Drax

# BECCS ENVIRONMENTAL PERMIT VARIATION APPLICATION

## Air Emissions Risk Assessment

AQ01
NOVEMBER 2024

PUBLIC

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## Air Emissions Risk Assessment

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# CONTENTS

## *TABLES*

## *FIGURES*

## *APPENDICES*

# 1 INTRODUCTION

## 1.1 PURPOSE OF STUDY

1.1.1. This report sets out methodology and results of the updated detailed dispersion modelling undertaken in support of the Permit Variation Application to operate carbon capture on Unit 2 and/or Unit 1 at Drax Power Station (VP3530LS).

1.1.2. The technology provider for the carbon capture plant is Mitsubishi Heavy Industries (MHI).

## 1.2 THE SITE

1.2.1. The site location is shown in **Figure A-1**, in **Appendix A**.

1.2.2. The area surrounding Drax Power Station is relatively sparsely populated. It is primarily under agricultural use, with scattered residential properties.

1.2.3. The closest settlements are the villages of Drax (1.3km to the east), Cambleforth (1.4km to the south-west) and Barlow (1.5km to the north-west). The larger towns of Selby and Goole and approximately 6km north-west and 8km south-east of the site.

1.2.4. There are several nature conservation sites in the wider area, including sites declared at local, national and international level.

1.2.5. Further information on potential sensitive receptors for air quality effects is provided in **Section 4.3**.

## 1.3 EMISSIONS TO AIR

1.3.1. The emissions to air considered in this report will occur via the main stack (A1) at the site. They will comprise a mix of pollutants generated by the combustion process (biomass) and those introduced by the amine-based carbon capture process. Details of the chemical species modelled are provided in Section 2.

1.3.2. There are currently 4 operational conventional combustion units, burning biomass (termed non-BECCS units where BECCS = Bio-energy Carbon Capture and Storage).

1.3.3. The Core Scenario in the dispersion assessment considers:

- **Full load, continuous operation of 2 x BECCS units and 2 x non-BECCS units**

1.3.4. The main stack contains 3 flues of diameter 8m, and each flue can serve up to 2 combustion units. In the future scenario, the plant design has the 2 x BECCS units discharging via one flue, and the 2 x non-BECCS units discharging via a second flue.

1.3.5. Sensitivity testing, described in Section 6, has been undertaken to demonstrate impacts under alternative operating scenarios such as

- Full load, continuous operation of 1 x BECCS unit and 3 x non-BECCS units,
- 2 x BECCS units alone and
- A mid merit scenario as considered within the Environmental Statement produced for the Development Consent Order application (continuous operation of 2 x BECCS units and 4000 hours of operation of the non-BECCS units

1.3.6. The ground level impacts are considered both in terms of the contribution of the facility to ground level pollutant concentrations and in comparison to the current permitted operations (as continuous operation of 4 x non-BECCS units, with an additional 2 x non-BECCS units being non-operational).

# 2 EMISSIONS AND ENVIRONMENTAL STANDARDS

## 2.1 POLLUTANT EMISSIONS

2.1.1. The exhaust gases from the Drax BECCS and non-BECCS units will include pollutants resulting directly from the combustion process and, for the BECCS units, those introduced by the addition of the carbon capture plant.

2.1.2. **Table 2-1** lists the emission compounds for the process.

2.1.3. Ammonia is listed as both a combustion and introduced emission. Ammonia generated by combustion will be directly emitted from the non-BECCS units, but largely removed from the flue gases prior to the carbon capture plant. Ammonia will however be introduced to the BECCS units flue gas as a degradation product of the amines within the carbon capture plant.

2.1.4. The existing permit for the main stack also includes mercury as a controlled emission. However, emissions of mercury are negligible from biomass fired boiler plant and are not considered in this air emissions risk assessment.

2.1.5. The post-combustion emissions for the BECCS units comprise 26 solvent and degradation[1] products identified by MHI as emissions from the carbon capture plant.

**Table 2-1 – Emission compounds for BECCS and non-BECCS units**

| Emission | Type | CAS |
|---|---|---|
| **Combustion Emissions (BECCS and non-BECCS sources)** | | |
| Nitrogen Oxides | | na |
| Sulphur Dioxide | | 7446-09-5 |
| Ammonia | | 7664-41-7 |
| Hydrogen Chloride | | 7647-01-0 |
| Hydrogen Fluoride | | 7664-39-3 |
| Particulate Matter | | na |
| **Emissions Introduced by Carbon Capture Plant (BECCS only)** | | |
| Acetaldehyde | Aldehyde | 75-07-0 |
| Formaldehyde | Aldehyde | 50-00-0 |
| Ammonia | Ammonia | 7664-41-7 |
| Ethylamine | 1º Amine | 75-04-7 |
| Methylamine | 1º Amine | 74-89-5 |

[1] This is degradation that occurs within the carbon capture plant itself. The degradation of amines in ambient air is considered separately.

| Emission | Type | CAS |
|---|---|---|
| Monoethanolamine | 1º Amine | 141-43-5 |
| Diethanolamine | 2º Amine | 111-42-2 |
| Diethylamine | 2º Amine | 109-89-7 |
| Dimethylamine | 2º Amine | 124-40-3 |
| Ethyl ethanolamine | 2º Amine | 110-7306 |
| Ethyl methylamine | 2º Amine | 624-78-2 |
| Piperazine | 2º Amine | 110-85-0 |
| N-Dimethylethylenediamine | 3º Amine | 108-00-9 |
| Ethyl diethanolamine | 3º Amine | 139-87-7 |
| N-(2-hydroxyethyl) acetamide | Amide | 142-26-7 |
| N-(2-hydroxyethyl) formamide | Amide | 693-06-1 |
| N-Nitrosomethylethylamine | Nitrosamine | 10595-95-6 |
| N-Ethyl-N-(2-hydroxyethyl) nitrosamine | Nitrosamine | 13147-25-6 |
| N-Nitrosodimethylamine | Nitrosamine | 62-75-9 |
| 1-Nitrosopiperazine | Nitrosamine | 5632-47-3 |
| N-Nitrosodiethylamine | Nitrosamine | 55-18-5 |
| N-Nitrosodiethanolamine | Nitrosamine | 1116-54-7 |
| N-Nitrosomorpholine | Nitrosamine | 59-89-2 |
| 1,4-Dinitrosopiperazine | Nitrosamine | 140-79-4 |
| 2-(Ethylnitroamino) ethanol | Nitramine | - |
| 1-Nitropiperazine | Nitramine | 42499-41-2 |

## 2.2 ENVIRONMENTAL STANDARDS

### HUMAN HEALTH

2.2.1. **Table 2-2** shows the environmental assessment levels for the protection of human health applied to this assessment. They comprise a mix of statutory air quality standards and non-statutory Environmental Assessment Levels (EALs) derived by Environment Agency and, for carbon capture plant emissions for which Environment Agency has not derived EALs, by MHI. These are jointly termed Air Quality Assessment Levels (AQAL).

### ECOLOGY

2.2.2. **Table 2-3** and **Table 2-4** show the environmental assessment levels for the protection of ecology applied to this assessment. They comprise a mix of statutory air quality standards and non-statutory critical levels and critical loads available from the APIS website (www.apis.ac.uk).

**Table 2-2 – Environmental standards (AQAL) for the assessment of impacts on human health**

| Emission | Long Term AQAL | | Short Term AQAL | | Origin |
|---|---|---|---|---|---|
| | Standard (µg/m$^3$) | Averaging Period (permitted exceedances per year) | Standard (µg/m$^3$) | Averaging Period (permitted exceedances per year) | |
| **Combustion Emissions (BECCS and non-BECCS sources)** | | | | | |
| Nitrogen Dioxide | 40 | Annual | 200 | Hourly (18) | Air Quality Standards Regulations 2010 |
| Sulphur Dioxide | 125 | Daily (3) | 266<br>350 | 15min (35)<br>Hourly (24) | Air Quality (England) Regulations 2000 (as amended)<br>Air Quality Standards Regulations 2010 |
| Ammonia | 180 | Annual | 2500 | Hourly | Non-statutory EAL, derived by Environment Agency |
| Hydrogen Chloride | | | 750 | Hourly | Non-statutory EAL, derived by Environment Agency |
| Hydrogen Fluoride | 16 | Monthly | 160 | Hourly | Non-statutory EAL, derived by Environment Agency |
| Particulate Matter (as $PM_{10}$) | 40 | Annual | 50 | Daily (35) | Air Quality Standards Regulations 2010 |
| Particulate Matter (as $PM_{2.5}$) | 20 | Annual | | | Air Quality Standards Regulations 2010 |
| **Emissions Introduced by Carbon Capture Plant (BECCS only)** | | | | | |
| Acetaldehyde | 370 | Annual | 9200 | Hourly | Non-statutory EAL, derived by Environment Agency |
| Formaldehyde | 5 | Annual | 100 | 30min | Non-statutory EAL, derived by Environment Agency |
| Ammonia | 180 | Annual | 2500 | Hourly | Non-statutory EAL, derived by Environment Agency |
| Ethylamine | 22 | Annual | 2800 | Hourly | Non-statutory EAL, derived by MHI |
| Methylamine | 15 | Annual | 1900 | Hourly | Non-statutory EAL, derived by MHI |
| Monoethanolamine | 100 | 24-Hour | 400 | Hourly | Non-statutory EAL, derived by Environment Agency |

| Emission | Long Term AQAL | | Short Term AQAL | | Origin |
|---|---|---|---|---|---|
| | Standard ($\mu g/m^3$) | Averaging Period (permitted exceedances per year) | Standard ($\mu g/m^3$) | Averaging Period (permitted exceedances per year) | |
| Diethanolamine | 3 | 24-Hour | - | - | Non-statutory EAL, derived by Environment Agency |
| Diethylamine | 33 | 24-Hour | 330 | Hourly | Non-statutory EAL, derived by Environment Agency† |
| Dimethylamine | 22 | Annual | 2800 | Hourly | Non-statutory EAL, derived by MHI |
| Ethyl ethanolamine | 50 | Annual | 300 | Hourly | Non-statutory EAL, derived by MHI |
| Ethyl methylamine | 250 | Annual | - | - | Non-statutory EAL, derived by MHI |
| N-Dimethylethylenediamine | 104 | Daily | 417 | Hourly | Non-statutory EAL, derived by MHI |
| Piperazine | 15 | 24-Hour | - | - | Non-statutory EAL, derived by Environment Agency§ |
| Ethyl diethanolamine | 440 | Annual | - | - | Non-statutory EAL, derived by MHI |
| N-(2-hydroxyethyl) acetamide | 0.085 | Annual | - | - | Non-statutory EAL, derived by MHI |
| N-(2-hydroxyethyl) formamide | 86 | Annual | - | - | Non-statutory EAL, derived by MHI |
| N-Nitrosomethylethylamine | 0.0002 | Annual | - | - | Non-statutory EAL, derived by Environment Agency‡ |
| N-Ethyl-N-(2-hydroxyethyl) nitrosamine | 0.0002 | Annual | - | - | Non-statutory EAL, derived by Environment Agency‡ |
| N-Nitrosodimethylamine | 0.0002 | Annual | - | - | Non-statutory EAL, derived by Environment Agency |
| 1-Nitrosopiperazine | 0.0002 | Annual | - | - | Non-statutory EAL, derived by Environment Agency‡ |
| N-Nitrosodiethylamine | 0.0002 | Annual | - | - | Non-statutory EAL, derived by Environment Agency‡ |
| N-Nitrosodiethanolamine | 0.0002 | Annual | - | - | Non-statutory EAL, derived by Environment Agency‡ |

| Emission | Long Term AQAL | | Short Term AQAL | | Origin |
|---|---|---|---|---|---|
| | Standard ($\mu g/m^3$) | Averaging Period (permitted exceedances per year) | Standard ($\mu g/m^3$) | Averaging Period (permitted exceedances per year) | |
| N-Nitrosomorpholine | 0.005 | Annual | 0.037 | 24-Hour | Non-statutory EAL, derived by Environment Agency† |
| 1,4-Dinitrosopiperazine | 0.0002 | Annual | - | - | Non-statutory EAL, derived by Environment Agency‡ |
| 2-(Ethylnitroamino) ethanol | 0.0002 | Annual | - | - | Non-statutory EAL, derived by Environment Agency‡ |
| 1-Nitropiperazine | 0.0002 | Annual | - | - | Non-statutory EAL, derived by Environment Agency‡ |
| **Pollutants formed by degradation of amines in ambient air** | | | | | |
| Nitrosamines | 0.0002 | Annual | | | Non-statutory EAL, derived by Environment Agency‡ |
| Nitramines | 0.0002 | Annual | | | Non-statutory EAL, derived by Environment Agency‡ |

† These EAL are subject to finalisation by EA, followed by public consultation

§ This EAL is subject to public consultation

‡ This is set at the EAL for Nitrosodimethylamine

Ammonia included both as a combustion related emission and as introduced by the carbon capture plant

**Table 2-3 – Environmental standards for the assessment of impacts on sites designated for nature conservation at international and national levels**

| Ecological Site | Critical Levels (µg/m$^3$) | | | Critical Loads | | |
|---|---|---|---|---|---|---|
| | Nitrogen Oxides | Sulphur Dioxide | Ammonia | Most Sensitive Habitat in Study Area | Nitrogen Deposition (kgN/ha/yr) | Acid Deposition (keq/ha/yr) (minimum $CL_{minN}$ \| $CL_{maxN}$ \| $CL_{maxS}$) |
| River Derwent SAC | 30 | 10 | 3 | *Not applicable* | | |
| Thorne Moor SAC/SPA/SSSI | 30 | 10 | 1 | Raised and blanket bogs | 5 – 10 | 0.321 \| 0.462 \| 0.131 |
| Lower Derwent Valley SAC/SPA | 30 | 10 | 1 | Lowland hay meadow | 10 - 20 | 0.856 \| 4.856 \| 4.000 |
| Skipwith Common SAC/SSSI | 30 | 10 | 1 | Dry heaths | 5 - 15 | 0.642 \| 0.802 \| 0.160 |
| Humber Estuary SAC/SPA/SSSI | 30 | 10 | 3 | Saltmarsh | 10 - 20 | Not applicable |
| Breighton Meadows SSSI | 30 | 20 | 3 | Low and medium altitude hay meadows | 10 - 20 | 0.856 \| 4.856 \| 4.000 |
| Eskamhorn Meadows SSSI | 30 | 20 | 3 | Low and medium altitude hay meadows | 10 - 20 | 1.071 \| 5.071 \| 4.000 |
| Derwent Ings SSSI | 30 | 20 | 3 | Low and medium altitude hay meadows | 10 - 20 | 0.856 \| 4.856 \| 4.000 |
| Went Ings SSSI | 30 | 20 | 3 | Low and medium altitude hay meadows | 10 - 20 | 1.071 \| 5.071 \| 4.000 |
| Barn Hill Meadows SSSI | 30 | 20 | 3 | Low and medium altitude hay meadows | 10 - 20 | 0.856 \| 4.856 \| 4.000 |
| Burr Closes SSSI | 30 | 20 | 3 | Low and medium altitude hay meadows | 10 - 20 | 1.071 \| 5.071 \| 4.000 |

**Table 2-4 – Environmental standards for the assessment of impacts on sites designated for nature conservation at local level**

| Ecological Site | Critical Levels (µg/m$^3$) | | | Critical Loads | | |
|---|---|---|---|---|---|---|
| | Nitrogen Oxides | Sulphur Dioxide | Ammonia | Most Sensitive Habitat in Study Area | Nitrogen Deposition (kgN/ha/yr) | Acid Deposition (keq/ha/yr) (minimum $CL_{minN}$ \| $CL_{maxN}$ \| $CL_{maxS}$) |
| Common Plantation SINC | 30 | 20 | 3 | Broadleaved Woodland | 10 - 15 | 0.357 \| 1.805 \| 1.448 |
| Barmby-on-the-Marsh LWS | 30 | 20 | 3 | Broadleaved Woodland | 10 - 15 | 0.142 \| 10.902 \| 10.76 |
| Brockholes SINC | 30 | 20 | 3 | Lowland fen | 15 - 25 | Not sensitive to acid |
| Orchard Farm SINC | 30 | 20 | 3 | Grazing marsh | 10 - 20 | No critical load set |
| Barmby Pond LWS | 30 | 20 | 3 | Reedbeds | 15 - 25 | Not sensitive to acid |
| Cobble Croft Wood SINC | 30 | 20 | 3 | Broadleaved Woodland | 10 - 15 | 0.357 \| 1.805 \| 1.448 |
| Hagg Green Lane SINC | 30 | 20 | 3 | Broadleaved Woodland | 10 - 15 | 0.357 \| 1.822 \| 1.465 |
| Sand Pit Wood SINC | 30 | 20 | 3 | Broadleaved Woodland | 10 - 15 | 0.357 \| 1.805 \| 1.448 |
| Barlow Common LNR | 30 | 20 | 3 | Broadleaved Woodland | 10 - 15 | 0.357 \| 1.805 \| 1.448 |

# 3 BACKGROUND AIR QUALITY

## 3.1 OVERVIEW

3.1.1. Background air quality within the study area is influenced by emissions from Drax Power Station itself, road transport and agricultural practices.

3.1.2. There is just one Air Quality Management Area (AQMA) within the study area, along New Street in Selby Town, approximately 6km north-west of the Site. The AQMA has been declared due to historic exceedances of the annual mean objective for $NO_2$. Elevated concentrations of $NO_2$ in the AQMA are attributed to local traffic rather than Drax. Selby District Council's Air Quality Action Plan (May 2018) outlines traffic related measures designed

## 3.2 POLLUTANTS RELEVANT TO HUMAN HEALTH

3.2.1. Background pollutant concentrations for pollutants relevant to human health are summarised in **Table 3-1**. Data are obtained from the mapped data provided by Defra (for $NO_2$ and particulate matter) and by APIS (for $SO_2$ and $NH_3$) at 1km x 1km resolution. The Defra data are taken from modelled concentrations for 2024; The APIS data are taken from the 3 year average data for 2020 – 2022 (assumed applicable to 2021). Taking into account national measures to reduce pollutant emissions in the UK and recent emission trends, these concentrations will be representative of background pollution levels during the early years of operation of the carbon capture plant at Drax, albeit adopting a somewhat conservative approach. All background pollutant concentrations are well within their respective assessment quality assessment levels (AQAL) set out in **Table 2-2**.

**Table 3-1 – Background pollutant concentrations relevant to human health (µg/m$^3$)**

| Source | Nitrogen Dioxide | Particulate Matter $PM_{10}$ | Particulate Matter $PM_{2.5}$ | Sulphur Dioxide | Ammonia |
|---|---|---|---|---|---|
| Defra for 2024 | 4.1 – 15.5 | 9.9 – 16.8 | 5.0 – 8.0 | | |
| APIS for 2021 | | | | 1.0 – 5.1 | 1.5 – 2.9 |

3.2.2. No relevant background data are available for the remaining pollutants relevant to human health.

## 3.3 POLLUTANTS RELEVANT TO ECOLOGICAL RECEPTORS

3.3.1. Background pollutant concentrations and deposition over the nature conservation sites are shown in **Table 3-2** and **Table 3-3**.

3.3.2. Background concentrations of all NOx and $SO_2$ are within the critical level for all sites. Background concentrations of ammonia are within the critical level for all sites except Lower Derwent Valley SAC/SPA, Skipwith Common SAC/SSSI and Humber Estuary SAC/SPA/SSSI where the critical level is 1µg/m$^3$.

3.3.3. Nitrogen deposition exceeds the critical load over all sites except Brockholes SINC and Barmby Pond SINC. Whilst there is a contribution from Drax in these background levels, the level of exceedance is such that deposition would exceed the critical load whether or not this contribution is excluded from background levels. Therefore, to ensure a conservative assessment no discounting of the Drax contribution is made in the assessment.

3.3.4. Exceedance of the critical load function for acidity is less widespread than exceedance of the critical load for nitrogen deposition. Exceedances are seen over Thorne Moor SAC/SPA/SSSI and Skipwith Common SAC/SSSI (**Table 3-2**), and at all locally designated sites except Barmby on the Marsh SINC (**Table 3-3**).

**Table 3-2 – Background pollutant concentration and deposition over sites designated for nature conservation at a national and international level. Values in bold exceed either the critical level or critical load.**

| Ecological Site | Pollutant Concentrations (µg/m$^3$) | | | Deposition | |
|---|---|---|---|---|---|
| | Nitrogen Oxides | Sulphur Dioxide | Ammonia | Nitrogen Deposition (kgN/ha/yr) | Acid Deposition (keq/ha/yr)§ |
| River Derwent SAC | 5.33 - 9.25 | 0.69 - 4.09 | 1.73 - 2.61 | **14.02 - 19.82** | |
| Thorne Moor SAC/SPA/SSSI | 7.55 - 10.11 | 0.90 - 1.09 | 1.38 - 1.80 | **12.58 - 14.1** | **0.90 - 0.97** |
| Lower Derwent Valley SAC/SPA | 6.22 - 8.26 | 0.91 - 1.43 | **1.90 – 3.00** | **14.92 - 19.75** | 1.07 - 1.42 |
| Skipwith Common SAC/SSSI | 6.77 - 7.53 | 0.99 - 1.16 | **1.82 – 2.00** | **15.01 - 15.53** | **1.09 - 1.12** |
| Humber Estuary SAC/SPA/SSSI† | 7.76 - 12.76 | 1.05 - 2.13 | **1.65 - 1.79** | **13.85 - 14.69** | |
| Breighton Meadows SSSI | 7.06 - 7.13 | 1.04 - 1.11 | 1.9 - 1.94 | **14.92 - 15.48** | 1.07 - 1.11 |
| Eskamhorn Meadows SSSI | 7.72 - 8.01 | 1.04 - 1.08 | 1.63 - 1.63 | **13.54 - 13.71** | 0.98 - 0.98 |
| Derwent Ings SSSI | 6.38 - 8.26 | 0.95 - 1.43 | 1.94 - 2.45 | **15.48 - 17.83** | 1.11 - 1.29 |
| Went Ings SSSI | 9.08 - 9.27 | 1.02 - 1.07 | 1.58 - 1.62 | **13.35 - 13.43** | 0.95 - 0.96 |
| Barn Hill Meadows SSSI | 7.62 - 9.58 | 1.18 - 2.27 | 1.78 - 1.84 | **14.71 - 14.89** | 1.06 - 1.07 |
| Burr Closes SSSI | 7.92 - 8.11 | 1.09 - 1.11 | 1.79 - 1.8 | **14.53 - 14.56** | 1.07 - 1.08 |

† Limited to area of designated sites within the study area
§ Total acid deposition

**Table 3-3 – Background pollutant concentration and deposition over sites designated for nature conservation at a local level. Values in bold exceed either the critical level or critical load**

| Ecological Site | Pollutant Concentrations (µg/m³) | | | Deposition | |
|---|---|---|---|---|---|
| | Nitrogen Oxides | Sulphur Dioxide | Ammonia | Nitrogen Deposition (kgN/ha/yr) | Acid Deposition (keq/ha/yr) (N \| S) |
| Common Plantation SINC | 8.45 | 1.65 | 1.17 | **26.3** | **1.88 \| 0.18** |
| Barmby-on-the-Marsh LWS | 7.56 | 1.75 | 1.12 | **27.05** | 1.93 \| 0.18 |
| Brockholes SINC | 7.73 | 1.63 | 1.05 | 13.69 | N/A |
| Orchard Farm SINC | 8.08 | 1.68 | 1.49 | **13.94** | N/A |
| Barmby Pond LWS | 7.25 | 1.85 | 1.04 | 14.47 | N/A |
| Cobble Croft Wood SINC | 8.54 | 1.64 | 1.13 | **26.32** | **1.88 \| 0.18** |
| Hagg Green Lane SINC | 8.03 | 1.84 | 1.32 | **27.75** | **1.98 \| 0.17** |
| Sand Pit Wood SINC | 8.45 | 1.65 | 1.17 | **26.30** | **1.88 \| 0.18** |
| Barlow Common LNR | 8.35 | 1.68 | 1.41 | **26.56** | **1.90 \| 0.18** |

## 3.4 SHORT TERM BACKGROUND CONCENTRATIONS

3.4.1. Short term background concentrations, used in the calculation of total environmental concentrations, are assumed to equate to 2 times the annual mean background concentrations presented above.

# 4 METHODOLOGY

## 4.1 MODEL

4.1.1. The dispersion model is ADMS v6.0.0.1. This is a new generation Gaussian plume air dispersion model in which the atmospheric boundary layer properties are characterised by the boundary layer depth and the Monin-Obukhov length.

4.1.2. It is widely used for industrial applications across the UK and in many countries worldwide.

## 4.2 EMISSION PARAMETERS

4.2.1. The bulk exhaust parameters for the four biomass combustion units (2 x BECCS and 2 x non-BECCS) are provided in **Table 4-1**. The table also includes the combined exhaust parameters as modelled for the core scenario (4 units combined) and the sensitivity test (2 BECCS units alone).

**Table 4-1 – Exhaust parameters for the four biomass units at Drax**

| Parameter | BECCS Unit 1 | BECCS Unit 2 | Non-BECCS Unit 3 | Non-BECCS Unit 4 |
|---|---|---|---|---|
| Location | 466124, 427224 | | | |
| Stack Height (m) | 259 | | | |
| Flue Diameter (m) | 8 | | 8 | |
| Flow Rate (Actual, $m^3$/s) | 725 | 725 | 993 | 993 |
| Exit Temperature (ºC) | 100 | 100 | 144 | 144 |
| Exit Velocity | 28.9 | | 39.5 | |
| Oxygen (%, actual) | 7.4 | 7.4 | 5.6 | 5.6 |
| H2O (%, actual) | 4.9 | 4.9 | 10.8 | 10.8 |
| Oxygen (%, dry) | 7.8 | 7.8 | 6.3 | 6.3 |
| Normalised Flow (@6% O2, dry, $m^3$/s) | 444 | 444 | 573 | 573 |
| **Combined Exhaust (4 units)** | | | | |
| Effective Diameter | 11.3 | | | |
| Exhaust Flow (actual, $m^3$) | 3441 | | | |
| Exit Temperature (ºC) | 125 | | | |
| Exit Velocity (m/s) | 34.2 | | | |

4.2.2. The existing (non-BECCS units) and proposed (BECCS units) emission limit values (reference conditions: standard temperature and pressure and 6%$O_2$, dry) together with calculated mass emission rates are provided in **Table 4-2**.

4.2.3. In the assessment of impacts against standards identified as 'Short' or 'Long' term AQAL in **Table** 2-2, emissions are assumed to occur at the rates denoted 'ST' (Short Term) and 'LT' (Long Term) respectively in **Table 4-2**. This ensures a conservative assessment.

4.2.4. The impacts of the speciated amines, nitrosamines and nitramines have, in the core scenario, been assessed with each amine individually at the ELV for total amines. This is a worst case assumption for each compound since, compliance with the ELV requires that no more than one amine / nitrosamine is emitted at the ELV at any given time. The process contributions to nitrosamines and nitramines presented for the core scenario should not, therefore, be added together but interpreted as the upper limit of the likely impact from that individual nitrosamine.

**Table 4-2 – Proposed (BECCS Units) and Existing (Non-BECCS Units) Emission Limit Values and equivalent mass emission rates at full load operation. (LT = Long Term, ST = Short Term)**

| Emission | BECCS Units (per Unit) | | Non-BECCS Units (per Unit) | | Total Mass Emissions in Core Scenario (g/s) | Total Mass Emissions with 2 x BECCS Units (g/s) |
|---|---|---|---|---|---|---|
| | Proposed Emission Limit Value (mg/Nm$^3$) | Mass Emission Rate at ELV (g/s) | Existing Emission Limit Value (mg/Nm$^3$) | Mass Emission Rate at ELV (g/s) | | |
| Nitrogen Oxides – LT | 207 | 92.0 | 160 | 91.6 | 367.3 | 184.0 |
| Nitrogen Oxides – ST | 258 | 114.7 | 200 | 114.5 | 458.4 | 229.3 |
| Sulphur Dioxide – LT | 60 | 26.7 | 100 | 57.3 | 167.9 | 53.3 |
| Sulphur Dioxide – ST | 129 | 57.3 | 215 | 123.1 | 360.9 | 114.7 |
| Ammonia | 10 | 4.4 | 10 | 5.7 | 20.3 | 8.9 |
| Hydrogen Chloride – LT | 5 | 2.2 | 5 | 2.9 | 10.2 | 4.4 |
| Hydrogen Chloride – ST | 12 | 5.3 | 12 | 6.9 | 24.4 | 10.7 |
| Hydrogen Fluoride | | | | | | |
| Particulate Matter | 12.9 | 5.7 | 10 | 5.7 | 22.9 | 11.5 |
| Acetaldehyde | 15 | 6.66 | - | - | 13.3 | 13.3 |
| Formaldehyde | 2 | 0.89 | - | - | 1.78 | 1.78 |
| Primary Amines | 2.5 | 1.11 | - | - | 2.22 | 2.22 |
| Secondary/Tertiary Amines | 1.5 | 0.67 | - | - | 1.33 | 1.33 |
| Nitrosamines | 0.003 | 0.0013 | - | - | 0.0027 | 0.0027 |
| Nitramines | 0.0005 | 0.00022 | - | - | 0.00044 | 0.00044 |
| Amides | 1.0 | 0.00044 | - | - | 0.89 | 0.89 |

4.2.5. **Table 4-3** shows the expected maximum emission concentration of each individual amine compound and degradation product, as provided by the MHI for Drax-specific conditions, and the equivalent expected maximum mass emission rates. These reduced emission rates are considered in the analysis of results, but the core results are presented on the basis of emissions at the ELV.

**Table 4-3 – Speciated emission concentrations and emission rates for amines, nitrosamines and nitramines**

| Emission | Proposed Emission Limit Value ($mg/Nm^3$, at 6%$O_2$, dry) | Expected Maximum Concentration ($mg/Nm^3$, at actual $O_2$, $H_2O$) | Expected Maximum Proportion of ELV | Mass Emissions at ELV from 2 x BECCS Units (g/s) | Expected Maximum Mass Emissions from 2 x BECCS Units (g/s) |
|---|---|---|---|---|---|
| Ethylamine | Primary Amines 2.5mg/Nm$^3$ | 1.5 | 73% | 2.22 | 1.62 |
| Methylamine | | <0.1 | <5% | | <0.11 |
| Monoethanolamine | | <0.1 | <5% | | <0.11 |
| Diethanolamine | Secondary / Tertiary Amines 1.5mg/Nm$^3$ | <0.1 | <8% | 1.33 | <0.11 |
| Diethylamine | | <0.1 | <8% | | <0.11 |
| Dimethylamine | | <0.1 | <8% | | <0.11 |
| Ethyl ethanolamine | | 0.3 | 24% | | 0.32 |
| Ethyl methylamine | | 0.2 | 16% | | 0.21 |
| N-Dimethylethylenediamine | | <0.1 | <8% | | <0.11 |
| Piperazine | | <0.1 | <8% | | <0.11 |
| Ethyl diethanolamine | | <0.1 | <8% | | <0.11 |
| N-Nitrosomethylethylamine | Total Nitrosamines 0.003mg/Nm$^3$ | 0.001 | 40% | 0.0027 | 0.00106 |
| N-Ethyl-N-(2-hydroxyethyl) nitrosamine | | 0.0004 | 16% | | 0.00042 |
| N-Nitrosodimethylamine | | 0.0002 | 8% | | 0.00021 |
| 1-Nitrosopiperazine | | 0.0001 | 4% | | 0.00011 |
| N-Nitrosodiethylamine | | <0.0001 | <4% | | <0.00011 |
| N-Nitrosodiethanolamine | | <0.0001 | <4% | | <0.00011 |
| N-Nitrosomorpholine | | <0.0001 | <4% | | <0.00011 |
| 1,4-Dinitrosopiperazine | | <0.0001 | <4% | | <0.00011 |
| 2-(Ethylnitroamino) ethanol | Total Nitramines 0.0005mg/Nm$^3$ | 0.0001 | 24% | 0.00044 | 0.00011 |
| 1-Nitropiperazine | | 0.0001 | 24% | | 0.00011 |

## 4.3 MODEL DOMAIN AND RECEPTORS

4.3.1. The model domain extends a minimum of 15km in all directions from the main stack. Concentrations are modelled within this domain at a resolution of 250m. This grid resolution is well within the recommended minimum grid spacing of 1.5 x the stack height and ensures that the maximum impacts are well resolved spatially.

4.3.2. Whilst residential properties are ubiquitous throughout the model domain, 45 illustrative human receptors have been specified, as set out in Appendix A, including receptors within the Selby AQMA. The receptors are shown in **Figure A-2** and **Figure A-3**.

4.3.3. Where appropriate, ecological receptors are modelled on a grid of receptors of minimum resolution 200m and at a height of 0.5m.

4.3.4. The designated ecological sites considered in the assessment conform to the Environment Agency's most stringent distance screening criteria, namely:

- 15km for SACs, SPAs and Ramsar sites
- 15km for SSSI
- 2km for local nature sites (in this case SINCs and LNR)

4.3.5. The sites are listed in **Table 2-3** and **Table 2-4**, and shown in **Figure A-4**.

## 4.4 METEOROLOGICAL DATA AND SURFACE CHARACTERISTICS

4.4.1. The model uses 5 years of hourly sequential meteorological data from RAF Waddington, from 2019 to 2023. Wind roses for the site are shown in **Appendix C**.

4.4.2. Waddington lies 69km to the south of the power station. Both the power station and RAF Waddington are inland sites, to the east of England and east of the Peak District, in areas of limited terrain influence. As such, the data from the RAF station are considered appropriately representation of conditions on site for dispersion modelling purposes.

4.4.3. The open setting of the power station, with relatively sparse development in the vicinity, is taken into account in the modelling by setting the surface roughness length to 0.2m. This is the value recommended by the model developers for agricultural areas with low growing vegetation. The minimum Monin-Obukhov (MO) length scale is set to the model default. Sensitivity testing was undertaken with increased roughness length (0.5m, representative of parkland and open suburbia) and for minimum MO lengths of 10m and 30m.

## 4.5 BUILDINGS

4.5.1. Buildings influence the dispersion of pollutants by increasing turbulence levels in their wake. The ADMS building module ignores any buildings whose height, H, is less than a fraction 1/α of the source height where

$$\alpha = 1 + 2 \times min\left(1, \left(\frac{W}{H}\right)\right)$$

and W is the crosswind width of the building.

4.5.2. At Drax, this implies that any building less than 86m tall will be ignored, irrespective of its crosswind width. The only structures on site over 86m tall are the cooling towers, and these are included within the dispersion model as circular buildings. Details are provided in **Table 4-4**, and shown in **Figure A-3**.

4.5.3. CT5B is selected as the ADMS 'main building', due to its proximity to the main stack. However, sensitivity testing shows that these buildings have very limited impact on ground level concentrations and the model results are not sensitive to the specification of the main building.

**Table 4-4 – Buildings included within the model**

| Building | Easting | Northing | Height | Diameter |
|---|---|---|---|---|
| CT5B | 466219.1 | 427631.3 | 114 | 95.6 |
| CT4A | 466596.6 | 427571.8 | 114 | 95.6 |
| CT4B | 466464.1 | 427529.7 | 114 | 95.6 |
| CT5A | 466326.6 | 427539.8 | 114 | 95.6 |
| CT6A | 466351.3 | 427674.5 | 114 | 95.6 |
| CT6B | 466490.2 | 427665.4 | 114 | 95.6 |
| CTS1 | 466175.4 | 426796.2 | 114 | 95.6 |
| CTS2 | 466306.7 | 426775.5 | 114 | 95.6 |
| CTS3 | 466097.8 | 426680.4 | 114 | 95.6 |
| CTS4 | 466117.2 | 426548.6 | 114 | 95.6 |
| CTS5 | 466254.5 | 426519.1 | 114 | 95.6 |
| CTS6 | 466327.3 | 426632.4 | 114 | 95.6 |

## 4.6 TERRAIN

4.6.1. There are no significant terrain gradients in the study area, defined as large scale slopes in excess of 10% gradient. Therefore, terrain effects are not included within the model.

## 4.7 CHEMISTRY

### $NO_X$ TO $NO_2$

4.7.1. To model concentrations of nitrogen dioxide and its subsequent deposition, the following NOx to $NO_2$ conversion ratio has been used in the post-processing of nitrogen oxides concentrations:

- Annual mean concentrations 0.7
- Hourly mean concentrations 0.35

4.7.2. These are the 'Worse Case' values recommended by Environment Agency.

### AMINE CHEMISTRY

4.7.3. For the assessment of amines and nitrosamines from the carbon capture unit, the ADMS Amine Chemistry Module has been used to model the chemical reactions associated with the formation of nitrosamines and nitramines in the atmosphere. Reaction rate coefficients required by the module have been derived from information provided in the CERC Report on Improving Post-Combustion Carbon Capture Air Quality Risk Assessment Techniques (May 2024)[3].

4.7.4. The mechanisms for the formation of nitrosamines and nitramines in the atmosphere are, as for the degradation within the carbon capture plant itself, complex. However, the main initial reaction of amines in the atmosphere is with hydroxyl (OH) radicals and it is this reaction on which the ADMS amine chemistry scheme is based. The formation of nitrosamines and nitramines are attributed to reactions with NO and $NO_2$, but these degradation products can further degrade in the atmosphere through photo-oxidation and subsequent reaction with oxygen molecules to form imines which are relatively stable and non-toxic compounds.

4.7.5. Primary amines do not form stable nitrosamines, meaning that any such nitrosamines would be rapidly isomerised to the respective imine. Since the assessment is based on process-specific and compound specific modelling of amines, nitrosamines formed from primary amines are not assessed against an AQAL.

4.7.6. The input parameters used in the modelling are set out in **Appendix D**.

## 4.8 SUB-HOURLY AVERAGING PERIODS

4.8.1. Sulphur dioxide and formaldehyde have air quality standards that are based on sub-hourly averaging periods i.e. 15minutes and 30minutes respectively.

4.8.2. The model has been set up to output sub-hourly average concentrations but, with the meteorological data used for the model being hourly sequential, it is possible that peak concentrations will be underestimated since sub-hourly variations in meteorological conditions may not be fully accounted for.

4.8.3. Therefore, in addition to the direct output from the model, consideration has also been given to the conservative relationships derived by Environment Agency to convert between hourly and sub-hourly average peak concentrations:

- Hourly mean to 30minute mean = 1.3
- Hourly mean to 15minute mean = 1.34

## 4.9 DEPOSITION

4.9.1. For the core scenario, deposition is calculated in post-processing, using a deposition velocity approach, and ignores plume depletion. This is a conservative approach. Sensitivity testing has been undertaken to understand the level of conservatism.

4.9.2. Deposition velocities for non-amine pollutants were taken from AQTAG06.

4.9.3. The deposition velocity for amines has been set to that for ammonia. Karl et al (2014)[2] advised treating amines as ammonia since they are both basic compounds with high solubility.

**Table 4-5 – Deposition velocities used in post-processing**

| Pollutant | Deposition Velocity for Moorland/Short Vegetation (mm/s) | Deposition Velocity for Forest/Tall Vegetation (mm/s) |
|---|---|---|
| Nitrogen Dioxide | 1.5 | 3.0 |
| Sulphur Dioxide | 12 | 24 |
| Ammonia | 20 | 30 |
| Hydrogen Chloride | 25 | 60 |
| Amines | 20 | 30 |

4.9.4. The factors for the conversion of μg/m²/s of the individual amines to nitrogen deposition in kgN/ha/yr are provided in Table 4-6.

