Cambridge Environmental Research Consultants

Dispersion modelling assessment for proposed replacement furnace, Essar Stanlow Refinery: CD4 furnace stack comparison – all receptors

Final report

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1 Summary

Cambridge Environmental Research Consultants Ltd (CERC) was commissioned by Essar Oil (UK) Limited (Essar Oil) to carry out dispersion modelling of emissions to air at Essar Stanlow Refinery, in support of the planning and permit applications for a replacement furnace on the CD4 plant.

A dispersion modelling assessment of combustion emissions was carried out using the ADMS 5 model (version 5.2.4.0). Essar Oil provided all site, stack and emissions data.

The assessment described in this report considers the impact of emissions from the proposed CD4 combined furnace stack and compares the impact to that from the current CD4 furnace stack, which is to be replaced. Three concentrations of sulphur in fuel gas were evaluated: a representative average concentration; a typical value for sustained periods of running with high sulphur fuel gas; and the peak sulphur in fuel gas value observed from fuel gas analysis (a worst case value).

1.1 Human health impacts

For both the current CD4 furnace stack and the proposed CD4 combined furnace stack, the maximum offsite NO_2, SO_2, PM_{10} and $PM_{2.5}$ Process Contributions (PCs) are screened out at all locations, for all years and all scenarios, as they are less than 1% of the long-term and 10% of the short-term objective in each case.

1.2 Ecological impacts

For both the current CD4 furnace stack and the proposed CD4 combined furnace stack, the NO_x PCs are screened out at all ten of the designated conservation areas, as the annual average PCs are less than 1% of the critical level of 30 $\mu g/m^3$ and the daily average PCs are less than 10% of the critical level of 75 $\mu g/m^3$.

For both the current CD4 furnace stack and the proposed CD4 combined furnace stack, and for all scenarios, the maximum SO_2 PECs are well below the critical level at all ten designated conservation areas.

2 Introduction

Cambridge Environmental Research Consultants Ltd (CERC) was commissioned by Essar Oil (UK) Limited (Essar Oil) to carry out dispersion modelling of emissions to air at Essar Stanlow Refinery, in support of the planning and permit applications for a replacement furnace on the CD4 plant.

A dispersion modelling assessment of combustion emissions was carried out using the ADMS 5 model (version 5.2.4.0). Essar Oil provided all site, stack and emissions data.

The assessment described in this report considers the impact of emissions from the proposed CD4 combined furnace stack and compares the impact to that from the current CD4 furnace stack, which is to be replaced. Three concentrations of sulphur in fuel gas were evaluated: a representative average concentration; a typical value for sustained periods of running with high sulphur fuel gas; and the peak sulphur in fuel gas value observed from fuel gas analysis (a worst case value).

The model inputs and the results of the dispersion modelling are described in this report. Section 3 presents the air quality standards with which the modelled results are compared. Details of the site location and surrounding area are given in Section 4, along with background concentrations for the area. Model input data, including stack emissions, are detailed in Section 5. The meteorological data input to the modelling are described in Section 6.

Sections 7 and 8 present maximum offsite concentrations for the protection of human health for the proposed CD4 combined furnace stack and the current CD4 furnace stack, respectively.

Sections 9 and 10 present concentrations for the assessment of vegetation and ecosystems at sensitive ecological sites, for the proposed CD4 combined furnace stack and current CD4 furnace stack, respectively.

A discussion of the implications of all of the modelling results is provided in Section 11. Finally, a description of the ADMS model used in the assessment is given in Appendix A.

3 Air quality standards

3.1 Protection of human health

UK air quality objectives for nitrogen dioxide (NO_2), particulate matter (PM_{10} and $PM_{2.5}$) and sulphur dioxide (SO_2), set for the protection of human health, are summarised in Table 3.1. The year by which each objective is to be achieved is also shown in the table. 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 (µg/m^3)

Substance	Limit value (µg/m3)	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
$PM_{2.5}$	25 [1]	annual mean
SO_2	350	hourly mean not to be exceeded more than 24 times a year (modelled as 99.73rd percentile)
	125	daily mean not to be exceeded more than 3 times per year (modelled as 99.18th percentile)
	266	15 minute average not to be exceeded more than 35 times per year (modelled as 99.9th percentile)

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.

[1] The Environment Agency web site mistakenly states 20 µg/m^3; CERC is waiting for a response from the Environment Agency regarding this issue. https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit#environmental-standards-for-air-emissions

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.

3.2 Protection of vegetation and ecosystems

Critical levels for the protection of vegetation and ecosystems, as set out in the Environment Agency's guidance for environmental permits, are summarised in Table 3.2.

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 and ancient woodland within 2 km of the installation.

Table 3.2: Critical levels for the Protection of Vegetation and Ecosystems (µg/m^3)

Pollutant	Critical Level	Comment
SO_2	10	annual mean (for sensitive lichen and bryophytes communities and ecosystems where lichens and bryophytes are an important part of the ecosystem's integrity)
	20	annual mean (for all higher plants - all other ecosystems)
NO_x	30	annual mean
	75	daily mean

[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

Stanlow Refinery is located close to the banks of the Mersey, east of Ellesmere Port. The villages of Thornton-le-Moors and Elton lie to the south and east of the refinery, respectively. Figure 4.1 shows the location of the site.

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 surface roughness value of 0.5 metres was used for the modelled area, which represents the land use around the site. A surface roughness value of 0.2 metres was used for Liverpool Airport meteorological station. See Section 6 for further information regarding the meteorological data used in the modelling. In the ADMS 5 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 30 metres was used in this modelling, which is suitable for a mixed urban and industrial area. The model default value of 1 metre was used for Liverpool Airport meteorological site.

The surrounding area is generally flat, and so the effects of terrain on dispersion were considered negligible and not taken into account in the modelling.

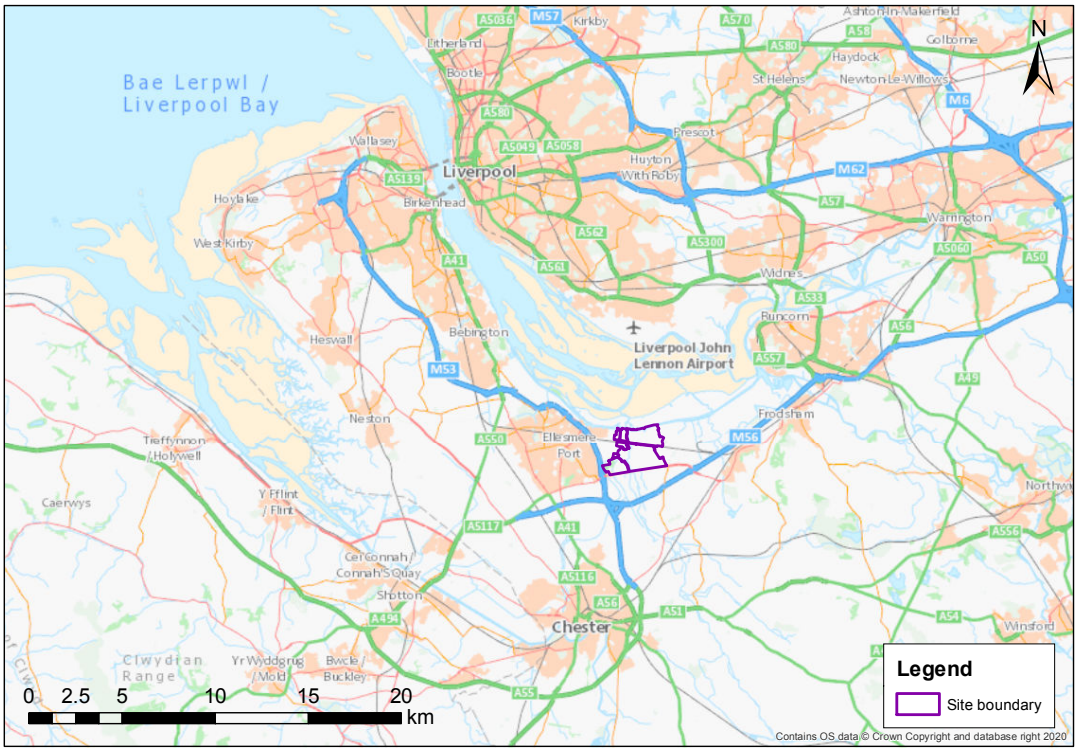

Figure 4.1: Location of site

4.2 Sensitive receptors for human health impact

Model output was generated at ground level on an output grid extending 8 km by 8 km, approximately centred on the site, with concentration values calculated at points 20 m apart on this grid, capturing the maximum predicted concentrations across the modelled area.

Model output was also generated at locations of specific sensitive receptors. The locations of these receptors are described in Table 4.1 and shown in Figure 4.2 and Figure 4.4. All sensitive receptors were modelled at ground level except those representing the monitoring sites, which were modelled at the inlet heights.

Table 4.1: Sensitive human health receptors

Id	Name	Type	Location (X, Y)	Height (m)
1	Elton Primary School	Education facility	345536, 375552	0
2	Wolverham Primary and Nursery School	Education facility	340750, 375776	0
3	The Oaks Community Primary School	Education facility	340767, 375059	0
4	St Bernard's Roman Catholic Primary School	Education facility	340784, 375323	0
5	Oval Crescent	Residential	341443, 375349	0
6	Robinson Road	Residential	341086, 375952	0
7	Griffiths Lane	Residential	340689, 376359	0
8	Shepherd Close	Residential	340742, 376708	0
9	Station Close	Residential	345375, 375889	0
10	Bare Brick House	Residential	345265, 376050	0
11	Meadow View	Residential	345178, 375354	0
12	Swiss Road	Residential	345185, 374995	0
13	The Bungalow	Residential	345043, 374657	0
14	Poole Lane	Residential	344272, 374734	0
15	Yewtree Farm	Residential	344789, 376549	0
16	The Square	Residential	345003, 376415	0
17	Kinseys Lane	Residential	344690, 376849	0
18	Cheshire Oaks Outlet	Leisure	341505, 374680	0
19	Stanlow and Thornton	Train Station	344004, 376035	0
20	Research Park	Offices	344510, 375924	0
21	Elton (ELT)	Monitoring site	345642, 375522	2.0
22	Thornton-le-Moors (TLP)	Monitoring site	344103, 374330	2.5

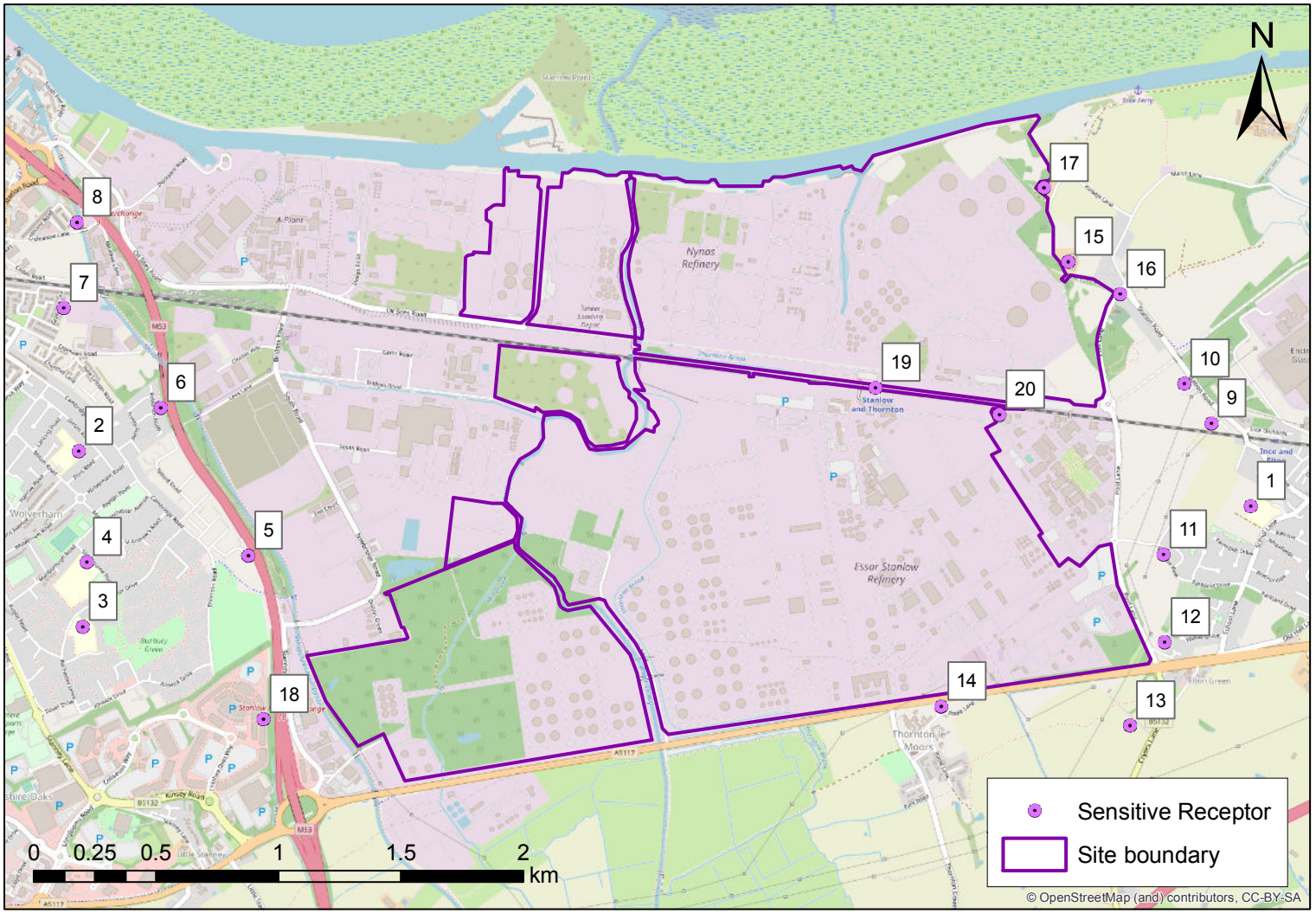

Figure 4.2: Location map of human health receptors (monitoring sites are shown on Figure 4.4)

4.3 Sensitive receptors for the protection of vegetation and ecosystems

Model output was calculated at designated sites within 10 km of the modelled stacks, at which potentially sensitive ecosystems were identified.

Ten designated sites were considered, as detailed in Table 4.2 and shown in Figure 4.3. Note that the extents of the Mersey Estuary and Stanney Wood vary depending on designation.

