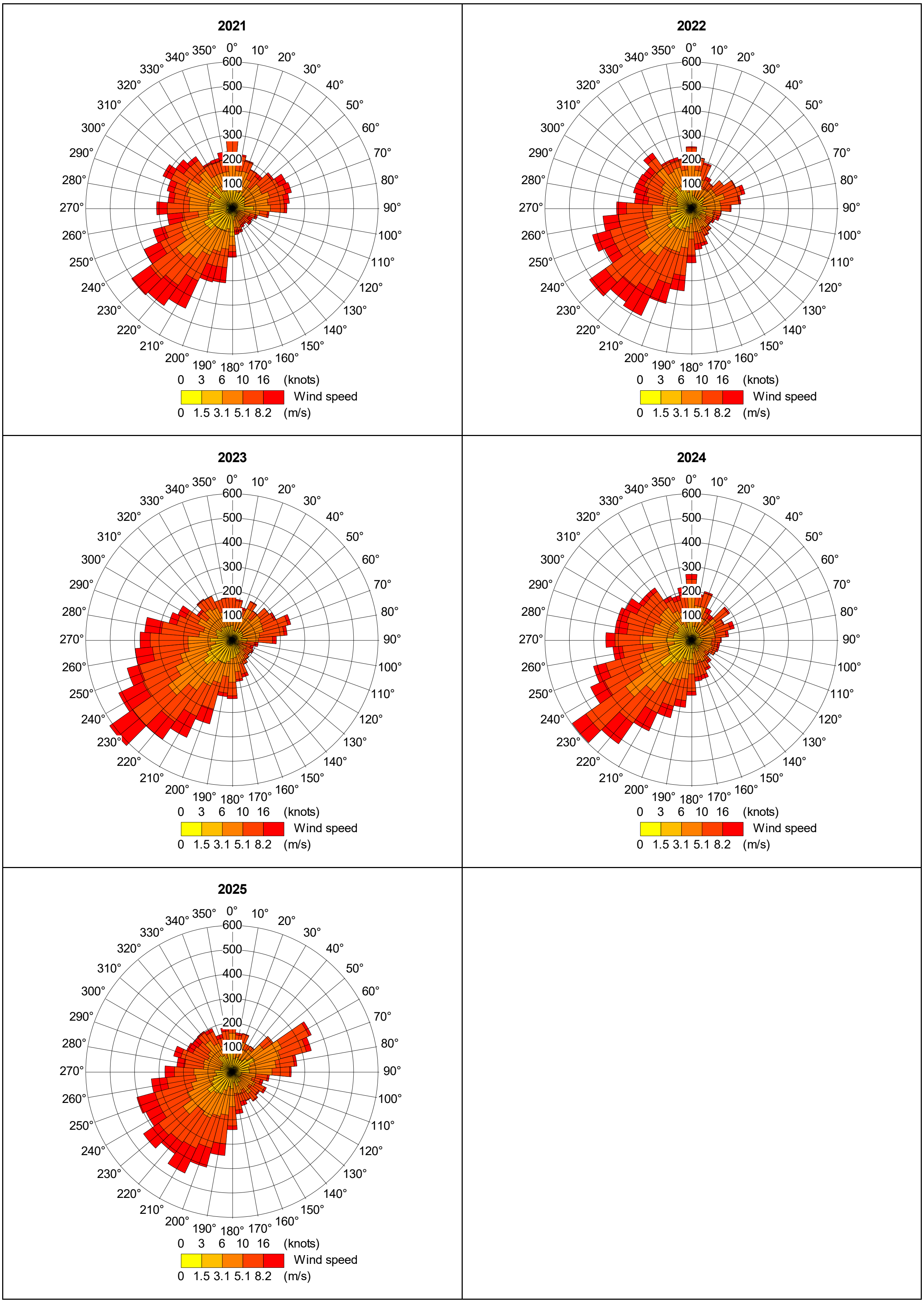

Figure 6.1: Wind roses for 52.00° N, 2.51° W

7 Consideration of objectives for the protection of human health

Ground-level concentrations were calculated on an output grid extending 2 km by 2 km, capturing the maximum predicted concentrations, with a resolution of 10 m, as well as at a set of fourteen sensitive receptor locations.

For long-term (annual average) standards and short-term standards with averaging periods of 8 or 24 hours, maximum concentrations are reported over all offsite locations. For short-term standards with averaging periods of an hour or less there is relevant public exposure onsite, as discussed in Section 4.3, so maximum concentrations are reported over all onsite and offsite locations.

Modelling was carried out to predict the Process Contribution (PC) to concentrations of NO_2, SO_2, PM, CO and VOCs.

Nitrogen oxides (NO_x) comprise nitric oxide (NO) and nitrogen dioxide (NO_2); only NO_2 poses a threat to human health. The PC to NO_2 concentrations depends on the total concentration of NO_x and the chemical reactions taking place between NO and NO_2. An empirical relationship defined by the Environment Agency is used to calculate the NO_2 PC, for direct comparison against the objectives for NO_2. This method assumes that a fixed proportion of the NO_x PC is NO_2.

The significance of the total pollutant release was assessed by comparing the PC to the relevant air quality standard. For long-term standards, the Environment Agency considers the release to be insignificant if the PC is less than 1% of the standard[11]. For short-term standards, including percentiles, the Agency considers the release to be insignificant if the PC is less than 10% of the standard. 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) is calculated.

PECs are calculated by adding the annual average background concentration to long-term (annual average) PCs, and twice the annual average background concentration to short-term PCs.

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

7.1 NO_2 concentrations

Table 7.1 shows the maximum annual average PCs and PECs of NO_2 using meteorological data for the years 2021 to 2025, at offsite locations across the modelled area. The PCs exceed the Environment Agency screening criterion of 1% of the objective value, so the PECs were calculated using a background concentration of 3.1 µg/m^3. Predicted concentrations are well below the objective for all five years of meteorological data.

Table 7.1: Maximum annual average NO_2 PCs and PECs (µg/m^3), offsite

Year	Objective value	PC					PEC	
		NO_x	NO_2 [12]	% of objective	Screened out?	Location (x, y)	NO_2	% of objective
2021	40	2.3	1.6	4	No	364730, 233080	4.7	12
2022		1.9	1.3	3		364730, 233080	4.4	11
2023		2.1	1.5	4		364730, 233080	4.6	12
2024		1.7	1.2	3		364850, 233060	4.3	11
2025		3.0	2.1	5		364730, 233080	5.2	13

Table 7.2 presents the maximum annual average PCs of NO_2 at each of the sensitive receptors, over the five years of meteorological data. The PCs are screened out at all sensitive receptors.

Table 7.2: Maximum annual average NO_2 PCs (µg/m^3), residential receptors

Receptor	Objective value	PC			
		NO_x	NO_2 [12]	% of objective	Screened out?
Applegarth	40	0.34	0.24	0.6	Yes
Upper Venning		0.21	0.15	0.4	Yes
Tavern Cottage		0.31	0.22	0.6	Yes
Watery Lane 1		0.32	0.22	0.6	Yes
Watery Lane 2		0.32	0.22	0.6	Yes
Watery Lane 3		0.29	0.20	0.5	Yes
Southbank		0.11	0.08	0.2	Yes
Lower Wolton		0.06	0.04	0.1	Yes
Lower Woltons		0.13	0.09	0.2	Yes
Old Pike		0.19	0.13	0.3	Yes
How Caple 1		0.43	0.30	0.8	Yes
How Caple 2		0.30	0.21	0.5	Yes
Cowlease		0.20	0.14	0.4	Yes
Much Marcle Primary		0.05	0.04	0.1	Yes

[12] Assuming 70% of total NO_x PC for long-term concentrations

A contour plot of the PC to annual average NO_2 concentrations, based on 2025 meteorological data, is shown in Figure 7.1.

