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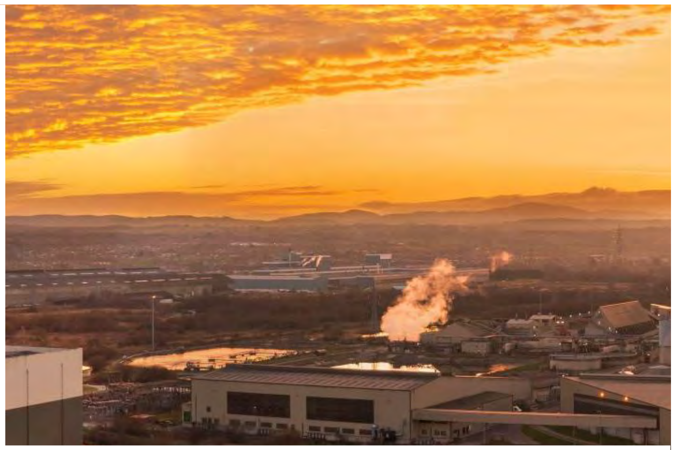

Parc Adfer - Carbon Capture Facility

enfinium Parc Adfer Operations Ltd

Dispersion Modelling Assessment

ENGINEERING + CONSULTING

Document approval

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Management Summary

Fichtner Consulting Engineers Ltd (Fichtner) has been engaged by enfinium to undertake a Dispersion Modelling Assessment to support the application for an Environmental Permit (EP) for a carbon capture (CC) facility to serve the Parc Adfer Energy Recovery Facility (ERF).

The ERF comprises a single incineration line. Within this application, enfinium is applying for a variation to the EP to incorporate the proposed carbon capture facility (CC facility) to extract carbon dioxide (CO_2) from the emissions produced by the ERF. Full details of the proposed changes being applied for can be found in the Supporting Information document.

Dispersion Modelling of Emissions

Dispersion modelling of emissions has been undertaken using ADMS 6. The ADMS dispersion model is routinely used for air quality assessments to the satisfaction of Natural Resources Wales (NRW) and the Environment Agency (EA). The model uses weather data from the local area to predict the spread and movement of the exhaust gases from the stack for each hour over a five-year period. The model takes account of wind speed, wind direction, temperature, humidity and the amount of cloud cover, as all of these factors influence the dispersion of emissions. The model also takes account of the effects of buildings and terrain on the movement of air.

Dispersion modelling has been carried out for the following scenarios:

1. Permitted Facility – the ERF operating as per the conditions of the existing EP; and
2. CC facility – the emissions from the ERF being ducted to the CC facility.

To set up the model, it has been assumed that the ERF operates for the whole year and releases emissions at the emission limits set out in the existing EP continuously, and these are either emitted from the stack of the ERF or pass through to the CC facility before emitting to atmosphere. The CC process alters the flue gas composition. The differences in the flue gas composition (temperature, moisture content and volume) as a result of the CC process have been accounted for. However, for modelling purposes it is assumed that the CC facility does not offer any additional abatement of emissions. This is an extremely conservative assumption given that the CC facility includes caustic (alkaline), water, and wash systems which are likely to significantly reduce emissions of many of the pollutants released, including acid gases, particulates and ammonia.

The model has been used to predict the ground level concentration of pollutants on a long-term and short-term basis across a grid of points. In addition, concentrations have been predicted at the identified sensitive receptors.

Approach and Assessment of Impact on Air Quality – Protection of Human Health

The air quality impact on human health has been assessed using a standard approach based on guidance provided by the EA, which has been applied in lieu of specific guidance from NRW. Using this approach, in relation to the Air Quality Assessment Levels (AQALs) set for the protection of human health the following can be concluded from the assessment.

1. Emissions from the operation of the CC facility will not cause a breach of any AQAL.
2. There is predicted to be an increase in the impacts as a result of the operation of the CC facility. For all pollutants already emitted by the ERF, the change in impact can be screened out as 'insignificant', and the overall impact of the emissions from the CC facility is not significant.

3. For additional products released from the CC facility such as amines, nitrosamines and nitramines the impact can either be screened out as 'insignificant' or is considered 'not significant' when baseline concentrations are taken into consideration.
4. There are no likely significant cumulative effects from other local plans or projects.

Approach and Assessment of Impact on Air Quality – Protection of Ecosystems

The impact of air quality on designated ecological sites has been assessed using a standard approach based on guidance provided by NRW and the EA. Using this approach the following can be concluded from the assessment.

1. All impacts at local nature sites can be screened out as 'insignificant';
2. The change in impact due to the operation of the CC facility and overall impact of emissions from the CC facility at the Dee Estuary designated site cannot be screened out for airborne ammonia impacts and nitrogen deposition impacts. Further assessment of the spatial extent of impacts and the sensitivity of the affected habitats has shown that no significant effects are likely.
3. There are no likely significant cumulative effects from other local plans or projects.

Summary and conclusions

In summary, the assessment has shown that the air quality impact of the CC facility would not have a significant impact on local air quality, the general population or the local community. As such there should be no air quality constraint in granting the variation to the EP to operate the CC facility

Contents

1 Introduction

1.1 Background

Fichtner Consulting Engineers Ltd (Fichtner) has been engaged by enfinium to undertake a Dispersion Modelling Assessment to support the application for a variation to the Environmental Permit (EP) (ref EPR/AB3092CV), for the Parc Adfer Energy Recovery Facility (ERF), located on Weighbridge Road, Deeside (the Site). The location of the Site is shown in Figure 1.

The ERF comprises a single incineration line. Within this application, enfinium is applying for a variation to the EP to incorporate the proposed carbon capture facility (CC facility) to extract carbon dioxide (CO_2) from the emissions produced by the ERF. Full details of the proposed changes being applied for can be found in the Supporting Information document.

This assessment has considered the following scenarios:

- the "Permitted facility" – the impact of the ERF operating at the maximum permitted emission limit values (ELVs); and
- the "CC facility" – the impact of the ERF including the CC facility assuming operation of the ERF at the ELVs.
- The difference in impact has been quantified to determine the impact of this application.

When considering the impact on human health, the predicted atmospheric concentrations have been compared to the Air Quality Assessment Levels (AQALs) for the protection of human health. For dioxins there is no AQAL set; the assessment level is a Tolerable Daily Intake (TDI) which considers the combination of the intake from inhalation and ingestion. As such, it is not possible to demonstrate compliance with the assessment level with just reference to the air concentration. A separate Dioxin Pathway Intake Assessment has been undertaken to assess the pathway intake of these pollutants and impacts compared to the TDI. This is provided as a separate technical report and is included as Appendix E of the Application Pack.

When considering the impact on ecosystems the predicted atmospheric concentrations have been compared to the Critical Levels for the protection of ecosystems. Deposition of emissions over a prolonged period can have nutrification and acidification impacts. An assessment of the long-term deposition of pollutants has been undertaken and the results compared to the habitat specific Critical Loads.

This assessment also includes consideration of the impact of the Facility during abnormal operations of the ERF as defined within the Industrial Emissions Directive (IED) (Directive 2010/75/EU) for the combustion of waste.

1.2 Structure of the report

This report has the following structure.

- National and international air quality legislation and guidance are considered in section 2.
- The human and ecological receptors which are sensitive to changes in air quality associated with the Facility and identified in section 3.
- The background levels of ambient air quality are described in section 4.
- The inputs used for the dispersion model are contained in section 5.
- Details of the sensitivity analysis carried out is presented in section 6.
- A discussion of the validity of the model and uncertainty is presented in section 7.

- The assessment methodology and results of the assessment of the impact of emissions on human health is presented in section 8.
- The assessment methodology and results of the assessment of the impact of emissions at ecological sites is presented in section 9.
- An assessment of potential cumulative impacts is presented in section 10.
- An overview of potential effect on the abnormal operations as defined within the IED are set out in section 11
- The conclusions of the assessment are set out in section 12.
- The Appendices include illustrative figures, detailed results tables and further information on the modelling of amine emissions from the CC facility.

2 Legislation Framework and Policy

2.1 Air quality assessment levels

In the UK, Ambient Air Directive (AAD) Limit Values, Targets, and air quality standards and objectives for major pollutants are described in The Air Quality Strategy (AQS). In addition, the Environment Agency (EA) include Environmental Assessment Levels (EALs) for other pollutants in the environmental management guidance 'Air Emissions Risk Assessment for your Environmental Permit'[1] ("Air Emissions Guidance"), which are also considered. The long-term and short-term EALs from these documents have been used when the AQS does not contain relevant objectives. Standards and objectives for the protection of sensitive ecosystems and habitats are also contained within the Air Emissions Guidance and the Air Pollution Information System (APIS).

AAD Target and Limit Values, AQS Objectives, and EALs are set at levels well below those at which significant adverse health effects have been observed in the general population and in particularly sensitive groups. For the remainder of this report these are collectively referred to as AQALs. All AQALs referred to below have been adopted by Natural Resources Wales (NRW) and are applicable in both England and Wales. Table 1 to Table 3 summarise the air quality objectives and guidelines used in this assessment.

Table 1: Air Quality Assessment Levels (AQALs)

Pollutant	AQAL (µg/m³)	Averaging Period	Frequency of Exceedances	Source
Nitrogen dioxide (NO_2)	200	1 hour	18 times per year (99.79th percentile)	AAD Limit Value
	40	Annual	-	AAD Limit Value
Sulphur dioxide (SO_2)	266	15 minutes	35 times per year (99.9th percentile)	AQS Objective
	350	1 hour	24 times per year (99.73rd percentile)	AAD Limit Value
	125	24 hours	3 times per year (99.18th percentile)	AAD Limit Value
Particulate matter (PM_{10})	50	24 hours	35 times per year (90.41st percentile)	AQS Objective
	40	Annual	-	AQS Objective
Particulate matter ($PM_{2.5}$)	10	Annual	-	Environmental Targets (fine particulate matter) (England) regulations 2023

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

Pollutant	AQAL (µg/m³)	Averaging Period	Frequency of Exceedances	Source
Carbon monoxide (CO)	10,000	8 hours, running	-	AAD Limit Value
	30,000	1 hour	-	Air Emissions Guidance
Hydrogen chloride (HCl)	750	1 hour	-	Air Emissions Guidance
Hydrogen fluoride (HF)	160	1 hour	-	Air Emissions Guidance
	16	Annual	-	Air Emissions Guidance
Ammonia (NH_3)	2,500	1 hour	-	Air Emissions Guidance
	180	Annual	-	Air Emissions Guidance
Benzene (C_6H_6)	5	Annual	-	Air Emissions Guidance
	30	24 hours	-	Air Emissions Guidance
Polychlorinated biphenyls (PCBs)	6	1-hour	-	Air Emissions Guidance
	0.2	Annual	-	Air Emissions Guidance
Polycyclic Aromatic Hydrocarbons (PAHs)	0.00025	Annual	-	AQS Objective
Formaldehyde (CH_2O)	100	30 minutes	-	Air Emissions Guidance
	5	Annual	-	Air Emissions Guidance
Monoethanolamine (MEA)	400	1-hour	-	Air Emissions Guidance
	100	24 hours	-	Air Emissions Guidance
Diethanolamine (DEA)	3	24 hours	-	EA Consultation(2)
Dimethylamine (DMA)	3.3	24 hours	-	Derived(3)
Total nitramines (as NDMA)	0.0002	Annual	-	Air Emissions Guidance
Total nitrosamines (as NDMA)	0.0002	Annual	-	Air Emissions Guidance
Total nitrosamines + nitramines (as NDMA(1))	0.0002	Annual	-	Air Emissions Guidance

Notes:

(1) NDMA is N-nitrosodimethylamine

(2) EA, Consultation on the Development of Environmental Assessment Levels (EALs) for the amine-based carbon capture process, January 2025.

(3) Refer to Appendix G.

Table 2: Air Quality Assessment Levels for Metals

Pollutant	AQAL (ng/m³)	Averaging Period	Source
Arsenic (As)	-	1 hour	-
	6	Annual	Air Emissions Guidance
Antimony (Sb)	150,000	1 hour	Air Emissions Guidance

Pollutant	AQAL (ng/m³)	Averaging Period	Source
	5,000	Annual	Air Emissions Guidance
Cadmium (Cd)	30	24 hour	Air Emissions Guidance
	5	Annual	AAD Target Value
Chromium (III) (Cr)	2,000	24 hour	Air Emissions Guidance
	-	Annual	-
Chromium (VI) (Cr (VI))	-	1 hour	-
	0.25	Annual	Air Emissions Guidance
Cobalt (Co)	-	1 hour	-
	-	Annual	-
Copper (Cu)	50	24 hour	Air Emissions Guidance
	-	Annual	-
Lead (Pb)	-	1 hour	-
	250	Annual	AQS Target
Manganese (Mn)	1,500,000	1 hour	Air Emissions Guidance
	150	Annual	Air Emissions Guidance
Mercury (Hg)	600	1 hour	Air Emissions Guidance
	60	24 hour	Air Emissions Guidance
	-	Annual	-
Nickel (Ni)	700	1 hour	Air Emissions Guidance
	20	Annual	AAD Limit
Vanadium (V)	1,000	24 hours	Air Emissions Guidance
	-	Annual	-

Table 3: Critical Levels for the Protection of Vegetation and Ecosystems

Pollutant	Concentration (µg/m³)	Measured as	Source
Nitrogen oxides NOx) (as NO_2)	75/200*	Daily mean	APIS
	30	Annual mean	AAD Critical Level
Sulphur dioxide (SO_2)	10	Annual mean where lichens and bryophytes are an important part of the ecosystem's integrity	Air Emissions Guidance / APIS
	20	Annual mean for all higher plants	AAD Critical Level
Hydrogen fluoride (HF)	5	Daily mean	Air Emissions Guidance / APIS
	0.5	Weekly mean	Air Emissions Guidance / APIS

Pollutant	Concentration ($\mu g/m^3$)	Measured as	Source
Ammonia (NH_3)	1	where lichens and bryophytes are an important part of the ecosystem's integrity	APIS
	3	Annual mean for all higher plants	APIS
Notes: **only for detailed assessments where the ozone is below the AOT40 Critical Level and sulphur dioxide is below the lower Critical Level of 10 µg/m³.* The *AOT40 for ozone is 3,000 ppb.h (6,000 µg/m³.h) calculated from accumulated hourly ozone concentrations – AOT40 means the sum of the difference between each hourly daytime (08:00 to 20:00 Central European Time, CET) ozone concentration greater than 80 µg/m³ (40 ppb) and 80 µg/m³, for the period between 01 May and 31 July.*			

In addition to the Critical Levels set out in Table 3, APIS provides habitat specific Critical Loads for nitrogen and acid deposition. Full details of the habitat specific Critical Loads can be found in Appendix B.

There is no AQAL for dioxins and dioxin-like PCBs. As there are other intake pathways besides inhalation for these substances, a separate assessment has been undertaken in which the total intake via inhalation and ingestion has been compared to the Tolerable Daily Intake (TDI). This assessment is presented in the Dioxin Pathway Intake Assessment, refer to Appendix E of the Application Pack.

For clarity, the guidance on EALs and screening criteria contained in the EA's Air Emissions Guidance have been adopted by NRW for use in Wales. There is no equivalent consolidated guidance document published by NRW, so the remainder of this report refers to the EA's guidance.

2.2 Areas of relevant exposure

The AQALs apply only at areas of exposure relevant to the assessment level. The following table extracted from Local Authority Air Quality Technical Guidance (2022) (LAQM.TG(22)) explains where the AQALs apply.

Table 4: Guidance on Where AQALs Apply

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

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

Source: Box 1.1 LAQM.TG(22)

2.3 Industrial pollution regulation

Atmospheric emissions from industrial processes are controlled in England through the Environmental Permitting (England and Wales) Regulations 2016 (and subsequent amendments). The Facility currently has an EP to operate. The EP includes conditions to ensure that the environmental impact of the operations is minimised. This includes conditions to prevent fugitive emissions of dust and odour beyond the boundary of the permitted activity, and limits on emissions to air.

The Industrial Emissions Directive (IED) (Directive 2010/75/EU), was adopted on 07 January 2013, and is the key European Directive which covers almost all regulation of industrial processes in the European Union (EU). Existing EU BAT conclusions (BATc) continue to have effect in the UK through the EU Withdrawal Act 2018.

Within the IED, the requirements of the relevant sector BREF (Best Available Techniques Reference documents) become binding as BAT (Best Available Techniques) guidance, as follows.

- Article 15, paragraph 2, of the IED requires that ELVs are based on best available techniques, referred to as BAT.

- Article 13 of the IED, requires that 'the Commission' develops BAT guidance documents (referred to as BREFs).
- Article 21, paragraph 3, of the IED, requires that when updated BAT conclusions are published, the Competent Authority (in Scotland this is SEPA) has up to four years to revise permits for facilities covered by that activity to comply with the requirements of the sector specific BREF.

NRW explains that the aim of ‘BAT’ is to prevent or reduce emissions and impacts on the environment. The EA explains that ‘BAT’ means the available techniques which are the best for preventing or minimising emissions and impacts on the environment where ‘techniques’ include both the technology used and the way the installation is designed, built, maintained, operated and decommissioned.

The current Waste Incineration BREF was published by the European Integrated Pollution Prevention and Control (IPPC) Bureau in December 2019. The existing EP has been varied to comply with the requirements of the Waste Incineration BREF.

2.4 Local air quality management

In accordance with Section 82 of the Environment Act 1995 (Part IV), local authorities are required to periodically review and assess air quality within their area of jurisdiction, under the system of Local Air Quality Management (LAQM). This review and assessment of air quality involves assessing present and likely future ambient pollutant concentrations against AQALs. If it is predicted that levels at the façade of buildings where members of the public are regularly present (normally residential properties) are likely to be exceeded, then the local authority is required to declare an Air Quality Management Area (AQMA). For each AQMA, the local authority is required to produce an Air Quality Action Plan (AQAP), the objective of which is to reduce pollutant levels in pursuit of the relevant AQALs.

3 Sensitive Receptors

3.1 Human sensitive receptors

The general approach to the assessment is to evaluate the highest predicted PC (PC) across an appropriate grid of points. In addition, the predicted PC at a number of sensitive receptors has been evaluated. These sensitive receptors are displayed in Figure 2 of Appendix A and listed in Table 5.

These receptors are a representative sample of the residential properties and schools closest to the Facility, which are most likely to be affected by emissions from the Facility. It is not possible to include every occupied area and as such the assessment also considers the point of maximum impact and interpretation of plot files.

Table 5: Human Sensitive Receptors

ID	Receptor name	Location		Distance from the CC facility stack (km)
		X (m)	Y (m)	
R1	Leighton Court, Golftyn	329290	369868	2.3
R2	Bridge Street, Shotton	330531	369154	2.3
R3	Sealand Avenue, Sealand	332542	369380	2.5
R4	New housing development, Sealand	332375	369657	2.2
R5	Vicarage Lane, Shotwick	333655	371861	2.7
R6	Chapel House Lane, Puddington	333235	373017	2.7
R7	Old Hall Lane, Puddington	332602	373347	2.5
R8	Burton Marsh Farm	330254	374349	3.0
R9	Sea View, Little Neston	329182	375852	4.8
R10	Sealand Primary School	332508	368926	2.9

3.2 Ecological sensitive receptors

A study was undertaken to identify the following sites of ecological importance in accordance with NRW's screening criteria:

- Special Protection Areas (SPAs), Special Areas of Conservation (SACs), Ramsar sites, or Sites of Special Scientific Interest (SSSIs) within 10 km of the Facility; and
- National Nature Reserves (NNR), Local Nature Reserves (LNRs), Local Wildlife Sites and ancient woodlands within 2 km of the Facility.

The sensitive ecological receptors identified are presented by distance from absorber column stack in Table 6 and are displayed in Figure 3 of Appendix A.

Table 6: Ecological Sensitive Receptors

ID	Name	Location		Distance from CC facility stack at closest point (km)
		X (m)	Y (m)	
European and UK designated sites				
E1	Dee Estuary SAC/SSSI/SPA/Ramsar	330795	372120	0.8
E2	Deeside and Buckley Newt Sites SAC	329890	368540	3.1
E3	Halkyn Mountain SAC	321620	369785	9.5
E4	River Dee and Bala Lake SAC/LWS	330505	369850	1.7
E5	Inner Marsh Farm SSSI	330720	372980	1.6
E6	River Dee SSSI	330505	369850	1.7
E7	Shotton Lagoons and Reedbeds SSSI(1)	330220	371055	0.8
Local nature sites				
E8	Dee Rifle LWS	330330	373300	2.0

Note:
(1) Also designated as Shotton Steelworks LWS.

When undertaking the assessment the maximum impact within each designated site has been considered, with the exception of Dee Rifle LWS which has been assessed using a single receptor point at the location shown in Table 6.

A review of the citation for each site has been undertaken to determine if lichens and bryophytes are an important part of the ecosystem's integrity for the purposes of determining the relevant Critical Level for the habitats present. For all sites except Inner Marsh Farm SSSI, the lower Critical Levels apply for the most sensitive features within each site. At Inner Marsh Farm SSSI none of the designated features are sensitive to airborne pollutants.

Reference should be made to Appendix B for full details of the habitats present at each site and the habitat-specific Critical Loads.

4 Baseline Air Quality

The Facility is located in Deeside in a predominantly industrial area within the administrative area of Flintshire County Council (FCC). The border with England (Cheshire West and Chester Council, CWACC) lies less than 1.5 km to the north-east. The location of the Facility is shown on Figure 1 of Appendix A.

Within this section a review of the existing air quality has been carried out with reference to local monitoring data. Where local monitoring data is not available reference has been made to national datasets from a similar setting.

4.1 Air quality management areas

Under Section 82 of the Environment Act 1995 (Part IV), local authorities are required to undertake an ongoing exercise to review air quality within their area of jurisdiction. There are no AQMAs within FCC's administrative area. The closest AQMA is located in Chester city centre approximately 10 km south-east of the Facility. Due to the distance from the Facility it is considered that there will be no significant impacts on air quality in this AQMA and the no further consideration has been given to the impact within the AQMA.

4.2 National modelling – mapped background data

The Department for Environment Food and Rural Affairs (Defra) provides modelled background concentrations of pollutants across the UK on a 1 km by 1 km grid under the Modelling of Ambient Air Quality (MAAQ) contract. This model is based on known pollution sources and background measurements and provides a source of background concentrations in lieu of suitable monitoring data. Mapped background concentrations have been downloaded for the grid squares containing the Site and immediate surroundings. In addition, mapped atmospheric concentrations of ammonia are available from the Air Pollution Information System (APIS) throughout the UK.

Concentrations vary across the modelling domain. Therefore, the maximum mapped background concentration data within 5 km of the Facility have been downloaded along with the concentrations for the grid square containing the Facility. A summary is presented in Table 7.

Table 7: Mapped Background Data

Pollutant	Annual mean concentration (µg/m³)		Dataset
	At Facility	Max within 5 km	
Nitrogen dioxide	10.7	12.2	2023 Defra dataset
Sulphur dioxide	2.2	5.8	2023 Defra dataset
Particulate matter (as PM_{10})	10.7	11.5	2023 Defra dataset
Particulate matter (as $PM_{2.5}$)	5.6	7.4	2023 Defra dataset
Carbon monoxide	223	237	2010 Defra dataset(1)
Benzene	0.50	1.44	2023 Defra dataset
Ammonia	2.0	2.3	APIS mid-year 3 year average 2020 to 2022

Note:
(1) Most recent year of mapped background data for carbon monoxide is 2010.

Source: © Crown 2025 copyright Defra via uk-air.defra.gov.uk, licenced under the Open Government Licence (OGL).

4.3 AURN and LAQM monitoring data

The UK Automatic Urban and Rural Network (AURN) is a country-wide network of air quality monitoring stations operated on behalf of Defra. This includes automatic monitoring of oxides of nitrogen, nitrogen dioxide, sulphur dioxide, ozone, carbon monoxide and particulates. In addition to the national AURN, local authorities undertake monitoring of a range of pollutants as part of the LAQM review process.

AURN and local monitoring sites are broadly categorised as 'background' or 'roadside' sites. Background sites are positioned that they are not influenced significantly by any single source or street but rather by the integrate contribution from all sources upwind of the station and are considered broadly representative for several square kilometres. Conversely, roadside sites are intended to measure the effect of emissions from nearby traffic and are only representative of air quality for the immediate area of the analyser. As such, consideration has been given to background monitoring within 5 km of the site and roadside monitoring within 3 km of the site.

The closest AURN monitoring stations to the Facility are in Wrexham and Wirral Tranmere. Both are well over 5 km from the Site so data from these analysers is not considered representative of concentrations in the vicinity of the site. Data from these site has not been considered further in this analysis.

A review of the monitoring undertaken by FCC has shown that FCC does not undertake continuous monitoring within its administrative area. FCC undertakes diffusion tube monitoring of nitrogen dioxide as part of the LAQM process. Of the diffusion tube monitoring sites, there are seven background or industrial type monitoring locations within 5 km of the Site and three roadside/kerbside monitoring locations within 3 km of the Site. Monitoring data from these sites is presented in Table 8.

Table 8: Diffusion Tube Nitrogen Dioxide Monitoring

Diffusion Tube ID	Site type	Location		NO_2 annual mean concentration (µg/m³)			
		X	Y	2023 Mapped bg	2021	2022	2023
Background monitoring							
ADDC-013	Rural bg	327307	369856	5.4	8.6	7.2	8.5
ADDC-015	Urban bg	328032	370647	7.4	10.1	10.0	10.2
ADDC-023	Urban bg	331663	368028	8.4	20.1	19.3	19.8
ADDC-029	Rural bg	333645	370898	12.2	12.3	12.5	13.8
ADDC-030	Industrial	332764	370981	9.8	18.5	17.2	14.0
ADDC-032	Industrial	332031	371562	8.8	14.9	14.6	13.0
ADDC-033	Industrial	329906	370882	8.2	11.1	10.6	10.1
Roadside and kerbside monitoring							
ADDC-024	Kerbside	330599	368922	8.1	20.5	20.1	18.0
ADDC-116	Kerbside	332535	368907	9.1	14.7	15.5	15.2
ADDC-036	Kerbside	330575	371802	6.9	11.4	11.6	12.5

Source: NW Authorities Collaborative Project 2024 Air Quality Progress Report

The maximum concentration recorded at any site within the most recent three years of monitoring data is 20.5 µg/m³, and the maximum at a background site is 20.1 µg/m³, well below the AQAL of

40 µg/m³. Monitored concentrations are higher than mapped background concentrations at all sites.

The maximum monitored nitrogen dioxide concentration at a background site (20.1 µg/m³) has been used as the baseline concentration for the purpose of this assessment. Further consideration has been given to baseline concentrations at any areas of relevant exposure where the change in concentrations as a result of operation of the CC facility cannot be screened out as 'insignificant'.

4.4 Other national monitoring networks data

Neither the Defra mapped background dataset, AURN, or LAQM include monitoring of other pollutants released from the Facility such as hydrogen chloride, hydrogen fluoride, or VOCs. As such reference has been made to national modelling to determine a suitable background concentration for these pollutants.

4.4.1 Hydrogen chloride

Hydrogen chloride was measured until the end of 2015 on behalf of Defra as part of the UK Eutrophying and Acidifying Atmospheric Pollutants (UKEAP) project. This consolidates the previous Acid Deposition Monitoring Network (ADMN), and National Ammonia Monitoring Network (NAMN). Monitoring of hydrogen chloride ceased at the end of 2015 and none of the historic sites were located within 10 km of the Site. Prior to the cessation of the monitoring concentrations were fairly constant.

The maximum annual average monitored within the UK between 2011 and 2015 was 0.76 µg/m³. In lieu of any recent representative monitoring this has been used as the background concentration for this assessment as a conservative estimate.

4.4.2 Hydrogen fluoride

Baseline concentrations of hydrogen fluoride are neither measured locally nor nationally, since these are not generally of concern in terms of local air quality. However, the EPAQS report 'Guidelines for halogens and hydrogen halides in ambient air for protecting human health against acute irritancy effects' contains some estimates of baseline levels, reporting that measured concentrations have been in the range of 0.036 µg/m³ to 2.35 µg/m³.

In lieu of any local monitoring, the maximum measured baseline hydrogen fluoride concentration has been used as the background concentration for the purpose of this assessment as a conservative estimate.

4.4.3 Ammonia

Ammonia is also measured as part of the UKEAP project at rural background locations. There are no UKEAP monitoring locations within 10 km of the Site. In lieu of any local UKEAP monitoring, the maximum mapped background value from APIS within 5 km of the site (2.3 µg/m³) has been used for the purpose of this assessment when considering the impact with reference to the AQALs for the protection of human health. Site and location-specific background concentrations from each designated ecological site from APIS have been used when evaluating the impact at ecological receptors, if needed.

4.4.4 Volatile Organic Compounds

As part of the Automatic and Non-Automatic Hydrocarbon Network, benzene concentrations are measured at sites co-located with the AURN across the UK. There are monitoring locations within 10 km of the Site. As such2, the maximum mapped background concentration within 5 km of the Facility has been used. This value is 1.44 µg/m³.

4.4.5 Metals

In addition to the local monitoring, metals are measured as part of the Rural Metals and UK Urban/Industrial Networks (previously the Lead, Multi-Element and Industrial Metals Networks). No monitoring sites are located within 10 km of the Site. In lieu of any local monitoring data, the maximum from across the UK background monitoring sites has been used. A summary of the maximum annual data across all UK urban and rural background monitoring sites is presented in the following table.

Table 9: Metals Monitoring Maximum of all Background Sites – Urban and Rural

Substance	Annual mean concentration (ng/m³)						Max (as % of AQAL)
	AQAL	2020	2021	2022	2023	2024	
Arsenic	6	1.00	0.98	0.90	0.80	0.94	16.7%
Cadmium	5	0.42	0.35	0.29	0.29	0.25	8.4%
Chromium	-	3.70	4.80	4.60	4.80	4.60	-
Cobalt	-	0.84	0.65	1.50	0.86	0.56	-
Copper	-	18.00	16.00	18.00	15.00	13.00	-
Lead	250	7.80	15.00	8.00	7.60	5.40	6.0%
Manganese	150	10.00	7.60	8.50	8.00	7.00	6.7%
Nickel	20	1.70	2.20	2.50	2.40	1.80	12.5%
Vanadium	-	3.00	3.00	1.90	1.90	1.20	-

Notes:
Excludes data from Sheffield Tinsley and Swansea Coedgwilym – although classified as urban background sites, these are located close to large industrial sources of metals and as such has high levels of these pollutants far greater than those monitored at other sites.

Source: © Crown 2025 copyright Defra via uk-air.defra.gov.uk, licenced under the Open Government Licence (OGL).

As shown, the concentrations monitored were significantly lower than the AQALs at all monitoring sites considered.

The surroundings of the Site is a mixture of rural and suburban areas and some light industrial uses. No significant emission sources of metals have been identified in the local area, so it is deemed appropriate to use the maximum metal concentrations from 2019 – 2023 across all urban and rural background sites (excluding Sheffield Tinsley and Swansea Coedgwilym, which are close to significant sources of metals) as the baseline concentrations within this assessment, in lieu of any representative local monitoring.

No data is available for antimony and mercury as monitoring of these metals across the UK ceased at the end of 2013, except for at London Westminster and Runcorn Weston Point where mercury was monitored until the end of 2018. Runcorn is not representative of the surroundings of the Proposed Development due to elevated local concentrations from industrial sources in Weston

Point. The concentration monitored at London Westminster in 2018 (2.80 ng/m³) has been used as the baseline mercury concentration for the assessment.

The maximum monitored concentration of antimony at a background location in 2013 was 1.30 ng/m³ at Detling, which has been used as the baseline concentration for the assessment. This value is only 0.026% of the annual mean AQAL of 5,000 ng/m³.

4.4.6 Dioxins, furans and polychlorinated biphenyl (PCBs)

Dioxins, furans and PBCs are monitored on a quarterly basis at a number of urban and rural stations in the UK as part of the Toxic Organic Micro Pollutants (TOMPs) network. There are no national monitoring locations within 10 km of the site.

A summary of dioxin and furan and PCB concentrations from all monitoring sites across the UK is presented in Table 10 and Table 11. Monitoring data for dioxins and furans is only available up to the end of 2016 from the UK-Air website. For PCBs, data is only available up to the end of 2018 from the UK-Air website.

Table 10: Dioxin and Furans Monitoring

Site	Annual mean concentration (fgTEQ/m³)				
	2012	2013	2014	2015	2016
Auchencorth Moss	0.13	0.86	0.01	0.01	0.13
Hazelrigg	8.75	2.02	2.61	5.27	4.59
High Muffles	4.32	0.6	1.07	0.54	2.73
London Nobel House	15.42	3.47	2.89	4.34	21.27
Manchester Law Courts	32.99	10.19	16.52	5.94	12.23
Weybourne	9.3	2.34	1.61	1.42	16.32

Source: © Crown 2025 copyright Defra via uk-air.defra.gov.uk, licenced under the Open Government Licence (OGL).

Table 11:TOMPS – PCB Monitoring

Site	Annual mean concentration (pg/m³)				
	2014	2015	2016	2017	2018
Auchencorth Moss	23.23	24.27	25.32	19.09	12.31
Hazelrigg	25.84	41.68	52.58	33.15	22.22
High Muffles	26.11	33.43	37.76	31.63	8.86
London Nobel House	107.49	121.39	110.46	121.87	46.63
Manchester Law Courts	128.93	97.99	92.6	97.27	40.10
Weybourne	17.00	20.95	38.61	32.26	11.23

Source: © Crown 2025 copyright Defra via uk-air.defra.gov.uk, licenced under the Open Government Licence (OGL).

This analysis shows that the concentrations vary significantly between sites and years. The maximum monitored concentration from the past five years of available monitoring data has been used as the background concentration within this assessment. These values are 32.99 fg/TEQ/m³ for dioxins and furans and 128.93 pg/m³ for PCBs.

4.4.7 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic Aromatic Hydrocarbons (PAHs) are monitored at a number of stations in the UK as part of the PAH network. For the purpose of this assessment, benzo(a)pyrene is considered as this is the only PAH which an AQAL has been set.

There are no monitoring locations within 10 km of the Site. This assessment has considered monitored data from all background sites, shown in Table 12.

Table 12: Benzo(a)pyrene

Site	AQAL (ng/m^3)	Annual mean concentration (ng/m^3)				
		2018	2019	2020	2021	2022
Min	0.25	0.01	0.02	0.02	0.01	0.01
Max		0.55	0.68	0.60	0.62	0.52
Average		0.16	0.19	0.19	0.16	0.12

As shown, the maximum at any background site exceeds the AQAL. A major source of PAHs in the UK is domestic wood burning. However, this is unlikely to be a significant source in the vicinity of the Facility. As such, the maximum annual average monitored concentration from the last five years of monitoring data (0.19 ng/m^3) is considered to be a conservative estimate of benzo(a)pyrene concentrations in the vicinity of the Facility.