Table 4.2: Designated sites

Name	Designation	Distance from site boundary
Mersey Estuary	SPA, Ramsar, SSSI	500 m north
River Dee and Bala Lake	SAC	8.8 km south
Midland Meres and Mosses	Ramsar	10 km south east
Stanney Wood	LNR, AW, LWS	1.6 km west
Whitby Park	LNR	1.4 km west
Frodsham and Helsby and Ince Marshes	LWS	750 m east
Gowy Meadows and Ditches	LWS	60 m south
Hoblane Ponds	LWS	1.6 km south
Jack's Wood	LWS	2.9 km west
Shropshire Union Canal (Main Line)	LWS	2.1 km south

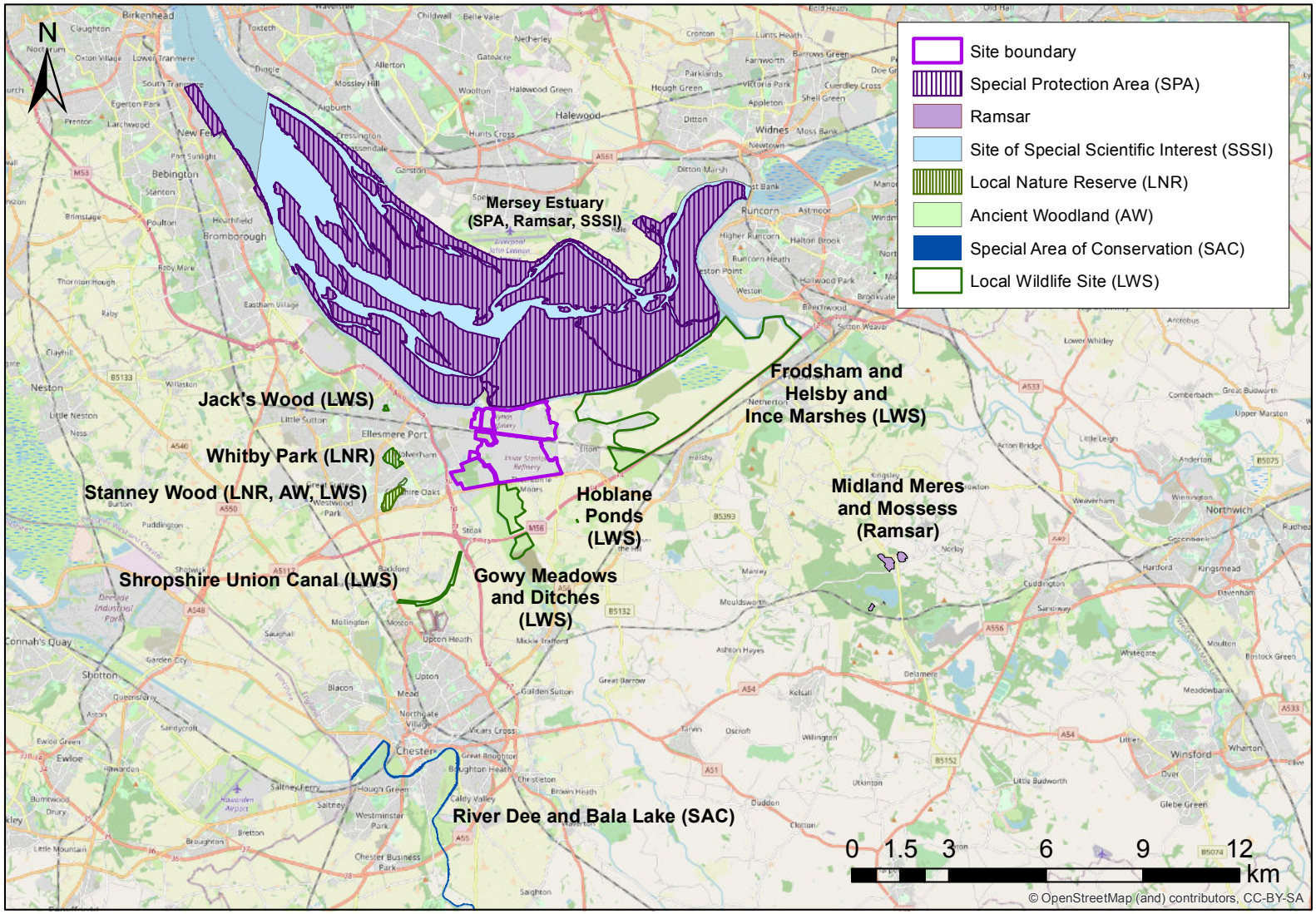

Figure 4.3: Locations of designated sites

4.4 Local air quality

4.4.1 AQMAs

Cheshire West and Chester Council have declared an Air Quality Management Area (AQMA) for SO_2 concentrations, which includes an area encompassing the entire village of Thornton le Moors and parts of Stanlow Refinery.

Three further AQMAs have been declared for NO_2 concentrations. The closest is approximately 2.2 km west of the site, an area incorporating residential properties on Whitby Road, in Ellesmere Port. The locations of the SO_2 AQMA and the Whitby Road NO_2 AQMA are shown in Figure 4.4.

4.4.2 Monitoring sites

Monitoring data for the years 2018 to 2020, at locations within the vicinity of the site, were obtained from Cheshire West and Chester Air Quality Annual Status Reports and directly from Cheshire West and Chester Council.

Automatic monitors and diffusion tubes within 5 km of the site boundary are summarised in Table 4.3 and Table 4.4.

Figure 4.4 shows the locations of these sites.

Table 4.3: Continuous monitoring sites, 2018-2020

ID	Name	Type	Location (m)	Pollutants monitored
ELT	Elton	Industrial	345642, 375522	SO_2
LR-JG	Library	Urban background	339947, 375889	NO_2 SO_2 PM_{10}
TLP	Thornton-le-Moors	Industrial	344103, 374330	NO_2 SO_2 PM_{10}
WH	Whitby Rd	Roadside	340197, 376363	NO_2

Table 4.4: Diffusion tube monitoring sites, 2018-2020

ID	Name	Type	Location (m)
BSP	Brookside Primary	Roadside	338380, 375840
HHS	Helsby Hillside School	Roadside	349518, 375954
MOS	Moston Road	Roadside	341245, 369610
MUL	Mulberry Close	Roadside	346258, 375321
NS	Newsagent Station Rd	Roadside	340406, 376724
RR	Richfield Recruitment	Roadside	340180, 376338
SLW	Stanney Lane	Roadside	339889, 375755
SR	Station Road	Roadside	340435, 376790
UCA	U of C Academy	Roadside	339687, 375972
WH1-3	Whitby Road	Roadside	340196, 376363

4.4.3 Monitoring data for NO_2

Table 4.5 to Table 4.6 provide the monitored concentrations of NO_2 for the years 2018 to 2020.

Table 4.5: Continuous monitoring data for NO_2, 2018-2020 ($\mu g/m^3$)

	2018		2019		2020	
ID	Annual average	1-hour means > 200	Annual average	1-hour means > 200	Annual average	1-hour means > 200
LR-JG	19	0	-	-	-	-
TLP	13	0	13	0	9	0
WH	37	0	35	0	28	0

Table 4.6: Diffusion tube monitoring data for NO_2, 2018-2020 ($\mu g/m^3$)

ID	NO_2 annual mean		
	2018	2019	2020
BSP	-	-	16.2
HHS	22.7	21.4	-
MOS	28.1	24.2	-
MUL	-	16.8	13.4
NS	32.4	-	-
RR	36.5	35.2	30.0
SLW	-	-	16.8
SR	33.8	31.0	26.3
UCA	28.6	24.9	-
WH1-3	37.0	31.4	25.8

4.4.4 Monitoring data for PM_{10}

Table 4.7 provides the monitored concentrations of PM_{10} for the years 2018 to 2020.

Table 4.7: Continuous monitoring data for PM_{10}, 2018 - 2020 ($\mu g/m^3$)

	2018		2019		2020	
ID	Annual average	24-hour means > 50	Annual average	24-hour means > 50	Annual average	24-hour means > 50
LR-JG	12	0	-	-	-	-
TLP	13	0	14	3	13	0

4.4.5 Monitoring data for SO_2

Table 4.8 provides the monitored concentrations of SO_2 for the years 2018 to 2020.

Table 4.8: Continuous monitoring data for SO_2, 2018-2020 ($\mu g/m^3$)

	2018			2019			2020		
ID	15-minute means > 266	1-hour means > 350	24-hour means > 125	15-minute means > 266	1-hour means > 350	24-hour means > 125	15-minute means > 266	1-hour means > 350	24-hour means > 125
ELT	25	4	0	22	1	0	8	0	0
LR-JG	0	0	0	-	-	-	-	-	-
TLP	66	0	0	10	0	0	21	0	0

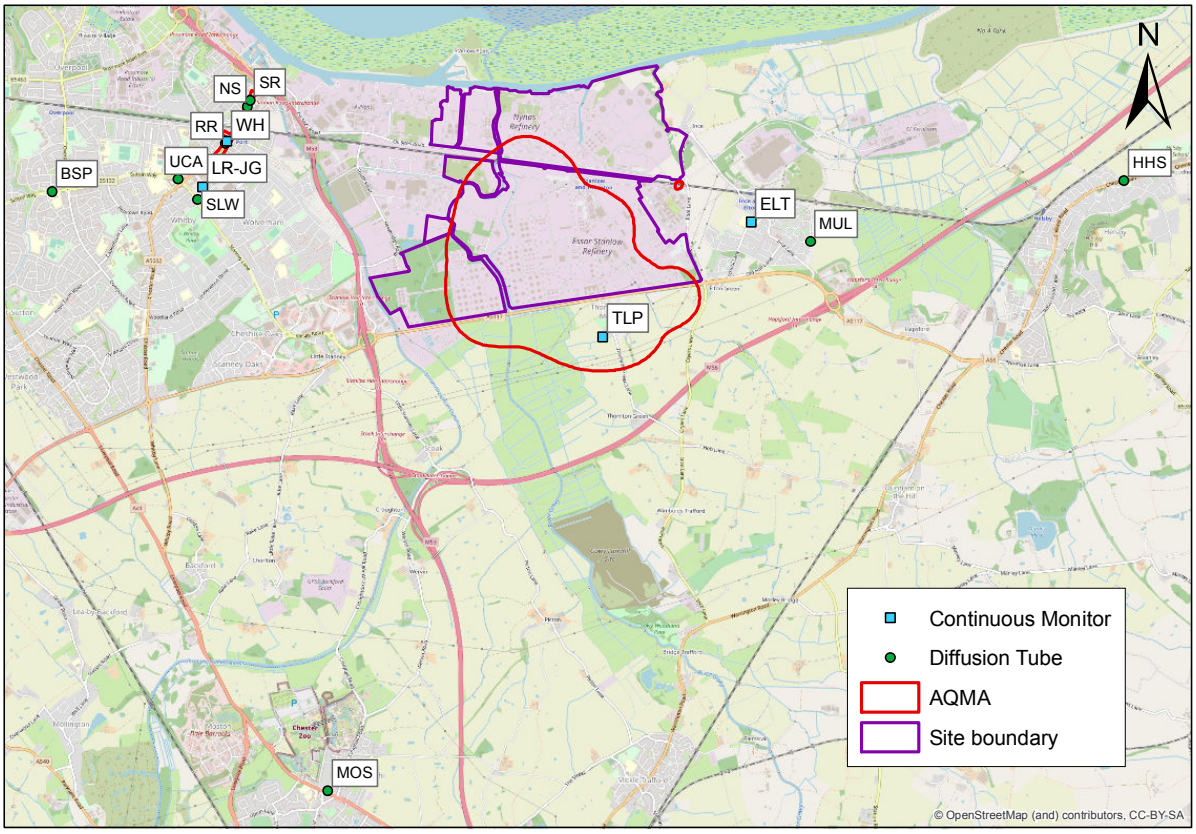

Figure 4.4: Locations of nearby monitoring sites

4.4.6 Mapped background data

4.4.6.1 Human health impacts

Local Air Quality Management support background air pollution maps, published by Defra [7], provide annual average background concentrations on a 1 km by 1 km grid square basis, representing projections of pollution concentrations away from major roads. The latest background maps for NO_2 and PM are produced for a base year of 2018, with projections for future years. The background maps for SO_2 have not been updated since 2001, as SO_2 concentrations are well below objectives in most locations in the UK.

The furnace stacks are located in the grid square centred on (343500, 374500). Table 4.9 provides the background concentrations for this grid square. These values were used as an estimate of background concentration in order to calculate total concentrations of each pollutant, referred to as Predicted Environmental Concentrations (PECs).

Table 4.9: Background concentrations of NO_2, PM_{10}, $PM_{2.5}$ and SO_2 (µg/m^3)

Grid square (x, y)	2018			2001
	NO_2	PM_{10}	$PM_{2.5}$	SO_2
343500, 374500	13.5	10.8	7.2	5.6

It should be noted that the other local sources of these pollutants on the refinery site have not been taken into account in this report, and so the PECs calculated in this way should be treated with caution. The impact of emissions of SO_2 from all relevant sources on the site has been considered in report (b).

4.4.6.2 Ecological impacts

Mapped background data for NO_x and SO_2 at the location of each designated site, taken from the Air Pollution Information System (APIS) website,[8] are shown in Table 4.10. These values represent three year averages, over the period 2017 to 2019.

Table 4.10: Background concentrations for habitat sites from APIS website (µg/m^3)

Habitat Site	Site Type	SO_2	NO_x
Mersey Estuary	SPA, Ramsar, SSSI	4.3	26.2
River Dee and Bala Lake	SAC	1.6	21.1
Midland Meres and Mosses	Ramsar	1.4	9.9
Stanney Wood	LNR, AW, LWS	1.9	18.7
Whitby Park	LNR	6.7	18.6
Frodsham and Helsby and Ince Marshes	LWS	3.4	23.1
Gowy Meadows and Ditches	LWS	1.9	27.8
Hoblane Ponds	LWS	1.8	20.0
Jack's Wood	LWS	1.7	22.5
Shropshire Union Canal (Main Line)	LWS	1.9	18.2

[7] https://uk-air.defra.gov.uk/data/laqm-background-home
[8] http://www.apis.ac.uk/search-location

5 Modelled stack and emissions data

5.1 Modelled stacks

This report considers emissions from the current CD4 furnace stack and the proposed CD4 combined furnace stack at Essar Stanlow Refinery.

Table 5.1 and Table 5.2 present the modelled stacks and emissions data.

Three concentrations of sulphur in fuel gas were evaluated: a representative average concentration (1060 ppm); a typical value for sustained periods of running with high sulphur fuel gas (1250 ppm); and the peak sulphur in fuel gas value observed from fuel gas analysis (a worst case value, 2000 ppm).

Figure 5.1 presents the locations of the modelled stacks.

Table 5.1: Source details

Source Name	Location		Height (m)	Diameter (m)	Velocity (m/s)	Temperature (°C)
	X	Y				
Current CD4 furnace stack	343951	374892	143	3.71	9.05	220
Proposed CD4 combined furnace stack	343884	374867	72	3.85	7.90	220

Table 5.2: Emission rates (g/s)

Source Name	Sulphur in fuel gas scenario	SO_2	NO_x	Particulates (PM_{10} and $PM_{2.5}$)[9]
Current CD4 furnace stack	Average (1060 ppm)	15.85	13.0	0.22
	High (1250 ppm)	17.06		
	Peak (2000 ppm)	22.09		
Proposed CD4 combined furnace stack	Average (1060 ppm)	8.77	4.7	0.21
	High (1250 ppm)	10.00		
	Peak (2000 ppm)	15.10		

[9] Note that, in the absence of any particle size data, Total Particulate Matter was assumed to be 100% PM_{10} and 100% $PM_{2.5}$, as a worst case

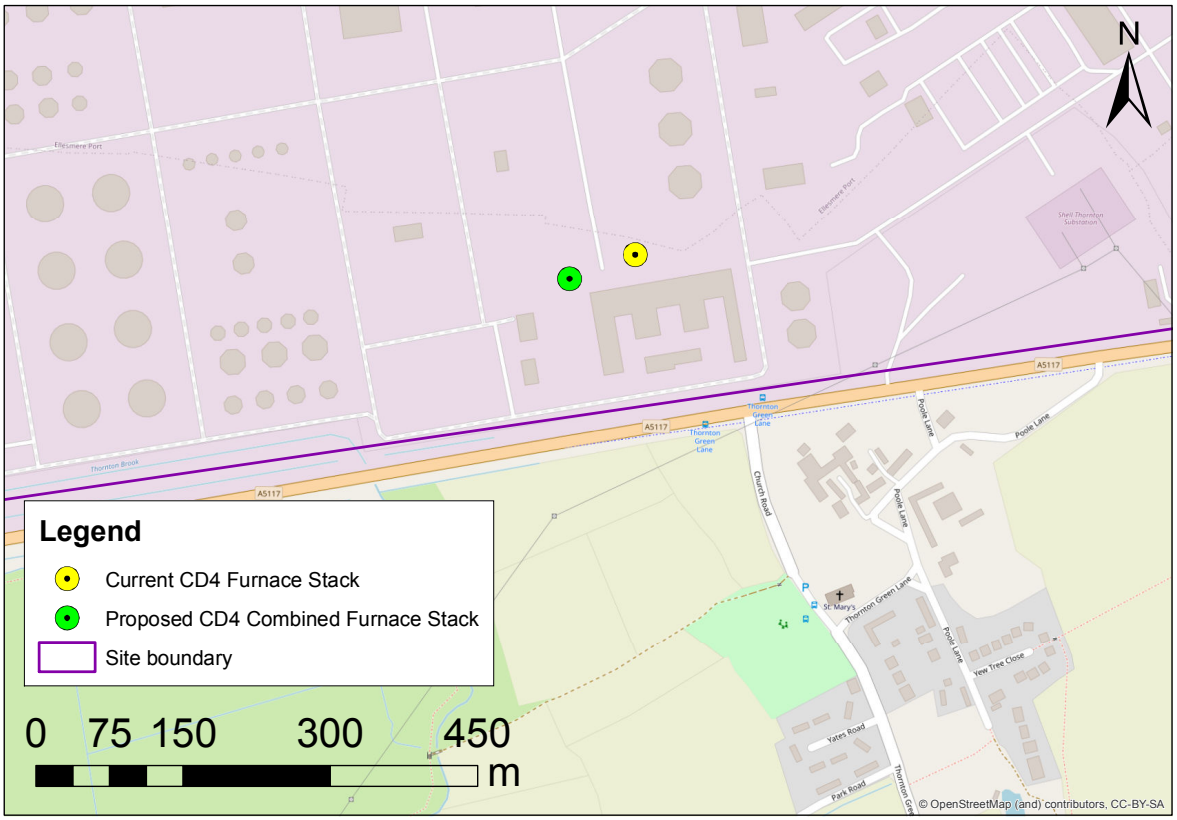

Figure 5.1: Locations of modelled stacks

5.2 Modelled buildings

Buildings that are relatively close to the modelled stack and higher than one third of the stack height can have an effect on dispersion, by disturbing wind flows and increasing turbulence.