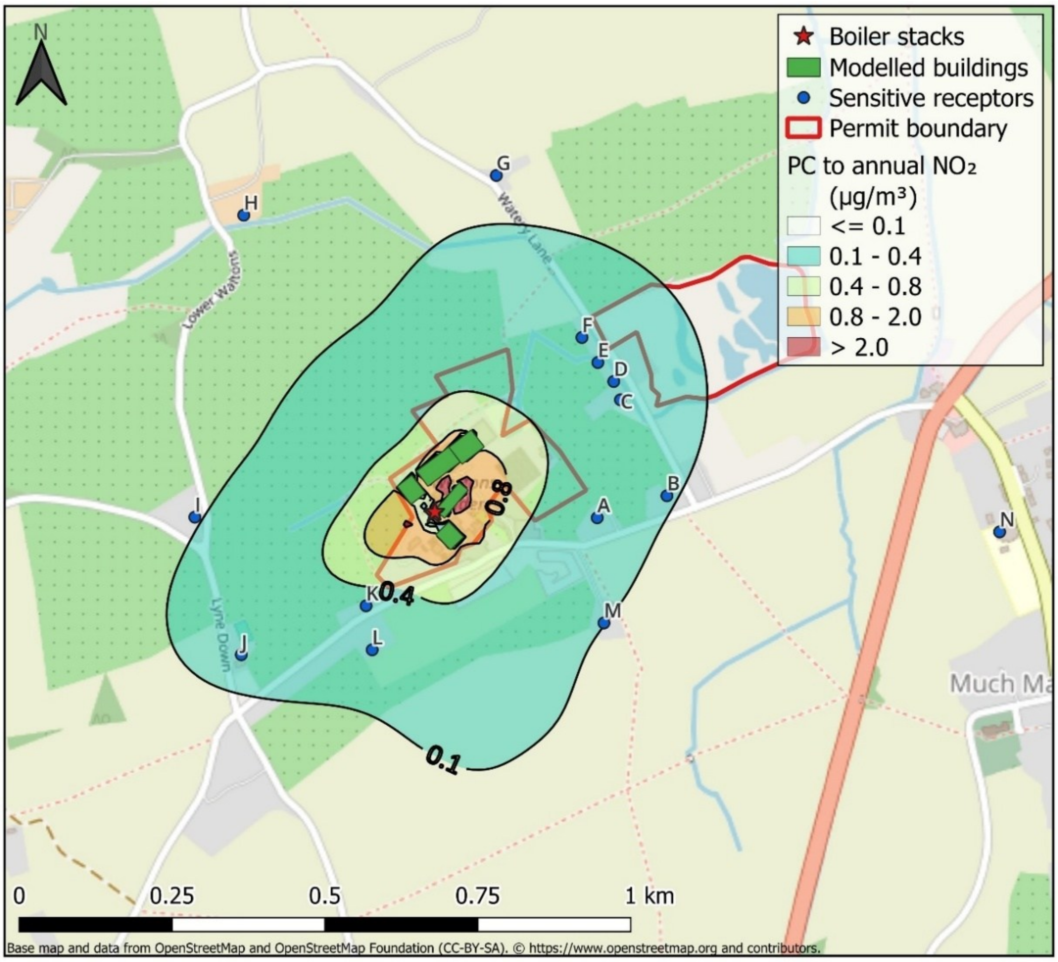

Figure 7.1: Annual average NO_2 PC (µg/m³), 2025 meteorological data

Table 7.3 shows the maximum hourly PCs of NO_2 using meteorological data for the years 2021 to 2025. Results represent the maximum across all offsite and onsite locations, due to onsite public exposure over short averaging periods. The PCs are less than the Environment Agency screening criterion of 10% of the short-term objective value, so the concentrations are screened out, and PCs at specific receptor locations are not presented.

Table 7.3: Maximum 99.79th percentile of hourly average NO_2 PCs (µg/m³)

Year	Objective value	PC				
		NO_x	NO_2 [13]	% of objective	Screened out?	Location (x, y)
2021	200	41	14	7	Yes	364830, 233100
2022		38	13	7		364830, 233120
2023		39	14	7		364840, 233110
2024		39	14	7		364830, 233100
2025		39	14	7		364840, 233100

[13] Assuming 35% of total NO_x PC for short-term concentrations

7.2 PM concentrations

It is assumed that 100% of the emitted particulates are PM_{10} and $PM_{2.5}$, in each case.

Table 7.4 shows the maximum annual average PCs of particulates using meteorological data for the years 2021 to 2025, at offsite locations across the modelled area. The PCs are less than 1% of both the PM_{10} and $PM_{2.5}$ objective values, so are screened out.

Table 7.4: Maximum annual average particulate PCs (µg/m³), offsite

Year	Objective value	PC				
		PM	% of PM_{10} objective	% of $PM_{2.5}$ objective	Screened out?	Location (x, y)
2021	40 (PM_{10}) 20 ($PM_{2.5}$)	0.08	0.2	0.4	Yes	364730, 233080
2022		0.06	0.2	0.3		364730, 233080
2023		0.07	0.2	0.4		364730, 233080
2024		0.06	0.2	0.3		364850, 233060
2025		0.10	0.3	0.5		364730, 233080

Table 7.5 shows the maximum 24-hour average PM_{10} PCs, using meteorological data for the five years 2021 to 2025, at offsite locations across the modelled area. The impacts are screened out, as they are less than 10% of the air quality objective.

Table 7.5: Maximum 90.41st percentile of daily average PM_{10} PCs (µg/m³), offsite

Year	Objective value	PC			
		PM_{10}	% of objective	Screened out?	Location (x, y)
2021	50	0.3	0.6	Yes	364730, 233090
2022		0.3	0.6		364730, 233080
2023		0.3	0.6		364730, 233080
2024		0.2	0.4		364850, 233060
2025		0.5	1.0		364730, 233080

As all offsite particulate PCs are screened out, impacts at specific receptor locations are not presented for this pollutant.

7.3 SO_2 concentrations

Table 7.6 shows the maximum 15-minute average PCs and PECs of SO_2 using meteorological data for the years 2021 to 2025. Results represent the maximum across all offsite and onsite locations, due to onsite public exposure over short averaging periods.

The SO_2 PCs exceed the Environment Agency screening criterion of 10% of the objective value, so the PECs were calculated using double the long-term background concentration, 1.7 µg/m^3. Predicted concentrations are well below the objective for all five years of meteorological data.