4.4.8 Aldehydes

Baseline concentrations of aldehydes are neither measured locally nor nationally, since these are not generally of concern in terms of local air quality. Formaldehyde is the aldehyde with the most stringent AQAL. The Defra report 'Non-methane Volatile Organic Compounds in the UK'[2] presents the results of some monitoring studies, reporting a maximum measured formaldehyde concentration in the UK of 2.37 $\mu g/m^3$.

In lieu of any local monitoring, the maximum measured baseline formaldehyde concentration has been used for the purpose of this assessment as a conservative estimate.

4.4.9 Amines, nitrosamines and nitramines

The concentrations of amines and amine degradation products (i.e. nitrosamines and nitramines) in ambient air, and their consequent impacts on human health, are active areas of research. Inhalation of these compounds is only one potential pathway, with other known sources including dietary exposure, drinking water, and some pharmaceuticals. Nitrosamines have been detected in food and drink, particularly those with high concentrations of nitrites such as processed meat, cheese, alcoholic beverages and processed vegetables. However, this assessment is concerned only with exposure via inhalation, and has therefore only considered ambient air concentrations. The solvent to be used in the CC facility, MEA, does not form a stable nitrosamine. However, as it has the potential to degrade into substances that do form stable nitrosamines, it is appropriate to consider baseline concentrations of amines, nitrosamines and nitramines.

[2] Defra Air Quality Expert Group, Non-methane Volatile Organic Compounds in the UK, 2020

The EA's Air Quality Modelling and Assessment Unit (AQMAU) produced a report in 2021[3] which details their recommendations for the assessment of emissions from amine-based CCS systems. With regard to baseline concentrations, the report states:

> *"we found no ambient air measurements of amines, nitrosamines or nitramines in the UK."*

Nitrosamines, which are the compounds with the greatest potential human health effects, have short atmospheric lifetimes on the order of hours before undergoing photolysis. As such, only local sources would contribute significantly to baseline concentrations. There are no known industrial sources of amines to the atmosphere in the local area.

No existing local sources of point source emissions of amines have been identified. Therefore, in the first instance it has been assumed that ambient air concentrations of these pollutants in the vicinity of the Site are below the limit of detection (LOD) of any currently available monitoring techniques and have been assumed to be zero.

4.5 Summary of background concentration used in assessment

In summary, there is some local monitoring of nitrogen dioxide. For other pollutants background concentrations have conservatively been estimated from background mapping, national monitoring networks, and literature reviews.

The concentrations of road traffic pollutants (in particular nitrogen dioxide, and to a lesser degree particulate matter) vary spatially across the modelling domain. As such, additional consideration will be given to determine the baseline concentration for these pollutants taking into account the local monitoring data and other sources of data regarding local concentrations, such as Defra's ambient air quality mapping.

For other pollutants, in the first instance it will be assumed that baseline concentrations are as per those set out in the following table. These are based on a mixture of monitoring, modelled datasets, and published reports. Where the contribution from the CC facility cannot be screened out as 'insignificant' (see Section 8.1 for methodology), the choice of baseline concentration will be given additional consideration, taking into account the local monitoring and the contribution from other local sources, and noting that any local monitoring data includes a contribution from the Existing Facility.

Table 13: Summary of Baseline Concentrations

Pollutant	Annual mean concentration	Units	Justification
Nitrogen dioxide	20.1	µg/m³	Maximum monitored concentration at a background site within 5 km, 2021 – 2023
Sulphur dioxide	5.80	µg/m³	Maximum mapped background concentration within 5 km of the Site (2023 Defra dataset; 2010 dataset for carbon monoxide).
Particulate matter (as PM_{10})	11.50	µg/m³	
Particulate matter (as $PM_{2.5}$)	7.40	µg/m³	
Carbon monoxide	237	µg/m³	
Benzene	1.44	µg/m³	

[3] AQMAU (Environment Agency), Recommendations for the assessment and regulation of impacts to air quality from amine-based post-combustion carbon capture plants, November 2021

Pollutant	Annual mean concentration	Units	Justification
Hydrogen chloride	0.76	µg/m³	Maximum monitored concentration across the UK 2011 to 2015
Hydrogen fluoride	2.35	µg/m³	Maximum measured concentration from EPAQS report
Ammonia	2.30	µg/m³	Maximum mapped background concentration within 5 km of the Site (APIS 2020 – 2022 mid year)
Mercury	2.80	ng/m³	Monitored annual mean concentration, London Westminster, 2018.
Antimony	1.30	ng/m³	Maximum monitored across UK in latest year of monitoring data (Detling, 2013)
Arsenic	1.00	ng/m³	Maximum monitored at a background site 2020 – 2024. Chromium VI assumed to be 20% of total chromium in line with EA guidance.
Cadmium	0.42	ng/m³	
Chromium	4.80	ng/m³	
Chromium VI	0.96	ng/m³	
Cobalt	1.50	ng/m³	
Copper	18.0	ng/m³	
Lead	15.0	ng/m³	
Manganese	10.0	ng/m³	
Nickel	2.50	ng/m³	
Vanadium	3.00	ng/m³	
Dioxins and furans	32.99	fg/m³	Maximum UK monitored concentration between 2012 and 2016
Polychlorinated biphenyl (PCBs)	128.93	pg/m³	Maximum UK monitored concentration between 2014 and 2018
Benzo(a)pyrene (PAHs)	0.19	ng/m³	Highest annual average of monitored concentrations across all background sites, 2020-2024
Formaldehyde	2.37	µg/m³	Maximum measured concentration from Defra report
Amines	0	-	No monitoring available. Assumed to be below the LOD of current monitoring techniques and effectively zero.
Nitramines	0	-	
Nitrosamines	0	-	

4.6 Baseline conditions at ecological sites

The Air Pollution Information System (APIS) database sets out the baseline concentrations on a grid across the UK. Atmospheric concentrations of oxides of nitrogen, ammonia, acid and nitrogen deposition are provided on a 1 km x 1 km grid. A large quantity of data is available but is only considered relevant where the impact of emissions cannot be screened out as 'insignificant' without reference to baseline conditions (as per the methodology detailed in section 9.1. The site-specific baseline concentrations relevant to the assessment are detailed in section 9.4.

5 Modelling Methodology

5.1 Selection of model

Detailed dispersion modelling was undertaking using the model ADMS 6, developed and supplied by Cambridge Environmental Research Consultants (CERC) This is a new generation dispersion model, which characterises the atmospheric boundary layer in terms of the atmospheric stability and the boundary layer height. In addition, the model uses a skewed Gaussian distribution for dispersion under convective conditions, to take into account the skewed nature of turbulence. The model also includes modules to take account of the effect of buildings and complex terrain.

ADMS is routinely used for modelling of emissions for environmental permitting purposes to the satisfaction of NRW. An analysis of the variation in model outputs has been undertaken and the maximum predicted concentration for each pollutant and averaging period has been used to determine the significance of any potential impacts.

5.2 Source and emissions data – ERF – i.e. the Permitted Facility

The source and emissions input data utilised within the modelling for the ERF are presented in Table 15 to Table 16. These are presented per line and are based on operational data obtained from the continuous emissions monitoring system (CEMS), representative of normal operation. These inputs have been used to determine the impact for the Permitted Facility.

Table 14: Stack Data - ERF

Item	Unit	Value
Height	m	85
Internal diameter	m	1.9
Stack location	m, m	331093.4, 371418.0

Table 15: Flue Gas Conditions – ERF

Item	Unit	Value
Temperature	°C	165
Exit moisture content	% v/v	18.90%
	kg/kg	0.140
Exit oxygen content	% v/v dry	6.78%
Reference oxygen content	% v/v dry	11.00%
Volume at reference conditions (273.15K, dry, ref O_2)	Nm^3/h	182,808
	Nm^3/s	50.78
Volume at actual conditions	Am^3/h	253,923
	Am^3/s	70.53
Flue gas exit velocity	m/s	24.88

Table 16: Stack Emissions Data – ERF

Pollutant	Daily or periodic		Half-hourly	
	ELV (mg/Nm³, unless stated)	Release rate (g/s, unless stated)	ELV (mg/Nm³, unless stated)	Release rate (g/s, unless stated)
Oxides of nitrogen (as NO_2)	180	9.140	400	19.48
Sulphur dioxide	40	2.031	200	9.740
Carbon monoxide(1)	50	2.539	150(1)	7.305
Total dust (PM)(2)	5	0.254	30	1.461
Hydrogen chloride	8	0.406	60	2.922
Volatile organic compounds (as TOC)	10	0.508	20	0.974
Hydrogen fluoride	1	50.78 mg/s	-	-
Ammonia	10	0.508	-	-
Cadmium and thallium	0.02	1.016 mg/s	-	-
Mercury	0.02	1.016 mg/s	-	-
Other metals(3)	0.3	15.24 mg/s	-	-
Benzo(a)pyrene (PAHs)(4)	0.2 µg/Nm³	10.16 µg/s	-	-
Dioxins and furans(5)	0.06 ng/Nm³	3.047 ng/s	-	-
PCBs(6)	5 µg/Nm³	0.254 mg/s	-	-

Notes:

All emissions are expressed at reference conditions of dry gas, 11% oxygen, 273.15K, 101.3 kPa.

(1) Averaging period for carbon monoxide is 95% of all 10-minute averages in any 24-hour period.

(2) As a worst-case it has been assumed that the entire dust emissions consist of either PM_{10} or $PM_{2.5}$ for comparison with the relevant AQALs.

(3) Other metals consist of antimony (Sb), arsenic (As), lead (Pb), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni) and vanadium (V).

(4) 0.2 µg/m³ is the maximum recorded at a UK plant (2019 Waste Incineration BREF, Figure 8.121). This is assumed to be the emission concentration for the ERF.

(5) The EP includes a limit of 0.06 ng I-TEQ/Nm³ as an average over a minimum of 6 hours, and a limit of 0.08 ng I-TEQ/Nm³ as a long-term average over a minimum of 2 weeks. The long-term average sampling is only required if it cannot be demonstrated that emissions are low and stable. It has been assumed that the long-term average monitoring will not be required and an emission limit of 0.06 ng I-TEQ/Nm³ is representative of the maximum annual mean emission concentration from the Facility.

(6) Table 3.8 of the 2006 Waste Incineration BREF states that the annual average total PCBs is less than 0.005 mg/Nm³ (dry, 11% oxygen, 273K). In lieu of other available operational data, this has been assumed to be the emission concentration for the ERF.

If the ERF continually operated at the half-hourly limits, the daily limits would be exceeded. The ERF is designed to achieve the daily limits and as such will only operate at the short-term ELVs for short periods on rare occasions.

5.3 Source and emissions data – CC facility

The source and emissions input data utilised within the modelling for the CC facility are presented in Table 17 to Table 19. These have been used to determine the impact of emissions from the CC facility. The mass release rate of emissions of pollutants emitted from the ERF is assumed to be unchanged in passing through the CC facility.

Table 17: Stack Data – CC facility

Item	Unit	Value
Height	m	85
Internal diameter	m	1.9
CC facility stack location	m, m	331021, 371421

Table 18: Flue Gas Conditions – CC facility

Item	Unit	Value
Temperature	°C	80
Exit moisture content	% v/v	9.40%
	kg/kg	0.068
Exit oxygen content	% v/v dry	8.82%
Reference oxygen content	% v/v dry	11%
Volume at reference conditions (273.15K, dry, ref O_2)	Nm^3/h	137,400
	Nm^3/s	38.17
Volume at actual conditions	Am^3/h	160,848
	Am^3/s	44.68
Flue gas exit velocity	m/s	15.76

Table 19: Stack Emissions Data – CC facility

Pollutant	Daily or periodic	
	Emission conc. (mg/Nm^3, unless stated)	Release rate (g/s, unless stated)
MEA - primary amine(1)	5	0.1908
Nitrosamines from MEA(2)	None emitted	None emitted
Nitramines from MEA(3)	0.0909 $\mu g/Nm^3$	3.469 µg/s
DEA – secondary amine(1)	0.25	9.540 mg/s
Nitrosamines from DEA(4)	1 $\mu g/Nm^3$	38.16 µg/s
Nitramines from DEA(3)	4.55 ng/Nm^3	0.173 µg/s
DMA – secondary amine(1)	0.25	9.540 mg/s
Nitrosamines from DMA(4)	1 $\mu g/Nm^3$	38.16 µg/s
Nitramines from DMA(3)	4.55 ng/Nm^3	0.173 µg/s

Pollutant	Daily or periodic	
	Emission conc. (mg/Nm³, unless stated)	Release rate (g/s, unless stated)
Aldehydes	5	0.1908

Notes:
All emissions are expressed at reference conditions of dry gas, 11% oxygen, 273.15K, 101.3 kPa, for the flue gas flow rate at the CC facility stack.
For pollutants with an ELV from the ERF the same g/s release rate has been assumed from the CC facility – refer to Table 16 for the relevant release rates.
(1) MEA based system with the main primary amine being MEA with trace amounts of DEA and DMA. Emissions of DEA and DMA in total assumed to be 10% of the MEA emissions with a 50/50 split of each.
(2) No nitrosamines from MEA emitted.
(3) Total nitramines assumed to be 0.1 µg/Nm³ apportioned as per the amine concentration – i.e. 95% from MEA, with 2.5% from DEA and DMA.
(4) Total nitrosamines assumed to be 2 µg/m³ apportioned equally between nitrosamines formed from DEA and from DMA.

The emissions concentrations for MEA (5 mg/Nm³), total nitrosamines (2 µg/Nm³), and aldehydes (5 mg/Nm³) are proposed as ELVs for the CC facility. Emissions concentrations of other substances presented in Table 19 are not proposed as ELVs but are included as the likely upper end of long-term average emissions from the CC facility to allow the impact to be quantified.

5.4 Other inputs

5.4.1 Modelling domain

For pollutants for which amine chemistry is not relevant, modelling has been undertaken over a grid of 20 km x 20 km with grid spacing of 200 m, with a smaller nested grid of 5 km x 5 km with a grid spacing of 50 m, which is much less than 1.5 times the stack height as recommended by Defra in LAQM.TG(22).

Table 20: Modelling Domain – Non-Amine Chemistry Model Runs

Parameter	Wide grid	Fine grid
Grid Spacing (m)	200	50
Grid Start X	320000	328500
Grid Finish X	340000	333500
Grid Start Y	364000	369000
Grid Finish Y	384000	374000

Amine chemistry modelling has been undertaken over a larger grid as chemical reactions which form amine degradation products can occur a considerable distance downwind of the source. Amine chemistry modelling has been undertaken over a grid of 40 km x 40 km with grid spacing of

500 m, with a smaller nested grid of 10 km x 10 km with a grid spacing of 100 m, which is less than 1.5 times the stack height as recommended by Defra in LAQM.TG(22).

Table 21: Modelling Domain – Amine Chemistry Model Runs

Parameter	Wide grid	Fine grid
Grid Spacing (m)	500	100
Grid Start X	311000	326000
Grid Finish X	351000	336000
Grid Start Y	352000	367000
Grid Finish Y	392000	377000

Reference should be made to Figure 4 of Appendix A for a graphical representation of the modelling domain.

5.4.2 Meteorological data and surface characteristics

The impact of meteorological data has been taken into account by using meteorological data from the Hawarden meteorological recording station for the years 2020 – 2024 sourced from Air Pollution Services (APS) Limited. Hawarden is located approximately 7 km to the south-east of Site. Wind roses for each year of meteorological data can be found in Figure 5 of Appendix A.

The minimum Monin-Obukhov length utilised in ADMS can be selected for both the dispersion site and meteorological site. This is a measure of the minimum stability of the atmosphere and can be adjusted to account for urban heat island effects which prevent the atmosphere in urban areas from ever becoming completely stable. Surface conditions surrounding the Facility are mixed industrial with rural and coastal areas nearby, whilst conditions at Hawarden are mainly open grassland and rural with airport infrastructure and some residential areas in the vicinity. The minimum Monin-Obukhov length has been set to 10 m at the dispersion site and 1 m at the meteorological site, which is considered appropriate for the setting of each site.

The surface roughness length utilised in ADMS can be selected for both the dispersion site and meteorological site. The surface roughness length varies widely across the modelling domain, from very low values over the estuary to much higher values over built-up areas. To account for the varying surface roughness length, two a spatially-varying surface roughness files has been used as model inputs, of sufficient size to cover the output grid extents detailed in section 5.4.1. The land-use class for each point in the file has been extracted from the UK Land Cover database[4] and cross-referenced with the most likely surface roughness length value[5].

A surface roughness length of 0.2 m has been selected for the Hawarden meteorological site. CERC recommends that this value is the minimum value suitable for “agricultural areas” and is considered representative of the mainly open surroundings of the meteorological site.

The parameters for the spatially-varying surface roughness file are shown in Table 22. Reference should be made to Figure 6 of Appendix A for a visualisation of the surface roughness file used (showing the larger of the two files).

4 UK Centre for Ecology and Hydrology, UK Land Cover Map for 2021.

5 Taken from “Roughness length classification of Corine Land Cover classes”, Megajoule Consultants, 2007.

Table 22: Terrain and Surface Roughness Extents

Terrain and surface roughness	Non-Amine Chemistry Model Runs	Amine Chemistry Model Runs
Grid spacing (m)	150	300
Grid points	150 x 150	150 x 150
Processing resolution	64 x 64	128 x 128
Grid Start X	318825	308550
Grid Finish X	341025	353250
Grid Start Y	362925	349650
Grid Finish Y	385125	394350

Table 23: Surface Roughness Lengths Used for Different Land Use Classes

Land Use Classification	UK Land Cover Identifier	Surface Roughness Length (m)
Urban	20	1.2
Deciduous woodland, Coniferous woodland	1, 2	0.75
Suburban	21	0.5
Arable, saltmarshes	3, 19	0.05
Acid grassland, heather	7, 9	0.03
Bare rock	12	0.005
Littoral sediment	18	0.0005
Water(1)	14	0.0001
Note: *(1) The 'most likely' value for water is given as zero. ADMS cannot model a surface roughness length of zero, so areas of water have been assigned a roughness length of 0.0001 m which is the value recommended by CERC for 'sea'.*		

A summary of the meteorological parameters used in the dispersion modelling is shown in Table 24.

Table 24: Meteorological parameters

Parameter	Dispersion Site Value (m)	Met Site Value (m)
Surface roughness length	Variable	0.2
Minimum Monin-Obukhov length	10	1

5.4.3 Terrain

It is recommended that by CERC, where gradients within 500 m of the modelling domain are greater than 1 in 10, the complex terrain module within ADMS (FLOWSTAR) should be used. Terrain files have been created using Ordnance Survey Terrain 50 data covering the same points as the surface roughness files shown in Table 22. Reference should be made to Figure 7 of Appendix A for a visualisation of the terrain file used (showing the larger of the two files)..

5.4.4 Buildings

The presence of adjacent buildings can significantly affect the dispersion of the atmospheric emissions in various ways:

- Wind blowing around a building distorts the flow and creates zones of turbulence. The increased turbulence can cause greater plume mixing.
- The rise and trajectory of the plume may be depressed slightly by the flow distortion. This downwash leads to higher ground level concentrations closer to the stack than those which would be present without the building.

It is recommended that buildings should be included in the modelling if they are both:

- Within 5L of the stack (where L is the smaller of the building height and maximum projected width of the building); and
- Taller than 40% of the stack.

The ADMS 6 user guide also states that buildings less than one third of the stack height will not have any effect on the dispersion calculations in the model.

A review of the Site layout has been undertaken, and the details of the applicable buildings are presented in Table 25. None of the buildings proposed as part of the CC facility are tall enough or close enough to the CC facility stack to influence dispersion. A plan showing which buildings have been included in the model is presented in Figure 8 of Appendix A.

Table 25: Building Details

Buildings	Centre point		Height (m)	Length (m)	Width (m)	Angle (°)
	X (m)	Y (m)				
Boiler House*	331074	371470	42.0	43.0	22.0	161
Bunker	331063	371502	36.7	53.0	27.0	71
FGT	331087	371433	29.5	14.0	12.0	71

Note:
** Selected as the main building in the dispersion model.*

5.4.5 Wind turbines

Wind turbines have the potential to affect the dispersion of emissions if the wind is blowing from the stack towards the turbines, or from the turbines to the stack, causing a wake. This can be accounted for within ADMS by using the wind turbines module. However, wind turbine wakes are generally dissipated within 12-15 rotor diameters, with the wind turbine effects becoming more noticeable when the stack is within a few rotor diameters of the turbine. No wind turbines have been identified which lie within 12-15 rotor diameters of the Facility, so this option has not been used.

5.5 Plume depletion

Within ADMS when modelling deposition an option is to include plume depletion, where the concentration of pollutants in the plume reduce as the pollutants are deposited. This has not been included in the model as a conservative assumption.

5.6 Chemistry

The Facility will release nitric oxide (NO) and nitrogen dioxide (NO_2) which are collectively referred to as oxides of nitrogen (NOx). In the atmosphere, NO will be converted to NO_2 in a reaction with ozone (O_3) which is influenced by solar radiation. Since the AQALs are expressed in terms of NO_2, it is important to be able to assess the conversion rate of NO to NO_2.

Ground level NOx concentrations have been predicted through dispersion modelling. NO_2 concentrations reported in the results section assume 70% conversion from NOx to NO_2 for annual means and a 35% conversion for short term (hourly) concentrations, based upon the worst-case scenario specified in the EA's guidance for dispersion modelling[6] which is appropriate where the primary NO_2 to NOx ratio is less than 10%. Given the short travel time to the areas of maximum concentrations, this approach is considered conservative.

5.6.1 Amine chemistry

Directly-emitted amines have the potential to react in the atmosphere to form amine degradation products – nitramines and nitrosamines. The ADMS 6 amine chemistry module calculates concentrations of amines, nitramines and nitrosamines based on the release rate of pollutants and a number of user-defined parameters. The parameters used in the dispersion modelling of amine releases are detailed in Table 26.

The primary amine emitted by the CC facility would be MEA. However, it has been assumed that trace amounts of both DEA and DMA would also be emitted. Amines can form both nitrosamines and nitramines. However, the nitrosamines formed from primary amines such as MEA are unstable, forming isomers known as imines within a few seconds. Imines are not reactive nor significantly harmful to human health. Therefore, any directly emitted nitrosamines will be formed from another, secondary amine formed from reactions within the absorber tower. The exact type of secondary amine(s) and resultant nitrosamine(s) are not known at this stage. For the purpose of this assessment it has been assumed that the secondary amines emitted are equal concentrations of DMA and DEA, and the directly emitted nitrosamines are consequently equal concentrations of NDMA (formed from DMA) and n-nitrosodiethanolamine (NDELA, formed from DEA).

The amine chemistry module requires the user to input reaction rate parameters for a number of reactions which are detailed in Appendix F. The values used for the main model runs are detailed in Table 26.

Table 26: Amine Chemistry Module Input Parameters

Parameter	Units	MEA	DEA	DMA
% of NOx that is NO_2 (primary NO_2)	%			1.5%
k1 amine/OH reaction rate constant(1)	$ppb^{-1}s^{-1}$	1.900	2.525	1.625
k2 amino radical/O_2 reaction rate constant(1)	$ppb^{-1}s^{-1}$	$3.10x10^{-9}$	$4.45x10^{-10}$	$3.10x10^{-9}$

6 https://www.gov.uk/guidance/environmental-permitting-air-dispersion-modelling-reports

Parameter	Units	MEA	DEA	DMA
k3 rate constant for formation of nitrosamine[1]	$ppb^{-1}s^{-1}$	$2.13x10^{-3}$	$1.78x10^{-2}$	$2.13x10^{-3}$
k4a rate constant for formation of nitramine[1]	$ppb^{-1}s^{-1}$	$7.95x10^{-3}$	$7.95x10^{-3}$	$7.95x10^{-3}$
k4 Amino radical/NO_2 reaction rate constant[1]	$ppb^{-1}s^{-1}$	$9.70x10^{-3}$	$9.70x10^{-3}$	$9.70x10^{-3}$
Branching ratio for amine/OH reaction[1]	-	0.08	0.41	0.41
Ratio of J(nitrosamine)to J(NO_2) [1][2]	-	0.53	0.15	0.34
Constant for OH concentration calculations[3]	s			0.001111
Formation of stable nitrosamines[4]	-	No	Yes	Yes

Notes:
[1] Taken from the Carbon Capture and Storage Association (CCSA) Position Paper 'Carbon Capture Chemistry Parameters, N-Amines Chemistry'[7], except for the values for DEA which are taken from Larsen (2011)[8].
[2] J refers to the photolysis rate of each molecule.
[3] Calculated using CERC Amine Chemistry User Input Tool, from typical concentrations of OH ($1x10^6$ molecules/cm^3), ozone and solar radiation calculated from the met data files. Background ozone taken from Liverpool Speke.
[4] The CERC Amine Chemistry Supplement states that the nitrosamine produced by primary amines is unstable and will rapidly isomerise to form an imine. Therefore, primary amines will not form stable nitrosamines.

In addition, the amine chemistry module requires the user to input hourly varying background concentrations of nitric oxide (NO), nitrogen dioxide (NO_2), and ozone (O_3). The closest AURN monitoring site which measures ozone is at Wirral Tranmere, approximately 16 km to the north. This is an urban background site at which it is unlikely that concentrations are representative of those at the Site. Liverpool Speke is a similar distance to the north east and is likely to be more representative of conditions at the Site due to its semi-rural location close to an estuary (the Mersey estuary). The most recent five years of background data from Liverpool Speke has been used. Any missing data in a given year has been infilled using the average for that hour from the remaining years of data.

The amine chemistry parameters and other aspects of modelling amine chemistry are subject to uncertainties. A detailed description of the ADMS amine chemistry module and analysis of the sensitivity of the results to the choice of amine chemistry parameters is presented in Appendix F.

5.7 Other local point sources of emissions

It is not necessary to consider the Permitted Facility as a point source in the assessment of emissions from the CC facility, as the flue gas will be emitted from either the ERF stack or the CC facility stack, but not both at the same time. Existing local sources are captured in local monitoring and mapped background data.

The following additional local point sources have been identified which may have a cumulative impact with the Facility:

7 C.Hazell-Marshall, C Nielsen, Carbon Capture Chemistry Parameters, N-Amines Chemistry, CCSA, January 2023

8 Larsen, Atmospheric Chemistry – Nitrosamine Photolysis. SINFEF 257430177: D3+D4. Version 3, 2011

The following cumulative schemes are considered to have a potential cumulative effect with emissions from the Proposed Development:

1. Planning ref 63104 & PP-09932097. Arrow Bio Plant. Anaerobic Digestion (AD) aspect only (point source emissions only). The gasification aspect cannot be built given its footprint is taken up by the AD plant under construction.
2. Planning ref FUL/000011/22, FUL/000040/24 & DNS/3279559. Shotton Paper Mill.
3. Planning ref EN010166. Connah's Quay power station and carbon capture.
4. Planning ref 063721 & PP-10295886, Airfields Paper Mill.
5. Planning ref CAS-02009-W1R1Z7, Padeswood cement carbon capture.

For the Shotton Paper Mill and Connah's Quay developments the sources have been explicitly included in the dispersion modelling (excluding amine modelling for Connah's Quay). The AD development and Airfields Paper Mill development only emit oxides of nitrogen and result in a small PC so have been considered using the worst-case PC from their respective air quality assessments. The air quality assessments submitted to support the Padeswood and Connah's Quay developments have been reviewed to inform the cumulative assessment of amine degradation products.

The model input parameters for the cumulative sources that have been explicitly modelled are presented in Appendix E. All other sources have been considered on a semi-quantitative basis. The location of each source is shown on Figure 9. A discussion of the potential cumulative impact is presented in section 10.

5.8 Baseline concentrations

Background concentrations for the assessment have been derived from monitoring and national mapping as summarised in Table 13. For short term averaging periods, the background concentration has been assumed to be twice the long-term ambient concentration following the EA recommendation within the Air Emission Guidance.

The background concentrations set out in Table 13 have been used to define the total PECs. However, where the contribution from the Facility cannot be screened out as 'insignificant', additional consideration has been made of the contribution from other local sources and road sources to determine an appropriate baseline concentration for the specific receptors of concern. This is then combined with the contribution from the CC facility to determine the PEC. As a conservative measure no adjustment has been made to locally monitored pollutant concentrations to account for the contribution of the operational ERF.

6 Sensitivity Analysis

The following section details the sensitivity of the model to certain input parameters. This has considered the impact of emissions of NOx from the CC facility assuming continual operation with the ERF operating at the ELV and this exhaust being ducted to the CC facility. Where the changes to model inputs result in an increase in impacts the results are highlighted orange, and where they result in a decrease in impacts the results are highlighted green.

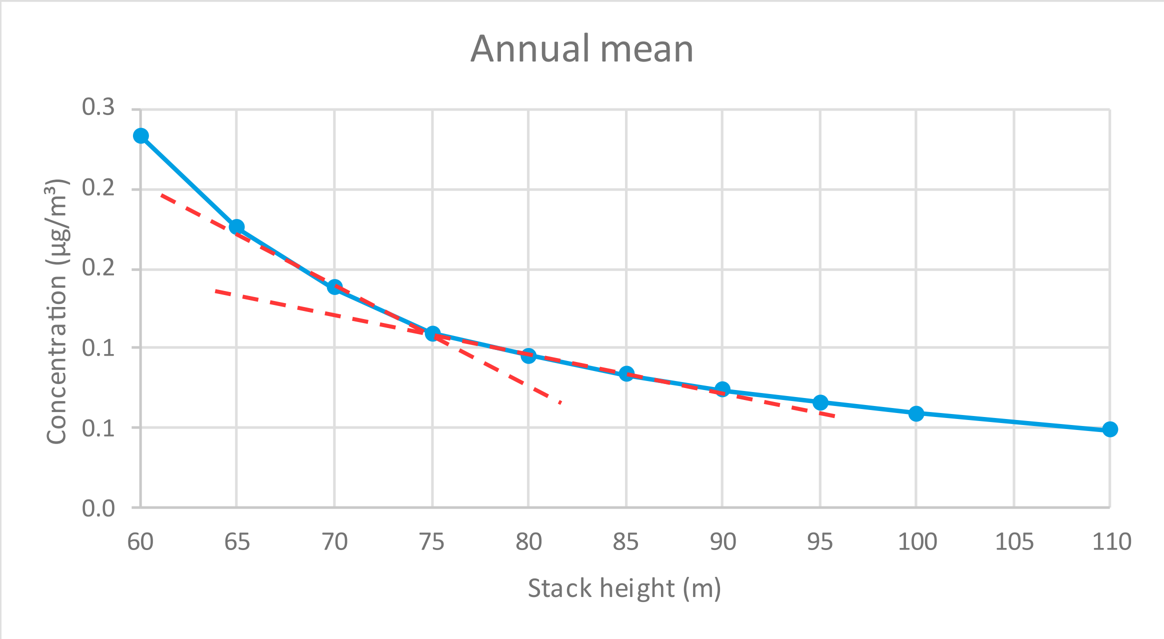
6.1 Stack height justification

When determining a suitable stack height, it is best practice to identify the stack height where the rate of reduction in maximum ground level concentration with increased height slows down. This can be identified on a graph as a step change in the slope. A range of stack heights from 60 m to 110 m has been considered.

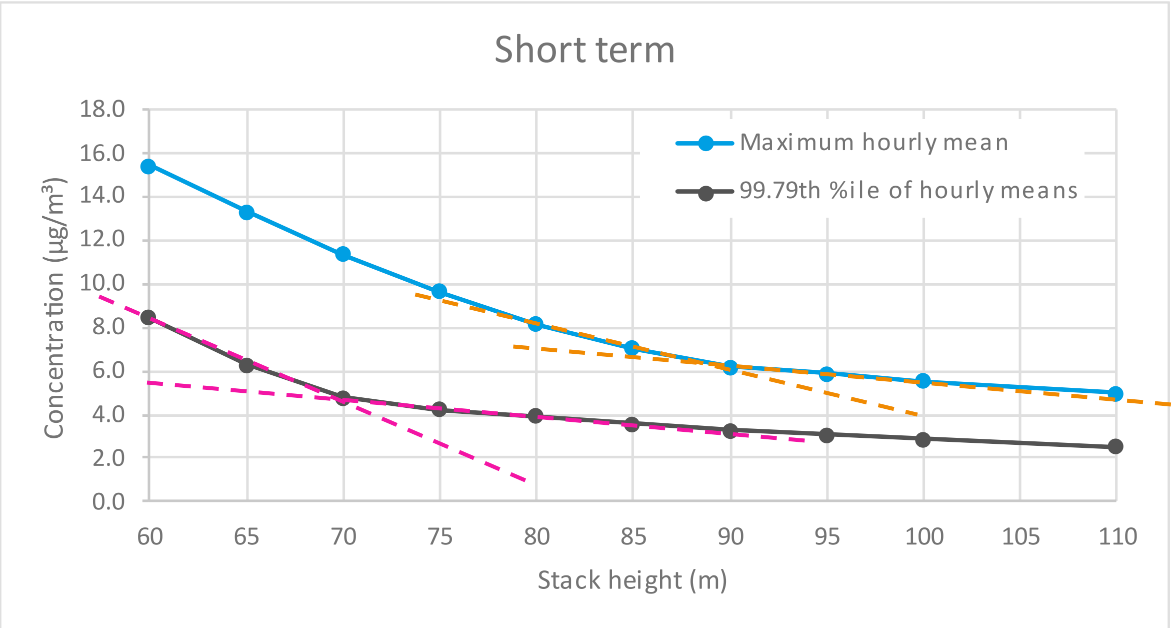
The following parameters were kept constant:

- Source - CC facility;
- Grid – 5 km x 5 km grid at 50 m resolution;
- Buildings – included;
- Terrain file – included at 64 x 64 resolution;
- Dispersion site surface roughness value – varying at 64 x 64 resolution;
- Meteorological site surface roughness – 0.2 m;
- Dispersion site Monin-Obukhov length – 10 m;
- Meteorological site Monin-Obukhov length – 10 m; and
- Meteorological data used – Hawarden 2020 - 2024.

The following graphs show the ground level concentration at the point of maximum impact for a range of stack heights for the CC facility, for a nominal 1 g/s release rate.