**Table 4-6 – Conversion factors for deposition of amines**

| Amine | Molecular Weight | Nitrogen atoms per molecule | μg/m²/s to kgN/ha/yr conversion |
|---|---|---|---|
| Ethylamine | 45.08 | 1 | 97.9 |
| Methylamine | 31.1 | 1 | 142.0 |
| Monoethanolamine | 61.08 | 1 | 72.3 |
| Diethanolamine | 105.14 | 1 | 42.0 |
| Diethylamine | 73.14 | 1 | 60.4 |
| Dimethylamine | 45.08 | 1 | 97.9 |
| Ethyl ethanolamine | 89.14 | 1 | 49.5 |
| Ethyl methylamine | 59.112 | 1 | 74.7 |
| N-Dimethylethylenediamine | 88.151 | 2 | 100.2 |

[2] M. Karl, N. Castell, D. Simpson, S. Solberg, J. Starrfelt , T. Svendby, S.-E. Walker, and R. F. Wright, 2014, Uncertainties in assessing the environmental impact of amine emissions from a CO2 capture plant, *Atmos. Chem. Phys. Discussions*, **14**, 8633-8693

| Amine | Molecular Weight | Nitrogen atoms per molecule | $\mu g/m^2/s$ to kgN/ha/yr conversion |
|---|---|---|---|
| Piperazine | 86.138 | 2 | 102.5 |
| Ethyl diethanolamine | 133.19 | 1 | 33.1 |

# 5 IMPACT ASSESSMENT

## 5.1 INSIGNIFICANCE CRITERIA

5.1.1. Following Environment Agency guidance, if impacts meet both of the following criteria, then the impacts can be classed as insignificant:

- the short term Process Contribution (PC) is less than 10% of the short term AQAL for protected conservation areas
- the long term PC is less than 1% of the long term environmental standard for protected conservation areas

5.1.2. If these criteria are exceeded, then the long term Predicted Environmental Concentration (PEC) must be calculated (as PC + Background) and no further analysis is required if:

- the long term PEC is less than 70% of the long term environmental standard, and
- the short term PC is less than 20% of the available headroom, defined as the air quality standard – 2 x background concentrations.

5.1.3. These latter criteria are widely applied, *de facto*, as a second stage insignificance screening.

5.1.4. For this assessment, daily mean impacts are screened for insignificance as long term impacts.

5.1.5. The insignificance criteria above are applied to human receptors and to ecological receptors designated at international or national level (SAC/SPA/Ramsar/SSSI). For local nature sites, the following insignificance criteria apply:

- the short term PC is less than 100% of the short term environmental standard for protected conservation areas
- the long term PC is less than 100% of the long term environmental standard for protected conservation areas

5.1.6. There is no requirement set out in Environment Agency guidance to calculate the PEC for local sites.

## 5.2 PRESENTATION OF RESULTS

5.2.1. Process contributions are presented with the number of decimal places necessary to demonstrate the scale of the impact. This should not be taken to be representative of the accuracy / level of uncertainty in the modelling.

5.2.2. Where the PC or PEC is shown as a percentage of the AQAL, the percentage is shown to 1 decimal place only.

5.2.3. Where short term impacts are presented, the allowed exceedances of the AQAL within the year are discounted from the results, as per the following:

- Hourly Mean $NO_2$, 18 exceedances allowed, modelled as the 99.79$^{th}$ %ile
- Hourly Mean $SO_2$, 36 exceedances allowed, modelled as the 99.73$^{rd}$ %ile
- Daily Mean $SO_2$, 12 exceedances allowed, modelled as the 99.18$^{th}$ %ile
- 15min Mean $SO_2$, 36 exceedances allowed, modelled as the 99.9$^{th}$ %ile
- Daily Mean $PM_{10}$, 35 exceedances allowed, modelled as the 90.41$^{st}$ %ile
- All non-statutory EALs, 0 exceedances allowed, modelled as the 100$^{th}$ %ile

## 5.3 HUMAN HEALTH – CORE SCENARIO

### NON-AMINE POLLUTANTS

5.3.1. Table 5-1 shows the maximum PCs for all non-amine pollutants, taken across the entire study area and all meteorological years. Results for the individual years are provided in **Appendix E**.

5.3.2. The process contribution is insignificant for all pollutants i.e. less than 1% of any long term AQAL, and less than 10% of any short term AQAL. This conclusion holds irrespective of the PEC, but furthermore, for those pollutants for which background data are available, the PEC is also within the AQAL.

5.3.3. For 15minute mean $SO_2$ and 30minute mean formaldehyde, impacts are insignificant whether modelled as a direct output at sub-hourly timescales or estimated from hourly concentrations using Environment Agency conversion factors.

5.3.4. **Figure A-5** to **Figure A-11** show the spatial distribution of various PCs, as follows:

- Figure A-5 – Annual Mean $NO_2$
- Figure A-6 – Hourly Mean $NO_2$
- Figure A-7 – Annual Mean $NH_3$
- Figure A-8 – Daily Mean $PM_{10}$
- Figure A-9 – Hourly Mean $SO_2$
- Figure A-10 – Daily Mean $SO_2$
- Figure A-11 – 15 minute Mean $SO_2$

5.3.5. For the majority of pollutants and averaging periods, the maximum impacts occur to the north-east of the power station, near the village of Holme-on-Spalding Moor, around 18km from the stack. This distribution reflects the prevailing south-westerly wind seen in the wind roses in **Appendix C**, and applies to all meteorological years. Model results at the illustrative receptors are provided in **Appendix E**. The closest receptor to the general area of maximum impacts is Receptor 21 – Fogathorpe.

5.3.6. Whilst not shown in the figures, the study area has been extended in some models and the extended model confirms that the primary model domain (a square domain, bounded at +/-15km from the stack) is sufficient to capture maximum impacts from the process.

5.3.7. Metrics with a short averaging period (hourly, 30min, 15min) follow a more concentric pattern around the stack, reflecting the fact that meteorological conditions giving rise to poor dispersion occur under winds from all directions. Maximum concentrations occur between 17 and 19km from the stack, with the highest again occurring near the village of Holme-on-Spalding Moor.

5.3.8. The impacts of non-amine pollutants introduced by the carbon capture process, namely ammonia, aldehydes and amides, are insignificant.

**Table 5-1 – Maximum process contribution (PC) to non-amine pollutants across the study area and all meteorological years in the Core Scenario (2 BECCS Units + 2 Non-BECCS Units at full load). The predicted environmental concentration (PEC) is shown at the point of maximum PC.**

| Pollutant | Averaging Period | AQAL | PC (µg/m³) | PC as % of AQAL | Background (µg/m³) | PEC (µg/m³) | PEC as % of AQAL | Insignificant |
|---|---|---|---|---|---|---|---|---|
| $NO_2$ | Annual | 40 | 0.16 | 0.4% | 4.58 | 4.73 | 11.8% | Yes |
| | 1hr | 200 | 4.82 | 2.4% | 8.89 | 13.71 | 6.9% | Yes |
| $NH_3$ | Annual | 180 | 0.01 | 0.0% | 2.90 | 2.91 | 1.6% | Yes |
| | 1hr | 2500 | 1.37 | 0.1% | 5.80 | 7.17 | 0.3% | Yes |
| $PM_{10}$ | Annual | 40 | 0.01 | 0.0% | 12.37 | 12.39 | 31.0% | Yes |
| | 24hr | 50 | 0.32 | 0.6% | 12.37 | 12.69 | 25.4% | Yes |
| $PM_{2.5}$ | Annual | 20 | 0.01 | 0.1% | 5.45 | 5.46 | 27.3% | Yes |
| $SO_2$ | 1hr | 350 | 10.31 | 2.9% | 10.20 | 20.51 | 5.9% | Yes |
| | 24hr | 125 | 1.32 | 1.1% | 5.10 | 6.42 | 5.1% | Yes |
| | 15min | 266 | 19.22 | 7.2% | 10.20 | 29.42 | 11.1% | Yes |
| HCl | 1hr | 750 | 1.64 | 0.2% | | | | Yes |
| Formaldehyde | Annual | 5 | 0.001 | 0.0% | | | | Yes |
| | 30min | 100 | 0.155 | 0.2% | | | | Yes |

| Pollutant | Averaging Period | AQAL | PC (µg/m$^3$) | PC as % of AQAL | Background (µg/m$^3$) | PEC (µg/m$^3$) | PEC as % of AQAL | Insignificant |
|---|---|---|---|---|---|---|---|---|
| Acetaldehyde | Annual | 370 | 0.008 | 0.0% | | | | Yes |
| | 1hr | 9200 | 0.894 | 0.0% | | | | Yes |
| N-(2-hydroxyethyl) acetamide | Annual | 0.085 | 0.0005 | 0.6% | | | | Yes |
| N-(2-hydroxyethyl) formamide | Annual | 86 | 0.0005 | 0.0% | | | | Yes |

## AMINES AND DEGRADATION PRODUCTS

5.3.9. The impacts of amines and degradation products are considered for:

- Direct impacts – the impacts of the emissions of amines and degradation products without consideration of atmospheric chemistry, and
- Indirect impacts – the impacts of the degradation of the amines in ambient air, modelled using the ADMS chemistry module

5.3.10. For nitrosamines and nitramines, the direct impacts relate to degradation products formed within the carbon capture plant prior to release to ambient air. Indirect impacts relate to the degradation of amines in ambient air. There is some overlap between the two groups as set out in **Table 5-2**. Indirect impacts are considered for the degradation of secondary and tertiary amines only, since primary amines are generally considered to produce unstable nitrosamines that very quickly isomerize to different species[3].

5.3.11. For each amine (and corresponding degradation product), impacts are considered with emissions for each amine individually at the emission limit value for its group of pollutants (primary amines, secondary amines, nitrosamines, nitramines) and with emissions of amines at their likely maximum percentage of the ELV (as provided by MHI and set out in **Table 4-3**).

5.3.12. The direct impacts for amines represent the worst case scenario for impacts from the amines themselves, since the resulting ground level concentrations do not account for the degradation of the amines in ambient air.

5.3.13. As will be seen in the results, direct emissions of nitrosamines and nitramines account for a minor proportion of the total impact and, therefore, for nitrosamines, worst case impacts are seen with the indirect impacts.

**Table 5-2 – Direct and indirect nitrosamines and nitramines**

| Nitrosamine/Nitramines | Direct | Indirect |
|---|---|---|
| ***Nitrosamines*** | | |
| N-Nitrosomethylethylamine | Yes | Yes from Ethyl methylamine |
| N-Ethyl-N-(2-hydroxyethyl) nitrosamine | Yes | - |
| N-Nitrosodimethylamine | Yes | Yes, from Dimethylamine |
| 1-Nitrosopiperazine | Yes | Yes, from Piperazine |
| N-Nitrosodiethylamine | Yes | Yes, from Diethylamine |
| N-Nitrosodiethanolamine | Yes | Yes, from Diethanolamine |

[3] CERC, May 2024, Improving post-combustion carbon capture air quality risk assessment techniques

| Nitrosamine/Nitramines | Direct | Indirect |
|---|---|---|
| N-Nitrosomorpholine | Yes | - |
| 1,4-Dinitrosopiperazine | Yes | - |
| Nitrosamine2 | | Yes, from Ethyl ethanolamine |
| Nitrosamine7 | | Yes, from Ethyl diethanolamine |
| Nitrosamine11 | | Yes, from N-Dimethylethylenediamine |
| ***Nitramines*** | | |
| 2-(Ethylnitroamino) ethanol | Yes | Yes, from Ethylethanolamine |
| 1-Nitropiperazine | Yes | Yes, from piperazine |
| Nitramine3 | | Yes, from Ethylmethylamine |
| Nitramine5 | | Yes, from Diethanolamine |
| Nitramine6 | | Yes, from Dimethylamine |
| Nitramine7 | | Yes, from Ethyl diethanolamine |
| Nitramine8 | | Yes, from Diethylamine |
| Nitramine11 | | Yes, from N-Dimethylethylenediamine |

*Direct Impacts*

5.3.14. **Table 5-3** to **Table 5-5** show the maximum modelled annual, daily and hourly mean process contribution for all amine emissions in the Core Scenario and at maximum likely emission rates. The amines in each table are subset by the amines with EALs at the relevant averaging period.

5.3.15. The impacts of all amines, whether emitted at their ELV or at the expected maximum emission rate, is insignificant.

5.3.16. If emitted at the ELV, the maximum annual mean impact as a percentage of the EAL arises from methylamine, which amounts to just 0.009% of the EAL. If maximum likely emissions are considered, maximum impacts arise from ethylamine (0.005% of the EAL). Ethylamine is a primary amine and the most prevalent amine in the flue gas.

5.3.17. Diethanolamine, a secondary amine, gives rise to the maximum daily mean impacts, whether emissions are considered at the ELV or expected maximum rates (0.6% or 0.05% of the AQAL respectively). This is due to its low EAL for this amine rather than its emission rate, since emissions themselves are expected to amount to less than 10% of secondary amines.

5.3.18. Maximum hourly mean impacts arise from monoethanolamine with emissions at the ELV (a primary amine) and ethyl ethanolamine with emissions at their maximum likely concentration. Ethyl ethanolamine is the most prevalent secondary amine in the flue gas.

5.3.19. The impacts of direct emissions of nitrosamines and nitramines are provided in **Table 5-6** and **Table 5-7** respectively. Impacts are insignificant for all nitrosamines, whether considered with emissions at their ELV or at their maximum expected rate.

5.3.20. At the maximum expected emission rate, impacts from N-Nitrosomethylethylamine, the most prevalent nitrosamine in the flue gas, amount to 0.3% of the AQAL.

5.3.21. Direct nitramine emissions are likely to contribute less than 0.035% of the AQAL.

**Table 5-3 – Maximum annual mean process contribution for amines across the study area and all meteorological years in the Core Scenario (2 BECCS Units + 2 Non-BECCS Units at full load) and at maximum likely emission rates.**

| Pollutant | EAL (AQAL) (µg/m$^3$) | Maximum PC at Emission Limit (µg/m$^3$) | Maximum PC as % of AQAL | Maximum Likely PC (µg/m$^3$) | Maximum Likely PC as % of AQAL | Insign-ificant? |
|---|---|---|---|---|---|---|
| Ethylamine | 22 | 1.36E-03 | 0.0% | 9.99E-04 | 0.0% | Yes |
| Ethyl ethanolamine | 50 | 8.19E-04 | 0.0% | 1.96E-04 | 0.0% | Yes |
| Ethyl methylamine | 250 | 8.19E-04 | 0.0% | 1.31E-04 | 0.0% | Yes |
| Dimethylamine | 22 | 8.19E-04 | 0.0% | 6.53E-05 | 0.0% | Yes |
| Ethyl diethanolamine | 440 | 1.36E-03 | 0.0% | 1.09E-04 | 0.0% | Yes |
| Methylamine | 15 | 1.36E-03 | 0.0% | 6.53E-05 | 0.0% | Yes |

**Table 5-4 – Maximum daily mean process contribution for amines across the study area and all meteorological years in the Core Scenario (2 BECCS Units + 2 Non-BECCS Units at full load) and at maximum likely emission rates**

| Pollutant | EAL (AQAL) (µg/m$^3$) | Maximum PC at Emission Limit (µg/m$^3$) | Maximum PC as % of AQAL | Maximum Likely PC (µg/m$^3$) | Maximum Likely PC as % of AQAL | Insign-ificant? |
|---|---|---|---|---|---|---|
| Piperazine | 15 | 1.85E-02 | 0.1% | 1.48E-03 | 0.0% | Yes |
| Diethanolamine | 3 | 1.85E-02 | 0.6% | 1.48E-03 | 0.0% | Yes |
| Diethylamine | 33 | 1.85E-02 | 0.1% | 1.48E-03 | 0.0% | Yes |
| Monoethanolamine | 100 | 3.09E-02 | 0.0% | 1.48E-03 | 0.0% | Yes |
| N-Dimethylethylenediamine | 104 | 1.85E-02 | 0.0% | 1.48E-03 | 0.0% | Yes |

**Table 5-5 – Maximum hourly mean process contribution for amines across the study area and all meteorological years in the Core Scenario (2 BECCS Units + 2 Non-BECCS Units at full load) and at maximum likely emission rates**

| Pollutant | EAL (AQAL) (µg/m$^3$) | Maximum PC at Emission Limit (µg/m$^3$) | Maximum PC as % of AQAL | Maximum Likely PC (µg/m$^3$) | Maximum Likely PC as % of AQAL | Insign-ificant? |
|---|---|---|---|---|---|---|
| Ethylamine | 2800 | 2.99E-01 | 0.0% | 2.19E-01 | 0.0% | Yes |
| Ethylethanolamine | 300 | 1.79E-01 | 0.1% | 4.29E-02 | 0.0% | Yes |
| Diethanolamine | 3000 | 1.79E-01 | 0.0% | 1.43E-02 | 0.0% | Yes |
| Dimethylamine | 2800 | 1.79E-01 | 0.0% | 1.43E-02 | 0.0% | Yes |
| Diethylamine | 330 | 1.79E-01 | 0.1% | 1.43E-02 | 0.0% | Yes |
| Monoethanolamine | 400 | 2.99E-01 | 0.1% | 1.43E-02 | 0.0% | Yes |
| N-Dimethylethylenediamine | 417 | 1.79E-01 | 0.0% | 1.43E-02 | 0.0% | Yes |
| Methylamine | 1900 | 2.99E-01 | 0.0% | 1.43E-02 | 0.0% | Yes |

**Table 5-6 – Maximum process contribution for nitrosamines across the study area and all meteorological years in the Core Scenario (2 BECCS Units + 2 Non-BECCS Units at full load) and at maximum likely emission rates. Concentrations are annual means except where indicated.**

| Pollutant | EAL (AQAL) (µg/m$^3$) | Max PC at Emission Limit (µg/m$^3$) | Max PC as % of AQAL | Maximum Likely PC (µg/m$^3$) | Maximum Likely PC as % of AQAL | Insign-ificant? |
|---|---|---|---|---|---|---|
| N-Ethyl-N-(2-hydroxyethyl)nitrosamine | 0.0002 | 1.64E-06 | 0.8% | 2.61E-07 | 0.1% | Yes |
| 1-nitrosopiperazine | 0.0002 | 1.64E-06 | 0.8% | 6.53E-08 | 0.0% | Yes |
| 1,4-dinitrosopiperazine | 0.0002 | 1.64E-06 | 0.8% | 6.53E-08 | 0.0% | Yes |
| N-Nitrosomethylethylamine | 0.0002 | 1.64E-06 | 0.8% | 6.53E-07 | 0.3% | Yes |
| N-Nitrosodiethanolamine | 0.0002 | 1.64E-06 | 0.8% | 6.53E-08 | 0.0% | Yes |
| N-Nitrosodimethylamine | 0.0002 | 1.64E-06 | 0.8% | 1.31E-07 | 0.1% | Yes |
| N-Nitrosomorpholine | 0.005 | 1.64E-06 | 0.0% | 6.53E-08 | 0.0% | Yes |
| N-Nitrosomorpholine (Daily) | 0.037 | 3.71E-05 | 0.1% | 1.48E-06 | 0.0% | Yes |
| N_Nitrosodiethylamine | 0.0002 | 1.64E-06 | 0.8% | 6.53E-08 | 0.0% | Yes |

**Table 5-7 – Maximum process contribution for nitramines across the study area and all meteorological years in the Core Scenario (2 BECCS Units + 2 Non-BECCS Units at full load) and at maximum likely emission rates**

| Pollutant | EAL (AQAL) (µg/m³) | Max PC at Emission Limit (µg/m³) | Max PC as % of AQAL | Maximum Likely PC (µg/m³) | Maximum Likely PC as % of AQAL | Insign-ificant? |
|---|---|---|---|---|---|---|
| 2-(ethylnitroamino)ethanol | 0.0002 | 2.73E-07 | 0.1% | 6.53E-08 | 0.0% | Yes |
| 1-nitropiperazine | 0.0002 | 2.73E-07 | 0.1% | 6.53E-08 | 0.0% | Yes |

*Indirect Impacts from Degradation in Ambient Air*

5.3.22. Table 5-8 and Table 5-9 show the assessment of impacts from indirect degradation products (nitrosamines and nitramines) modelled using the ADMS Chemistry Module for the Core Scenario, and with maximum likely emissions. Data are provided for the secondary/tertiary amine group only since primary amines do not form stable nitrosamines.

5.3.23. With emissions of individual amines at the ELV, the maximum impact of any individual nitrosamine amounts to just under 25% of the AQAL (i.e. for N-Nitrosomethylethylamine, which is both a direct emissions and formed in air from ethyl methylamine). Impacts do not screen as insignificant for any nitrosamine. However, to reiterate, these impacts assume that each amine is, independently, emitted at the ELV for amines (either primary or secondary/tertiary as appropriate) and the PCs should not be summed, since not all amines could be emitted at the ELV simultaneously.

5.3.24. If the maximum likely emissions of the individual amines, as provided in **Table 4-3,** are considered, then maximum impacts reduce markedly. In particular, the impacts for N-Nitrosodiethanolamine, N-Nitrosodimethylamine and Nitrosamine7 screen as insignificant. The maximum impact from N-Nitrosomethylethylamine reduces to 4.0% of the AQAL. The combined impact of all nitrosamines in this case is 12.5% of the AQAL.

5.3.25. The maximum impact on nitramines with emissions at the ELV is 50.5% of the AQAL, for Nitramine11 (formed from N-Dimethylethylenediamine). However, this reduces to 4.0% of the AQAL when maximum likely emissions are considered. Moreover, the AQAL for all nitramines in this assessment has been set at the EAL for N-Nitrosodimethylamine. Nitramines are likely to have lower toxicity than nitrosamines, for example, Wagner et al[4] concluded that N-nitrosamines were approximately 15 fold more mutagenic than their N-nitramine analogues. The assessment of nitramines is, therefore, likely to be highly conservative. It is also noted that the reaction rates for N-Dimethylethylenediamine have been set conservatively by selecting a rate for its reaction with the OH radical that is equivalent to the maximum value reported by CERC for any tertiary amine. This

[4] Wagner, ED, J Osiol, WA Mitch, MJ Plewa, 2014, Comparative in vitro toxicity of nitrosamines and nitramines associated with amine-based carbon capture and storage, Environ Sci Technol., 48(13) 8203

compound therefore serves as an upper bound on the generation of nitrosamines and nitramines from tertiary amine releases.

5.3.26. If the maximum likely emissions of the individual amines, as provided in **Table 4-3,** are considered, then maximum impacts screen as negligible for Nitramine3, 1-nitropiperazine, Nitramine7 and Nitramine8. Maximum impacts occur for Nitramine2, at 4.3% of the AQAL.

5.3.27. **Figure A-12** and **Figure A-13** show the spatial distribution of annual mean ethyl methylamine for the Core Scenario, modelled as a direct emission (no degradation) and with the ADMS Chemistry module (including degradation to nitrosamines and nitramines) respectively. Maximum impacts occur 18km to the north-east of the stack without degradation (as for other non-amine pollutants) and 14km to the north-east with degradation, and the maximum impact decreases by around 25%. The degree of degradation of the amine increases with distance from the stack. It is just 5% -15% within 5km of the stack, 15% - 30% between 5km and 10km, and 30% to 50% between 10km and 20km.

5.3.28. **Figure A-14** and **Figure A-15** show the annual mean concentrations of N-Nitrosomethylethylamine and Nitramine3 formed from the degradation of ethyl methylamine in the Core Scenario. Maximum impacts occur, as for ethyl methylamine with chemistry, at around 14km to the north-east of the stack.

5.3.29. The ratio between N-Nitrosomethylethylamine and ethyl methylamine in increases from 2% - 3% at 2km to 3% - 5% at 5km and then 5% to 10% at 10km. Within the model domain, the maximum ratio is 12.5% (at 15km due south of the stack). With distance from the stack, the nitrosamine and nitramine concentrations are likely to become increasingly conservative since not all removal processes are represented in the chemistry module.

5.3.30. **Figure A-16** shows the concentration of N-Nitrosomethylethylamine, modelled with emissions of ethyl methylamine at their likely maximum (approximately 16% of the ELV). The figure should be compared to **Figure A-14**, which is the impact with emissions at the ELV. As is to be expected, whilst the spatial distribution of impacts is unaffected by the emission rate, maximum concentrations decrease markedly. Less than 1% of the modelled domain experiences an impact above 4% of the AQAL.

**Table 5-8 – Maximum direct and indirect contribution to nitrosamines across the study area and all meteorological years in the Core Scenario (2 BECCS Units + 2 Non-BECCS Units at full load). Concentrations are annual mean concentrations unless stated otherwise.**

| Pollutant | EAL (AQAL) (µg/m$^3$) | Max Indirect PC at Emission Limit (µg/m$^3$) | Max Direct PC at Emission Limit (µg/m$^3$) | Max Total PC at Emission Limit (µg/m$^3$) | Max PC as % of AQAL | Max Likely Indirect PC (µg/m$^3$) | Max Likely Direct PC (µg/m$^3$) | Max Likely Total PC (µg/m$^3$) | Max PC as % of AQAL | Insign-ificant |
|---|---|---|---|---|---|---|---|---|---|---|
| *Nitrosamine2* | 0.0002 | 1.27E-05 | | 1.27E-05 | 6.4% | 3.04E-06 | | 3.04E-06 | 1.5% | *Poss.* |
| N-Nitrosomethylethylamine | 0.0002 | 4.92E-05 | 6.53E-07 | 4.98E-05 | 24.9% | 7.84E-06 | 2.60E-07 | 8.10E-06 | 4.0% | *Poss.* |
| 1-nitrosopiperazine | 0.0002 | 3.88E-05 | 6.53E-08 | 3.89E-05 | 19.5% | 3.10E-06 | 2.60E-09 | 3.10E-06 | 1.5% | *Poss.* |
| N-Nitrosodiethanolamine | 0.0002 | 2.01E-05 | 6.53E-08 | 2.01E-05 | 10.1% | 1.60E-06 | 2.60E-09 | 1.60E-06 | 0.8% | Yes |
| N-Nitrosodimethylamine | 0.0002 | 1.32E-05 | 1.31E-07 | 1.34E-05 | 6.7% | 1.05E-06 | 1.04E-08 | 1.06E-06 | 0.5% | Yes |
| *Nitrosamine7* | 0.0002 | 1.03E-05 | | 1.03E-05 | 5.2% | 8.23E-07 | | 8.23E-07 | 0.4% | Yes |
| N-Nitrosodiethylamine | 0.0002 | 4.61E-05 | 6.53E-08 | 4.62E-05 | 23.1% | 3.68E-06 | 2.60E-09 | 3.68E-06 | 1.8% | *Poss.* |
| *Nitrosamine11* | 0.0002 | 3.60E-05 | | 3.60E-05 | 18.01% | 2.87E-06 | | 2.87E-06 | 1.4% | *Poss.* |
| **Total Nitrosamines** | | | | | **≤24.9%** | | | | **12.5%** | ***Poss.*** |

Compounds shown in italics are formed as follow: Nitrosamine2 from ethyl ethanolamine; Nitrosamine7 from ethyl diethanolamine; Nitrosamine11 from N-Dimethylethylenediamine

Insignificant rating shown as *Poss* indicates a compound that does not screen as insignificant on the basis of the PC and stated EAL. Further discussion included in Section 6.

For emissions at the Emission Limit, total nitrosamines are taken to be less than or equal to the maximum impact from any individual nitrosamines when the corresponding amine is emitted at the ELV.

**Table 5-9 – Maximum direct and indirect contribution to nitramines across the study area and all meteorological years in the Core Scenario (2 BECCS Units + 2 Non-BECCS Units at full load). Concentrations are annual mean concentrations unless stated otherwise.**

| Pollutant | EAL (AQAL) (µg/m³) | Max Indirect PC at Emission Limit (µg/m³) | Max Direct PC at Emission Limit (µg/m³) | Max Total PC at Emission Limit (µg/m³) | Max PC as % of AQAL | Max Likely Indirect PC (µg/m³) | Max Likely Direct PC (µg/m³) | Max Likely Total PC (µg/m³) | Max PC as % of AQAL | Insign-ificant |
|---|---|---|---|---|---|---|---|---|---|---|
| *Nitramine2* | 0.0002 | 3.58E-05 | | 3.58E-05 | 17.9% | 8.56E-06 | | 8.56E-06 | 4.3% | *Poss.* |
| *Nitramine3* | 0.0002 | 1.17E-05 | | 1.17E-05 | 5.9% | 1.87E-06 | | 1.87E-06 | 0.9% | Yes |
| 1-nitropiperazine | 0.0002 | 1.12E-06 | 6.53E-08 | 1.19E-06 | 0.6% | 8.94E-08 | 2.60E-09 | 9.20E-08 | 0.0% | Yes |
| *Nitramine5* | 0.0002 | 4.98E-05 | | 4.98E-05 | 24.9% | 3.97E-06 | | 3.97E-06 | 2.0% | *Poss.* |
| *Nitramine6* | 0.0002 | 3.37E-05 | | 3.37E-05 | 16.9% | 2.69E-06 | | 2.69E-06 | 1.3% | *Poss.* |
| *Nitramine7* | 0.0002 | 2.49E-06 | | 2.49E-06 | 1.2% | 1.99E-07 | | 1.99E-07 | 0.1% | Yes |
| *Nitramine8* | 0.0002 | 1.07E-05 | | 1.07E-05 | 5.4% | 8.55E-07 | | 8.55E-07 | 0.4% | Yes |
| *Nitramine11* | 0.0002 | 1.01E-04 | | 1.01E-04 | 50.5% | 8.05E-06 | | 8.05E-06 | 4.0% | *Poss.* |
| **Total Nitramines** | | | | | **≤50.5%** | | | | **13.0%** | *Poss.* |

Compounds shown in italics are formed as follow: Nitramine2 from ethyl ethanolamine; Nitramine3 from Ethyl methylamine; Nitramine5 from diethanolamine; Nitramine6 from dimethylamine, Nitramine7 from ethyl diethanolamine; Nitramine8 from diethylamine; Nitramine11 from N-Dimethylethylenediamine

Insignificant rating shown as Poss indicates a compound that does not screen as insignificant on the basis of the PC and stated EAL. Further discussion provided in Section 6.

For emissions at the Emission Limit, total nitramines are taken to be less than or equal to the maximum impact from any individual nitrosamines when the corresponding amine is emitted at the ELV.

## 5.4 ECOLOGICAL IMPACTS

5.4.1. This section provides the maximum impacts on sites designated for nature conservation at international/national and local levels. The sites included in the assessment are listed in **Table 2-3** and **Table 2-4** respectively, with the distance scoping criteria provided in **Section 4.3** and the insignificance criteria provided in **Section 5.1** above.

### CRITICAL LEVELS

**Nitrogen Oxides**

5.4.2. **Table 5-10** and **Table 5-11** show the maximum modelled process contributions for annual mean nitrogen oxides concentrations across all years, for international/national sites and local sites respectively. The process contribution is insignificant over all sites and predicted environmental concentrations (PEC=PC + Background) are well within the critical level.

5.4.3. **Figure A-17** shows the spatial distribution of annual mean NOx across the study area. Maximum ground level concentrations occur around 18km to the north-east of the stacks where there are no protected conservation areas. The local nature conservation sites all lie inside the zone of maximum impacts, before the plume grounds to any significant extent, and impacts are small (< 0.4% of the critical level). Over an international/national site, impacts are greatest over the Lower Derwent Valley SPA/SAC (Breighton Meadows SSSI), where they are less than 0.6% of the critical level.

**Table 5-10 – Maximum Core Scenario process contribution to annual mean NOx over sites designated for nature conservation at international and national level**

| Name | Critical Level ($\mu g/m^3$) | PC $NO_X$ ($\mu g/m^3$) | % PC of Critical Level | PEC $NO_X$ ($\mu g/m^3$) | % PEC of Critical Level | Insign-ificant? |
|---|---|---|---|---|---|---|
| River Derwent | 30 | 0.18 | 0.6% | 7.31 | 24.4% | Yes |
| Thorne Moor SAC (SPA/SSSI) | 30 | 0.11 | 0.4% | 1.01 | 3.4% | Yes |
| Lower Derwent Valley SAC | 30 | 0.18 | 0.6% | 6.49 | 21.6% | Yes |
| Lower Derwent Valley SPA | 30 | 0.18 | 0.6% | 6.49 | 21.6% | Yes |
| Skipwith Common SAC | 30 | 0.09 | 0.3% | 6.86 | 22.9% | Yes |
| Skipwith Common SSSI | 30 | 0.09 | 0.3% | 6.86 | 22.9% | Yes |
| Humber Estuary SAC | 30 | 0.13 | 0.4% | 7.74 | 25.8% | Yes |
| Humber Estuary SPA | 30 | 0.13 | 0.4% | 7.74 | 25.8% | Yes |
| Breighton Meadows SSSI | 30 | 0.18 | 0.6% | 7.31 | 24.4% | Yes |
| Eskamhorn Meadows SSSI | 30 | 0.02 | 0.1% | 7.95 | 26.5% | Yes |
| Derwent Ings SSSI | 30 | 0.17 | 0.6% | 7.17 | 23.9% | Yes |
| Went Ings SSSI | 30 | 0.05 | 0.2% | 9.32 | 31.1% | Yes |

| Name | Critical Level (µg/m³) | PC $NO_x$ (µg/m³) | % PC of Critical Level | PEC $NO_x$ (µg/m³) | % PEC of Critical Level | Insign-ificant? |
|---|---|---|---|---|---|---|
| Barn Hill Meadows SSSI | 30 | 0.10 | 0.3% | 8.38 | 27.9% | Yes |
| Burr Closes_SSSI | 30 | 0.06 | 0.2% | 8.17 | 27.2% | Yes |

**Table 5-11 - Maximum process contribution to annual mean NOx over sites designated for nature conservation at local level**

| Name | Critical Level (µg/m³) | PC $NO_x$ (µg/m³) | % PC of CL | Insign-ificant? |
|---|---|---|---|---|
| Common Plantation | 30 | 0.007 | 0.02% | Yes |
| Barmby-on-the-Marsh | 30 | 0.041 | 0.14% | Yes |
| Brock Holes | 30 | 0.007 | 0.02% | Yes |
| Orchard Farm | 30 | 0.003 | 0.01% | Yes |
| Barmby Pond | 30 | 0.092 | 0.31% | Yes |
| Cobble Croft Wood | 30 | 0.014 | 0.05% | Yes |
| Hagg Green Lane | 30 | 0.110 | 0.37% | Yes |
| Sand Pit Wood | 30 | 0.015 | 0.05% | Yes |
| Barlow Common LNR | 30 | 0.008 | 0.03% | Yes |

5.4.4. **Table 5-12** and **Table 5-13** show the maximum modelled process contributions for daily mean nitrogen oxides concentrations across all years, for international/national sites and local sites respectively.

5.4.5. **Figure A-18** shows the spatial distribution of daily mean NOx across the study area. Maximum ground level concentrations occur around 8.5km to the north of the stacks, near the River Derwent and Lower Derwent designated sites. The local nature conservation sites all lie inside the zone of maximum impacts, before the plume grounds to any significant extent, and impacts are small (< 5% of the critical level). Over an international/national site, impacts are greatest over the Lower Derwent Valley SPA/SAC (Breighton Meadows SSSI), where they are less than 7% of the critical level.

5.4.6. Impacts over the local protected sites screen as insignificant on the basis of the process contribution being less than 100% of the critical level. Impacts over nationally and internationally designated sites screen as insignificant on the basis of the total predicted environmental concentration (PEC) being much less than 70% of the critical level.

**Table 5-12 - Maximum process contribution to daily mean NOx over sites designated for nature conservation at international and national level**

| Name | Critical Level (µg/m³) | PC $NO_X$ (µg/m³) | % PC of Critical Level | PEC $NO_X$ (µg/m³) | % PEC of Critical Level | Insign-ificant? |
|---|---|---|---|---|---|---|
| River Derwent | 75 | 4.84 | 6.4% | 11.97 | 16.0% | Yes |
| Thorne Moor SAC (SPA/SSSI) | 75 | 2.63 | 3.5% | 3.55 | 4.7% | Yes |
| Lower Derwent Valley SAC | 75 | 4.98 | 6.6% | 12.11 | 16.1% | Yes |
| Lower Derwent Valley SPA | 75 | 4.98 | 6.6% | 12.11 | 16.1% | Yes |
| Skipwith Common SAC | 75 | 2.10 | 2.8% | 9.40 | 12.5% | Yes |
| Skipwith Common SSSI | 75 | 2.10 | 2.8% | 9.40 | 12.5% | Yes |
| Humber Estuary SAC | 75 | 2.90 | 3.9% | 12.78 | 17.0% | Yes |
| Humber Estuary SPA | 75 | 2.90 | 3.9% | 12.78 | 17.0% | Yes |
| Breighton Meadows SSSI | 75 | 4.98 | 6.6% | 12.11 | 16.1% | Yes |
| Eskamhorn Meadows SSSI | 75 | 2.31 | 3.1% | 10.21 | 13.6% | Yes |
| Derwent Ings SSSI | 75 | 3.56 | 4.7% | 10.62 | 14.2% | Yes |
| Went Ings SSSI | 75 | 1.45 | 1.9% | 10.58 | 14.1% | Yes |
| Barn Hill Meadows SSSI | 75 | 2.44 | 3.3% | 10.06 | 13.4% | Yes |
| Burr Closes_SSSI | 75 | 1.65 | 2.2% | 9.76 | 13.0% | Yes |

**Table 5-13 - Maximum process contribution to daily mean NOx over sites designated for nature conservation at local level**

| Name | Critical Level (µg/m³) | PC $NO_X$ (µg/m³) | % PC of Critical Level | Insign-ificant? |
|---|---|---|---|---|
| Common Plantation | 75 | 0.46 | 0.6% | Yes |
| Barmby-on-the-Marsh | 75 | 1.49 | 2.0% | Yes |
| Brock Holes | 75 | 0.45 | 0.6% | Yes |
| Orchard Farm_1 | 75 | 0.21 | 0.3% | Yes |
| Barmby Pond | 75 | 2.96 | 3.9% | Yes |

| Name | Critical Level (µg/m³) | PC $NO_x$ (µg/m³) | % PC of Critical Level | Insign-ificant? |
|---|---|---|---|---|
| Cobble Croft Wood | 75 | 0.75 | 1.0% | Yes |
| Hagg Green Lane | 75 | 3.67 | 4.9% | Yes |
| Sand Pit Wood | 75 | 0.90 | 1.2% | Yes |
| Barlow Common LNR | 75 | 0.85 | 1.1% | Yes |

**Sulphur Dioxide**

5.4.7. **Table 5-14** and **Table 5-15** show the maximum modelled process contributions for annual mean sulphur dioxide concentrations across all years, for international/national sites and local sites respectively. The process contribution is insignificant over all sites and predicted environmental concentrations (PEC=PC + Background) are well within the critical level.

5.4.8. **Figure A-19** shows the spatial distribution of annual mean $SO_2$ across the study area. Maximum ground level concentrations occur around 18km to the north-east of the stacks where there are no protected conservation areas. The local nature conservation sites all lie inside the zone of maximum impacts, before the plume grounds to any significant extent, and impacts are small (< 0.3% of the critical level). Over an international/national site, impacts are greatest over the Lower Derwent Valley SPA/SAC (and Breighton Meadows SSSI), where they are less than 0.8% of the critical level (0.4% over habitats within the SSSI, where the critical level is the less stringent 20µg/m³).