Table 7.6: Maximum 99.9th percentile of 15-minute average SO_2 PCs and PECs (µg/m^3)

Year	Objective value	PC				PEC	
		SO_2	% of objective	Screened out?	Location (x, y)	SO_2	% of objective
2021	266	106	40	No	364820, 233100	108	41
2022		99	37		364820, 233110	101	38
2023		102	38		364820, 233100	104	39
2024		106	40		364820, 233100	108	41
2025		98	37		364830, 233100	100	38

Table 7.7 shows the maximum 15-minute average PCs of SO_2 over the five years of meteorological data, at residential receptors. The PCs are screened out at all but one receptor, where the maximum PEC only just exceeds the screening criterion, at 11% of the objective.

Table 7.7: Maximum 99.9th percentile of 15-minute average SO_2 PCs and PECs (µg/m^3), residential receptors

Receptor	Objective value	PC			PEC	
		SO_2	% of objective	Screened out?	SO_2	% of objective
Applegarth	266	16	6	Yes	-	-
Upper Venning		12	5	Yes	-	-
Tavern Cottage		16	6	Yes	-	-
Watery Lane 1		18	7	Yes	-	-
Watery Lane 2		18	7	Yes	-	-
Watery Lane 3		15	6	Yes	-	-
Southbank		10	4	Yes	-	-
Lower Wolton		9	3	Yes	-	-
Lower Woltons		15	6	Yes	-	-
Old Pike		21	8	Yes	-	-
How Caple 1		28	11	No	30	11
How Caple 2		26	10	Yes	-	-
Cowlease		13	5	Yes	-	-
Much Marcle Primary		6	2	Yes	-	-

Table 7.8 shows the maximum hourly average PCs and PECs of SO_2 using meteorological data for the years 2021 to 2025. Results represent the maximum across all offsite and onsite locations, due to onsite public exposure over short averaging periods.

The SO_2 PCs exceed the Environment Agency screening criterion of 10% of the objective value, so the PECs were calculated using double the long-term background concentration, 1.7 µg/m^3. Predicted concentrations are well below the objective for all five years of meteorological data.

Table 7.8: Maximum 99.73rd percentile of hourly average SO_2 PCs and PECs (µg/m^3)

Year	Objective value	PC				PEC	
		SO_2	% of objective	Screened out?	Location (x, y)	SO_2	% of objective
2021	350	92	26	No	364820, 233080	94	27
2022		87	25		364830, 233120	89	25
2023		90	26		364840, 233110	92	26
2024		90	26		364840, 233100	92	26
2025		89	25		364840, 233100	91	26

Table 7.9 shows the maximum hourly average PCs of SO_2 over the five years of meteorological data, at residential receptors. The PCs are screened out, as they are less than 10% of the objective value.

Table 7.9: Maximum 99.73rd percentile of hourly average SO_2 PCs (µg/m^3), residential receptors

Receptor	Objective value	PC		
		SO_2	% of objective	Screened out?
Applegarth	350	12	3	Yes
Upper Venning		8	2	Yes
Tavern Cottage		10	3	Yes
Watery Lane 1		11	3	Yes
Watery Lane 2		10	3	Yes
Watery Lane 3		9	3	Yes
Southbank		5	1	Yes
Lower Wolton		5	1	Yes
Lower Woltons		8	2	Yes
Old Pike		11	3	Yes
How Caple 1		22	6	Yes
How Caple 2		16	5	Yes
Cowlease		9	3	Yes
Much Marcle Primary		3	1	Yes

Table 7.10 shows the maximum daily average PCs and PECs of SO_2 using meteorological data for the years 2021 to 2025, at offsite locations across the modelled area.

The SO_2 PCs exceed the Environment Agency screening criterion of 10% of the objective value, so the PECs were calculated using double the long-term background concentration, 1.7 µg/m^3. Predicted concentrations are well below the objective for all five years of meteorological data.

Table 7.10: Maximum 99.18th percentile of daily average SO_2 PCs and PECs (µg/m^3), offsite

Year	Objective value	PC				PEC	
		SO_2	% of objective	Screened out?	Location (x, y)	SO_2	% of objective
2021	125	45	36	No	364730, 233080	47	37
2022		48	38		364730, 233080	50	40
2023		50	40		364730, 233080	52	41
2024		46	37		364730, 233080	48	38
2025		52	42		364730, 233080	54	43

Table 7.11 shows the maximum daily average PCs of SO_2 over the five years of meteorological data, at residential receptors. The PCs are screened out, as they are less than 10% of the objective value.

Table 7.11: Maximum 99.18th percentile of daily average SO_2 PCs (µg/m^3), residential receptors

Receptor	Objective value	PC		
		SO_2	% of objective	Screened out?
Applegarth	125	5.0	4	Yes
Upper Venning		3.1	2	Yes
Tavern Cottage		4.2	3	Yes
Watery Lane 1		4.3	3	Yes
Watery Lane 2		4.4	4	Yes
Watery Lane 3		3.4	3	Yes
Southbank		2.2	2	Yes
Lower Wolton		2.2	2	Yes
Lower Woltons		3.2	3	Yes
Old Pike		3.6	3	Yes
How Caple 1		8.9	7	Yes
How Caple 2		6.6	5	Yes
Cowlease		4.0	3	Yes
Much Marcle Primary		1.0	1	Yes

Contour plots of the PCs to the 99.9th percentile of 15-minute average, the 99.73rd percentile of hourly average and the 99.18th percentile of daily average SO_2 concentrations, based on the worst case year of meteorological data in each case, are shown in Figure 7.2 to Figure 7.4.