In the surrounding area of the current and proposed CD4 combined furnace stacks, there are no buildings larger than one third of the stack height and so the effects of modelled buildings were considered negligible and were not taken into account in the modelling.

6 Meteorological data

Modelling was carried out using hourly sequential meteorological data obtained from the Liverpool Airport for the five years 2016 to 2020 inclusive. Liverpool Airport is located approximately 5 km north of Stanlow Refinery.

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 Liverpool Airport, 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

Year	Percentage used	Parameter	Minimum	Maximum	Mean
2016	95.9	Temperature (°C)	-3.0	30.0	10.8
		Wind speed (m/s)	0	17.5	4.5
		Cloud cover (oktas)	0	8	3.6
2017	95.5	Temperature (°C)	-3.0	28.0	11.2
		Wind speed (m/s)	0	22.7	4.8
		Cloud cover (oktas)	0	8	4.2
2018	93.9	Temperature (°C)	-5.0	30.0	11.2
		Wind speed (m/s)	0	22.1	4.6
		Cloud cover (oktas)	0	8	3.9
2019	95.3	Temperature (°C)	-4.0	31.0	11.1
		Wind speed (m/s)	0	18.0	4.6
		Cloud cover (oktas)	0	8	3.8
2020	96.6	Temperature (°C)	-1	30	11.5
		Wind speed (m/s)	0	16.5	4.9
		Cloud cover (oktas)	0	8	4.0

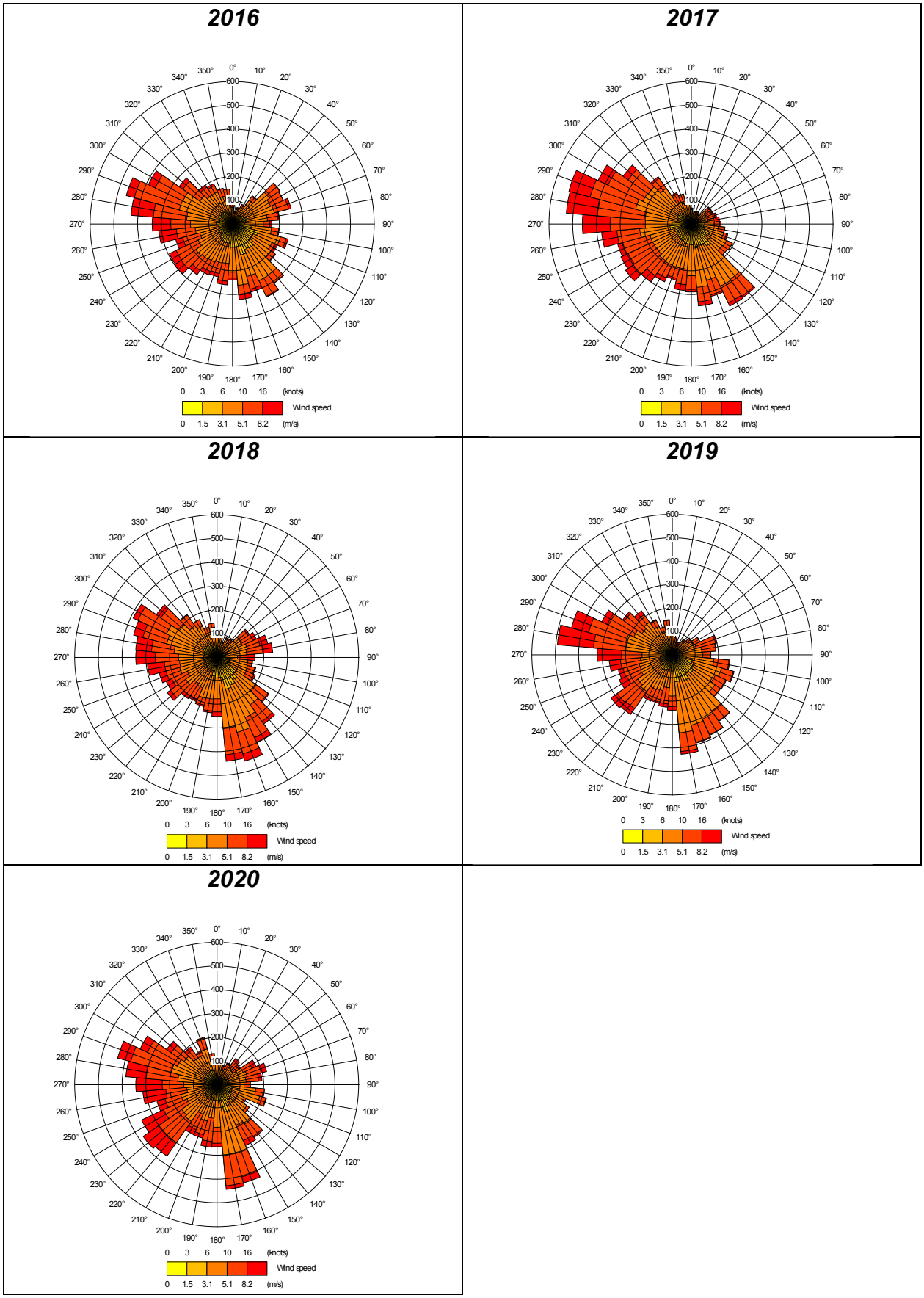

Figure 6.1: Wind roses for Liverpool Airport

7 Proposed CD4 combined furnace stack: consideration of concentrations for the protection of human health

The significance of the total release of each pollutant was assessed by comparing the PC to the relevant air quality objective. For long-term objectives, the Environment Agency considers the release to be insignificant if the PC is less than 1% of the air quality standard[10]. For short-term objectives, including percentiles, 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 Predicted Environmental Concentration (PEC) was calculated. For long-term objectives, the PEC is calculated by adding the PC to the estimated background concentration of the pollutant. For short-term objectives, including percentiles, the PEC is calculated by adding the PC to twice the estimated background concentration of the pollutant.

All maximum concentrations represent the maximum offsite concentrations; that is, concentrations within the site boundary were excluded.

7.1 Predicted concentrations of sulphur dioxide

Table 7.1 to Table 7.3 show the maximum predicted offsite concentrations of SO_2 for the proposed CD4 combined furnace stack, for the three sulphur in fuel gas concentration scenarios, calculated using meteorological data for the years 2016 to 2020.

For all scenarios, all SO_2 PCs are screened out for all years, as they are less than 10% of the air quality objectives.

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

Table 7.1: Maximum predicted offsite concentrations of SO_2 for the proposed CD4 combined furnace stack ($\mu g/m^3$), representative average sulphur in fuel gas concentration (1060 ppm)

Year	Standard	Measured as	Objective value	PC	PC % of objective	Location	
						x	y
2016	Short-term AQO	99.9th percentile of 15-minute averages	266	14	5	344420	374780
		99.73rd percentile of hourly averages	350	12	3	344420	374760
		99.18th percentile of 24 hour averages	125	5	4	344600	374620
2017		99.9th percentile of 15-minute averages	266	13	5	344460	374720
		99.73rd percentile of hourly averages	350	11	3	344420	374660
		99.18th percentile of 24 hour averages	125	5	4	344620	374780
2018		99.9th percentile of 15-minute averages	266	13	5	344320	374640
		99.73rd percentile of hourly averages	350	11	3	344440	374660
		99.18th percentile of 24 hour averages	125	5	4	343100	374720
2019		99.9th percentile of 15-minute averages	266	13	5	344400	374720
		99.73rd percentile of hourly averages	350	11	3	344480	374660
		99.18th percentile of 24 hour averages	125	5	4	344680	374760
2020		99.9th percentile of 15-minute averages	266	13	5	344420	374580
		99.73rd percentile of hourly averages	350	11	3	344480	374600
		99.18th percentile of 24 hour averages	125	5	4	344640	374600

Table 7.2: Maximum predicted offsite concentrations of SO_2 for the proposed CD4 combined furnace stack ($\mu g/m^3$), sustained periods of running with high sulphur fuel gas (1250 ppm)

Year	Standard	Measured as	Objective value	PC	PC % of objective	Location	
						x	y
2016	Short-term AQO	99.9th percentile of 15-minute averages	266	16	6	344420	374780
		99.73rd percentile of hourly averages	350	13	4	344420	374760
		99.18th percentile of 24 hour averages	125	5	4	344600	374620
2017		99.9th percentile of 15-minute averages	266	15	6	344460	374720
		99.73rd percentile of hourly averages	350	13	4	344420	374660
		99.18th percentile of 24 hour averages	125	6	5	344620	374780
2018		99.9th percentile of 15-minute averages	266	15	6	344320	374640
		99.73rd percentile of hourly averages	350	13	4	344440	374660
		99.18th percentile of 24 hour averages	125	6	5	343100	374720
2019		99.9th percentile of 15-minute averages	266	15	6	344400	374720
		99.73rd percentile of hourly averages	350	13	4	344480	374660
		99.18th percentile of 24 hour averages	125	6	5	344680	374760
2020		99.9th percentile of 15-minute averages	266	14	5	344420	374580
		99.73rd percentile of hourly averages	350	12	3	344480	374600
		99.18th percentile of 24 hour averages	125	5	4	344640	374600

Table 7.3: Maximum predicted offsite concentrations of SO_2 for the proposed CD4 combined furnace stack ($\mu g/m^3$), peak sulphur in fuel gas concentration (a worst case value, 2000 ppm)

Year	Standard	Measured as	Objective value	PC	PC % of objective	Location	
						x	y
2016	Short-term AQO	99.9th percentile of 15-minute averages	266	23	9	344420	374780
		99.73rd percentile of hourly averages	350	20	6	344420	374760
		99.18th percentile of 24 hour averages	125	8	6	344600	374620
2017		99.9th percentile of 15-minute averages	266	22	8	344460	374720
		99.73rd percentile of hourly averages	350	20	6	344420	374660
		99.18th percentile of 24 hour averages	125	9	7	344620	374780
2018		99.9th percentile of 15-minute averages	266	23	9	344320	374640
		99.73rd percentile of hourly averages	350	20	6	344440	374660
		99.18th percentile of 24 hour averages	125	9	7	343100	374720
2019		99.9th percentile of 15-minute averages	266	22	8	344400	374720
		99.73rd percentile of hourly averages	350	19	5	344480	374660
		99.18th percentile of 24 hour averages	125	9	7	344680	374760
2020		99.9th percentile of 15-minute averages	266	22	8	344420	374580
		99.73rd percentile of hourly averages	350	19	5	344480	374600
		99.18th percentile of 24 hour averages	125	8	6	344640	374600

Table 7.4, Table 7.5 and Table 7.6 show the predicted 15-minute, hourly and 24-hourly average concentrations of SO_2, respectively, at each of the sensitive receptors described in Section 4.2, for the peak sulphur in fuel gas concentration scenario. For each receptor, the maximum value over the five years of meteorological data is presented. All concentrations are screened out, as they are less than 10% of the air quality objectives. The results for the lower sulphur in fuel gas concentration scenarios are therefore not presented.

Table 7.4: Maximum PCs to 99.9th percentile of 15-minute average ground level SO_2 concentrations at sensitive receptors ($\mu g/m^3$), proposed CD4 combined furnace stack, peak sulphur in fuel gas concentration (a worst case value, 2000 ppm)

ID	Receptor	Objective value	PC		
			SO_2	% of objective	Screened out?
1	Elton Primary School	266	11	4	Yes
2	Wolverham Primary and Nursery School		14	5	
3	The Oaks Community Primary School		13	5	
4	St Bernard's Roman Catholic Primary School		15	6	
5	Oval Crescent		16	6	
6	Robinson Road		14	5	
7	Griffiths Lane		14	5	
8	Shepherd Close		13	5	
9	Station Close		11	4	
10	Bare Brick House		12	5	
11	Meadow View		14	5	
12	Swiss Road		14	5	
13	The Bungalow		16	6	
14	Poole Lane		20	8	
15	Yewtree Farm		12	5	
16	The Square		11	4	
17	Kinseys Lane		13	5	
18	Cheshire Oaks Outlet		13	5	
19	Stanlow and Thornton		17	6	
20	Research Park		15	6	
21	Elton (ELT)		12	5	
22	Thornton-le-Moors (TLP)		20	8	

Table 7.5: Maximum PCs to 99.73rd percentile of hourly average ground level SO_2 concentrations at sensitive receptors (µg/m³), proposed CD4 combined furnace stack, peak sulphur in fuel gas concentration (a worst case value, 2000 ppm)

ID	Receptor	Objective value	PC		
			SO_2	% of objective	Screened out?
1	Elton Primary School	350	9	3	Yes
2	Wolverham Primary and Nursery School		7	2	
3	The Oaks Community Primary School		7	2	
4	St Bernard's Roman Catholic Primary School		8	2	
5	Oval Crescent		8	2	
6	Robinson Road		8	2	
7	Griffiths Lane		7	2	
8	Shepherd Close		7	2	
9	Station Close		9	3	
10	Bare Brick House		9	3	
11	Meadow View		11	3	
12	Swiss Road		12	3	
13	The Bungalow		13	4	
14	Poole Lane		16	5	
15	Yewtree Farm		8	2	
16	The Square		9	3	
17	Kinseys Lane		9	3	
18	Cheshire Oaks Outlet		7	2	
19	Stanlow and Thornton		13	4	
20	Research Park		13	4	
21	Elton (ELT)		9	3	
22	Thornton-le-Moors (TLP)		15	4	

Table 7.6: Maximum PCs to 99.18th percentile of 24-hour average ground level SO_2 concentrations at sensitive receptors ($\mu g/m^3$), proposed CD4 combined furnace stack, peak sulphur in fuel gas concentration (a worst case value, 2000 ppm)

ID	Receptor	Objective value	PC		
			SO_2	% of objective	Screened out?
1	Elton Primary School	125	3	2	Yes
2	Wolverham Primary and Nursery School		2	2	
3	The Oaks Community Primary School		2	2	
4	St Bernard's Roman Catholic Primary School		2	2	
5	Oval Crescent		3	2	
6	Robinson Road		2	2	
7	Griffiths Lane		2	2	
8	Shepherd Close		2	2	
9	Station Close		4	3	
10	Bare Brick House		4	3	
11	Meadow View		5	4	
12	Swiss Road		6	5	
13	The Bungalow		8	6	
14	Poole Lane		4	3	
15	Yewtree Farm		3	2	
16	The Square		3	2	
17	Kinseys Lane		2	2	
18	Cheshire Oaks Outlet		3	2	
19	Stanlow and Thornton		5	4	
20	Research Park		4	3	
21	Elton (ELT)		4	3	
22	Thornton-le-Moors (TLP)		4	3	

7.2 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 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.