**Table 5-14 - Maximum Core Scenario process contribution to annual mean $SO_2$ over sites designated for nature conservation at international and national level**

| Name | Critical Level (µg/m³) | PC $SO_2$ (µg/m³) | % PC of Critical Level | PEC $SO_2$ (µg/m³) | % PEC of Critical Level | Insign-ificant? |
|---|---|---|---|---|---|---|
| River Derwent | 10 | 0.08 | 0.8% | 1.19 | 11.9% | Yes |
| Thorne Moor SAC (SPA/SSSI) | 10 | 0.05 | 0.5% | 0.95 | 9.5% | Yes |
| Lower Derwent Valley SAC | 10 | 0.08 | 0.8% | 1.05 | 10.5% | Yes |
| Lower Derwent Valley SPA | 10 | 0.08 | 0.8% | 1.05 | 10.5% | Yes |
| Skipwith Common SAC | 10 | 0.04 | 0.4% | 1.03 | 10.3% | Yes |
| Skipwith Common SSSI | 10 | 0.04 | 0.4% | 1.03 | 10.3% | Yes |
| Humber Estuary SAC | 10 | 0.06 | 0.6% | 1.13 | 11.3% | Yes |
| Humber Estuary SPA | 10 | 0.06 | 0.6% | 1.13 | 11.3% | Yes |

| Name | Critical Level (µg/m³) | PC $SO_2$ (µg/m³) | % PC of Critical Level | PEC $SO_2$ (µg/m³) | % PEC of Critical Level | Insign-ificant? |
|---|---|---|---|---|---|---|
| Breighton Meadows SSSI | 20 | 0.08 | 0.4% | 1.19 | 6.0% | Yes |
| Eskamhorn Meadows SSSI | 20 | 0.01 | 0.0% | 1.07 | 5.3% | Yes |
| Derwent Ings SSSI | 20 | 0.08 | 0.4% | 1.20 | 6.0% | Yes |
| Went Ings SSSI | 20 | 0.02 | 0.1% | 1.09 | 5.5% | Yes |
| Barn Hill Meadows SSSI | 20 | 0.05 | 0.2% | 1.51 | 7.5% | Yes |
| Burr Closes_SSSI | 20 | 0.03 | 0.1% | 1.14 | 5.7% | Yes |

**Table 5-15 - Maximum Core Scenario process contribution to annual mean $SO_2$ over sites designated for nature conservation at local level**

| Name | Critical Level (µg/m³) | PC $SO_2$ (µg/m³) | % PC of Critical Level | Insign-ificant? |
|---|---|---|---|---|
| Common Plantation | 20 | 0.003 | 0.0% | Yes |
| Barmby-on-the-Marsh | 20 | 0.019 | 0.1% | Yes |
| Brock Holes | 20 | 0.003 | 0.0% | Yes |
| Orchard Farm_1 | 20 | 0.001 | 0.0% | Yes |
| Barmby Pond | 20 | 0.042 | 0.2% | Yes |
| Cobble Croft Wood | 20 | 0.006 | 0.0% | Yes |
| Hagg Green Lane | 20 | 0.050 | 0.3% | Yes |
| Sand Pit Wood | 20 | 0.007 | 0.0% | Yes |
| Barlow Common LNR | 20 | 0.004 | 0.0% | Yes |

**Ammonia**

5.4.9. **Table 5-16** and **Table 5-17** show the maximum modelled process contributions for annual mean ammonia concentrations across all years, for international/national sites and local sites respectively. The process contribution is insignificant over all sites.

5.4.10. **Figure A-20** shows the spatial distribution of annual mean ammonia across the study area. Maximum ground level concentrations occur around 18km to the north-east of the stacks where there are no protected conservation areas. The local nature conservation sites all lie inside the zone of maximum impacts, before the plume grounds to any significant extent, and impacts are small

(<0.2% of the critical level). Over an international/national site, impacts are greatest over the Lower Derwent Valley SPA/SAC (and Breighton Meadows SSSI), where they are 1.0% of the critical level of 1µg/m$^3$ (0.3% over habitats within the SSSI, where the critical level is the less stringent 3µg/m$^3$).

5.4.11. For habitats where the critical level for ammonia is 3µg/m$^3$, the total concentration of ammonia is within the critical level, whilst for those where the critical level is 1µg/m$^3$, total concentrations exceed the critical level. The exceedance is, however, due to background ammonia concentrations, and the contribution from agricultural emissions in particular. The Drax PC will make no measurable or perceptible difference to the level of exceedance.

**Table 5-16 - Maximum Core Scenario process contribution to annual mean ammonia over sites designated for nature conservation at international and national level**

| Name | Critical Level (µg/m$^3$) | PC $NH_3$ (µg/m$^3$) | % PC of Critical Level | PEC $NH_3$ (µg/m$^3$) | % PEC of Critical Level | Insign-ificant? |
|---|---|---|---|---|---|---|
| River Derwent | 3 | 0.010 | 0.3% | 1.94 | 64.7% | Yes |
| Thorne Moor SAC (SPA/SSSI) | 1 | 0.006 | 0.6% | 1.58 | 157.6% | Yes |
| Lower Derwent Valley SAC | 1 | 0.010 | 1.0% | 2.28 | 227.6% | Yes |
| Lower Derwent Valley SPA | 1 | 0.010 | 1.0% | 2.28 | 227.6% | Yes |
| Skipwith Common SAC | 1 | 0.005 | 0.5% | 2.00 | 200.5% | Yes |
| Skipwith Common SSSI | 1 | 0.005 | 0.5% | 2.00 | 200.5% | Yes |
| Humber Estuary SAC | 3 | 0.007 | 0.2% | 1.84 | 61.2% | Yes |
| Humber Estuary SPA | 3 | 0.007 | 0.2% | 1.84 | 61.2% | Yes |
| Breighton Meadows SSSI | 3 | 0.010 | 0.3% | 1.94 | 64.7% | Yes |
| Eskamhorn Meadows SSSI | 3 | 0.001 | 0.0% | 1.63 | 54.4% | Yes |
| Derwent Ings SSSI | 3 | 0.010 | 0.3% | 1.98 | 66.0% | Yes |
| Went Ings SSSI | 3 | 0.003 | 0.1% | 1.58 | 52.8% | Yes |
| Barn Hill Meadows SSSI | 3 | 0.006 | 0.2% | 1.84 | 61.2% | Yes |
| Burr Closes_SSSI | 3 | 0.003 | 0.1% | 1.80 | 60.1% | Yes |

**Table 5-17 - Maximum Core Scenario process contribution to annual mean ammonia over sites designated for nature conservation at local level**

| Name | Critical Level ($\mu g/m^3$) | PC $NH_3$ ($\mu g/m^3$) | % PC of Critical Level | Insign-ificant? |
|---|---|---|---|---|
| Common Plantation | 3 | 0.0004 | 0.0% | Yes |
| Barmby-on-the-Marsh | 3 | 0.0023 | 0.1% | Yes |
| Brock Holes | 3 | 0.0004 | 0.0% | Yes |
| Orchard Farm_1 | 3 | 0.0002 | 0.0% | Yes |
| Barmby Pond | 3 | 0.0051 | 0.2% | Yes |
| Cobble Croft Wood | 3 | 0.0008 | 0.0% | Yes |
| Hagg Green Lane | 3 | 0.0061 | 0.2% | Yes |
| Sand Pit Wood | 3 | 0.0008 | 0.0% | Yes |
| Barlow Common LNR | 3 | 0.0004 | 0.0% | Yes |

## CRITICAL LOADS

### Nitrogen Deposition

5.4.12. **Table 5-18** and **Table 5-19** show the maximum modelled process contributions for annual mean nitrogen deposition across all years, for international/national sites and local sites respectively. The process contribution is insignificant over all sites.

5.4.13. **Figure A-20** shows the spatial distribution of annual mean nitrogen deposition across the study area. Maximum deposition rates occur around 18km to the north-east of the stacks where there are no protected conservation areas.

5.4.14. The local nature conservation sites all lie inside the zone of maximum impacts, before the plume grounds to any significant extent, and impacts are small (≤0.7% of the critical load). Maximum impacts occur over woodland in Hagg Green Lane SINC.

5.4.15. Over an international/national site, deposition is greatest over lowland hay meadow in Lower Derwent Valley SPA/SAC (and Breighton Meadows SSSI), where the impact is 0.7% of the critical load of 10kgN/ha/yr. As a proportion of the critical load, maximum impacts occur over Thorne Moor SAC, where they are 0.9% of the critical load of 5kgN/ha/yr.

5.4.16. **Table 5-18** shows that the total deposition (PEC) over the international and national sites exceeds the various critical loads, but the exceedance is due to background deposition rather than the contribution from Drax. Drax itself contributes less than 0.5% to the total deposition.

5.4.17. The tables assume all primary amines are in the form of ethylamine (the most prevalent primary amine expected in the flue gas) and that all secondary/tertiary amines are in the form of ethyl methylamine (the second most prevalent secondary amine but, taking into account the proportion of nitrogen in the amine, it gives the worst case for nitrogen deposition from secondary amines).

**Table 5-18 - Maximum Core Scenario process contribution to nitrogen deposition over sites designated for nature conservation at international and national level**

| Name | Critical Load (kgN/ha/yr) | PC NDep (kgN/ha/yr) | % PC of Critical Load | PEC (kgN/ha/yr) | % PEC of Critical Load | Insign-ificant? |
|---|---|---|---|---|---|---|
| Thorne Moor SAC (SPA/SSSI) | 5 | 0.043 | 0.9% | 13.57 | 271.5% | Yes |
| Lower Derwent Valley SAC | 10 | 0.073 | 0.7% | 15.32 | 153.2% | Yes |
| Lower Derwent Valley SPA | 10 | 0.073 | 0.7% | 15.32 | 153.2% | Yes |
| Skipwith Common SAC | 5 | 0.035 | 0.7% | 15.56 | 311.3% | Yes |
| Skipwith Common SSSI | 5 | 0.035 | 0.7% | 15.56 | 311.3% | Yes |
| Humber Estuary SAC | 10 | 0.053 | 0.5% | 15.05 | 150.5% | Yes |
| Humber Estuary SPA | 10 | 0.053 | 0.5% | 15.05 | 150.5% | Yes |
| Breighton Meadows SSSI | 10 | 0.073 | 0.7% | 15.32 | 153.2% | Yes |
| Eskamhorn Meadows SSSI | 10 | 0.009 | 0.1% | 13.55 | 135.5% | Yes |
| Derwent Ings SSSI | 10 | 0.070 | 0.7% | 15.95 | 159.5% | Yes |
| Went Ings SSSI | 10 | 0.019 | 0.2% | 13.37 | 133.7% | Yes |
| Barn Hill Meadows SSSI | 10 | 0.041 | 0.4% | 14.87 | 148.7% | Yes |
| Burr Closes_SSSI | 10 | 0.025 | 0.2% | 14.55 | 145.5% | Yes |

**Table 5-19 - Maximum Core Scenario process contribution to nitrogen deposition over sites designated for nature conservation at local level**

| Name | Critical Load (kgN/ha/yr) | PC N Dep (kgN/ha/yr) | % PC of Critical Load | Insign-ificant? |
|---|---|---|---|---|
| Common Plantation | 10 | 0.005 | 0.0% | Yes |
| Barmby-on-the-Marsh | 10 | 0.027 | 0.3% | Yes |
| Brock Holes | 15 | 0.003 | 0.0% | Yes |
| Orchard Farm_1 | 10 | 0.001 | 0.0% | Yes |
| Barmby Pond | 15 | 0.037 | 0.2% | Yes |
| Cobble Croft Wood | 10 | 0.009 | 0.1% | Yes |
| Hagg Green Lane | 10 | 0.072 | 0.7% | Yes |
| Sand Pit Wood | 10 | 0.010 | 0.1% | Yes |
| Barlow Common LNR | 10 | 0.005 | 0.1% | Yes |

**Acid Deposition**

5.4.18. **Table 5-20** and **Table 5-21** show the maximum modelled process contributions for annual mean acid deposition across all years, for international/national sites and local sites respectively.

5.4.19. Acid deposition is assessed against the critical load function such that the impact as a percentage of the critical load is defined as:

- the total acid deposition (from nitrogen and sulphur) divided by CLmaxN, if acid nitrogen deposition exceeds CLminN
- the acid deposition from sulphur divided by CLmaxS, if acid nitrogen deposition is lower than CLmin.

5.4.20. The process contribution is insignificant over all local sites. Furthermore, the contribution screens as insignificant over all international and national sites with the exception of Thorne Moor.

5.4.21. **Figure A-21** shows the spatial distribution of annual mean nitrogen deposition across the study area. Maximum deposition occurs around 18km to the north-east of the stacks where there are no protected conservation areas.

5.4.22. The local nature conservation sites all lie inside the zone of maximum impacts, before the plume grounds to any significant extent, and impacts are small (≤0.7% of the critical load). Maximum impacts occur over woodland in Hagg Green Lane SINC.

5.4.23. Over an international/national site, deposition is greatest over lowland hay meadow in Lower Derwent Valley SPA/SAC (and Breighton Meadows SSSI), where the impact is 0.3% of the critical load ($CL_{max}N$) of 4.856keq/ha/yr. As a proportion of the critical load, maximum impacts occur over Thorne Moor SAC/SPA, where they are 2.1% of the critical load ($CL_{max}N$) of 0.462keq/ha/yr.

5.4.24. **Table 5-20** shows that the total deposition (PEC) over the international and national sites exceeds the various critical loads over Thorne Moor and Skipwith Common. However, the exceedance is due to background deposition rather than the contribution from Drax. Drax itself contributes less than 1% of the total deposition.

**Table 5-20 - Maximum Core Scenario process contribution to acid deposition over sites designated for nature conservation at international and national level**

| Name | $CL_{max}N$ | Acid S Dep PC (keq/ha/yr) | Acid N Dep PC (keq/ha/yr) | Total Acid Dep PC (keq/ha/yr) | % PC of $CL_{max}N$ / $CL_{max}S$ | PEC Acid Dep (keq/ha/yr) | % PEC of $CL_{max}N$ / $CL_{max}S$ | Insign-ificant? |
|---|---|---|---|---|---|---|---|---|
| River Derwent | | | | | | | | na |
| Thorne Moor SAC (SPA/SSSI) | 0.462 | 0.0064 | 0.0031 | 0.0095 | 2.1% | 1.0995 | 238.1% | *Poss* |
| Lower Derwent Valley SAC | 4.856 | 0.0108 | 0.0052 | 0.016 | 0.3% | 1.2359 | 25.5% | Yes |
| Lower Derwent Valley SPA | 4.856 | 0.0108 | 0.0052 | 0.016 | 0.3% | 1.2359 | 25.5% | Yes |
| Skipwith Common SAC | 0.802 | 0.0052 | 0.0025 | 0.0076 | 1.0% | 1.2476 | 155.6% | Yes |
| Skipwith Common SSSI | 0.802 | 0.0052 | 0.0025 | 0.0076 | 1.0% | 1.2476 | 155.6% | Yes |
| Humber Estuary SAC | | | | | | | | na |
| Humber Estuary SPA | | | | | | | | na |
| Breighton Meadows SSSI | 4.856 | 0.0108 | 0.0052 | 0.0159 | 0.3% | 1.2359 | 25.5% | Yes |
| Eskamhorn Meadows SSSI | 5.701 | 0.0013 | 0.0006 | 0.0019 | 0.0% | 1.1119 | 3.5% | Yes |
| Derwent Ings SSSI | 4.856 | 0.0103 | 0.0050 | 0.0153 | 0.3% | 1.2753 | 26.3% | Yes |
| Went Ings SSSI | 5.701 | 0.0028 | 0.0014 | 0.0042 | 0.0% | 1.0842 | 3.3% | Yes |
| Barn Hill Meadows SSSI | 4.856 | 0.0061 | 0.0030 | 0.0091 | 0.2% | 1.2191 | 25.1% | Yes |
| Burr Closes_SSSI | 5.701 | 0.0037 | 0.0018 | 0.0054 | 0.1% | 1.1954 | 3.8% | Yes |

| Name | $CL_{max}N$ | Acid S Dep PC (keq/ha/yr) | Acid N Dep PC (keq/ha/yr) | Total Acid Dep PC (keq/ha/yr) | % PC of $CL_{max}N$ / $CL_{max}S$ | PEC Acid Dep (keq/ha/yr) | % PEC of $CL_{max}N$ / $CL_{max}S$ | Insign-ificant? |
|---|---|---|---|---|---|---|---|---|
| Insignificant rating shown as *Poss* indicates an impact on a designated site that does not screen as insignificant on the basis of the PC and critical load alone. Further discussion in Section 6 | | | | | | | | |

**Table 5-21 - Maximum Core Scenario process contribution to acid deposition over sites designated for nature conservation at local level**

| Name | $CL_{max}N$ | Acid S Dep PC (keq/ha/yr) | Acid N Dep PC (keq/ha/yr) | Total Acid Dep PC (keq/ha/yr) | % PC of $CL_{max}N$ | Insig-nificant? |
|---|---|---|---|---|---|---|
| Common Plantation | 1.805 | 0.0005 | 0.0003 | 0.0009 | 0.05% | Yes |
| Barmby-on-the-Marsh | 10.902 | 0.0028 | 0.0019 | 0.0047 | 0.04% | Yes |
| Brock Holes | | | | | | na |
| Orchard Farm_1 | | | | | | na |
| Barmby Pond | | | | | | na |
| Cobble Croft Wood | 1.805 | 0.0010 | 0.0006 | 0.0016 | 0.09% | Yes |
| Hagg Green Lane | 1.822 | 0.0075 | 0.0051 | 0.0126 | 0.69% | Yes |
| Sand Pit Wood | 1.805 | 0.0010 | 0.0007 | 0.0017 | 0.10% | Yes |
| Barlow Common LNR | 1.805 | 0.0005 | 0.0004 | 0.0009 | 0.05% | Yes |

# 6 SENSITIVITY AND UNCERTAINTY ANALYSIS

## 6.1 MODEL VALIDATION

6.1.1. The ADMS 6 model has been extensively validated against experimental datasets from field and wind tunnel studies.

6.1.2. Of these datasets, the Kincaid power plant tracer experiment is of particular relevance to Drax[5]. The power plant is surrounded by flat farmland and the tracer was released from a very tall (187m) stack with a 9m diameter. This is comparable to the 259m at Drax, where the flues are 8m in diameter.

6.1.3. Meteorological conditions during the study varied from neutral to convective, with data available from 2, 10, 50 and 100m. Importantly, the boundary layer height was calculated using the ADMS's meteorological pre-processor rather than taken from observations. Neutral stability conditions prevail at Drax and maximum ground level concentrations occur under slightly convective conditions.

6.1.4. Over the 170 hours of tests, there was significant scatter in the comparison of hour by hour data between the observations and the model results, but the modelled mean concentration was within 10% of the observed mean and 68% of modelled impacts were within a factor of 2 of the observed.

6.1.5. On quartile-quartile plots, ADMS tended to underestimate the absolute peak concentrations (within a factor of two), but typical concentrations were well represented.

6.1.6. The quartile – quartile plots are most relevant to the use of model output for compliance assessment i.e. there is no requirement to predict concentrations within specific hours, only to predict annual average concentrations and maximum short term concentrations over a year. Therefore, the Kincaid dataset indicates an underlying model uncertainty level of the order of +/-10% for long term (annual mean) concentrations, and -50% to +100% for short term concentrations before model parameter uncertainty is taken into account.

## 6.2 SENSITIVITY TESTING

6.2.1. The sensitivity testing has been undertaken with meteorological data from 2022, but the overall conclusions are applicable to all years.

6.2.2. The results presented ensure that the impacts of uncertainty within the model input parameters can be considered for the key air quality constraints identified in the previous section, **Section 5**, namely:

- Impacts on annual mean nitrosamines for human health and
- Nitrogen and acid deposition on Thorne Moor, Skipwith Common and Breighton Meadows.

6.2.3. Ethyl methylamine, likely to be one of the most prevalent secondary amines in the flue gases, has been used as the indicative amine compound for sensitivity testing purposes.

[5] CERC, 2023, ADMS 6 Flat Terrain Validation Kincaid, Indianapolis and Prairie Grass

### METEOROLOGY

6.2.4. The Core Scenario assessment is based on the highest process contribution (for each pollutant and metric individually) over the 5 meteorological years modelled. This is a conservative assumption that, in comparison to typical conditions over the 5 years, equates to an overestimation of maximum impacts by approximately 5% for annual averages, 25% for daily means and 2% for hourly means.

### SURFACE PARAMETERS

6.2.5. The Core Scenario used a roughness length of 0.2m and the model default minimum Monin-Obukhov length of 1m as surface parameters within the ADMS meteorological module. These values are representative of rural, agricultural areas with few areas of woodland.

6.2.6. Sensitivity testing was undertaken for an increased (0.3m) and decreased (0.1m) surface roughness length, and with the minimum Monin-Obukhov length set to 10m. Results are shown in **Table 6-1** for maximum concentrations of annual mean and hourly mean nitrogen dioxide within the study area and **Table 6-2** for nitrogen and acid deposition over key sites designated for nature conservation.

6.2.7. There is no universal worst case scenario in the tests, although in general, increasing the roughness length marginally increases the maximum ground level impacts, whilst decreasing the roughness length decreases the impact. Increasing the minimum Monin-Obukhov length has a lower impact that adjusting the surface roughness length.

6.2.8. For maximum ground level concentrations in the study area, the overall sensitivity to the choice of surface parameters is of the order of +/-10%. At ecological receptors, the sensitivity is around +15% to -40% (where a negative percentage indicates a decrease in impact).

6.2.9. The overall conclusion is that the uncertainty in the assessment arising from surface parameters is comparable to the level of uncertainty seen in the model validation tests, with a potential bias towards overestimation of impacts.

6.2.10. Taking into account the overall conservatism built into the model methodology and analysis, i.e. the assumption that emissions are constantly at their emission limit value, and basing impacts on the worst meteorological year, the specification of surface parameters is highly unlikely to significantly influence the assessment conclusions.

**Table 6-1 – Maximum nitrogen dioxide concentrations in study area for surface parameter sensitivity testing, modelled using meteorological data for 2022**

| Model Run (roughness length, minimum MO-length) | Annual Mean $NO_2$ | | Hourly Mean $NO_2$ | |
|---|---|---|---|---|
| | PC (µg/m$^3$) | PC as % of AQAL | PC (µg/m$^3$) | PC as % of AQAL |
| Core Scenario (0.2m, 1m) | 0.16 | 0.4% | 4.82 | 2.4% |
| Increased roughness (0.3m, 1m) | 0.17 | 0.4% | 4.83 | 2.4% |
| Decreased roughness (0.1m, 1m) | 0.13 | 0.4% | 4.48 | 2.2% |
| Increased MO Length (0.2m, 10m) | 0.16 | 0.4% | 4.72 | 2.4% |

**Table 6-2 - Maximum nitrogen and acid deposition over key ecological receptors for meteorological parameter sensitivity testing, modelled using meteorological data for 2022**

| Model Run (roughness length, minimum MO-length) | Thorne Moor SAC/SPA | | | | Skipwith Common SAC/SPA | | | | Breighton Meadows SSSI | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N-Dep | | Acid-Dep | | N-Dep | | Acid-Dep | | N-Dep | | Acid-Dep | |
| | PC (kgN/ha/yr) | PC as % of CLoad | PC (keq/ha/yr) | PC as % of CLoad | PC (kgN/ha/yr) | PC as % of CLoad | PC (keq/ha/yr) | PC as % of CLoad | PC (kgN/ha/yr) | PC as % of CLoad | PC (keq/ha/yr) | PC as % of CLoad |
| Core Scenario (0.2m, 1m) | 0.043 | 0.9% | 0.010 | 2.1% | 0.035 | 0.7% | 0.0076 | 1.0% | 0.07 | 0.7% | 0.02 | 0.3% |
| Increased roughness (0.3m, 1m) | 0.037 | 0.7% | 0.008 | 1.8% | 0.040 | 0.8% | 0.0088 | 1.1% | 0.08 | 0.8% | 0.02 | 0.4% |
| Decreased roughness (0.1m, 1m) | 0.031 | 0.6% | 0.007 | 1.4% | 0.026 | 0.5% | 0.0056 | 0.7% | 0.04 | 0.4% | 0.01 | 0.2% |
| Increased MO Length (0.2m, 10m) | 0.034 | 0.7% | 0.007 | 1.6% | 0.035 | 0.7% | 0.0076 | 1.0% | 0.06 | 0.6% | 0.01 | 0.3% |

## AMINE CHEMISTRY PARAMETERS

6.2.11. The assessment of direct emissions of amines and nitrosamines was undertaken as an inherent worst case, since it assumes that no degradation occurs in the atmosphere. The comparison of maximum amine concentrations modelled with and without the chemistry module, demonstrates that this assumption introduces an overestimation of amine concentrations by between 5% and 50%. However, since the modelled direct impacts of amines are very low, <0.1% of the AQAL, this assumption has no impact on the assessment conclusions.

6.2.12. The modelling of amine chemistry, set out in the methodology above and in **Appendix D**, implicitly provides a basic assessment of uncertainty associated with the specified reaction rates in the ADMS amine chemistry module, since it allows a comparison of the nitrosamines and nitramines formed from the various solvent and degradation product emissions.

6.2.13. There is around a factor of 5 variation in the concentration of nitrosamines formed from the degradation of amines in the atmosphere when emissions of each individual amine are considered at the emission limit value. To illustrate this, with all secondary/tertiary amines assumed to be in the form of diethylamine, the maximum ground level concentration of nitrosamines is a worst case of $4.98 \times 10^{-5}$µg/m$^3$ (24.9% of the AQAL), with all amines assumed to be ethyl diethanolamine, the maximum ground level concentration of nitrosamines is just $1.05 \times 10^{-5}$µg/m$^3$ (5.2% of the EAL), 5 times lower (**Table 5-8**). Similar variation is seen for nitrosamines.

6.2.14. If amines are modelled as being emitted at their likely maximum concentrations, still a conservative assumption since it will overestimate annual average conditions, the sum of all nitrosamines formed plus direct emissions amounts to $2.5 \times 10^{-5}$µg/m$^3$ (12.5% of the AQAL). This is 50% lower than the maximum impact presented for the Core Scenario with emissions at the limit value.

6.2.15. **Table 6-3** shows the results of the sensitivity testing for reaction rates set within the amine chemistry module. The sensitivity testing has been undertaken for ethyl methylamine and follows the sensitivity test logic set out within the CERC May Report. The specific reaction rates set in the model are shown in **Table D3** in **Appendix D**.

6.2.16. The amine concentration varies by -40% to +2% of the core scenario, but all maxima are 15% or more below the concentration when it is assessed as a direct emission without amine chemistry.

6.2.17. The nitrosamine concentration varies by +/-100% of the Core Scenario. Maximum impacts occur when reaction rate k1 is maximised – this maximises the initial reaction of the amine and the hydroxyl radical. Conversely, minimising k1 reduces impacts.

6.2.18. Compound specific reaction rates are not available for elected for ethyl methylamine (EMA). Therefore, in the Core Scenario, the parameters for diethylamine (DiEA, where available) and dimethylamine (DMA, where DiEA rates not available) were used as a proxy. These proxy compounds were selected on the basis of a conservative approach and EMA, DiEA and DMA all being secondary, complex (except DMA), alkyl amines. The maximum k1 reaction rate used in Amine Test T1 applies to piperazine, a cyclic amine, and it is over double the maximum value available for DiEA or DMA in the CERC report[3]. The minimum k1 reaction used applies to methylamine, a primary amine, and it is more than 2.5 times lower than the minimum reaction rate available for DiEA or DMA in the CERC report[3]. Amine Tests T1 and T2 are, therefore, likely to represent unrealistically high and low generation of nitrosamines. Tests T9 and T10 reduce the range of values for k1 and k3 (the critical parameters for nitrosamine formation) to those seen for

DiEA and DMA in the CERC report[3]. This reduces the variation in nitrosamine formation to -99% to +35% of the Core Scenario results.

6.2.19. The remaining test with very low generation of nitrosamines, Test T3, minimised k1 and k3, where k3 is the rate of formation of nitrosamines from reaction of the amine radical with nitrogen oxide. For the reasons set out above, this is also likely to underestimate the generation of amines.

6.2.20. Overall, based on the available data, an uncertainty range of +/-30% is supported for a realistic range of reaction rates set out in the CERC document[3].

**Table 6-3 - Maximum amine, nitrosamine and nitramine concentrations in the study area for amine chemistry parameter sensitivity testing, modelled using meteorological data for 2022**

| Sensitivity Test | Amine | | Nitrosamine | | Nitramine | |
|---|---|---|---|---|---|---|
| | PC | % PC of AQAL | PC | % PC of AQAL | PC | % PC of AQAL |
| Core Scenario | 6.89E-04 | 0.00% | 4.92E-05 | 24.58% | 1.17E-05 | 5.86% |
| T1: Reaction rate k1 max | 4.24E-04 | 0.00% | 1.02E-04 | 51.05% | 2.32E-05 | 11.59% |
| T2: Reaction rate k1 min | 7.04E-04 | 0.00% | 1.30E-05 | 6.52% | 3.35E-06 | 1.67% |
| T3: Reaction rates k1 min, k2 min ,k3 min, k1a/k1 ratio min | 7.04E-04 | 0.00% | 3.38E-08 | 0.02% | 5.89E-04 | 294.67% |
| T4: Reaction rates k1 min, k2 max, k3 average, k1a/k1 ratio min | 5.89E-04 | 0.00% | 1.22E-07 | 0.06% | 2.95E-07 | 0.15% |
| T5: Reaction rates k4a, k4 max | 5.89E-04 | 0.00% | 4.42E-05 | 22.09% | 1.07E-05 | 5.34% |
| T6: Reaction rates k4a, k4 min | 5.89E-04 | 0.00% | 4.99E-05 | 24.93% | 3.28E-07 | 0.16% |
| T7: Reaction ratio k1a/k1 average | 5.89E-04 | 0.00% | 9.59E-06 | 4.80% | 2.34E-06 | 1.17% |
| T8: Reaction rate ratio k1a/k1 minimum | 5.89E-04 | 0.00% | 7.02E-06 | 3.51% | 1.71E-06 | 0.86% |
| T9: Realistic min k1 and k3 min | 6.62E-04 | 0.00% | 6.19E-07 | 0.31% | 1.70E-05 | 8.48% |
| T10: Realistic max k1 and k3 max | 5.54E-04 | 0.00% | 6.63E-05 | 33.16% | 1.94E-05 | 9.70% |
| T11: Reaction rates k1 max, k2 min,k3 ave, k1a/k1 ratio min | 4.26E-04 | 0.00% | 1.47E-05 | 7.35% | 4.49E-05 | 22.47% |
| T12: Calculation of c | 7.04E-04 | 0.00% | 2.41E-05 | 12.06% | 7.47E-06 | 3.73% |
| T13: Increased $NO_2$% to 10% | 6.00E-04 | 0.00% | 5.25E-05 | 26.27% | 1.62E-05 | 8.08% |

6.2.21. Amines contribute only a marginal amount to the process contribution to nitrogen and acid deposition, and nitrosamines and nitramines even less. Therefore, uncertainty in reaction rates or amine composition has no significant impact on conclusions relating to ecological effects.

6.2.22. Adopting the ADMS v6 approach to the calculation of the OH concentration constant 'c' (Test T12) reduces the modelled generation of nitrosamines and nitramines by over 50% and over 36% in comparison to the Core Scenario.

6.2.23. Increasing the proportion of $NO_2$ in the plume from 5% (Core Scenario) to 10% (Test 13) increases nitrosamine formation by less than 10%, and nitramine formation by 30%.

### PLUME DEPLETION

6.2.24. The Core Scenario assessment was undertaken without consideration of the depletion of the plume through the deposition of material to the ground and with the deposition of material to ecological sites estimated in post-processing of model output using a deposition velocity approach. This is a conservative assessment since it leads to an overestimation of ground level concentrations over both designated sites and, more generally at any human receptor.

6.2.25. As noted in Section 1.2, the land surrounding the power station is largely under agricultural use with only scattered residences and hamlets. It is, therefore, reasonable to assume that surface deposition of pollutants will occur at rates typical of short/moorland vegetation set out in **Table 4-5**.

6.2.26. **Table 6-4** shows the comparison of modelling undertaken without plume depletion (Core Scenario) and with plume depletion.

6.2.27. The Core Scenario overestimates the deposition of nitrogen and acid by 12% to 15%. A similar overestimation would apply to the concentration of reactive/soluble pollutants such as sulphur dioxide, ammonia, hydrogen chloride and amines.

### OPERATING SCENARIO

6.2.28. **Table 6-5** and **Table 6-6** show the results of the operation scenario sensitivity tests. Data are shown for the following operating scenarios:

- Core Scenario (With $CC_{CS}$)
  - Continuous, full load operation of 2 x BECCS Units and 2 x Non-BECCS Units
- $Baseline_{CS}$ (for Core Scenario)
  - Continuous, full load operation of 4 x Non-BECCS Units
- 2 x BECCS Units (With $CC_2$)
  - Continuous, full load operation of 2 x BECCS Units
- Mid Merit (With $CC_{MM}$)
  - Continuous, full load operation of 2 x BECCS Units
  - Full load operation of 2 x Non-BECCS Units for 4000 hours
- $Baseline_{MM}$ (for Mid Merit)
  - Full load operation of 4 x Non-BECCS Units for 4000 hours

6.2.29. The mid merit scenario reflects the impacts of a potential future capacity market on the operations of the power station. It is modelled using a simple scaling approach for annual mean concentrations and deposition, as 0.46 (4000/8760) of the core scenario result and 0.54 (4760/8760) of the 2

BECCS only scenario. The 2 BECCS Units alone scenario is not a realistic operating pattern for annual operation of the power station.

6.2.30. The tables also show the impact of the operation of carbon capture i.e. on a receptor by receptor basis, the difference between the With CC and Baseline scenarios, for the Core Scenario and the Mid Merit Scenario.

6.2.31. For pollutants related to combustion i.e. in the tables nitrogen dioxide, nitrogen deposition and acid deposition, the process contribution with CC decreases between the Core Scenario and the 2 BECCS Only scenario. This is due to the removal of the contribution from the non-BECCS Units.

6.2.32. For carbon capture related pollutants i.e. amines and nitrosamines, the process contribution with CC increases between the Core Scenario and the 2 BECCS Only scenario. This is due to a reduction in the buoyancy of the plume, without any reduction in mass emissions, from the removal of the non-BECCS Units exhaust gases.

6.2.33. The mid merit scenario lies between these two operational scenarios. Therefore, for combustion-related pollutants, the Core Scenario is a worst case. For carbon capture related pollutants, the mid merit scenario process contribution is approximately 25% to 50% higher than the Core Scenario.

6.2.34. An operating scenario with carbon capture fitted to a single BECCS unit, would result in impacts that lie between the existing operations (Baseline) and the 2 BECCS units scenarios (whether at full load, or in mid merit operations).

**Table 6-4 - Maximum nitrogen and acid deposition over key ecological receptors for plume depletion sensitivity testing, modelled using meteorological data for 2022**

| Model Run (roughness length, minimum MO-length) | Thorne Moor SAC/SPA | | | | Skipwith Common SAC/SPA | | | | Breighton Meadows SSSI | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N-Dep | | Acid-Dep | | N-Dep | | Acid-Dep | | N-Dep | | Acid-Dep | |
| | PC (kgN/ha/yr) | PC as % of CLoad | PC (keq/ha/yr) | PC as % of CLoad | PC (kgN/ha/yr) | PC as % of CLoad | PC (keq/ha/yr) | PC as % of CLoad | PC (kgN/ha/yr) | PC as % of CLoad | PC (keq/ha/yr) | PC as % of CLoad |
| Core Scenario (0.2m, 1m) | 0.043 | 0.9% | 0.010 | 2.1% | 0.035 | 0.7% | 0.008 | 1.0% | 0.07 | 0.7% | 0.016 | 0.3% |
| Modelled with plume depletion | 0.037 | 0.7% | 0.008 | 1.8% | 0.030 | 0.6% | 0.007 | 0.9% | 0.06 | 0.6% | 0.015 | 0.3% |

**Table 6-5 – Maximum nitrogen dioxide, amine and nitrosamine concentrations in study area for operating scenario sensitivity testing, modelled using meteorological data for 2022**

| Scenario | Annual Mean NO2 | | Hourly Mean NO2 | | Ethyl Methylamine | | N-methylethylamine | |
|---|---|---|---|---|---|---|---|---|
| | PC / Impact | % PC / Impact of AQAL | PC / Impact | % PC / Impact of AQAL | PC / Impact | % PC / Impact of AQAL | PC / Impact | % PC / Impact of AQAL |
| Core Scenario (With CC: 2 BECCS Units and 2 Non-BECCS Units, full load; Baseline: 4 Non-BECCS Units, full load) | | | | | | | | |
| $Baseline_{CS}$ | 0.14 | 0.34% | 4.10 | 2.05% | n/a | n/a | n/a | n/a |
| With $CC_{CS}$ | 0.16 | 0.39% | 4.82 | 2.41% | 6.89E-04 | 0.00% | 4.92E-05 | 24.58% |
| $Impact_{CS}$ | 0.03 | 0.07% | 2.19 | 1.10% | n/a | n/a | n/a | n/a |
| 2 BECCS Units Only (With CC: 2 BECCS Units, full load) | | | | | | | | |
| With $CC_2$ | 0.15 | 0.38% | 4.55 | 2.28% | 1.43E-03 | 0.00% | 8.50E-05 | 42.50% |
| Mid Merit Scenario (With CC: 2 BECCS Units for 8760 hours and 2 Non-BECCS Units for 4000 hours, full load; Baseline: 4 Non-BECCS Units, for 4000 hours) | | | | | | | | |
| $Baseline_{MM}$ | 0.06 | 0.15% | 1.87 | 0.94% | n/a | n/a | n/a | n/a |
| With $CC_{MM}$ | 0.16 | 0.39% | 4.63 | 2.32% | 1.03E-03 | 0.00% | 6.13E-05 | 30.65% |
| $Impact_{MM}$ | 0.10 | 0.24% | 2.95 | 1.48% | n/a | n/a | n/a | n/a |

**Table 6-6 - Maximum nitrogen and acid deposition over key ecological receptors for operating scenario sensitivity testing, modelled using meteorological data for 2022**

| Model Run (roughness length, minimum MO-length) | Thorne Moor SAC/SPA | | | | Skipwith Common SAC/SPA | | | | Breighton Meadows SSSI | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N-Dep | | Acid-Dep | | N-Dep | | Acid-Dep | | N-Dep | | Acid-Dep | |
| | PC / Impact (kgN/ha/yr) | PC / Impact as % of CLoad | PC / Impact (keq/ha/yr) | PC / Impact as % of CLoad | PC / Impact (kgN/ha/yr) | PC / Impact as % of CLoad | PC / Impact (keq/ha/yr) | PC / Impact as % of CLoad | PC / Impact (kgN/ha/yr) | PC / Impact as % of CLoad | PC / Impact (keq/ha/yr) | PC / Impact as % of CLoad |
| Core Scenario (With CC: 2 BECCS Units and 2 Non-BECCS Units, full load; Baseline: 4 Non-BECCS Units, full load) | | | | | | | | | | | | |
| Baseline | 0.03 | 0.63% | 0.006 | 1.24% | 0.024 | 0.47% | 0.0043 | 0.54% | 0.05 | 0.49% | 0.03 | 0.63% |
| With CC | 0.04 | 0.86% | 0.010 | 2.06% | 0.035 | 0.69% | 0.0076 | 0.95% | 0.07 | 0.73% | 0.04 | 0.86% |
| Impact | 0.03 | 0.62% | 0.003 | 0.73% | 0.023 | 0.45% | 0.0035 | 0.44% | 0.07 | 0.67% | 0.03 | 0.62% |
| 2 BECCS Units Only (With CC: 2 BECCS Units, full load) | | | | | | | | | | | | |
| With CC | 0.037 | 0.75% | 0.006 | 1.41% | 0.033 | 0.66% | 0.006 | 0.72% | 0.08 | 0.80% | 0.037 | 0.75% |
| Mid Merit Scenario (With CC: 2 BECCS Units for 8760 hours and 2 Non-BECCS Units for 4000 hours, full load; Baseline: 4 Non-BECCS Units, for 4000 hours) | | | | | | | | | | | | |
| Baseline | 0.014 | 0.29% | 0.0026 | 0.57% | 0.011 | 0.22% | 0.0020 | 0.25% | 0.023 | 0.23% | 0.0041 | 0.09% |
| With CC | 0.039 | 0.78% | 0.008 | 1.67% | 0.034 | 0.67% | 0.007 | 0.83% | 0.076 | 0.76% | 0.0150 | 0.31% |
| Impact | 0.026 | 0.51% | 0.005 | 1.12% | 0.023 | 0.46% | 0.005 | 0.58% | 0.054 | 0.54% | 0.0110 | 0.23% |

# 7 CONCLUSIONS

## 7.1 HUMAN HEALTH

### COMBUSTION-RELATED POLLUTANTS

7.1.1. The process contribution to concentrations of combustion-related pollutants including nitrogen dioxide, sulphur dioxide, particulate matter, hydrogen chloride and ammonia in the Core Scenario is **insignificant**. This conclusion is robust since taking a conservative view of overall model uncertainty of +/-25% for long term concentrations (with the upper limit driven by surface parameters and model uncertainty) and +/-100% for short term concentrations (with the upper limit driven by model uncertainty), the process contribution will remain insignificant for all metrics.