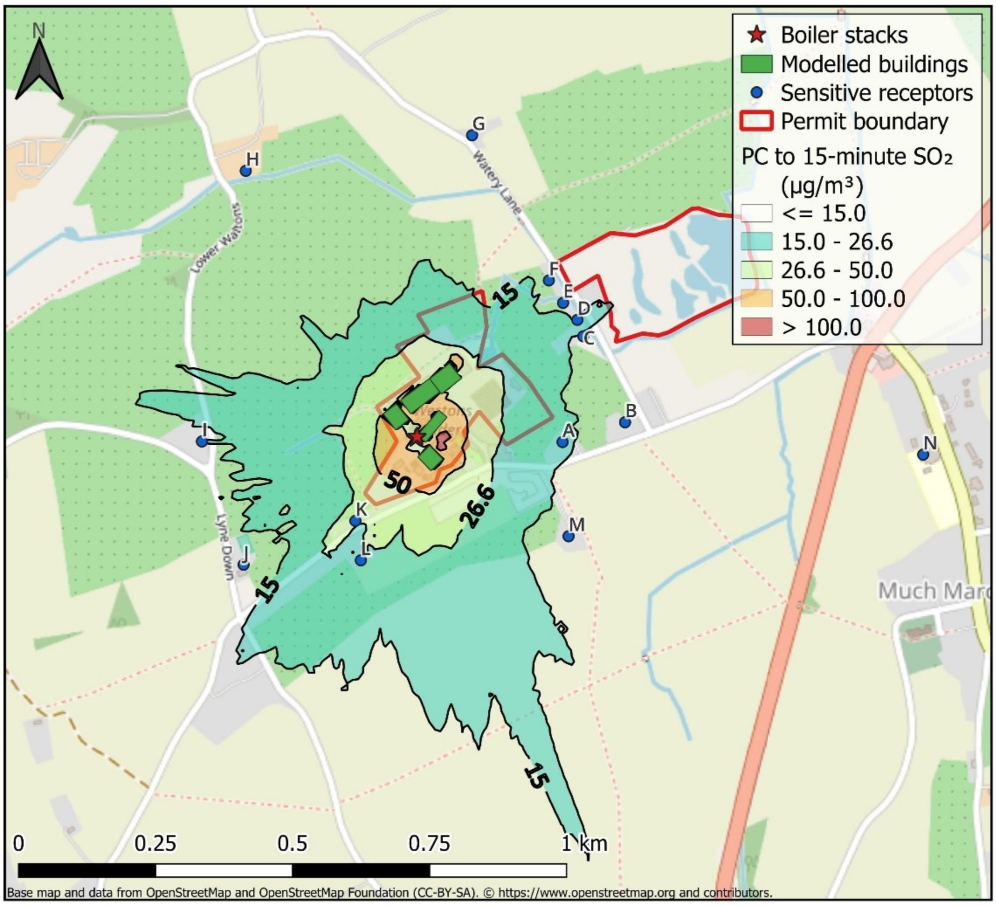

Figure 7.2: Maximum 15-minute average SO_2 PC (µg/m³), 2021 meteorological data

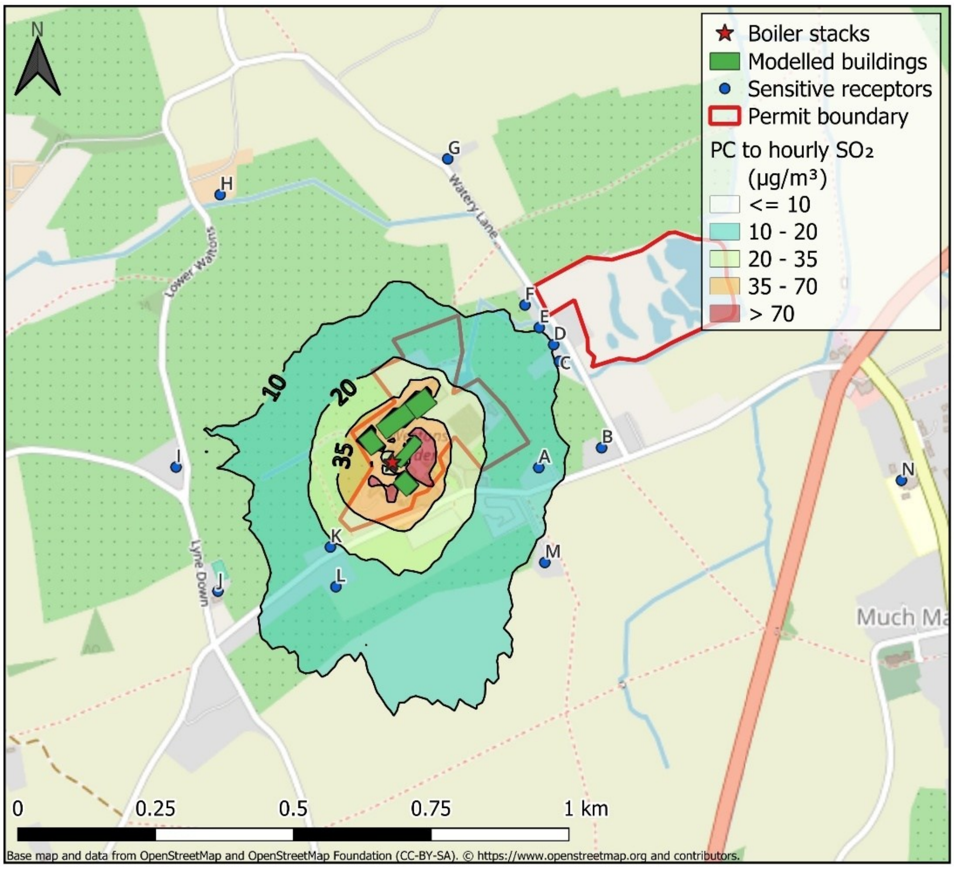

Figure 7.3: Maximum hourly average SO_2 PC (µg/m³), 2021 meteorological data

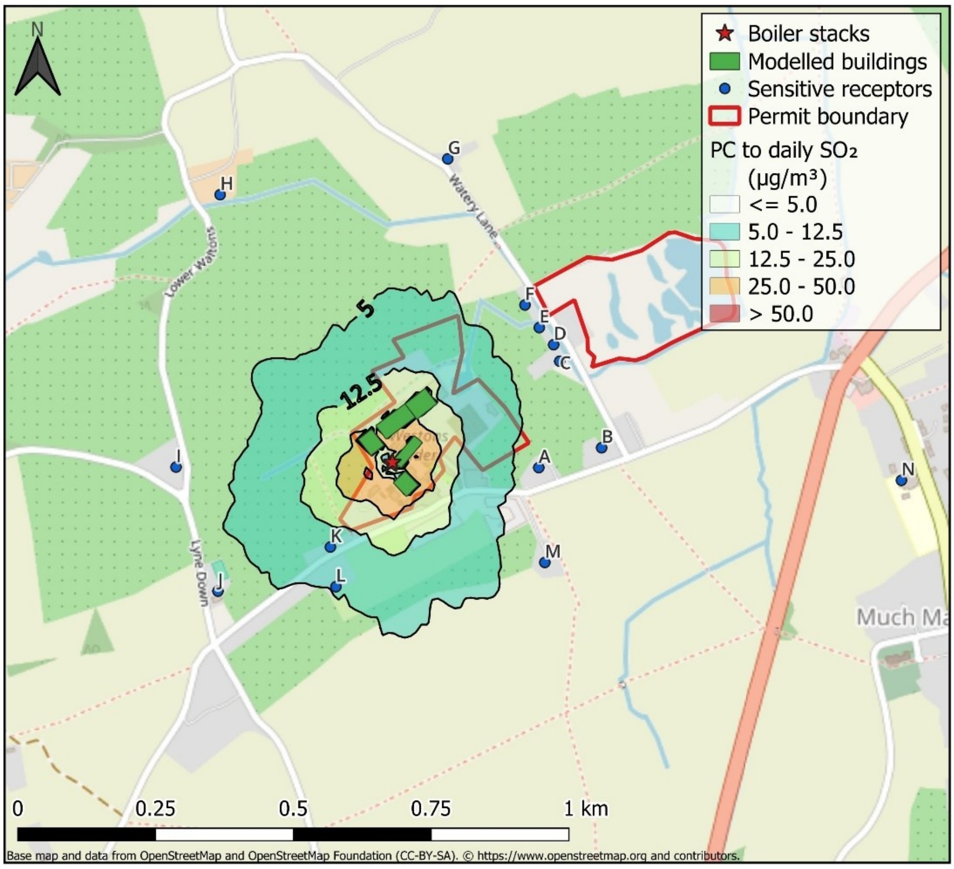

Figure 7.4: Maximum daily average SO_2 PC (µg/m³), 2025 meteorological data

7.4 CO concentrations

Table 7.12 shows the maximum 8-hour average PCs of CO using meteorological data for the years 2021 to 2025, at offsite locations across the modelled area.

The CO PCs are screened out as they are lower than the Environment Agency screening criterion of 10% of the short-term objective value.