Table 7.7 shows the maximum predicted offsite concentrations of NO_2 for the proposed CD4 combined furnace stack, calculated using meteorological data for the five years 2016 to 2020.

The maximum offsite NO_2 PCs are screened out for all years, as they are less than 1% of the long-term objective and less than 10% of the short-term objective.

Table 7.7: Maximum predicted offsite concentrations of NO_2 for the proposed CD4 combined furnace stack ($\mu g/m^3$)

Year	Standard	Measured as	Objective value	PC (NO_x)	PC (NO_2)[11]	PC % of objective	Screened out?	Location	
								x	y
2016	Short-term AQO	99.79th percentile of hourly averages	200	6.4	2.2	1	Yes	344460	374740
	Long-term AQO	Annual average	40	0.40	0.28	0.7		344620	374700
2017	Short-term AQO	99.79th percentile of hourly averages	200	6.3	2.2	1		344480	374720
	Long-term AQO	Annual average	40	0.47	0.33	0.8		344640	374720
2018	Short-term AQO	99.79th percentile of hourly averages	200	6.2	2.2	1		344420	374660
	Long-term AQO	Annual average	40	0.32	0.22	0.6		344620	374700
2019	Short-term AQO	99.79th percentile of hourly averages	200	6.1	2.1	1		344480	374660
	Long-term AQO	Annual average	40	0.39	0.27	0.7		344620	374720
2020	Short-term AQO	99.79th percentile of hourly averages	200	6.0	2.1	1		344420	374520
	Long-term AQO	Annual average	40	0.34	0.25	0.6		344640	374680

[11] 35% of short-term NO_x PC and 70% of long term NO_x PC

Table 7.8 and Table 7.9 show the maximum predicted concentrations of NO_2, at each of the sensitive receptors described in Section 4.2. For each receptor, the maximum value over the five years of meteorological data is presented. Note that annual average NO_2 concentrations are only presented for locations relevant for long term exposure.

All concentrations are screened out, as they are less than 1% of the long-term and 10% of the short-term air quality objectives.

Table 7.8: Maximum PCs to annual average ground level NO_2 concentrations at sensitive receptors ($\mu g/m^3$), proposed CD4 combined furnace stack

ID	Receptor	Objective value	PC			
			NO_x	NO_2	% of objective	Screened out?
1	Elton Primary School	40	0.2	0.1	0.3	Yes
2	Wolverham Primary and Nursery School		0.1	0.1	0.3	
3	The Oaks Community Primary School		0.1	0.1	0.3	
4	St Bernard's Roman Catholic Primary School		0.1	0.1	0.3	
5	Oval Crescent		0.1	0.1	0.3	
6	Robinson Road		0.1	0.1	0.3	
7	Griffiths Lane		0.1	0.1	0.3	
8	Shepherd Close		0.1	0.1	0.3	
9	Station Close		0.2	0.1	0.3	
10	Bare Brick House		0.2	0.1	0.3	
11	Meadow View		0.2	0.1	0.3	
12	Swiss Road		0.3	0.2	0.5	
13	The Bungalow		0.4	0.3	0.8	
14	Poole Lane		0.2	0.1	0.3	
15	Yewtree Farm		0.1	0.1	0.3	
16	The Square		0.1	0.1	0.3	
17	Kinseys Lane		0.1	0.1	0.3	
21	Elton (ELT)		0.2	0.1	0.3	
22	Thornton-le-Moors (TLP)		0.1	0.1	0.3	

Table 7.9: Maximum PCs to 99.79th percentile of hourly average ground level NO_2 concentrations at sensitive receptors (µg/m³), proposed CD4 combined furnace stack

ID	Receptor	Objective value	PC			
			NO_x	NO_2	% of objective	Screened out?
1	Elton Primary School	200	2.8	1.0	0.5	Yes
2	Wolverham Primary and Nursery School		2.6	0.9	0.5	
3	The Oaks Community Primary School		2.5	0.9	0.5	
4	St Bernard's Roman Catholic Primary School		2.9	1.0	0.5	
5	Oval Crescent		3.2	1.1	0.6	
6	Robinson Road		2.6	0.9	0.5	
7	Griffiths Lane		2.3	0.8	0.4	
8	Shepherd Close		2.4	0.8	0.4	
9	Station Close		2.8	1.0	0.5	
10	Bare Brick House		2.8	1.0	0.5	
11	Meadow View		3.6	1.3	0.7	
12	Swiss Road		3.8	1.3	0.7	
13	The Bungalow		4.2	1.5	0.8	
14	Poole Lane		5.1	1.8	0.9	
15	Yewtree Farm		2.7	0.9	0.5	
16	The Square		2.7	0.9	0.5	
17	Kinseys Lane		2.9	1.0	0.5	
18	Cheshire Oaks Outlet		2.4	0.8	0.4	
19	Stanlow and Thornton		4.2	1.5	0.8	
20	Research Park		4.0	1.4	0.7	
21	Elton (ELT)		2.7	0.9	0.5	
22	Thornton-le-Moors (TLP)		4.9	1.7	0.9	

7.3 Predicted concentrations of particulates

Table 7.10 shows the maximum predicted offsite concentrations of PM_{10} for the proposed CD4 combined furnace stack, calculated using meteorological data for the five years 2016 to 2020.

Table 7.11 shows the maximum predicted offsite concentrations of $PM_{2.5}$ for the proposed CD4 combined furnace stack, calculated using meteorological data for the five years 2016 to 2020.

The maximum offsite concentrations are screened out for all years.

Table 7.10: Maximum predicted offsite concentrations of PM_{10} for the proposed CD4 combined furnace stack ($\mu g/m^3$)

Year	Standard	Measured as	Objective value	PC	PC % of objective	Location	
						x	y
2016	Short-term AQO	90.41st percentile of 24-hour averages	50	0.07	0.1	344580	374700
	Long-term AQO	Annual average	40	0.02	< 0.1	344620	374700
2017	Short-term AQO	90.41st percentile of 24-hour averages	50	0.07	0.1	344620	374720
	Long-term AQO	Annual average	40	0.02	< 0.1	344640	374720
2018	Short-term AQO	90.41st percentile of 24-hour averages	50	0.05	0.1	344580	374580
	Long-term AQO	Annual average	40	0.01	< 0.1	344620	374700
2019	Short-term AQO	90.41st percentile of 24-hour averages	50	0.07	0.1	344580	374680
	Long-term AQO	Annual average	40	0.02	< 0.1	344620	374720
2020	Short-term AQO	90.41st percentile of 24-hour averages	50	0.06	0.1	344660	374680
	Long-term AQO	Annual average	40	0.02	< 0.1	344640	374680

Table 7.11: Maximum predicted offsite concentrations of $PM_{2.5}$ for the proposed CD4 combined furnace stack ($\mu g/m^3$)

Year	Standard	Measured as	Objective value	PC	PC % of objective	Location	
						x	y
2016	Long-term AQO	Annual average	25	0.02	< 0.1	344620	374700
2017	Long-term AQO	Annual average	25	0.02	< 0.1	344640	374720
2018	Long-term AQO	Annual average	25	0.01	< 0.1	344620	374700
2019	Long-term AQO	Annual average	25	0.02	< 0.1	344620	374720
2020	Long-term AQO	Annual average	25	0.02	< 0.1	344640	374680

Table 7.12 and Table 7.13 show the maximum predicted concentrations of particulates, at each of the sensitive receptors described in Section 4.2. For each receptor, the maximum value over the five years of meteorological data is presented. Note that annual average particulate concentrations are only presented for locations relevant for long term exposure.

All concentrations are screened out, as they are less than 1% of the long-term and 10% of the short-term air quality objectives.

Table 7.12: Maximum PCs to annual average ground level particulate concentrations at sensitive receptors ($\mu g/m^3$), proposed CD4 combined furnace stack

ID	Receptor	Objective value	PC			
			PM	% of PM_{10} objective	% of $PM_{2.5}$ objective	Screened out?
1	Elton Primary School	40 (PM_{10}) 25 ($PM_{2.5}$)	0.007	< 0.1	< 0.1	Yes
2	Wolverham Primary and Nursery School		0.003	< 0.1	< 0.1	
3	The Oaks Community Primary School		0.003	< 0.1	< 0.1	
4	St Bernard's Roman Catholic Primary School		0.003	< 0.1	< 0.1	
5	Oval Crescent		0.003	< 0.1	< 0.1	
6	Robinson Road		0.003	< 0.1	< 0.1	
7	Griffiths Lane		0.003	< 0.1	< 0.1	
8	Shepherd Close		0.003	< 0.1	< 0.1	
9	Station Close		0.007	< 0.1	< 0.1	
10	Bare Brick House		0.007	< 0.1	< 0.1	
11	Meadow View		0.009	< 0.1	< 0.1	
12	Swiss Road		0.012	< 0.1	< 0.1	
13	The Bungalow		0.017	< 0.1	< 0.1	
14	Poole Lane		0.010	< 0.1	< 0.1	
15	Yewtree Farm		0.005	< 0.1	< 0.1	
16	The Square		0.006	< 0.1	< 0.1	
17	Kinseys Lane		0.004	< 0.1	< 0.1	
21	Elton (ELT)		0.007	< 0.1	< 0.1	
22	Thornton-le-Moors		0.003	< 0.1	< 0.1	

Table 7.13: Maximum PCs to 90.41st percentile of 24-hourly average ground level PM_{10} concentrations at sensitive receptors (µg/m³), proposed CD4 combined furnace stack

ID	Receptor	Objective value	PC		
			PM_{10}	% of objective	Screened out?
1	Elton Primary School	50	0.02	< 0.1	Yes
2	Wolverham Primary and Nursery School		0.01	< 0.1	
3	The Oaks Community Primary School		0.01	< 0.1	
4	St Bernard's Roman Catholic Primary School		0.01	< 0.1	
5	Oval Crescent		0.01	< 0.1	
6	Robinson Road		0.01	< 0.1	
7	Griffiths Lane		0.01	< 0.1	
8	Shepherd Close		0.01	< 0.1	
9	Station Close		0.03	< 0.1	
10	Bare Brick House		0.02	< 0.1	
11	Meadow View		0.03	< 0.1	
12	Swiss Road		0.04	< 0.1	
13	The Bungalow		0.06	0.1	
14	Poole Lane		0.03	< 0.1	
15	Yewtree Farm		0.02	< 0.1	
16	The Square		0.02	< 0.1	
17	Kinseys Lane		0.01	< 0.1	
18	Cheshire Oaks Outlet		0.01	< 0.1	
19	Stanlow and Thornton		0.02	< 0.1	
20	Research Park		0.02	< 0.1	
21	Elton (ELT)		0.02	< 0.1	
22	Thornton-le-Moors (TLP)		0.01	< 0.1	

8 Current CD4 furnace stack: consideration of concentrations for the protection of human health

8.1 Predicted concentrations of sulphur dioxide

Table 8.1, Table 8.2 and Table 8.3 show the maximum predicted offsite concentrations of SO_2 for the current CD4 furnace stack, for the three sulphur in fuel gas concentration scenarios, calculated using meteorological data for the years 2016 to 2020.

For all scenarios, all SO_2 PCs are screened out for all years, as they are less than 10% of the air quality objectives.

Table 8.1: Maximum predicted offsite concentrations of SO_2 for the current CD4 furnace stack (µg/m^3), representative average sulphur in fuel gas concentration (1060 ppm)

Year	Standard	Measured as	Objective value	PC	PC % of objective	Location	
						x	y
2016	Short-term AQO	99.9th percentile of 15-minute averages	266	12	5	342820	377980
		99.73rd percentile of hourly averages	350	8	2	344820	374780
		99.18th percentile of 24 hour averages	125	2	2	342800	373880
2017		99.9th percentile of 15-minute averages	266	12	5	341740	377780
		99.73rd percentile of hourly averages	350	8	2	343500	376100
		99.18th percentile of 24 hour averages	125	2	2	345360	374540
2018		99.9th percentile of 15-minute averages	266	13	5	341760	377280
		99.73rd percentile of hourly averages	350	8	2	343480	376100
		99.18th percentile of 24 hour averages	125	2	2	343320	376120
2019		99.9th percentile of 15-minute averages	266	11	4	342340	377180
		99.73rd percentile of hourly averages	350	8	2	343640	376080
		99.18th percentile of 24 hour averages	125	2	2	345540	374640
2020		99.9th percentile of 15-minute averages	266	12	5	342040	377320
		99.73rd percentile of hourly averages	350	8	2	343480	376100
		99.18th percentile of 24 hour averages	125	2	2	345480	374360

Table 8.2: Maximum predicted offsite concentrations of SO_2 for the current CD4 furnace stack ($\mu g/m^3$), sustained periods of running with high sulphur fuel gas (1250 ppm)

Year	Standard	Measured as	Objective value	PC	PC % of objective	Location	
						x	y
2016	Short-term AQO	99.9th percentile of 15-minute averages	266	13	5	342820	377980
		99.73rd percentile of hourly averages	350	9	3	344820	374780
		99.18th percentile of 24 hour averages	125	2	2	342800	373880
2017		99.9th percentile of 15-minute averages	266	12	5	341740	377780
		99.73rd percentile of hourly averages	350	8	2	343500	376100
		99.18th percentile of 24 hour averages	125	3	2	345360	374540
2018		99.9th percentile of 15-minute averages	266	14	5	341760	377280
		99.73rd percentile of hourly averages	350	9	3	343480	376100
		99.18th percentile of 24 hour averages	125	2	2	343320	376120
2019		99.9th percentile of 15-minute averages	266	12	5	342340	377180
		99.73rd percentile of hourly averages	350	9	3	343640	376080
		99.18th percentile of 24 hour averages	125	2	2	345540	374640
2020		99.9th percentile of 15-minute averages	266	13	5	342040	377320
		99.73rd percentile of hourly averages	350	8	2	343480	376100
		99.18th percentile of 24 hour averages	125	2	2	345480	374360

Table 8.3: Maximum predicted offsite concentrations of SO_2 for the current CD4 furnace stack (µg/m^3), peak sulphur in fuel gas concentration (a worst case value, 2000 ppm)

Year	Standard	Measured as	Objective value	PC	PC % of objective	Location	
						x	y
2016	Short-term AQO	99.9th percentile of 15-minute averages	266	17	6	342820	377980
		99.73rd percentile of hourly averages	350	11	3	344820	374780
		99.18th percentile of 24 hour averages	125	3	2	342800	373880
2017		99.9th percentile of 15-minute averages	266	16	6	341740	377780
		99.73rd percentile of hourly averages	350	11	3	343500	376100
		99.18th percentile of 24 hour averages	125	3	2	345360	374540
2018		99.9th percentile of 15-minute averages	266	18	7	341760	377280
		99.73rd percentile of hourly averages	350	11	3	343480	376100
		99.18th percentile of 24 hour averages	125	3	2	343320	376120
2019		99.9th percentile of 15-minute averages	266	16	6	342340	377180
		99.73rd percentile of hourly averages	350	11	3	343640	376080
		99.18th percentile of 24 hour averages	125	3	2	345540	374640
2020		99.9th percentile of 15-minute averages	266	17	6	342040	377320
		99.73rd percentile of hourly averages	350	11	3	343480	376100
		99.18th percentile of 24 hour averages	125	3	2	345480	374360

Table 8.4, Table 8.5 and Table 8.6 show the predicted 15-minute, hourly and 24-hourly average concentrations of SO_2, respectively, at each of the sensitive receptors described in Section 4.2, for the peak sulphur in fuel gas concentration scenario. For each receptor, the maximum value over the five years of meteorological data is presented. All concentrations are screened out, as they are less than 10% of the air quality objectives. The results for the lower sulphur in fuel gas concentration scenarios are therefore not presented.