### CARBON-CAPTURE RELATED POLLUTANTS

7.1.2. The process contribution to concentrations of non-amine carbon capture pollutants including aldehydes and amides in the Core Scenario is **insignificant**. This conclusion is robust since taking a conservative view of overall model uncertainty of +/-40% for long term concentrations and +/-100% for short term concentrations, the process contribution will remain insignificant for all metrics.

7.1.3. The process contribution to concentrations of amines in the Core Scenario is **insignificant**. This conclusion is robust since taking a conservative view of overall model uncertainty for amines of +/-50% (with the upper limit driven by the operating scenario sensitivity, and the lower limit driven by amine degradation in the atmosphere sensitivity), the process contribution will remain insignificant for all amines.

7.1.4. The process contributions to concentrations of nitrosamines and nitramines in the Core Scenario do not screen as insignificant, and the maximum modelled contribution with amines at their emission limit value is approximately 25% of the EAL for nitrosamines and 50% of the EAL for nitramines. If emissions of amines are assessed at their likely maximum emissions as estimated by MHI, then the process contribution reduces to less than 15% for both nitrosamines and nitramines. Applying uncertainty bounds of +/-60% to these realistic worst case impacts (with the upper limit driven by a combination of amine degradation sensitivity and operating scenario sensitivity), maximum impacts on nitrosamines and nitramines will be <25% of the EAL. Since this EAL has been set conservatively at the EAL for one of the most toxic nitrosamines (NDMA) and, taking into account the likely underestimation of nitrosamine and nitramine degradation/removal processes in the ADMS chemistry module, this is an **acceptable** maximum impact within the study area.

## 7.2 ECOLOGY

### CRITICAL LEVELS

7.2.1. The process contribution to concentrations of NOx and $SO_2$ over sites designated for nature conservation is **insignificant** in the Core Scenario. The conclusion is robust since taking a conservative view of overall model uncertainty of +/-25% for long term concentrations (with the upper limit driven by surface parameters and model uncertainty) and +/-100% for short term concentrations (with the upper limit driven by model uncertainty), the process contribution would either remain insignificant or the predicted environmental concentration will remain below 70% of the relevant critical level.

7.2.2. The process contribution to concentrations of ammonia is **insignificant** in the Core Scenario. Taking into account uncertainty, the impact might marginally exceed 1% of the critical level where this has been set conservatively at 1µg/m$^3$ due to the potential presence of lichen/bryophytes within the Lower Derwent Valley SAC/SPA. However, taking into account the inherently conservative assumption that emissions will be at the ELV of 10mg/Nm$^3$ when the likely maximum concentration is <6mg/Nm$^3$ post carbon capture, **no significant adverse effects are likely**.

### CRITICAL LOADS

7.2.3. The process contribution to nitrogen and acid deposition is **insignificant** in the Core Scenario over all designated sites except acid deposition over Thorne Moor SAC/SPA. Taking into account uncertainty (+/-10% driven by model uncertainty, with the conservative assumption around plume depletion partially offsetting overall uncertainty), this conclusion is robust for all sites except Thorne Moor (for nitrogen and acid deposition) and Skipwith Common SAC (for acid deposition).

7.2.4. Taking into account the conservative assumptions around emission rates of ammonia post carbon capture, as stated above, which dominates nitrogen deposition, and sulphur dioxide which dominates acid deposition but will be largely removed by the pre-carbon capture caustic wash, long term impacts on Thorne Moor and Skipwith Common are likely to be lower than presented in the Core Scenario and any exceedance of the 1% insignificance threshold will be marginal. Moreover, the impact of the installation of carbon capture in the plant will be insignificant, and **no significant adverse effects are likely**.

# Appendix A

## FIGURES

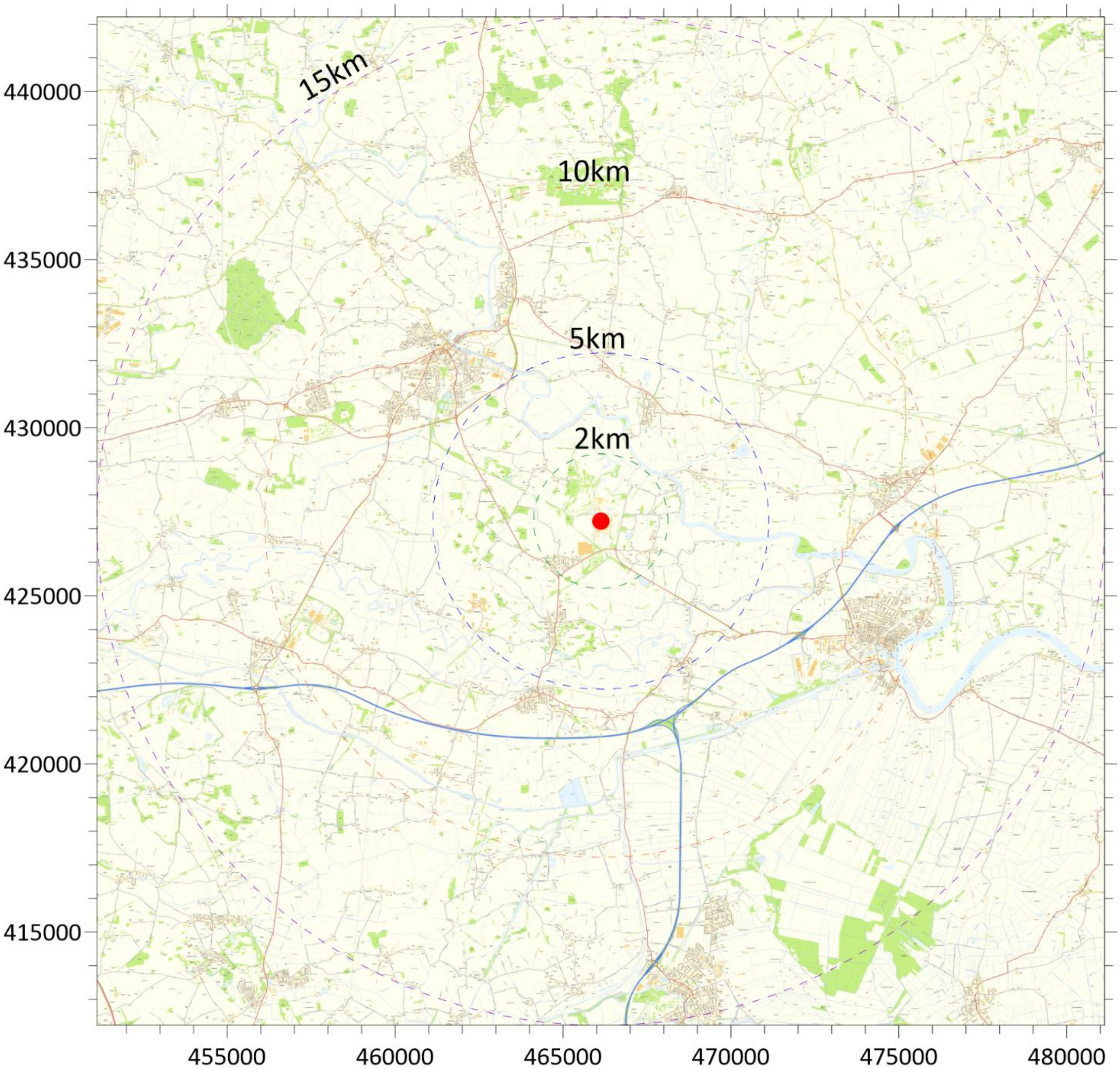



**Figure A-1 - Site setting and study area. The main stack at Drax is shown as a red circle. Dotted lines show the distance from the stack.**

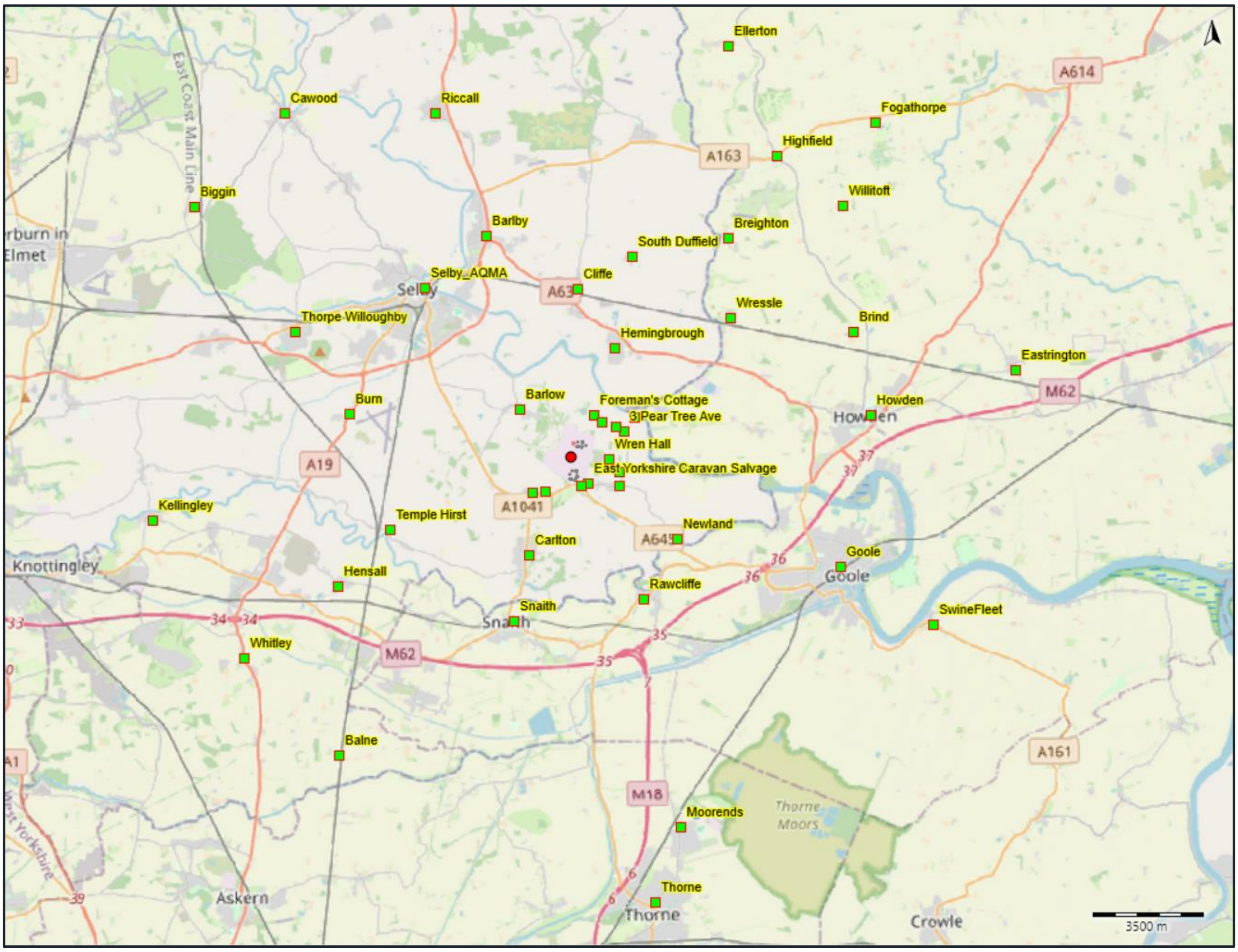



**Figure A-2 - Illustrative receptors for human health effects in wider study area (green filled squares). The Drax main stack is shown as a red filled circle.**


**Figure A-3 - Illustrative receptors for human health effects in the vicinity of Drax power station (green filled squares). The Drax main stack is shown as a red filled circle. Buildings included in the modelling are shown as dark green filled circles.**

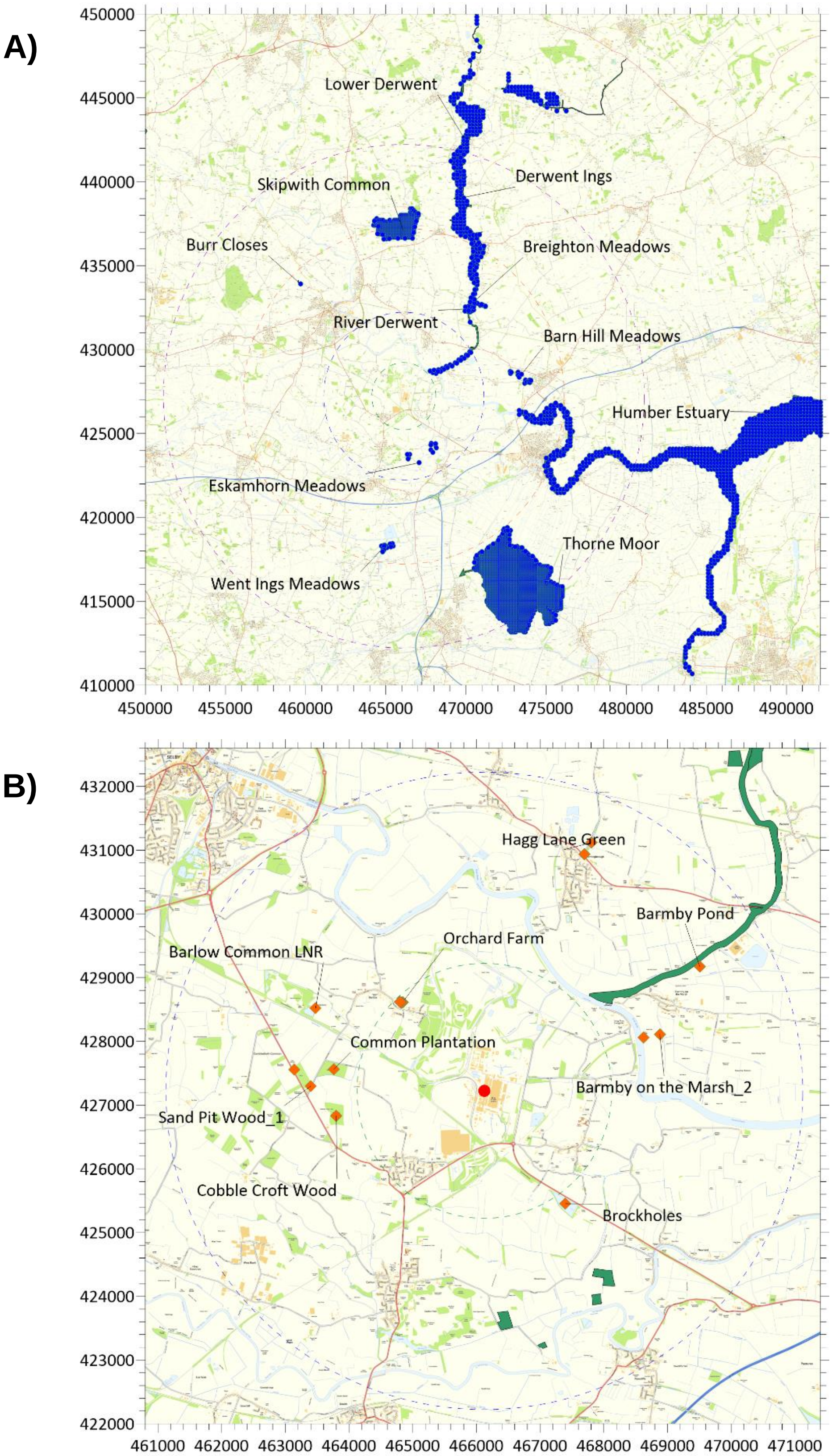



**Figure A-4 – Ecological sites and receptors included in the modelling. The Drax main stack is shown as a red filled circle. A) International and national nature sites are shown in blue. B) Local sites are shown in orange.**

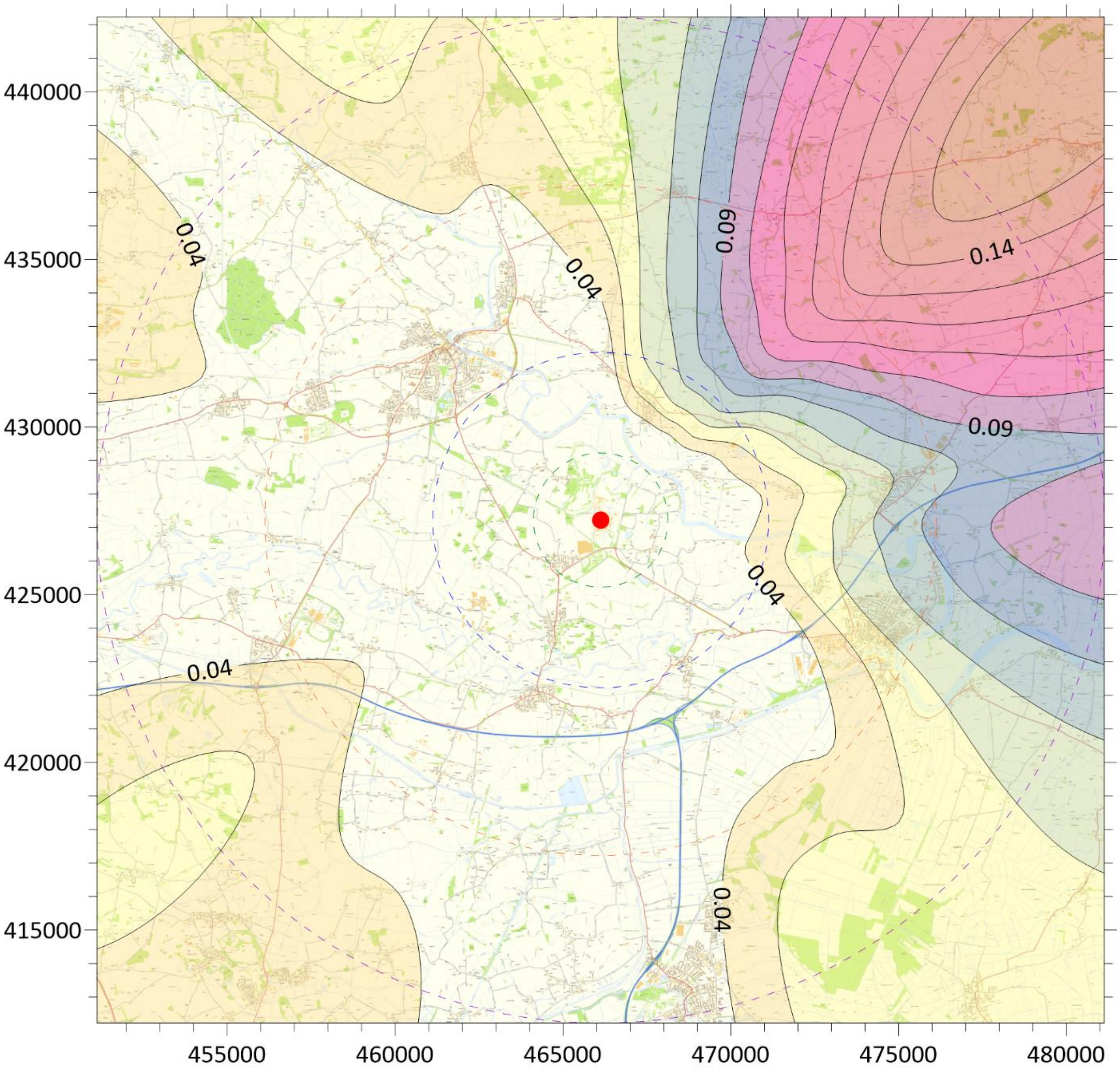



**Figure A-5 - Annual mean nitrogen dioxide process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 0.01µg/m³ (0.025% of AQAL)**

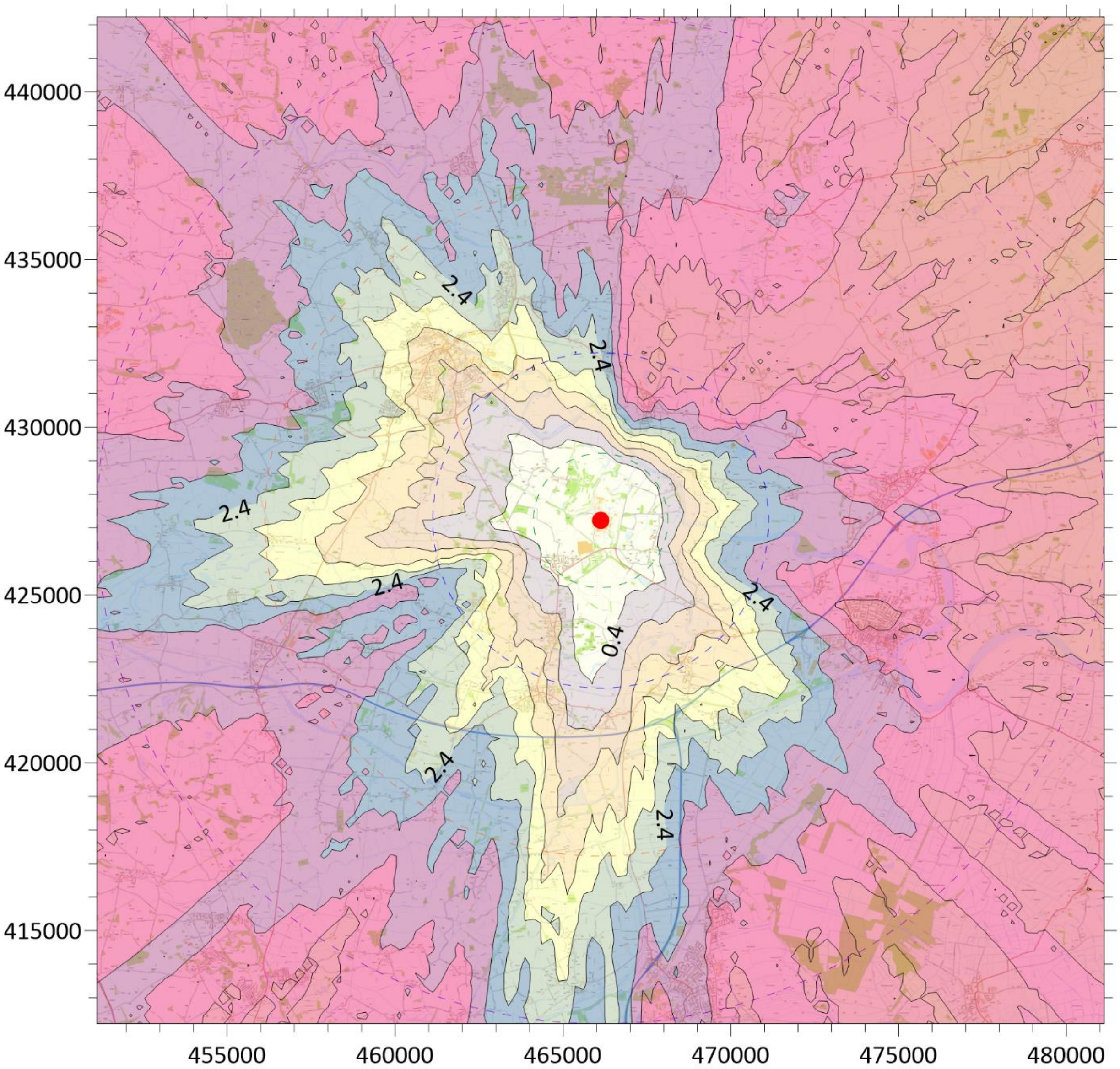



**Figure A-6 - Hourly mean nitrogen dioxide (99.79th %ile) process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 0.4µg/m³ (0.2% of AQAL)**

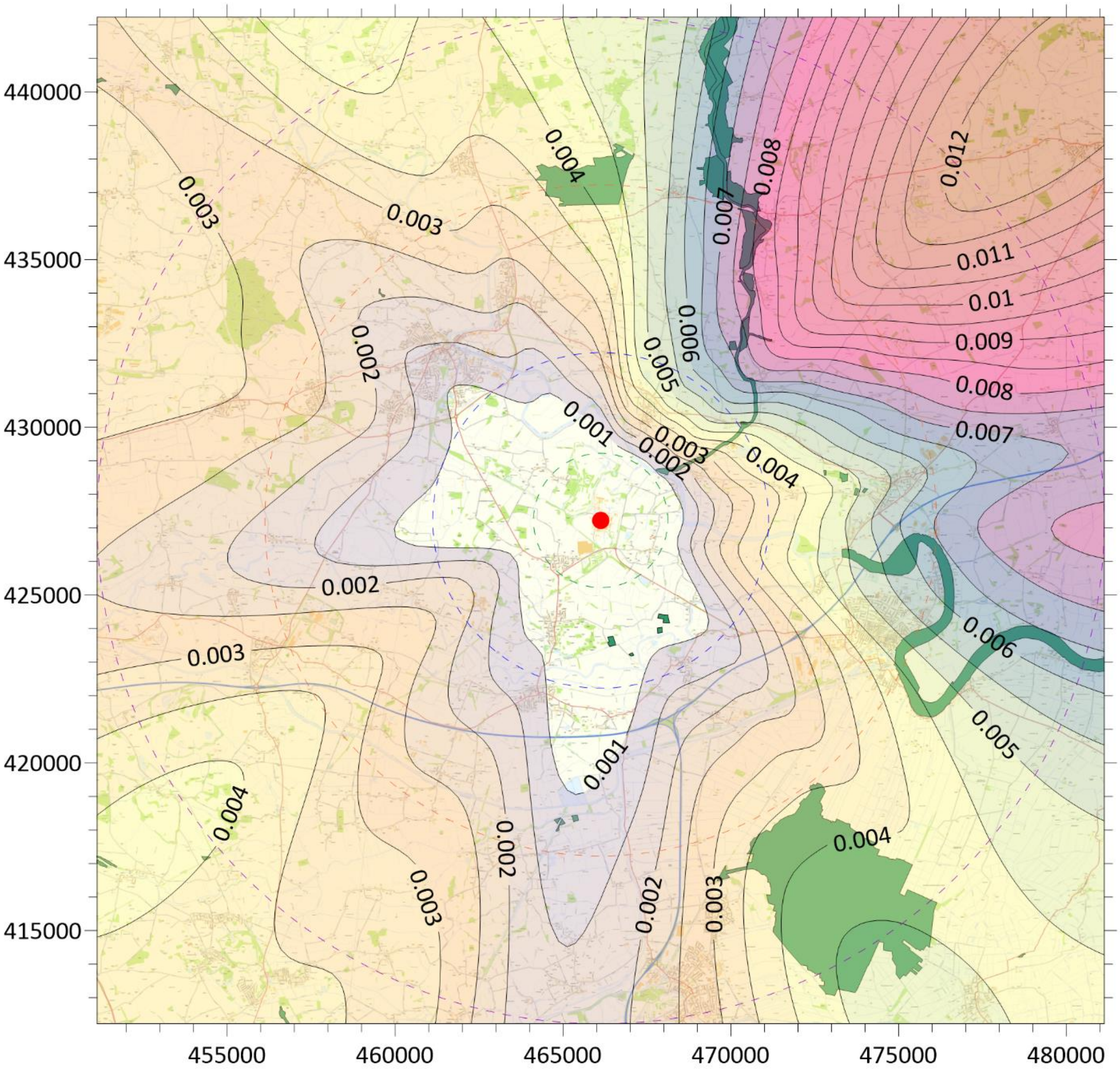



**Figure A-7 - Annual mean ammonia process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 0.0005µg/m$^3$ (0.0003% of AQAL)**

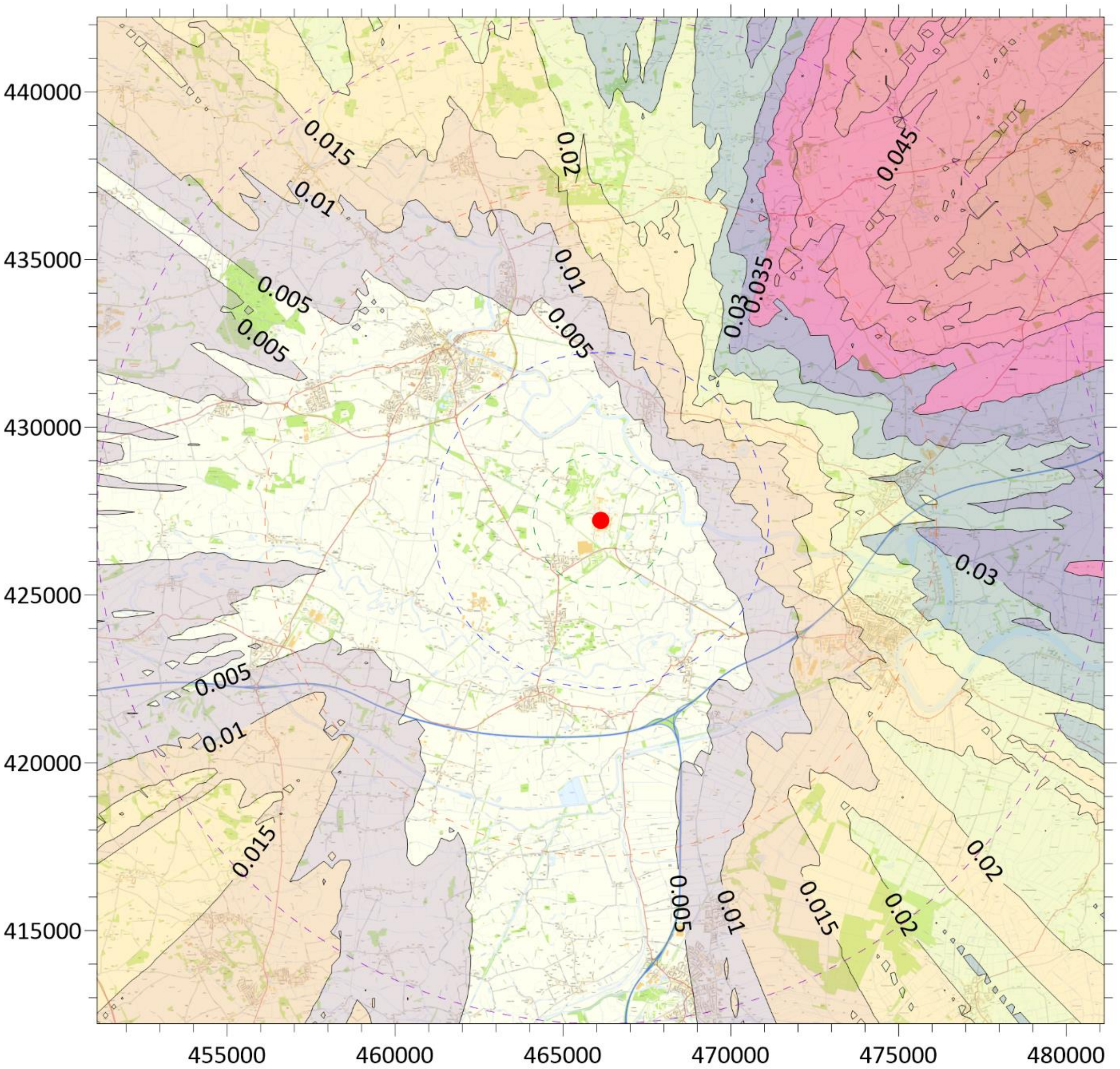



**Figure A-8 – Daily mean $PM_{10}$ (90.4th %ile) process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 0.005µg/m$^3$ (0.01% of AQAL)**

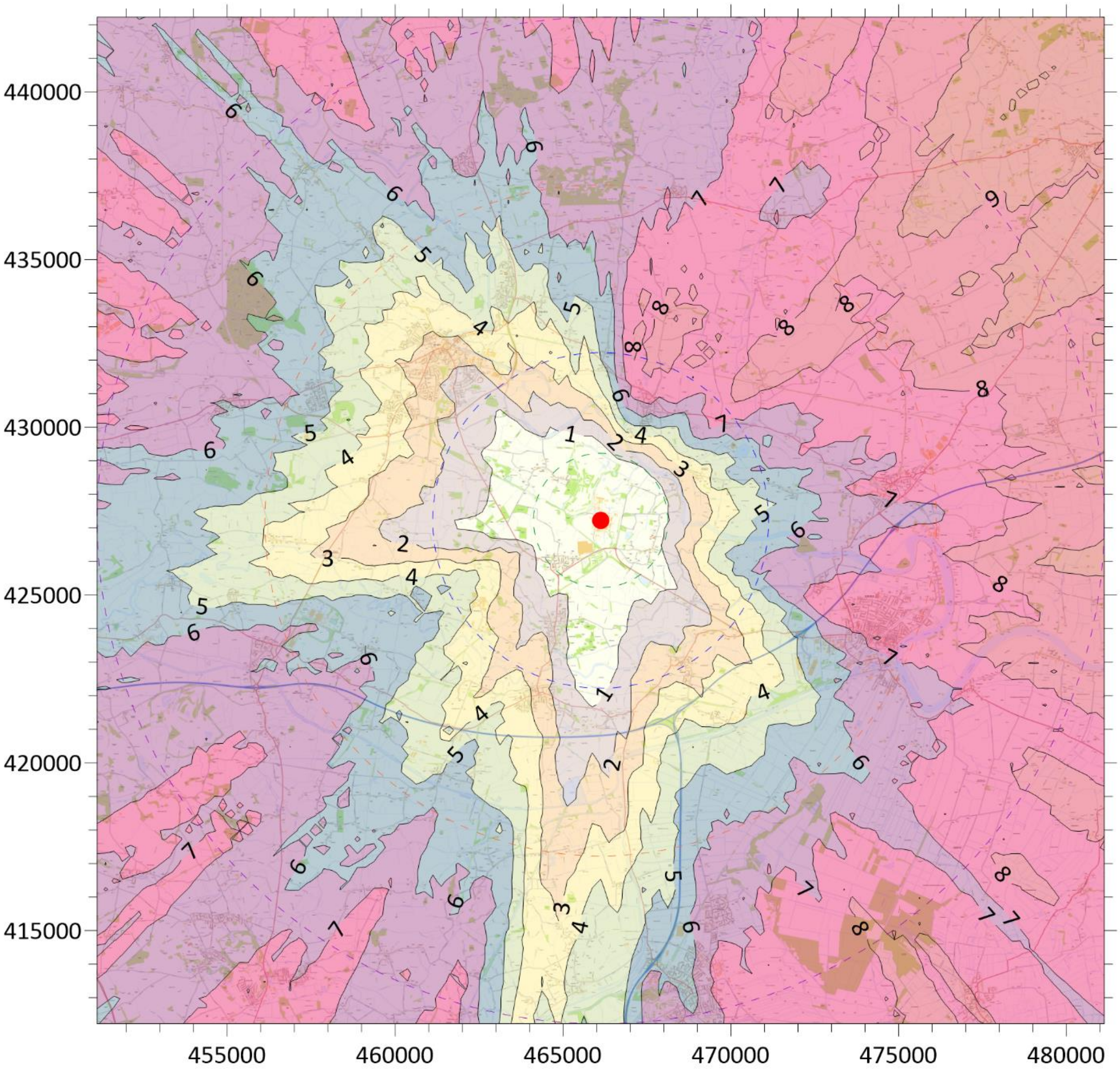



**Figure A-9 - Hourly mean sulphur dioxide (99.73rd %ile) process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 1.0µg/m³ (0.3% of AQAL)**

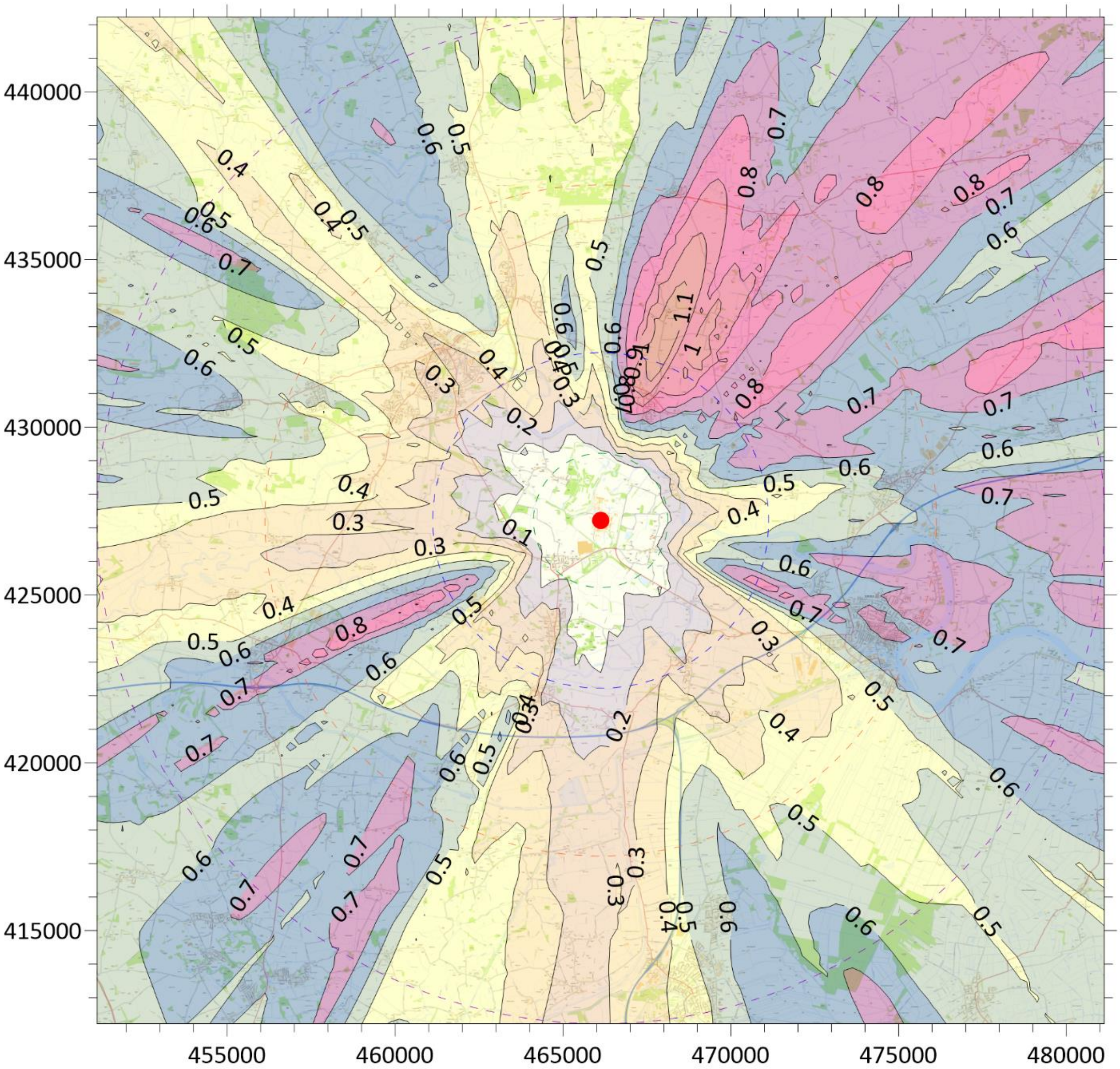



**Figure A-10 - Daily mean sulphur dioxide (99.18th %ile) process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 0.1µg/m³ (0.08% of AQAL)**