Table 7.12: Maximum daily running 8-hour average CO PCs (µg/m³), offsite

Year	Objective value	PC			
		CO	% of objective	Screened out?	Location (x, y)
2021	10,000	18	0.2	Yes	364730, 233090
2022		18	0.2		364730, 233080
2023		18	0.2		364730, 233090
2024		18	0.2		364730, 233090
2025		20	0.2		364730, 233090

Table 7.13 shows the maximum hourly average PCs of CO using meteorological data for the years 2021 to 2025. Results represent the maximum across all offsite and onsite locations, due to onsite public exposure over short averaging periods.

The CO PCs are screened out as they are lower than the Environment Agency screening criterion of 10% of the short-term Environmental Assessment Level (EAL).

Table 7.13: Maximum 100th percentile of hourly average CO PCs (µg/m³)

Year	EAL	PC			
		CO	% of objective	Screened out?	Location (x, y)
2021	30,000	38	0.1	Yes	364780, 233080
2022		35	0.1		364810, 233080
2023		34	0.1		364760, 233070
2024		36	0.1		364760, 233070
2025		34	0.1		364770, 233060

As all CO PCs are screened out, impacts at specific receptor locations are not presented for this pollutant.

7.5 VOC concentrations

There are no air quality standards for Volatile Organic Compounds (VOCs) as a group of pollutants. In line with Environment Agency guidance, it is assumed that 100% of the emitted VOCs are benzene and the predicted concentrations are compared against the air quality standards for benzene.

Table 7.14 show the maximum annual average PCs and PECs of VOCs, using meteorological data for the years 2021 to 2025, at offsite locations across the modelled area. The PCs exceed the Environment Agency screening criterion of 1% of the objective value, so the PECs were calculated using a benzene background concentration of 0.17 µg/m^3. Predicted concentrations are well below the objective for all five years of meteorological data.

Table 7.14: Maximum annual average VOC PCs and PECs (µg/m^3), offsite

Year	Objective value (benzene)	PC				PEC	
		VOC	% of benzene objective	Screened out?	Location (x, y)	VOC	% of benzene objective
2021	5	0.75	15	No	364730, 233080	0.92	18
2022		0.65	13		364730, 233080	0.82	16
2023		0.70	14		364730, 233080	0.87	17
2024		0.58	12		364850, 233060	0.75	15
2025		0.99	20		364730, 233080	1.16	23

Table 7.15 presents the maximum annual average PCs and PECs of VOCs at each of the sensitive receptors, over the five years of meteorological data. The PCs are screened out at four of the receptors; PECs are well below the objective for benzene at all receptors.

Table 7.15: Maximum annual average VOC PCs and PECs (µg/m^3), residential receptors

Receptor	Objective value (benzene)	PC			PEC	
		VOC	% of benzene objective	Screened out?	VOC	% of benzene objective
Applegarth	5	0.113	2.3	No	0.28	6
Upper Venning		0.069	1.4	No	0.24	5
Tavern Cottage		0.104	2.1	No	0.27	5
Watery Lane 1		0.105	2.1	No	0.28	6
Watery Lane 2		0.108	2.2	No	0.28	6
Watery Lane 3		0.098	2.0	No	0.27	5
Southbank		0.037	0.7	Yes	-	-
Lower Wolton		0.020	0.4	Yes	-	-
Lower Woltons		0.045	0.9	Yes	-	-
Old Pike		0.063	1.3	No	0.23	5
How Caple 1		0.143	2.9	No	0.31	6
How Caple 2		0.101	2.0	No	0.27	5
Cowlease		0.068	1.4	No	0.24	5
Much Marcle Primary		0.016	0.3	Yes	-	-

Table 7.16 shows the maximum daily average VOC PCs and PECs, using meteorological data for the five years 2021 to 2025, at offsite locations across the modelled area.

The PCs exceed the Environment Agency screening criterion of 10% of the EAL, so the PECs were calculated using double the benzene background concentration, 0.34 µg/m^3. Concentrations are well below the benzene EAL for all five years of meteorological data.

Table 7.16: Maximum 100th percentile of daily average VOC PCs and PECs (µg/m^3), offsite

Year	EAL (benzene)	PC				PEC	
		VOC	% of benzene EAL	Screened out?	Location (x, y)	VOC	% of benzene EAL
2021	30	7.9	26	No	364730, 233090	8.2	27
2022		7.8	26		364730, 233080	8.1	27
2023		7.5	25		364730, 233080	7.8	26
2024		7.8	26		364730, 233080	8.1	27
2025		7.8	26		364730, 233080	8.1	27

Table 7.17 presents the maximum daily average PCs of VOCs over the five years of meteorological data, at residential receptors. The PCs are screened out, as they are less than 10% of the EAL.

Table 7.17: Maximum 100th percentile of daily average VOC PCs (µg/m3), residential receptors

Receptor	EAL (benzene)	PC		
		VOC	% of benzene EAL	Screened out?
Applegarth	30	0.8	3	Yes
Upper Venning		0.6	2	Yes
Tavern Cottage		0.7	2	Yes
Watery Lane 1		0.8	3	Yes
Watery Lane 2		0.8	3	Yes
Watery Lane 3		0.8	3	Yes
Southbank		0.4	1	Yes
Lower Wolton		0.4	1	Yes
Lower Woltons		0.7	2	Yes
Old Pike		0.8	3	Yes
How Caple 1		1.6	5	Yes
How Caple 2		1.2	4	Yes
Cowlease		0.7	2	Yes
Much Marcle Primary		0.2	1	Yes

Figure 7.5 and Figure 7.6 show contour plots of annual and daily average VOC PCs, respectively, based on meteorological data for the year giving rise to the highest predicted concentration in each case.