Table 8.4: Maximum PCs to 99.9th percentile of 15-minute average ground level SO_2 concentrations at sensitive receptors ($\mu g/m^3$), current CD4 furnace stack, peak sulphur in fuel gas concentration (a worst case value, 2000 ppm)

ID	Receptor	Objective value	PC		
			SO_2	% of objective	Screened out?
1	Elton Primary School	266	11	4	Yes
2	Wolverham Primary and Nursery School		13	5	
3	The Oaks Community Primary School		12	4	
4	St Bernard's Roman Catholic Primary School		13	5	
5	Oval Crescent		14	5	
6	Robinson Road		12	4	
7	Griffiths Lane		12	5	
8	Shepherd Close		13	5	
9	Station Close		10	4	
10	Bare Brick House		10	4	
11	Meadow View		13	5	
12	Swiss Road		13	5	
13	The Bungalow		13	5	
14	Poole Lane		3	1	
15	Yewtree Farm		12	5	
16	The Square		13	5	
17	Kinseys Lane		13	5	
18	Cheshire Oaks Outlet		13	5	
19	Stanlow and Thornton		11	4	
20	Research Park		14	5	
21	Elton (ELT)		10	4	
22	Thornton-le-Moors (TLP)		7	3	

Table 8.5: Maximum PCs to 99.73rd percentile of hourly average ground level SO_2 concentrations at sensitive receptors (µg/m³), current CD4 furnace stack, peak sulphur in fuel gas concentration (a worst case value, 2000 ppm)

ID	Receptor	Objective value	PC		
			SO_2	% of objective	Screened out?
1	Elton Primary School	350	9	3	Yes
2	Wolverham Primary and Nursery School		7	2	
3	The Oaks Community Primary School		7	2	
4	St Bernard's Roman Catholic Primary School		7	2	
5	Oval Crescent		7	2	
6	Robinson Road		7	2	
7	Griffiths Lane		7	2	
8	Shepherd Close		7	2	
9	Station Close		8	2	
10	Bare Brick House		8	2	
11	Meadow View		10	3	
12	Swiss Road		11	3	
13	The Bungalow		11	3	
14	Poole Lane		1	0	
15	Yewtree Farm		7	2	
16	The Square		10	3	
17	Kinseys Lane		10	3	
18	Cheshire Oaks Outlet		8	2	
19	Stanlow and Thornton		8	2	
20	Research Park		9	2	
21	Elton (ELT)		8	2	
22	Thornton-le-Moors (TLP)		3	1	

Table 8.6: Maximum PCs to 99.18th percentile of 24-hour average ground level SO_2 concentrations at sensitive receptors (µg/m^3), current CD4 furnace stack, peak sulphur in fuel gas concentration (a worst case value, 2000 ppm)

ID	Receptor	Objective value	PC		
			SO_2	% of objective	Screened out?
1	Elton Primary School	125	2	2	Yes
2	Wolverham Primary and Nursery School		2	1	
3	The Oaks Community Primary School		2	2	
4	St Bernard's Roman Catholic Primary School		2	2	
5	Oval Crescent		2	2	
6	Robinson Road		2	2	
7	Griffiths Lane		2	1	
8	Shepherd Close		2	1	
9	Station Close		3	2	
10	Bare Brick House		3	2	
11	Meadow View		2	2	
12	Swiss Road		3	2	
13	The Bungalow		3	2	
14	Poole Lane		0	0	
15	Yewtree Farm		2	2	
16	The Square		2	2	
17	Kinseys Lane		2	2	
18	Cheshire Oaks Outlet		2	2	
19	Stanlow and Thornton		2	2	
20	Research Park		2	1	
21	Elton (ELT)		2	2	
22	Thornton-le-Moors (TLP)		1	1	

8.2 Predicted concentrations of nitrogen dioxide

Table 8.7 shows the maximum predicted offsite concentrations of NO_2 for the current CD4 furnace stack, calculated using meteorological data for the five years 2016 to 2020.

The maximum offsite NO_2 PCs are screened out for all years, as they are less than 1% of the long-term objective and less than 10% of the short-term objective.

Table 8.7: Maximum predicted offsite concentrations of NO_2 for the current CD4 furnace stack ($\mu g/m^3$)

Year	Standard	Measured as	Objective value	PC (NO_x)	PC (NO_2)[12]	PC % of objective	Screened out?	Location	
								x	y
2016	Short-term AQO	99.79th percentile of hourly averages	200	7.0	2.5	1	Yes	344900	374720
	Long-term AQO	Annual average	40	0.29	0.20	0.5		345400	374540
2017	Short-term AQO	99.79th percentile of hourly averages	200	6.7	2.3	1		343780	376060
	Long-term AQO	Annual average	40	0.33	0.23	0.6		345480	374580
2018	Short-term AQO	99.79th percentile of hourly averages	200	6.8	2.4	1		343620	376080
	Long-term AQO	Annual average	40	0.23	0.16	0.4		345420	374460
2019	Short-term AQO	99.79th percentile of hourly averages	200	6.8	2.4	1		343620	376080
	Long-term AQO	Annual average	40	0.27	0.19	0.5		345460	374560
2020	Short-term AQO	99.79th percentile of hourly averages	200	6.5	2.3	1		343500	376100
	Long-term AQO	Annual average	40	0.24	0.17	0.4		345480	374460

[12] 35% of short-term NO_x PC and 70% of long term NO_x PC

Table 8.8 and Table 8.9 show the maximum predicted concentrations of NO_2, at each of the sensitive receptors described in Section 4.2. For each receptor, the maximum value over the five years of meteorological data is presented. Note that annual average NO_2 concentrations are only presented for locations relevant for long term exposure.

All concentrations are screened out, as they are less than 1% of the long-term and 10% of the short-term air quality objectives.

Table 8.8: Maximum PCs to annual average ground level NO_2 concentrations at sensitive receptors ($\mu g/m^3$), current CD4 furnace stack

ID	Receptor	Objective value	PC			
			NO_x	NO_2	% of objective	Screened out?
1	Elton Primary School	40	0.17	0.12	0.3	Yes
2	Wolverham Primary and Nursery School		0.09	0.07	0.2	
3	The Oaks Community Primary School		0.07	0.05	0.1	
4	St Bernard's Roman Catholic Primary School		0.09	0.06	0.1	
5	Oval Crescent		0.10	0.07	0.2	
6	Robinson Road		0.10	0.07	0.2	
7	Griffiths Lane		0.09	0.07	0.2	
8	Shepherd Close		0.09	0.06	0.2	
9	Station Close		0.18	0.12	0.3	
10	Bare Brick House		0.18	0.12	0.3	
11	Meadow View		0.16	0.11	0.3	
12	Swiss Road		0.23	0.16	0.4	
13	The Bungalow		0.28	0.20	0.5	
14	Poole Lane		0.01	0.00	< 0.1	
15	Yewtree Farm		0.08	0.06	0.1	
16	The Square		0.13	0.09	0.2	
17	Kinseys Lane		0.11	0.08	0.2	
21	Elton (ELT)		0.12	0.08	0.2	
22	Thornton-le-Moors (TLP)		0.14	0.10	0.2	

Table 8.9: Maximum PCs to 99.79th percentile of hourly average ground level NO_2 concentrations at sensitive receptors (µg/m^3), current CD4 furnace stack

ID	Receptor	Objective value	PC			
			NO_x	NO_2	% of objective	Screened out?
1	Elton Primary School	200	5.4	1.9	0.9	Yes
2	Wolverham Primary and Nursery School		4.6	1.6	0.8	
3	The Oaks Community Primary School		4.3	1.5	0.8	
4	St Bernard's Roman Catholic Primary School		4.5	1.6	0.8	
5	Oval Crescent		4.7	1.6	0.8	
6	Robinson Road		4.7	1.6	0.8	
7	Griffiths Lane		4.6	1.6	0.8	
8	Shepherd Close		4.7	1.7	0.8	
9	Station Close		5.2	1.8	0.9	
10	Bare Brick House		5.1	1.8	0.9	
11	Meadow View		6.0	2.1	1.0	
12	Swiss Road		6.6	2.3	1.2	
13	The Bungalow		6.5	2.3	1.1	
14	Poole Lane		0.6	0.2	0.1	
15	Yewtree Farm		4.3	1.5	0.8	
16	The Square		6.5	2.3	1.1	
17	Kinseys Lane		6.3	2.2	1.1	
18	Cheshire Oaks Outlet		5.5	1.9	1.0	
19	Stanlow and Thornton		5.1	1.8	0.9	
20	Research Park		5.7	2.0	1.0	
21	Elton (ELT)		5.2	1.8	0.9	
22	Thornton-le-Moors (TLP)		2.5	0.9	0.4	

8.3 Predicted concentrations of particulates

Table 8.10 shows the maximum predicted offsite concentrations of PM_{10} for the current CD4 combined furnace stack, calculated using meteorological data for the five years 2016 to 2020.

Table 8.11 shows the maximum predicted offsite concentrations of $PM_{2.5}$ for the current CD4 combined furnace stack, calculated using meteorological data for the five years 2016 to 2020.

The maximum offsite concentrations are screened out for all years.

Table 8.10: Maximum predicted offsite concentrations of PM_{10} for the current CD4 furnace stack ($\mu g/m^3$)

Year	Standard	Measured as	Objective value	PC	PC % of objective	Location	
						x	y
2016	Short-term AQO	90.41st percentile of 24-hour averages	50	0.02	< 0.1	345580	374560
	Long-term AQO	Annual average	40	0.00	< 0.1	345400	374540
2017	Short-term AQO	90.41st percentile of 24-hour averages	50	0.02	< 0.1	345440	374680
	Long-term AQO	Annual average	40	0.01	< 0.1	345480	374580
2018	Short-term AQO	90.41st percentile of 24-hour averages	50	0.02	< 0.1	345420	374280
	Long-term AQO	Annual average	40	0.00	< 0.1	345420	374460
2019	Short-term AQO	90.41st percentile of 24-hour averages	50	0.02	< 0.1	345280	374560
	Long-term AQO	Annual average	40	0.00	< 0.1	345460	374560
2020	Short-term AQO	90.41st percentile of 24-hour averages	50	0.01	< 0.1	345600	374440
	Long-term AQO	Annual average	40	0.00	< 0.1	345480	374460

Table 8.11: Maximum predicted offsite concentrations of $PM_{2.5}$ for the current CD4 furnace stack ($\mu g/m^3$)

Year	Standard	Measured as	Objective value	PC	PC % of objective	Location	
						x	y
2016	Long-term AQO	Annual average	25	0.00	< 0.1	345400	374540
2017	Long-term AQO	Annual average	25	0.01	< 0.1	345480	374580
2018	Long-term AQO	Annual average	25	0.00	< 0.1	345420	374460
2019	Long-term AQO	Annual average	25	0.00	< 0.1	345460	374560
2020	Long-term AQO	Annual average	25	0.00	< 0.1	345480	374460

Table 8.12 and Table 8.13 show the maximum predicted concentrations of particulates, at each of the sensitive receptors described in Section 4.2. For each receptor, the maximum value over the five years of meteorological data is presented. Note that annual average particulate concentrations are only presented for locations relevant for long term exposure.

All concentrations are screened out, as they are less than 1% of the long-term and 10% of the short-term air quality objectives.

Table 8.12: Maximum PCs to annual average ground level particulate concentrations at sensitive receptors (μg/m^3), current CD4 furnace stack

ID	Receptor	Objective value	PC			
			PM	% of PM_{10} objective	% of $PM_{2.5}$ objective	Screened out?
1	Elton Primary School	40 (PM_{10}) 25 ($PM_{2.5}$)	0.003	< 0.1	< 0.1	Yes
2	Wolverham Primary and Nursery School		0.002	< 0.1	< 0.1	
3	The Oaks Community Primary School		0.001	< 0.1	< 0.1	
4	St Bernard's Roman Catholic Primary School		0.001	< 0.1	< 0.1	
5	Oval Crescent		0.002	< 0.1	< 0.1	
6	Robinson Road		0.002	< 0.1	< 0.1	
7	Griffiths Lane		0.002	< 0.1	< 0.1	
8	Shepherd Close		0.002	< 0.1	< 0.1	
9	Station Close		0.003	< 0.1	< 0.1	
10	Bare Brick House		0.003	< 0.1	< 0.1	
11	Meadow View		0.003	< 0.1	< 0.1	
12	Swiss Road		0.004	< 0.1	< 0.1	
13	The Bungalow		0.005	< 0.1	< 0.1	
14	Poole Lane		0.000	< 0.1	< 0.1	
15	Yewtree Farm		0.001	< 0.1	< 0.1	
16	The Square		0.002	< 0.1	< 0.1	
17	Kinseys Lane		0.002	< 0.1	< 0.1	
21	Elton (ELT)		0.002	< 0.1	< 0.1	
22	Thornton-le-Moors (TLP)		0.002	< 0.1	< 0.1	

Table 8.13: Maximum PCs to 90.41st percentile of 24-hourly average ground level PM_{10} concentrations at sensitive receptors (µg/m³), current CD4 furnace stack

ID	Receptor	Objective value	PC		
			PM_{10}	% of objective	Screened out?
1	Elton Primary School	50	0.01	< 0.1	Yes
2	Wolverham Primary and Nursery School		0.01	< 0.1	
3	The Oaks Community Primary School		0.00	< 0.1	
4	St Bernard's Roman Catholic Primary School		0.01	< 0.1	
5	Oval Crescent		0.01	< 0.1	
6	Robinson Road		0.01	< 0.1	
7	Griffiths Lane		0.01	< 0.1	
8	Shepherd Close		0.01	< 0.1	
9	Station Close		0.01	< 0.1	
10	Bare Brick House		0.01	< 0.1	
11	Meadow View		0.01	< 0.1	
12	Swiss Road		0.01	< 0.1	
13	The Bungalow		0.02	< 0.1	
14	Poole Lane		0.00	< 0.1	
15	Yewtree Farm		0.00	< 0.1	
16	The Square		0.01	< 0.1	
17	Kinseys Lane		0.01	< 0.1	
18	Cheshire Oaks Outlet		0.01	< 0.1	
19	Stanlow and Thornton		0.01	< 0.1	
20	Research Park		0.01	< 0.1	
21	Elton (ELT)		0.01	< 0.1	
22	Thornton-le-Moors (TLP)		0.00	< 0.1	

9 Proposed CD4 combined furnace stack: consideration of concentrations for the protection of vegetation and ecosystems

Modelling was carried out to predict the maximum PC to the ground level concentrations of sulphur dioxide (SO_2) and nitrogen oxides (NO_x) at the designated conservation areas. Note that the maximum concentrations quoted 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 the sensitive habitat sites 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. For short-term critical levels, the Agency considers the release to be insignificant if the PC is less than 10% of the critical level. Where a release is insignificant the pollutant is screened out and no further assessment undertaken.

Where a release is significant, the PEC for that substance is calculated. For long-term impacts, the PEC is calculated by adding the PC to the estimated background concentration of the pollutant. For short-term impacts, the PEC is calculated by adding the PC to twice the estimated background concentration of the pollutant.

Where a release is significant, the PEC for that substance is calculated by adding the PC to the estimated background concentration of the pollutant.