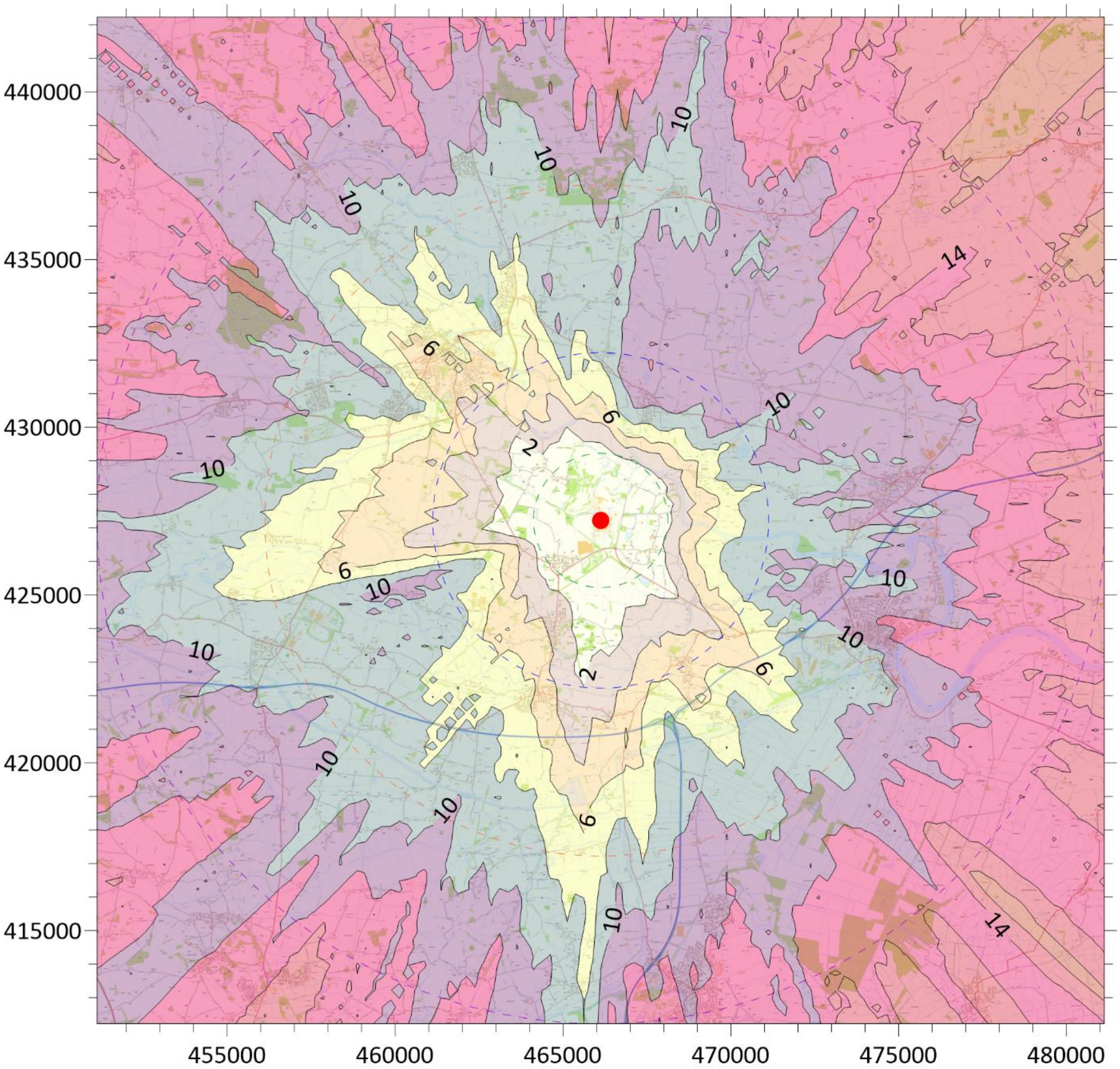



**Figure A-11 – 15minute mean sulphur dioxide (99.9th %ile) process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 2.0µg/m³ (0.75% of AQAL)**

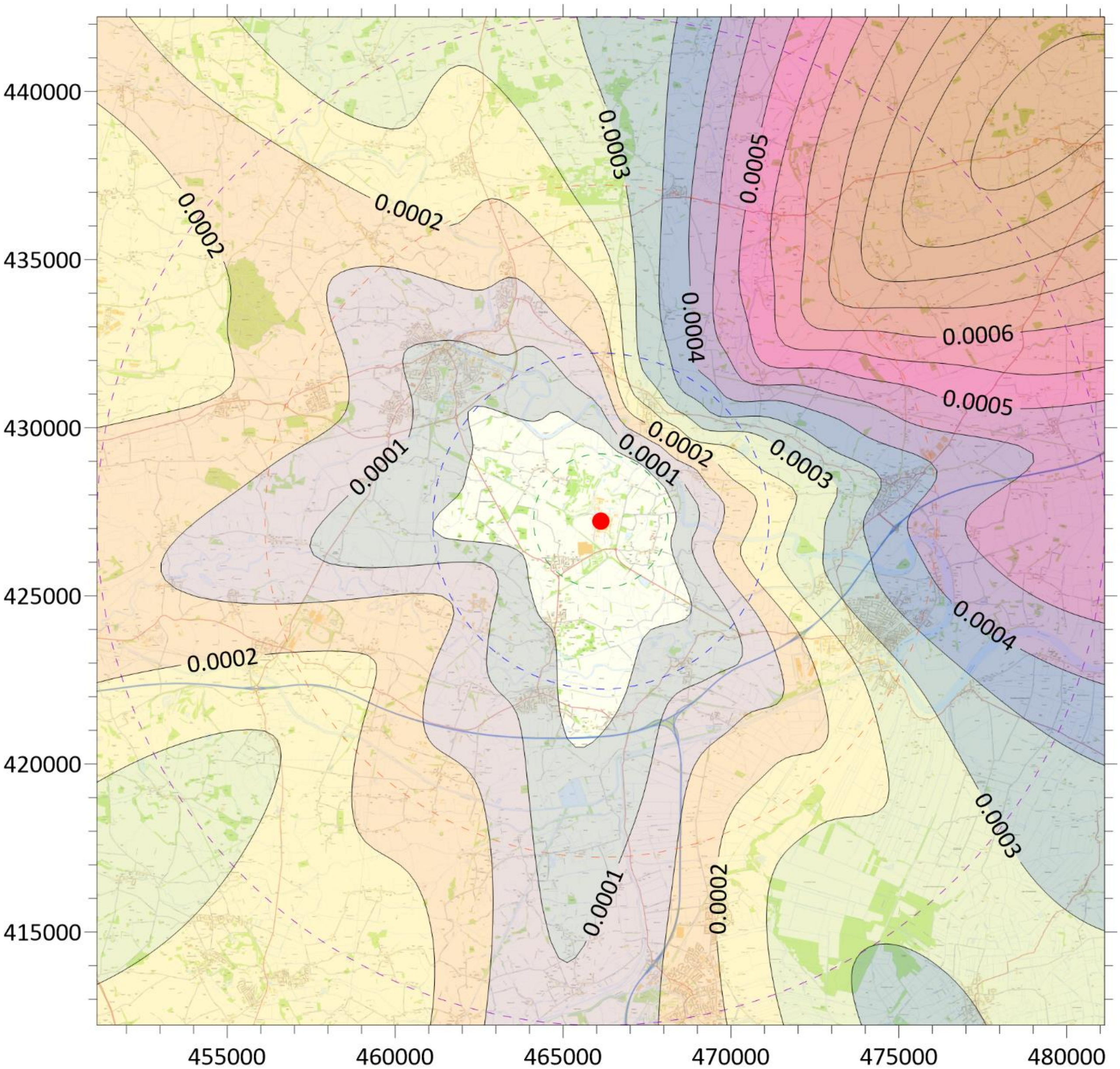



**Figure A-12 – Annual Mean Ethyl Methylamine process contribution for the Core Scenario, modelled using meteorological data from 2022, without chemical degradation. Contour interval: 5x10$^{-5}$µg/m$^3$ (0.00002% of AQAL)**

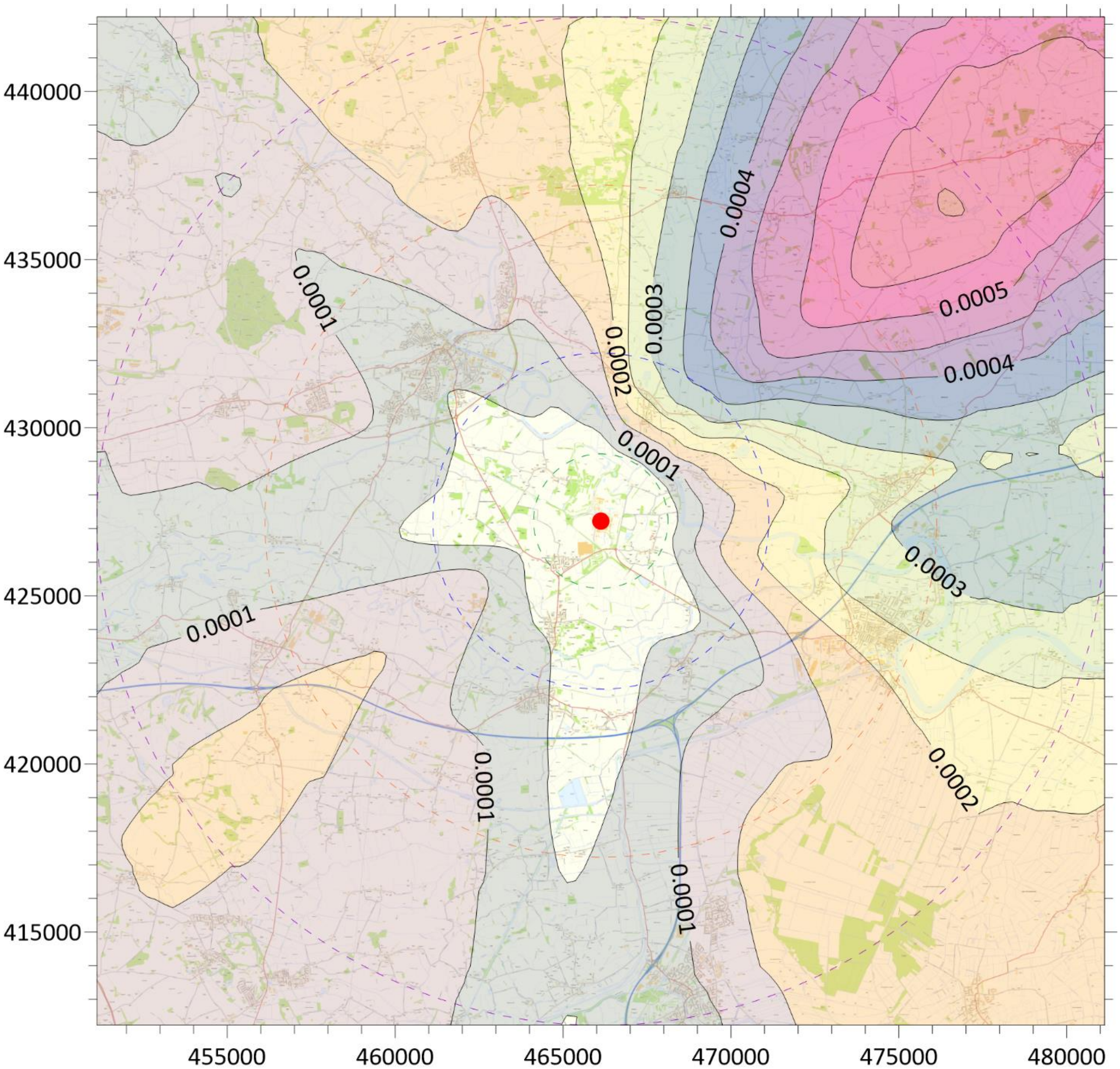



**Figure A-13 – Annual Mean Ethyl Methylamine process contribution for the Core Scenario, modelled using meteorological data from 2022 and the ADMS chemistry module. Contour interval: 5x10$^{-5}$µg/m$^3$ (0.00002% of AQAL))**

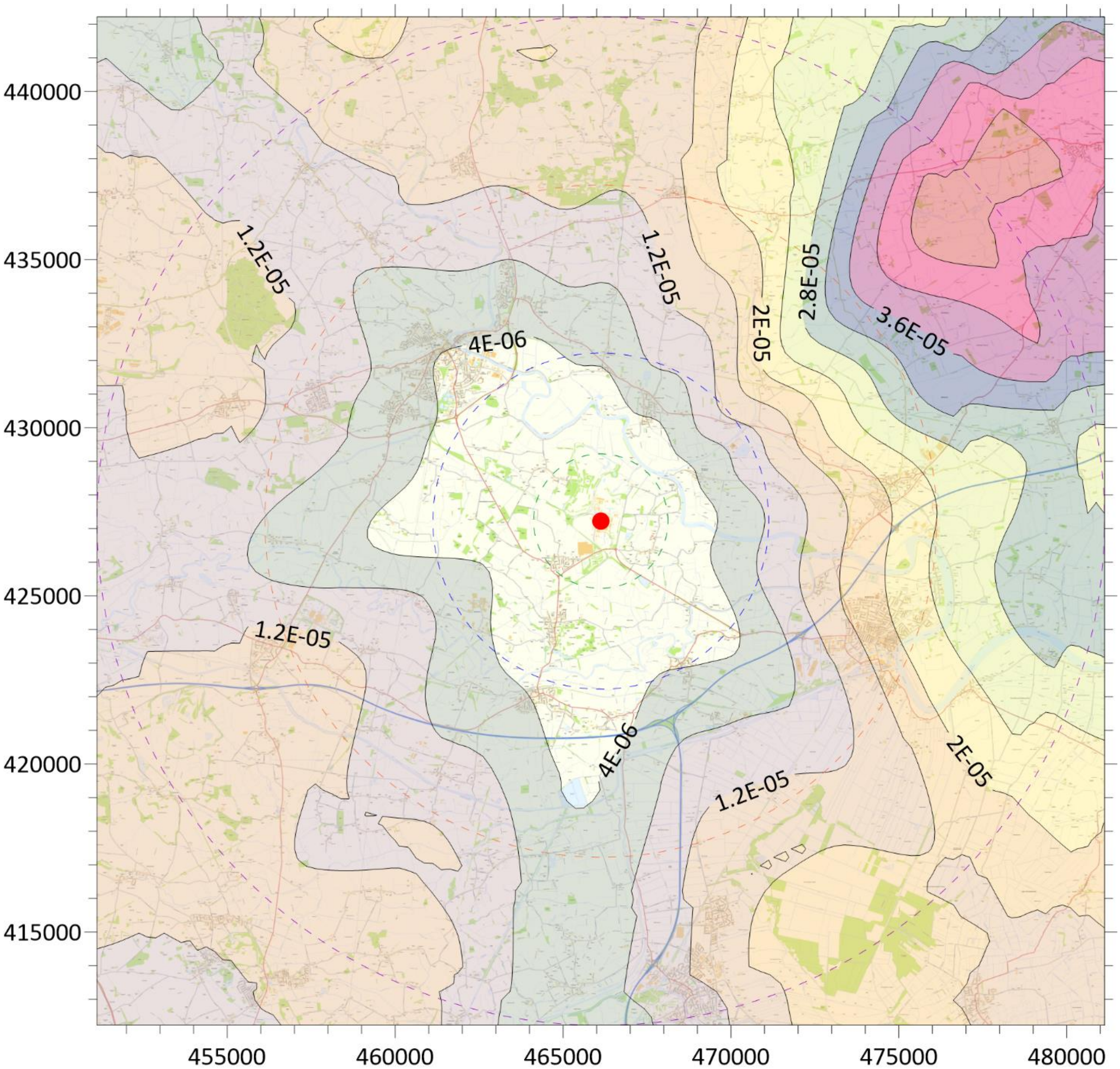



**Figure A-14 – Annual Mean N-Nitrosomethylethylamine process contribution for the Core Scenario, modelled using meteorological data from 2022 and the ADMS chemistry module. Contour interval: $4x10^{-6}$µg/m$^3$ (0.004ng/m$^3$, 2% of EAL)**

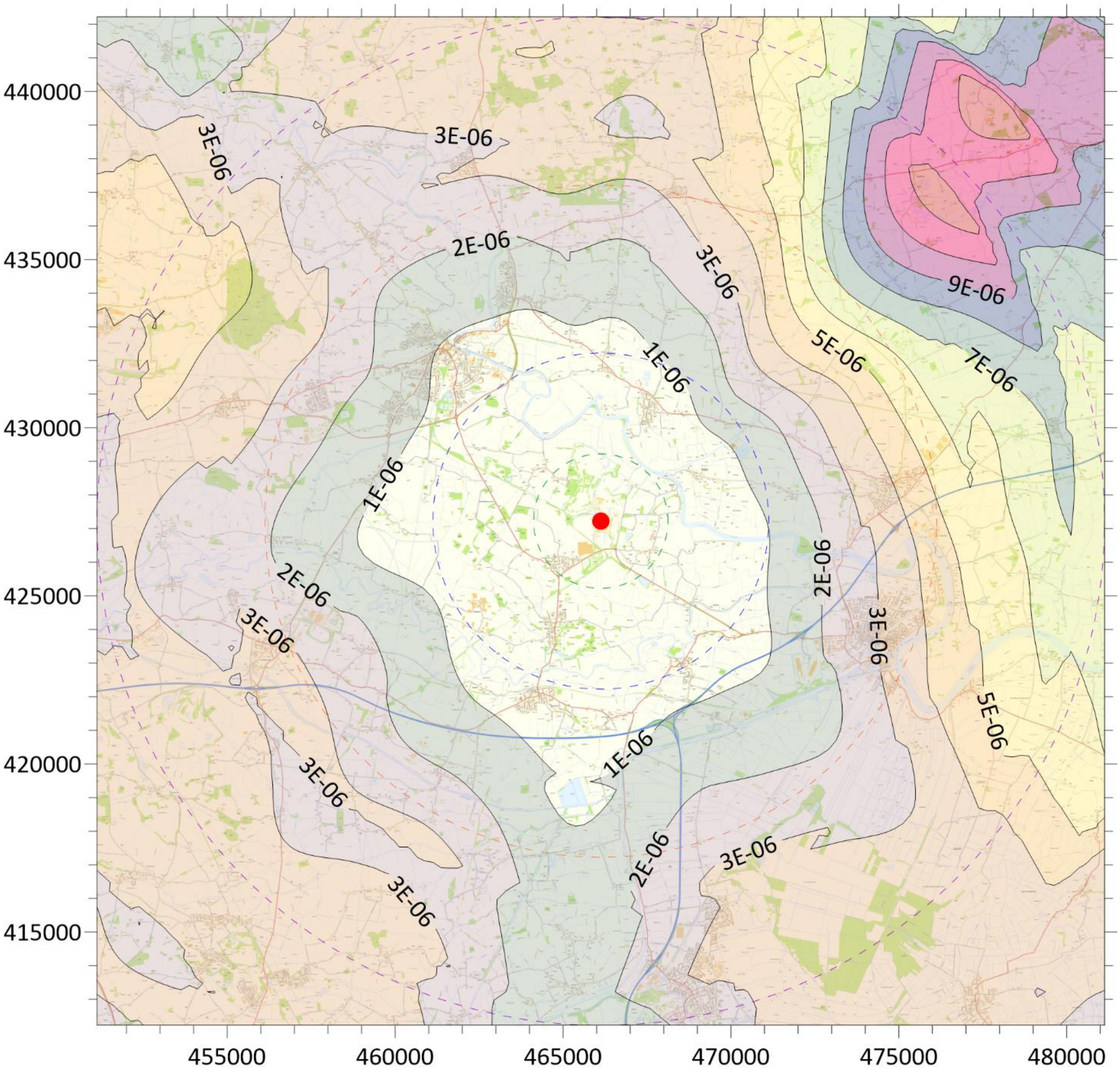



**Figure A-15 – Annual Mean Nitramine3 (from ethylmethylamine) process contribution for the Core Scenario, modelled using meteorological data from 2022 and the ADMS chemistry module. Contour interval: 1x10$^{-6}$µg/m$^3$ (0.001ng/m$^3$, 0.5% of EAL)**

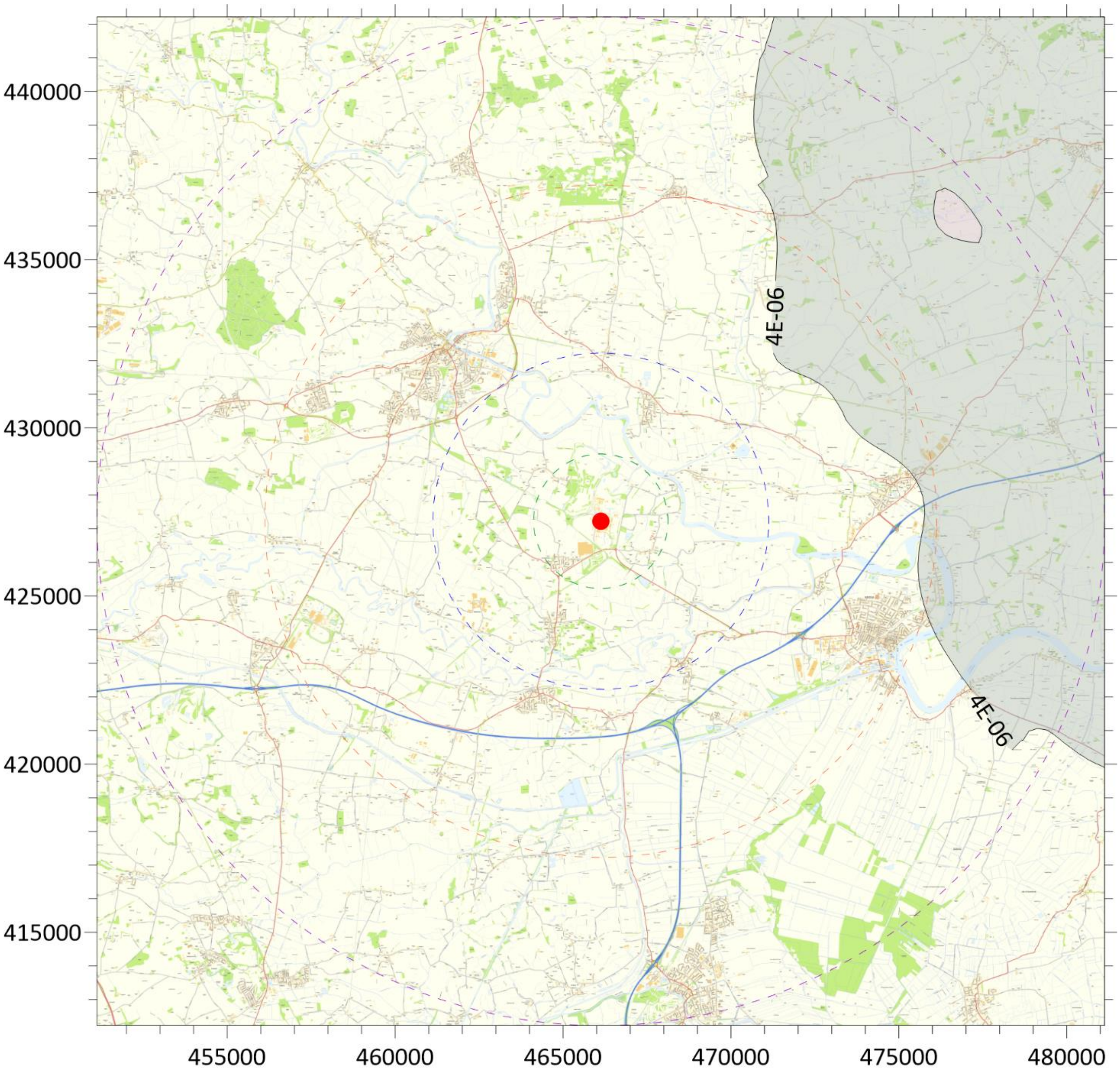



**Figure A-16 – Annual Mean N-Nitrosomethylethylamine process contribution with emissions at their likely maximum, modelled using meteorological data from 2022 and the ADMS chemistry module. Contour interval: $4x10^{-6}$µg/$m^3$ (0.004ng/$m^3$, 2% of EAL)**

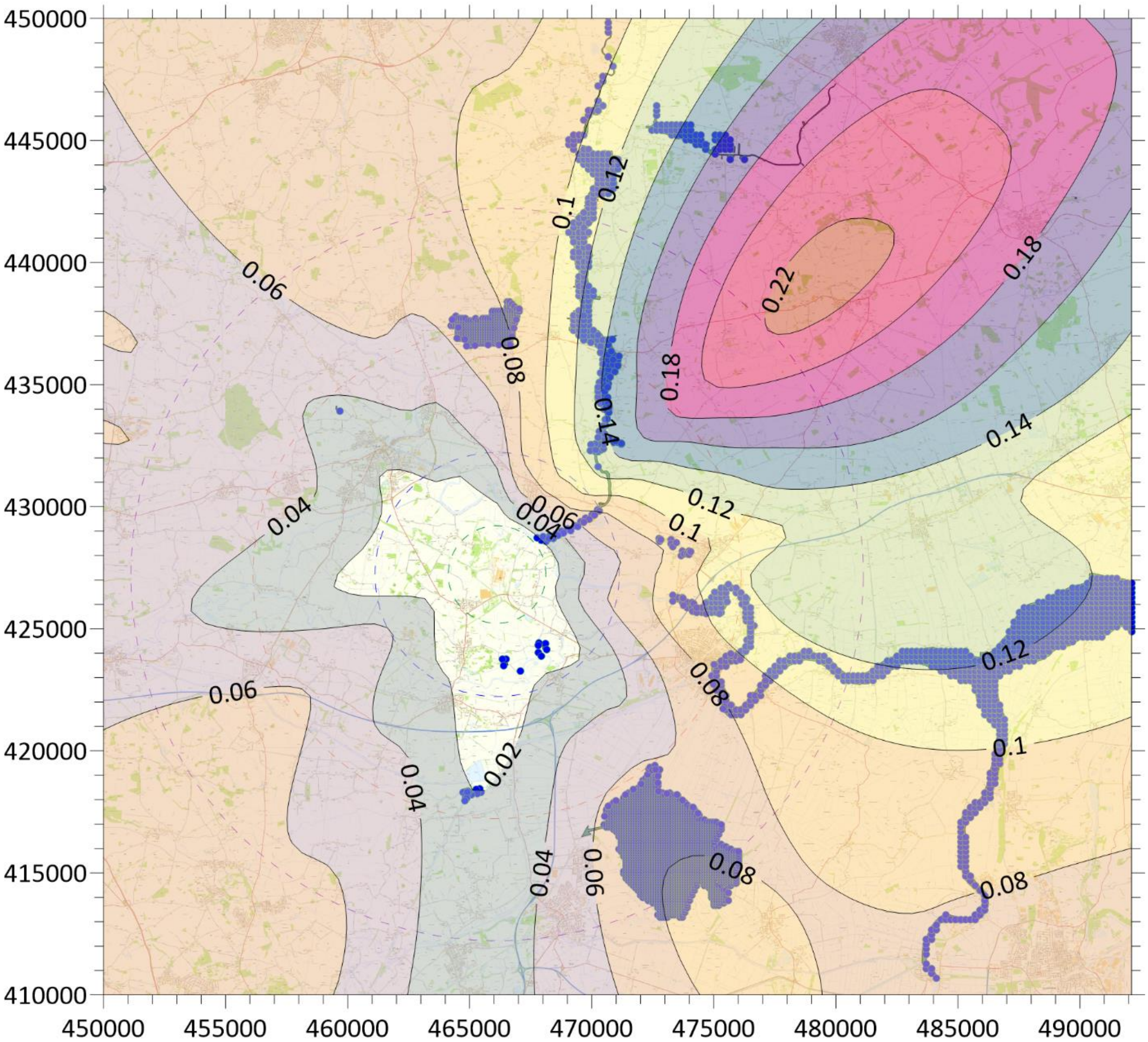



**Figure A-17 – Annual Mean NOx process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 0.02µg/m³ (0.067% of Critical Level)**

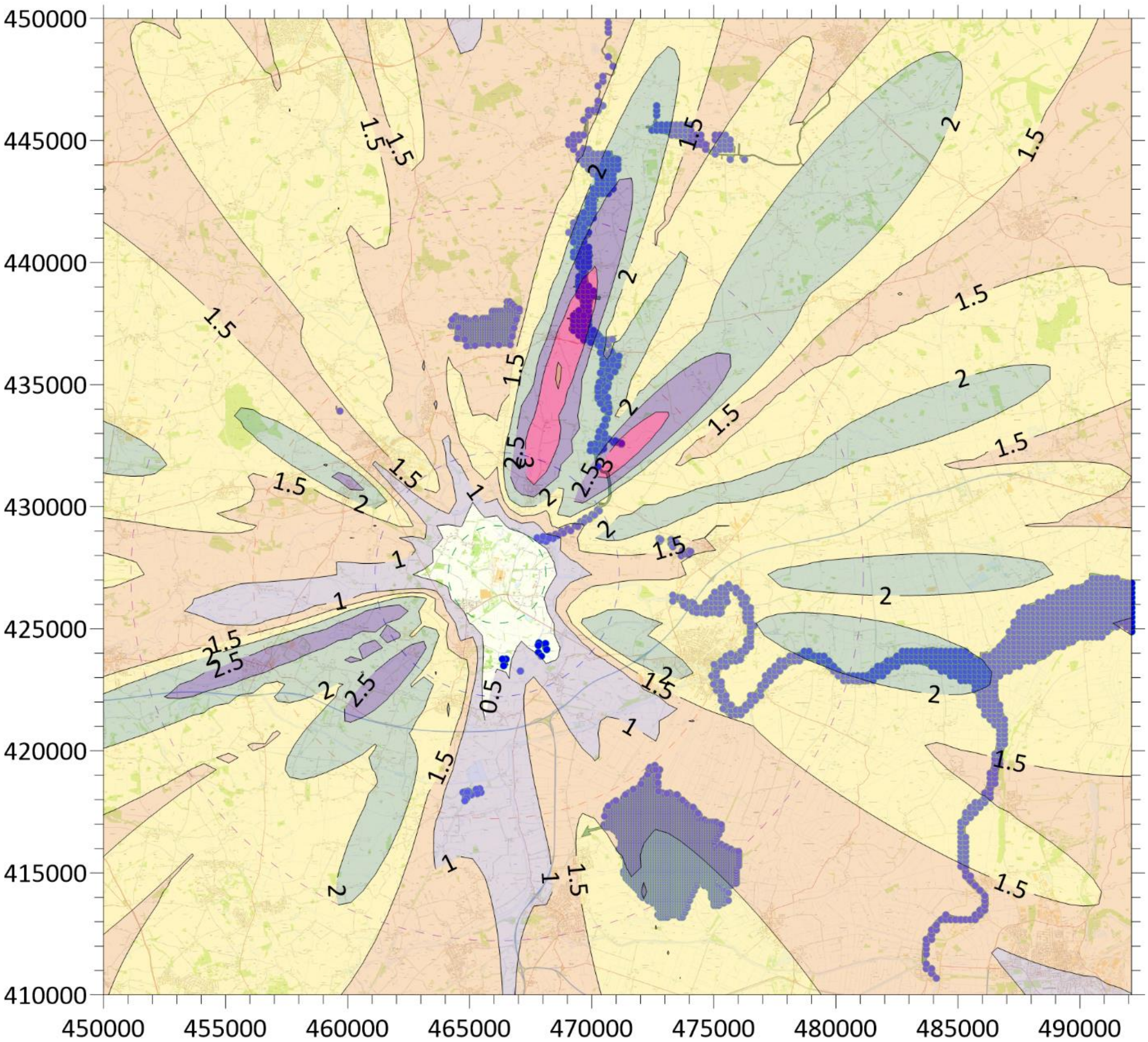



**Figure A-18 - Daily Mean NOx process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 0.5µg/m³ (0.67% of Critical Level)**

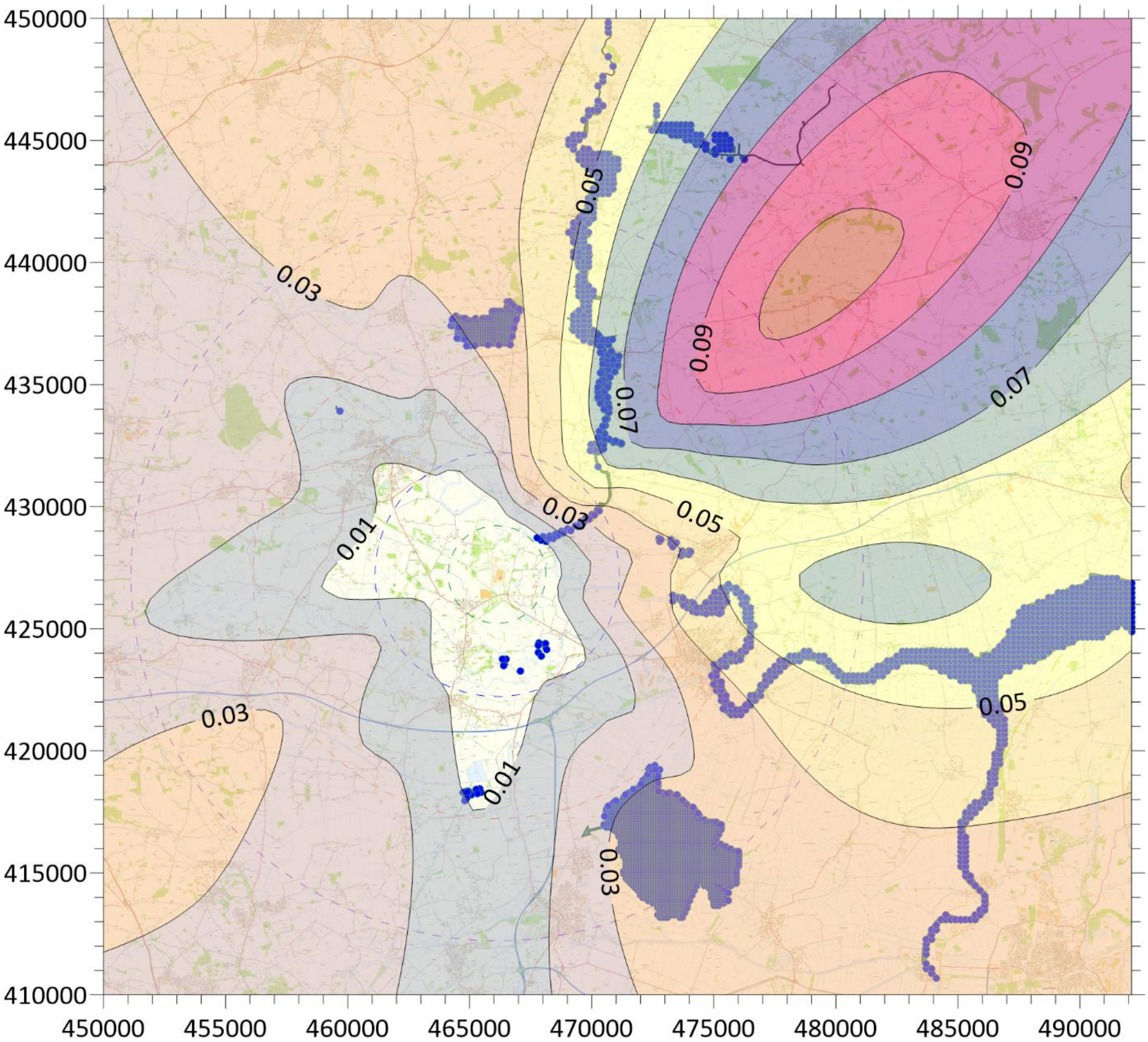



**Figure A-19 - Annual Mean $SO_2$ process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 0.01µg/m$^3$ (0.1% of Critical Level of 10µg/m$^3$)**

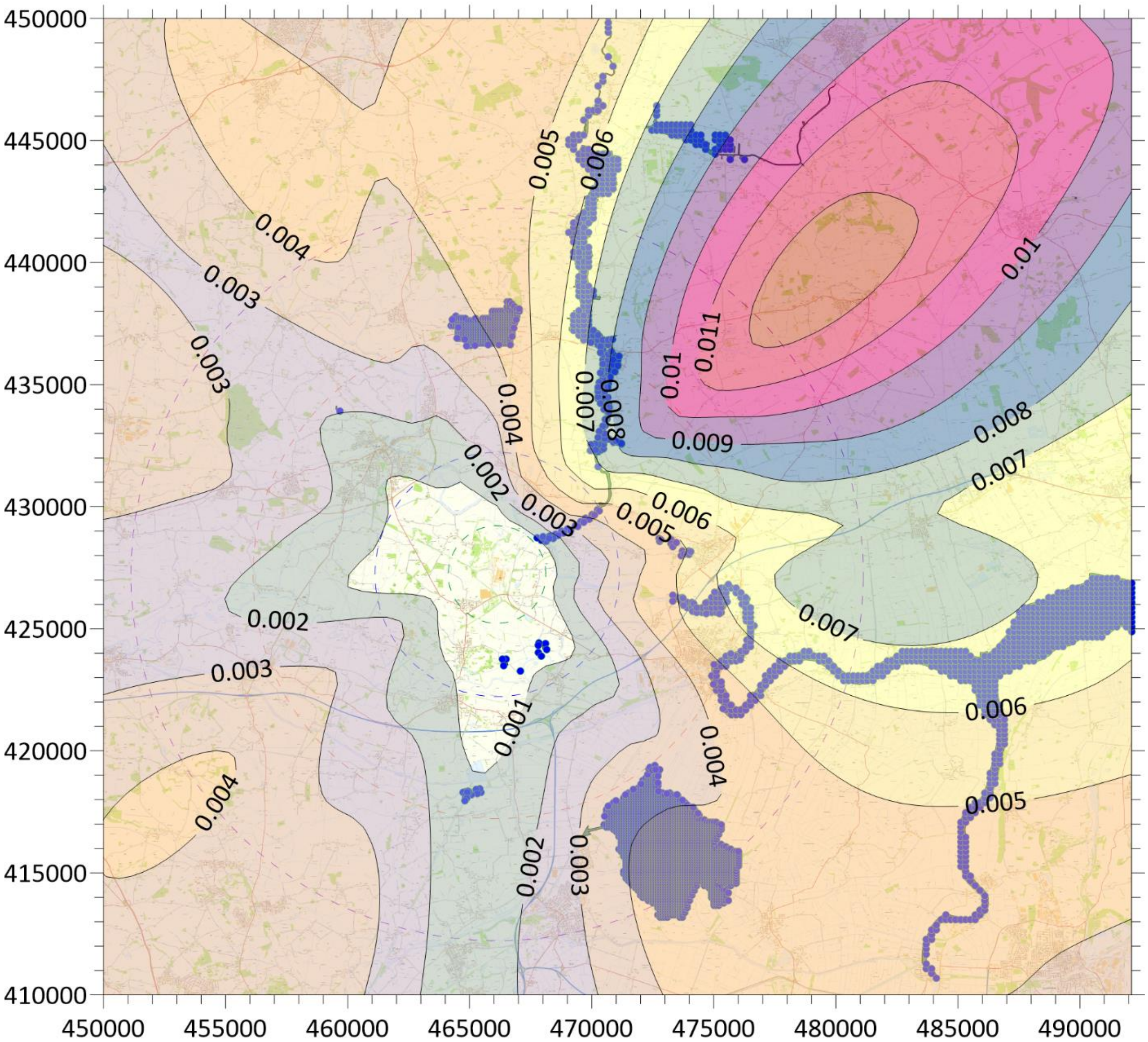



**Figure A-20 - Annual Mean $NH_3$ process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 0.001µg/m$^3$ (0.1% of Critical Level of 1µg/m$^3$)**