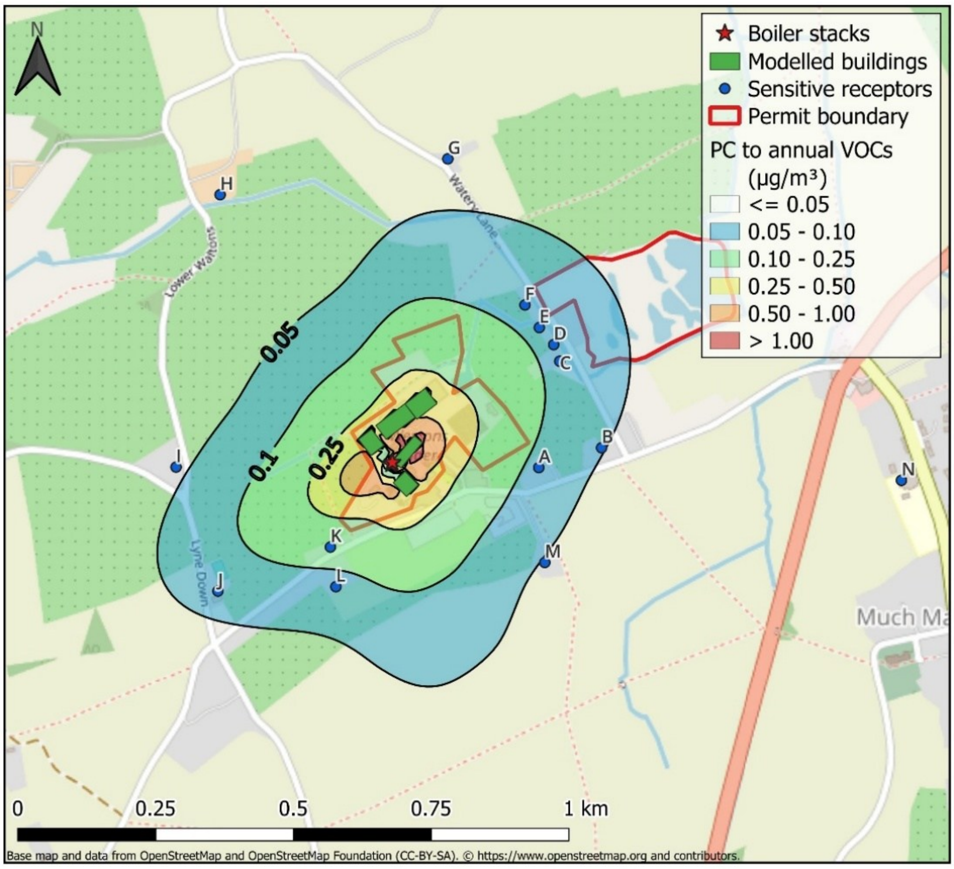

Figure 7.5: Annual average VOC PC (µg/m³), 2025 meteorological data

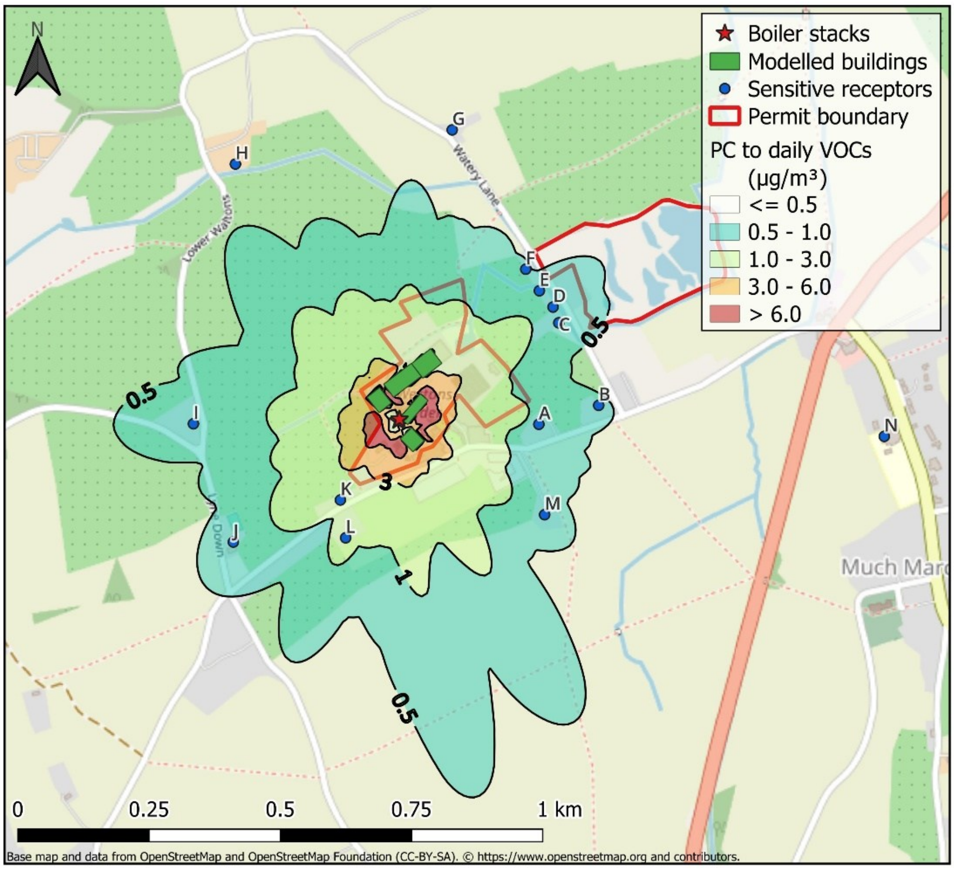

Figure 7.6: Maximum daily average VOC PC (µg/m³), 2021 meteorological data

8 Consideration of critical levels for the protection of vegetation and ecosystems

Concentrations of NO_x and SO_2 were calculated at the location of all identified ecologically sensitive sites for comparison with critical levels for the protection of vegetation and ecosystems.

The significance of the total pollutant release was assessed by comparing the PC to the relevant critical level. 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[11]. For short-term standards, the Agency considers the release to be insignificant if the PC is less than 10% of the air quality standard.

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 PEC is calculated.

8.1 NO_x concentrations

Table 8.1 shows the maximum annual average PCs NO_x within the ecologically sensitive sites, using meteorological data for the years 2021 to 2025.

The annual average PCs are screened out as insignificant for all years of meteorological data at River Wye SAC and at all areas of Ancient Woodland.

Table 8.1: Maximum annual average NO_x concentrations at ecologically sensitive sites ($\mu g/m^3$)

Site	Year	Critical level	PC	PC as % of critical level	Screened out?
River Wye SAC	2021	30	0.004	< 0.1	Yes
	2022		0.003		
	2023		0.003		
	2024		0.002		
	2025		0.004		
Foxhalls Wood AW	2021	30	0.011	< 0.1	Yes
	2022		0.010		
	2023		0.010		
	2024		0.007		
	2025		0.015		
Unnamed AW	2021	30	0.010	< 0.1	Yes
	2022		0.009		
	2023		0.008		
	2024		0.006		
	2025		0.011		

Table 8.2 shows the maximum daily average PCs of NO_x within the ecologically sensitive sites, using meteorological data for the years 2021 to 2025.

The daily average PCs are screened out as insignificant for all years of meteorological data at River Wye SAC and at all areas of Ancient Woodland.

Table 8.2: Maximum daily average NO_x concentrations at ecologically sensitive sites ($\mu g/m^3$)

Site	Year	Critical level	PC	PC as % of critical level	Screened out?
River Wye SAC	2021	75	0.2	0.3	Yes
	2022		0.1	0.1	
	2023		0.1	0.1	
	2024		0.1	0.1	
	2025		0.1	0.1	
Foxhalls Wood AW	2021	75	0.2	0.3	Yes
	2022		0.1	0.1	
	2023		0.1	0.1	
	2024		0.1	0.1	
	2025		0.2	0.3	
Unnamed AW	2021	75	0.3	0.4	Yes
	2022		0.1	0.1	
	2023		0.1	0.1	
	2024		0.2	0.3	
	2025		0.2	0.3	

8.2 SO_2 concentrations

Table 8.3 shows the maximum annual average PCs of SO_2 within the ecologically sensitive sites, using meteorological data for the years 2021 to 2025.

The annual average PCs are screened out as insignificant for all years of meteorological data at River Wye SAC and at all areas of Ancient Woodland.

Table 8.3: Maximum annual average SO_2 concentrations at ecologically sensitive sites ($\mu g/m^3$)

Site	Year	Critical level	PC	PC as % of critical level	Screened out?
River Wye SAC	2021	10	0.01	0.1	Yes
	2022		0.01	0.1	
	2023		0.01	0.1	
	2024		0.01	0.1	
	2025		0.01	0.1	
Foxhalls Wood AW	2021	20	0.03	0.2	Yes
	2022		0.02	0.1	
	2023		0.02	0.1	
	2024		0.02	0.1	
	2025		0.04	0.2	
Unnamed AW	2021	20	0.02	0.1	Yes
	2022		0.02	0.1	
	2023		0.02	0.1	
	2024		0.01	0.1	
	2025		0.03	0.2	

9 Consideration of critical loads for the protection of vegetation and ecosystems

Material from a plume can be lost to the ground, at the surface (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.