Graph 1 – Stack Height Analysis for Annual Mean Concentrations



Graph 2 – Stack Height Analysis for 99.79th Percentile of Hourly Mean Concentrations

For annual mean concentrations there is a change in the angle of the slope evident at a height of 75 m, as indicated by the red lines. There is a slight flattening of the slope for stack heights above 75 m, but no significant step changes in the angle of the slope.

For the 99.79th percentile of hourly mean concentrations, which has been selected for its relevance to the short-term AQAL for nitrogen dioxide, there is a change in the angle of the slope at 70 m, as indicated by the magenta lines, while for maximum hourly concentrations there is a change in the angle of the slope evident at 90 m.

When considering the stack height, greater weight is to be given to the annual mean concentrations rather than short-term concentrations, for which modelling uncertainty is greater and duration and likelihood of exposure is lower. Therefore, the minimum recommended stack height based on the shape of the graphs is 75 m.

As the height of the existing ERF stack is 85 m, this EP application is made on the basis of a stack of the same height. This provides some additional reduction in impacts compared to the minimum recommended height of 75 m and is within the envelope of consented heights on the Site.

It is noted that the planning application has applied for a stack height of up to 95 m in the event that detailed design indicates a taller stack is required. For the purposes of this EP application, the stack height being applied for is 85m and if a taller stack was required, a further variation to the EP would also be applied for.

6.2 Surface roughness

The sensitivity of the results to using varying surface roughness length has been considered by running the model with a variable surface roughness file and a constant surface roughness value across the modelling domain. For all sensitivity analysis the impact of changing model parameters on the maximum annual mean and short-term concentrations of oxides of nitrogen have been considered.

The following parameters have been kept constant:

- Source - CC facility;
- Stack height - 85 m;
- Grid – 5 km x 5 km grid at 50 m resolution;
- Buildings – included;
- Terrain file – included at 64 x 64 resolution;
- Meteorological site surface roughness – 0.2 m;
- Dispersion site Monin-Obukhov length – 10 m;
- Meteorological site Monin-Obukhov length – 10 m; and
- Meteorological data used – Hawarden 2022.

The contribution of oxides of nitrogen emissions from the CC facility stack at the point of maximum ground level impact and the maximum impacted receptor are presented in Table 27. In addition, the difference between in impact using the variable surface roughness file has been calculated. Where the impact is less than using the variable surface roughness file this is highlighted in green, and where the impact is greater this is highlighted in yellow.

Table 27: Surface Roughness Sensitivity Analysis

Surface roughness (m)	Concentration (µg/m³)			
	Point of maximum impact – ground level		Maximum impacted receptor	
	Annual mean	Max 1-hour mean	Annual mean	Max 1-hour mean
Variable	**0.76**	**61.12**	**0.35**	**24.42**
0.02	0.41	49.85	0.28	28.29
0.1	0.57	50.29	0.32	27.45
0.3	0.74	49.02	0.33	26.27
0.5	0.85	43.75	0.34	25.84

Surface roughness (m)	Concentration (µg/m³)			
	Point of maximum impact – ground level		Maximum impacted receptor	
	Annual mean	Max 1-hour mean	Annual mean	Max 1-hour mean
% change from variable surface roughness file				
0.02	-46.1%	-18.4%	-18.4%	15.8%
0.1	-25.8%	-17.7%	-6.7%	12.4%
0.3	-2.8%	-19.8%	-3.1%	7.6%
0.5	11.0%	-28.4%	-2.5%	5.8%

As shown, increasing surface roughness lengths result in higher annual mean concentrations. Short-term concentrations are less affected. The spatially varying surface roughness file results in similar annual maximum impacts to a constant surface roughness length of 0.3 – 0.5 m.

Due to the variations in the surface roughness values across the modelling domain and the sensitivity of the results to the choice of surface roughness length, it is considered appropriate to use the variable surface roughness file.

6.3 Terrain

The sensitivity of the results to the effect of terrain has been considered by running the model with and without the terrain file.

The following parameters have been kept constant:

- Source - CC facility;
- Stack height 85 m;
- Grid – 5 km x 5 km grid at 50 m resolution;
- Buildings – included;
- Dispersion site surface roughness – variable at 64 x 64 resolution;
- Meteorological site surface roughness – 0.2 m;
- Dispersion site Monin-Obukhov length – 10 m;
- Meteorological site Monin-Obukhov length – 10 m; and
- Meteorological data used – Hawarden 2022.

The contribution of oxides of nitrogen emissions from the CC facility stack at the point of maximum ground level impact and the maximum impacted receptor are presented in Table 28.

Table 28: Effect of Terrain

Scenario	Concentration (µg/m³)			
	Point of maximum impact		Maximum impacted receptor	
	Annual mean	Max 1-hour mean	Annual mean	Max 1-hour mean
Including terrain	**0.76**	**61.12**	**0.35**	**24.42**
Excluding terrain	0.69	48.41	0.32	16.12
% change from including terrain				
Excluding terrain	-9.1%	-20.8%	-6.5%	-34.0%

As shown, the inclusion of terrain effects results in higher impacts. The terrain file has been included as this is the most realistic scenario.

6.4 Building parameters

ADMS 6 has a buildings effects module to account for the impact of buildings when it calculates the air flow and dispersion of pollutants from a source. The model works by combining the inputted individual buildings into a single effective building for each wind direction.

The sensitivity of the results to the effect of buildings has been considered by running the model with and without the buildings presented in Table 25.

The following parameters have been kept constant:

- Source - CC facility;
- Stack height 85 m;
- Grid – 5 km x 5 km grid at 50 m resolution;
- Terrain – included at 64 x 64 resolution;
- Dispersion site surface roughness – variable at 64 x 64 resolution;
- Meteorological site surface roughness – 0.2 m;
- Dispersion site Monin-Obukhov length – 10 m;
- Meteorological site Monin-Obukhov length – 10 m; and
- Meteorological data used – Hawarden 2022.

The contribution of oxides of nitrogen emissions from the CC facility stack at the point of maximum ground level impact and the maximum impacted receptor are presented in Table 29.

Table 29: Effect of Buildings

Scenario	Concentration (µg/m³)			
	Point of maximum impact – ground level		Maximum impacted receptor	
	Annual Mean	Max 1-hour mean	Annual Mean	Max 1-hour mean
Including buildings	**0.76**	**61.12**	**0.35**	**24.42**
Excluding buildings	0.76	48.36	0.35	21.76

Scenario	Concentration (µg/m³)			
	Point of maximum impact – ground level		Maximum impacted receptor	
	Annual Mean	Max 1-hour mean	Annual Mean	Max 1-hour mean
As % of including buildings				
Excluding buildings	0.0%	-20.9%	0.0%	-10.9%

As shown the inclusion of buildings has no effect on the maximum annual mean concentrations but does result in higher short-term impacts. The effect of buildings has been included in the modelling as this is the most realistic scenario.

7 Model Validation and Uncertainty

In line with the EA's Air Emissions Guidance the level of uncertainty in the predictions is estimated. To do so, the results of the model validation documentation and the sensitivities have been considered, and the conservatism in the modelling has been reviewed.

7.1 Validation of ADMS model

7.1.1 Introduction

Dispersion modelling of process emission from the Facility has been carried out using ADMS (version 6) produced by CERC.

This section of the report describes the model and explains why it is considered appropriate for modelling the impacts of the Facility.

7.1.2 Model description

ADMS is a new generation dispersion model which characterises the atmospheric boundary layer in terms of the atmospheric stability and the boundary layer height. In addition, the model uses a skewed Gaussian distribution for dispersion under convective conditions, to take into account the skewed nature of turbulence. The model also includes modules to take account of the effect of buildings and complex terrain.

Within ADMS, the FLOWSTAR module is used to generate a new flow and turbulence field based on the terrain. This simulates the changes to the movement of air in the horizontal and vertical direction as a result of the terrain features in that the air flow is simulated flowing above and around raised ground. This modified flow field is then used by the model to adjust the plume height and plume spread parameters calculated by the flat terrain model. The ADMS model can also handle cases of strongly stable flow using a separate plume impingement model.

The technical specification document for the complex terrain module[9] explains that *"terrain should have no more than moderate slopes (up to 1:3) although the model is useful even when this criterion is not met (say up to 1:2)"*.

The surroundings of the site are generally flat or gently sloping, with only a few areas where the gradient is greater than 1:10 and no areas where it is greater than 1:3. CERC notes that during very low wind stable conditions in hilly terrain, horizontal gradients in density can cause katabatic (downslope) winds, which may influence the background flow in deep valleys[10]. These effects are not specifically accounted for in ADMS. However, the local area does not include such valleys and as such this limitation of the model is not relevant to this project.

ADMS 6 includes the option to model the effect of coastlines on diurnal air flows. However, it is not possible to include the effect of buildings or complex terrain and variable surface roughness when modelling the effect of the coastline. As shown in section 6 the model results are sensitive to the spatially varying surface roughness, terrain, and building effects. Therefore, it is considered that model results are likely to be more accurate with these effects included and the coastline effect excluded. The exclusion of coastline effects however is a limitation to the modelling methodology.

[9] CERC, P14/01S/17 Complex Terrain Module, March 2020

[10] CERC, Note 110 Temperature Inversions in ADMS, 20 April 2017

7.1.3 Model validation

CERC validates its models against available measured data obtained from real world situations, field campaigns and wind tunnel experiments. Validation studies are published on the CERC website[11] Not all of the validation studies are for settings similar to the study area (flat and/or gently sloping terrain). There are two validation studies that are considered to be in locations similar to the study area. These are detailed in Table 30.

Table 30: Model Validation Studies

Study	Notes
Baldwin Power Plant	Characterised as "complex terrain below the stack height". Complex terrain is included in model for the Facility but it does not rise above the stack height within several kilometres of the Site.
Kincaid, Indianapolis and Prairie Grass experiments	Kincaid – flat farmland with lakes Indianapolis – flat land, mixed industrial/commercial/urban. Although the model for the Facility includes terrain effects, these are relatively minor (see section 6.3). Prairie Grass experiment – ground level release, not relevant to Facility study area.

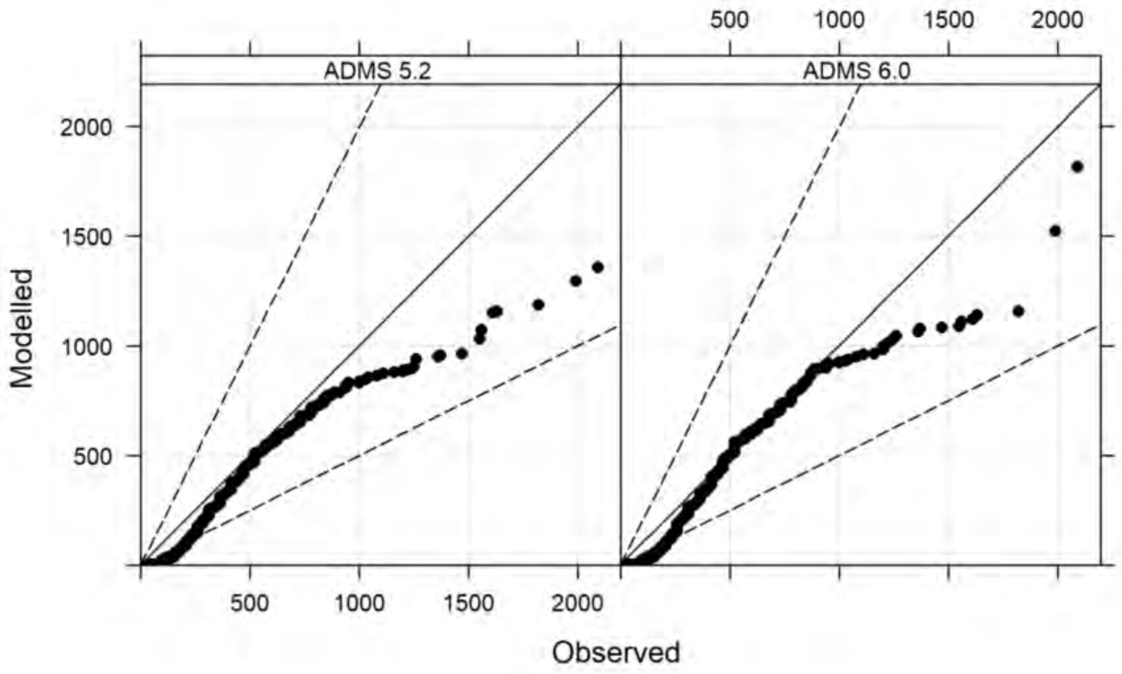
The validation studies include scatter plots, quantile-quantile plots, and a comparison between the observed and modelled maximum and robust highest concentration (Baldwin Power Station only).

- The scatter plots compare predicted and measured concentrations at a particular location at a particular time.
- The quantile-quantile plots compare the distribution of predicted and measured concentrations during the period having abandoned the (x,t) pairing – i.e. comparing the first highest concentration from the monitored with the first highest concentration predicted.
- The highest concentration is subject to extreme variations. Therefore, the robust highest concentration (RHC) is used due to its stability which is based on a tail exponential fit to the upper end of the distribution. The RHC is strongly related to the average and standard deviation.

The most useful visual aid for evaluating model performance is the quantile-quantile plot which shows how the model performs across the full range of modelled and observed concentrations. The quantile-quantile plots for each validation study are shown below.

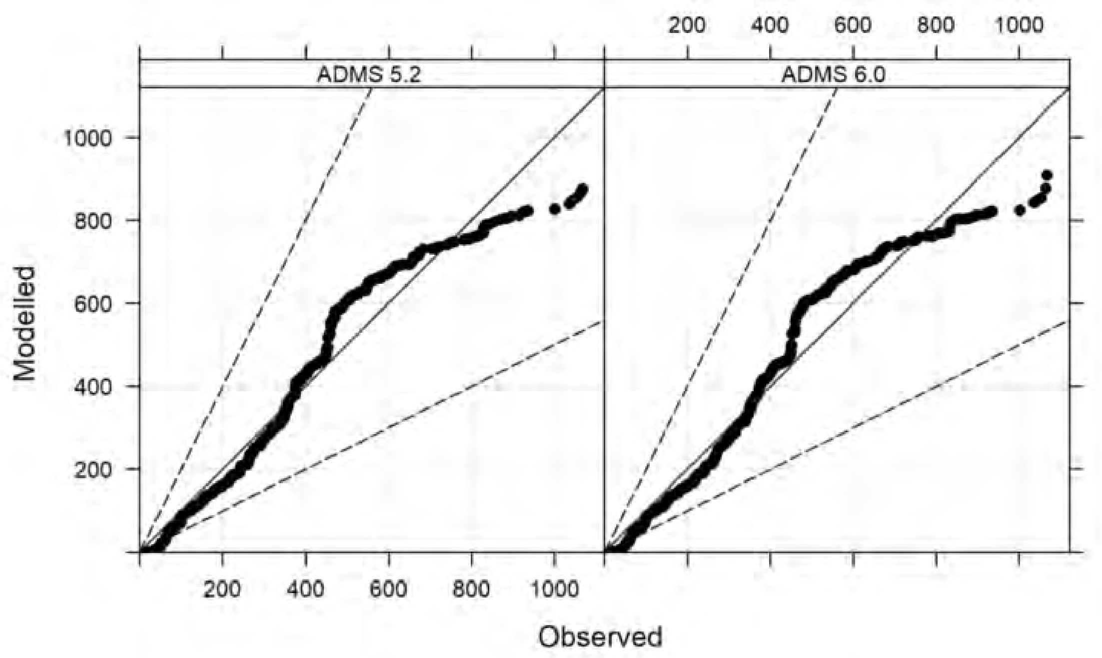
11 https://www.cerc.co.uk/environmental-software/model-validation.html

Quantile – Quantile Plot – Baldwin Power Station



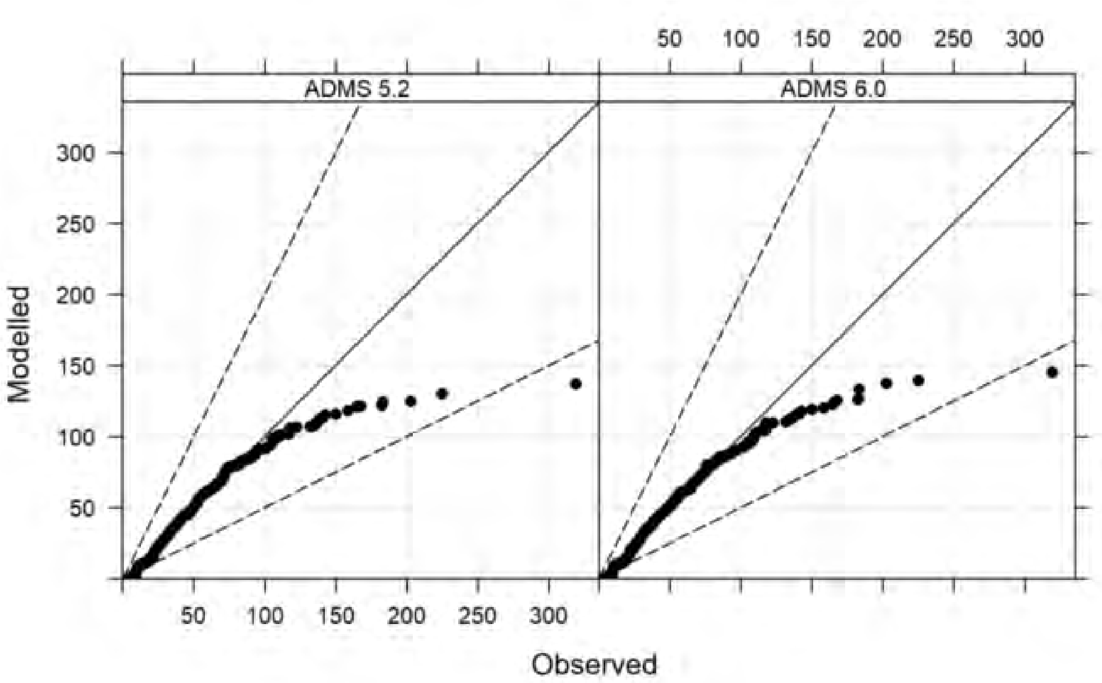
Source: CERC, ADMS 6 Complex Terrain Validation Baldwin Power Plant, April 2023

Quantile – Quantile Plot – Indianapolis



Source: CERC, ADMS 6 Flat Terrain Validation Kincaid, Indianapolis and Prairie Grass, April 2023

Quantile – Quantile Plot – Kincaid



Source: CERC, ADMS 6 Flat Terrain Validation Kincaid, Indianapolis and Prairie Grass, April 2023

These plots show that at the most common (median) concentrations the modelled and observed concentrations are very similar, giving high confidence in annual mean concentrations. However, the maximum concentrations tended to be under-predicted in two out of the three studies (Baldwin and Kincaid), albeit these are based on a very small sample size.

For the Baldwin Power Plant validation is carried out against sulphur dioxide concentrations. In the validation document[12] CERC explain that there are issues with using sulphur dioxide as a tracer which include:

- The limitations of detection are usually of the order of 16 µg/m^3, and concentrations below these are set to one-half of the limit. This leads to considerable inaccuracy when modelled concentrations are low.
- Sulphur dioxide is released from other sources. If estimates of these background concentrations are not available, then the model will underestimate concentrations, particularly long-term averages.

CERC does not report the modelled long-term or annual average concentration against the observed concentration and has only reported the RHC for the Baldwin Power Station study. This is reported for 1-hour, 3-hour and 24-hour averages. The ratio of mean to observed concentrations for the RHC varies from 0.67 to 0.71 across these averaging periods, indicating that the model may be under-estimating the very highest concentrations by up to 33%.

Taking the above into account, it is likely that annual mean concentrations are modelled with a high degree of accuracy. However, the extreme maximum concentrations are less certain, subject to up to 33% uncertainty based on the Baldwin validation study, and potentially over 50% based on the quantile-quantile plot for the Kincaid validation study.

[12] CERC, ADMS 5 Complex Terrain Validation Baldwin Power Plant, November 2016

7.2 Uncertainty

The validation documentation shows that the levels of uncertainty in the ADMS model with respect to the peak predicted concentrations are typically within 10% of the hourly and daily concentrations, with accuracy over long time frames expected to be at least as high as this.

The sensitivity analysis in section 6 shows that varying terrain parameters leads to changes in the peak annual mean results of up to around 10%, but changes in hourly results of up to 34%. These changes are larger than the inherent model uncertainty.

Variations in weather data are more complex and feed into the inter-annual variability discussed below.

In order to allow for modelling uncertainty, this assessment includes a number of conservative assumptions. These are explained and quantified in this section.

7.2.1 Interannual variability

The detailed results tables presented in in Appendix C and Appendix D include the breakdown of the peak concentration using each year of meteorological data. The maximum predicted impact over the five years of data was then used as the basis of the assessment. Table 31 provides a breakdown of the range of the predicted impacts from the CC facility at the point of maximum impact for each averaging period (excluding amine chemistry).

Table 31: Interannual Variability

Averaging time	Impact from CC facility as percentage of maximum	
	Minimum	Average
Annual mean	87%	93%
Max 1-hour	67%	81%
99.79%ile 1-hour	84%	89%
99.73%ile 1-hour	81%	87%
99.9%ile 15-min	83%	91%
Max 24-hour	75%	86%

For the point of maximum impact, the annual average over all five years of weather data is 93% of the highest year, and the minimum is 87% of the highest year. This suggests that using the peak year introduces a conservatism of around 7%. There is greater inter-annual variability for shorter-term impacts which are reported as percentile values or the maximum hourly or daily value, where an 9-19% conservatism is introduced. Therefore, the use of the maximum over the five years is likely to over-estimate the concentrations that occur in any given year.

7.2.2 Plant availability

The results are based on the assumption that the CC facility would operate for 100% of the time. This is a very conservative assumption. Both the CC facility and the ERF would be offline for periods of maintenance. Routine maintenance would be managed so that the CC facility and ERF are offline at the same time. The CC facility would only be able to operate when the ERF is operational, and emissions are suitably stable. Assuming continual operation is a therefore conservative, with likely availability around 92% for the ERF, with the CC facility expected to be operational for around 95% of the time that the ERF is operational.

7.2.3 Emission limits

The results are based on the assumption that the ERF will operate continuously at the long term ELVs. However, the ERF is designed to operate below these with a safety margin. It is assumed that the mass release rate of pollutants from the ERF at the ELVs is released via the CC facility with no allowance for any additional abatement of emissions which would occur within the CC facility.

As explained within section the Supporting Information, the CC facility includes a caustic wash, water wash, acid wash, and demister. These would remove a majority of dust, sulphur dioxide, hydrogen chloride, and hydrogen fluoride. Therefore, actual emissions of these pollutants, and any substances in the particulate phase including metals and dioxins, would be significantly reduced. These flue gas cleaning systems would also reduce emissions of amines and ammonia. Therefore, the impacts predicted for these pollutants from the CC facility are expected to be significantly lower than set out in this assessment.

7.2.4 Short term impacts

For short term impacts it has been assumed that the period when the ERF would need to operate at the half-hourly ELV for an entire hour, during the worst-case weather conditions for dispersion and these emissions would transfer through to the CC facility and no further abatement of the pollutants would take place. This is a highly conservative assumption. In order to achieve the daily ELV, the ERF will be operated to achieve the daily ELV for each hour, with only occasional emissions above this and as set out in Section 7.2.3 the CC facility would provide additional abatement for some pollutants.

Furthermore, the half-hourly ELV is that from the IED. The Waste Incineration BAT Conclusions introduce a lower daily limit for oxides of nitrogen and sulphur dioxide which has been transposed into the existing EP. The IED half-hourly limit for oxides of nitrogen is twice the IED daily limit, whilst the half-hourly limit for sulphur dioxide is four times the daily limit. With the reduced daily ELVs in the existing EP, the half-hourly limit is 2.2 times the daily ELV for oxides of nitrogen, and five times the daily ELV for sulphur dioxide. Therefore, it is unlikely that peaks in short term emissions would be this high given that a lower daily ELV needs to be achieved.

7.3 Overall effect on results

The conservative assumptions explained above mean that the overall impacts presented in this assessment will be overestimates.

1. Annual mean impacts are overstated by around 10% due to plant availability, by around 7% when inter-annual variability is considered and by at least 10% when allowing for operation below the emission limits. This means that, overall, the annual mean impacts in this assessment have inbuilt conservatism of at least 25-30%.
2. For short term impacts (where these are expressed as percentiles), selecting the worst-case weather conditions across all five years of weather data introduces conservatism of at least 9%, and assuming operation at the short term ELVs introduces conservatism of as much as 50-70%.
3. The validation documentation shows that the level of uncertainty in the model are on average within 10% of the hourly and daily concentrations, with accuracy over long time frames expected to be at least as high as this.

4. The sensitivity analysis presented in section 6 shows that (reasonable) variations in modelling assumptions lead to changes in the annual mean peak concentrations of up to 10%, and up to 30% for short-term concentrations.

Therefore, it is considered that the results presented in this assessment are robust as the inbuilt conservatism is of a similar order to the uncertainty in the modelling.

8 Impact on Human Health

8.1 Screening criteria

The predicted PCs have been compared to the AQALs detailed in section 2.1. The Air Emissions Guidance states that to screen out 'insignificant' PCs:

- *the long-term PC must be less than 1% of the long-term environmental standard; and*
- *the short-term PC must be less than 10% of the short-term environmental standard.*

If either of the above criteria are not met, a second stage of screening is applied to determine the impact of the predicted environmental concentration (PEC). To screen out a PEC for any substance, the PEC must meet both of the following criteria:

- the short-term PC is less than 20% of the short-term environmental standard minus twice the long-term background concentration for the substance.
- the long-term PEC is less than 70% of the long-term environmental standard for the substance.

It is considered appropriate to apply the same screening criteria to dispersion modelling results. The long-term 1% PC threshold is based on the judgement that:

- It is unlikely that an emission at this level will make a significant contribution to air quality even if an AQAL is exceeded.
- For long-term releases, it is usually the existing background concentration of a substance that dominates, rather than the long-term PC.
- As the proposed 1% criterion is two orders of magnitude below the AQAL that represents maximum acceptable concentration for the protection of the environment, a substantial safety factor is built in.
- Even if the existing ambient quality meant that an AQAL was already at risk due to releases from other sources, a contribution from the process of less than 1% (which is in itself likely to be an overestimate) would be only a small proportion of the total.

The short-term 10% PC threshold is based on the judgement that:

- Differences in spatial and temporal conditions mean that the PCs themselves are more likely to dominate and not the ambient environmental concentrations.
- If a maximum error factor of 10 is assumed for the estimation of short-term contributions, it suggested that those emissions below 100% of the short term EAL are unlikely to lead to breaches of a short-term benchmark.

For impacts that cannot be screened out based on either the PC or the PEC, consideration is given to the full range of factors influencing the dispersion modelling results to assess the risk of exceedance of an AQAL.

8.2 Results

Table 32 and Table 33 present the results of the dispersion modelling of process emissions from the Permitted Facility and the CC facility at the point of maximum impact, along with the change in maximum impact. This is a summary of the maximum predicted impact using five years of weather data. Detailed results tables for each year of weather data are provided in Appendix C and Appendix D for the Permitted Facility and CC facility respectively. Results have been presented at the point of maximum ground level impact of emissions from the Facility.

Results are based on the following:

- Modelling domain size – 20 km x 20 km wide grid of 200 m resolution with 5 km x 5 km nested grid of 50 m resolution;
- Buildings – included;
- ERF stack height – 85 m
- CC facility stack height – 85 m;
- Five years of weather data 2020 to 2024 from Hawarden meteorological recording station;
- Operation at the long term ELVs for the entire year;
- Operation at the short term ELVs during the worst-case conditions for dispersion of emissions;
- Worst case conversion of NOx to nitrogen dioxide;
- The entire dust emissions consist of either PM_{10} of $PM_{2.5}$;
- The entire VOC emissions are assumed to consist entirely of benzene;
- Cadmium and thallium are released at the combined emission limit for cadmium and thallium;
- All amines are summed for comparison with the AQAL for MEA;
- All nitrosamines and nitramines are summed for comparison with the AQAL for NDMA;
- There is no additional abatement of emissions through the CC facility.

PCs that cannot be screened out as 'insignificant' are highlighted. Where the PC cannot be screened out as 'insignificant', further analysis has been undertaken.

Table 32: Dispersion Modelling Results – Point of Maximum Impact - Daily ELVs

Pollutant	Quantity	Units	AQAL	Bg conc.	Permitted Facility		CC facility				Change in max PC	
					Max PC	As % of AQAL	Max PC	As % of AQAL	Max PEC	As % of AQAL	Conc.	As % of AQAL
Nitrogen dioxide	Annual mean	µg/m³	40	20.10	0.39	0.97%	0.53	**1.34%**	20.63	51.59%	0.15	0.37%
	99.79th %ile of hourly means	µg/m³	200	40.20	6.03	3.02%	11.46	5.73%	51.66	25.83%	5.43	2.71%
Sulphur dioxide	99.18th %ile of daily means	µg/m³	125	11.60	1.15	0.92%	1.80	1.44%	13.40	10.72%	0.64	0.52%
	99.73rd %ile of hourly means	µg/m³	350	11.60	3.59	1.03%	6.85	1.96%	18.45	5.27%	3.26	0.93%
	99.9th %ile of 15 min. means	µg/m³	266	11.60	4.55	1.71%	8.89	3.34%	20.49	7.70%	4.34	1.63%
PM_{10}	Annual mean	µg/m³	40	11.50	0.02	0.04%	0.02	0.05%	11.52	28.80%	0.01	0.01%
	90.41st %ile of daily means	µg/m³	50	23.00	0.06	0.11%	0.08	0.16%	23.08	46.16%	0.02	0.04%
$PM_{2.5}$	Annual mean	µg/m³	10	7.40	0.02	0.15%	0.02	0.21%	7.42	74.21%	0.01	0.06%
Carbon monoxide	8 hour running mean	µg/m³	10,000	474	4.10	0.04%	7.32	0.07%	481.32	4.81%	3.23	0.03%
	Hourly mean	µg/m³	30,000	474	8.37	0.03%	21.89	0.07%	495.89	1.65%	13.52	0.05%
Hydrogen chloride	Hourly mean	µg/m³	750	1.52	1.34	0.18%	3.50	0.47%	5.02	0.67%	2.16	0.29%
Hydrogen fluoride	Annual mean	µg/m³	16	2.35	0.00	0.02%	0.00	0.03%	2.35	14.71%	0.00	0.01%
	Hourly mean	µg/m³	160	4.70	0.17	0.10%	0.44	0.27%	5.14	3.21%	0.27	0.17%
Ammonia	Annual mean	µg/m³	180	2.30	0.03	0.02%	0.04	0.02%	2.34	1.30%	0.01	0.01%
	Hourly mean	µg/m³	2,500	4.60	1.67	0.07%	4.38	0.18%	8.98	0.36%	2.70	0.11%
VOCs (as benzene)	Annual mean	µg/m³	5	1.44	0.03	0.61%	0.04	0.85%	1.48	29.65%	0.01	0.23%

Pollutant	Quantity	Units	AQAL	Bg conc.	Permitted Facility		CC facility				Change in max PC	
					Max PC	As % of AQAL	Max PC	As % of AQAL	Max PEC	As % of AQAL	Conc.	As % of AQAL
	Daily mean	µg/m³	30	2.88	0.34	1.13%	0.65	2.15%	3.53	11.75%	0.31	1.02%
Mercury	Daily mean	ng/m³	60	5.60	0.68	1.13%	1.29	2.15%	6.89	11.49%	0.61	1.02%
	Hourly mean	ng/m³	600	5.60	3.35	0.56%	8.75	1.46%	14.35	2.39%	5.41	0.90%
Cadmium	Annual mean	ng/m³	5	0.42	0.06	**1.23%**	0.08	**1.70%**	0.50	10.10%	0.02	0.47%
	Daily mean	ng/m³	30	0.84	0.68	2.26%	1.29	4.31%	2.13	7.11%	0.61	2.05%
PAHs	Annual mean	pg/m³	250	190	0.61	0.25%	0.85	0.34%	190.85	76.34%	0.23	0.09%
Dioxins	Annual mean	fg/m³	-	32.99	0.18	-	0.25	-	33.24	-	0.07	-
PCBs	Annual mean	ng/m³	200	0.129	0.02	0.01%	0.02	0.011%	0.15	0.08%	0.01	0.003%
	Hourly mean	ng/m³	6,000	0.258	0.84	0.01%	2.19	0.04%	2.45	0.04%	1.35	0.02%
Sum of amines (as MEA)	Hourly mean	µg/m³	400	0	-	-	2.47	0.62%	2.47	0.62%	-	-
	Daily mean	µg/m³	100	0	-	-	0.27	0.27%	0.27	0.27%	-	-
MEA	Hourly mean	µg/m³	400	0	-	-	2.25	0.56%	2.47	0.62%	-	-
	Daily mean	µg/m³	100	0	-	-	0.25	0.25%	0.27	0.27%	-	-
DEA	Daily mean	µg/m³	3	0			0.012	0.41%				
DMA	Daily mean	µg/m³	3.3	0			0.013	0.38%				
Sum of NS (as NDMA)	Annual mean	pg/m³	200	0	-	-	15.36	**7.68%**	15.36	7.68%	-	-
Sum of NS + NA (as NDMA)	Annual mean	pg/m³	200	0	-	-	31.67	**15.83%**	31.67	15.83%	-	-
Aldehydes (as formaldehyde)	Annual mean	µg/m³	5	2.37	-	-	0.02	0.40%	2.39	47.8%	-	-
	30-minute mean	µg/m³	100	4.74	-	-	2.23	2.23%	6.97	6.97%	-	-

Notes:
Maximum PC using all 5 years of weather data. "CC facility" based on continuous emissions from the ERF at daily ELV via the CC facility. NS = nitrosamines, NA = nitramines.

Table 33: Dispersion Modelling Results – Point of Maximum Impact - Short-Term ELVs

Pollutant	Quantity	Units	AQAL	Bg conc.	Permitted Facility		CC facility				Change in PC	
					Max PC	Max PC as % of AQAL	Max PC	Max PC as % of AQAL	Max PEC	Max PEC as % of AQAL	Conc.	as % of AQAL
Nitrogen dioxide	99.79th%ile of hourly means	µg/m³	200	40.2	13.40	6.70%	25.46	**12.73%**	65.66	32.83%	12.06	6.03%
Sulphur dioxide	99.73rd%ile of hourly means	µg/m³	350	11.6	17.97	5.13%	34.25	9.78%	45.85	13.10%	16.28	4.65%
	99.9th%ile of 15 min. means	µg/m³	266	11.6	22.74	8.55%	44.44	**16.71%**	56.04	21.07%	21.70	8.16%
Carbon monoxide	8 hour running mean	µg/m³	10,000	474	12.30	0.12%	21.97	0.22%	495.97	4.96%	9.68	0.10%
	Hourly mean	µg/m³	30,000	474	25.11	0.08%	65.66	0.22%	539.66	1.80%	40.55	0.14%
Hydrogen chloride	Hourly mean	µg/m³	750	1.52	10.03	1.34%	26.24	3.50%	27.76	3.70%	16.20	2.16%

Notes:

Maximum PC using all 5 years of weather data. Based on the ERF operating at short-term ELVs during worst-case weather conditions for dispersion, emitting via ERF stack in 'Permitted Facility' scenario and via the CC facility stack in 'CC facility' scenario.