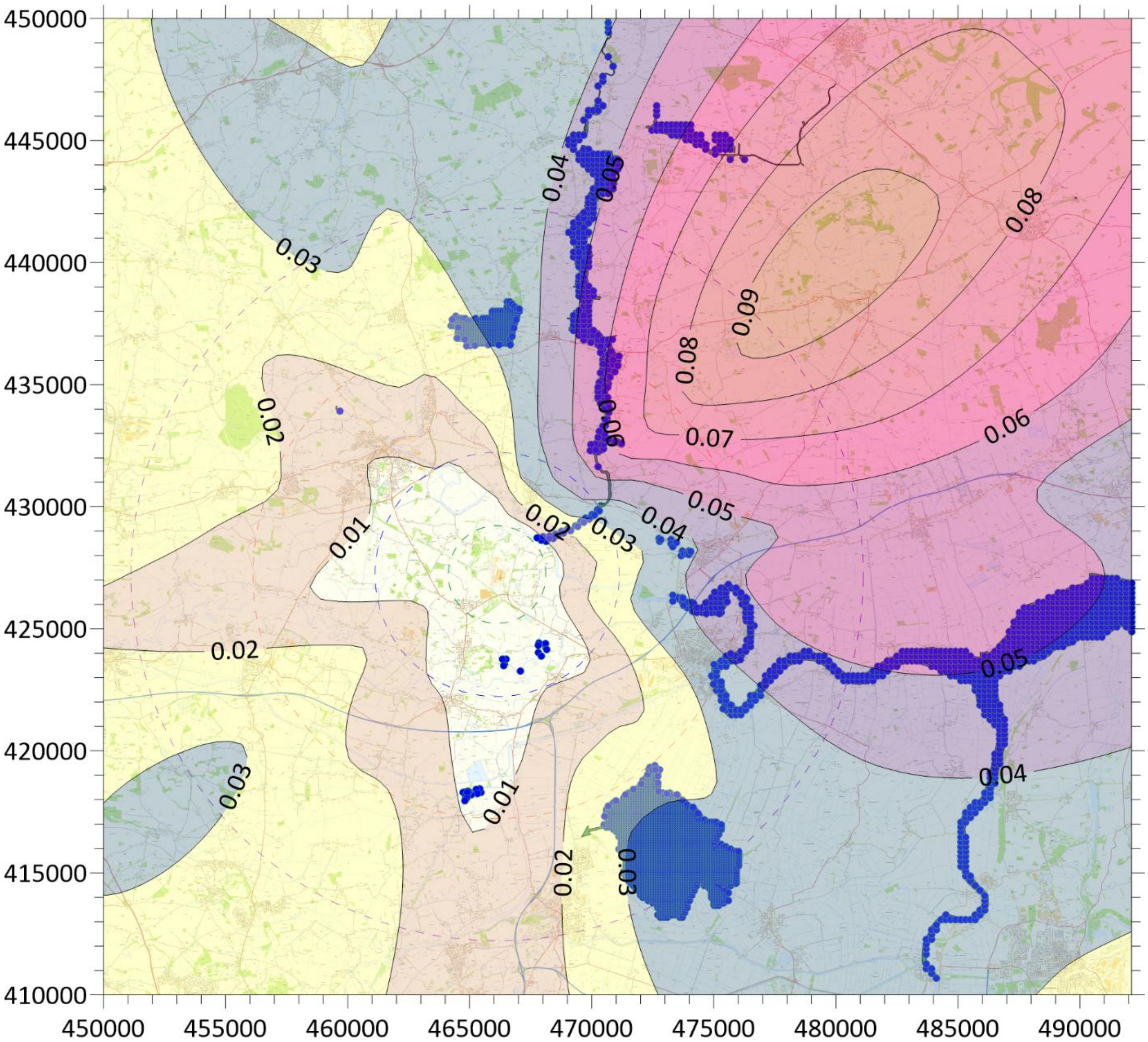



**Figure A-21 - Annual Mean Nitrogen Deposition process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 0.01kgN/ha/yr (0.2% of Critical Load of 5kgN/ha/yr; 0.1% of Critical Load of 10kgN/ha/yr)**

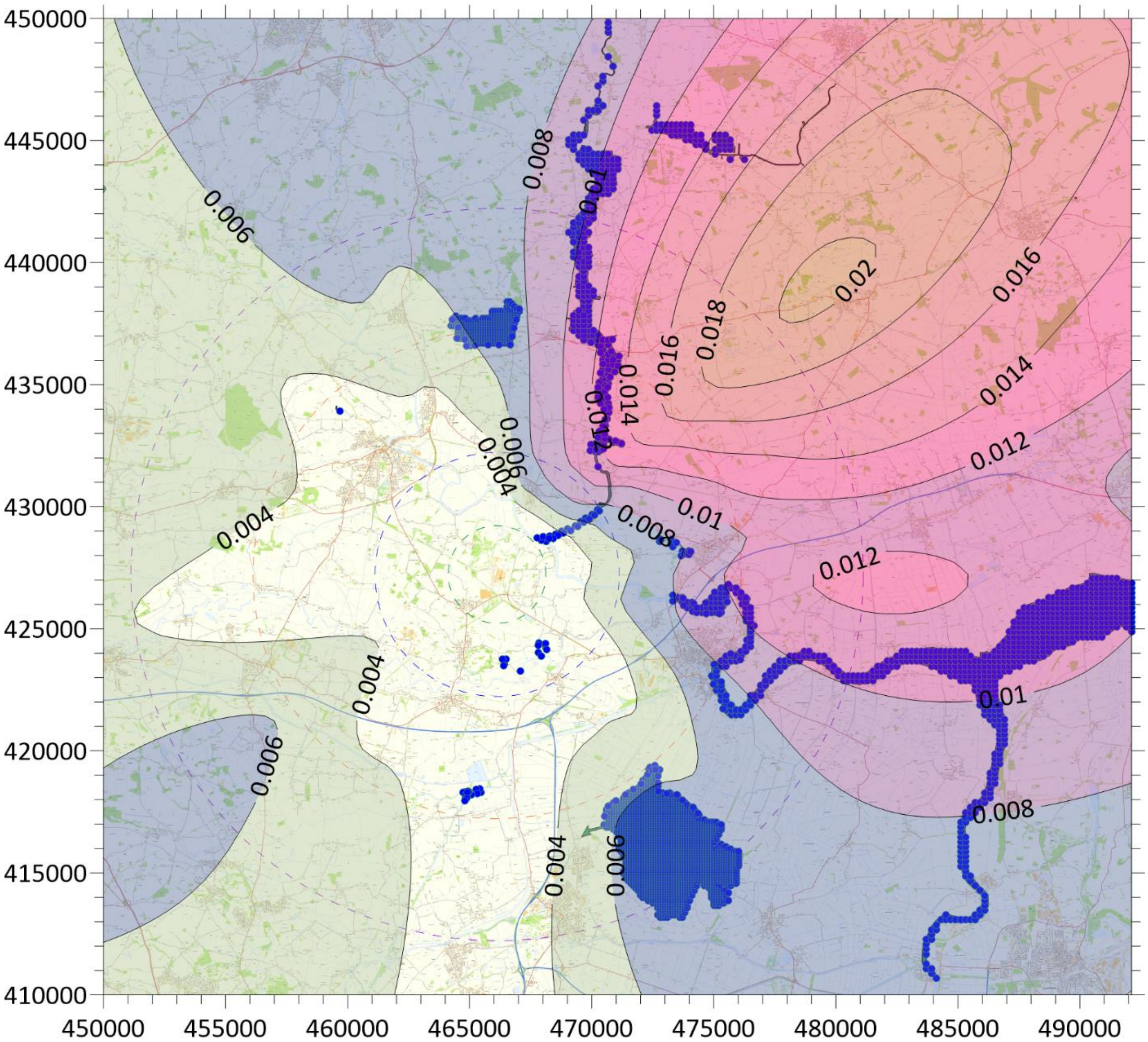



**Figure A-22 - Annual Mean Acid Deposition process contribution for the Core Scenario, modelled using meteorological data from 2022. Contour interval: 4x10$^{-6}$µg/m$^{3}$ (0.004ng/m$^{3}$, 2% of EAL)**

# Appendix B

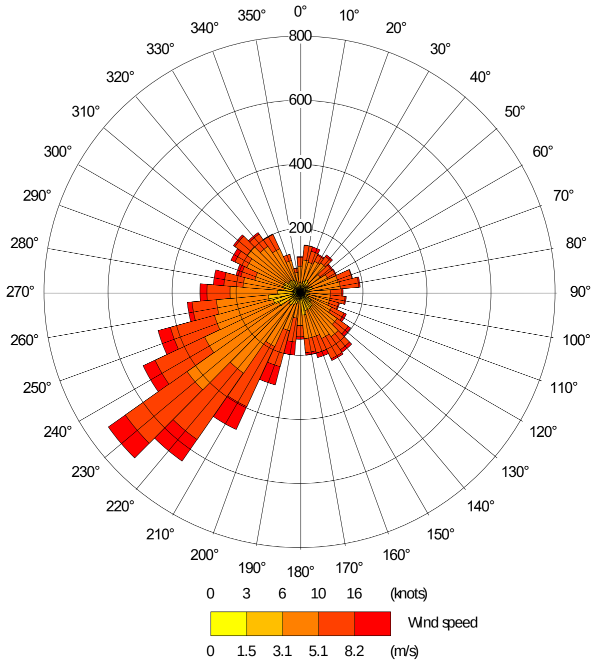
## RECEPTORS

# Appendix C

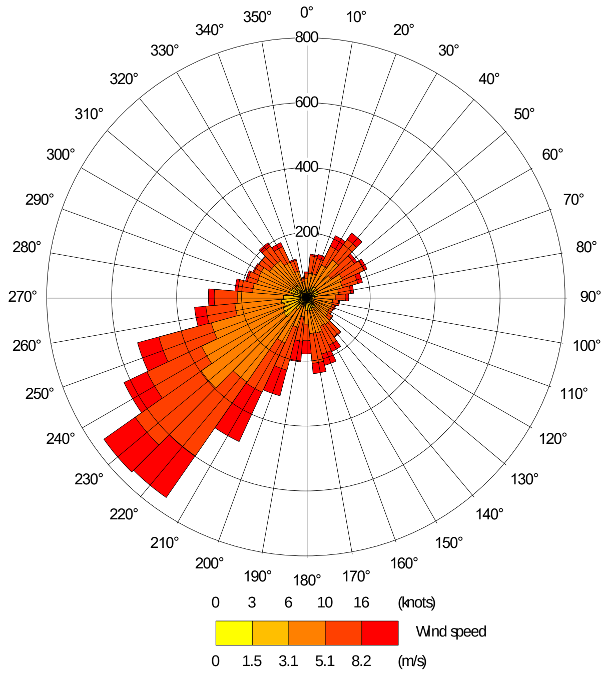
## WIND ROSES

## Waddington Wind Roses

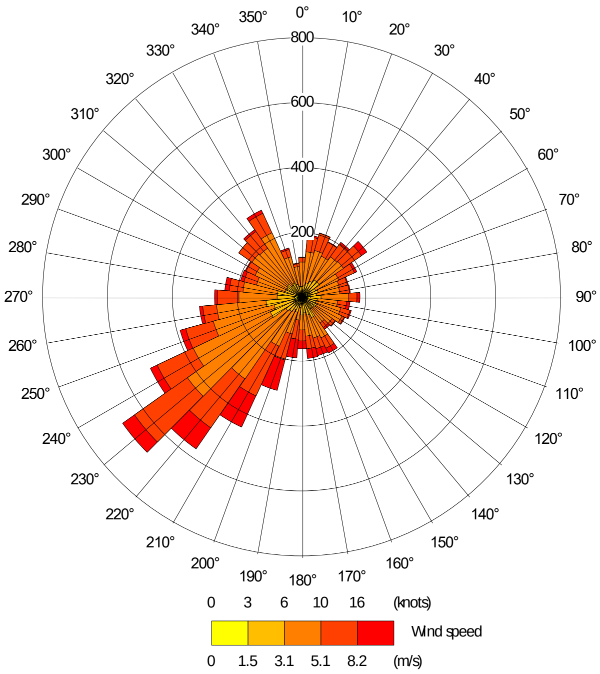
### 2019



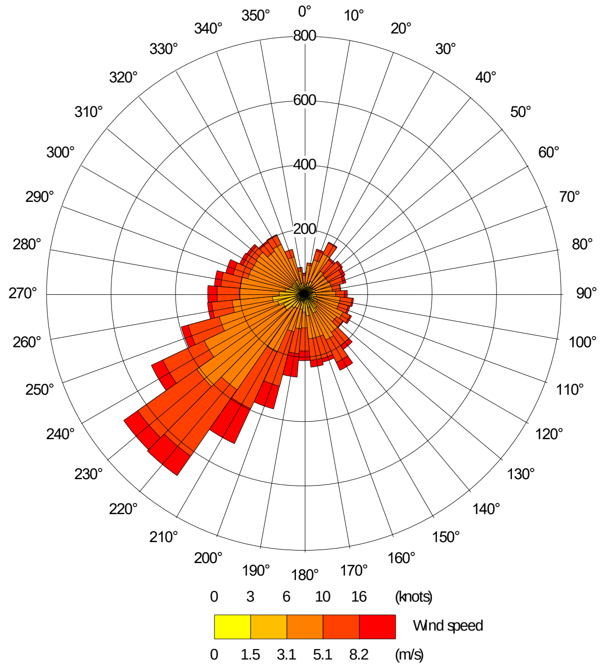

### 2020



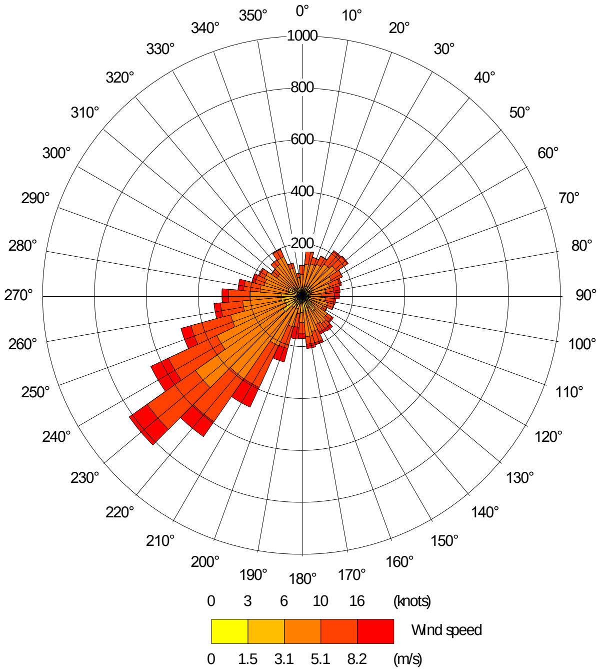

### 2021




### 2022



**2023**



0°
10°
20°
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40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
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270°
280°
290°
300°
310°
320°
330°
340°
350°
1000
800
600
400
200
0 3 6 10 16 (knots)
Wind speed
0 1.5 3.1 5.1 8.2 (m/s)

# Appendix D

## AMINE CHEMISTRY MODULE PARAMETERS

Public

**Table D-1 – Overarching amine chemistry modelling input parameters and rationale**

| Parameter | Value | Notes |
|---|---|---|
| Amine emissions | Table 4-3 for speciated emissions at emission limit value and likely maximum emissions | ELV proposed for primary amines and combined secondary/tertiary amines; Likely maximum emission concentrations provided by MHI<br>11 amine species modelled, with species provided by MHI<br>Impacts assessed as direct emissions with no degradation (worst case) and with degradation. |
| Direct nitrosamine emissions | Table 4-3 for speciated emissions at emission limit value and likely maximum emissions | ELV proposed for total nitrosamines; Likely maximum emission concentrations provided by MHI<br>8 nitrosamines assessed for direct emissions, 5 of which are also included within the degradation products from amines. |
| Direct nitramine emissions | Table 4-3 for speciated emissions at emission limit value and likely maximum emissions | ELV proposed for total nitramines; Likely maximum emission concentrations provided by MHI<br>3 nitramines assessed for direct emissions, 1 of which is also included within the degradation products from amines. |
| NOx emission | Table 4-2 | Emissions assumed to be at ELV at all times with 5% of $NO_X$ emissions as $NO_2$. A sensitivity test was undertaken with 10% of NOx emissions as $NO_2$. |
| Amine reaction rate constants | Table D-2 for Core Scenario<br>Sensitivity test parameters provided in Table D-3 | Data taken from CERC, May 2024, Improving Post-Combustion Carbon Capture Modelling report. |

| Parameter | Value | Notes |
| --- | --- | --- |
| Constant, c, for OH concentration calculations | $1.14 \times 10^{-3}$ s | Calculated using CERC recommended relationship between annual average $jNO_2$, $O_3$ and OH concentrations for each met year and then averaged across 5 years of Waddington meteorological data. Range of values is $1.14 \times 10^{-3}$ s to $1.22 \times 10^{-3}$ s.<br>OH concentration is 3.78x10-5 ppb, from L. S. Jackson, N. Carslaw, D. C. Carslaw, and K. M. Emmerson, 2009, Modelling trends in OH radical concentrations using generalized additive models, Atmospheric Chemistry and Physics, Vol 9, issue 6, 2021-2033.<br>$O_3$ concentration annual average from Hull Freetown AURN station for each meteorological year.<br>There was a subtle change in advice between ADMS v5 and ADMS v6 regarding the calculation of the constant c. The approach adopted here follows the ADMS v5 advice and is more conservative than the revised approach. A sensitivity test has been included to demonstrate this (c = $4.44 \times 10^{-4}$ s) |
| Background $NOx/NO_2/O_3$ concentrations | Year specific, hourly concentrations | Data taken from Hull Freetown AURN site for 2019 – 2023. Testing undertaken using Ladybower AURN site for the Drax BECCS DCO demonstrates that Hull is more conservative. |

**Table D-2 – Amine specific reaction rate constants (ppb/s) and rationale**

| Amine | k1 | k2 | k3 | k4a | k4 | k1a/k1 | J/JNO$_2$ | Notes |
|---|---|---|---|---|---|---|---|---|
| Ethylamine | 6.23E-01 | 6.33E-08 | 2.53E+00 | 2.10E-04 | 3.14E-04 | 9.00E-02 | 0.32 | Average rates in CERC, with MEA used as proxy since primary amine for k3 and k4a |
| Ethyl Ethanolamine | 9.33E-01 | 4.45E-10 | 1.78E-02 | 7.91E-03 | 8.19E-03 | 6.00E-01 | 0.32 | Average rates in CERC, with DEA (preferred), DiEA, or DMA used as proxy. DEA selected as a secondary complex amine with ethanol group, followed by other secondary amines |
| Ethyl methylamine | 2.10E+00 | 5.65E-09 | 2.26E-01 | 7.91E-03 | 8.19E-03 | 6.00E-01 | 0.32 | Average rates in CERC, with DiEA (preferred), or DMA used as proxy. DiEA selected as a secondary complex alkyl amine, followed by other secondary amines |
| Piperazine | 6.67E+00 | 4.63E-11 | 1.80E+00 | 7.91E-03 | 7.91E-03 | 8.78E-02 | 0.32 | Average rates in CERC |
| Diethanolamine | 2.42E+00 | 4.45E-10 | 1.78E-02 | 7.91E-03 | 1.58E-02 | 6.00E-01 | 0.32 | Average rates in CERC, with DMA (preferred) or DiEA used as proxy since secondary amines for k4a and k4b |
| Dimethylamine | 1.54E+00 | 9.29E-10 | 1.99E-02 | 7.91E-03 | 8.19E-03 | 3.84E-01 | 0.32 | Average rates in CERC |
| Ethyl diethanolamine | 2.63E-01 | 5.65E-09 | 2.26E-01 | 7.91E-03 | 8.19E-03 | 6.00E-01 | 0.32 | Few data available for tertiary amines. Average rates in CERC with DiEA (preferred, typical of tertiary amines for k1) or DMA used as proxy since secondary amines and conservative |

| Amine | k1 | k2 | k3 | k4a | k4 | k1a/k1 | $J/JNO_2$ | Notes |
|---|---|---|---|---|---|---|---|---|
| Diethylamine | 2.10E+00 | 5.65E-09 | 2.26E-01 | 7.91E-03 | 8.19E-03 | 6.00E-01 | 0.32 | Average rates in CERC, with DMA (preferred) used as proxy since secondary amines for k4a and k4b |
| Monoethanolamine | 1.71E+00 | 5.22E-08 | 1.77E-03 | 2.10E-04 | 3.14E-04 | 1.23E-01 | 0.32 | Average rates in CERC |
| N-Dimethylethylenediamine | 2.42E+00 | 4.45E-10 | 1.78E-02 | 7.91E-03 | 8.19E-03 | 6.00E-01 | 0.32 | Few data available for tertiary amines. Average rates in CERC, with DEA (preferred and conservative re koh for tertiary amines i.e. represents maximum k1 provided in CERC for tertiary amines), DiEA, or DMA used as proxy. DEA selected as a complex linear amine, followed by other secondary amines with conservative selection. Approach likely to be conservative |
| Methylamine | 4.79E-01 | 5.90E-08 | 9.83E-01 | 2.10E-04 | 3.14E-04 | 2.72E-01 | 0.32 | Average rates in CERC |

CERC = CERC, May 2024, Improving post carbon capture air quality risk assessment techniques

MEA = Monoethanolamine; DiEA = Diethylamine; DMA = Dimethylamine; DEA = Diethanolamine

**Table D-3 – Ethyl methylamine specific reaction rate constants used for sensitivity tests**

| Test | k1 | k2 | k3 | k4a | k4 | k1a/k1 | J/JNO$_2$ | Notes |
|---|---|---|---|---|---|---|---|---|
| T1 | 6.67E+00 | 5.65E-09 | 2.26E-01 | 7.91E-03 | 8.19E-03 | 6.00E-01 | 0.32 | k1 max |
| T2 | 4.79E-01 | 5.65E-09 | 2.26E-01 | 7.91E-03 | 8.19E-03 | 6.00E-01 | 0.32 | k1 min |
| T3 | 4.79E-01 | 5.90E-08 | 1.78E-02 | 7.91E-03 | 8.19E-03 | 9.00E-02 | 0.32 | k1 min, k2 min,k3 min, k1a/k1 min |
| T4 | 4.79E-01 | 6.33E-08 | 1.78E-02 | 7.91E-03 | 7.91E-03 | 9.00E-02 | 0.32 | k1 min, k2 max, k3 min, k1a/k1 min (over all amines) |
| T5 | 2.10E+00 | 5.65E-09 | 2.26E-01 | 7.91E-03 | 1.58E-02 | 6.00E-01 | 0.32 | k4a and k4 max (over all amines) |
| T6 | 2.10E+00 | 5.65E-09 | 2.26E-01 | 2.10E-04 | 3.14E-04 | 6.00E-01 | 0.32 | k4a and k4 min (over all amines) |
| T7 | 2.10E+00 | 5.65E-09 | 2.26E-01 | 7.91E-03 | 8.19E-03 | 1.23E-01 | 0.32 | k1a/k1 average (over all amines) |
| T8 | 2.10E+00 | 5.65E-09 | 2.26E-01 | 7.91E-03 | 8.19E-03 | 9.00E-02 | 0.32 | k1a/k1 min (over all amines) |
| T9 | 2.10E+00 | 5.65E-09 | 2.53E+00 | 7.91E-03 | 8.19E-03 | 6.00E-01 | 0.32 | Min k1 for DiEA, k3 min for DMA/DiEA |
| T10 | 1.30E+00 | 5.65E-09 | 2.09E-03 | 7.91E-03 | 8.19E-03 | 6.00E-01 | 0.32 | Max k1 for DiEA, k3 max for DMA/DiEA |
| T11 | 6.67E+00 | 5.90E-08 | 1.78E-02 | 7.91E-03 | 7.91E-03 | 9.00E-02 | 0.32 | k1 max, k2min, k3ave, k1a/k1 min (over all amines) |
| T12 | 2.10E+00 | 5.65E-09 | 2.26E-01 | 7.91E-03 | 8.19E-03 | 6.00E-01 | 0.32 | As Core Scenario, test changes value of ‘c’ constant |
| T13 | 2.10E+00 | 5.65E-09 | 2.26E-01 | 7.91E-03 | 8.19E-03 | 6.00E-01 | 0.32 | As Core Scenario, test changes value of $NO_2/NO_X$ ratio |

# Appendix E

## CORE MODEL RESULTS

Table E-1 – Annual Mean $NO_2$ Process Contribution (PC)

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| Max on Grid | 0.152 | 0.156 | 0.147 | 0.158 | 0.155 | 0.158 | 0.39% |
| R1 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 | 0.002 | 0.01% |
| R2 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.001 | 0.00% |
| R3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.00% |
| R4 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.001 | 0.00% |
| R5 | 0.006 | 0.007 | 0.004 | 0.005 | 0.004 | 0.007 | 0.02% |
| R6 | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.00% |
| R7 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.01% |
| R8 | 0.003 | 0.003 | 0.002 | 0.003 | 0.001 | 0.003 | 0.01% |
| R9 | 0.004 | 0.005 | 0.003 | 0.004 | 0.004 | 0.005 | 0.01% |
| R10 | 0.028 | 0.015 | 0.020 | 0.018 | 0.011 | 0.028 | 0.07% |
| R11 | 0.052 | 0.046 | 0.043 | 0.059 | 0.030 | 0.059 | 0.15% |
| R12 | 0.044 | 0.060 | 0.051 | 0.047 | 0.037 | 0.060 | 0.15% |
| R13 | 0.010 | 0.022 | 0.019 | 0.016 | 0.008 | 0.022 | 0.05% |
| R14 | 0.014 | 0.020 | 0.014 | 0.014 | 0.007 | 0.020 | 0.05% |
| R15 | 0.028 | 0.053 | 0.036 | 0.039 | 0.037 | 0.053 | 0.13% |
| R16 | 0.020 | 0.036 | 0.028 | 0.037 | 0.024 | 0.037 | 0.09% |
| R17 | 0.096 | 0.128 | 0.098 | 0.102 | 0.089 | 0.128 | 0.32% |
| R18 | 0.089 | 0.113 | 0.083 | 0.091 | 0.089 | 0.113 | 0.28% |
| R19 | 0.098 | 0.105 | 0.081 | 0.090 | 0.071 | 0.105 | 0.26% |
| R20 | 0.076 | 0.085 | 0.083 | 0.095 | 0.069 | 0.095 | 0.24% |
| R21 | 0.133 | 0.154 | 0.137 | 0.146 | 0.131 | 0.154 | 0.38% |
| R22 | 0.017 | 0.032 | 0.029 | 0.027 | 0.015 | 0.032 | 0.08% |
| R23 | 0.032 | 0.039 | 0.042 | 0.042 | 0.028 | 0.042 | 0.11% |
| R24 | 0.026 | 0.019 | 0.025 | 0.032 | 0.018 | 0.032 | 0.08% |

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| R25 | 0.055 | 0.048 | 0.051 | 0.029 | 0.055 | 0.055 | 0.14% |
| R26 | 0.033 | 0.029 | 0.035 | 0.038 | 0.022 | 0.038 | 0.10% |
| R27 | 0.031 | 0.022 | 0.033 | 0.033 | 0.019 | 0.033 | 0.08% |
| R28 | 0.057 | 0.056 | 0.053 | 0.065 | 0.036 | 0.065 | 0.16% |
| R29 | 0.031 | 0.062 | 0.055 | 0.038 | 0.048 | 0.062 | 0.16% |
| R30 | 0.032 | 0.064 | 0.056 | 0.048 | 0.052 | 0.064 | 0.16% |
| R31 | 0.003 | 0.001 | 0.002 | 0.001 | 0.001 | 0.003 | 0.01% |
| R32 | 0.014 | 0.019 | 0.011 | 0.013 | 0.013 | 0.019 | 0.05% |
| R33 | 0.003 | 0.003 | 0.002 | 0.003 | 0.001 | 0.003 | 0.01% |
| R34 | 0.011 | 0.012 | 0.010 | 0.015 | 0.007 | 0.015 | 0.04% |
| R35 | 0.006 | 0.015 | 0.007 | 0.008 | 0.003 | 0.015 | 0.04% |
| R36 | 0.001 | 0.002 | 0.002 | 0.001 | 0.002 | 0.002 | 0.01% |
| R37 | 0.021 | 0.020 | 0.020 | 0.019 | 0.019 | 0.021 | 0.05% |
| R38 | 0.032 | 0.041 | 0.020 | 0.030 | 0.027 | 0.041 | 0.10% |
| R39 | 0.061 | 0.030 | 0.037 | 0.038 | 0.027 | 0.061 | 0.15% |
| R40 | 0.042 | 0.024 | 0.033 | 0.039 | 0.021 | 0.042 | 0.11% |
| R41 | 0.078 | 0.078 | 0.059 | 0.073 | 0.049 | 0.078 | 0.20% |
| R42 | 0.108 | 0.126 | 0.082 | 0.093 | 0.092 | 0.126 | 0.31% |
| R43 | 0.055 | 0.071 | 0.071 | 0.069 | 0.050 | 0.071 | 0.18% |
| R44 | 0.105 | 0.133 | 0.108 | 0.118 | 0.105 | 0.133 | 0.33% |
| R45 | 0.130 | 0.147 | 0.131 | 0.138 | 0.134 | 0.147 | 0.37% |

## Table E-2 – Hourly Mean $NO_2$ Process Contribution (PC)

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| Max on Grid | 4.487 | 4.513 | 4.822 | 4.725 | 4.645 | 4.822 | 2.41% |
| R1 | 0.132 | 0.155 | 0.148 | 0.098 | 0.092 | 0.155 | 0.08% |
| R2 | 0.025 | 0.034 | 0.036 | 0.035 | 0.015 | 0.036 | 0.02% |
| R3 | 0.010 | 0.015 | 0.021 | 0.032 | 0.010 | 0.032 | 0.02% |
| R4 | 0.064 | 0.133 | 0.059 | 0.074 | 0.025 | 0.133 | 0.07% |
| R5 | 0.366 | 0.373 | 0.282 | 0.328 | 0.250 | 0.373 | 0.19% |
| R6 | 0.012 | 0.074 | 0.055 | 0.059 | 0.053 | 0.074 | 0.04% |
| R7 | 0.084 | 0.114 | 0.153 | 0.118 | 0.139 | 0.153 | 0.08% |
| R8 | 0.225 | 0.262 | 0.170 | 0.214 | 0.070 | 0.262 | 0.13% |
| R9 | 0.224 | 0.272 | 0.246 | 0.211 | 0.271 | 0.272 | 0.14% |
| R10 | 2.406 | 1.427 | 1.991 | 1.327 | 1.010 | 2.406 | 1.20% |
| R11 | 3.310 | 3.332 | 3.158 | 3.505 | 2.859 | 3.505 | 1.75% |
| R12 | 3.285 | 3.607 | 3.312 | 3.203 | 2.375 | 3.607 | 1.80% |
| R13 | 0.979 | 1.980 | 1.712 | 1.275 | 1.016 | 1.980 | 0.99% |
| R14 | 1.210 | 1.858 | 1.155 | 1.347 | 0.637 | 1.858 | 0.93% |
| R15 | 2.458 | 3.373 | 2.401 | 2.781 | 2.811 | 3.373 | 1.69% |
| R16 | 1.818 | 2.792 | 2.528 | 2.633 | 2.158 | 2.792 | 1.40% |
| R17 | 3.574 | 3.604 | 3.643 | 3.552 | 3.174 | 3.643 | 1.82% |
| R18 | 3.879 | 3.801 | 3.897 | 3.896 | 3.676 | 3.897 | 1.95% |
| R19 | 4.077 | 3.895 | 3.737 | 3.839 | 3.561 | 4.077 | 2.04% |
| R20 | 3.071 | 3.233 | 3.361 | 3.831 | 3.262 | 3.831 | 1.92% |
| R21 | 3.289 | 4.203 | 4.072 | 4.119 | 3.872 | 4.203 | 2.10% |
| R22 | 1.374 | 2.683 | 2.401 | 2.035 | 1.476 | 2.683 | 1.34% |
| R23 | 2.189 | 2.739 | 3.072 | 2.881 | 2.505 | 3.072 | 1.54% |
| R24 | 2.123 | 2.177 | 2.309 | 2.589 | 1.807 | 2.589 | 1.29% |
| R25 | 3.474 | 3.058 | 3.708 | 2.574 | 3.248 | 3.708 | 1.85% |
| R26 | 3.084 | 2.847 | 2.974 | 3.232 | 2.462 | 3.232 | 1.62% |
| R27 | 2.856 | 2.540 | 2.925 | 3.095 | 2.044 | 3.095 | 1.55% |
| R28 | 3.255 | 3.595 | 3.951 | 3.498 | 2.955 | 3.951 | 1.98% |
| R29 | 2.962 | 3.328 | 3.200 | 2.782 | 3.353 | 3.353 | 1.68% |
| R30 | 2.950 | 3.529 | 3.046 | 3.175 | 3.321 | 3.529 | 1.76% |
| R31 | 0.373 | 0.114 | 0.227 | 0.129 | 0.045 | 0.373 | 0.19% |
| R32 | 0.786 | 1.186 | 0.740 | 0.718 | 0.791 | 1.186 | 0.59% |
| R33 | 0.262 | 0.233 | 0.202 | 0.253 | 0.113 | 0.262 | 0.13% |
| R34 | 0.925 | 1.029 | 0.992 | 1.261 | 0.489 | 1.261 | 0.63% |
| R35 | 0.560 | 1.385 | 0.720 | 0.909 | 0.315 | 1.385 | 0.69% |
| R36 | 0.060 | 0.187 | 0.161 | 0.151 | 0.173 | 0.187 | 0.09% |

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| R37 | 1.964 | 1.631 | 1.421 | 1.498 | 1.473 | 1.964 | 0.98% |
| R38 | 2.681 | 3.059 | 1.613 | 2.933 | 1.879 | 3.059 | 1.53% |
| R39 | 3.932 | 2.841 | 3.403 | 2.994 | 2.616 | 3.932 | 1.97% |
| R40 | 3.062 | 2.482 | 2.867 | 3.248 | 2.244 | 3.248 | 1.62% |
| R41 | 3.620 | 3.386 | 3.292 | 3.590 | 2.989 | 3.620 | 1.81% |
| R42 | 3.710 | 3.613 | 3.558 | 3.686 | 3.520 | 3.710 | 1.86% |
| R43 | 3.712 | 3.830 | 3.926 | 3.975 | 3.378 | 3.975 | 1.99% |
| R44 | 3.425 | 3.123 | 3.468 | 3.459 | 3.398 | 3.468 | 1.73% |
| R45 | 3.677 | 3.719 | 4.250 | 3.880 | 4.027 | 4.250 | 2.13% |

**Table E-3 – Particulate Matter (PM) Process Contribution (PC)**

| | $PM_{10}$ Annual Mean | | $PM_{10}$ Daily Mean | | $PM_{2.5}$ Annual Mean | |
|---|---|---|---|---|---|---|
| | Max (µg/m³) | PC as % AQAL | Max (µg/m³) | PC as % AQAL | Max (µg/m³) | PC as % AQAL |
| Max on Grid | 0.014 | 0.04% | 0.318 | 0.64% | 0.014 | 0.07% |
| R1 | 0.000 | 0.00% | 0.000 | 0.00% | 0.000 | 0.00% |
| R2 | 0.000 | 0.00% | 0.000 | 0.00% | 0.000 | 0.00% |
| R3 | 0.000 | 0.00% | 0.000 | 0.00% | 0.000 | 0.00% |
| R4 | 0.000 | 0.00% | 0.000 | 0.00% | 0.000 | 0.00% |
| R5 | 0.001 | 0.00% | 0.002 | 0.00% | 0.001 | 0.00% |
| R6 | 0.000 | 0.00% | 0.000 | 0.00% | 0.000 | 0.00% |
| R7 | 0.000 | 0.00% | 0.000 | 0.00% | 0.000 | 0.00% |
| R8 | 0.000 | 0.00% | 0.000 | 0.00% | 0.000 | 0.00% |
| R9 | 0.000 | 0.00% | 0.001 | 0.00% | 0.000 | 0.00% |
| R10 | 0.002 | 0.01% | 0.004 | 0.01% | 0.002 | 0.01% |
| R11 | 0.005 | 0.01% | 0.017 | 0.03% | 0.005 | 0.03% |
| R12 | 0.005 | 0.01% | 0.015 | 0.03% | 0.005 | 0.03% |
| R13 | 0.002 | 0.00% | 0.002 | 0.00% | 0.002 | 0.01% |
| R14 | 0.002 | 0.00% | 0.003 | 0.01% | 0.002 | 0.01% |
| R15 | 0.005 | 0.01% | 0.014 | 0.03% | 0.005 | 0.02% |
| R16 | 0.003 | 0.01% | 0.009 | 0.02% | 0.003 | 0.02% |
| R17 | 0.011 | 0.03% | 0.045 | 0.09% | 0.011 | 0.06% |
| R18 | 0.010 | 0.03% | 0.038 | 0.08% | 0.010 | 0.05% |
| R19 | 0.009 | 0.02% | 0.039 | 0.08% | 0.009 | 0.05% |
| R20 | 0.008 | 0.02% | 0.035 | 0.07% | 0.008 | 0.04% |
| R21 | 0.014 | 0.03% | 0.049 | 0.10% | 0.014 | 0.07% |
| R22 | 0.003 | 0.01% | 0.007 | 0.01% | 0.003 | 0.01% |
| R23 | 0.004 | 0.01% | 0.012 | 0.02% | 0.004 | 0.02% |
| R24 | 0.003 | 0.01% | 0.004 | 0.01% | 0.003 | 0.01% |
| R25 | 0.005 | 0.01% | 0.016 | 0.03% | 0.005 | 0.02% |
| R26 | 0.003 | 0.01% | 0.010 | 0.02% | 0.003 | 0.02% |
| R27 | 0.003 | 0.01% | 0.007 | 0.01% | 0.003 | 0.01% |
| R28 | 0.006 | 0.01% | 0.021 | 0.04% | 0.006 | 0.03% |
| R29 | 0.006 | 0.01% | 0.021 | 0.04% | 0.006 | 0.03% |
| R30 | 0.006 | 0.01% | 0.022 | 0.04% | 0.006 | 0.03% |
| R31 | 0.000 | 0.00% | 0.000 | 0.00% | 0.000 | 0.00% |
| R32 | 0.002 | 0.00% | 0.004 | 0.01% | 0.002 | 0.01% |
| R33 | 0.000 | 0.00% | 0.000 | 0.00% | 0.000 | 0.00% |
| R34 | 0.001 | 0.00% | 0.002 | 0.00% | 0.001 | 0.01% |
| R35 | 0.001 | 0.00% | 0.000 | 0.00% | 0.001 | 0.01% |

| | $PM_{10}$ Annual Mean | | $PM_{10}$ Daily Mean | | $PM_{2.5}$ Annual Mean | |
|---|---|---|---|---|---|---|
| | Max (µg/m$^3$) | PC as % AQAL | Max (µg/m$^3$) | PC as % AQAL | Max (µg/m$^3$) | PC as % AQAL |
| R36 | 0.000 | 0.00% | 0.000 | 0.00% | 0.000 | 0.00% |
| R37 | 0.002 | 0.00% | 0.003 | 0.01% | 0.002 | 0.01% |
| R38 | 0.004 | 0.01% | 0.005 | 0.01% | 0.004 | 0.02% |
| R39 | 0.005 | 0.01% | 0.023 | 0.05% | 0.005 | 0.03% |
| R40 | 0.004 | 0.01% | 0.009 | 0.02% | 0.004 | 0.02% |
| R41 | 0.007 | 0.02% | 0.028 | 0.06% | 0.007 | 0.03% |
| R42 | 0.011 | 0.03% | 0.048 | 0.10% | 0.011 | 0.06% |
| R43 | 0.006 | 0.02% | 0.022 | 0.04% | 0.006 | 0.03% |
| R44 | 0.012 | 0.03% | 0.045 | 0.09% | 0.012 | 0.06% |
| R45 | 0.000 | 0.00% | 0.048 | 0.10% | 0.000 | 0.00% |