The PCs to the nitrogen and acid deposition rates were calculated at the location of all identified ecologically sensitive sites for comparison with critical loads for the protection of vegetation and ecosystems.

The significance of the total pollutant release was assessed by comparing the PC to the relevant critical loads. 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 APIS web site gives critical load values for specific SACs. For areas of Ancient Woodland, this information must be found by location.

Table 9.1 shows the habitat types, critical loads and total nitrogen deposition values at each of the ecologically sensitive sites. The total nitrogen deposition values presented represent the average deposition over the years 2022 to 2024, due to existing local sources and background contributions, within the relevant SAC or 1 km grid square.

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
River Wye SAC	Bog woodland	Raised and blanket bogs	5 - 10	25.8
	Dry heaths	Dry heaths	5 - 15	14.9
	Transition mires and quaking bogs	Valley mires, poor fens and transition mires	5 - 15	14.9
	Western acidic oak woodland	Acidophilous Quercus forest	10 - 15	25.8
	Mixed woodland on base-rich soils	Carpinus and Quercus mesic deciduous forest	15 - 20	25.8
Foxhalls Wood AW	Broadleaved, mixed and yew woodland	Broadleaved deciduous woodland	10 - 15	25.4
Unnamed AW	Broadleaved, mixed and yew woodland	Broadleaved deciduous woodland	10 - 15	25.4

9.1.2 Process contribution to nitrogen deposition

The deposition of nitrogen from concentrations of NO_2 (assumed to be 70% of NO_x) was considered.

The Environment Agency Air Quality Technical Advisory Group (AQTAG)[14] recommend a dry deposition velocity for forest of 0.003 m/s for NO_2. This value was used for all three sites as a conservative approach, as some woodland features are present at each site. Wet deposition for this pollutant was not included, as advised by AQTAG.

The maximum predicted annual PC to deposition rates of nitrogen at each ecologically sensitive site is presented in Table 9.2, together with the PC as a percentage of the most stringent applicable critical load. The PC percentage was calculated using the lower value of the critical load range.

The contribution to nitrogen deposition is screened out as insignificant for all sites.

Table 9.2: Maximum calculated nitrogen deposition (kg N ha^{-1} yr^{-1})

Site name	Critical load Class	Critical load	Year	PC	PC as % of critical load	Screened out?
River Wye SAC	Raised and blanket bogs	5 - 10	2021	0.0006	< 0.1	Yes
			2022	0.0005		
			2023	0.0004		
			2024	0.0004		
			2025	0.0007		
Foxhalls Wood AW	Broadleaved deciduous woodland	10 - 15	2021	0.0020	< 0.1	Yes
			2022	0.0018		
			2023	0.0018		
			2024	0.0013		
			2025	0.0028		
Unnamed AW	Broadleaved deciduous woodland	10 - 15	2021	0.0018	< 0.1	Yes
			2022	0.0015		
			2023	0.0014		
			2024	0.0011		
			2025	0.0019		

[14] Environment Agency AQTAG06, *Detailed air dispersion modelling approach in support of stage 1 and stage 2 Habitats Regulations Assessment*, updated version, approved July 2025

9.2 Acid deposition

9.2.1 Critical loads and existing levels of acid deposition

The APIS web site gives critical load values for specific SACs. For areas of Ancient Woodland, this information must be found by location.

Table 9.3 shows the habitat types, critical loads and total acid deposition values at each of the ecologically sensitive sites. The total acid deposition values presented represent the average deposition over the three years 2022 to 2024, due to existing local sources and background contributions, within the relevant SAC or 1 km grid square. The nitrogen (N) and sulphur (S) contributions are presented.

The critical load function is defined by three quantities to account for the contribution of different species to total acid deposition. 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[14]. 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.

Table 9.3: Total acid deposition (keq ha^{-1} yr^{-1})

<table>
<tr><th>Site name</th><th>Feature name</th><th>Acidity critical load Class</th><th>Critical load</th><th>Total acid deposition N | S</th></tr>
<tr><td rowspan="6">River Wye SAC</td><td>Bog woodland</td><td rowspan="2">Bogs</td><td rowspan="2">CLmaxS: 0.166
CLminN: 0.321
CLmaxN: 0.487</td><td>1.83 | 0.12</td></tr>
<tr><td>Transition mires and quaking bogs</td><td>1.06 | 0.10</td></tr>
<tr><td>Dry heaths</td><td>Dwarf shrub heath</td><td>CLmaxS: 0.210
CLminN: 0.499
CLmaxN: 0.709</td><td>1.06 | 0.10</td></tr>
<tr><td>Western acidic oak woodland/Mixed woodland on base-rich soils</td><td>Unmanaged Broadleafed/ Coniferous Woodland</td><td>CLmaxS: 0.566
CLminN: 0.142
CLmaxN: 0.708</td><td>1.83 | 0.12</td></tr>
<tr><td>Rivers with floating vegetation often dominated by water-crowfoot</td><td>Freshwater</td><td>No critical load information</td><td>0.56 | 0.10</td></tr>
<tr></tr>
<tr><td>Foxhalls Wood AW</td><td>Unmanaged woodland</td><td>Unmanaged Broadleafed/ Coniferous Woodland</td><td>CLmaxS: 10.775
CLminN: 0.142
CLmaxN: 10.917</td><td>1.81 | 0.12</td></tr>
<tr><td>Unnamed AW</td><td>Unmanaged woodland</td><td>Unmanaged Broadleafed/ Coniferous Woodland</td><td>CLmaxS: 1.552
CLminN: 0.142
CLmaxN: 1.694</td><td>1.81 | 0.12</td></tr>
</table>

9.2.2 Process contribution to acid deposition

The rate of acid deposition calculated in this assessment is based on the PC to acid deposition from nitrogen, presented in Section 9.1. The contributions from SO_2 are also included.

The Environment Agency AQTAG recommend dry deposition velocities for forest of 0.003 m/s for NO_2 and 0.024 m/s for SO_2. These values were used for all three sites as a conservative approach, as some woodland features are present at each site. Wet deposition for this pollutant was not included, as advised by AQTAG.

The maximum predicted annual PC to acid deposition rates at each ecologically sensitive site is presented in Table 9.4.

Table 9.4: Contributions to acid deposition (keq ha^{-1} yr^{-1}) at ecologically sensitive sites

Site name	Year	PC (N)	PC (S)
River Wye SAC	2021	0.00004	0.0010
	2022	0.00004	0.0008
	2023	0.00003	0.0007
	2024	0.00003	0.0007
	2025	0.00005	0.0010
Foxhalls Wood AW	2021	0.00014	0.0042
	2022	0.00013	0.0038
	2023	0.00013	0.0038
	2024	0.00009	0.0028
	2025	0.00020	0.0057
Unnamed AW	2021	0.00013	0.0037
	2022	0.00011	0.0032
	2023	0.00010	0.0030
	2024	0.00008	0.0023
	2025	0.00014	0.0039

The APIS Critical Load Function Tool[9] was used to assess the combined impact of the nitrogen and sulphur contributions to acid deposition at each of the sites.