As shown, the peak PC from the CC facility is predicted to be greater than the ERF. This is attributed to the cooler release temperature of the emissions from the CC process.

At the point of maximum impact the change in impact can be screened out as 'insignificant' for all pollutants except annual mean nitrosamines and nitramines impacts.

In addition, the total impact of the CC facility cannot be screened out as 'insignificant' for the following pollutants:

- Hourly mean nitrogen dioxide impacts when operating at the half-hourly ELV; and
- 15-minute mean sulphur dioxide impacts when operating at the half-hourly ELV.

Further analysis of these impacts has been undertaken to determine whether emissions from the CC facility would result in a significant impact.

8.2.1 Further analysis – annual mean nitrogen dioxide

As shown in the detailed tables in Appendix C and Appendix D, there is predicted to be an increase in annual mean nitrogen dioxide impacts as a result of the proposed EP variation.

The maximum annual mean contribution from the CC facility is 1.34% of the AQAL compared to 0.97% for the Permitted Facility. The change in maximum impact between the two scenarios is 0.37% of the AQAL, although due to the change in dispersion pattern between the two scenarios the maximum change in impact at any single point may be greater than 0.37% of the AQAL.

Figure 10 of Appendix A shows the area where the total impact of the CC facility cannot be screened out as 'insignificant' and further consideration of baseline concentrations is needed. The area where the change in impact exceeds 1% of the AQAL is small and there are no areas of relevant exposure (residential dwellings, schools, hospitals etc) in this area. As such, in addition to the change in impact being screened out as 'insignificant', the total PC from the CC facility can also be screened out as 'insignificant' at all areas of relevant exposure.

For completeness, Table 34 presents the PC from the Permitted Facility, the CC facility, the change in impact, and the PEC at all receptor locations (assuming the baseline concentration of 20.1 µg/m³; as the PC can be screened out, detailed consideration of the PEC is not required).

Table 34: Annual Mean Nitrogen Dioxide - Impacts at Receptors

Receptor	Annual mean concentration							
	Permitted Facility		CC facility		Change		PEC	
	µg/m³	% AQAL	µg/m³	% AQAL	µg/m³	% AQAL	µg/m³	% AQAL
R1	0.05	0.11%	0.08	0.21%	0.04	0.09%	20.18	50.46%
R2	0.03	0.08%	0.05	0.13%	0.02	0.05%	20.15	50.38%
R3	0.21	0.52%	0.28	0.69%	0.07	0.18%	20.38	50.94%
R4	0.23	0.58%	0.31	0.79%	0.08	0.20%	20.41	51.04%
R5	0.07	0.18%	0.11	0.27%	0.04	0.09%	20.21	50.52%
R6	0.11	0.27%	0.16	0.39%	0.05	0.12%	20.26	50.64%
R7	0.09	0.23%	0.16	0.40%	0.07	0.17%	20.26	50.65%
R8	0.17	0.44%	0.22	0.54%	0.04	0.11%	20.32	50.79%
R9	0.17	0.43%	0.21	0.53%	0.04	0.11%	20.31	50.78%
R10	0.16	0.41%	0.22	0.55%	0.06	0.14%	20.32	50.80%

8.2.2 Further analysis – annual mean cadmium

As shown in the detailed tables in Appendix C and Appendix D, there is predicted to be an increase in annual mean cadmium impacts as a result of the proposed EP variation. The maximum annual mean contribution from the CC facility is 1.70% of the AQAL for cadmium compared to 1.23% for the Permitted Facility. The change in maximum impact between the two scenarios is 0.47% of the AQAL, although due to the change in dispersion pattern between the two scenarios the maximum change in impact at any single point may be greater than 0.47% of the AQAL.

These results are calculated under the conservative assumption that cadmium is emitted at the combined cadmium and thallium ELV. Monitoring undertaken in 2024 shows that the highest emission concentration for cadmium and thallium in 2024 was 0.0011 mg/Nm³, only 5.5% of the combined ELV. Taking this as the emission concentration for cadmium, the impact of the CC facility would be 0.09% of the AQAL and would be screened out as 'insignificant'.

For completeness, further analysis has been carried out to determine the impact at receptor locations. The use of the baseline concentration detailed in Table 13 is considered appropriate at the point of maximum impact and all receptor locations. Figure 11 of Appendix A shows the area where the impact of the CC facility cannot be screened out as 'insignificant'. The area where the change in impact exceeds 1% of the AQAL is small, but there are some areas of relevant exposure (residential dwellings) in this area. Table 35 sets out the PC from the Permitted Facility, the CC facility, the change in impact, and the PEC at all receptor locations. As shown, the PC from the CC facility is less than 1% and is 'insignificant' at all receptors except R4; however the PEC is well below 70% so can be screened out.

Table 35: Annual Mean Cadmium - Impacts at Receptors

Receptor	Annual mean concentration as % of AQAL							
	Permitted Facility		CC facility		Change		PEC	
	ng/m³	% AQAL	ng/m³	% AQAL	ng/m³	% AQAL	ng/m³	% AQAL
R1	0.007	0.14%	0.013	0.26%	0.006	0.12%	0.43	8.66%
R2	0.005	0.10%	0.008	0.16%	0.003	0.06%	0.43	8.56%
R3	0.033	0.66%	0.044	0.88%	0.011	0.22%	0.46	9.28%
R4	0.037	0.74%	0.050	**1.00%**	0.013	0.26%	0.47	9.40%
R5	0.012	0.23%	0.017	0.35%	0.006	0.11%	0.44	8.75%
R6	0.017	0.35%	0.025	0.49%	0.007	0.15%	0.44	8.89%
R7	0.015	0.29%	0.025	0.51%	0.011	0.22%	0.45	8.91%
R8	0.028	0.56%	0.035	0.69%	0.007	0.13%	0.45	9.09%
R9	0.027	0.55%	0.034	0.68%	0.007	0.13%	0.45	9.08%
R10	0.026	0.52%	0.035	0.70%	0.009	0.18%	0.46	9.10%

8.2.3 Further analysis – annual mean nitrosamines and nitramines

As shown in Table 32, at the point of maximum impact of emissions the total impact of nitrosamine and nitramines when summed and compared to the AQAL of 0.2 ng/Nm³ is predicted to be 15.83% of the AQAL. The annual mean contribution from each substance has been summed for each grid point and the maximum of all grid points determined. This approach has been used as the peak impact for each substance occurs in different locations owing to the atmospheric reactions. This conservatively assumes that the CC facility continually operates and no allowance for periods when the CC facility would be offline have been accounted for. Additional consideration of the sensitivity of the modelling to the choice of amine chemistry inputs is presented within Appendix F. This shows that whilst there is some variability in the results based on the choice of value used the impact remains below the AQAL.

As noted in section 4.4.9, no monitoring of nitrosamines and nitramines is available and baseline concentrations are assumed to be below the LOD and effectively zero. Therefore, as the maximum impact is much less than 70% of the AQAL, it follows that the PEC is also much less than 70% of the AQAL and the impact is 'not significant'. Nonetheless, consideration has been given to the extent of impacts that cannot be screened out as 'insignificant'.

The following plot files are presented in Appendix A to illustrate the distribution of emissions:

Figure 12 – annual mean nitrosamines;

Figure 13 – annual mean nitramines;

Figure 14 – annual mean nitrosamines + nitramines as % of AQAL.

Table 36 sets out the PC from the CC facility at receptor locations. As shown, the annual mean impact on concentrations of nitrosamines + nitramines cannot be screened out as 'insignificant' at all receptor locations; however, as the baseline is assumed to be zero, the PEC is much less than 70% of the AQAL and the impact is 'not significant'. As such, no further assessment is required to conclude that there will be no significant impacts.

Table 36: Annual Mean Nitrosamines + Nitramines - Impacts at Receptors

Receptor	**Annual mean concentration**			
	Sum of nitrosamines		**Sum of nitrosamines + nitramines**	
	pg/m³	**% AQAL**	**pg/m³**	**% AQAL**
R1	3.74	**1.87%**	15.14	**7.57%**
R2	2.73	**1.36%**	9.62	**4.81%**
R3	8.70	**4.35%**	23.25	**11.63%**
R4	9.77	**4.88%**	24.71	**12.35%**
R5	2.21	**1.10%**	6.56	**3.28%**
R6	2.90	**1.45%**	7.13	**3.57%**
R7	2.76	**1.38%**	6.18	**3.09%**
R8	4.74	**2.37%**	12.61	**6.31%**
R9	5.13	**2.57%**	15.81	**7.90%**
R10	6.97	3.49%	19.98	**9.99%**

Notes:
Maximum impact using 5 years of weather data. Impacts presented as % of the AQAL for NDMA of 0.2 ng/m³ (200 pg/m³).

8.2.4 Further analysis – short term impacts

As shown in the detailed tables in Appendix C, it is predicted that there will be an increase in impacts as a result of the proposed EP variation. If it is assumed that the ERF operates at the half-hourly ELVs and these emissions are passed through to the CC facility, and that this occurs during the worst-case conditions for dispersion, at the point of maximum impact the contribution from the CC facility is 12.73% of the AQAL for hourly mean nitrogen dioxide and 16.71% of the AQAL for 15-

minute mean sulphur dioxide. These impacts cannot be screened out as 'insignificant'. The change in maximum impact is 6.03% of the AQAL for hourly mean nitrogen dioxide and 8.16% of the AQAL for 15-minute mean sulphur dioxide. The changes in the impacts can be screened out as 'insignificant'.

The change in impact and the area where the impacts of the CC facility cannot be screened out as 'insignificant' is shown in Figure 15 and Figure 16 of Appendix A. There are no areas where members of the public are expected to regularly spend a period of at least 15 minutes in this area. Furthermore, the maximum PC is only 15.9% of the headroom for hourly mean nitrogen dioxide and 17.5% of the headroom for 15-minute mean sulphur dioxide. As the PC is less than 20% of the headroom for both pollutants, it can be concluded that there is little risk of the PEC exceeding the AQAL and the impact is 'not significant'.

8.2.5 Heavy metals – at the point of maximum impact

The detailed results tables in Appendix C detail the predicted impact of emissions of metals from the CC facility.

If the PC is greater than 1% of the long-term AQAL or 10% of the short-term AQAL when it is assumed that each metal is emitted at the total metal ELV, further analysis has been undertaken. The EA's metals guidance details the maximum monitored concentrations of Group 3 metals emitted by municipal waste incinerators and waste wood co-Incinerators as a percentage of the ELV for Group 3 metals. The maximum monitored emission presented in the EA's analysis has been used as a conservative assumption.

As shown, if it is assumed that the entire emissions of metals consist of only one metal, the impact of the operation of the CC facility is generally less than 1% of the long-term AQAL and less than 10% of the short-term AQAL, with the exception of annual mean impacts of arsenic, chromium VI, and nickel, daily mean copper and hourly mean nickel. The second stage of screening is to assume that the ERF would perform no worse than the maximum monitored concentration from the EA metals guidance and that all metals pass through the CC facility without additional abatement. Under the second stage screening the impact of the CC facility would be below 1% of the long-term AQAL and 10% of the short-term AQAL for all metals with the exception of annual mean arsenic and nickel and hourly mean nickel. The PEC is only predicted to exceed the long term AQAL for chromium VI, which is due to the high assumed background concentration, and the PC from the CC facility is well below 1% of the AQAL (0.22%). For annual mean arsenic and nickel and hourly mean nickel the PEC is well below the AQAL so can be screened out as 'insignificant'.

This analysis has shown there is no risk of exceeding an AQAL for any metals either on a long-term or short-term basis as a result of emissions from the CC facility. This analysis conservatively assumes that the CC facility would continually operate and there is no additional abatement of metals through the CC process.

9 Impact at Ecological Receptors

9.1 Screening

The EA's Air Emissions Guidance states that to screen out impacts as 'insignificant' at European and UK statutory designated sites:

- the long-term PC must be less than 1% of the long-term environmental standard (i.e. the Critical Level or Load); and
- the short-term PC must be less than 10% of the short-term environmental standard.

If the above criteria are met, no further assessment is required. If the long-term PC exceeds 1% of the long-term environmental standard, the PEC must be calculated and compared to the standard. If the resulting PEC is less than 70% of the long-term environmental standard, the Air Emissions Guidance states that the emissions are 'insignificant' and further assessment is not required. In accordance with the guidance, calculation of the PEC for short-term standards is not required.

The EA's Air Emissions Guidance states further that to screen out impacts as 'insignificant' at local nature sites[13]:

- the long-term PC must be less than 100% of the long-term environmental standard; and
- the short-term PC must be less than 100% of the short-term environmental standard.

In accordance with the guidance, calculation of the PEC for local nature sites is not required. However, this has been calculated for completeness.

9.2 Daily mean Critical Level for oxides of nitrogen

As detailed in Table 3 the daily mean Critical Level for oxides of nitrogen is 75 µg/m³, or 200 µg/m³ where sulphur dioxide and ozone are below their respective Critical Levels. A review of sulphur dioxide and ozone concentrations has been undertaken to determine the appropriate Critical Level.

As shown in Table 7, sulphur dioxide concentrations in the vicinity of the Site are well below the lower Critical Level of 10 µg/m³. For ozone the Critical Level is expressed as an AO40 of 6,000 µg/m³.h (refer to Table 3 for details). Defra produces mapping of five-year average AOT40[14] which shows that ozone concentrations have been below the Critical Level in the vicinity of the Site. The five-year average AOT40 is 3,439 µg/m³.h for the 1 km x 1 km grid square containing the Site with similar concentrations in the surrounding grid squares.

As sulphur dioxide and ozone concentrations are below their respective Critical Levels, it is considered that the daily mean NOx Critical Level of 200 µg/m³ is appropriate.

9.3 Methodology

9.3.1 Atmospheric emissions – Critical Levels

The impact of emissions has been compared to the Critical Levels listed in Table 3. Further assessment would be undertaken where the PC of a particular pollutant is greater than 1% of the

13 Ancient woodlands, local wildlife sites and national and local nature reserves.

14 https://compliance-data.defra.gov.uk/datasets/Defra::ozone-aot40-avg-over-5y-modelled-background-2023/

long term or 10% of the short-term Critical Level for European and UK designated sites, and where the PC of a particular pollutant is greater than 100% of the Critical Level for locally designated sites.

9.3.2 Deposition of emissions – Critical Loads

In addition to the Critical Levels for the protection of ecosystems, habitat specific Critical Loads for nature conservation sites at risk from acidification and nitrogen deposition (eutrophication) are outlined in APIS. In terms of acid deposition, the APIS Database contains a maximum critical load for sulphur (ClmaxS), a minimum Critical Load for nitrogen (CLminN) and a maximum Critical Load for nitrogen (ClmaxN). These components define the Critical Load function for acid deposition. Where the acid deposition flux falls within the area under the Critical Load function, no exceedances are predicted.

An assessment has been made for each habitat feature identified in APIS and identified in the SSSI citation for the specific site. The map function tool has been used to identify the features and habitat specific Critical Loads. However, the APIS database does not include many of the local wildlife sites. As such the project ecologist has been consulted to determine the most appropriate Critical Load for assessment purposes. The relevant Critical Loads are presented in Appendix B. The lowest Critical Load for each designated site has been used to ensure a robust assessment.

9.3.3 Calculation methodology

9.3.3.1 Nitrogen deposition

The impact of deposition has been assessed using the methodology detailed within the Habitats Directive AQTAG 6 (March 2014). The steps to this method are as follows.

1. Determine the annual mean ground level concentrations of nitrogen dioxide, ammonia and amines at each site.
2. Calculate the dry deposition flux (µg/m^2/s) at each site by multiplying the annual mean ground level concentration by the relevant deposition velocity presented in Table 37.
3. Convert the dry deposition flux into units of kgN/ha/yr using the conversion factors presented in Table 37.
4. Compare this result to the nitrogen deposition Critical Load.

Table 37: Deposition Factors

Pollutant	Deposition velocity (m/s)		Conversion factor (µg/m^2/s to kg/ha/year)
	Grassland	Woodland	
Nitrogen dioxide	0.0015	0.003	96.0
Sulphur dioxide	0.0120	0.024	157.7
Ammonia	0.0200	0.030	259.7
Hydrogen chloride	0.0250	0.060	306.7
MEA	0.0200	0.030	72.2
DEA			41.9
DMA			97.8

Source: AQTAG 6 (March 2014), except for amines which are detailed below.

As amines are derived from ammonia, as a screening assumption it has been assumed that amines have the same deposition velocity as ammonia. The conversion factor from µg/m^2/s to kg/ha/year for each amine has been derived from the percentage of the molecular mass of each amine that is nitrogen (each amine contains one nitrogen atom).

The concentration of amines has been factored from a non-reactive pollutant (particulate matter). This is considered appropriate as a screening assumption, as the sensitivity analysis presented in Appendix F shows that the maximum predicted concentrations of amines are not highly sensitive to the inclusion of amine chemistry. In addition, the predicted concentrations of nitrosamines and nitramines (and therefore their contribution to total nitrogen and acid deposition) are exceptionally small in comparison to amines, so their exclusion from the analysis will not affect the results.

9.3.3.2 Acidification

Deposition of nitrogen, sulphur, hydrogen chloride, ammonia and amines can cause acidification and should be taken into consideration when assessing the impact of the Facility.

The steps to determine the acid deposition flux are as follows.

1. Determine the dry deposition rate in kg/ha/yr of nitrogen, sulphur, hydrogen chloride, ammonia and amines using the methodology outlined in Section 9.3.3.
2. Apply the conversion factor for N outlined in Table 38 to the nitrogen, ammonia and amine deposition rate in kg/ha/year to determine the total keq N/ha/year.
3. Apply the conversion factor for S to the sulphur deposition rate in kg/ha/year to determine the total keq S/ha/year.
4. Apply the conversion factor for HCl to the hydrogen chloride deposition rate in kg/ha/year to determine the dry keq Cl/ha/year.
5. Add the contribution from S to HCl and treat this sum as the total contribution from S.
6. Plot the results against the Critical Load functions.

Table 38: Conversion Factors

Pollutant	Conversion factor (kg/ha/year to keq/ha/year)
Nitrogen	Divide by 14
Sulphur	Divide by 16
Hydrogen chloride	Divide by 35.5

Source: AQTAG (March 2014)

The March 2014 version of the AQTAG 6 document states that, for installations with an HCl emission, the PC of HCl, in addition to S and N, should be considered in the acidity Critical Load assessment. The H+ from HCl should be added to the S contribution (and treated as S in APIS tool). This should include the contribution of HCl from wet deposition.

Consultation with AQMAU confirmed that the maximum of the wet or dry deposition rate for HCl should be included in the calculation. For the purpose of this analysis, it has been assumed that wet deposition of HCl is double dry deposition.

The contribution from the Facility has been calculated using APIS formula:

Where PEC N Deposition < CLminN:

PC as % of CL function = PC S deposition / ClmaxS

Where PEC N Deposition > CLminN:

PC as % of CL function = (PC S + N deposition) / ClmaxN

In the first instance, the background acid deposition is only required to determine whether there is an exceedance of CLminN, so that the correct function can be used in the calculation. A search of the APIS database has shown that the minimum nitrogen-based acid deposition for any 1 km x 1km grid square within 10 km of the Site is 1.03 keq/ha/yr to short vegetation and 1.79 keq/ha/yr to forest. The highest CLminN at any designated ecological site within 10 km of the Site is 1.071 keq/ha/yr (for grassland, at Shotton Lagoons and Reedbeds SSSI). For all other sites/habitats the CLminN is already exceeded so nitrogen and sulphur will contribute to acid deposition at all ecological sites, except Shotton Lagoons and Reedbeds SSSI. The total site-specific background acid deposition has been obtained from APIS for any ecological sites where the PC cannot be screened out as 'insignificant'. This analysis is presented in Appendix D.

9.4 Results

Detailed results tables are provided in Appendix D. The results are based on the following:

- Modelling domain size – 20 km x 20 km wide grid of 200 m resolution with 5 km x 5 km nested grid of 50 m resolution;
- Buildings – included;
- ERF stack height – 85 m
- CC facility stack height – 85 m;
- Five years of weather data 2020 to 2024 from Hawarden meteorological recording station;
- Operation at the long term ELVs for the entire year;
- Worst case conversion of NOx to nitrogen dioxide;
- The nitrogen deposition impacts include the contribution from nitrogen dioxide, ammonia and amine emissions;
- The acid deposition impacts include the contribution from nitrogen dioxide, ammonia, amines, sulphur dioxide and hydrogen chloride;
- Wet deposition of HCl has been included in the acid S calculation as double dry deposition;
- It has been assumed the most sensitive habitat is present at the point of maximum impact of emissions in each site; and
- There is no additional abatement of emissions through the CC facility.

PCs that cannot be screened out as 'insignificant' are highlighted. Where the PC cannot be screened out as 'insignificant', further analysis has been undertaken.

As shown the peak PC from the CC facility is predicted to be greater than the ERF. This is attributed to the cooler release of the emissions post the CC process.

9.4.1 European and UK designated sites

The detailed results tables are provided in Appendix D. As shown, the change in PC is less than 1% of the long-term Critical Level or Load and less than 10% of the short-term Critical Level at all designated sites, except for:

- annual mean ammonia at the Dee Estuary;
- nitrogen deposition on sand dune and saltmarsh habitats at the Dee Estuary; and
- nitrogen deposition on lake and woodland habitats at the River Dee and Bala Lake; and
- acid deposition on heathland habitats at the Dee Estuary.

The change in impacts that cannot be screened out as 'insignificant' are shown on the following figures:

- Figure 17: Annual Mean Ammonia;
- Figure 18: Nitrogen Deposition – Grassland Deposition Velocity;
- Figure 19: Nitrogen Deposition – Woodland Deposition Velocity; and
- Figure 20: Acid Deposition – Grassland Deposition Velocity.

It can be seen on Figure 17 that the area where the change in ammonia impact exceeds 1% of the lower Critical Level is limited to saltmarsh habitats. APIS advises that the ammonia Critical Level for saltmarsh is 1 or 3 µg/m³ to be considered on a site-specific basis. An initial assessment has been undertaken on the conservative assumption that the lower Critical Level of 1 µg/m³ is applicable.

Figure 18 shows the area where the change in nitrogen deposition exceeds 0.05 kgN/ha/yr, equivalent to 1% of the lower Critical Load for sand dune habitats, and 0.02 kgN/ha/yr, equivalent to 1% of the lower Critical Load for lake habitats. No sand dune or lake habitats have been identified in the relevant areas so the change in nitrogen deposition on sand dune and lake habitats is less than 1% of the Critical Load and can be screened out as 'insignificant'.

The area of saltmarsh habitat within the 0.1 kgN/ha/yr contour is predicted to experience a change in nitrogen deposition exceeding 1% of the Critical Load and has been considered further in section 9.4.1.2.

Figure 19 shows the area where the change in nitrogen deposition to woodland exceeds 0.1 kgN/ha/yr, equivalent to 1% of the lower Critical Load for the designated woodland habitats. No designated woodland features have been identified within this area, so the change in nitrogen deposition on woodland can be screened out as 'insignificant'.

Figure 20 shows the area where the change in acid deposition exceeds 0.013 keq/ha/yr, equivalent to 1% of the minimum CLMaxN for heathland habitats. The only habitat present in this area within the Dee Estuary designated site is saltmarsh. As no heathland habitat is present in this area, the change in acid deposition on heathland can be screened out as 'insignificant'.

9.4.1.1 Ammonia impacts - Dee Estuary

The change in PC for annual mean ammonia cannot be screened out as 'insignificant'. The maximum change in ammonia concentration is predicted to be 1.15% of the lower Critical Level. This is only 0.38% of the higher Critical Level. The maximum baseline ammonia concentration in this area is 1.9 µg/m³, i.e. already exceeds the lower Critical Level. The maximum PEC is 1.91 µg/m³, 191% of the lower Critical Level. This is only 64% of the higher Critical Level of 3 µg/m³.

It has been assumed that the CC facility continually emits ammonia at the release rate shown in Table 16 (i.e. that the ammonia release rate is the same as the maximum permitted for the ERF). This is highly conservative as the CC facility will implement an acid wash which is expected to be highly effective at removing ammonia, resulting in average emissions well below the ELV. As such, it is anticipated that the ammonia impact will be much lower in reality.

Even assuming the maximum permitted ammonia emissions, the area where the change in PC exceeds 1% of the lower Critical Level is small and only just over 1% at 1.15%. No exceedance of the higher Critical Level is predicted. Due to nutrient inputs to the saltmarsh habitat from tides and rivers, it is considered unlikely that nutrient-intolerant lichens or bryophytes are present in the saltmarsh habitat at the Dee Estuary designated site. As such, it is considered that no significant effects are likely.

9.4.1.2 Nitrogen deposition impacts - Dee Estuary

The change in PC for nitrogen deposition cannot be screened out as 'insignificant'. The maximum change in nitrogen deposition to saltmarsh habitats is predicted to be 1.14% of the lower Critical Load. The maximum baseline nitrogen deposition in this area is 16.3 kgN/ha/yr, i.e. it already exceeds the lower Critical Load. The maximum PEC is 16.4 µg/m³, 164% of the lower Critical Level.

As detailed in section 9.4.1.1 it is anticipated that the wash systems to be implemented as part of the CC facility will result in ammonia emissions well below the ELV, such that the contribution of ammonia to nitrogen deposition will be much lower in reality.

Even assuming the maximum permitted ammonia emissions, the area where the change in PC exceeds 1% of the lower Critical Load is small and only just over 1% at 1.14%. As such, it is considered that no significant effects are likely.

9.4.2 Local nature sites

As shown in Appendix D all impacts at local nature sites are less than the relevant Critical Levels and Critical Loads and can be screened out as 'insignificant'.

10 Cumulative Assessment

10.1 Human health

10.1.1 Non-amine substances

As detailed in section 8.2 the change in PC for all non-amine pollutants is less than 1% of the long-term or 10% of the short-term AQAL and can be screened out as 'insignificant'. The total impact of the CC facility is also 'insignificant' for all pollutants except annual mean nitrogen dioxide and cadmium, and short term nitrogen dioxide and sulphur dioxide.

The identified cumulative sources do not include emissions of cadmium or sulphur dioxide, so these pollutants do not require further consideration.

For annual mean nitrogen dioxide the total PC from the CC facility at a receptor location is no more than 0.79% of the AQAL and is 'insignificant', and the change from the permitted impact of the ERF is no more than 0.20% of the AQAL. As shown in section 4 baseline concentrations are well below the AQAL. As both the total PC and the change in PC due to emissions from the CC facility are 'insignificant' and there is no risk of exceedance of the AQAL, it is considered that there is no potential for a significant cumulative impact on nitrogen dioxide concentrations.

For short-term nitrogen dioxide concentrations, there are no areas of relevant exposure where the PC exceeds 10% of the AQAL and cannot be screened out as 'insignificant'. The risk of a significant cumulative short-term effect is further reduced as the PEC is well below the AQAL, and plumes from multiple cumulative point sources are unlikely to overlap over short timescales.

Based on the above, it is considered that there is no risk of significant cumulative effect on annual mean or short-term nitrogen dioxide concentrations, and therefore no potential for a significant cumulative effect on human heath from non-amine pollutants.

10.1.2 Amine degradation products

10.1.2.1 Discussion

Two of the cumulative sources identified emit amines and amine degradation products: The Padeswood and Connah's Quay developments. Padeswood has planning consent, and the EP application is being determined by NRW at the time of writing of this report. Connah's Quay is at planning consultation stage and an EP application has not yet been submitted. A review of the available documentation for each project has been undertaken to consider the potential for a significant cumulative effect, namely:

- Castle Cement Limited, Carbon Capture and Storage Project – Padeswood, North Wales, Volume 2, Environmental Statement Chapter 6 – Air Quality (RSK, 2024);
- Castle Cement Limited, Carbon Capture and Storage Project – Padeswood, North Wales, Volume 4, Technical Appendix 6.1 – Air Quality Assessment (RSK, 2024);
- Connah's Quay Low Carbon Power, Preliminary Environmental Information Report, Volume II, Chapter 8: Air Quality (AECOM, 2024);
- Connah's Quay Low Carbon Power, Preliminary Environmental Information Report, Volume IV, Appendix 8-D, Air Quality Operational Assessment (AECOM, 2024); and

- Connah's Quay Low Carbon Power, Consultation May 2025 – Supporting Technical Information Report (AECOM, 2025).

As detailed in section 8.2, the PC of amines from the CC facility can be screened out as 'insignificant'. The documents referenced above confirm that the maximum PC of amines from Padeswood and Connah's Quay are also less than 1% of the 1-hour and 24-hour AQALs. On this basis, it is considered that there is no potential for a significant cumulative effect on human heath from amines, so this assessment only considers amine degradation products.

The methodologies employed for modelling amine degradation products presented in the assessments for Connah's Quay and Padeswood have been reviewed. Both use a number of highly conservative assumptions, of which two in particular are of note:

1. No photolysis of directly-emitted nitrosamines occurs; and
2. Primary amines form stable nitrosamines.

Regarding the first point, there is no distinction between the chemical properties of directly emitted nitrosamines and those formed by atmospheric chemical reactions; in reality they both undergo photolysis, which reduces the concentrations of nitrosamines.

Regarding the second point, published literature on the subject (including the ADMS 6 Amine Chemistry Supplement published by CERC) confirms the scientific consensus that primary amines such as MEA do not form stable nitrosamines. Nitrosamines formed from primary amines almost immediately isomerise to form other species which are not significantly harmful to human health and are therefore not relevant to the air quality assessment. The dispersion model allows the user to select whether or not each amine forms stable nitrosamines. This option is included because none of the other input parameters contain information as to whether the amine is primary or not, hence why it is possible to model the formation of stable nitrosamines from primary amines.

These assumptions would result in the dispersion model predicting significantly higher concentrations of nitrosamines that would occur in reality, so could be considered over-conservative. As detailed in Appendix F neither of these assumptions have been used in the dispersion modelling for the CC facility.

In addition, other conservative assumptions such as comparing the total concentration of nitrosamines and nitramines to the AQAL for NDMA have been applied for both the CC facility and for the cumulative sources.

The effect of such over-conservative assumptions can be seen in the results of the dispersion modelling for each source. The maximum predicted PC of nitrosamines and nitramines for the CC facility is approximately 16% of the AQAL of 0.2 ng/m³. The maximum PC at any location for Connah's Quay (taken from the May 2025 Consultation Supporting Technical Information Report) is 86% of the AQAL, and 72% at a receptor, and the maximum PC (at a receptor) for Padeswood is 30% of the AQAL. The maximum at any location for Padeswood was not reported, and it is noted from the plot file (Figure F7 of Technical Appendix 6.1) that the maximum affected discrete receptor is not representative of the maximum PC in a residential area. From the plot file it is only possible to confirm that the maximum PC is less than 0.14 ng/m³, which is 70% of the AQAL.

10.1.2.2 Assessment

Due to the differences in modelling methodology detailed above it is not considered appropriate to model amine chemistry for the cumulative sources as the results will be significantly different from those in the submitted documents for each project. Therefore, a semi-quantitative assessment has been undertaken based on the publicly information submitted for each project.

The Supporting Technical Information Report for Connah's Quay does not include any plot files showing the extent of nitrosamine impacts, while Figure F7 of Technical Appendix 6.1 for Padeswood covers only a relatively small area extending approximately 2 km to the north and south of the source. With no detail available on the wider spatial distribution of emissions, there is insufficient information available to fully quantify the cumulative impacts. As Connah's Quay is at consultation stage it is expected that the dispersion modelling will undergo further refinement and a revised set of results will be published, which will allow a more thorough cumulative assessment to be undertaken and presented to NRW during determination of the EP application for the CC facility.

It is reasonable to assume that the maximum cumulative PC at a receptor will be much less than the sum of the maximum PCs at receptor locations reported for each project in isolation. This is summarised in Table 39.

Table 39: Cumulative PCs – Amine Degradation Products

Source	Max PC at a receptor	
	pg/m³	% of AQAL
CC facility	24.7	12.4%
Connah's Quay	144.2	72.1%
Padeswood	60.8	30.4%
Sum of sources(1)	229.7	114.9%

Note:

(1) Assumes the impacts occur at the same location.

As shown, if it is assumed that the maximum impacts at a receptor location overlap, a slight exceedance of the AQAL for NDMA is predicted. However, the cumulative impact would be much less in reality, as:

1. The impacts would not overlap to such a significant extent. However, the submitted documents for Connah's Quay and Padeswood do not provide sufficient information to accurately assess the spatial distribution of emissions.
2. The PCs for Connah's Quay and Padeswood have been modelled by the applicants using two over-conservative assumptions, as detailed in section 10.1.2.1. The PCs are expected to be much lower in reality.
3. All PCs have been compared to the AQAL for NDMA, which is itself highly conservative but is the accepted best-practice in the absence of reliable AQALs for other amine degradation products.

Even with such highly conservative assumptions, the theoretical maximum cumulative PC only slightly exceeds the AQAL. As such, it is concluded that the cumulative PC would remain well below the AQAL in reality; as the baseline concentration is assumed to be zero, the cumulative PEC would also remain well below the AQAL.

10.2 Ecology

As detailed in section 9.4, taking into account the distribution of sensitive habitats, the change in PC due to emissions from the CC facility is less than 1% of the long-term Critical Levels and Loads and less than 10% of the short-term Critical Levels, except for:

- annual mean ammonia at the Dee Estuary; and

- nitrogen deposition on saltmarsh habitats at the Dee Estuary.

Where the change in PC due to emissions from the CC facility is less than the screening criteria, it is considered that the impact is insignificant either alone or in-combination with other plans and projects. Therefore, consideration has been given to cumulative impacts at the Dee Estuary due to ammonia and nitrogen deposition only.

Emissions from all cumulative schemes listed in section 5.7 have been considered, except for Padeswood; this is because the implementation of the Carbon Capture scheme at Padeswood is predicted to result in a reduction in nitrogen deposition. The submitted documents for Connah's Quay and the Shotton Paper Mill did not provide sufficient information on the spatial distribution of emission to assess the potential cumulative impact of point source emissions. Therefore, these sources have been explicitly modelled (refer to Appendix E for model inputs). The predicted PCs from the AD facility and Airfields Paper Mill are comparatively small and these sources are relatively close the Site. Therefore, the maximum PCs at the Dee Estuary reported for these sources has been used to calculate the cumulative PC.