Table E-4 – $SO_2$ Process Contribution (PC)

| | Daily Mean | | Hourly Mean | | 15min Mean | |
|---|---|---|---|---|---|---|
| | Max ($\mu g/m^3$) | PC as % AQAL | Max ($\mu g/m^3$) | PC as % AQAL | Max ($\mu g/m^3$) | PC as % AQAL |
| Max on Grid | 1.319 | 3.30% | 10.308 | 25.77% | 19.222 | 48.06% |
| R1 | 0.041 | 0.10% | 0.151 | 0.38% | 0.645 | 1.61% |
| R2 | 0.017 | 0.04% | 0.026 | 0.07% | 0.276 | 0.69% |
| R3 | 0.014 | 0.04% | 0.023 | 0.06% | 0.144 | 0.36% |
| R4 | 0.037 | 0.09% | 0.092 | 0.23% | 0.404 | 1.01% |
| R5 | 0.091 | 0.23% | 0.360 | 0.90% | 1.565 | 3.91% |
| R6 | 0.031 | 0.08% | 0.060 | 0.15% | 0.410 | 1.02% |
| R7 | 0.052 | 0.13% | 0.133 | 0.33% | 0.777 | 1.94% |
| R8 | 0.059 | 0.15% | 0.217 | 0.54% | 1.202 | 3.01% |
| R9 | 0.076 | 0.19% | 0.248 | 0.62% | 1.104 | 2.76% |
| R10 | 0.644 | 1.61% | 2.221 | 5.55% | 7.532 | 18.83% |
| R11 | 0.705 | 1.76% | 3.374 | 8.44% | 11.577 | 28.94% |
| R12 | 1.175 | 2.94% | 3.259 | 8.15% | 10.532 | 26.33% |
| R13 | 0.544 | 1.36% | 1.881 | 4.70% | 8.171 | 20.43% |
| R14 | 0.533 | 1.33% | 1.487 | 3.72% | 7.711 | 19.28% |
| R15 | 0.741 | 1.85% | 3.207 | 8.02% | 10.247 | 25.62% |
| R16 | 0.549 | 1.37% | 2.507 | 6.27% | 9.248 | 23.12% |
| R17 | 0.913 | 2.28% | 3.633 | 9.08% | 10.743 | 26.86% |
| R18 | 1.156 | 2.89% | 3.907 | 9.77% | 11.624 | 29.06% |
| R19 | 0.781 | 1.95% | 4.090 | 10.23% | 14.431 | 36.08% |
| R20 | 0.766 | 1.91% | 3.552 | 8.88% | 14.174 | 35.43% |
| R21 | 0.950 | 2.37% | 4.100 | 10.25% | 15.655 | 39.14% |
| R22 | 0.661 | 1.65% | 2.450 | 6.13% | 9.130 | 22.82% |
| R23 | 0.610 | 1.53% | 2.913 | 7.28% | 11.031 | 27.58% |
| R24 | 0.550 | 1.37% | 2.451 | 6.13% | 9.386 | 23.47% |
| R25 | 0.772 | 1.93% | 3.410 | 8.52% | 13.206 | 33.01% |
| R26 | 0.585 | 1.46% | 3.066 | 7.67% | 11.565 | 28.91% |
| R27 | 0.452 | 1.13% | 2.760 | 6.90% | 11.169 | 27.92% |
| R28 | 0.668 | 1.67% | 3.644 | 9.11% | 14.046 | 35.11% |
| R29 | 0.680 | 1.70% | 3.275 | 8.19% | 11.933 | 29.83% |
| R30 | 0.726 | 1.81% | 3.504 | 8.76% | 11.041 | 27.60% |
| R31 | 0.095 | 0.24% | 0.234 | 0.58% | 1.195 | 2.99% |
| R32 | 0.281 | 0.70% | 1.159 | 2.90% | 3.526 | 8.82% |
| R33 | 0.072 | 0.18% | 0.214 | 0.54% | 1.211 | 3.03% |
| R34 | 0.255 | 0.64% | 0.997 | 2.49% | 4.710 | 11.77% |

| | Daily Mean | | Hourly Mean | | 15min Mean | |
|---|---|---|---|---|---|---|
| | Max ($\mu g/m^3$) | PC as % AQAL | Max ($\mu g/m^3$) | PC as % AQAL | Max ($\mu g/m^3$) | PC as % AQAL |
| R35 | 0.380 | 0.95% | 1.063 | 2.66% | 5.927 | 14.82% |
| R36 | 0.055 | 0.14% | 0.168 | 0.42% | 0.730 | 1.82% |
| R37 | 0.533 | 1.33% | 1.809 | 4.52% | 7.253 | 18.13% |
| R38 | 0.737 | 1.84% | 2.723 | 6.81% | 10.833 | 27.08% |
| R39 | 0.751 | 1.88% | 3.548 | 8.87% | 13.390 | 33.47% |
| R40 | 0.670 | 1.67% | 3.034 | 7.59% | 12.654 | 31.63% |
| R41 | 0.673 | 1.68% | 3.624 | 9.06% | 11.374 | 28.44% |
| R42 | 0.879 | 2.20% | 3.696 | 9.24% | 12.213 | 30.53% |
| R43 | 1.195 | 2.99% | 3.930 | 9.83% | 11.993 | 29.98% |
| R44 | 0.868 | 2.17% | 3.406 | 8.51% | 11.780 | 29.45% |
| R45 | 0.843 | 2.11% | 3.938 | 9.85% | 15.190 | 37.97% |

**Table E-5 – HCl and $NH_3$ Process Contribution (PC)**

| | NH3 Annual Mean | | NH3 Hourly Mean | | HCl Hourly Mean | |
|---|---|---|---|---|---|---|
| | Max (µg/m$^3$) | PC as % AQAL | Max (µg/m$^3$) | PC as % AQAL | Max (µg/m$^3$) | PC as % AQAL |
| Max on Grid | 0.012 | 0.01% | 1.367 | 0.05% | 1.640 | 0.22% |
| R1 | 0.000 | 0.00% | 0.080 | 0.00% | 0.096 | 0.01% |
| R2 | 0.000 | 0.00% | 0.112 | 0.00% | 0.134 | 0.02% |
| R3 | 0.000 | 0.00% | 0.056 | 0.00% | 0.067 | 0.01% |
| R4 | 0.000 | 0.00% | 0.086 | 0.00% | 0.103 | 0.01% |
| R5 | 0.001 | 0.00% | 0.148 | 0.01% | 0.178 | 0.02% |
| R6 | 0.000 | 0.00% | 0.079 | 0.00% | 0.095 | 0.01% |
| R7 | 0.000 | 0.00% | 0.098 | 0.00% | 0.118 | 0.02% |
| R8 | 0.000 | 0.00% | 0.134 | 0.01% | 0.161 | 0.02% |
| R9 | 0.000 | 0.00% | 0.130 | 0.01% | 0.156 | 0.02% |
| R10 | 0.002 | 0.00% | 0.565 | 0.02% | 0.678 | 0.09% |
| R11 | 0.005 | 0.00% | 0.935 | 0.04% | 1.123 | 0.15% |
| R12 | 0.005 | 0.00% | 0.731 | 0.03% | 0.878 | 0.12% |
| R13 | 0.002 | 0.00% | 0.614 | 0.02% | 0.737 | 0.10% |
| R14 | 0.002 | 0.00% | 0.605 | 0.02% | 0.726 | 0.10% |
| R15 | 0.004 | 0.00% | 0.951 | 0.04% | 1.141 | 0.15% |
| R16 | 0.003 | 0.00% | 0.638 | 0.03% | 0.765 | 0.10% |
| R17 | 0.010 | 0.01% | 1.179 | 0.05% | 1.415 | 0.19% |
| R18 | 0.009 | 0.00% | 0.825 | 0.03% | 0.990 | 0.13% |
| R19 | 0.008 | 0.00% | 1.015 | 0.04% | 1.218 | 0.16% |
| R20 | 0.008 | 0.00% | 0.962 | 0.04% | 1.154 | 0.15% |
| R21 | 0.012 | 0.01% | 0.935 | 0.04% | 1.122 | 0.15% |
| R22 | 0.003 | 0.00% | 0.697 | 0.03% | 0.837 | 0.11% |
| R23 | 0.003 | 0.00% | 1.044 | 0.04% | 1.253 | 0.17% |
| R24 | 0.003 | 0.00% | 1.285 | 0.05% | 1.543 | 0.21% |
| R25 | 0.004 | 0.00% | 0.900 | 0.04% | 1.080 | 0.14% |
| R26 | 0.003 | 0.00% | 0.932 | 0.04% | 1.118 | 0.15% |
| R27 | 0.003 | 0.00% | 0.866 | 0.03% | 1.039 | 0.14% |
| R28 | 0.005 | 0.00% | 0.859 | 0.03% | 1.030 | 0.14% |
| R29 | 0.005 | 0.00% | 1.078 | 0.04% | 1.294 | 0.17% |
| R30 | 0.005 | 0.00% | 1.045 | 0.04% | 1.255 | 0.17% |
| R31 | 0.000 | 0.00% | 0.130 | 0.01% | 0.155 | 0.02% |
| R32 | 0.002 | 0.00% | 0.271 | 0.01% | 0.326 | 0.04% |
| R33 | 0.000 | 0.00% | 0.232 | 0.01% | 0.279 | 0.04% |
| R34 | 0.001 | 0.00% | 0.649 | 0.03% | 0.779 | 0.10% |
| R35 | 0.001 | 0.00% | 0.680 | 0.03% | 0.816 | 0.11% |

| | NH3 Annual Mean | | NH3 Hourly Mean | | HCl Hourly Mean | |
|---|---|---|---|---|---|---|
| | Max (µg/m$^3$) | PC as % AQAL | Max (µg/m$^3$) | PC as % AQAL | Max (µg/m$^3$) | PC as % AQAL |
| R36 | 0.000 | 0.00% | 0.178 | 0.01% | 0.214 | 0.03% |
| R37 | 0.002 | 0.00% | 0.619 | 0.02% | 0.743 | 0.10% |
| R38 | 0.003 | 0.00% | 0.814 | 0.03% | 0.977 | 0.13% |
| R39 | 0.005 | 0.00% | 0.705 | 0.03% | 0.846 | 0.11% |
| R40 | 0.003 | 0.00% | 0.791 | 0.03% | 0.949 | 0.13% |
| R41 | 0.006 | 0.00% | 1.249 | 0.05% | 1.499 | 0.20% |
| R42 | 0.010 | 0.01% | 1.278 | 0.05% | 1.533 | 0.20% |
| R43 | 0.006 | 0.00% | 0.799 | 0.03% | 0.959 | 0.13% |
| R44 | 0.011 | 0.01% | 1.003 | 0.04% | 1.204 | 0.16% |
| R45 | 0.012 | 0.01% | 1.154 | 0.05% | 1.385 | 0.18% |

### Table E-6 – Alderhydes Process Contribution (PC)

| | Formaldehyde Annual Mean | | Formaldehyde 30min Mean | | Acetaldehyde Annual Mean | | Acetaldehyde Hourly Mean | |
|---|---|---|---|---|---|---|---|---|
| | Max (µg/m³) | PC as % AQAL | Max (µg/m³) | PC as % AQAL | Max (µg/m³) | PC as % AQAL | Max (µg/m³) | PC as % AQAL |
| Max on Grid | 0.001 | 0.02% | 0.155 | 0.15% | 0.008 | 0.00% | 0.893 | 0.01% |
| R1 | 0.000 | 0.00% | 0.007 | 0.01% | 0.000 | 0.00% | 0.052 | 0.00% |
| R2 | 0.000 | 0.00% | 0.010 | 0.01% | 0.000 | 0.00% | 0.073 | 0.00% |
| R3 | 0.000 | 0.00% | 0.005 | 0.01% | 0.000 | 0.00% | 0.036 | 0.00% |
| R4 | 0.000 | 0.00% | 0.008 | 0.01% | 0.000 | 0.00% | 0.056 | 0.00% |
| R5 | 0.000 | 0.00% | 0.014 | 0.01% | 0.000 | 0.00% | 0.097 | 0.00% |
| R6 | 0.000 | 0.00% | 0.007 | 0.01% | 0.000 | 0.00% | 0.052 | 0.00% |
| R7 | 0.000 | 0.00% | 0.009 | 0.01% | 0.000 | 0.00% | 0.064 | 0.00% |
| R8 | 0.000 | 0.00% | 0.012 | 0.01% | 0.000 | 0.00% | 0.088 | 0.00% |
| R9 | 0.000 | 0.00% | 0.012 | 0.01% | 0.000 | 0.00% | 0.085 | 0.00% |
| R10 | 0.000 | 0.00% | 0.055 | 0.06% | 0.001 | 0.00% | 0.369 | 0.00% |
| R11 | 0.000 | 0.01% | 0.102 | 0.10% | 0.003 | 0.00% | 0.612 | 0.01% |
| R12 | 0.000 | 0.01% | 0.068 | 0.07% | 0.003 | 0.00% | 0.478 | 0.01% |
| R13 | 0.000 | 0.00% | 0.059 | 0.06% | 0.001 | 0.00% | 0.401 | 0.00% |
| R14 | 0.000 | 0.00% | 0.058 | 0.06% | 0.001 | 0.00% | 0.395 | 0.00% |
| R15 | 0.000 | 0.01% | 0.108 | 0.11% | 0.003 | 0.00% | 0.622 | 0.01% |
| R16 | 0.000 | 0.01% | 0.060 | 0.06% | 0.002 | 0.00% | 0.417 | 0.00% |
| R17 | 0.001 | 0.02% | 0.132 | 0.13% | 0.007 | 0.00% | 0.771 | 0.01% |
| R18 | 0.001 | 0.02% | 0.093 | 0.09% | 0.006 | 0.00% | 0.539 | 0.01% |
| R19 | 0.001 | 0.01% | 0.117 | 0.12% | 0.005 | 0.00% | 0.664 | 0.01% |
| R20 | 0.001 | 0.01% | 0.108 | 0.11% | 0.005 | 0.00% | 0.629 | 0.01% |
| R21 | 0.001 | 0.02% | 0.107 | 0.11% | 0.008 | 0.00% | 0.611 | 0.01% |
| R22 | 0.000 | 0.00% | 0.068 | 0.07% | 0.002 | 0.00% | 0.456 | 0.00% |
| R23 | 0.000 | 0.01% | 0.114 | 0.11% | 0.002 | 0.00% | 0.683 | 0.01% |
| R24 | 0.000 | 0.00% | 0.143 | 0.14% | 0.002 | 0.00% | 0.840 | 0.01% |
| R25 | 0.000 | 0.01% | 0.100 | 0.10% | 0.003 | 0.00% | 0.588 | 0.01% |
| R26 | 0.000 | 0.01% | 0.105 | 0.10% | 0.002 | 0.00% | 0.609 | 0.01% |
| R27 | 0.000 | 0.00% | 0.090 | 0.09% | 0.002 | 0.00% | 0.566 | 0.01% |
| R28 | 0.000 | 0.01% | 0.090 | 0.09% | 0.003 | 0.00% | 0.561 | 0.01% |
| R29 | 0.000 | 0.01% | 0.121 | 0.12% | 0.003 | 0.00% | 0.705 | 0.01% |
| R30 | 0.000 | 0.01% | 0.113 | 0.11% | 0.003 | 0.00% | 0.683 | 0.01% |
| R31 | 0.000 | 0.00% | 0.012 | 0.01% | 0.000 | 0.00% | 0.085 | 0.00% |
| R32 | 0.000 | 0.00% | 0.025 | 0.03% | 0.001 | 0.00% | 0.177 | 0.00% |
| R33 | 0.000 | 0.00% | 0.021 | 0.02% | 0.000 | 0.00% | 0.152 | 0.00% |
| R34 | 0.000 | 0.00% | 0.061 | 0.06% | 0.001 | 0.00% | 0.424 | 0.00% |

| | Formaldehyde Annual Mean | | Formaldehyde 30min Mean | | Acetaldehyde Annual Mean | | Acetaldehyde Hourly Mean | |
|---|---|---|---|---|---|---|---|---|
| | Max (µg/m$^3$) | PC as % AQAL | Max (µg/m$^3$) | PC as % AQAL | Max (µg/m$^3$) | PC as % AQAL | Max (µg/m$^3$) | PC as % AQAL |
| R35 | 0.000 | 0.00% | 0.064 | 0.06% | 0.001 | 0.00% | 0.445 | 0.00% |
| R36 | 0.000 | 0.00% | 0.017 | 0.02% | 0.000 | 0.00% | 0.117 | 0.00% |
| R37 | 0.000 | 0.00% | 0.068 | 0.07% | 0.001 | 0.00% | 0.405 | 0.00% |
| R38 | 0.000 | 0.01% | 0.077 | 0.08% | 0.002 | 0.00% | 0.532 | 0.01% |
| R39 | 0.000 | 0.01% | 0.077 | 0.08% | 0.003 | 0.00% | 0.461 | 0.01% |
| R40 | 0.000 | 0.01% | 0.082 | 0.08% | 0.002 | 0.00% | 0.517 | 0.01% |
| R41 | 0.001 | 0.01% | 0.138 | 0.14% | 0.004 | 0.00% | 0.817 | 0.01% |
| R42 | 0.001 | 0.02% | 0.146 | 0.15% | 0.006 | 0.00% | 0.835 | 0.01% |
| R43 | 0.001 | 0.01% | 0.091 | 0.09% | 0.004 | 0.00% | 0.522 | 0.01% |
| R44 | 0.001 | 0.02% | 0.113 | 0.11% | 0.007 | 0.00% | 0.656 | 0.01% |
| R45 | 0.001 | 0.02% | 0.129 | 0.13% | 0.008 | 0.00% | 0.754 | 0.01% |

**Table E-7 – Amides Process Contribution (PC)**

| | N-(2-hydroxyethyl) acetamide Annual Mean | | N-(2-hydroxyethyl) formamide Annual Mean | |
|---|---|---|---|---|
| | Max ($\mu g/m^3$) | PC as % AQAL | Max ($\mu g/m^3$) | PC as % AQAL |
| Max on Grid | 5.46E-07 | 0.01% | 5.46E-07 | 0.00% |
| R1 | 7.31E-09 | 0.00% | 7.31E-09 | 0.00% |
| R2 | 2.22E-09 | 0.00% | 2.22E-09 | 0.00% |
| R3 | 1.72E-09 | 0.00% | 1.72E-09 | 0.00% |
| R4 | 4.19E-09 | 0.00% | 4.19E-09 | 0.00% |
| R5 | 2.28E-08 | 0.00% | 2.28E-08 | 0.00% |
| R6 | 2.75E-09 | 0.00% | 2.75E-09 | 0.00% |
| R7 | 7.53E-09 | 0.00% | 7.53E-09 | 0.00% |
| R8 | 1.11E-08 | 0.00% | 1.11E-08 | 0.00% |
| R9 | 1.65E-08 | 0.00% | 1.65E-08 | 0.00% |
| R10 | 9.65E-08 | 0.00% | 9.65E-08 | 0.00% |
| R11 | 2.03E-07 | 0.00% | 2.03E-07 | 0.00% |
| R12 | 2.08E-07 | 0.00% | 2.08E-07 | 0.00% |
| R13 | 7.44E-08 | 0.00% | 7.44E-08 | 0.00% |
| R14 | 6.98E-08 | 0.00% | 6.98E-08 | 0.00% |
| R15 | 1.83E-07 | 0.00% | 1.83E-07 | 0.00% |
| R16 | 1.28E-07 | 0.00% | 1.28E-07 | 0.00% |
| R17 | 4.41E-07 | 0.01% | 4.41E-07 | 0.00% |
| R18 | 3.92E-07 | 0.00% | 3.92E-07 | 0.00% |
| R19 | 3.63E-07 | 0.00% | 3.63E-07 | 0.00% |
| R20 | 3.28E-07 | 0.00% | 3.28E-07 | 0.00% |
| R21 | 5.32E-07 | 0.01% | 5.32E-07 | 0.00% |
| R22 | 1.11E-07 | 0.00% | 1.11E-07 | 0.00% |
| R23 | 1.47E-07 | 0.00% | 1.47E-07 | 0.00% |
| R24 | 1.12E-07 | 0.00% | 1.12E-07 | 0.00% |
| R25 | 1.90E-07 | 0.00% | 1.90E-07 | 0.00% |
| R26 | 1.32E-07 | 0.00% | 1.32E-07 | 0.00% |
| R27 | 1.13E-07 | 0.00% | 1.13E-07 | 0.00% |
| R28 | 2.26E-07 | 0.00% | 2.26E-07 | 0.00% |
| R29 | 2.15E-07 | 0.00% | 2.15E-07 | 0.00% |
| R30 | 2.23E-07 | 0.00% | 2.23E-07 | 0.00% |
| R31 | 1.13E-08 | 0.00% | 1.13E-08 | 0.00% |
| R32 | 6.71E-08 | 0.00% | 6.71E-08 | 0.00% |
| R33 | 1.02E-08 | 0.00% | 1.02E-08 | 0.00% |
| R34 | 5.02E-08 | 0.00% | 5.02E-08 | 0.00% |
| R35 | 5.29E-08 | 0.00% | 5.29E-08 | 0.00% |
| R36 | 7.55E-09 | 0.00% | 7.55E-09 | 0.00% |

| | N-(2-hydroxyethyl) acetamide Annual Mean | | N-(2-hydroxyethyl) formamide Annual Mean | |
|---|---|---|---|---|
| | Max (µg/m$^3$) | PC as % AQAL | Max (µg/m$^3$) | PC as % AQAL |
| R37 | 7.38E-08 | 0.00% | 7.38E-08 | 0.00% |
| R38 | 1.42E-07 | 0.00% | 1.42E-07 | 0.00% |
| R39 | 2.12E-07 | 0.00% | 2.12E-07 | 0.00% |
| R40 | 1.46E-07 | 0.00% | 1.46E-07 | 0.00% |
| R41 | 2.70E-07 | 0.00% | 2.70E-07 | 0.00% |
| R42 | 4.34E-07 | 0.01% | 4.34E-07 | 0.00% |
| R43 | 2.47E-07 | 0.00% | 2.47E-07 | 0.00% |
| R44 | 4.61E-07 | 0.01% | 4.61E-07 | 0.00% |
| R45 | 5.10E-07 | 0.01% | 5.10E-07 | 0.00% |

### Table E-8 – Amine 1 Annual Mean Process Contribution (PC)

| | 2019 (µg/m$^3$) | 2020 (µg/m$^3$) | 2021 (µg/m$^3$) | 2022 (µg/m3) | 2023 (µg/m$^3$) | Max (µg/m$^3$) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| Max on Grid | 1.32E-03 | 1.35E-03 | 1.27E-03 | 1.36E-03 | 1.34E-03 | 1.36E-03 | 0.01% |
| R1 | 1.34E-05 | 1.83E-05 | 1.83E-05 | 1.24E-05 | 1.24E-05 | 1.83E-05 | 0.00% |
| R2 | 3.57E-06 | 5.54E-06 | 4.86E-06 | 3.39E-06 | 2.06E-06 | 5.54E-06 | 0.00% |
| R3 | 2.37E-06 | 4.30E-06 | 2.30E-06 | 2.81E-06 | 2.09E-06 | 4.30E-06 | 0.00% |
| R4 | 9.79E-06 | 1.05E-05 | 6.88E-06 | 8.22E-06 | 3.50E-06 | 1.05E-05 | 0.00% |
| R5 | 4.91E-05 | 5.71E-05 | 3.40E-05 | 4.36E-05 | 3.51E-05 | 5.71E-05 | 0.00% |
| R6 | 3.51E-06 | 5.87E-06 | 6.01E-06 | 6.87E-06 | 6.75E-06 | 6.87E-06 | 0.00% |
| R7 | 1.14E-05 | 1.64E-05 | 1.88E-05 | 1.52E-05 | 1.83E-05 | 1.88E-05 | 0.00% |
| R8 | 2.33E-05 | 2.78E-05 | 1.59E-05 | 2.32E-05 | 8.48E-06 | 2.78E-05 | 0.00% |
| R9 | 3.19E-05 | 4.13E-05 | 2.85E-05 | 3.21E-05 | 3.36E-05 | 4.13E-05 | 0.00% |
| R10 | 2.41E-04 | 1.27E-04 | 1.75E-04 | 1.59E-04 | 9.84E-05 | 2.41E-04 | 0.00% |
| R11 | 4.48E-04 | 3.94E-04 | 3.75E-04 | 5.08E-04 | 2.62E-04 | 5.08E-04 | 0.00% |
| R12 | 3.82E-04 | 5.20E-04 | 4.44E-04 | 4.03E-04 | 3.23E-04 | 5.20E-04 | 0.00% |
| R13 | 9.02E-05 | 1.86E-04 | 1.62E-04 | 1.38E-04 | 7.02E-05 | 1.86E-04 | 0.00% |
| R14 | 1.18E-04 | 1.74E-04 | 1.21E-04 | 1.17E-04 | 6.42E-05 | 1.74E-04 | 0.00% |
| R15 | 2.45E-04 | 4.56E-04 | 3.08E-04 | 3.36E-04 | 3.22E-04 | 4.56E-04 | 0.00% |
| R16 | 1.75E-04 | 3.12E-04 | 2.41E-04 | 3.20E-04 | 2.10E-04 | 3.20E-04 | 0.00% |
| R17 | 8.27E-04 | 1.10E-03 | 8.46E-04 | 8.86E-04 | 7.66E-04 | 1.10E-03 | 0.01% |
| R18 | 7.71E-04 | 9.79E-04 | 7.21E-04 | 7.84E-04 | 7.67E-04 | 9.79E-04 | 0.00% |
| R19 | 8.46E-04 | 9.06E-04 | 6.98E-04 | 7.78E-04 | 6.13E-04 | 9.06E-04 | 0.00% |
| R20 | 6.56E-04 | 7.39E-04 | 7.16E-04 | 8.20E-04 | 6.01E-04 | 8.20E-04 | 0.00% |
| R21 | 1.15E-03 | 1.33E-03 | 1.19E-03 | 1.26E-03 | 1.14E-03 | 1.33E-03 | 0.01% |
| R22 | 1.46E-04 | 2.78E-04 | 2.47E-04 | 2.29E-04 | 1.32E-04 | 2.78E-04 | 0.00% |
| R23 | 2.77E-04 | 3.39E-04 | 3.59E-04 | 3.67E-04 | 2.41E-04 | 3.67E-04 | 0.00% |
| R24 | 2.26E-04 | 1.62E-04 | 2.16E-04 | 2.79E-04 | 1.54E-04 | 2.79E-04 | 0.00% |
| R25 | 4.76E-04 | 4.14E-04 | 4.41E-04 | 2.50E-04 | 4.73E-04 | 4.76E-04 | 0.00% |
| R26 | 2.83E-04 | 2.47E-04 | 3.03E-04 | 3.30E-04 | 1.88E-04 | 3.30E-04 | 0.00% |
| R27 | 2.65E-04 | 1.93E-04 | 2.83E-04 | 2.84E-04 | 1.68E-04 | 2.84E-04 | 0.00% |
| R28 | 4.90E-04 | 4.83E-04 | 4.62E-04 | 5.64E-04 | 3.12E-04 | 5.64E-04 | 0.00% |
| R29 | 2.68E-04 | 5.37E-04 | 4.78E-04 | 3.30E-04 | 4.16E-04 | 5.37E-04 | 0.00% |
| R30 | 2.74E-04 | 5.57E-04 | 4.86E-04 | 4.16E-04 | 4.46E-04 | 5.57E-04 | 0.00% |
| R31 | 2.82E-05 | 1.14E-05 | 2.15E-05 | 1.22E-05 | 7.19E-06 | 2.82E-05 | 0.00% |
| R32 | 1.25E-04 | 1.68E-04 | 9.33E-05 | 1.10E-04 | 1.14E-04 | 1.68E-04 | 0.00% |
| R33 | 2.46E-05 | 2.56E-05 | 2.03E-05 | 2.38E-05 | 1.18E-05 | 2.56E-05 | 0.00% |
| R34 | 9.54E-05 | 1.05E-04 | 9.01E-05 | 1.25E-04 | 5.77E-05 | 1.25E-04 | 0.00% |
| R35 | 5.58E-05 | 1.32E-04 | 6.10E-05 | 7.13E-05 | 2.82E-05 | 1.32E-04 | 0.00% |
| R36 | 6.35E-06 | 1.89E-05 | 1.57E-05 | 1.25E-05 | 1.84E-05 | 1.89E-05 | 0.00% |

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| R37 | 1.84E-04 | 1.73E-04 | 1.71E-04 | 1.62E-04 | 1.65E-04 | 1.84E-04 | 0.00% |
| R38 | 2.80E-04 | 3.55E-04 | 1.74E-04 | 2.57E-04 | 2.36E-04 | 3.55E-04 | 0.00% |
| R39 | 5.30E-04 | 2.59E-04 | 3.16E-04 | 3.28E-04 | 2.32E-04 | 5.30E-04 | 0.00% |
| R40 | 3.66E-04 | 2.07E-04 | 2.85E-04 | 3.40E-04 | 1.84E-04 | 3.66E-04 | 0.00% |
| R41 | 6.74E-04 | 6.71E-04 | 5.13E-04 | 6.29E-04 | 4.25E-04 | 6.74E-04 | 0.00% |
| R42 | 9.30E-04 | 1.09E-03 | 7.05E-04 | 8.03E-04 | 7.92E-04 | 1.09E-03 | 0.00% |
| R43 | 4.74E-04 | 6.18E-04 | 6.15E-04 | 5.93E-04 | 4.33E-04 | 6.18E-04 | 0.00% |
| R44 | 9.09E-04 | 1.15E-03 | 9.30E-04 | 1.02E-03 | 9.05E-04 | 1.15E-03 | 0.01% |
| R45 | 1.13E-03 | 1.27E-03 | 1.13E-03 | 1.20E-03 | 1.16E-03 | 1.27E-03 | 0.01% |

**Table E-9 – Amine 1 Hourly Mean Process Contribution (PC)**

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| Max on Grid | 0.14 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.01% |
| R1 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00% |
| R2 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00% |
| R3 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00% |
| R4 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00% |
| R5 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.00% |
| R6 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00% |
| R7 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00% |
| R8 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00% |
| R9 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00% |
| R10 | 0.06 | 0.06 | 0.06 | 0.06 | 0.04 | 0.06 | 0.00% |
| R11 | 0.09 | 0.09 | 0.10 | 0.08 | 0.10 | 0.10 | 0.00% |
| R12 | 0.07 | 0.08 | 0.07 | 0.07 | 0.07 | 0.08 | 0.00% |
| R13 | 0.05 | 0.07 | 0.06 | 0.05 | 0.04 | 0.07 | 0.00% |
| R14 | 0.06 | 0.06 | 0.05 | 0.07 | 0.03 | 0.07 | 0.00% |
| R15 | 0.07 | 0.09 | 0.05 | 0.08 | 0.10 | 0.10 | 0.00% |
| R16 | 0.06 | 0.07 | 0.07 | 0.07 | 0.06 | 0.07 | 0.00% |
| R17 | 0.09 | 0.13 | 0.09 | 0.10 | 0.10 | 0.13 | 0.00% |
| R18 | 0.09 | 0.07 | 0.09 | 0.08 | 0.08 | 0.09 | 0.00% |
| R19 | 0.10 | 0.10 | 0.08 | 0.11 | 0.09 | 0.11 | 0.00% |
| R20 | 0.10 | 0.11 | 0.09 | 0.09 | 0.09 | 0.11 | 0.00% |
| R21 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.00% |
| R22 | 0.06 | 0.08 | 0.07 | 0.05 | 0.05 | 0.08 | 0.00% |
| R23 | 0.07 | 0.08 | 0.08 | 0.11 | 0.11 | 0.11 | 0.00% |
| R24 | 0.12 | 0.08 | 0.09 | 0.14 | 0.07 | 0.14 | 0.01% |
| R25 | 0.08 | 0.07 | 0.08 | 0.07 | 0.10 | 0.10 | 0.00% |
| R26 | 0.08 | 0.10 | 0.08 | 0.08 | 0.07 | 0.10 | 0.00% |
| R27 | 0.07 | 0.09 | 0.07 | 0.09 | 0.06 | 0.09 | 0.00% |
| R28 | 0.09 | 0.08 | 0.08 | 0.08 | 0.09 | 0.09 | 0.00% |
| R29 | 0.10 | 0.07 | 0.09 | 0.08 | 0.12 | 0.12 | 0.00% |
| R30 | 0.08 | 0.11 | 0.07 | 0.09 | 0.11 | 0.11 | 0.00% |
| R31 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00% |
| R32 | 0.03 | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 | 0.00% |
| R33 | 0.02 | 0.02 | 0.03 | 0.01 | 0.02 | 0.03 | 0.00% |
| R34 | 0.05 | 0.07 | 0.06 | 0.05 | 0.05 | 0.07 | 0.00% |
| R35 | 0.04 | 0.07 | 0.04 | 0.06 | 0.03 | 0.07 | 0.00% |
| R36 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.02 | 0.00% |

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| R37 | 0.07 | 0.07 | 0.06 | 0.06 | 0.06 | 0.07 | 0.00% |
| R38 | 0.09 | 0.07 | 0.04 | 0.07 | 0.07 | 0.09 | 0.00% |
| R39 | 0.07 | 0.07 | 0.08 | 0.07 | 0.08 | 0.08 | 0.00% |
| R40 | 0.08 | 0.08 | 0.08 | 0.09 | 0.08 | 0.09 | 0.00% |
| R41 | 0.14 | 0.08 | 0.08 | 0.12 | 0.08 | 0.14 | 0.00% |
| R42 | 0.14 | 0.12 | 0.09 | 0.07 | 0.10 | 0.14 | 0.00% |
| R43 | 0.07 | 0.09 | 0.07 | 0.07 | 0.07 | 0.09 | 0.00% |
| R44 | 0.10 | 0.11 | 0.07 | 0.11 | 0.11 | 0.11 | 0.00% |
| R45 | 0.11 | 0.11 | 0.13 | 0.10 | 0.11 | 0.13 | 0.00% |

**Table E-10 – Amine 3 Annual Mean Process Contribution (PC)**

| | 2019 (µg/m$^3$) | 2020 (µg/m$^3$) | 2021 (µg/m$^3$) | 2022 (µg/m3) | 2023 (µg/m$^3$) | Max (µg/m$^3$) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| Max on Grid | 6.40E-04 | 6.89E-04 | 5.55E-04 | 6.04E-04 | 6.25E-04 | 6.89E-04 | 0.00% |
| R1 | 7.70E-06 | 1.05E-05 | 1.02E-05 | 6.99E-06 | 7.00E-06 | 1.05E-05 | 0.00% |
| R2 | 1.98E-06 | 3.10E-06 | 2.71E-06 | 1.90E-06 | 1.13E-06 | 3.10E-06 | 0.00% |
| R3 | 1.33E-06 | 2.37E-06 | 1.28E-06 | 1.56E-06 | 1.14E-06 | 2.37E-06 | 0.00% |
| R4 | 5.42E-06 | 5.80E-06 | 3.82E-06 | 4.59E-06 | 1.94E-06 | 5.80E-06 | 0.00% |
| R5 | 2.73E-05 | 3.23E-05 | 1.89E-05 | 2.44E-05 | 1.95E-05 | 3.23E-05 | 0.00% |
| R6 | 1.90E-06 | 3.26E-06 | 3.44E-06 | 3.80E-06 | 3.70E-06 | 3.80E-06 | 0.00% |
| R7 | 6.49E-06 | 9.30E-06 | 1.05E-05 | 8.43E-06 | 1.02E-05 | 1.05E-05 | 0.00% |
| R8 | 1.28E-05 | 1.52E-05 | 8.72E-06 | 1.29E-05 | 4.76E-06 | 1.52E-05 | 0.00% |
| R9 | 1.77E-05 | 2.33E-05 | 1.59E-05 | 1.79E-05 | 1.86E-05 | 2.33E-05 | 0.00% |
| R10 | 1.07E-04 | 5.57E-05 | 7.74E-05 | 7.69E-05 | 4.33E-05 | 1.07E-04 | 0.00% |
| R11 | 2.02E-04 | 1.71E-04 | 1.51E-04 | 2.31E-04 | 1.25E-04 | 2.31E-04 | 0.00% |
| R12 | 2.19E-04 | 3.01E-04 | 2.55E-04 | 2.29E-04 | 1.84E-04 | 3.01E-04 | 0.00% |
| R13 | 4.19E-05 | 9.73E-05 | 8.25E-05 | 6.72E-05 | 3.14E-05 | 9.73E-05 | 0.00% |
| R14 | 6.08E-05 | 9.25E-05 | 5.89E-05 | 5.74E-05 | 2.96E-05 | 9.25E-05 | 0.00% |
| R15 | 1.00E-04 | 2.11E-04 | 1.30E-04 | 1.50E-04 | 1.34E-04 | 2.11E-04 | 0.00% |
| R16 | 9.43E-05 | 1.72E-04 | 1.31E-04 | 1.75E-04 | 1.14E-04 | 1.75E-04 | 0.00% |
| R17 | 4.42E-04 | 6.09E-04 | 4.40E-04 | 4.56E-04 | 4.01E-04 | 6.09E-04 | 0.00% |
| R18 | 4.19E-04 | 5.39E-04 | 3.78E-04 | 4.10E-04 | 4.08E-04 | 5.39E-04 | 0.00% |
| R19 | 3.62E-04 | 3.87E-04 | 2.61E-04 | 3.06E-04 | 2.73E-04 | 3.87E-04 | 0.00% |
| R20 | 3.14E-04 | 3.60E-04 | 3.42E-04 | 3.88E-04 | 2.83E-04 | 3.88E-04 | 0.00% |
| R21 | 5.71E-04 | 6.88E-04 | 5.43E-04 | 5.85E-04 | 5.45E-04 | 6.88E-04 | 0.00% |
| R22 | 6.69E-05 | 1.46E-04 | 1.15E-04 | 1.13E-04 | 6.05E-05 | 1.46E-04 | 0.00% |
| R23 | 1.17E-04 | 1.60E-04 | 1.36E-04 | 1.61E-04 | 1.02E-04 | 1.61E-04 | 0.00% |
| R24 | 9.19E-05 | 5.26E-05 | 7.70E-05 | 1.19E-04 | 5.44E-05 | 1.19E-04 | 0.00% |
| R25 | 1.81E-04 | 1.52E-04 | 1.37E-04 | 8.32E-05 | 1.75E-04 | 1.81E-04 | 0.00% |
| R26 | 9.74E-05 | 8.92E-05 | 1.16E-04 | 1.24E-04 | 6.72E-05 | 1.24E-04 | 0.00% |
| R27 | 8.31E-05 | 5.92E-05 | 1.01E-04 | 9.55E-05 | 5.30E-05 | 1.01E-04 | 0.00% |
| R28 | 1.96E-04 | 1.94E-04 | 1.53E-04 | 2.32E-04 | 1.34E-04 | 2.32E-04 | 0.00% |
| R29 | 1.06E-04 | 2.42E-04 | 1.97E-04 | 1.21E-04 | 1.65E-04 | 2.42E-04 | 0.00% |
| R30 | 1.01E-04 | 2.32E-04 | 1.81E-04 | 1.60E-04 | 1.68E-04 | 2.32E-04 | 0.00% |
| R31 | 1.51E-05 | 5.69E-06 | 1.14E-05 | 6.62E-06 | 3.94E-06 | 1.51E-05 | 0.00% |
| R32 | 6.95E-05 | 9.54E-05 | 5.21E-05 | 6.20E-05 | 6.39E-05 | 9.54E-05 | 0.00% |
| R33 | 1.34E-05 | 1.40E-05 | 1.10E-05 | 1.33E-05 | 6.62E-06 | 1.40E-05 | 0.00% |
| R34 | 4.90E-05 | 5.35E-05 | 4.39E-05 | 6.66E-05 | 2.98E-05 | 6.66E-05 | 0.00% |
| R35 | 3.07E-05 | 7.39E-05 | 3.28E-05 | 3.85E-05 | 1.44E-05 | 7.39E-05 | 0.00% |
| R36 | 3.41E-06 | 1.05E-05 | 9.21E-06 | 6.93E-06 | 1.03E-05 | 1.05E-05 | 0.00% |