For each identified habitat, CLmaxS, CLmaxN and CLminN were input to the tool, along with the maximum background deposition, presented in Table 9.3.

The maximum PCs to the nitrogen and sulphur contributions, as presented in Table 9.4, were input to the tool.

Table 9.5 presents the PC as a percentage of the critical load function, as output from the APIS Critical Load Function Tool, at each ecologically sensitive site.

The contribution to acid deposition is screened out as insignificant for all sites for which relevant critical load information is available.

Table 9.5: Results of APIS Critical Load Function Tool

Site name	Acidity critical load class	PC as % of CL function	Screened out?
River Wye SAC	Bogs	0.2	Yes
	Dwarf shrub heath	0.1	Yes
	Unmanaged Broadleafed/ Coniferous Woodland	0.1	Yes
Foxhalls Wood AW	Unmanaged Broadleafed/ Coniferous Woodland	0.1	Yes
Unnamed AW	Unmanaged Broadleafed/ Coniferous Woodland	0.2	Yes

10 Discussion

Air dispersion modelling of emissions of NO_x, SO_2, PM, CO and VOCs from two boilers at the H Westons cider manufacturing facility was carried out using ADMS (version 6.0.2.7).

Ground level concentrations of NO_x, NO_2, SO_2, PM, CO and VOCs were calculated for comparison with the air quality objectives for human health and critical levels for the protection of vegetation and ecosystems. Nitrogen and acid deposition rates were calculated for comparison with critical loads for the protection of vegetation and ecosystems.

10.1 Human health

The maximum offsite annual average NO_2 Process Contributions (PCs) are not screened out, though the Predicted Environmental Concentrations (PECs, including local background concentrations) are well below the objective values for all five years of meteorological data. The annual average PCs are screened out at all sensitive receptor locations. The maximum hourly average NO_2 PCs are screened out at all locations, including onsite, where there may be public exposure.

The maximum predicted 15-minute, hourly, and daily average SO_2 concentrations are not screened out at relevant locations, though the PECs are well below the objective values for all five years of meteorological data. The SO_2 PCs for all averaging periods are screened out at most residential receptors, except at two residential properties on How Caple, approximately 200 m from the stacks, where the 15-minute average PEC is 11% of the objective.

All predicted 8-hourly rolling and hourly average concentrations of CO, at relevant offsite and onsite locations, are screened out as they are less than 10% of the objective and EAL for the protection of human health.

All predicted offsite annual and maximum daily average concentrations of particulate matter are screened out as they are less than the relevant long-term and short-term screening criteria for the $PM_{2.5}$ and PM_{10} objectives for the protection of human health.

Although the maximum offsite annual average VOC PCs are not screened out, the PECs are well below the objective values for all five years of meteorological data. The PCs are screened out at all sensitive receptor locations. The maximum daily average VOC PCs are screened out at all locations, including onsite, where there may be public exposure.

10.2 Vegetation and ecosystems

The annual and daily average PCs of NO_x and the annual average PCs of SO_2 are screened out as insignificant against the relevant critical levels for all years of meteorological data at all sensitive habitat sites.

The contribution to nitrogen and acid deposition is screened out as insignificant against the relevant critical loads for all years of meteorological data, at all sites.

APPENDIX A: Summary of ADMS 6

ADMS, the **A**tmospheric **D**ispersion **M**odelling **S**ystem[15], 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.

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 website 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. Relevant features of ADMS also include the ability 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;
- 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; and,
- determine the quantities of an emission deposited to the ground by both dry and wet deposition processes.

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

[15] 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.

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.

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.

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

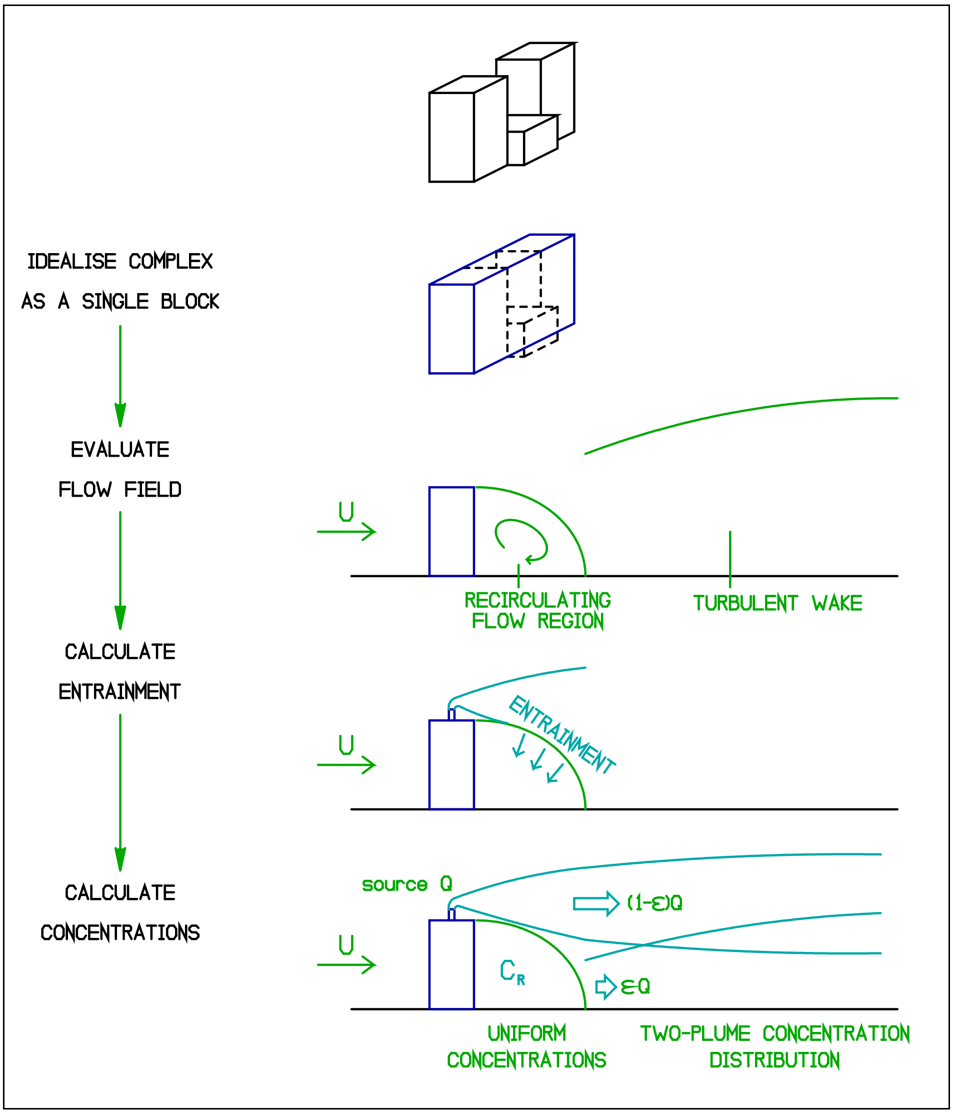

Figure A1: Stages in the modelling of building effects

Complex Effects – 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.

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 website at www.cerc.co.uk.