10.2.1 Ammonia

The maximum change in ammonia PC at the Dee Estuary due to emissions from the CC facility is predicted to be 1.15% of the lower Critical Level. The only other cumulative source of ammonia is Connah's Quay. The maximum cumulative PC in the Dee Estuary is 0.055 µg/m³, which is 5.5% of the lower Critical Level. As this exceeds 1% of the Critical Level and the baseline ammonia concentration ranges from 1.5-1.9 µg/m³ across the area of potential cumulative impacts, the cumulative ammonia PC cannot be screened out as 'insignificant'.

A plot file of the cumulative PC and the change in PC due to emissions from the CC facility is presented as Figure 21. This shows that emissions from Connah's Quay have a greater magnitude impact, and affect a wider area than, emissions from the CC facility. In the area of maximum impact of emissions from Connah's Quay the change in PC due to emissions from the CC facility is much less than 1% of the Critical Level, so no significant cumulative effects are likely in this area.

In the area of maximum impact of emissions from the CC facility, the PC from Connah's Quay is of a similar magnitude to emissions from the Facility. The maximum PC from Connah's Quay at any location in the Dee Estuary where the change in PC due to emissions from the CC facility exceeds 1% of the Critical Level is 0.012 µg/m³, which is 1.2% of lower Critical Level and results in a maximum cumulative PC of 0.023 µg/m³, which is 2.3% of lower Critical Level. This is only 0.77% of the higher Critical Level.

Exceedances of the screening criteria are only predicted if the lower Critical Level of 1 µg/m³ is applicable in this section of the Dee Estuary designated site. As noted in section 9.4.1.1 it is considered unlikely that nutrient-intolerant lichens or bryophytes are present in the saltmarsh habitat at the Dee Estuary designated site. As such, it is considered that no significant effects are likely.

10.2.2 Nitrogen deposition

The maximum change in nitrogen deposition at the Dee Estuary due to emissions from the CC facility is predicted to be 1.14% of the lower Critical Load for saltmarsh habitats. The maximum PC from each of the cumulative sources at the Dee Estuary designated site is presented in Table 40, along with the maximum PC from each source at the point of maximum change in impact due to emissions from the CC facility.

Table 40: Cumulative PCs – Nitrogen Deposition to Saltmarsh Habitat

Source	Max PC in Dee Estuary		Max PC at point of maximum change in PC due to emissions from of CC facility in Dee Estuary	
	kgN/ha/yr	% of lower CL	kgN/ha/yr	% of lower CL
CC facility (change)	0.114	1.14%	0.114	1.14%
Connah's Quay	0.645	6.45%	0.135	1.35%
Shotton Paper Mill	0.061	0.61%	0.059	0.59%
AD Plant	0.035	0.35%	0.035	0.35%
Airfield Paper Mill	0.030	0.30%	0.030	0.30%
Sum of sources	0.771(1)	7.71%(1)	0.373	3.73%
Sum of sources excluding Connah's Quay	0.240	2.40%	0.238	2.38%

Note:
(1) Assumes the impacts occur at the same location.

The maximum cumulative PC in the Dee Estuary is 0.771 kgN/ha/yr, which is 7.7% of the lower Critical Level. As this exceeds 1% of the Critical Level and the baseline nitrogen deposition ranges from 14.9-16.4 kgN/ha/yr across the area of potential cumulative impacts, the cumulative nitrogen deposition PC cannot be screened out as 'insignificant'.

A plot file of the cumulative PC and the change in PC due to emissions from the CC facility is presented as Figure 22; this only includes modelled cumulative sources. It is noted that the AD Plant and Airfield Paper Mill each result in very small PCs of 0.35% and 0.30% or the lower Critical Load respectively, so would not significantly affect the analysis of cumulative impacts. Figure 22 shows that, similarly to the plot file of ammonia, emissions from Connah's Quay have a greater magnitude impact, and affect a wider area than, emissions from the CC facility and Shotton Paper Mill.

In the area of maximum impact of emissions from Connah's Quay the change in PC due to emissions from the CC facility is much less than 1% of the Critical Level, so no significant cumulative effects are likely in this area. In the area of maximum impact of emissions from the CC facility, the PC from Connah's Quay is of a similar magnitude to emissions from the Facility.

Overall, it is noted that even at the point of maximum change in PC due to emissions from the CC facility, the nitrogen deposition impact due to emissions from Connah's Quay (1.35%) is greater than the change in PC due to emissions from the CC facility (1.14%). The maximum impact of emissions from Connah's Quay (which occurs over another section of the Dee Estuary as shown on Figure 22, albeit the predominant habitat in this area is also saltmarsh) is 6.45% of the Critical Load. Therefore, if Connah's Quay were to obtain planning consent and an EP to operate on the basis of a PC of 6.45%, it follows that a cumulative PC of 3.73% would also be an acceptable impact.

As the Connah's Quay project is still at consultation stage and has not yet obtained planning consent or an EP to operate, consideration has been given to the cumulative impact excluding this source. As shown in Table 40 the maximum cumulative impact in this scenario is 2.40% of the Critical Load. Whilst this impact cannot be screened out, taking into account the small change in contribution from the CC facility of 1.14% of the Critical Load (which is based on the worst-case year of weather data and continual operation at the ELVs), it is considered that there is no likely significant effect.

11 Abnormal Operation

11.1 Background

The Environmental Permitting Regulations require that abnormal event scenarios are considered. Article 46(6) of the Industrial Emissions Directive (IED) states that:

"… the waste incineration plant … shall under no circumstances continue to incinerate waste for a period of more than 4 hours uninterrupted where emission limit values are exceeded.

The cumulative duration or operation in such conditions over 1 year shall not exceed 60 hours."

Article 47 continues with:

"In the case of a breakdown, the operator shall reduce or close down operations as soon as practicable until normal operations can be restored."

The conditions detailed in Article 46(6) are considered to be "abnormal operating conditions" for the purpose of this assessment applies to the Facility.

11.2 Identification of abnormal operating conditions

The following are considered to be examples of abnormal operating conditions which may lead to 'abnormal emission levels' of pollutants:

1. Reduced efficiency of lime injection system such as through blockages or failure of fans leading to elevated acid gas emissions (with the exception of hydrogen chloride);
2. Complete failure of the lime injection system leading to unabated emissions of hydrogen chloride. (Note: this would require the ERF to have complete failure of the bag filter system. As an ERF of modern design the ERF would have shut down before reaching these operating conditions);
3. Reduced efficiency of particulate filtration system due to bag failure and inadequate isolation, leading to elevated particulate emissions and metals in the particulate phase;
4. Reduced efficiency of the selective non-catalytic reduction (SNCR) system as a result of blockages or failure of urea injection system, leading to elevated oxides of nitrogen emissions; and
5. Complete failure of the activated carbon injection system and loss of temperature control leading to high levels of dioxin reformation and their unabated release.

The CC facility is designed to treat flue gas during normal operation. Depending on the cause of abnormal operating conditions, the CC facility would be bypassed during abnormal operation.

If the lime injection and/or SNCR system failed, elevated NOx and acid gas concentrations would significantly degrade the amine solvent in the CC facility. High levels of metals and particulates resulting from a failure of the bag filter and/or activated carbon filter would also degrade the amine solvent and the reduce the overall performance of the CC facility. Therefore, as soon as any failure of abatement technology was identified, bypass of the CC facility would be implemented.

Depending on detailed design and development of operational procedures, the CC facility may also be bypassed during periods when the continuous emissions monitoring system (CEMS) is unavailable, i.e. the pollutant concentrations are unknown. If the CC facility is not bypassed during these periods, the monitoring of the combustion, reagent dosing and CC facility processes would be used as proxies to ensure that the processes and resulting emissions remain controlled.

As the flue gas would bypass the CC facility and be emitted from the main stack during abnormal operation, the impact of emissions during abnormal operation would be no worse than previously assessed for the Facility.

11.3 ERF Plant start-up and shutdown

The CC facility requires steam from the combustion process to operate. Therefore, the CC facility will be bypassed during start-up and shut-down of the ERF. Start-up from cold will be conducted with clean support fuel (low sulphur light fuel oil). Waste is not introduced onto the grate unless the temperature is above the minimum requirement (850ºC) and other operating parameters (for example, air flow and oxygen levels) are within the range stipulated in the permit. During the warming up period the gas cleaning plant will be operational as will be the control systems and monitoring equipment.

The same is true during plant shutdown. The waste remaining on the grate is allowed to burn out, the temperature not being permitted to drop below 850ºC by the simultaneous introduction of clean support auxiliary fuel. After complete burnout of the waste, the burners are turned off and the ERF is allowed to cool. During this period, the gas cleaning equipment, control systems and monitoring equipment will be fully operational.

Start-up and shutdown are infrequent events; the Facility is designed to operate continuously, and ideally only close down for its annual maintenance programme.

In relation to the magnitude of dioxin emissions during plant start-up and shutdown, research has been undertaken by AEA Technology on behalf of the EA. Whilst elevated emissions of dioxins (within one order of magnitude) were found during shutdown and start-up phases where the waste was not fully established on the grate, the report concluded that:

"The mass of dioxin emitted during start-up and shutdown for a 4-5 day planned outage was similar to the emission which would have occurred during normal operation in the same period. The emission during the shutdown and restart is equivalent to less than 1 % of the estimated annual emission (if operating normally all year)."

There is therefore no reason why such start-up and shutdown operations will affect the long term impact of the Facility.

11.4 Summary

The CC facility will be bypassed during any periods of abnormal operation during which elevated emissions may occur. Therefore, the impact of emissions during abnormal operation as permissible under the IED (Article 46) would be no worse than currently allowed for within the EP for the Facility.

12 Conclusions

This Dispersion Modelling Assessment has been undertaken to support an application for a variation to the EP to include the CC facility. The modelling has assumed that the ERF operates at the ELVs in the existing EP. It has been assumed that the CC facility does not offer any additional abatement of emissions from the ERF which is highly conservative given that the CC facility is likely to significantly reduce concentrations of some pollutants.

This assessment has included a review of baseline pollution levels, dispersion modelling of emissions and quantification of the impact of these emissions on local air quality.

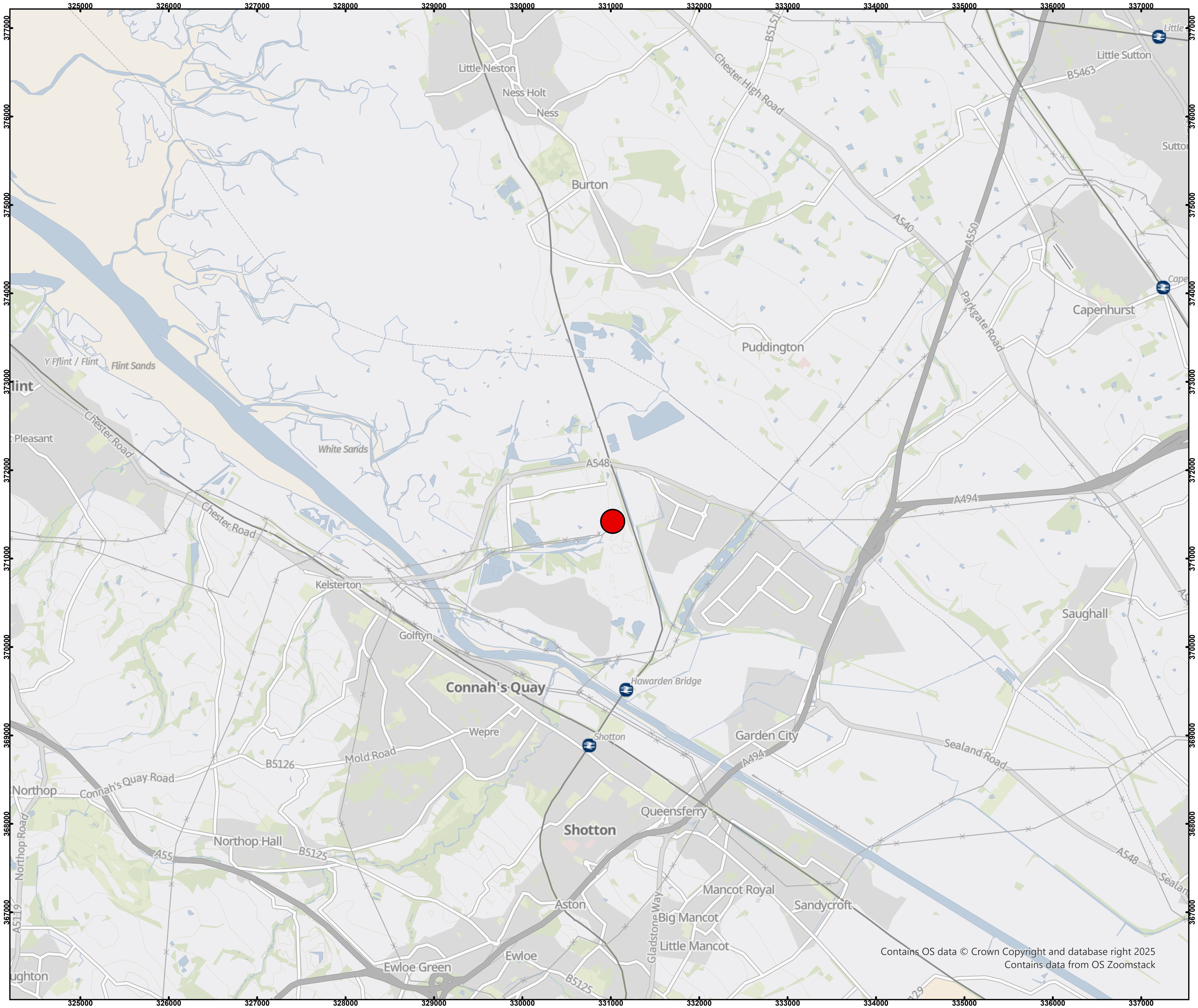
The primary conclusions of the assessment are presented below.

1. In relation to the impact on human health:
   a. Emissions from the operation of the CC facility will not cause a breach of any AQAL.
   b. There is predicted to be an increase in the impacts as a result of the operation of the CC facility. For all pollutants already emitted by the ERF, the change in impact can be screened out as 'insignificant', and the overall impact of the emissions from the CC facility is not significant.
   c. For additional products released from the CC facility such as amines, nitrosamines and nitramines the impact can either be screened out as 'insignificant' or is considered 'not significant' when baseline concentrations are taken into consideration.
   d. There are no likely significant cumulative effects from other local plans or projects.
2. In relation to the impact on ecologically sensitive sites:
   a. All impacts at local nature sites can be screened out as 'insignificant';
   b. The change in impact due to the operation of the CC facility and overall impact of emissions from the CC facility at the Dee Estuary designated site cannot be screened out for airborne ammonia impacts and nitrogen deposition impacts. Further assessment of the spatial extent of impacts and the sensitivity of the affected habitats has shown that no significant effects are likely.
   c. There are no likely significant cumulative effects from other local plans or projects.

In summary, the assessment has shown that the operation of the CC facility would not have a significant impact on local air quality, the general population or the local community. As such there should be no air quality constraint in granting the variation to the EP to operate the CC facility.

Appendices

A Figures



Legend

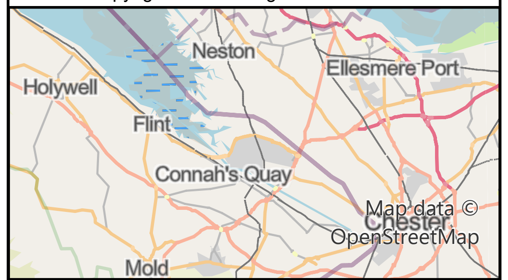
Site location

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 1 - Site Location

Drawn by: SMN | Date: 24/07/2025



0 0.4 0.8 1.6 km

N

Scale: 1:40,000

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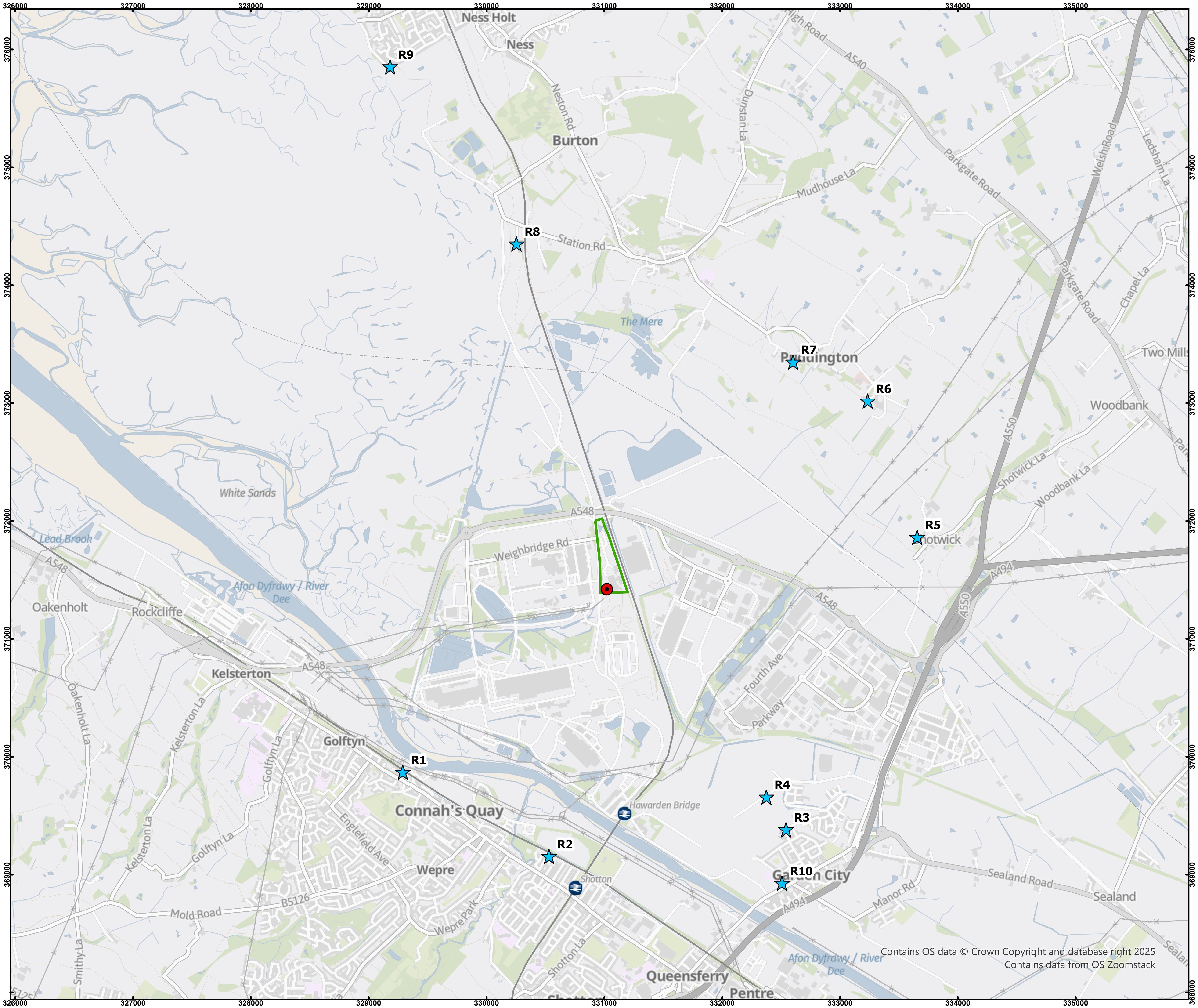


Legend

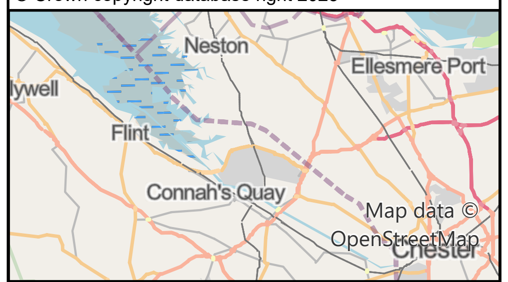
- Installation boundary
- CC facility stack
- Human receptors

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 2 - Human Receptors

Drawn by: SMN | Date: 24/07/2025



0 0.3 0.6 1.2 km

N

Scale: 1:30,000

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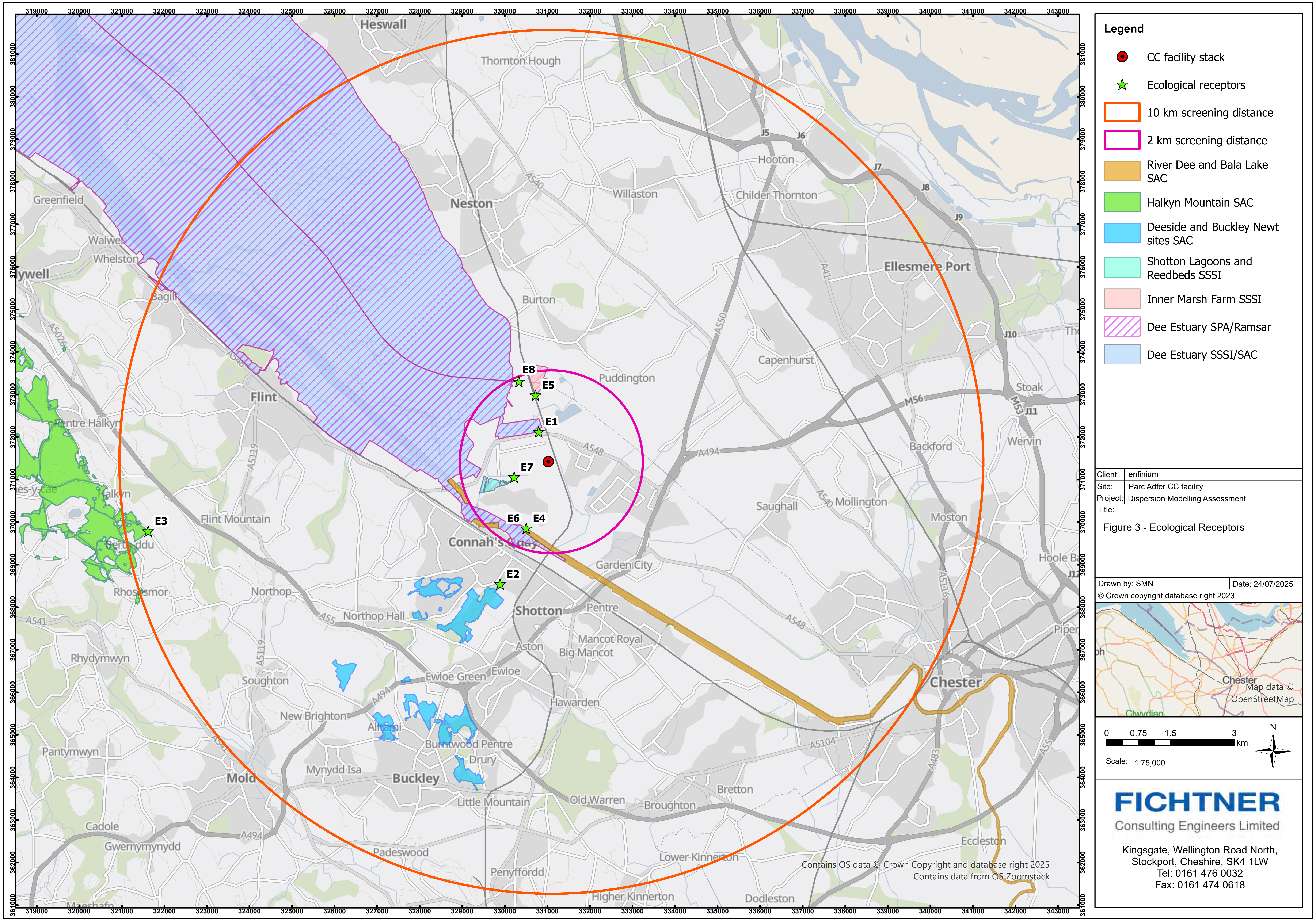
Legend
CC facility stack
Ecological receptors
10 km screening distance
2 km screening distance
River Dee and Bala Lake SAC
Halkyn Mountain SAC
Deeside and Buckley Newt sites SAC
Shotton Lagoons and Reedbeds SSSI
Inner Marsh Farm SSSI
Dee Estuary SPA/Ramsar
Dee Estuary SSSI/SAC
E1
E2
E3
E4
E5
E6
E7
E8
Client: enfinium
Site: Parc Adfer CC facility
Project: Dispersion Modelling Assessment
Title:
Figure 3 - Ecological Receptors
Drawn by: SMN
Date: 24/07/2025
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Map data © OpenStreetMap
0 0.75 1.5 3 km
Scale: 1:75,000
N
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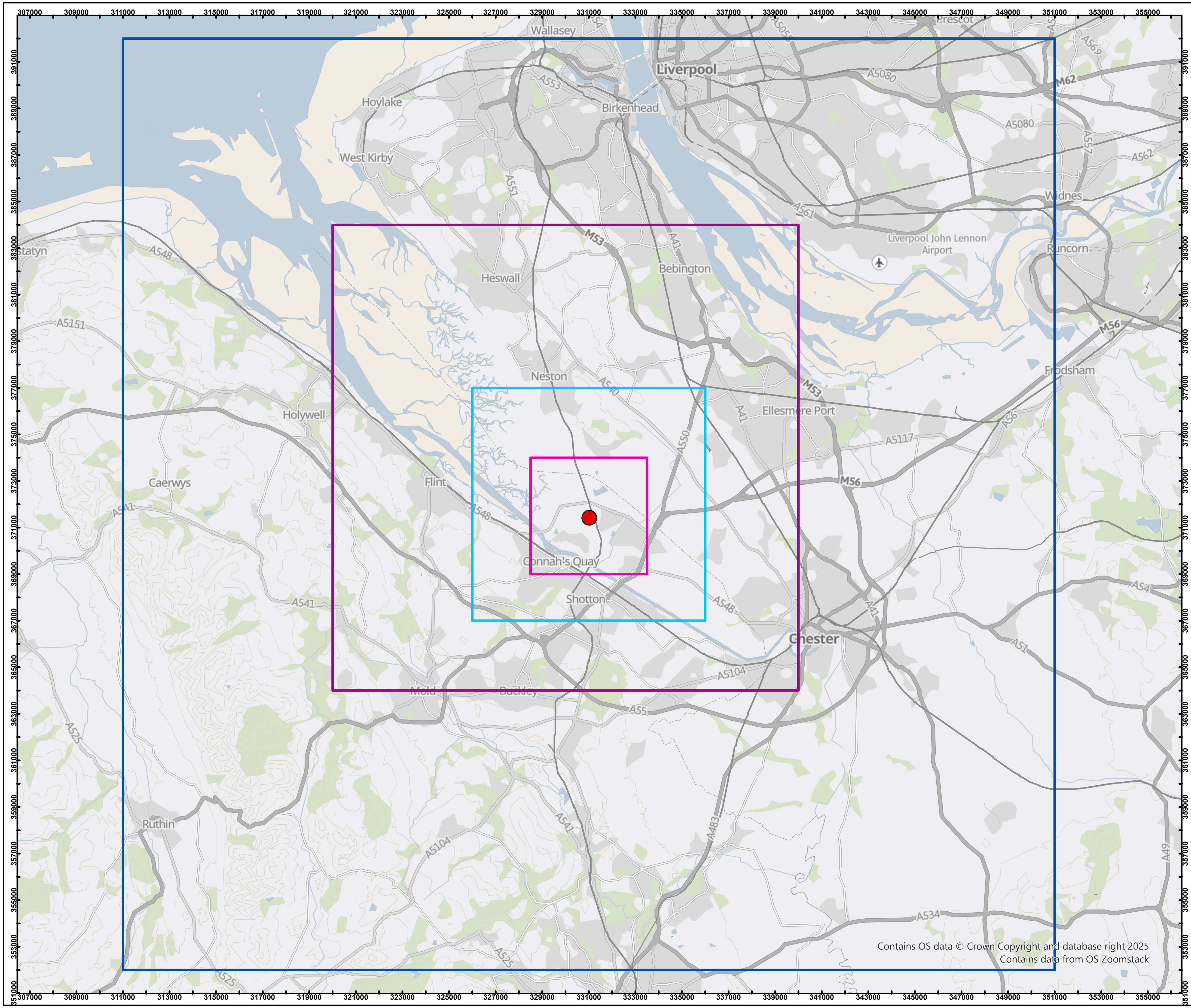

Legend

- Site location
- Non-amine modelling wide grid extent
- Non-amine modelling fine grid extent
- Amine modelling wide grid extent
- Amine modelling fine grid extent

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 4 - Modelling Domain

Drawn by: SMN | Date: 24/07/2025

0 1.5 3 6 km

Scale: 1:150,000

N

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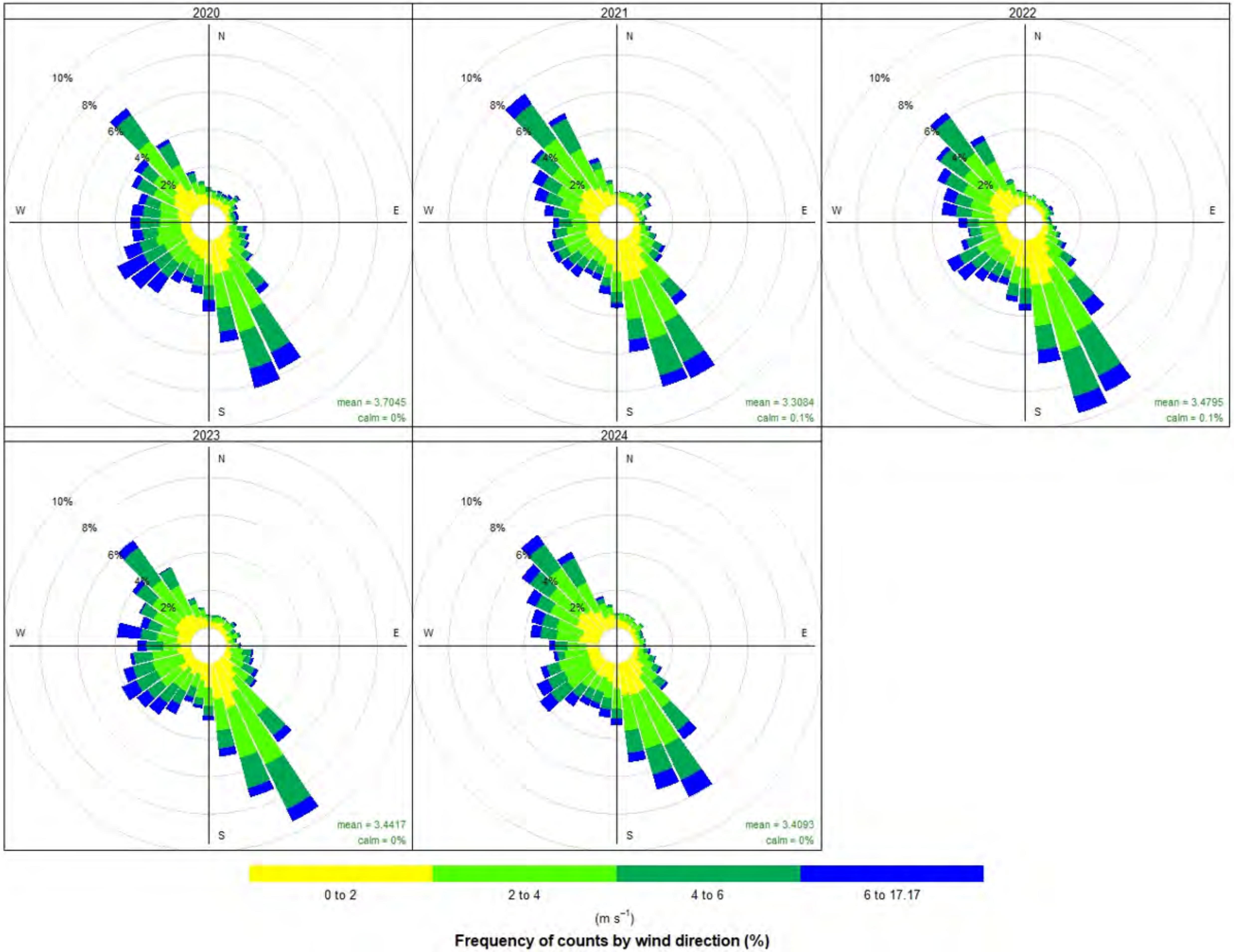

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 5 - Wind Roses Hawarden 2020 - 2024

Drawn by: SMN	Date: 24/07/2025

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Legend

- Site location

Surface roughness (m)