9.1 Predicted concentrations of sulphur dioxide

Table 9.1, Table 9.2 and Table 9.3 show the maximum predicted annual average PCs to ground level concentrations of SO_2 at the designated conservation areas for the proposed CD4 combined furnace stack, for three sulphur in fuel gas concentration scenarios, calculated using meteorological data for the five years 2016 to 2020.

Maximum predicted concentrations across designated sites within 5 km of the site boundary were captured by the model output grid. Concentrations at designated sites further away, namely Midland Meres and Mosses Ramsar and River Dee and Bala Lake SAC, were represented by the point on the designated site closest to the site boundary.

For the representative average sulphur in fuel gas concentration (1060 ppm), the maximum annual average SO_2 PCs are screened out at seven out of the ten designated conservation areas.

- At Mersey Estuary, the maximum PC is 0.28 $\mu g/m^3$, 1.4% of the critical level.
- At Gowy Meadows and Ditches, the maximum PC is 0.28 $\mu g/m^3$, 1.4% of the critical level.
- At Frodsham and Helbsy and Ince Marshes, the maximum PC is 0.23 $\mu g/m^3$, 1.2% of the critical level.

For sustained periods of running with high sulphur fuel gas (1250 ppm), the maximum annual average SO_2 PCs are screened out at six out of the ten designated conservation areas.

- At Mersey Estuary, the maximum PC is 0.32 $\mu g/m^3$, 1.6% of the critical level.
- At Gowy Meadows and Ditches, the maximum PC is 0.32 $\mu g/m^3$, 1.6% of the critical level.
- At Frodsham and Helbsy and Ince Marshes, the maximum PC is 0.26 $\mu g/m^3$, 1.3% of the critical level.
- At Hoblane Ponds, the maximum PC is 0.23 $\mu g/m^3$, 1.2% of the critical level.

For the peak sulphur in fuel gas concentration (a worst case value, 2000 ppm), the maximum annual average SO_2 PCs are screened out at six out of the ten designated conservation areas.

- At Mersey Estuary, the maximum PC is 0.49 $\mu g/m^3$, 2.5% of the critical level.
- At Gowy Meadows and Ditches, the maximum PC is 0.49 $\mu g/m^3$, 2.5% of the critical level.
- At Frodsham and Helbsy and Ince Marshes, the maximum PC is 0.39 $\mu g/m^3$, 2.0% of the critical level.
- At Hoblane Ponds, the maximum PC is 0.35 $\mu g/m^3$, 1.8% of the critical level.

For all three sulphur in fuel gas concentration scenarios, the maximum PECs, with site-specific background data added where necessary, are well below the critical level.

Figure 10.1 shows a contour plot of the annual average SO_2 PC, generated using meteorological data for the year 2018, for the peak sulphur in fuel gas concentration (a worst case value, 2000 ppm).

Table 9.1: Predicted annual average SO_2 concentrations for the proposed CD4 combined furnace stack (µg/m^3), representative average sulphur in fuel gas concentration (1060 ppm)

Site name	Critical level	Year	PC			Background	PEC	
			SO_2	% of critical level	Screened out?		SO_2	% of critical level
Mersey Estuary (SPA, Ramsar, SSSI)	20	2016	0.20	1.0	Yes	-	-	-
		2017	0.21	1.1	No	4.3	4.5	23
		2018	0.28	1.4			4.6	
		2019	0.23	1.2			4.5	
		2020	0.26	1.3			4.6	
Gowy Meadows And Ditches (LWS)		2016	0.23	1.2	No	1.9	2.1	11
		2017	0.11	0.6	Yes	-	-	-
		2018	0.28	1.4	No	1.9	2.2	11
		2019	0.16	0.8	Yes	-	-	-
		2020	0.24	1.2	No	1.9	2.1	11
Frodsham and Helsby and Ince Marshes (LWS)		2016	0.18	0.9	Yes	-	-	-
		2017	0.23	1.2	No	3.4	3.6	18
		2018	0.17	0.9	Yes	-	-	-
		2019	0.18	0.9				
		2020	0.22	1.1	No	3.4	3.6	18
Stanney Wood (LNR, AW, LWS)		2016	0.08	0.4	Yes	-	-	-
		2017	0.05	0.3				
		2018	0.08	0.4				
		2019	0.08	0.4				
		2020	0.08	0.4				
Whitby Park (LNR)		2016	0.08	0.4	Yes	-	-	-
		2017	0.06	0.3				
		2018	0.07	0.4				
		2019	0.10	0.5				
		2020	0.08	0.4				

Site name	Critical level	Year	PC			Background	PEC	
			SO_2	% of critical level	Screened out?		SO_2	% of critical level
Hoblane Ponds (LWS)	20	2016	0.18	0.9	Yes	-	-	-
		2017	0.20	1.0				
		2018	0.19	1.0				
		2019	0.16	0.8				
		2020	0.15	0.8				
Jack's Wood (LWS)		2016	0.08	0.4	Yes	-	-	-
		2017	0.07	0.4				
		2018	0.08	0.4				
		2019	0.10	0.5				
		2020	0.07	0.4				
Shropshire Union Canal (Main Line) (LWS)		2016	0.07	0.4	Yes	-	-	-
		2017	0.02	0.1				
		2018	0.05	0.3				
		2019	0.04	0.2				
		2020	0.06	0.3				
River Dee and Bala Lake (SAC)		2016	0.01	0.1	Yes	-	-	-
		2017	0.01	0.1				
		2018	0.02	0.1				
		2019	0.02	0.1				
		2020	0.02	0.1				
Midland Meres and Mosses (Ramsar)		2016	0.05	0.3	Yes	-	-	-
		2017	0.06	0.3				
		2018	0.04	0.2				
		2019	0.05	0.3				
		2020	0.05	0.3				

Table 9.2: Predicted annual average SO_2 concentrations for the proposed CD4 combined furnace stack (µg/m^3), sustained periods of running with high sulphur fuel gas (1250 ppm)

Site name	Critical level	Year	PC			Background	PEC	
			SO_2	% of critical level	Screened out?		SO_2	% of critical level
Mersey Estuary (SPA, Ramsar, SSSI)	20	2016	0.23	1.2	No	4.3	4.5	23
		2017	0.24	1.2				
		2018	0.32	1.6			4.6	
		2019	0.27	1.4				
		2020	0.30	1.5				
Gowy Meadows and Ditches (LWS)		2016	0.26	1.3	No	1.9	2.2	11
		2017	0.13	0.7	Yes	-	-	-
		2018	0.32	1.6	No	1.9	2.2	11
		2019	0.19	1.0	Yes	-	-	-
		2020	0.27	1.4	No	1.9	2.2	11
Frodsham and Helsby and Ince Marshes (LWS)		2016	0.20	1.0	Yes	-	-	-
		2017	0.26	1.3	No	3.4	3.7	19
		2018	0.20	1.0	Yes	-	-	-
		2019	0.20	1.0				
		2020	0.25	1.3	No	3.4	3.6	18
Stanney Wood (LNR, AW, LWS)		2016	0.09	0.5	Yes	-	-	-
		2017	0.06	0.3				
		2018	0.10	0.5				
		2019	0.10	0.5				
		2020	0.09	0.5				
Whitby Park (LNR)		2016	0.09	0.5	Yes	-	-	-
		2017	0.07	0.4				
		2018	0.08	0.4				
		2019	0.12	0.6				
		2020	0.10	0.5				

Site name	Critical level	Year	PC			Background	PEC	
			SO_2	% of critical level	Screened out?		SO_2	% of critical level
Hoblane Ponds (LWS)	20	2016	0.20	1.0	Yes	-	-	-
		2017	0.23	1.2	No	1.8	2.0	10
		2018	0.22	1.1				
		2019	0.18	0.9	Yes	-	-	-
		2020	0.17	0.9				
Jack's Wood (LWS)		2016	0.09	0.5	Yes	-	-	-
		2017	0.08	0.4				
		2018	0.09	0.5				
		2019	0.11	0.6				
		2020	0.08	0.4				
Shropshire Union Canal (Main Line) (LWS)		2016	0.08	0.4	Yes	-	-	-
		2017	0.03	0.2				
		2018	0.06	0.3				
		2019	0.04	0.2				
		2020	0.07	0.4				
River Dee and Bala Lake (SAC)		2016	0.02	0.1	Yes	-	-	-
		2017	0.01	0.1				
		2018	0.03	0.2				
		2019	0.02	0.1				
		2020	0.02	0.1				
Midland Meres and Mosses (Ramsar)		2016	0.06	0.3	Yes	-	-	-
		2017	0.07	0.4				
		2018	0.05	0.3				
		2019	0.05	0.3				
		2020	0.05	0.3				

Table 9.3: Predicted annual average SO_2 concentrations for the proposed CD4 combined furnace stack (µg/m^3), peak sulphur in fuel gas concentration (a worst case value, 2000 ppm)

Site name	Critical level	Year	PC			Background	PEC	
			SO_2	% of critical level	Screened out?		SO_2	% of critical level
Mersey Estuary (SPA, Ramsar, SSSI)	20	2016	0.34	1.8	No	4.3	4.7	24
		2017	0.36	1.8			4.7	
		2018	0.49	2.5			4.8	
		2019	0.40	2.0			4.7	
		2020	0.45	2.3			4.8	
Gowy Meadows and Ditches (LWS)		2016	0.39	2.0	No	1.9	2.3	12
		2017	0.19	1.0	Yes	-	-	-
		2018	0.49	2.5	No	1.9	2.4	12
		2019	0.28	1.4			2.2	11
		2020	0.41	2.1			2.3	12
Frodsham and Helsby and Ince Marshes (LWS)		2016	0.31	1.6	No	3.4	3.7	19
		2017	0.39	2.0			3.8	
		2018	0.30	1.5			3.7	
		2019	0.30	1.5			3.7	
		2020	0.37	1.9			3.8	
Stanney Wood (LNR, AW, LWS)		2016	0.14	0.7	Yes	-	-	-
		2017	0.09	0.5				
		2018	0.15	0.8				
		2019	0.14	0.7				
		2020	0.13	0.7				
Whitby Park (LNR)		2016	0.14	0.7	Yes	-	-	-
		2017	0.11	0.6				
		2018	0.12	0.6				
		2019	0.18	0.9				
		2020	0.14	0.7				

Site name	Critical level	Year	PC			Background	PEC	
			SO_2	% of critical level	Screened out?		SO_2	% of critical level
Hoblane Ponds (LWS)	20	2016	0.31	1.6	No	1.8	2.1	11
		2017	0.35	1.8			2.2	
		2018	0.33	1.7			2.1	
		2019	0.28	1.4			2.1	
		2020	0.26	1.3			2.1	
Jack's Wood (LWS)		2016	0.14	0.7	Yes	-	-	-
		2017	0.11	0.6				
		2018	0.13	0.7				
		2019	0.16	0.8				
		2020	0.12	0.6				
Shropshire Union Canal (Main Line) (LWS)		2016	0.11	0.6	Yes	-	-	-
		2017	0.04	0.2				
		2018	0.09	0.5				
		2019	0.06	0.3				
		2020	0.10	0.5				
River Dee and Bala Lake (SAC)		2016	0.02	0.1	Yes	-	-	-
		2017	0.02	0.1				
		2018	0.04	0.2				
		2019	0.03	0.2				
		2020	0.04	0.2				
Midland Meres and Mosses (Ramsar)		2016	0.08	0.4	Yes	-	-	-
		2017	0.10	0.5				
		2018	0.07	0.4				
		2019	0.08	0.4				
		2020	0.08	0.4				

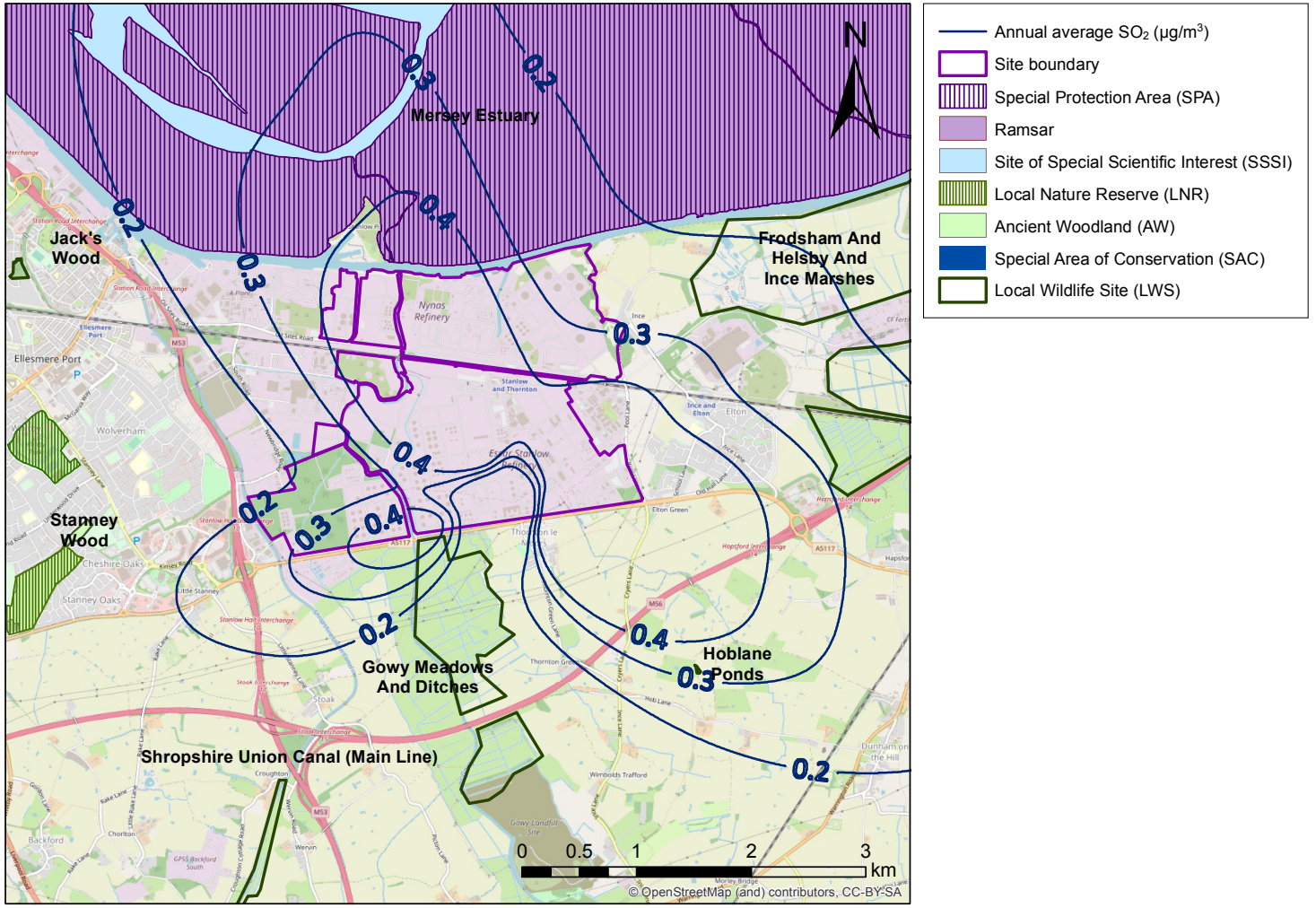

Figure 9.1: Contour plot of annual average SO_2 PC, proposed CD4 combined furnace stack, peak sulphur in fuel gas concentration (a worst case value, 2000 ppm), 2018 meteorological data

9.2 Predicted concentrations of nitrogen oxides

Table 9.4 and Table 9.5 show the maximum predicted annual and daily average PCs to ground level concentrations of NO_x at the designated sites, using meteorological data for the five years 2016 to 2020. Maximum predicted concentrations across designated sites within 5 km of the site boundary were captured by the model output grid. Concentrations at designated sites further away, namely Midland Meres and Mosses Ramsar and River Dee and Bala Lake SAC, were represented by the point on the designated site closest to the site boundary.