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| R37 | 8.26E-05 | 7.51E-05 | 7.07E-05 | 7.37E-05 | 7.22E-05 | 8.26E-05 | 0.00% |
| R38 | 1.32E-04 | 1.75E-04 | 7.74E-05 | 1.25E-04 | 1.08E-04 | 1.75E-04 | 0.00% |
| R39 | 1.86E-04 | 9.22E-05 | 1.03E-04 | 1.20E-04 | 6.75E-05 | 1.86E-04 | 0.00% |
| R40 | 1.31E-04 | 5.93E-05 | 8.61E-05 | 1.21E-04 | 5.74E-05 | 1.31E-04 | 0.00% |
| R41 | 3.14E-04 | 3.11E-04 | 2.21E-04 | 2.84E-04 | 2.05E-04 | 3.14E-04 | 0.00% |
| R42 | 4.56E-04 | 5.44E-04 | 3.17E-04 | 3.76E-04 | 3.93E-04 | 5.44E-04 | 0.00% |
| R43 | 2.60E-04 | 3.40E-04 | 3.40E-04 | 3.21E-04 | 2.35E-04 | 3.40E-04 | 0.00% |
| R44 | 4.63E-04 | 6.16E-04 | 4.61E-04 | 4.98E-04 | 4.56E-04 | 6.16E-04 | 0.00% |
| R45 | 5.75E-04 | 6.62E-04 | 5.38E-04 | 5.69E-04 | 5.73E-04 | 6.62E-04 | 0.00% |

**Table E-11 – Nitrosamine 3 Annual Mean (Indirect +Direct) Process Contribution (PC)**

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| Max on Grid | 5.06E-05 | 4.22E-05 | 4.44E-05 | 4.96E-05 | 4.88E-05 | 5.06E-05 | 25.30% |
| R1 | 1.44E-07 | 1.51E-07 | 2.68E-07 | 1.36E-07 | 1.51E-07 | 2.68E-07 | 0.13% |
| R2 | 5.21E-08 | 5.95E-08 | 6.70E-08 | 3.33E-08 | 2.39E-08 | 6.70E-08 | 0.03% |
| R3 | 3.20E-08 | 5.37E-08 | 2.64E-08 | 2.77E-08 | 2.57E-08 | 5.37E-08 | 0.03% |
| R4 | 1.75E-07 | 1.24E-07 | 9.10E-08 | 1.05E-07 | 4.97E-08 | 1.75E-07 | 0.09% |
| R5 | 7.92E-07 | 7.33E-07 | 5.43E-07 | 6.02E-07 | 5.57E-07 | 7.92E-07 | 0.40% |
| R6 | 5.95E-08 | 5.86E-08 | 7.32E-08 | 8.85E-08 | 9.21E-08 | 9.21E-08 | 0.05% |
| R7 | 1.44E-07 | 1.73E-07 | 3.00E-07 | 2.12E-07 | 2.75E-07 | 3.00E-07 | 0.15% |
| R8 | 3.93E-07 | 4.04E-07 | 2.40E-07 | 2.97E-07 | 1.04E-07 | 4.04E-07 | 0.20% |
| R9 | 5.15E-07 | 5.06E-07 | 4.40E-07 | 4.31E-07 | 5.41E-07 | 5.41E-07 | 0.27% |
| R10 | 1.06E-05 | 4.94E-06 | 7.25E-06 | 4.25E-06 | 3.00E-06 | 1.06E-05 | 5.31% |
| R11 | 1.87E-05 | 1.59E-05 | 1.43E-05 | 1.87E-05 | 7.96E-06 | 1.87E-05 | 9.37% |
| R12 | 5.35E-06 | 5.04E-06 | 4.82E-06 | 5.15E-06 | 3.91E-06 | 5.35E-06 | 2.67% |
| R13 | 3.35E-06 | 3.84E-06 | 4.28E-06 | 4.15E-06 | 2.38E-06 | 4.28E-06 | 2.14% |
| R14 | 2.76E-06 | 3.81E-06 | 3.62E-06 | 3.35E-06 | 1.55E-06 | 3.81E-06 | 1.91% |
| R15 | 1.22E-05 | 1.50E-05 | 1.05E-05 | 1.22E-05 | 1.33E-05 | 1.50E-05 | 7.51% |
| R16 | 3.84E-06 | 4.78E-06 | 4.44E-06 | 5.43E-06 | 3.80E-06 | 5.43E-06 | 2.72% |
| R17 | 2.06E-05 | 1.96E-05 | 2.30E-05 | 2.13E-05 | 2.01E-05 | 2.30E-05 | 11.49% |
| R18 | 1.92E-05 | 1.80E-05 | 1.89E-05 | 2.04E-05 | 1.90E-05 | 2.04E-05 | 10.22% |
| R19 | 1.93E-05 | 1.79E-05 | 1.88E-05 | 2.04E-05 | 1.88E-05 | 2.04E-05 | 10.22% |
| R20 | 2.45E-05 | 1.95E-05 | 1.92E-05 | 2.43E-05 | 1.87E-05 | 2.45E-05 | 12.26% |
| R21 | 4.01E-05 | 3.38E-05 | 4.32E-05 | 4.44E-05 | 4.12E-05 | 4.44E-05 | 22.18% |
| R22 | 6.20E-06 | 6.33E-06 | 8.26E-06 | 6.57E-06 | 4.36E-06 | 8.26E-06 | 4.13% |
| R23 | 1.29E-05 | 1.12E-05 | 1.54E-05 | 1.37E-05 | 9.80E-06 | 1.54E-05 | 7.70% |
| R24 | 9.92E-06 | 9.19E-06 | 1.08E-05 | 1.01E-05 | 6.97E-06 | 1.08E-05 | 5.39% |
| R25 | 2.57E-05 | 1.92E-05 | 1.93E-05 | 9.60E-06 | 2.14E-05 | 2.57E-05 | 12.83% |
| R26 | 1.15E-05 | 9.25E-06 | 1.14E-05 | 1.40E-05 | 7.99E-06 | 1.40E-05 | 7.00% |
| R27 | 9.88E-06 | 6.42E-06 | 1.07E-05 | 1.22E-05 | 6.52E-06 | 1.22E-05 | 6.10% |
| R28 | 2.11E-05 | 2.06E-05 | 1.54E-05 | 2.40E-05 | 1.15E-05 | 2.40E-05 | 11.99% |
| R29 | 9.49E-06 | 1.82E-05 | 1.80E-05 | 1.15E-05 | 1.85E-05 | 1.85E-05 | 9.25% |
| R30 | 1.53E-05 | 1.92E-05 | 1.61E-05 | 1.47E-05 | 1.94E-05 | 1.94E-05 | 9.68% |
| R31 | 6.06E-07 | 2.76E-07 | 4.21E-07 | 1.56E-07 | 9.19E-08 | 6.06E-07 | 0.30% |
| R32 | 2.07E-06 | 2.08E-06 | 1.47E-06 | 1.59E-06 | 1.61E-06 | 2.08E-06 | 1.04% |
| R33 | 4.46E-07 | 3.80E-07 | 3.74E-07 | 3.02E-07 | 1.43E-07 | 4.46E-07 | 0.22% |
| R34 | 2.53E-06 | 2.40E-06 | 2.92E-06 | 2.54E-06 | 1.48E-06 | 2.92E-06 | 1.46% |
| R35 | 8.64E-07 | 2.14E-06 | 1.30E-06 | 1.40E-06 | 5.45E-07 | 2.14E-06 | 1.07% |
| R36 | 1.23E-07 | 2.06E-07 | 2.18E-07 | 1.58E-07 | 2.82E-07 | 2.82E-07 | 0.14% |

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| R37 | 8.67E-06 | 7.22E-06 | 6.92E-06 | 5.80E-06 | 6.18E-06 | 8.67E-06 | 4.33% |
| R38 | 1.21E-05 | 1.09E-05 | 6.28E-06 | 8.54E-06 | 8.60E-06 | 1.21E-05 | 6.07% |
| R39 | 2.60E-05 | 1.13E-05 | 1.62E-05 | 1.08E-05 | 7.61E-06 | 2.60E-05 | 13.01% |
| R40 | 2.00E-05 | 1.12E-05 | 1.21E-05 | 1.48E-05 | 8.26E-06 | 2.00E-05 | 10.00% |
| R41 | 2.72E-05 | 2.33E-05 | 2.09E-05 | 2.34E-05 | 1.30E-05 | 2.72E-05 | 13.62% |
| R42 | 3.51E-05 | 2.98E-05 | 2.79E-05 | 3.05E-05 | 2.51E-05 | 3.51E-05 | 17.55% |
| R43 | 1.06E-05 | 1.05E-05 | 1.05E-05 | 1.18E-05 | 8.20E-06 | 1.18E-05 | 5.89% |
| R44 | 2.85E-05 | 2.56E-05 | 2.99E-05 | 2.86E-05 | 2.87E-05 | 2.99E-05 | 14.96% |
| R45 | 3.81E-05 | 3.20E-05 | 3.95E-05 | 4.17E-05 | 3.94E-05 | 4.17E-05 | 20.85% |

Table E-12 – Nitramine 3 Annual Mean (Indirect +Direct) Process Contribution (PC)

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| Max on Grid | 9.88E-06 | 8.16E-06 | 9.20E-06 | 1.20E-05 | 1.03E-05 | 1.20E-05 | 5.99% |
| R1 | 1.58E-08 | 1.77E-08 | 3.08E-08 | 1.64E-08 | 1.65E-08 | 3.08E-08 | 0.02% |
| R2 | 5.12E-09 | 5.03E-09 | 6.92E-09 | 3.39E-09 | 2.58E-09 | 6.92E-09 | 0.00% |
| R3 | 3.30E-09 | 4.57E-09 | 2.91E-09 | 2.74E-09 | 2.74E-09 | 4.57E-09 | 0.00% |
| R4 | 1.73E-08 | 1.34E-08 | 9.28E-09 | 1.00E-08 | 5.02E-09 | 1.73E-08 | 0.01% |
| R5 | 8.10E-08 | 7.28E-08 | 5.90E-08 | 6.27E-08 | 5.87E-08 | 8.10E-08 | 0.04% |
| R6 | 5.99E-09 | 6.72E-09 | 7.43E-09 | 9.13E-09 | 8.94E-09 | 9.13E-09 | 0.00% |
| R7 | 1.52E-08 | 1.82E-08 | 3.30E-08 | 2.43E-08 | 2.80E-08 | 3.30E-08 | 0.02% |
| R8 | 4.04E-08 | 3.80E-08 | 2.40E-08 | 2.64E-08 | 9.88E-09 | 4.04E-08 | 0.02% |
| R9 | 5.20E-08 | 5.09E-08 | 4.86E-08 | 4.76E-08 | 5.58E-08 | 5.58E-08 | 0.03% |
| R10 | 2.42E-06 | 1.19E-06 | 1.57E-06 | 9.15E-07 | 8.19E-07 | 2.42E-06 | 1.21% |
| R11 | 3.35E-06 | 2.76E-06 | 2.90E-06 | 3.08E-06 | 1.37E-06 | 3.35E-06 | 1.67% |
| R12 | 4.68E-07 | 5.18E-07 | 5.08E-07 | 4.96E-07 | 4.16E-07 | 5.18E-07 | 0.26% |
| R13 | 5.06E-07 | 4.79E-07 | 5.66E-07 | 5.96E-07 | 4.04E-07 | 5.96E-07 | 0.30% |
| R14 | 4.01E-07 | 4.23E-07 | 5.38E-07 | 4.71E-07 | 3.40E-07 | 5.38E-07 | 0.27% |
| R15 | 2.45E-06 | 2.85E-06 | 2.26E-06 | 2.23E-06 | 2.85E-06 | 2.85E-06 | 1.42% |
| R16 | 5.52E-07 | 7.34E-07 | 6.28E-07 | 7.51E-07 | 6.03E-07 | 7.51E-07 | 0.38% |
| R17 | 2.78E-06 | 2.86E-06 | 4.03E-06 | 4.12E-06 | 3.00E-06 | 4.12E-06 | 2.06% |
| R18 | 2.15E-06 | 2.21E-06 | 2.96E-06 | 3.07E-06 | 2.60E-06 | 3.07E-06 | 1.53% |
| R19 | 2.17E-06 | 2.19E-06 | 2.95E-06 | 3.07E-06 | 2.57E-06 | 3.07E-06 | 1.53% |
| R20 | 4.57E-06 | 4.25E-06 | 4.40E-06 | 5.35E-06 | 3.79E-06 | 5.35E-06 | 2.68% |
| R21 | 6.30E-06 | 5.72E-06 | 8.48E-06 | 1.14E-05 | 7.46E-06 | 1.14E-05 | 5.71% |
| R22 | 1.28E-06 | 1.16E-06 | 1.76E-06 | 1.26E-06 | 9.85E-07 | 1.76E-06 | 0.88% |
| R23 | 3.41E-06 | 2.85E-06 | 3.89E-06 | 3.24E-06 | 2.68E-06 | 3.89E-06 | 1.95% |
| R24 | 2.65E-06 | 2.43E-06 | 3.07E-06 | 2.51E-06 | 2.08E-06 | 3.07E-06 | 1.53% |
| R25 | 5.52E-06 | 5.15E-06 | 5.27E-06 | 2.72E-06 | 6.67E-06 | 6.67E-06 | 3.33% |
| R26 | 2.57E-06 | 2.32E-06 | 2.70E-06 | 2.95E-06 | 1.98E-06 | 2.95E-06 | 1.47% |
| R27 | 2.43E-06 | 2.03E-06 | 2.97E-06 | 3.08E-06 | 1.88E-06 | 3.08E-06 | 1.54% |
| R28 | 4.56E-06 | 4.25E-06 | 3.29E-06 | 4.93E-06 | 2.11E-06 | 4.93E-06 | 2.47% |
| R29 | 2.11E-06 | 4.10E-06 | 3.67E-06 | 2.86E-06 | 4.29E-06 | 4.29E-06 | 2.15% |
| R30 | 3.85E-06 | 4.11E-06 | 3.71E-06 | 3.05E-06 | 4.98E-06 | 4.98E-06 | 2.49% |
| R31 | 7.59E-08 | 4.34E-08 | 5.21E-08 | 2.06E-08 | 1.25E-08 | 7.59E-08 | 0.04% |
| R32 | 1.95E-07 | 1.87E-07 | 1.54E-07 | 1.60E-07 | 1.66E-07 | 1.95E-07 | 0.10% |
| R33 | 4.47E-08 | 3.47E-08 | 3.72E-08 | 3.00E-08 | 1.36E-08 | 4.47E-08 | 0.02% |
| R34 | 3.31E-07 | 2.84E-07 | 4.09E-07 | 3.08E-07 | 1.77E-07 | 4.09E-07 | 0.20% |
| R35 | 9.33E-08 | 1.62E-07 | 1.32E-07 | 1.34E-07 | 7.57E-08 | 1.62E-07 | 0.08% |
| R36 | 1.37E-08 | 2.09E-08 | 2.12E-08 | 1.69E-08 | 2.58E-08 | 2.58E-08 | 0.01% |

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| R37 | 1.83E-06 | 1.51E-06 | 1.80E-06 | 1.20E-06 | 1.39E-06 | 1.83E-06 | 0.91% |
| R38 | 1.90E-06 | 1.63E-06 | 1.28E-06 | 1.21E-06 | 1.57E-06 | 1.90E-06 | 0.95% |
| R39 | 8.72E-06 | 3.08E-06 | 4.93E-06 | 2.92E-06 | 2.69E-06 | 8.72E-06 | 4.36% |
| R40 | 6.55E-06 | 4.00E-06 | 3.81E-06 | 4.67E-06 | 3.05E-06 | 6.55E-06 | 3.27% |
| R41 | 4.66E-06 | 4.22E-06 | 4.27E-06 | 4.60E-06 | 2.48E-06 | 4.66E-06 | 2.33% |
| R42 | 5.29E-06 | 4.99E-06 | 6.09E-06 | 5.33E-06 | 4.16E-06 | 6.09E-06 | 3.05% |
| R43 | 1.29E-06 | 1.66E-06 | 1.52E-06 | 1.61E-06 | 1.28E-06 | 1.66E-06 | 0.83% |
| R44 | 4.61E-06 | 4.53E-06 | 6.33E-06 | 6.75E-06 | 4.92E-06 | 6.75E-06 | 3.38% |
| R45 | 5.38E-06 | 5.34E-06 | 8.03E-06 | 8.88E-06 | 6.79E-06 | 8.88E-06 | 4.44% |

Table E-13 – $NO_x$ Annual Mean Process Contribution (PC)

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| River Derwent | 0.13 | 0.18 | 0.14 | 0.15 | 0.13 | 0.18 | 0.60% |
| Thorne Moor SAC (SPA/SSSI) | 0.08 | 0.09 | 0.11 | 0.08 | 0.05 | 0.11 | 0.36% |
| Lower Derwent Valley SAC | 0.15 | 0.18 | 0.15 | 0.18 | 0.16 | 0.18 | 0.60% |
| Lower Derwent Valley SPA | 0.15 | 0.18 | 0.15 | 0.18 | 0.16 | 0.18 | 0.60% |
| Skipwith Common SAC | 0.06 | 0.07 | 0.06 | 0.09 | 0.05 | 0.09 | 0.29% |
| Skipwith Common SSSI | 0.06 | 0.07 | 0.06 | 0.09 | 0.05 | 0.09 | 0.29% |
| Humber Estuary SAC | 0.13 | 0.11 | 0.11 | 0.13 | 0.10 | 0.13 | 0.44% |
| Humber Estuary SPA | 0.13 | 0.11 | 0.11 | 0.13 | 0.10 | 0.13 | 0.44% |
| Breighton Meadows SSSI | 0.14 | 0.18 | 0.14 | 0.15 | 0.13 | 0.18 | 0.60% |
| Eskamhorn Meadows SSSI | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.07% |
| Derwent Ings SSSI | 0.13 | 0.17 | 0.14 | 0.15 | 0.14 | 0.17 | 0.57% |
| Went Ings SSSI | 0.03 | 0.03 | 0.05 | 0.02 | 0.03 | 0.05 | 0.16% |
| Barn Hill Meadows SSSI | 0.10 | 0.10 | 0.07 | 0.09 | 0.06 | 0.10 | 0.34% |
| Burr Closes_SSSI | 0.06 | 0.03 | 0.04 | 0.04 | 0.02 | 0.06 | 0.20% |
| Common Plantation | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.02% |
| Barmby-on-the-Marsh | 0.04 | 0.04 | 0.02 | 0.03 | 0.02 | 0.04 | 0.14% |
| Brock Holes | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.02% |
| Orchard Farm | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01% |
| Barmby Pond | 0.07 | 0.09 | 0.05 | 0.06 | 0.06 | 0.09 | 0.31% |
| Cobble Croft Wood | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.05% |
| Hagg Green Lane | 0.08 | 0.11 | 0.09 | 0.09 | 0.07 | 0.11 | 0.37% |
| Sand Pit Wood | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.05% |
| Barlow Common LNR | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.03% |

**Table E-14 – $NO_x$ Daily Mean Process Contribution (PC)**

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| River Derwent | 3.59 | 3.82 | 4.84 | 3.27 | 2.80 | 4.84 | 6.45% |
| Thorne Moor SAC (SPA/SSSI) | 2.31 | 2.63 | 2.12 | 1.86 | 1.62 | 2.63 | 3.50% |
| Lower Derwent Valley SAC | 3.74 | 3.59 | 4.98 | 3.41 | 2.67 | 4.98 | 6.64% |
| Lower Derwent Valley SPA | 3.74 | 3.59 | 4.98 | 3.41 | 2.67 | 4.98 | 6.64% |
| Skipwith Common SAC | 1.14 | 2.10 | 1.60 | 1.32 | 1.56 | 2.10 | 2.80% |
| Skipwith Common SSSI | 1.14 | 2.10 | 1.60 | 1.32 | 1.56 | 2.10 | 2.80% |
| Humber Estuary SAC | 2.20 | 2.90 | 2.13 | 2.17 | 1.81 | 2.90 | 3.86% |
| Humber Estuary SPA | 2.20 | 2.90 | 2.13 | 2.17 | 1.81 | 2.90 | 3.86% |
| Breighton Meadows SSSI | 3.74 | 3.59 | 4.98 | 3.20 | 2.67 | 4.98 | 6.64% |
| Eskamhorn Meadows SSSI | 2.31 | 1.72 | 1.52 | 0.86 | 0.50 | 2.31 | 3.08% |
| Derwent Ings SSSI | 3.08 | 3.56 | 2.97 | 3.41 | 2.63 | 3.56 | 4.74% |
| Went Ings SSSI | 1.45 | 1.06 | 1.06 | 0.80 | 1.27 | 1.45 | 1.93% |
| Barn Hill Meadows SSSI | 2.03 | 2.44 | 2.38 | 1.68 | 1.70 | 2.44 | 3.25% |
| Burr Closes_SSSI | 1.52 | 1.65 | 1.48 | 1.30 | 0.89 | 1.65 | 2.19% |
| Common Plantation | 0.46 | 0.35 | 0.15 | 0.28 | 0.27 | 0.46 | 0.61% |
| Barmby-on-the-Marsh | 1.49 | 1.49 | 0.84 | 1.11 | 0.74 | 1.49 | 1.99% |
| Brock Holes | 0.24 | 0.38 | 0.45 | 0.21 | 0.23 | 0.45 | 0.60% |
| Orchard Farm | 0.19 | 0.12 | 0.21 | 0.10 | 0.07 | 0.21 | 0.28% |
| Barmby Pond | 1.28 | 2.96 | 1.49 | 1.42 | 1.98 | 2.96 | 3.95% |
| Cobble Croft Wood | 0.51 | 0.75 | 0.30 | 0.45 | 0.73 | 0.75 | 1.01% |
| Hagg Green Lane | 3.05 | 2.90 | 3.67 | 3.20 | 2.68 | 3.67 | 4.90% |
| Sand Pit Wood | 0.69 | 0.78 | 0.34 | 0.53 | 0.90 | 0.90 | 1.20% |
| Barlow Common LNR | 0.85 | 0.39 | 0.25 | 0.73 | 0.40 | 0.85 | 1.14% |

### Table E-15 – $SO_2$ Annual Mean Process Contribution (PC)

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| River Derwent | 0.06 | 0.08 | 0.06 | 0.07 | 0.06 | 0.08 | 0.82% |
| Thorne Moor SAC (SPA/SSSI) | 0.04 | 0.04 | 0.05 | 0.04 | 0.02 | 0.05 | 0.49% |
| Lower Derwent Valley SAC | 0.07 | 0.08 | 0.07 | 0.08 | 0.07 | 0.08 | 0.82% |
| Lower Derwent Valley SPA | 0.07 | 0.08 | 0.07 | 0.08 | 0.07 | 0.08 | 0.82% |
| Skipwith Common SAC | 0.03 | 0.03 | 0.03 | 0.04 | 0.02 | 0.04 | 0.39% |
| Skipwith Common SSSI | 0.03 | 0.03 | 0.03 | 0.04 | 0.02 | 0.04 | 0.39% |
| Humber Estuary SAC | 0.06 | 0.05 | 0.05 | 0.06 | 0.05 | 0.06 | 0.61% |
| Humber Estuary SPA | 0.06 | 0.05 | 0.05 | 0.06 | 0.05 | 0.06 | 0.61% |
| Breighton Meadows SSSI | 0.06 | 0.08 | 0.06 | 0.07 | 0.06 | 0.08 | 0.41% |
| Eskamhorn Meadows SSSI | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.05% |
| Derwent Ings SSSI | 0.06 | 0.08 | 0.06 | 0.07 | 0.06 | 0.08 | 0.39% |
| Went Ings SSSI | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.02 | 0.11% |
| Barn Hill Meadows SSSI | 0.05 | 0.05 | 0.03 | 0.04 | 0.03 | 0.05 | 0.23% |
| Burr Closes_SSSI | 0.03 | 0.01 | 0.02 | 0.02 | 0.01 | 0.03 | 0.14% |
| Common Plantation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02% |
| Barmby-on-the-Marsh | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.09% |
| Brock Holes | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01% |
| Orchard Farm | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01% |
| Barmby Pond | 0.03 | 0.04 | 0.02 | 0.03 | 0.03 | 0.04 | 0.21% |
| Cobble Croft Wood | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.03% |
| Hagg Green Lane | 0.04 | 0.05 | 0.04 | 0.04 | 0.03 | 0.05 | 0.25% |
| Sand Pit Wood | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.04% |
| Barlow Common LNR | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02% |

### Table E-16 – $NH_3$ Annual Mean Process Contribution (PC)

| | 2019 (µg/m³) | 2020 (µg/m³) | 2021 (µg/m³) | 2022 (µg/m3) | 2023 (µg/m³) | Max (µg/m³) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| River Derwent | 7.34E-03 | 9.90E-03 | 7.50E-03 | 8.32E-03 | 7.46E-03 | 9.90E-03 | 0.33% |
| Thorne Moor SAC (SPA/SSSI) | 4.66E-03 | 4.71E-03 | 5.94E-03 | 4.67E-03 | 2.95E-03 | 5.94E-03 | 0.59% |
| Lower Derwent Valley SAC | 8.21E-03 | 9.92E-03 | 8.27E-03 | 9.71E-03 | 8.59E-03 | 9.92E-03 | 0.99% |
| Lower Derwent Valley SPA | 8.21E-03 | 9.92E-03 | 8.27E-03 | 9.71E-03 | 8.59E-03 | 9.92E-03 | 0.99% |
| Skipwith Common SAC | 3.08E-03 | 4.02E-03 | 3.21E-03 | 4.75E-03 | 2.90E-03 | 4.75E-03 | 0.48% |
| Skipwith Common SSSI | 3.08E-03 | 4.02E-03 | 3.21E-03 | 4.75E-03 | 2.90E-03 | 4.75E-03 | 0.48% |
| Humber Estuary SAC | 7.38E-03 | 6.22E-03 | 5.99E-03 | 6.99E-03 | 5.53E-03 | 7.38E-03 | 0.25% |
| Humber Estuary SPA | 7.38E-03 | 6.22E-03 | 5.99E-03 | 6.99E-03 | 5.53E-03 | 7.38E-03 | 0.25% |
| Breighton Meadows SSSI | 7.65E-03 | 9.92E-03 | 7.87E-03 | 8.21E-03 | 7.28E-03 | 9.92E-03 | 0.33% |
| Eskamhorn Meadows SSSI | 6.33E-04 | 1.21E-03 | 1.05E-03 | 8.43E-04 | 4.02E-04 | 1.21E-03 | 0.04% |
| Derwent Ings SSSI | 7.31E-03 | 9.53E-03 | 7.51E-03 | 8.34E-03 | 7.48E-03 | 9.53E-03 | 0.32% |
| Went Ings SSSI | 1.66E-03 | 1.77E-03 | 2.62E-03 | 1.22E-03 | 1.69E-03 | 2.62E-03 | 0.09% |
| Barn Hill Meadows SSSI | 5.47E-03 | 5.66E-03 | 4.12E-03 | 5.12E-03 | 3.33E-03 | 5.66E-03 | 0.19% |
| Burr Closes_SSSI | 3.39E-03 | 1.59E-03 | 2.07E-03 | 2.03E-03 | 1.36E-03 | 3.39E-03 | 0.11% |
| Common Plantation | 3.90E-04 | 4.14E-04 | 2.19E-04 | 2.01E-04 | 3.45E-04 | 4.14E-04 | 0.01% |
| Barmby-on-the-Marsh | 2.10E-03 | 2.28E-03 | 1.32E-03 | 1.68E-03 | 1.19E-03 | 2.28E-03 | 0.08% |
| Brock Holes | 1.93E-04 | 3.32E-04 | 3.62E-04 | 2.67E-04 | 1.52E-04 | 3.62E-04 | 0.01% |
| Orchard Farm | 1.75E-04 | 8.28E-05 | 1.54E-04 | 8.13E-05 | 4.07E-05 | 1.75E-04 | 0.01% |
| Barmby Pond | 3.92E-03 | 5.07E-03 | 2.72E-03 | 3.24E-03 | 3.47E-03 | 5.07E-03 | 0.17% |
| Cobble Croft Wood | 6.36E-04 | 7.70E-04 | 3.13E-04 | 2.84E-04 | 7.34E-04 | 7.70E-04 | 0.03% |
| Hagg Green Lane | 4.46E-03 | 6.08E-03 | 5.20E-03 | 4.78E-03 | 3.97E-03 | 6.08E-03 | 0.20% |
| Sand Pit Wood | 6.86E-04 | 8.31E-04 | 3.81E-04 | 3.49E-04 | 8.49E-04 | 8.49E-04 | 0.03% |
| Barlow Common LNR | 4.35E-04 | 2.86E-04 | 3.35E-04 | 3.67E-04 | 2.49E-04 | 4.35E-04 | 0.01% |

**Table E-17 – Nitrogen Deposition Process Contribution (PC)**

| | 2019 (kgN/ha/y) | 2020 (kgN/ha/y) | 2021 (kgN/ha/y) | 2022 (kgN/ha/y) | 2023 (kgN/ha/y) | Max (kgN/ha/y) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| River Derwent | | | | | | | |
| Thorne Moor SAC (SPA/SSSI) | 3.37E-02 | 3.42E-02 | 4.31E-02 | 3.38E-02 | 2.14E-02 | 4.31E-02 | 0.86% |
| Lower Derwent Valley SAC | 5.87E-02 | 7.26E-02 | 5.91E-02 | 6.96E-02 | 6.12E-02 | 7.26E-02 | 0.73% |
| Lower Derwent Valley SPA | 5.87E-02 | 7.26E-02 | 5.91E-02 | 6.96E-02 | 6.12E-02 | 7.26E-02 | 0.73% |
| Skipwith Common SAC | 2.25E-02 | 2.93E-02 | 2.34E-02 | 3.46E-02 | 2.11E-02 | 3.46E-02 | 0.69% |
| Skipwith Common SSSI | 2.25E-02 | 2.93E-02 | 2.34E-02 | 3.46E-02 | 2.11E-02 | 3.46E-02 | 0.69% |
| Humber Estuary SAC | 5.30E-02 | 4.48E-02 | 4.31E-02 | 5.03E-02 | 4.00E-02 | 5.30E-02 | 0.53% |
| Humber Estuary SPA | 5.30E-02 | 4.48E-02 | 4.31E-02 | 5.03E-02 | 4.00E-02 | 5.30E-02 | 0.53% |
| Breighton Meadows SSSI | 5.59E-02 | 7.26E-02 | 5.75E-02 | 5.99E-02 | 5.32E-02 | 7.26E-02 | 0.73% |
| Eskamhorn Meadows SSSI | 4.62E-03 | 8.82E-03 | 7.68E-03 | 6.16E-03 | 2.93E-03 | 8.82E-03 | 0.09% |
| Derwent Ings SSSI | 5.34E-02 | 6.97E-02 | 5.49E-02 | 6.09E-02 | 5.46E-02 | 6.97E-02 | 0.70% |
| Went Ings SSSI | 1.21E-02 | 1.29E-02 | 1.90E-02 | 8.87E-03 | 1.22E-02 | 1.90E-02 | 0.19% |
| Barn Hill Meadows SSSI | 3.99E-02 | 4.13E-02 | 3.00E-02 | 3.73E-02 | 2.43E-02 | 4.13E-02 | 0.41% |
| Burr Closes_SSSI | 2.46E-02 | 1.15E-02 | 1.51E-02 | 1.48E-02 | 9.85E-03 | 2.46E-02 | 0.25% |
| Common Plantation | 4.63E-03 | 4.92E-03 | 2.60E-03 | 2.39E-03 | 4.10E-03 | 4.92E-03 | 0.05% |
| Barmby-on-the-Marsh | 2.49E-02 | 2.71E-02 | 1.57E-02 | 2.00E-02 | 1.42E-02 | 2.71E-02 | 0.27% |
| Brock Holes | 1.41E-03 | 2.43E-03 | 2.65E-03 | 1.95E-03 | 1.11E-03 | 2.65E-03 | 0.02% |
| Orchard Farm | 1.28E-03 | 6.05E-04 | 1.13E-03 | 5.94E-04 | 2.97E-04 | 1.28E-03 | 0.01% |
| Barmby Pond | 2.87E-02 | 3.71E-02 | 1.99E-02 | 2.37E-02 | 2.54E-02 | 3.71E-02 | 0.25% |
| Cobble Croft Wood | 7.55E-03 | 9.15E-03 | 3.71E-03 | 3.37E-03 | 8.72E-03 | 9.15E-03 | 0.09% |
| Hagg Green Lane | 5.30E-02 | 7.23E-02 | 6.18E-02 | 5.68E-02 | 4.72E-02 | 7.23E-02 | 0.72% |
| Sand Pit Wood | 8.14E-03 | 9.86E-03 | 4.52E-03 | 4.14E-03 | 1.01E-02 | 1.01E-02 | 0.10% |
| Barlow Common LNR | 5.17E-03 | 3.39E-03 | 3.97E-03 | 4.36E-03 | 2.96E-03 | 5.17E-03 | 0.05% |

**Table E-18 – Acid Deposition Process Contribution (PC)**

| | 2019 (keq/ha/y) | 2020 (keq/ha/y) | 2021 (keq/ha/y) | 2022 (keq/ha/y) | 2023 (keq/ha/y) | Max (keq/ha/y) | PC as % AQAL |
|---|---|---|---|---|---|---|---|
| River Derwent | | | | | | | |
| Thorne Moor SAC (SPA/SSSI) | 7.46E-03 | 7.55E-03 | 9.52E-03 | 7.47E-03 | 4.72E-03 | 9.52E-03 | 2.06% |
| Lower Derwent Valley SAC | 1.31E-02 | 1.59E-02 | 1.32E-02 | 1.55E-02 | 1.37E-02 | 1.59E-02 | 0.33% |
| Lower Derwent Valley SPA | 1.31E-02 | 1.59E-02 | 1.32E-02 | 1.55E-02 | 1.37E-02 | 1.59E-02 | 0.33% |
| Skipwith Common SAC | 4.94E-03 | 6.45E-03 | 5.15E-03 | 7.63E-03 | 4.66E-03 | 7.63E-03 | 0.95% |
| Skipwith Common SSSI | 4.94E-03 | 6.45E-03 | 5.15E-03 | 7.63E-03 | 4.66E-03 | 7.63E-03 | 0.95% |
| Humber Estuary SAC | | | | | | | |
| Humber Estuary SPA | | | | | | | |
| Breighton Meadows SSSI | 1.23E-02 | 1.59E-02 | 1.26E-02 | 1.32E-02 | 1.17E-02 | 1.59E-02 | 0.33% |
| Eskamhorn Meadows SSSI | 1.02E-03 | 1.94E-03 | 1.69E-03 | 1.35E-03 | 6.45E-04 | 1.94E-03 | 0.03% |
| Derwent Ings SSSI | 1.17E-02 | 1.53E-02 | 1.21E-02 | 1.34E-02 | 1.20E-02 | 1.53E-02 | 0.32% |
| Went Ings SSSI | 2.66E-03 | 2.84E-03 | 4.20E-03 | 1.96E-03 | 2.70E-03 | 4.20E-03 | 0.07% |
| Barn Hill Meadows SSSI | 8.77E-03 | 9.09E-03 | 6.61E-03 | 8.22E-03 | 5.35E-03 | 9.09E-03 | 0.19% |
| Burr Closes_SSSI | 5.43E-03 | 2.54E-03 | 3.32E-03 | 3.26E-03 | 2.17E-03 | 5.43E-03 | 0.10% |
| Common Plantation | 8.12E-04 | 8.63E-04 | 4.56E-04 | 4.19E-04 | 7.20E-04 | 8.63E-04 | 0.05% |
| Barmby-on-the-Marsh | 4.38E-03 | 4.75E-03 | 2.76E-03 | 3.51E-03 | 2.49E-03 | 4.75E-03 | 0.04% |
| Brock Holes | | | | | | | |
| Orchard Farm | | | | | | | |
| Barmby Pond | | | | | | | |
| Cobble Croft Wood | 1.32E-03 | 1.60E-03 | 6.51E-04 | 5.92E-04 | 1.53E-03 | 1.60E-03 | 0.09% |
| Hagg Green Lane | 9.30E-03 | 1.27E-02 | 1.08E-02 | 9.96E-03 | 8.27E-03 | 1.27E-02 | 0.70% |
| Sand Pit Wood | 1.43E-03 | 1.73E-03 | 7.93E-04 | 7.26E-04 | 1.77E-03 | 1.77E-03 | 0.10% |
| Barlow Common LNR | 9.07E-04 | 5.95E-04 | 6.97E-04 | 7.65E-04 | 5.19E-04 | 9.07E-04 | 0.05% |

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