- 0.0001
- 0.0005
- 0.005
- 0.03
- 0.05
- 0.5
- 0.75
- 1.2

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 6 - Surface Roughness File

Drawn by: SMN | Date: 24/07/2025

0 1.75 3.5 7 km

Scale: 1:170,000

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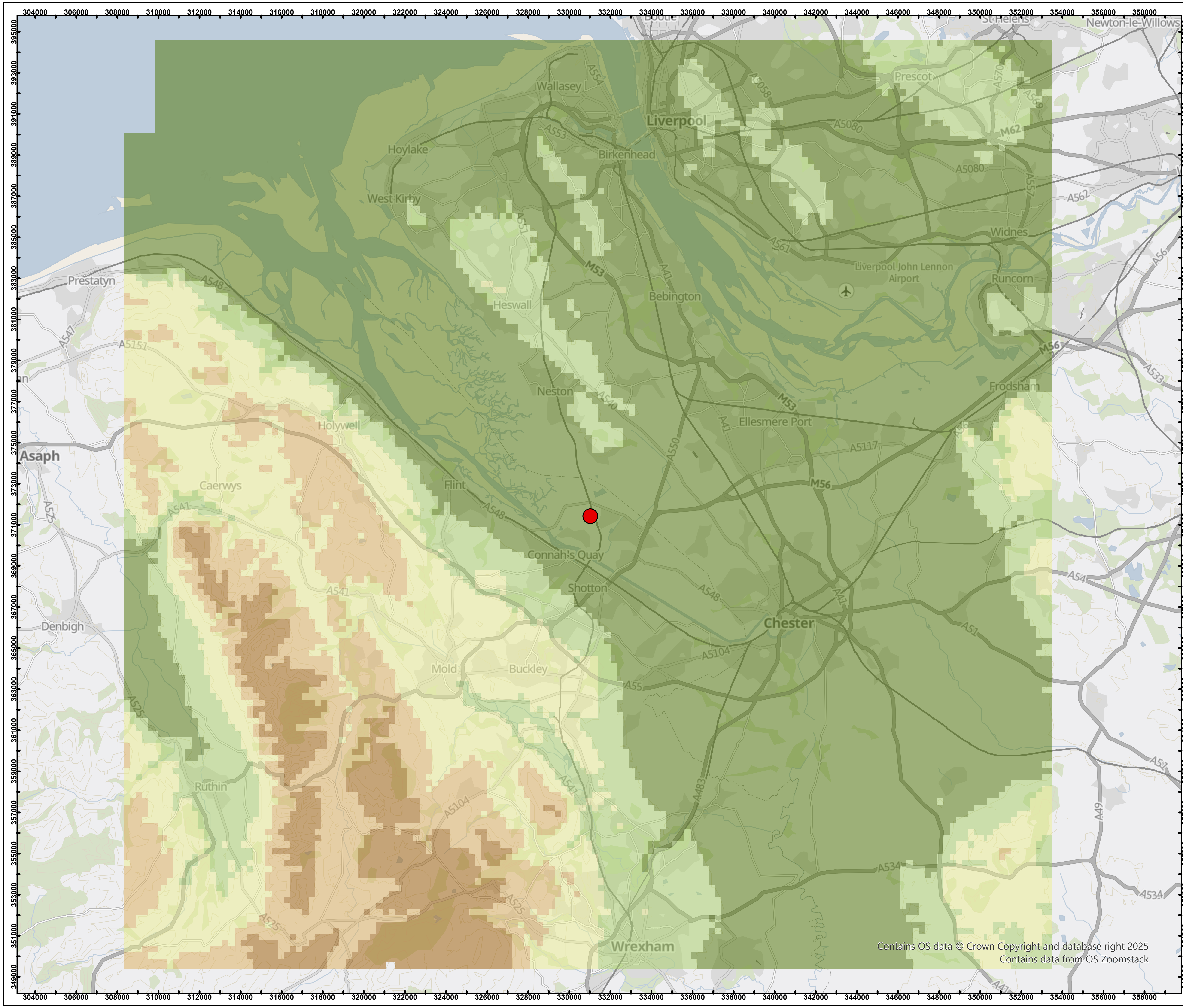

Legend

- Site location

Elevation (m)

- <50
- 50 - 100
- 100 - 200
- 200 - 300
- >300

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 7 - Terrain File

Drawn by: SMN | Date: 24/07/2025

0 1.75 3.5 7 km

N

Scale: 1:170,000

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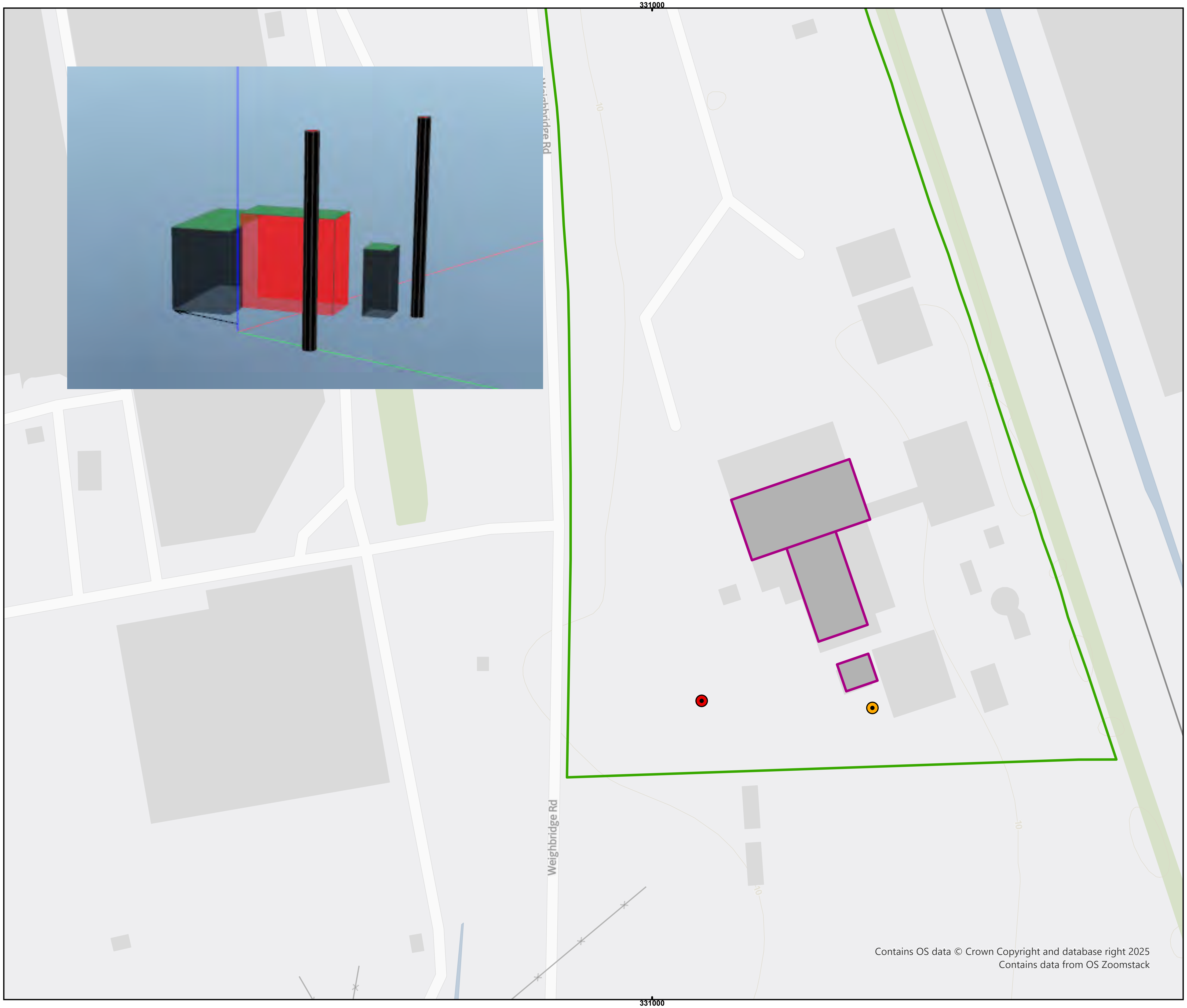


Legend

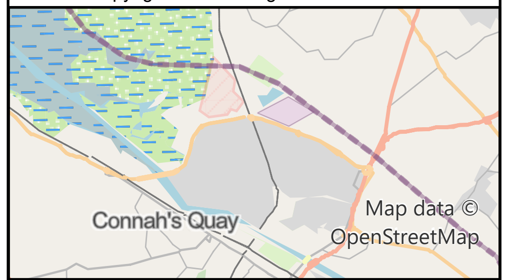
- Installation boundary
- ERF stack
- CC facility stack
- Buildings modelled

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 8 - Buildings Modelled

Drawn by: SMN	Date: 24/07/2025



0 0.01 0.03 0.06 km

N

Scale: 1:1,500

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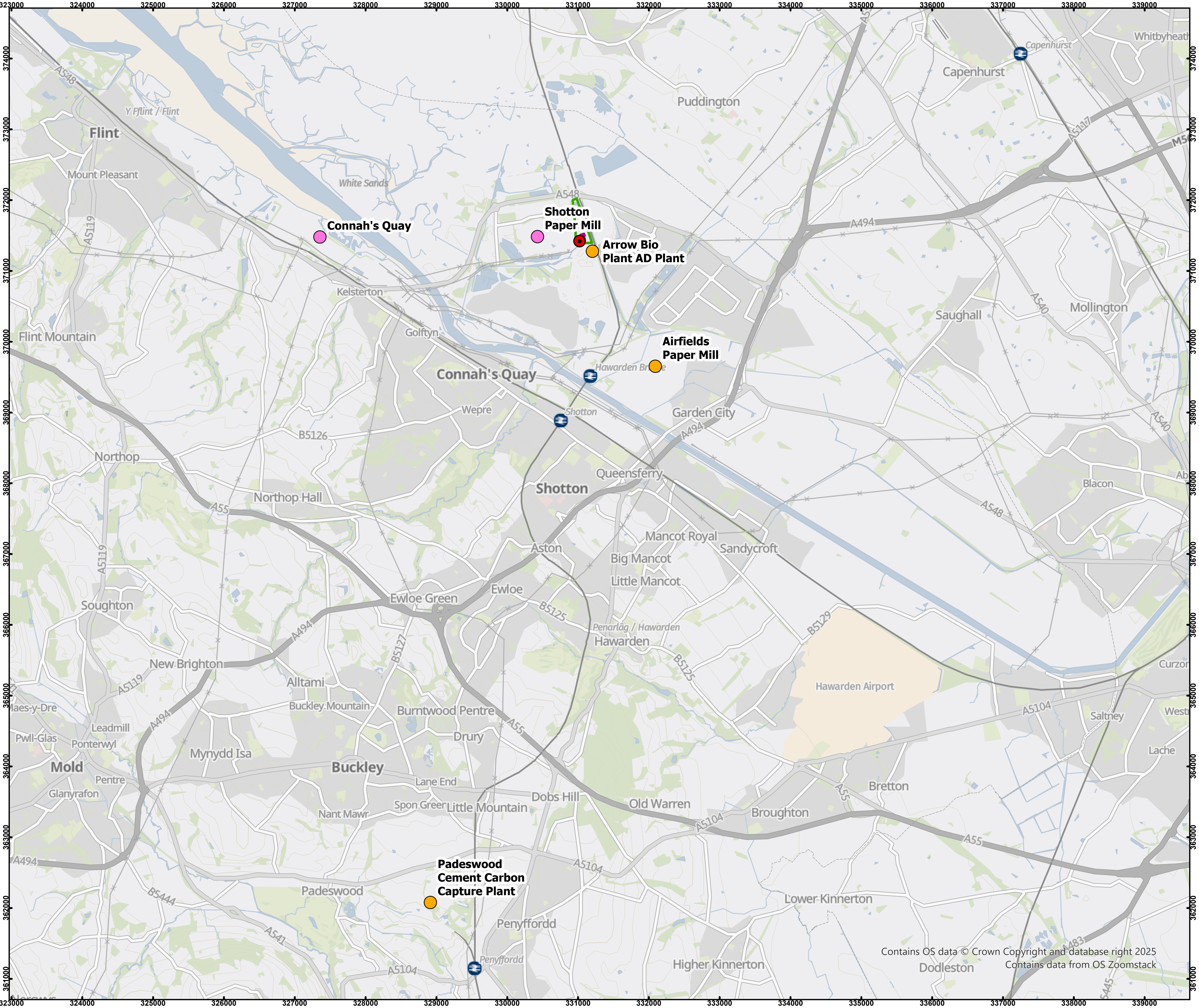


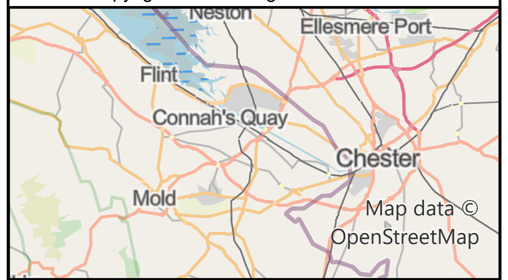
Legend

- Installation boundary
- CC facility stack

Cumulative sources

- Explicitly modelled
- Considered semi-quantitatively
- Buildings modelled

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment
Title:	Figure 9 - Cumulative Sources
Drawn by: SMN	Date: 24/07/2025



0 0.5 1 2 km

Scale: 1:50,000

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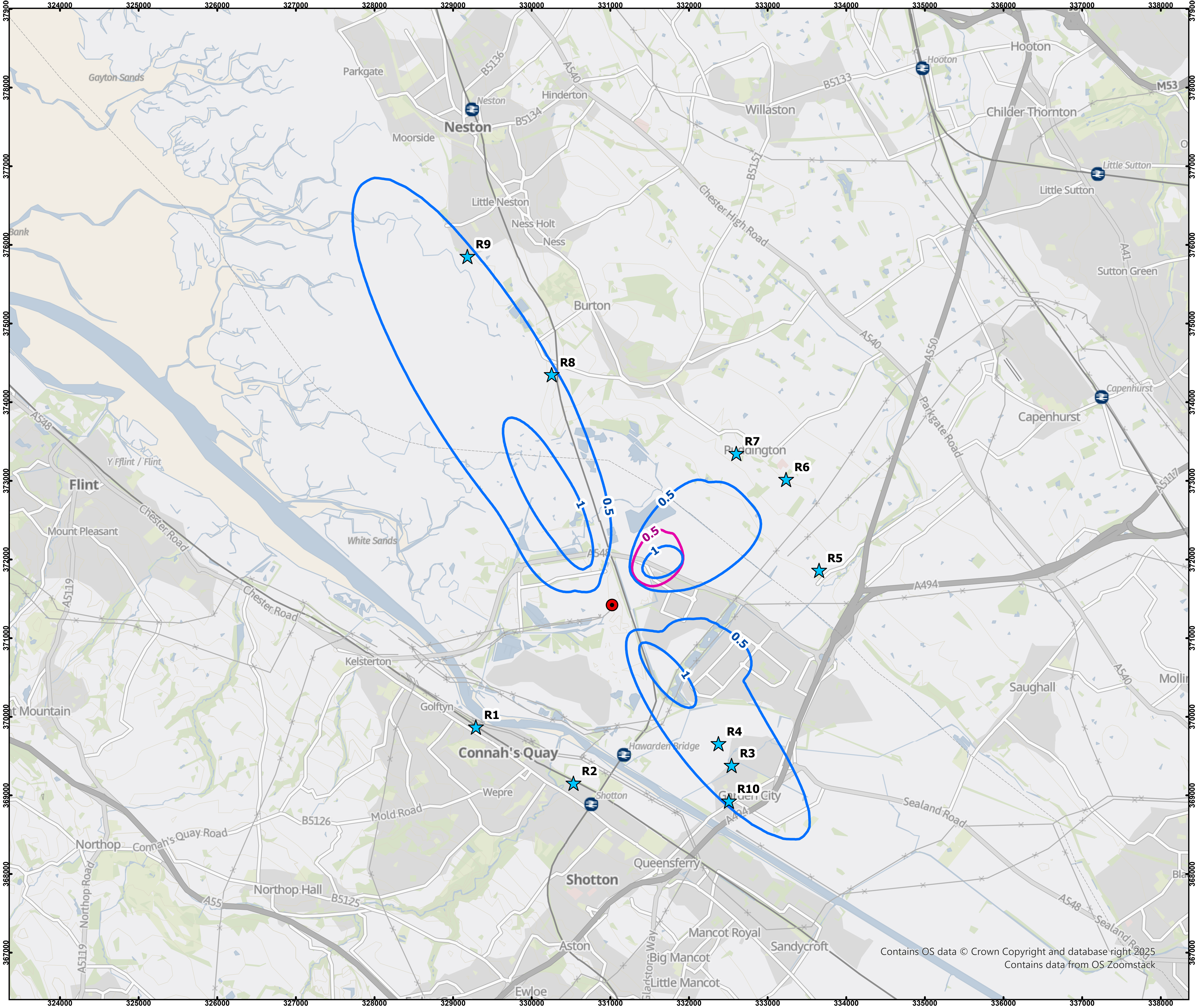


Legend

- Human receptors
- CC facility stack
- Annual mean nitrogen dioxide as % of AQAL - CC facility
- Annual mean nitrogen dioxide as % of AQAL - change

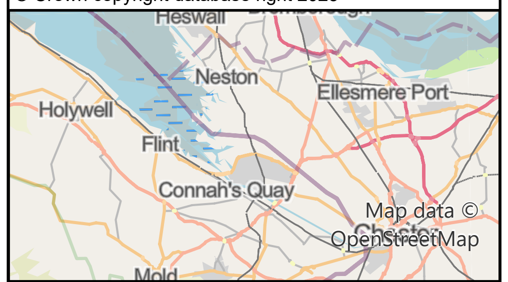
Notes:
Assumes 70% NOx to NO2 conversion rate

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 10 - Annual Mean Nitrogen Dioxide

Drawn by: SMN | Date: 24/07/2025



0 0.45 0.9 1.8 km

N

Scale: 1:45,000

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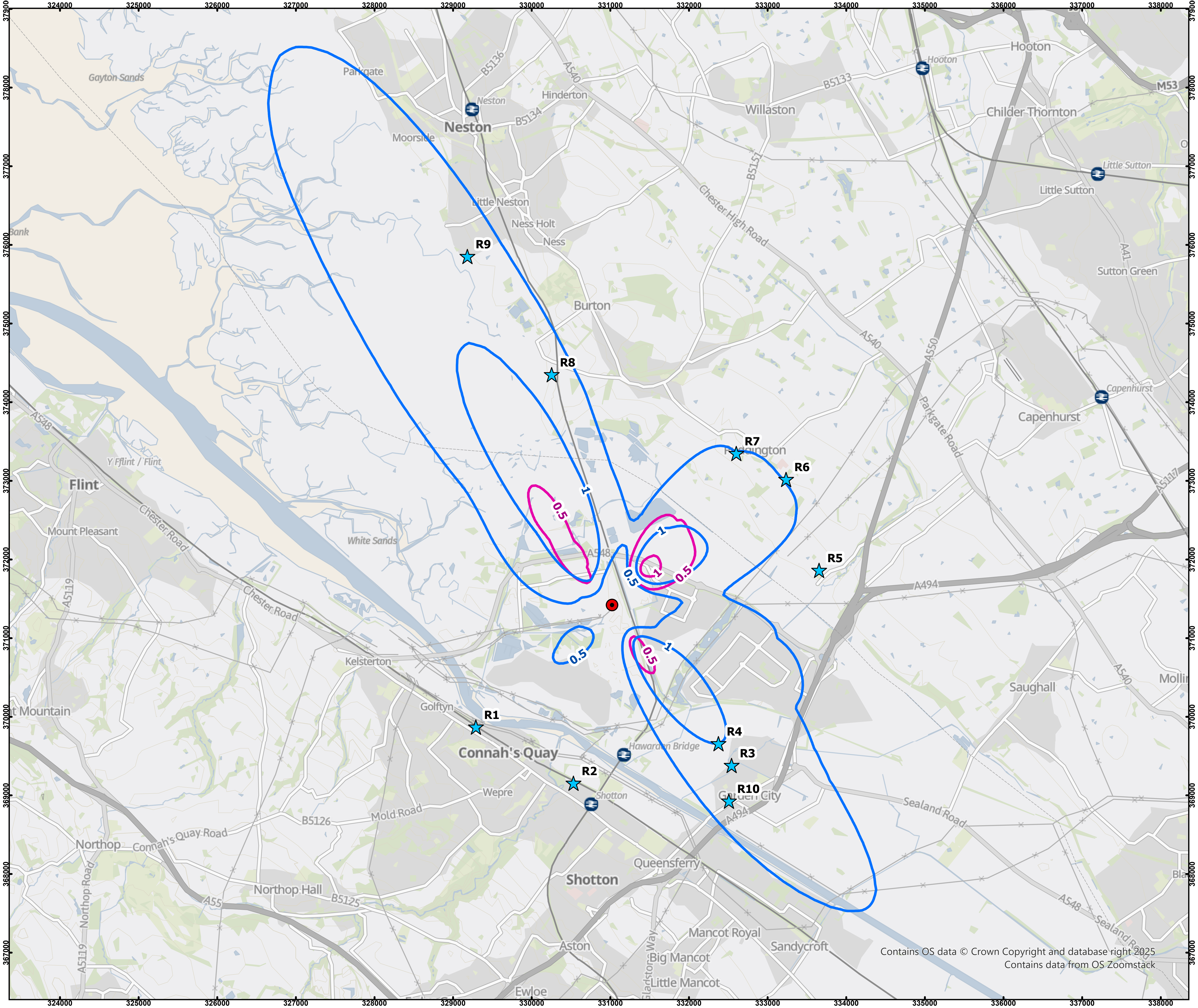


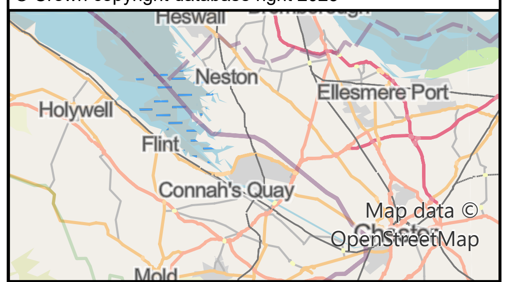
Legend

- Human receptors
- CC facility stack
- Annual mean cadmium as % of AQAL - CC facility
- Annual mean cadmium as % of AQAL - change

Notes:
Assumes cadmium emitted by ERF at the combined cadmium and thallium ELV, and no further abatement provided by the CC facility

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment
Title:	Figure 11 - Annual Mean Cadmium

Drawn by: SMN | Date: 24/07/2025



Scale: 1:45,000 (0 – 0.45 – 0.9 – 1.8 km)

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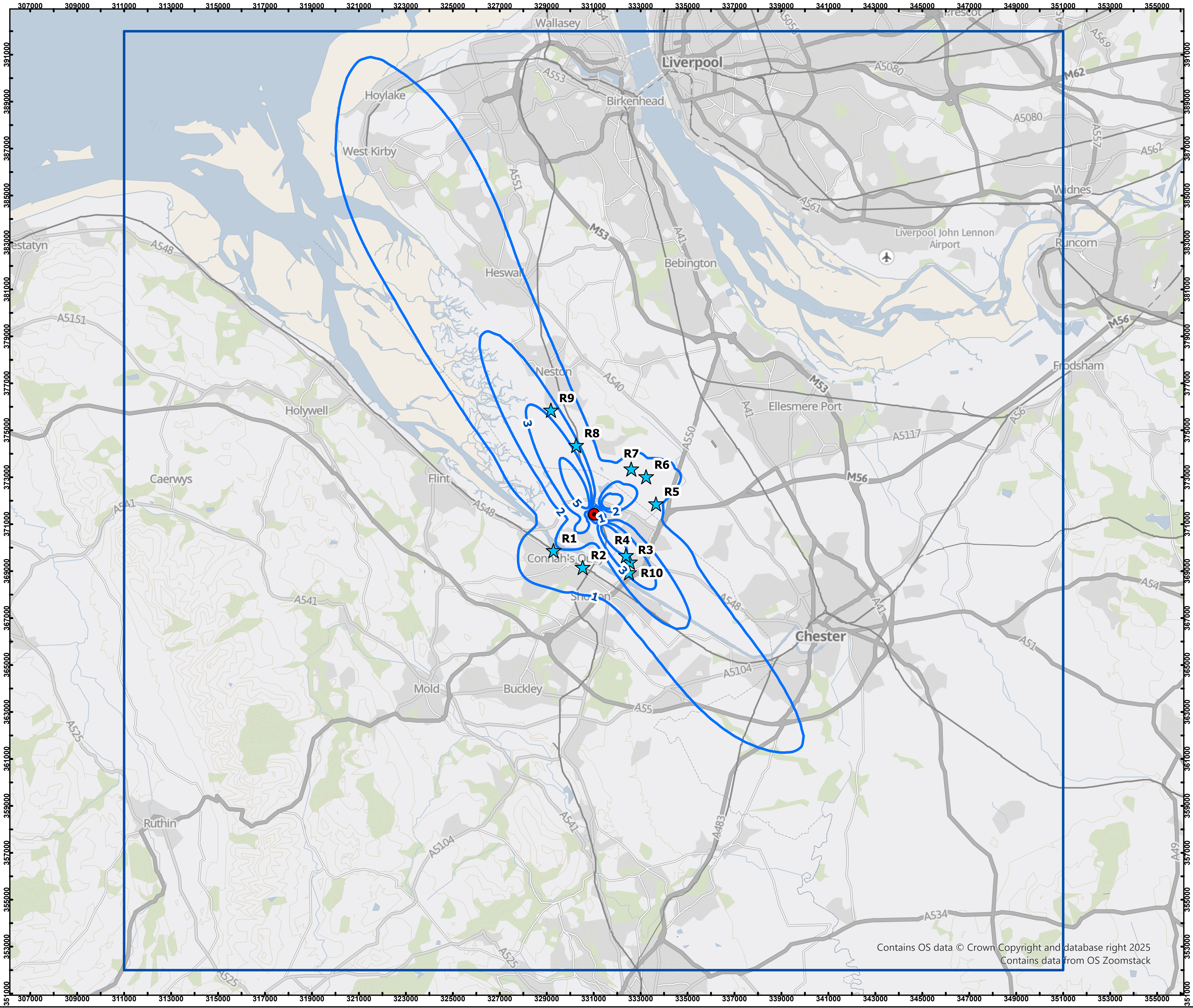

Legend

- Human receptors
- CC facility stack
- Amine modelling wide grid extent
- Annual mean nitrosamines as % of AQAL for NDMA

Notes:
Sum of nitramines + nitrosamines as % of the AQAL for NMDA (0.2 ng/m³)

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 12 - Annual Mean Nitrosamines

Drawn by: SMN | Date: 24/07/2025

Scale: 1:150,000

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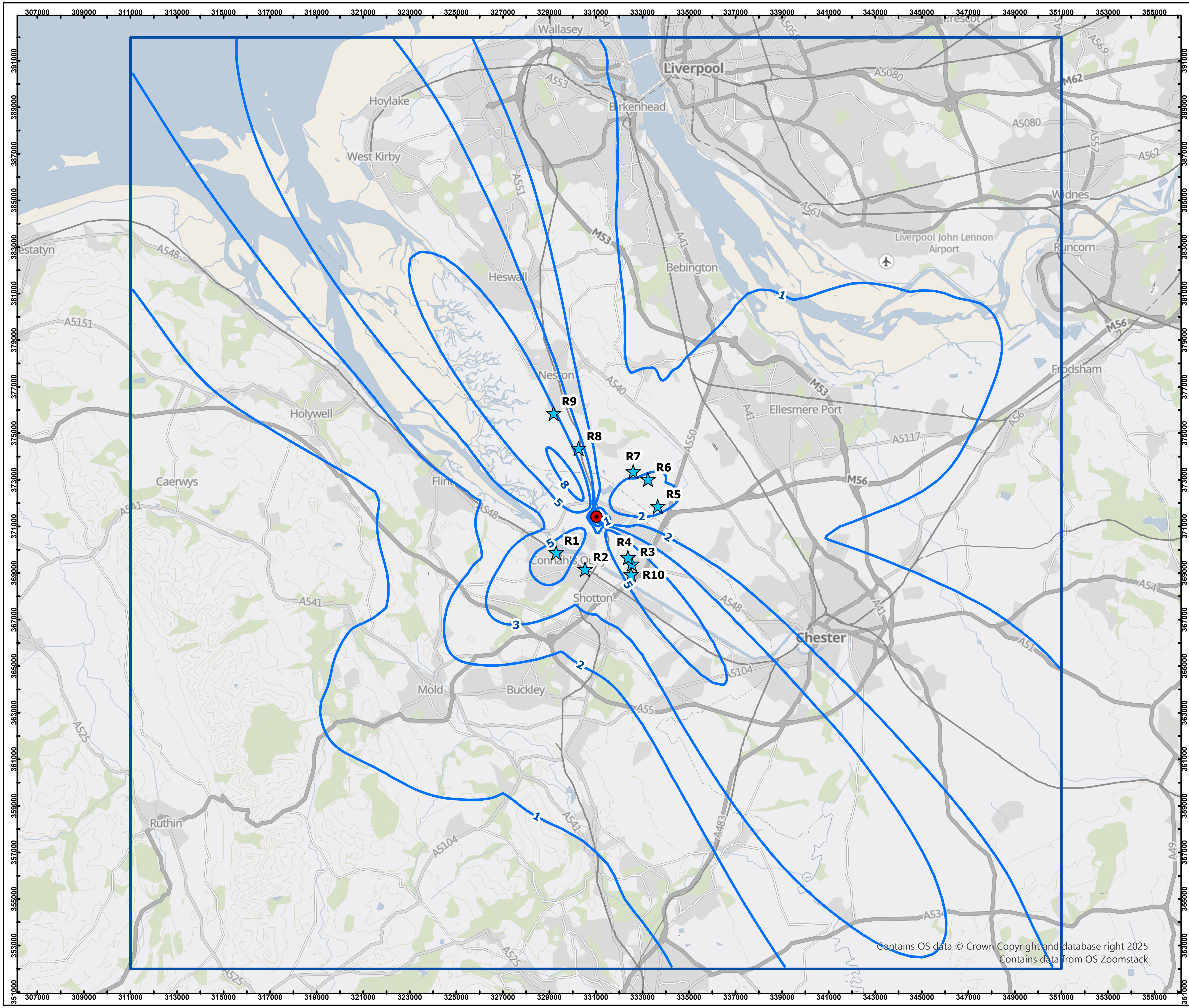

Legend

- Human receptors
- CC facility stack
- Amine modelling wide grid extent
- Annual mean nitramines as % of AQAL for NDMA

Notes:
Sum of nitramines as % of the AQAL for NMDA (0.2 ng/m³)

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 13 - Annual Mean Nitramines

Drawn by: SMN | Date: 24/07/2025

0 1.5 3 6 km

Scale: 1:150,000

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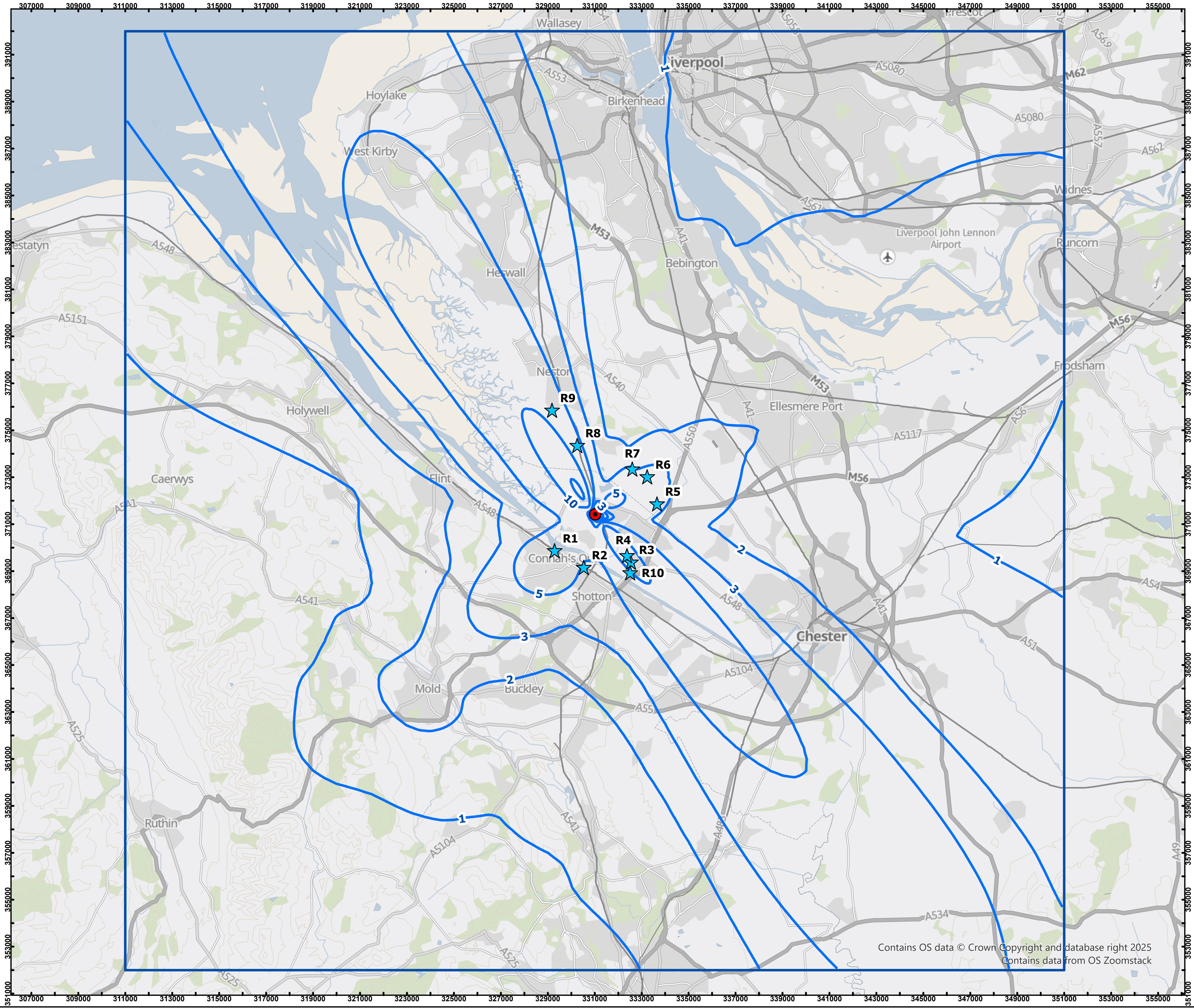


Legend

- Human receptors
- CC facility stack
- Amine modelling wide grid extent
- Annual mean nitrosamines + nitramines as % of AQAL for NDMA

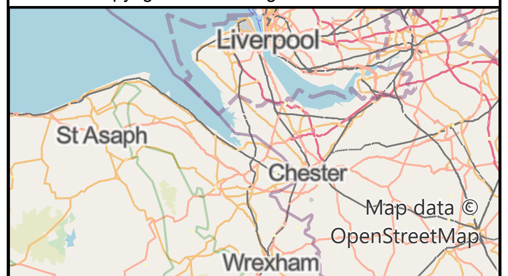
Notes:
Sum of nitramines as % of the AQAL for NDMA (0.2 ng/m³)

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 14 - Annual Mean Nitramines + Nitrosamines