At all ten of the designated conservation areas, all NO_x PCs are screened out, as the annual average PCs are less than 1% of the critical level of 30 µg/m^3 and the daily average PCs are less than 10% of the critical level of 75 µg/m^3.

Table 9.4: Predicted annual average NO_x concentrations for the proposed CD4 combined furnace stack (µg/m^3)

Site name	Critical level	Year	PC		
			NO_x	% of critical level	Screened out?
Mersey Estuary (SPA, Ramsar, SSSI)	30	2016	0.11	0.4	Yes
		2017	0.11	0.4	
		2018	0.15	0.5	
		2019	0.13	0.4	
		2020	0.14	0.5	
Gowy Meadows And Ditches (LWS)		2016	0.12	0.4	Yes
		2017	0.06	0.2	
		2018	0.15	0.5	
		2019	0.09	0.3	
		2020	0.13	0.4	
Frodsham And Helsby And Ince Marshes (LWS)		2016	0.10	0.3	Yes
		2017	0.12	0.4	
		2018	0.09	0.3	
		2019	0.09	0.3	
		2020	0.12	0.4	
Stanney Wood (LNR, AW, LWS)		2016	0.04	0.1	Yes
		2017	0.03	0.1	
		2018	0.05	0.2	
		2019	0.04	0.1	
		2020	0.04	0.1	
Whitby Park (LNR)		2016	0.04	0.1	Yes
		2017	0.03	0.1	
		2018	0.04	0.1	
		2019	0.06	0.2	
		2020	0.04	0.1	
Hoblane Ponds (LWS)		2016	0.10	0.3	Yes
		2017	0.11	0.4	
		2018	0.10	0.3	
		2019	0.09	0.3	
		2020	0.08	0.3	

Site name	Critical level	Year	PC		
			NO_x	% of critical level	Screened out?
Jack's Wood (LWS)	30	2016	0.04	0.1	Yes
		2017	0.04	0.1	
		2018	0.04	0.1	
		2019	0.05	0.2	
		2020	0.04	0.1	
Shropshire Union Canal (Main Line) (LWS)		2016	0.04	0.1	Yes
		2017	0.01	< 0.1	
		2018	0.03	0.1	
		2019	0.02	< 0.1	
		2020	0.03	0.1	
River Dee and Bala Lake (SAC)		2016	0.01	< 0.1	Yes
		2017	0.01	< 0.1	
		2018	0.01	< 0.1	
		2019	0.01	< 0.1	
		2020	0.01	< 0.1	
Midland Meres and Mosses (Ramsar)		2016	0.03	0.1	Yes
		2017	0.03	0.1	
		2018	0.03	0.1	
		2019	0.03	0.1	
		2020	0.02	< 0.1	

Table 9.5: Predicted daily average NO_x concentrations for the proposed CD4 combined furnace stack ($\mu g/m^3$)

Site name	Critical level	Year	PC		
			NO_x	% of critical level	Screened out?
Mersey Estuary (SPA, Ramsar, SSSI)	75	2016	1.9	3	Yes
		2017	1.0	1	
		2018	1.4	2	
		2019	1.2	2	
		2020	1.3	2	
Gowy Meadows And Ditches (LWS)		2016	3.5	5	Yes
		2017	2.1	3	
		2018	2.8	4	
		2019	2.4	3	
		2020	3.3	4	
Frodsham And Helsby And Ince Marshes (LWS)		2016	1.1	1	Yes
		2017	0.9	1	
		2018	0.8	1	
		2019	0.9	1	
		2020	0.9	1	
Stanney Wood (LNR, AW, LWS)		2016	0.6	0.8	Yes
		2017	0.7	0.9	
		2018	0.6	0.8	
		2019	0.7	0.9	
		2020	0.6	0.8	

Site name	Critical level	Year	PC		
			NO_x	% of critical level	Screened out?
Whitby Park (LNR)	75	2016	0.7	0.9	Yes
		2017	0.7	0.9	
		2018	0.6	0.8	
		2019	0.6	0.8	
		2020	0.6	0.8	
Hoblane Ponds (LWS)		2016	1.0	1	Yes
		2017	1.2	2	
		2018	1.3	2	
		2019	0.9	1	
		2020	0.8	1	
Jack's Wood (LWS)		2016	0.5	0.7	Yes
		2017	0.5	0.7	
		2018	0.5	0.7	
		2019	0.7	0.9	
		2020	0.4	0.5	
Shropshire Union Canal (Main Line) (LWS)		2016	0.8	1	Yes
		2017	0.4	0.5	
		2018	0.5	0.7	
		2019	0.5	0.7	
		2020	0.7	0.9	
River Dee and Bala Lake (SAC)		2016	0.2	0.3	Yes
		2017	0.5	0.7	
		2018	0.4	0.5	
		2019	0.2	0.3	
		2020	0.2	0.3	
Midland Meres and Mosses (Ramsar)		2016	0.2	0.3	Yes
		2017	0.3	0.4	
		2018	0.4	0.5	
		2019	0.2	0.3	
		2020	0.2	0.3	

10 Current CD4 furnace stack: consideration of concentrations for the protection of vegetation and ecosystems

10.1 Predicted concentrations of sulphur dioxide

Table 10.1 to Table 10.3 show the maximum predicted annual average PCs to ground level concentrations of SO_2 at the designated conservation areas for the current CD4 combined furnace stack, for the three sulphur in fuel gas concentration scenarios, calculated using meteorological data for the five years 2016 to 2020.

Maximum predicted concentrations across designated sites within 5 km of the site boundary were captured by the model output grid. Concentrations at designated sites further away, namely Midland Meres and Mosses Ramsar and River Dee and Bala Lake SAC, were represented by the point on the designated site closest to the site boundary.

For the representative average sulphur in fuel gas concentration (1060 ppm), the maximum annual average SO_2 PCs are screened out at eight out of the ten designated conservation areas, as they are less than 1% of the annual average critical level of 20 $\mu g/m^3$.

- At Mersey Estuary, the maximum PC is 0.23 $\mu g/m^3$, 1.2% of the critical level.
- At Frodsham and Helsby and Ince Marshes, the maximum PC is 0.24 $\mu g/m^3$, 1.2% of the critical level.

For sustained periods of running with high sulphur fuel gas (1250 ppm), the maximum annual average SO_2 PCs are screened out at eight out of the ten designated conservation areas.

- At Mersey Estuary, the maximum PC is 0.24 $\mu g/m^3$, 1.2% of the critical level.
- At Frodsham and Helsby and Ince Marshes, the maximum PC is 0.26 $\mu g/m^3$, 1.3% of the critical level.

For peak sulphur in fuel gas concentration (a worst case value, 2000 ppm), the maximum annual average SO_2 PCs are screened out at seven out of the ten designated conservation areas.

- At Mersey Estuary, the maximum PC is 0.32 $\mu g/m^3$, 1.6% of the critical level.
- At Frodsham and Helsby and Ince Marshes, the maximum PC is 0.34 $\mu g/m^3$, 1.7% of the critical level.
- At Hoblane Ponds, the maximum PC is 0.23 $\mu g/m^3$, 1.2% of the critical level.

For all three sulphur in fuel gas concentration scenarios, the maximum PECs, with site-specific background data added where necessary, are well below the critical level.

Figure 10.1 shows a contour plot of the annual average SO_2 PC, generated using meteorological data for the year 2018, for peak sulphur in fuel gas concentration (a worst case value, 2000 ppm).

Table 10.1: Predicted annual average SO_2 concentrations for the current CD4 furnace stack (µg/m^3), representative average sulphur in fuel gas concentration (1060 ppm)

Site name	Critical level	Year	PC			Background	PEC	
			SO_2	% of critical level	Screened out?		SO_2	% of critical level
Mersey Estuary (SPA, Ramsar, SSSI)	20	2016	0.17	0.9	Yes	-	-	-
		2017	0.17	0.9				
		2018	0.23	1.2	No	4.3	4.5	23
		2019	0.19	1.0	Yes	-	-	-
		2020	0.19	1.0				
Gowy Meadows And Ditches (LWS)		2016	0.06	0.3	Yes	-	-	-
		2017	0.03	0.2				
		2018	0.07	0.4				
		2019	0.04	0.2				
		2020	0.06	0.3				
Frodsham and Helsby and Ince Marshes (LWS)		2016	0.19	1.0	Yes	-	-	-
		2017	0.24	1.2	No	3.4	3.6	18
		2018	0.18	0.9	Yes	-	-	-
		2019	0.18	0.9				
		2020	0.19	1.0				
Stanney Wood (LNR, AW, LWS)		2016	0.07	0.4	Yes	-	-	-
		2017	0.04	0.2				
		2018	0.08	0.4				
		2019	0.07	0.4				
		2020	0.07	0.4				
Whitby Park (LNR)		2016	0.07	0.4	Yes	-	-	-
		2017	0.05	0.3				
		2018	0.06	0.3				
		2019	0.10	0.5				
		2020	0.08	0.4				

Site name	Critical level	Year	PC			Background	PEC	
			SO_2	% of critical level	Screened out?		SO_2	% of critical level
Hoblane Ponds (LWS)	20	2016	0.15	0.8	Yes	-	-	-
		2017	0.16	0.8				
		2018	0.17	0.9				
		2019	0.14	0.7				
		2020	0.13	0.7				
Jack's Wood (LWS)		2016	0.07	0.4	Yes	-	-	-
		2017	0.06	0.3				
		2018	0.07	0.4				
		2019	0.10	0.5				
		2020	0.07	0.4				
Shropshire Union Canal (Main Line) (LWS)		2016	0.05	0.3	Yes	-	-	-
		2017	0.02	0.1				
		2018	0.04	0.2				
		2019	0.03	0.2				
		2020	0.05	0.3				
River Dee and Bala Lake (SAC)		2016	0.01	0.1	Yes	-	-	-
		2017	0.01	< 0.1				
		2018	0.02	0.1				
		2019	0.01	0.1				
		2020	0.02	0.1				
Midland Meres and Mosses (Ramsar)		2016	0.06	0.3	Yes	-	-	-
		2017	0.07	0.4				
		2018	0.05	0.3				
		2019	0.06	0.3				
		2020	0.06	0.3				

Table 10.2: Predicted annual average SO_2 concentrations for the current CD4 furnace stack ($\mu g/m^3$), sustained periods of running with high sulphur fuel gas (1250 ppm)

Site name	Critical level	Year	PC			Background	PEC	
			SO_2	% of critical level	Screened out?		SO_2	% of critical level
Mersey Estuary (SPA, Ramsar, SSSI)	20	2016	0.18	0.9	Yes	-	-	-
		2017	0.19	1.0				
		2018	0.24	1.2	No	4.3	4.5	23
		2019	0.20	1.0	Yes	-	-	-
		2020	0.20					
Gowy Meadows And Ditches (LWS)		2016	0.06	0.3	Yes	-	-	-
		2017	0.03	0.2				
		2018	0.07	0.4				
		2019	0.04	0.2				
		2020	0.06	0.3				
Frodsham And Helsby And Ince Marshes (LWS)		2016	0.21	1.1	No	3.4	3.6	18
		2017	0.26	1.3			3.7	19
		2018	0.19	1.0	Yes	-	-	-
		2019	0.20					
		2020	0.21	1.1	No	3.4	3.6	18
Stanney Wood (LNR, AW, LWS)		2016	0.08	0.4	Yes	-	-	-
		2017	0.04	0.2				
		2018	0.09	0.5				
		2019	0.07	0.4				
		2020	0.07	0.4				
Whitby Park (LNR)		2016	0.08	0.4	Yes	-	-	-
		2017	0.06	0.3				
		2018	0.06	0.3				
		2019	0.11	0.6				
		2020	0.09	0.5				

Site name	Critical level	Year	PC			Background	PEC	
			SO_2	% of critical level	Screened out?		SO_2	% of critical level
Hoblane Ponds (LWS)	20	2016	0.17	0.9	Yes	-	-	-
		2017	0.17	0.9				
		2018	0.18	0.9				
		2019	0.15	0.8				
		2020	0.14	0.7				
Jack's Wood (LWS)		2016	0.08	0.4	Yes	-	-	-
		2017	0.07	0.4				
		2018	0.08	0.4				
		2019	0.10	0.5				
		2020	0.07	0.4				
Shropshire Union Canal (Main Line) (LWS)		2016	0.05	0.3	Yes	-	-	-
		2017	0.02	0.1				
		2018	0.05	0.3				
		2019	0.03	0.2				
		2020	0.05	0.3				
River Dee and Bala Lake (SAC)		2016	0.01	0.1	Yes	-	-	-
		2017	0.01	< 0.1				
		2018	0.02	0.1				
		2019	0.02	0.1				
		2020	0.02	0.1				
Midland Meres and Mosses (Ramsar)		2016	0.07	0.3	Yes	-	-	-
		2017	0.08	0.4				
		2018	0.06	0.3				
		2019	0.06	0.3				
		2020	0.06	0.3				

Table 10.3: Predicted annual average SO_2 concentrations for the current CD4 furnace stack (µg/m^3), peak sulphur in fuel gas concentration (a worst case value, 2000 ppm)

Site name	Critical level	Year	PC			Background	PEC	
			SO_2	% of critical level	Screened out?		SO_2	% of critical level
Mersey Estuary (SPA, Ramsar, SSSI)	20	2016	0.24	1.2	No	4.3	4.6	23
		2017	0.24	1.2				
		2018	0.32	1.6			4.7	24
		2019	0.26	1.3				
		2020	0.27	1.4				
Gowy Meadows And Ditches (LWS)		2016	0.08	0.4	Yes	-	-	-
		2017	0.04	0.2				
		2018	0.09	0.5				
		2019	0.06	0.3				
		2020	0.08	0.4				
Frodsham And Helsby And Ince Marshes (LWS)		2016	0.27	1.4	No	3.4	3.7	19
		2017	0.34	1.7				
		2018	0.25	1.3				
		2019	0.26	1.3				
		2020	0.27	1.4				
Stanney Wood (LNR, AW, LWS)		2016	0.10	0.5	Yes	-	-	-
		2017	0.05	0.3				
		2018	0.12	0.6				
		2019	0.10	0.5				
		2020	0.09	0.5				
Whitby Park (LNR)		2016	0.10	0.5	Yes	-	-	-
		2017	0.07	0.4				
		2018	0.08	0.4				
		2019	0.14	0.7				
		2020	0.11	0.6				

Site name	Critical level	Year	PC			Background	PEC	
			SO_2	% of critical level	Screened out?		SO_2	% of critical level
Hoblane Ponds (LWS)	20	2016	0.21	1.1	No	1.8	2.0	10
		2017	0.22	1.1				
		2018	0.23	1.2				
		2019	0.19	1.0	Yes	-	-	-
		2020	0.18	0.9				
Jack's Wood (LWS)		2016	0.10	0.5	Yes	-	-	-
		2017	0.09	0.5				
		2018	0.10	0.5				
		2019	0.13	0.7				
		2020	0.10	0.5				
Shropshire Union Canal (Main Line) (LWS)		2016	0.07	0.4	Yes	-	-	-
		2017	0.02	0.1				
		2018	0.06	0.3				
		2019	0.04	0.2				
		2020	0.07	0.4				
River Dee and Bala Lake (SAC)		2016	0.02	0.1	Yes	-	-	-
		2017	0.01	0.1				
		2018	0.03	0.1				
		2019	0.02	0.1				
		2020	0.03	0.1				
Midland Meres and Mosses (Ramsar)		2016	0.09	0.4	Yes	-	-	-
		2017	0.10	0.5				
		2018	0.07	0.4				
		2019	0.08	0.4				
		2020	0.08	0.4				