Drawn by: SMN | Date: 24/07/2025



0 1.5 3 6 km

Scale: 1:150,000

N

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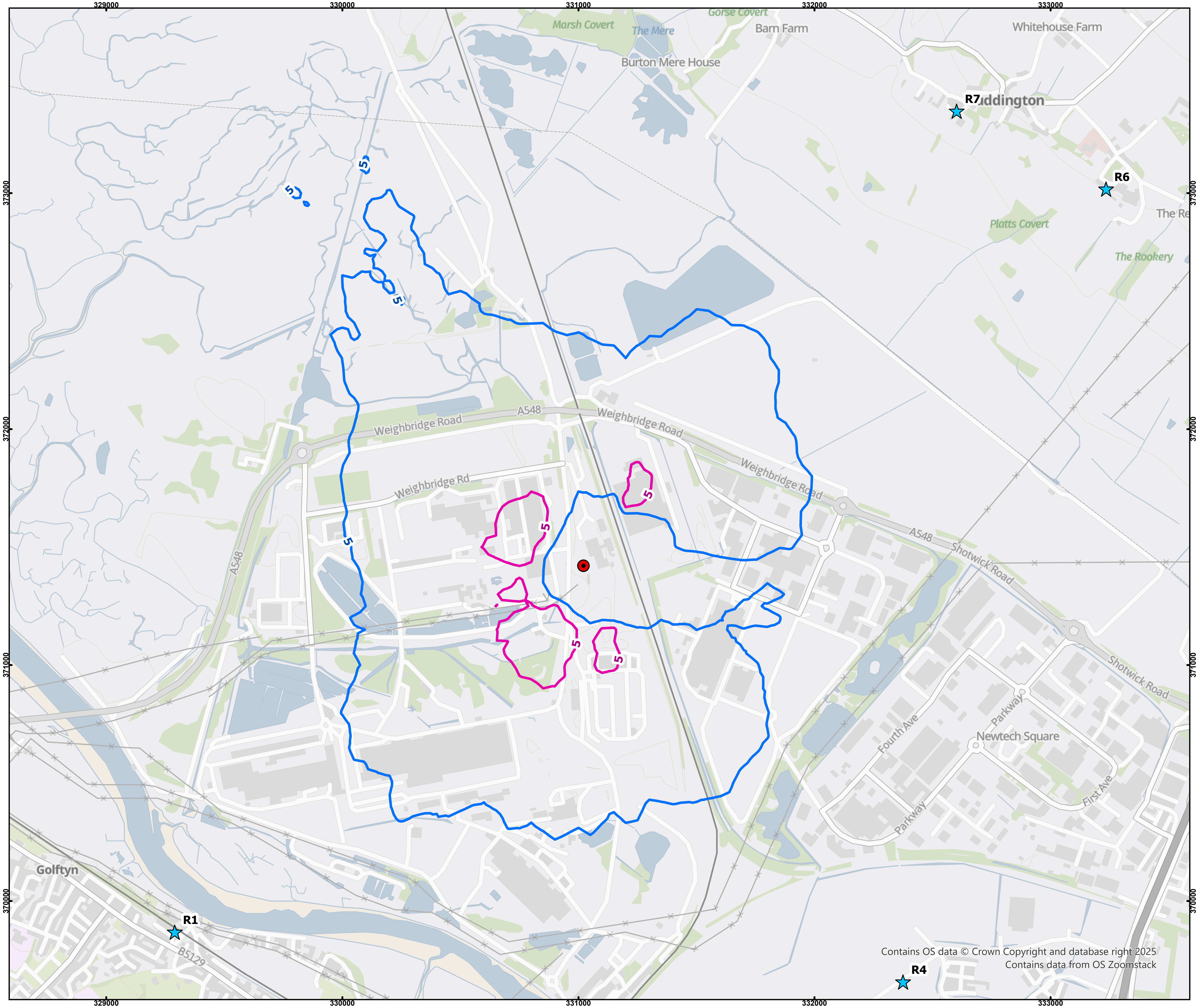

Legend

- Human receptors
- CC facility stack
- 99.79th percentile of 1 hour mean nitrogen dioxide as % of AQAL - CC facility
- 99.79th percentile of 1 hour mean nitrogen dioxide as % of AQAL - change

Notes:
Assumes emissions at the short-term ELV and 35% NOx to NO2 conversion rate

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 15 - 99.79th Percentile of Hourly Mean Nitrogen Dioxide

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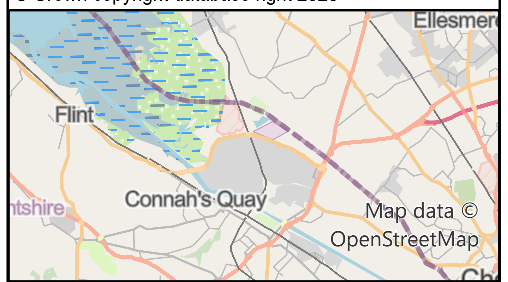

0 0.15 0.3 0.6 km

N

Scale: 1:15,000

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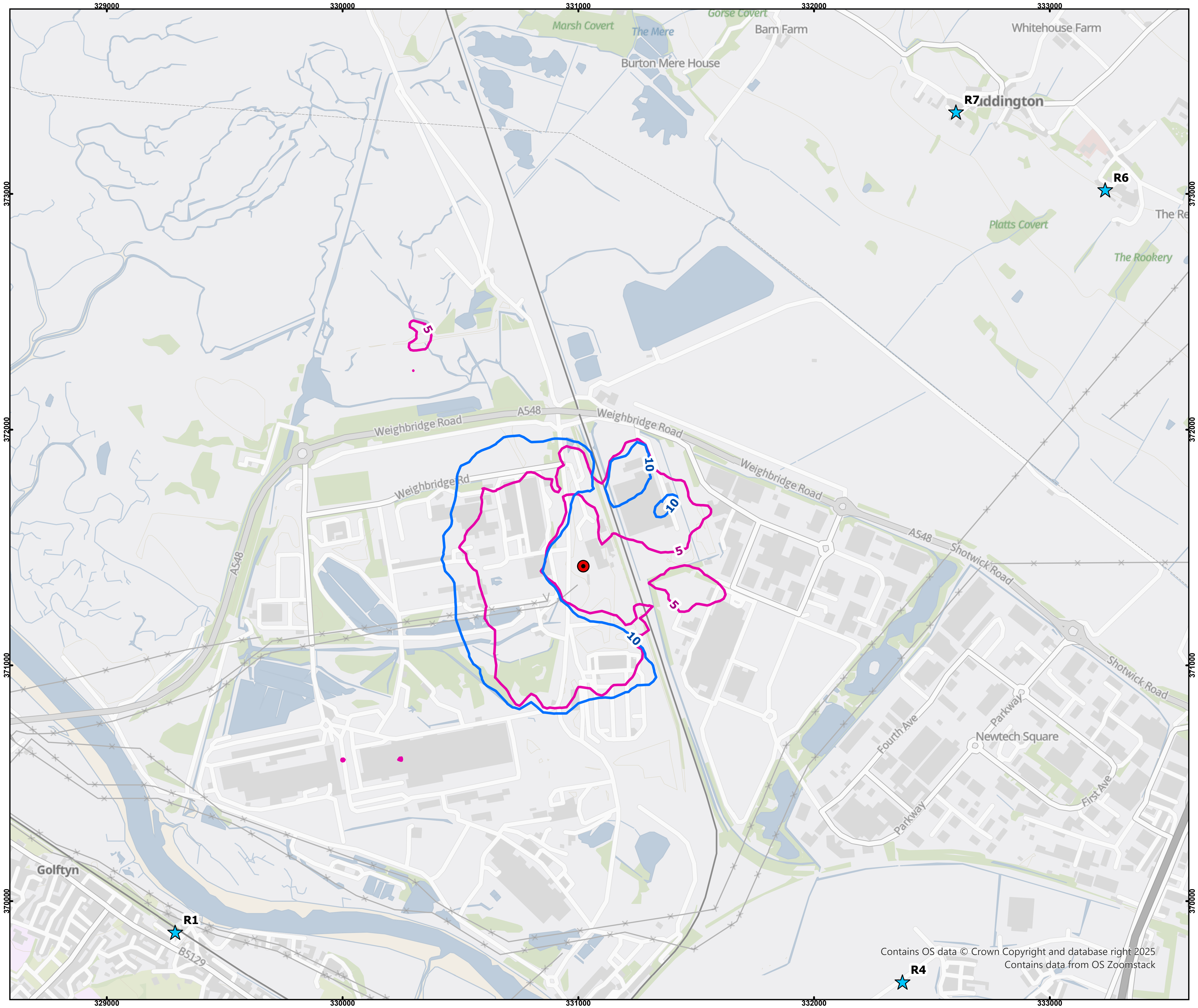


Legend

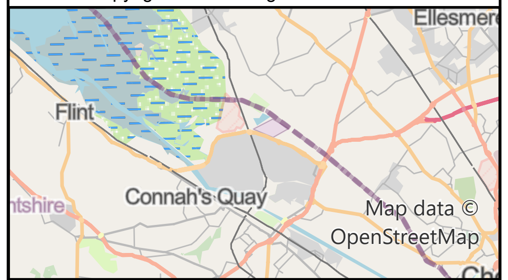
- Human receptors
- CC facility stack
- 99.9th percentile of 15 minute mean sulphur dioxide as % of AQAL - CC facility
- 99.9th percentile of 15 minute mean sulphur dioxide as % of AQAL - change

Notes:
Assumes emissions at the short-term ELV and no abatement of emissions by the CC facility

Client:	Enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment
Title:	

Figure 16 - 99.9th Percentile of 15-Minute Mean Sulphur Dioxide1

Drawn by: SMN	Date: 24/07/2025



0 0.15 0.3 0.6 km

N

Scale: 1:15,000

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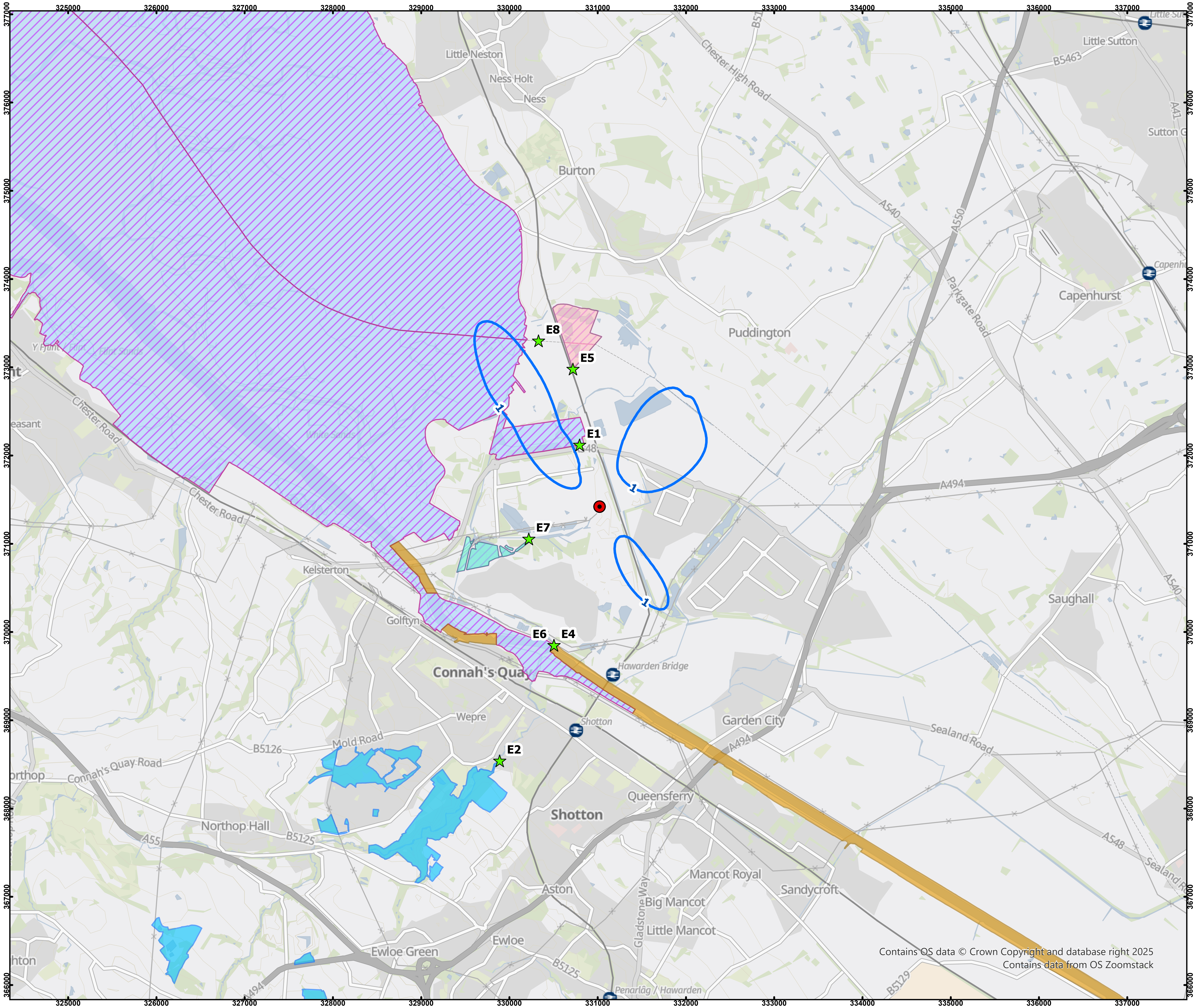


Legend

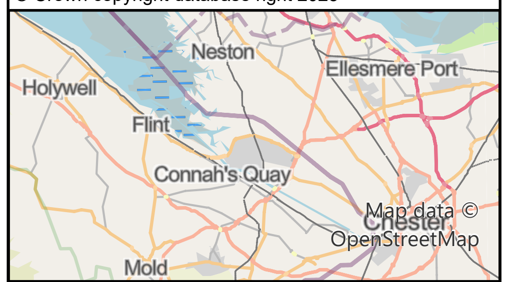
- CC facility stack
- Dee Estuary SPA/Ramsar
- Dee Estuary SSSI/SAC
- Deeside and Buckley Newt sites SAC
- Halkyn Mountain SAC
- River Dee and Bala Lake SAC
- Shotton Lagoons and Reedbeds SSSI
- Ecological receptors
- Annual mean ammonia - change in impact as % of Critical Level of 1 µg/m³

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 17 - Annual Mean Ammonia

Drawn by: SMN | Date: 24/07/2025



0 0.4 0.8 1.6 km

Scale: 1:40,000

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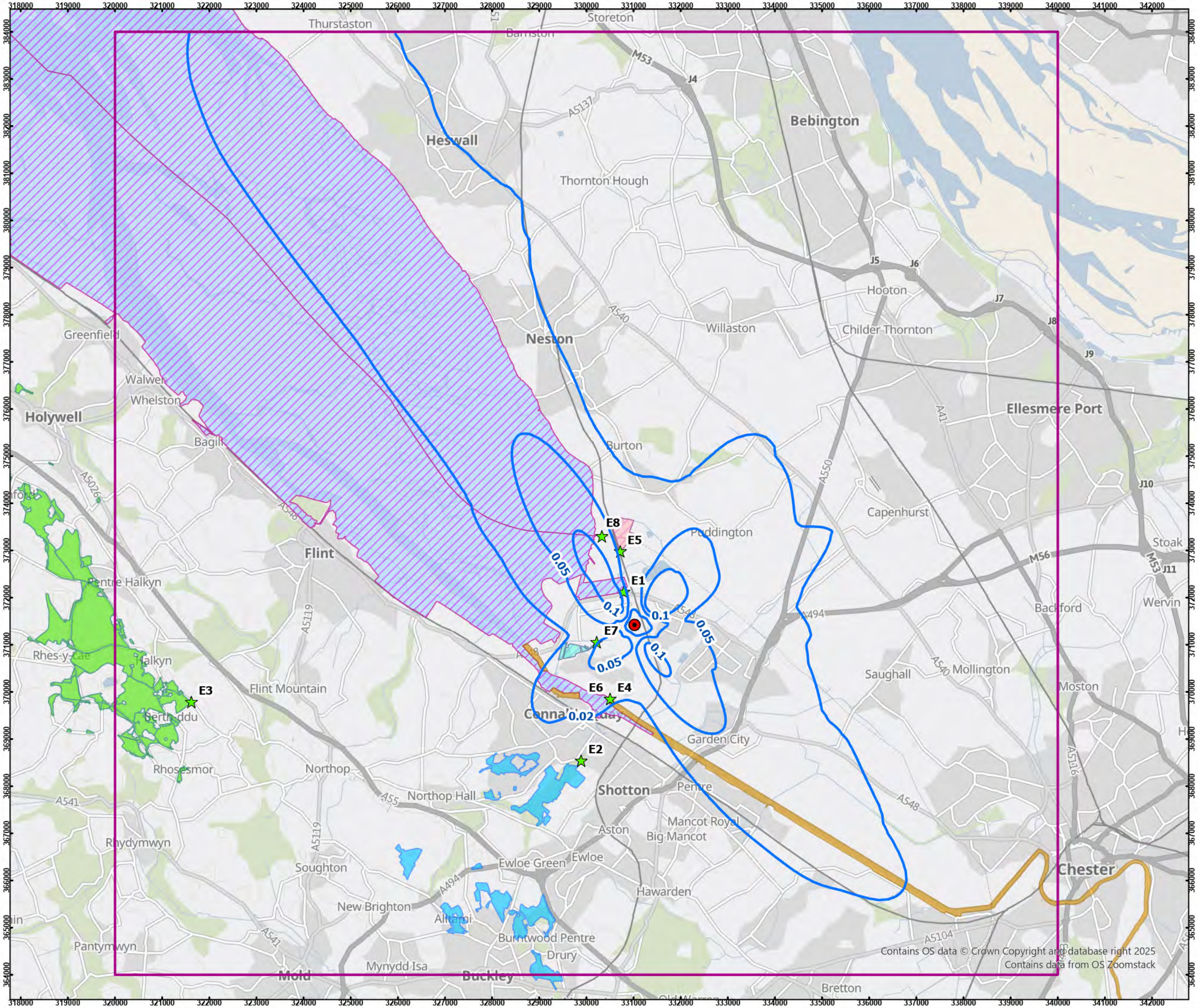

Legend

- CC facility stack
- Ecological receptors
- Non-amine modelling wide grid extent
- River Dee and Bala Lake SAC
- Halkyn Mountain SAC
- Deeside and Buckley Newt sites SAC
- Shotton Lagoons and Reedbeds SSSI
- Inner Marsh Farm SSSI
- Dee Estuary SPA/Ramsar
- Dee Estuary SSSI/SAC
- Change in Nitrogen Deposition to Grassland - kgNhayr

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 18 - Nitrogen Deposition – Grassland Deposition Velocity

Drawn by: SMN | Date: 06/08/2025

0 0.75 1.5 3 km

Scale: 1:75,000

N

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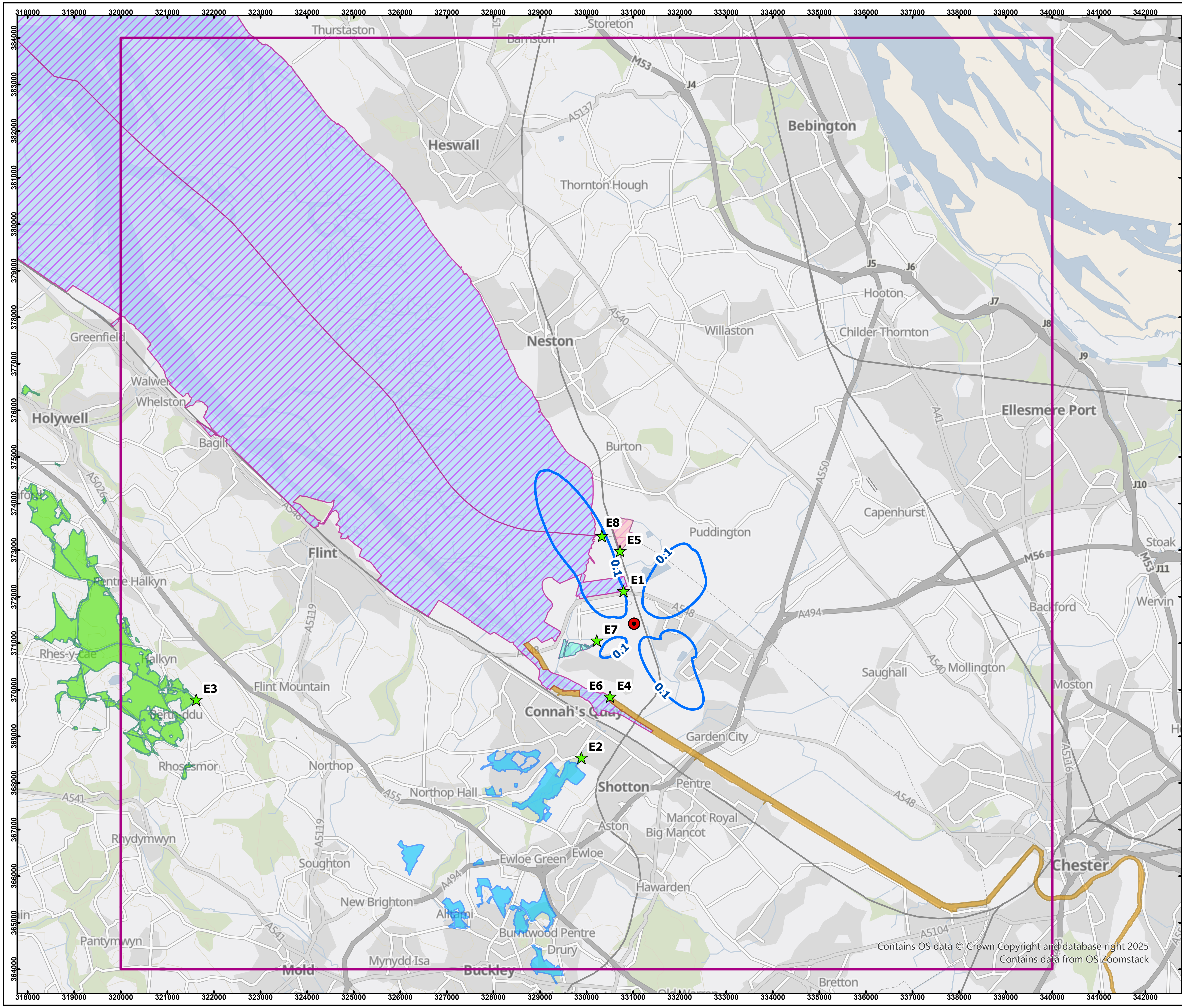


Legend

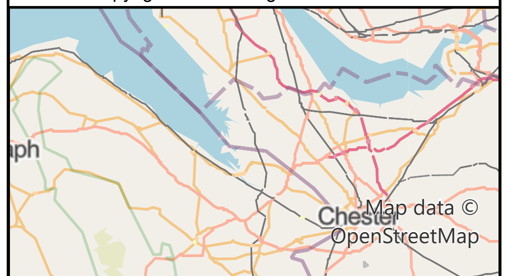
- CC facility stack
- Ecological receptors
- Non-amine modelling wide grid extent
- River Dee and Bala Lake SAC
- Halkyn Mountain SAC
- Deeside and Buckley Newt sites SAC
- Shotton Lagoons and Reedbeds SSSI
- Inner Marsh Farm SSSI
- Dee Estuary SPA/Ramsar
- Dee Estuary SSSI/SAC
- Change in Nitrogen Deposition to Woodland - kgN/ha/yr

Client:	enfinium
Site:	Parc Adfer CC facility
Project:	Dispersion Modelling Assessment

Title:

Figure 19 - Nitrogen Deposition – Woodland Deposition Velocity

Drawn by: SMN	Date: 24/07/2025



0 0.75 1.5 3 km

Scale: 1:75,000

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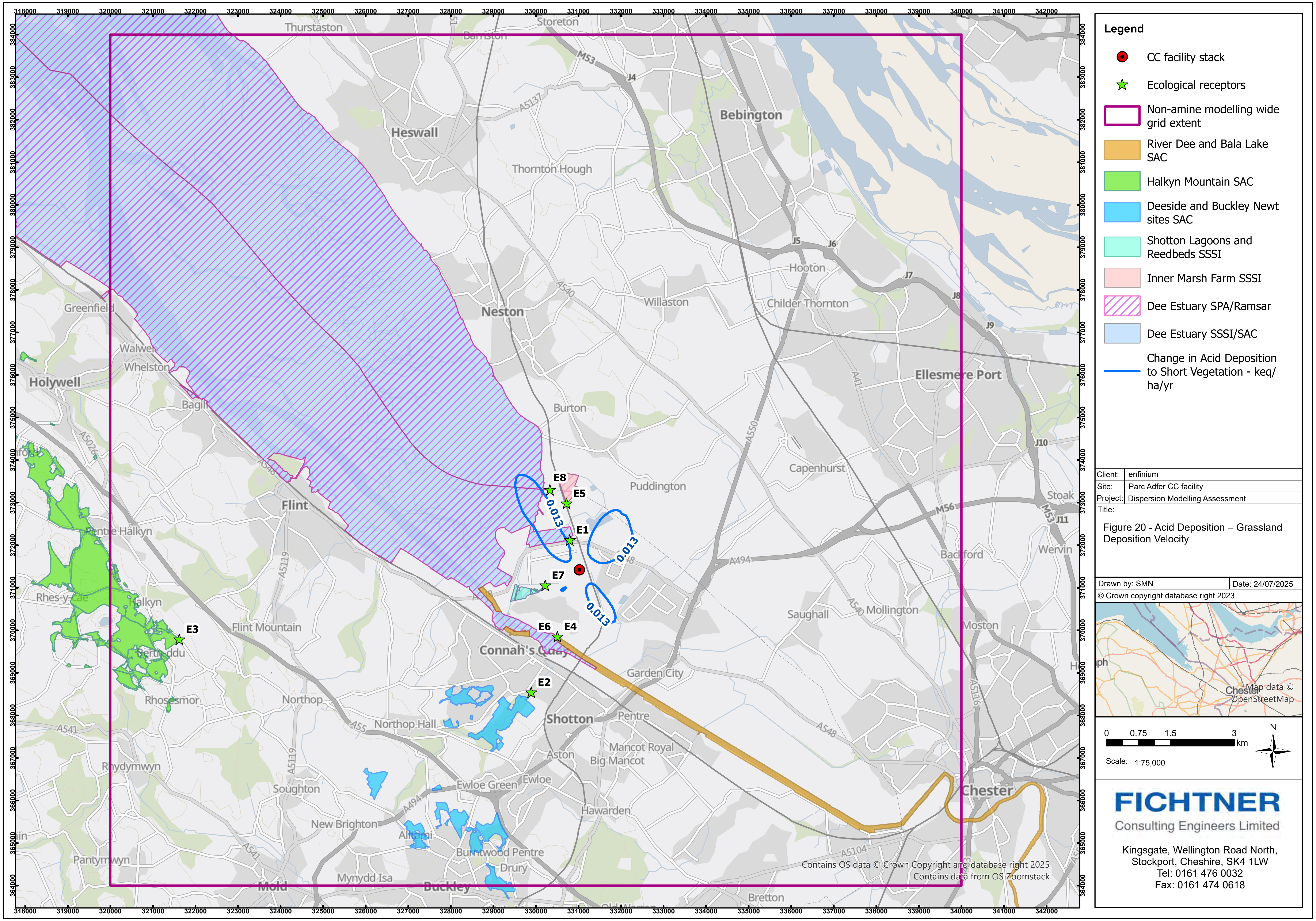
Legend
CC facility stack
Ecological receptors
Non-amine modelling wide grid extent
River Dee and Bala Lake SAC
Halkyn Mountain SAC
Deeside and Buckley Newt sites SAC
Shotton Lagoons and Reedbeds SSSI
Inner Marsh Farm SSSI
Dee Estuary SPA/Ramsar
Dee Estuary SSSI/SAC
Change in Acid Deposition to Short Vegetation - keq/ha/yr
E1
E2
E3
E4
E5
E6
E7
E8
0.013
Client: enfinium
Site: Parc Adfer CC facility
Project: Dispersion Modelling Assessment
Title:
Figure 20 - Acid Deposition – Grassland Deposition Velocity
Drawn by: SMN
Date: 24/07/2025
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Scale: 1:75,000
0 0.75 1.5 3 km
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Map data © OpenStreetMap

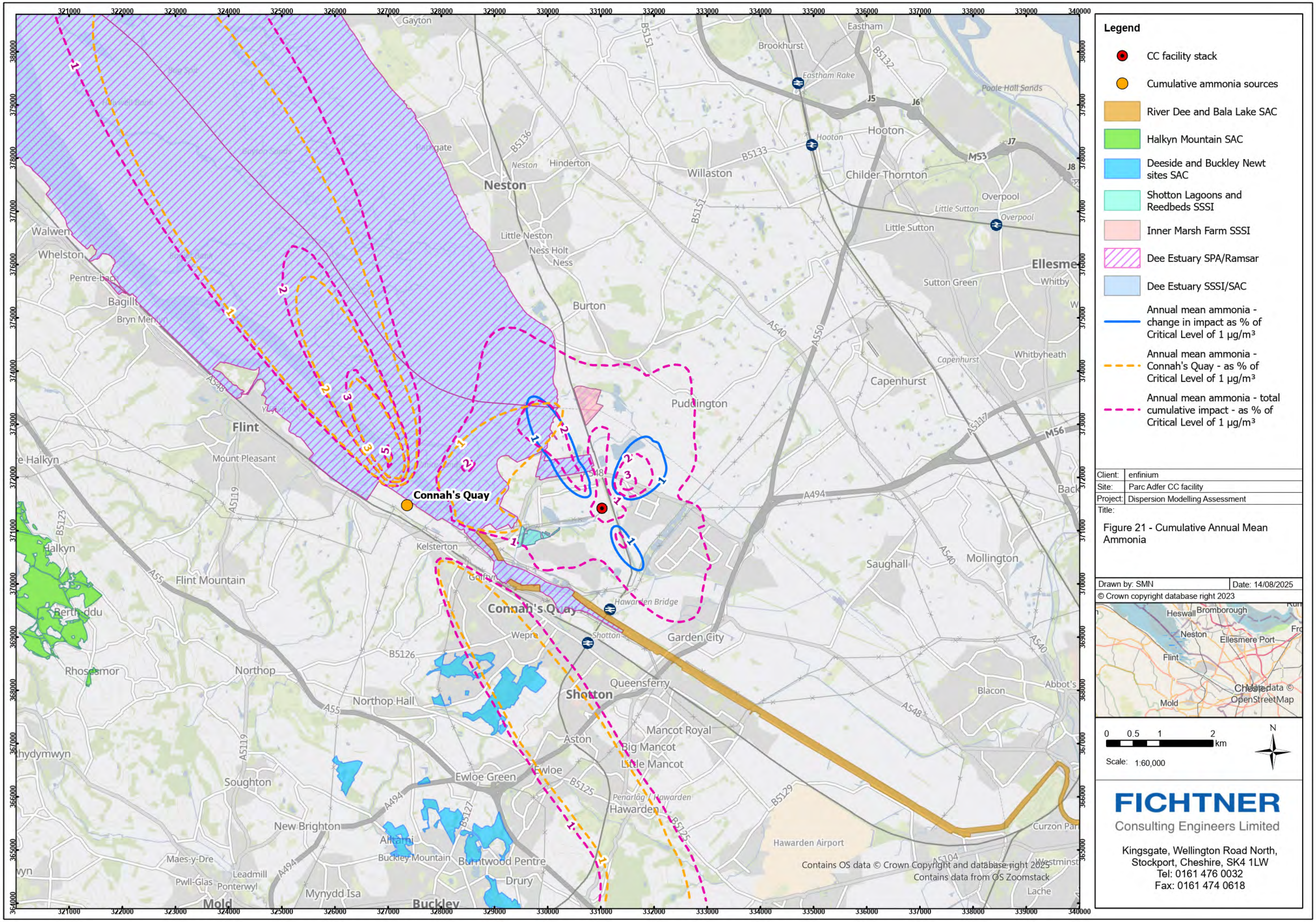
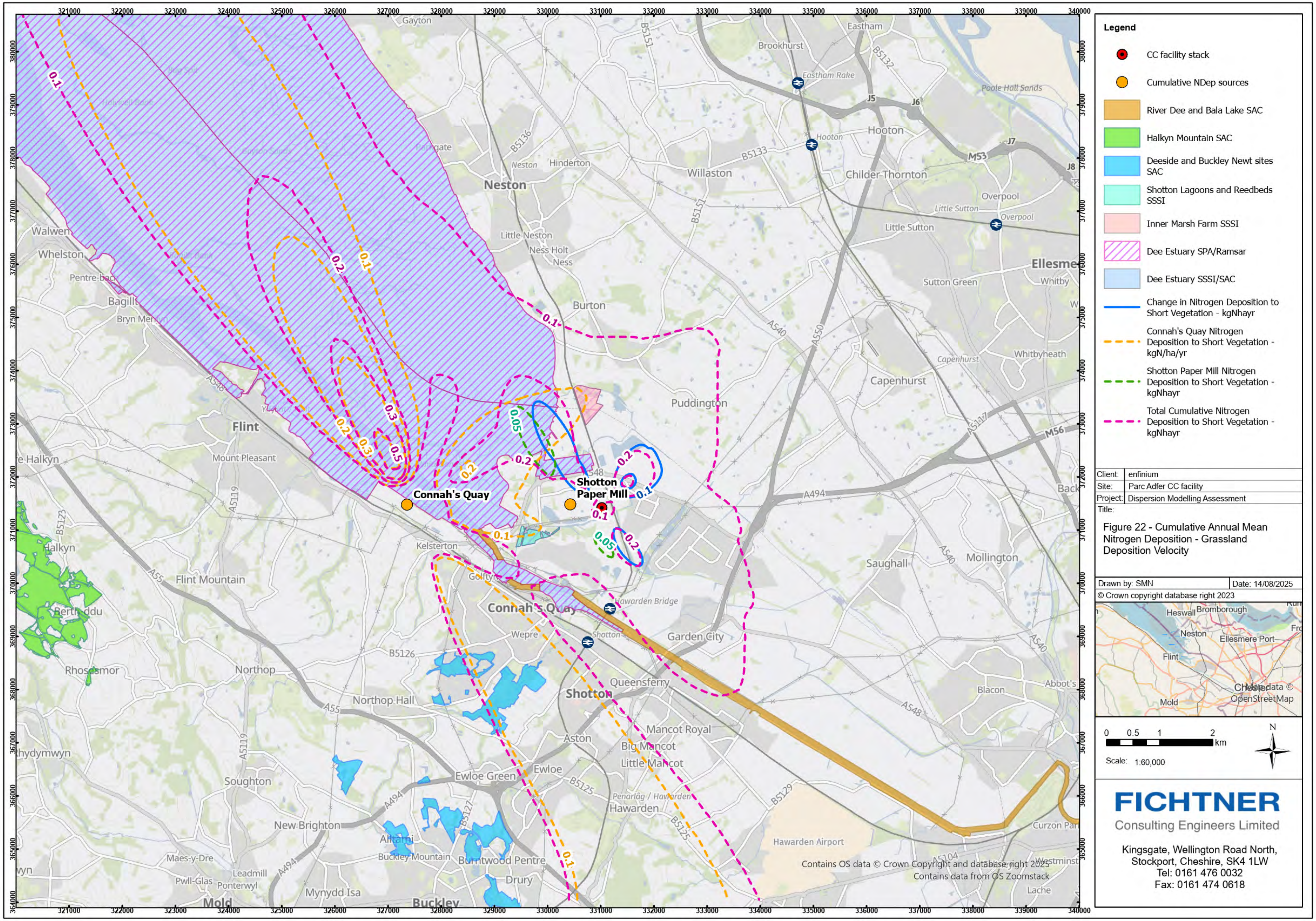