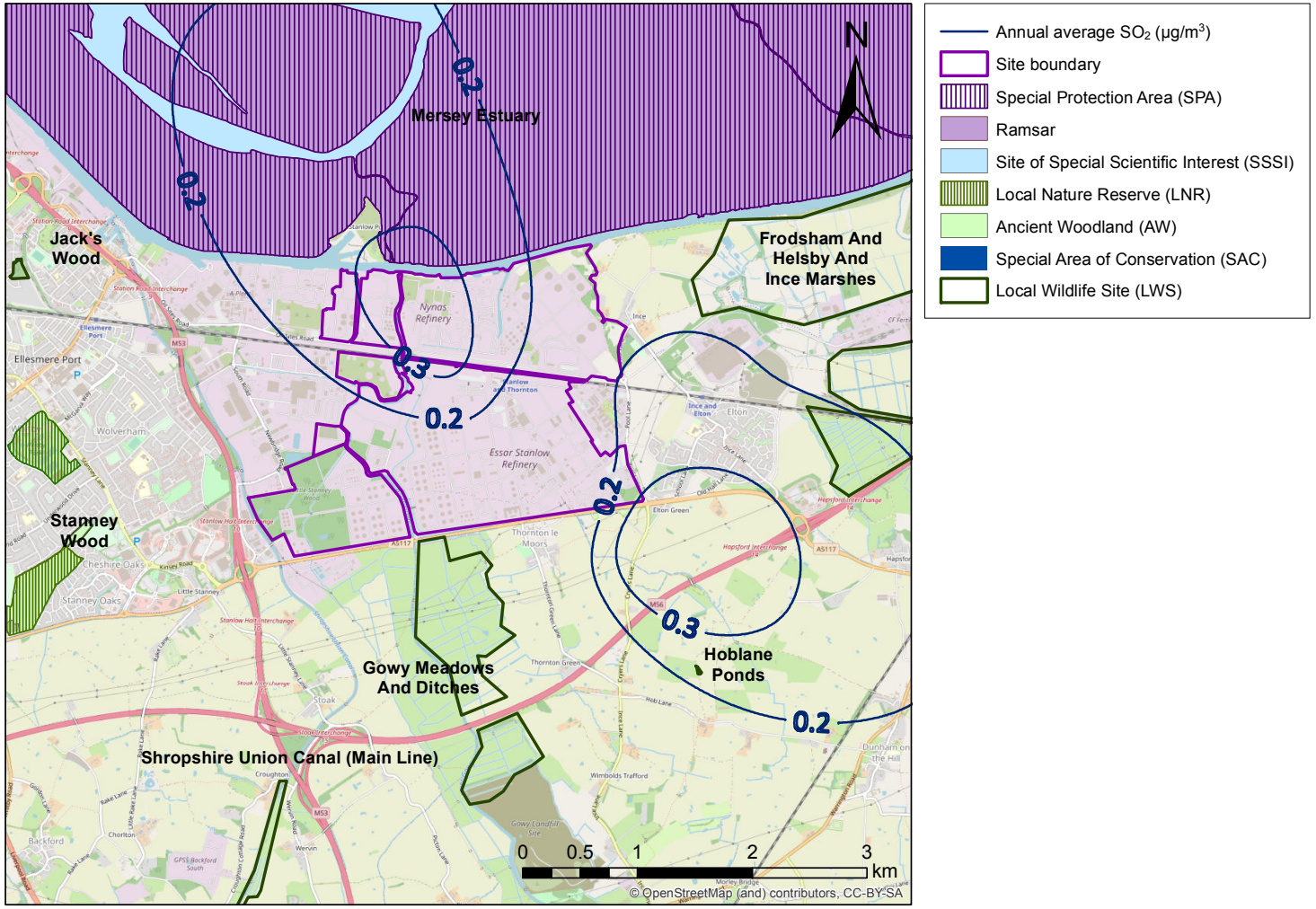

Figure 10.1: Contour plot of annual average SO_2 PC, current CD4 furnace stack, 2018 meteorological data, peak sulphur in fuel gas concentration (a worst case value, 2000 ppm)

10.2 Predicted concentrations of nitrogen oxides

Table 10.4 and Table 10.5 show the maximum predicted annual and daily average PCs to ground level concentrations of NO_x at the designated sites, using meteorological data for the five years 2016 to 2020.

Maximum predicted concentrations across designated sites within 5 km of the site boundary were captured by the model output grid. Concentrations at designated sites further away, namely Midland Meres and Mosses Ramsar and River Dee and Bala Lake SAC, were represented by the point on the designated site closest to the site boundary.

At all ten of the designated conservation areas, all NO_x PCs are screened out, as the annual average PCs are less than 1% of the critical level of 30 µg/m^3 and the daily average PCs are less than 10% of the critical level of 75 µg/m^3.

Table 10.4: Predicted annual average NO_x concentrations for the current CD4 furnace stack (µg/m^3)

Site name	Critical level	Year	PC		
			NO_x	% of critical level	Screened out?
Mersey Estuary (SPA, Ramsar, SSSI)	30	2016	0.14	0.5	Yes
		2017	0.14	0.5	
		2018	0.19	0.6	
		2019	0.15	0.5	
		2020	0.16	0.5	
Gowy Meadows And Ditches (LWS)		2016	0.05	0.2	Yes
		2017	0.02	0.1	
		2018	0.05	0.2	
		2019	0.03	0.1	
		2020	0.05	0.2	
Frodsham And Helsby And Ince Marshes (LWS)		2016	0.16	0.5	Yes
		2017	0.20	0.7	
		2018	0.15	0.5	
		2019	0.15	0.5	
		2020	0.16	0.5	
Stanney Wood (LNR, AW, LWS)		2016	0.06	0.2	Yes
		2017	0.03	0.1	
		2018	0.07	0.2	
		2019	0.06	0.2	
		2020	0.06	0.2	
Whitby Park (LNR)		2016	0.06	0.2	Yes
		2017	0.04	0.1	
		2018	0.05	0.2	
		2019	0.08	0.3	
		2020	0.07	0.2	

Site name	Critical level	Year	PC		
			NO_x	% of critical level	Screened out?
Hoblane Ponds (LWS)	30	2016	0.13	0.4	Yes
		2017	0.13	0.4	
		2018	0.14	0.5	
		2019	0.11	0.4	
		2020	0.10	0.3	
Jack's Wood (LWS)		2016	0.06	0.2	Yes
		2017	0.05	0.2	
		2018	0.06	0.2	
		2019	0.08	0.3	
		2020	0.06	0.2	
Shropshire Union Canal (Main Line) (LWS)		2016	0.04	0.1	Yes
		2017	0.01	< 0.1	
		2018	0.04	0.1	
		2019	0.02	< 0.1	
		2020	0.04	0.1	
River Dee and Bala Lake (SAC)		2016	0.01	< 0.1	Yes
		2017	0.01	< 0.1	
		2018	0.02	0.1	
		2019	0.01	< 0.1	
		2020	0.01	< 0.1	
Midland Meres and Mosses (Ramsar)		2016	0.05	0.2	Yes
		2017	0.06	0.2	
		2018	0.04	0.1	
		2019	0.05	0.2	
		2020	0.05	0.2	

Table 10.5: Predicted daily average NO_x concentrations for the current CD4 furnace stack ($\mu g/m^3$)

Site name	Critical level	Year	PC		
			NO_x	% of critical level	Screened out?
Mersey Estuary (SPA, Ramsar, SSSI)	75	2016	1.9	3	Yes
		2017	2.0	3	
		2018	2.6	3	
		2019	1.7	2	
		2020	1.8	2	
Gowy Meadows And Ditches (LWS)		2016	2.0	3	Yes
		2017	1.4	2	
		2018	2.2	3	
		2019	2.0	3	
		2020	1.6	2	
Frodsham And Helsby And Ince Marshes (LWS)		2016	1.6	2	Yes
		2017	1.4	2	
		2018	1.5	2	
		2019	1.4	2	
		2020	1.7	2	

Site name	Critical level	Year	PC		
			NO_x	% of critical level	Screened out?
Stanney Wood (LNR, AW, LWS)	75	2016	1.3	2	Yes
		2017	1.2	2	
		2018	1.1	1	
		2019	1.1	1	
		2020	0.9	1	
Whitby Park (LNR)		2016	1.3	2	Yes
		2017	1.1	1	
		2018	0.8	1	
		2019	1.0	1	
		2020	1.1	1	
Hoblane Ponds (LWS)		2016	1.3	2	Yes
		2017	1.6	2	
		2018	1.7	2	
		2019	1.5	2	
		2020	1.3	2	
Jack's Wood (LWS)		2016	0.9	1	Yes
		2017	0.9	1	
		2018	0.9	1	
		2019	1.4	2	
		2020	0.9	1	
Shropshire Union Canal (Main Line) (LWS)		2016	2.0	3	Yes
		2017	0.7	1	
		2018	1.0	1	
		2019	0.7	1	
		2020	1.0	1	
River Dee and Bala Lake (SAC)		2016	0.4	0.5	Yes
		2017	0.3	0.4	
		2018	0.5	0.7	
		2019	0.3	0.4	
		2020	0.3	0.4	
Midland Meres and Mosses (Ramsar)		2016	0.4	0.5	Yes
		2017	0.5	0.7	
		2018	0.6	0.8	
		2019	0.3	0.4	
		2020	0.4	0.5	

11 Discussion

This assessment considers the impact of emissions from the proposed CD4 combined furnace stack and compares the impact to that from the current CD4 furnace stack, which is to be replaced. Three concentrations of sulphur in fuel gas were evaluated: a representative average concentration; a typical value for sustained periods of running with high sulphur fuel gas; and the peak sulphur in fuel gas value observed from fuel gas analysis (a worst case value).

11.1 Human health impacts

For both the current CD4 furnace stack and the proposed CD4 combined furnace stack, the maximum offsite NO_2, SO_2, PM_{10} and $PM_{2.5}$ Process Contributions (PCs) are screened out at all locations, for all years and all scenarios, as they are less than 1% of the long-term and 10% of the short-term objective in each case.

11.2 Ecological impacts

For both the current CD4 furnace stack and the proposed CD4 combined furnace stack, the NO_x PCs are screened out at all ten of the designated conservation areas, as the annual average PCs are less than 1% of the critical level of 30 $\mu g/m^3$ and the daily average PCs are less than 10% of the critical level of 75 $\mu g/m^3$.

For both the current CD4 furnace stack and the proposed CD4 combined furnace stack, and for all three scenarios, the maximum SO_2 PECs are well below the critical level at all ten designated conservation areas.

APPENDIX A: Summary of ADMS 5

ADMS, the Atmospheric Dispersion Modelling System, has been developed to make use of the most up-to-date understanding of the behaviour of the lower levels of the atmosphere in an easy-to-use computer modelling system for atmospheric emissions. This allows the impacts of emissions from industrial and other facilities to be thoroughly investigated as part of an environmental assessment or for other regulatory purposes. The following is a summary of the capabilities and validation of ADMS 5. 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; and
- 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.

More details of these processes are given below.

ADMS runs in Windows 8, Windows 7, Windows Vista and XP environments. It has been developed by CERC in conjunction with the UK Meteorological Office and the Department of Mechanical Engineering at the University of Surrey. In its earlier stages, ADMS was developed with contributions from a number of sponsors, including the Environment Agency (originally under HMIP), the Health and Safety Executive and a number of the successor companies of the CEGB.

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 such as, 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 the ADMS-Mapper, and is also facilitated by a link with GIS[13] ESRI ArcGIS.

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 operates out to a distance of about 30 building heights from the building and has the following stages:

(i) A complex of buildings is reduced to a single 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 within the well-mixed recirculating flow region are uniform 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.

[13] Geographical Information System

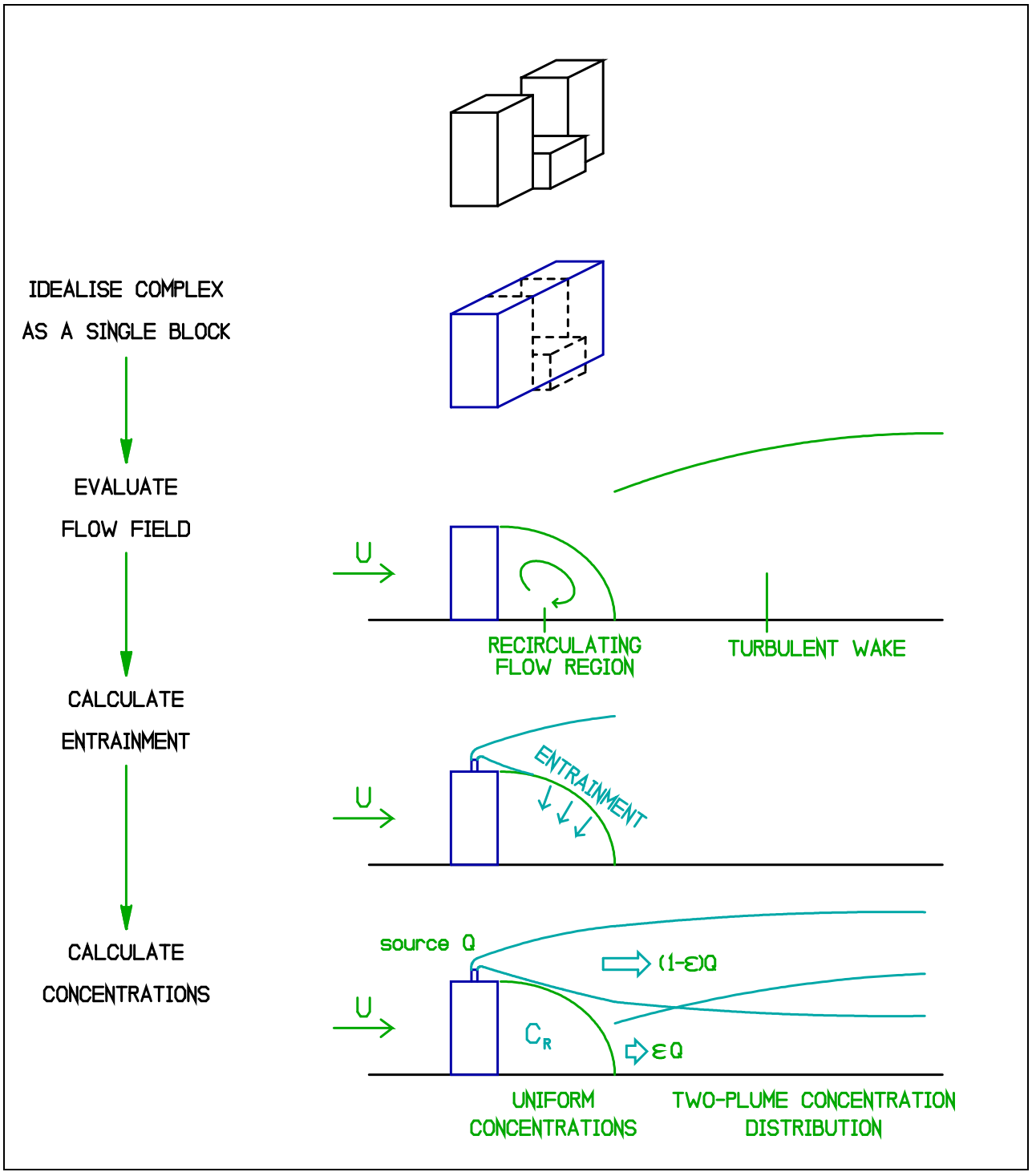

Figure A1: Stages in the modelling of building effects

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) $NO + O_3 \rightarrow NO_2$
(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. 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. Ideally hills should have moderate slopes (up to 1 in 2 on upwind slopes and hill summits, up to 1 in 3 in hill wakes), but the model is useful even when these criteria are not met. The terrain height is specified at up to 66,000 points that are interpolated by the model onto a regular grid of up to 256 by 256 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 for particles, and a deposition velocity based on aerodynamic, sub-layer and surface-layer resistance values for gases. 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.