Figure 21 - Cumulative Annual Mean Ammonia



Legend
CC facility stack
Cumulative NDep sources
River Dee and Bala Lake SAC
Halkyn Mountain SAC
Deeside and Buckley Newt sites SAC
Shotton Lagoons and Reedbeds SSSI
Inner Marsh Farm SSSI
Dee Estuary SPA/Ramsar
Dee Estuary SSSI/SAC
Change in Nitrogen Deposition to Short Vegetation - kgNhayr
Connah's Quay Nitrogen Deposition to Short Vegetation - kgN/ha/yr
Shotton Paper Mill Nitrogen Deposition to Short Vegetation - kgNhayr
Total Cumulative Nitrogen Deposition to Short Vegetation - kgNhayr
Connah's Quay
Shotton Paper Mill
Client: enfinium
Site: Parc Adfer CC facility
Project: Dispersion Modelling Assessment
Title:
Figure 22 - Cumulative Annual Mean Nitrogen Deposition - Grassland Deposition Velocity
Drawn by: SMN
Date: 14/08/2025
© Crown copyright database right 2023
Scale: 1:60,000
0 0.5 1 2 km
N
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B APIS Critical Loads

Table 41: Nitrogen Deposition Critical Loads

ID	Site	Species/Habitat Type	NCL Class	Nitrogen Deposition kgN/hr/yr		
				Lower Critical Load	Upper Critical Load	Bg(1)
European and UK designated sites						
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	Humid dune slacks	Moist and wet dune slacks - acid type	5	10	17.6
		Atlantic salt meadows (Glauco-Puccinellietalia maritimae)	Atlantic upper-mid & mid-low salt marshes	10	20	17.6
E2	Deeside and Buckley Newt Sites SAC	Old sessile oak woods with Ilex and Blechnum in the British Isles	Acidophilous Quercus forest	10	15	32.2
E3	Halkyn Mountain SAC	Limestone pavements	Arctic-alpine calcareous grassland	5	10	16.7
		Tilio-Acerion forests of slopes, screes and ravines	Carpinus and Quercus mesic deciduous forest	15	20	28.7
E4	River Dee and Bala Lake SAC, LWS	Luronium natans	Permanent oligotrophic lakes, ponds and pools (including softwater lakes)	2	10	24.2
		Old sessile oak woods with Ilex and Blechnum in the British Isles	Acidophilous Quercus forest	10	15	44.5
E5	Inner Marsh Farm SSSI	Limosa limosa islandica	Atlantic upper-mid & mid-low salt marshes	10	20	16.5
E6	River Dee SSSI	Luronium natans	Permanent oligotrophic lakes, ponds and pools (including softwater lakes)	2	10	23.6
		Salt-marsh (Elymus repens saltmarsh)	Atlantic upper-mid & mid-low salt marshes	10	20	23.6
E7	Shotton Lagoons and Reedbeds SSSI/LWS	Common tern (Sterna hirundo), breeding	Coastal dune grasslands (grey dunes)	5	15	17.0

ID	Site	Species/Habitat Type	NCL Class	Nitrogen Deposition kgN/hr/yr		
				Lower Critical Load	Upper Critical Load	Bg(1)
Local nature sites						
E8	Dee Rifle LWS	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)	Atlantic upper-mid & mid-low salt marshes	10	20	16.3
Note: *(1) Background deposition taken as the maximum across the European UK designated site as reported on APIS. For Local nature sites the background deposition rates reported on APIS for the receptor points presented in Table 6 have been used.*						

Source: APIS

Table 42: Acid Deposition Critical Loads

ID	Site	Species/Habitat Type	Acidity Class	Critical Load Function (keq/ha/yr)			Background (keq/ha/yr) (N+S)(1)
				CLminN	CLmaxN	CLmaxS	
European and UK designated sites							
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	European dry heath	Dwarf shrub heath	0.499	1.329	0.45	-
E2	Deeside and Buckley Newt Sites SAC	Old sessile oak woods with Ilex and Blechnum in the British Isles	Unmanaged Broadleafed/ Coniferous Woodland	0.357	2.999	2.642	
E3	Halkyn Mountain SAC	Tilio-Acerion forests of slopes, screes and ravines	Unmanaged Broadleafed/ Coniferous Woodland	0.142	1.006	0.721	
		European dry heath	Dwarf shrub heath	0.714	1.245	0.21	
E4	River Dee and Bala Lake SAC, LWS	Old sessile oak woods with Ilex and Blechnum in the British Isles	Unmanaged Broadleafed/ Coniferous Woodland	0.142	1.075	0.743	
E5	Inner Marsh Farm SSSI	No sensitive features	Not sensitive	-	-	-	
E6	River Dee SSSI	-	No CLs defined	-	-	-	
E7	Shotton Lagoons and Reedbeds SSSI/LWS	Common tern (Sterna hirundo), breeding	Calcareous grassland (using base cation)	-	-	-	
Local nature sites							
E8	Dee Rifle LWS	No sensitive features	Not sensitive	1.071	5.071	4	-

Note:

(1) Background deposition taken as the maximum across the European UK designated site as reported on APIS. For Local nature sites the background deposition rates reported on APIS for the receptor points presented in Table 6 have been used.

Source: APIS

C Detailed Results Tables – Human Health

Table 43: Dispersion Modelling Results – PC at Point of Maximum Impact - Daily ELVs - Permitted Facility

Pollutant	Quantity	Units	AQAL	Bg Conc.	2020	2021	2022	2023	2024	Max	as % of AQAL	PEC	as % of AQAL
Nitrogen dioxide	Annual mean	µg/m³	40	20.10	0.37	0.37	0.39	0.34	0.34	0.39	0.97%	20.49	51.22%
	99.79th %ile of hourly means	µg/m³	200	40.20	5.05	6.03	4.63	5.50	4.77	6.03	3.02%	46.23	23.12%
Sulphur dioxide	99.18th %ile of daily means	µg/m³	125	11.60	0.97	1.15	1.04	0.99	1.05	1.15	0.92%	12.75	10.20%
	99.73rd %ile of hourly means	µg/m³	350	11.60	3.01	3.59	2.82	3.11	2.87	3.59	1.03%	15.19	4.34%
	99.9th %ile of 15 min. means	µg/m³	266	11.60	3.96	4.55	3.53	4.05	3.93	4.55	1.71%	16.15	6.07%
Particulates (PM_{10})	Annual mean	µg/m³	40	11.50	0.01	0.01	0.02	0.01	0.01	0.02	0.04%	11.52	28.79%
	90.41st %ile of daily means	µg/m³	50	23.00	0.06	0.06	0.06	0.05	0.05	0.06	0.11%	23.06	46.11%
Particulates ($PM_{2.5}$)	Annual mean	µg/m³	10	7.40	0.01	0.01	0.02	0.01	0.01	0.02	0.15%	7.42	74.15%
Carbon monoxide	8 hour running mean	µg/m³	10,000	474	3.27	4.10	3.42	3.53	3.16	4.10	0.04%	478.10	4.78%
	Hourly mean	µg/m³	30,000	474	8.37	7.72	6.24	7.15	5.95	8.37	0.03%	482.37	1.61%
Hydrogen chloride	Hourly mean	µg/m³	750	1.52	1.34	1.23	1.00	1.14	0.95	1.34	0.18%	2.86	0.38%
Hydrogen fluoride	Annual mean	µg/m³	16	2.35	0.003	0.003	0.003	0.003	0.003	0.003	0.02%	2.35	14.71%
	Hourly mean	µg/m³	160	4.70	0.17	0.15	0.12	0.14	0.12	0.17	0.10%	4.87	3.04%
Ammonia	Annual mean	µg/m³	180	2.30	0.03	0.03	0.03	0.03	0.03	0.03	0.02%	2.33	1.29%
	Hourly mean	µg/m³	2,500	4.60	1.67	1.54	1.25	1.43	1.19	1.67	0.07%	6.27	0.25%

Pollutant	Quantity	Units	AQAL	Bg Conc.	2020	2021	2022	2023	2024	Max	as % of AQAL	PEC	as % of AQAL
VOCs (as benzene)	Annual mean	µg/m³	5	1.44	0.03	0.03	0.03	0.03	0.03	0.03	0.61%	1.47	29.41%
	Daily mean	µg/m³	30	2.88	0.28	0.34	0.29	0.33	0.33	0.34	1.13%	3.22	10.73%
Mercury	Daily mean	ng/m³	60	5.60	0.56	0.68	0.57	0.66	0.67	0.68	1.13%	6.28	10.46%
	Hourly mean	ng/m³	600	5.60	3.35	3.09	2.50	2.86	2.38	3.35	0.56%	8.95	1.49%
Cadmium	Annual mean	ng/m³	5	0.42	0.06	0.06	0.06	0.05	0.05	0.06	**1.23%**	0.48	9.63%
	Daily mean	ng/m³	30	0.84	0.56	0.68	0.57	0.66	0.67	0.68	2.26%	1.52	5.06%
PaHs	Annual mean	pg/m³	250	190	0.58	0.58	0.61	0.54	0.54	0.61	0.25%	190.61	76.25%
Dioxins and Furans	Annual mean	fg/m³	-	32.99	0.17	0.17	0.18	0.16	0.16	0.18	-	33.17	-
PCBs	Annual mean	ng/m³	200	0.129	0.01	0.01	0.02	0.01	0.01	0.02	0.01%	0.14	0.07%
	Hourly mean	ng/m³	6,000	0.258	0.84	0.77	0.62	0.72	0.59	0.84	0.01%	1.09	0.02%

Note:
Assumes continuous operation at the daily ELVs.

Table 44: Dispersion Modelling Results – PC at Point of Maximum Ground Level Impact - Short-Term ELVs - Permitted Facility

Pollutant	Quantity	Units	AQAL	Bg Conc.	2020	2021	2022	2023	2024	Max	as % of AQAL	PEC	as % of AQAL
Nitrogen dioxide	99.79th %ile of hourly means	µg/m³	200	40.20	11.21	13.40	10.29	12.22	10.60	13.40	6.70%	53.60	26.80%
Sulphur dioxide	99.73rd %ile of hourly means	µg/m³	350	11.60	15.07	17.97	14.12	15.56	14.34	17.97	5.13%	29.57	8.45%
	99.9th %ile of 15 min. means	µg/m³	266	11.60	19.81	22.74	17.66	20.26	19.65	22.74	8.55%	34.34	12.91%
Carbon monoxide	8 hour running mean	µg/m³	10,000	474	9.81	12.30	10.27	10.58	9.48	12.30	0.12%	486.30	4.86%
	Hourly mean	µg/m³	30,000	474	25.11	23.16	18.73	21.46	17.84	25.11	0.08%	499.11	1.66%
Hydrogen chloride	Hourly mean	µg/m³	750	1.52	10.03	9.25	7.48	8.58	7.13	10.03	1.34%	11.55	1.54%

Note:

Based on the ERF operating at short-term ELVs during worst-case weather conditions for dispersion.

Table 45: Dispersion Modelling Results – PC at Point of Maximum Impact - Daily ELVs - CC Facility

Pollutant	Quantity	Units	AQAL	Bg Conc.	2020	2021	2022	2023	2024	Max	as % of AQAL	PEC	as % of AQAL
Nitrogen dioxide	Annual mean	µg/m³	40	20.10	0.48	0.50	0.53	0.50	0.47	0.53	**1.34%**	20.63	51.59%
	99.79th %ile of hourly means	µg/m³	200	40.20	10.14	11.46	9.73	10.12	9.67	11.46	5.73%	51.66	25.83%
Sulphur dioxide	99.18th %ile of daily means	µg/m³	125	11.60	1.56	1.72	1.40	1.80	1.74	1.80	1.44%	13.40	10.72%
	99.73rd %ile of hourly means	µg/m³	350	11.60	5.58	6.85	5.58	5.84	5.78	6.85	1.96%	18.45	5.27%
	99.9th %ile of 15 min. means	µg/m³	266	11.60	8.20	8.89	8.06	7.86	7.34	8.89	3.34%	20.49	7.70%
Particulates (PM_{10})	Annual mean	µg/m³	40	11.50	0.02	0.02	0.02	0.02	0.02	0.02	0.05%	11.52	28.80%
	90.41st %ile of daily means	µg/m³	50	23.00	0.08	0.08	0.07	0.07	0.07	0.08	0.16%	23.08	46.16%
Particulates ($PM_{2.5}$)	Annual mean	µg/m³	10	7.40	0.02	0.02	0.02	0.02	0.02	0.02	0.21%	7.42	74.21%
Carbon monoxide	8 hour running mean	µg/m³	10,000	474	6.05	7.32	6.49	6.78	5.37	7.32	0.07%	481.32	4.81%
	Hourly mean	µg/m³	30,000	474	14.62	17.89	16.99	17.02	21.89	21.89	0.07%	495.89	1.65%
Hydrogen chloride	Hourly mean	µg/m³	750	1.52	2.34	2.86	2.72	2.72	3.50	3.50	0.47%	5.02	0.67%
Hydrogen fluoride	Annual mean	µg/m³	16	2.35	0.004	0.004	0.004	0.004	0.004	0.004	0.03%	2.35	14.71%
	Hourly mean	µg/m³	160	4.70	0.29	0.36	0.34	0.34	0.44	0.44	0.27%	5.14	3.21%
Ammonia	Annual mean	µg/m³	180	2.30	0.04	0.04	0.04	0.04	0.04	0.04	0.02%	2.34	1.30%
	Hourly mean	µg/m³	2,500	4.60	2.92	3.58	3.40	3.40	4.38	4.38	0.18%	8.98	0.36%
VOCs (as benzene)	Annual mean	µg/m³	5	1.44	0.04	0.04	0.04	0.04	0.04	0.04	0.85%	1.48	29.65%
	Daily mean	µg/m³	30	2.88	0.51	0.54	0.49	0.65	0.58	0.65	2.15%	3.53	11.75%

Pollutant	Quantity	Units	AQAL	Bg Conc.	2020	2021	2022	2023	2024	Max	as % of AQAL	PEC	as % of AQAL
Mercury	Daily mean	ng/m³	60	5.60	1.02	1.08	0.97	1.29	1.17	1.29	2.15%	6.89	11.49%
	Hourly mean	ng/m³	600	5.60	5.85	7.16	6.79	6.81	8.75	8.75	1.46%	14.35	2.39%
Cadmium	Annual mean	ng/m³	5	0.42	0.08	0.08	0.08	0.08	0.07	0.08	**1.70%**	0.50	10.10%
	Daily mean	ng/m³	30	0.84	1.02	1.08	0.97	1.29	1.17	1.29	4.31%	2.13	7.11%
PaHs	Annual mean	pg/m³	250	190	0.76	0.80	0.85	0.80	0.74	0.85	0.34%	190.85	76.34%
Dioxins and Furans	Annual mean	fg/m³	-	32.99	0.23	0.24	0.25	0.24	0.22	0.25	-	33.24	-
PCBs	Annual mean	ng/m³	200	0.129	0.02	0.02	0.02	0.02	0.02	0.02	0.011%	0.15	0.08%
	Hourly mean	ng/m³	6,000	0.258	1.46	1.79	1.70	1.70	2.19	2.19	0.04%	2.45	0.04%
Sum of amines (as MEA)	Hourly mean	µg/m³	400	0	2.47	2.45	2.06	1.73	2.29	2.47	0.62%	2.47	0.62%
	Daily mean	µg/m³	100	0	0.20	0.23	0.19	0.27	0.25	0.27	0.27%	0.27	0.27%
MEA	Hourly mean	µg/m³	400	0	2.25	2.23	1.88	1.57	2.08	2.25	0.56%	2.25	0.56%
	Daily mean	µg/m³	100	0	0.18	0.21	0.18	0.25	0.23	0.25	0.25%	0.25	0.25%
DEA	Daily mean	µg/m³	3	0	0.009	0.010	0.009	0.012	0.011	0.012	0.41%	0.01	0.41%
DMA	Daily mean	µg/m³	3.3	0	0.009	0.011	0.009	0.013	0.011	0.013	0.38%	0.01	0.38%
Sum of NS (as NDMA)	Annual mean	pg/m³	200	0	13.75	15.36	14.44	14.83	12.68	15.36	**7.68%**	15.36	7.68%
Sum of NS + NA (as NDMA)	Annual mean	pg/m³	200	0	29.18	31.54	30.38	31.67	24.69	31.67	**15.83%**	31.67	15.83%
Aldehydes (as formaldehyde)	Annual mean	µg/m³	5	2.37	0.019	0.020	0.021	0.020	0.018	0.021	0.42%	2.39	47.82%
	30-minute mean	µg/m³	100	4.74	1.78	1.82	1.73	1.72	2.23	2.23	2.23%	6.97	6.97%

Note:
Assumes continuous operation of the ERF at the daily ELVs and emitting via the CC facility stack. NS = nitrosamines, NA = nitramines.

Table 46: Dispersion Modelling Results – PC at Point of Maximum Impact - Short-Term ELVs - CC Facility

Pollutant	Quantity	Units	AQAL	Bg Conc.	2018	2019	2020	2021	2022	Max	Max as % of AQAL	PEC	PEC as % of AQAL
Nitrogen dioxide	99.79th %ile of hourly means	µg/m³	200	40.20	22.52	25.46	21.62	22.49	21.49	25.46	12.73%	65.66	32.83%
Sulphur dioxide	99.73rd %ile of hourly means	µg/m³	350	11.60	27.91	34.25	27.91	29.22	28.88	34.25	9.78%	45.85	13.10%
	99.9th %ile of 15 min. means	µg/m³	266	11.60	41.01	44.44	40.29	39.31	36.69	44.44	16.71%	56.04	21.07%
Carbon monoxide	8 hour running mean	µg/m³	10,000	474	18.15	21.97	19.47	20.33	16.10	21.97	0.22%	495.97	4.96%
	Hourly mean	µg/m³	30,000	474	43.86	53.68	50.96	51.07	65.66	65.66	0.22%	539.66	1.80%
Hydrogen chloride	Hourly mean	µg/m³	750	1.52	17.53	21.45	20.36	20.41	26.24	26.24	3.50%	27.76	3.70%
Hydrogen fluoride	Hourly mean	µg/m³	160	40.20	22.52	25.46	21.62	22.49	21.49	25.46	12.73%	65.66	32.83%

Notes:
Based on the ERF operating at short-term ELVs during worst-case weather conditions for dispersion, emitting via the CC facility stack.

Table 47: Long-Term Metals Results at Point of Maximum Impact – Permitted Facility

Metal	AQAL	Baseline conc.	Metals emitted at combined metal limit				Metal as % of ELV (1)	Each metal emitted at the maximum concentration from the EA metals guidance document			
			PC		PEC			PC		PEC	
	ng/m³	ng/m³	ng/m³	as % AQAL	ng/m³	as % AQAL		ng/m³	as % AQAL	ng/m³	as % AQAL
Arsenic	6	1.00	0.92	**15.36%**	1.92	32.03%	8.3%	0.08	**1.28%**	1.08	17.95%
Antimony	5,000	1.30	0.92	0.02%	2.22	0.04%	3.8%	0.04	0.001%	1.34	0.03%
Chromium	-	4.80	0.92	-	5.72	-	30.7%	0.28	-	5.08	-
Chromium (VI)	0.25	0.96	0.92	**368.7%**	1.88	**752.7%**	0.043%	0.00	0.16%	0.96	384.16%
Cobalt	-	1.50	0.92	-	2.42	-	1.9%	0.02	-	1.52	-
Copper	-	18.00	0.92	-	18.92	-	9.7%	0.09	-	18.09	-
Lead	250	15.00	0.92	0.37%	15.92	6.37%	16.8%	0.15	0.06%	15.15	6.06%
Manganese	150	10.00	0.92	0.61%	10.92	7.28%	20.0%	0.18	0.12%	10.18	6.79%
Nickel	20	2.50	0.92	**4.61%**	3.42	17.11%	73.3%	0.68	**3.38%**	3.18	15.88%
Vanadium	-	3.00	0.92	-	3.92	-	2.0%	0.02	-	3.02	-

Notes:

(1) Metal as maximum percentage of the group 3 ELV of 0.3 mg/Nm³, recalculated from the data presented in EA's metals guidance document (V.4) Table A1.

Table 48: Short-Term Metals Results at Point of Maximum Impact – Permitted Facility

Metal	AQAL	Baseline conc.	Metals emitted at combined metal limit				Metal as % of ELV [(1)]	Each metal emitted at the maximum concentration from the EA metals guidance document			
			PC		PEC			PC		PEC	
	ng/m³	ng/m³	ng/m³	as % AQAL	ng/m³	as % AQAL		ng/m³	as % AQAL	ng/m³	as % AQAL
Arsenic	-	2.00	50.22	-	52.22	-	8.3%	4.18	-	6.18	-
Antimony	150,000	2.60	50.22	0.03%	52.82	0.04%	3.8%	1.93	0.001%	4.53	0.003%
Chromium (daily mean)	2,000	9.60	10.18	0.51%	19.78	0.99%	30.7%	3.12	0.16%	12.72	0.64%
Chromium (VI)	-	1.92	50.22	-	52.14	-	0.043%	0.02	-	1.94	-
Cobalt	-	3.00	50.22	-	53.22	-	1.9%	0.94	-	3.94	-
Copper (daily mean)	50	36.00	10.18	**20.36%**	46.18	92.36%	9.7%	0.98	1.968%	36.98	73.97%
Lead	-	30.00	50.22	-	80.22	-	16.8%	8.42	-	38.42	-
Manganese	1,500,000	20.00	50.22	0.003%	70.22	0.00%	20.0%	10.04	0.001%	30.04	0.002%
Nickel	700	5.00	50.22	7.17%	55.22	7.89%	73.3%	36.83	5.26%	41.83	5.98%
Vanadium (daily mean)	1,000	6.00	10.18	1.02%	16.18	1.62%	2.0%	0.20	0.020%	6.20	0.62%

Notes:

(1) Metal as maximum percentage of the group 3 ELV of 0.3 mg/Nm³, recalculated from the data as presented in EA's metals guidance document (V.4) Table A1.

Table 49: Long-Term Metals Results at Point of Maximum Impact – CC facility

Metal	AQAL	Baseline conc.	Metals emitted at combined metal limit				Metal as % of ELV (1)	Each metal emitted at the maximum concentration from the EA metals guidance document			
			PC		PEC			PC		PEC	
	ng/m³	ng/m³	ng/m³	as % AQAL	ng/m³	as % AQAL		ng/m³	as % AQAL	ng/m³	as % AQAL
Arsenic	6	1.00	1.27	**21.20%**	2.27	37.87%	8.3%	0.11	**1.77%**	1.11	18.43%
Antimony	5,000	1.30	1.27	0.03%	2.57	0.05%	3.8%	0.05	0.001%	1.35	0.03%
Chromium	-	4.80	1.27	-	6.07	-	30.7%	0.39	-	5.19	-
Chromium (VI)	0.25	0.96	1.27	**508.8%**	2.23	**892.8%**	0.043%	0.00	0.22%	0.96	384.22%
Cobalt	-	1.50	1.27	-	2.77	-	1.9%	0.02	-	1.52	-
Copper	-	18.00	1.27	-	19.27	-	9.7%	0.12	-	18.12	-
Lead	250	15.00	1.27	0.51%	16.27	6.51%	16.8%	0.21	0.09%	15.21	6.09%
Manganese	150	10.00	1.27	**0.85%**	11.27	7.51%	20.0%	0.25	0.17%	10.25	6.84%
Nickel	20	2.50	1.27	**6.36%**	3.77	18.86%	73.3%	0.93	**4.66%**	3.43	17.16%
Vanadium	-	3.00	1.27	-	4.27	-	2.0%	0.03	-	3.03	-

Notes:

(1) Metal as maximum percentage of the group 3 ELV of 0.3 mg/Nm³, recalculated from the data presented in EA's metals guidance document (V.4) Table A1.

Table 50: Short-Term Metals Results at Point of Maximum Impact – CC facility

Metal	AQAL	Baseline conc.	Metals emitted at combined metal limit				Metal as % of ELV [(1)]	Each metal emitted at the maximum concentration from the EA metals guidance document			
			PC		PEC			PC		PEC	
	ng/m³	ng/m³	ng/m³	as % AQAL	ng/m³	as % AQAL		ng/m³	as % AQAL	ng/m³	as % AQAL
Arsenic	-	2.00	131.31	-	133.31	-	8.3%	10.94	-	12.94	-
Antimony	150,000	2.60	131.31	0.09%	133.91	0.09%	3.8%	5.03	0.003%	7.63	0.01%
Chromium (daily mean)	2,000	9.60	19.38	0.97%	28.98	1.45%	30.7%	5.94	0.30%	15.54	0.78%
Chromium (VI)	-	1.92	131.31	-	133.23	-	0.043%	0.06	-	1.98	-
Cobalt	-	3.00	131.31	-	134.31	-	1.9%	2.45	-	5.45	-
Copper (daily mean)	50	36.00	19.38	**38.77%**	55.38	110.77%	9.7%	1.87	3.748%	37.87	75.75%
Lead	-	30.00	131.31	-	161.31	-	16.8%	22.02	-	52.02	-
Manganese	1,500,000	20.00	131.31	0.01%	151.31	0.01%	20.0%	26.26	0.002%	46.26	0.003%
Nickel	700	5.00	131.31	**18.76%**	136.31	19.47%	73.3%	96.30	**13.76%**	101.30	14.47%
Vanadium (daily mean)	1,000	6.00	19.38	1.94%	25.38	2.54%	2.0%	0.39	0.039%	6.39	0.64%

Notes:

(1) Metal as maximum percentage of the group 3 ELV of 0.3 mg/Nm³, recalculated from the data as presented in EA's metals guidance document (V.4) Table A1.

Table 51: Long-Term Metals Results at Point of Maximum Impact – Change in Impact

Metal	AQAL	Baseline conc.	Metals emitted at combined metal limit				Metal as % of ELV (1)	Each metal emitted at the maximum concentration from the EA metals guidance document			
			PC		PEC(2)			PC		PEC(2)	
	ng/m³	ng/m³	ng/m³	as % AQAL	ng/m³	as % AQAL		ng/m³	as % AQAL	ng/m³	as % AQAL
Arsenic	6	1.00	0.35	**5.84%**	2.27	37.87%	8.3%	0.03	0.49%	1.11	18.43%
Antimony	5,000	1.30	0.35	0.01%	2.57	0.05%	3.8%	0.01	0.0003%	1.35	0.03%
Chromium	-	4.80	0.35	-	6.07	-	30.7%	0.11	-	5.19	-
Chromium (VI)	0.25	0.96	0.35	**140.1%**	2.23	**892.82%**	0.043%	0.00	0.06%	0.96	384.22%
Cobalt	-	1.50	0.35	-	2.77	-	1.9%	0.01	-	1.52	-
Copper	-	18.00	0.35	-	19.27	-	9.7%	0.03	-	18.12	-
Lead	250	15.00	0.35	0.14%	16.27	6.51%	16.8%	0.06	0.02%	15.21	6.09%
Manganese	150	10.00	0.35	0.23%	11.27	7.51%	20.0%	0.07	0.05%	10.25	6.84%
Nickel	20	2.50	0.35	**1.75%**	3.77	18.86%	73.3%	0.26	**1.28%**	3.43	17.16%
Vanadium	-	3.00	0.35	-	4.27	-	2.0%	0.01	-	3.03	-

Notes:

(1) Metal as maximum percentage of the group 3 ELV of 0.3 mg/Nm³, recalculated from the data presented in EA's metals guidance document (V.4) Table A1.

(2) PEC presented is for the CC facility.

Table 52: Short-Term Metals Results at Point of Maximum Impact – Change in Impact

Metal	AQAL	Baseline conc.	Metals emitted at combined metal limit				Metal as % of ELV (1)	Each metal emitted at the maximum concentration from the EA metals guidance document			
			PC		PEC			PC		PEC	
	ng/m³	ng/m³	ng/m³	as % AQAL	ng/m³	as % AQAL		ng/m³	as % AQAL	ng/m³	as % AQAL
Arsenic	-	2.00	81.09	-	133.31	-	8.3%	6.76	-	12.94	-
Antimony	150,000	2.60	81.09	0.05%	133.91	0.09%	3.8%	3.11	0.002%	7.63	0.01%
Chromium (daily mean)	2,000	9.60	9.21	0.46%	28.98	1.45%	30.7%	2.82	0.14%	15.54	0.78%
Chromium (VI)	-	1.92	81.09	-	133.23	-	0.043%	0.04	-	1.98	-
Cobalt	-	3.00	81.09	-	134.31	-	1.9%	1.51	-	5.45	-
Copper (daily mean)	50	36.00	9.21	**18.41%**	55.38	110.77%	9.7%	0.89	1.78%	37.87	75.75%
Lead	-	30.00	81.09	-	161.31	-	16.8%	13.60	-	52.02	-
Manganese	1,500,000	20.00	81.09	0.01%	151.31	0.01%	20.0%	16.22	0.001%	46.26	0.00%
Nickel	700	5.00	81.09	**11.58%**	136.31	19.47%	73.3%	59.47	8.50%	101.30	14.47%
Vanadium (daily mean)	1,000	6.00	9.21	0.92%	25.38	2.54%	2.0%	0.18	0.018%	6.39	0.64%

Notes:

(1) Metal as maximum percentage of the group 3 ELV of 0.3 mg/Nm³, recalculated from the data as presented in EA's metals guidance document (V.4) Table A1.

(2) PEC presented is for the CC facility.

D Detailed Results Tables – Ecology

Table 53: Impact at Ecological Sites - Permitted Facility - µg/m³

ID	Site	Oxides of nitrogen (µg/m³)		Sulphur dioxide (µg/m³)	Hydrogen fluoride (µg/m³)		Ammonia (µg/m³)
		Annual mean	Daily mean	Annual mean	Weekly mean	Daily mean	Annual mean
European and UK designated sites							
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	0.55	6.10	0.122	0.013	0.034	0.030
E2	Deeside and Buckley Newt Sites SAC	0.04	1.22	0.010	0.003	0.007	0.002
E3	Halkyn Mountain SAC	0.01	0.49	0.003	0.001	0.003	0.001
E4	River Dee and Bala Lake SAC, LWS	0.19	2.32	0.043	0.005	0.013	0.011
E5	Inner Marsh Farm SSSI	0.33	3.36	0.074	0.007	0.019	0.019
E6	River Dee SSSI	0.19	2.32	0.043	0.005	0.013	0.011
E7	Shotton Lagoons and Reedbeds SSSI/LWS	0.09	4.06	0.020	0.011	0.023	0.005
Local nature sites							
E8	Dee Rifle LWS	0.42	3.19	0.092	0.007	0.018	0.023

Table 54: Impact at Ecological Sites - Permitted Facility - % of Critical Level

ID	Site	Oxides of nitrogen (µg/m³)		Sulphur dioxide (µg/m³)	Hydrogen fluoride (µg/m³)		Ammonia (µg/m³)
		Annual mean	Daily mean	Annual mean	Weekly mean	Daily mean	Annual mean
Critical level (µg/m³)		**30**	**200**	**10**	**0.5**	**5**	**1**
European and UK designated sites							
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	**1.83%**	3.05%	**1.22%**	2.63%	0.68%	**3.05%**
E2	Deeside and Buckley Newt Sites SAC	0.15%	0.61%	0.10%	0.59%	0.14%	0.24%
E3	Halkyn Mountain SAC	0.04%	0.25%	0.03%	0.18%	0.05%	0.07%
E4	River Dee and Bala Lake SAC, LWS	0.64%	1.16%	0.43%	1.08%	0.26%	**1.07%**
E5	Inner Marsh Farm SSSI	Not sensitive					
E6	River Dee SSSI	0.64%	1.16%	0.43%	1.08%	0.26%	**1.07%**
E7	Shotton Lagoons and Reedbeds SSSI/LWS	0.30%	2.03%	0.20%	2.25%	0.45%	0.50%
Local nature sites							
E8	Dee Rifle LWS	1.39%	1.59%	0.92%	1.47%	0.35%	2.31%

Table 55: Impact at Ecological Sites - CC Facility - µg/m³

ID	Site	Oxides of nitrogen (µg/m³)		Sulphur dioxide (µg/m³)	Hydrogen fluoride (µg/m³)		Ammonia (µg/m³)
		Annual mean	Daily mean	Annual mean	Weekly mean	Daily mean	Annual mean
European and UK designated sites							
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	0.75	7.97	0.168	0.019	0.044	0.042
E2	Deeside and Buckley Newt Sites SAC	0.07	2.28	0.015	0.005	0.013	0.004
E3	Halkyn Mountain SAC	0.01	0.71	0.003	0.001	0.004	0.001
E4	River Dee and Bala Lake SAC, LWS	0.25	4.15	0.056	0.010	0.023	0.014
E5	Inner Marsh Farm SSSI	0.40	3.50	0.088	0.008	0.019	0.022
E6	River Dee SSSI	0.25	4.15	0.056	0.010	0.023	0.014
E7	Shotton Lagoons and Reedbeds SSSI/LWS	0.19	6.99	0.042	0.018	0.039	0.011
Local nature sites							
E8	Dee Rifle LWS	0.54	3.60	0.119	0.008	0.020	0.030

Table 56: Impact at Ecological Sites - CC Facility - % of Critical Level

ID	Site	Oxides of nitrogen (µg/m³)		Sulphur dioxide (µg/m³)	Hydrogen fluoride (µg/m³)		Ammonia (µg/m³)
		Annual mean	Daily mean	Annual mean	Weekly mean	Daily mean	Annual mean
Critical level (µg/m³)		**30**	**200**	**10**	**0.5**	**5**	**1**
European and UK designated sites							
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	**2.52%**	3.98%	**1.68%**	3.89%	0.89%	**4.20%**
E2	Deeside and Buckley Newt Sites SAC	0.22%	1.14%	0.15%	1.04%	0.25%	0.36%
E3	Halkyn Mountain SAC	0.04%	0.36%	0.03%	0.21%	0.08%	0.07%
E4	River Dee and Bala Lake SAC, LWS	0.83%	2.07%	0.56%	2.04%	0.46%	**1.39%**
E5	Inner Marsh Farm SSSI	Not sensitive					
E6	River Dee SSSI	0.83%	2.07%	0.56%	2.04%	0.46%	**1.39%**
E7	Shotton Lagoons and Reedbeds SSSI/LWS	0.64%	3.49%	0.42%	3.52%	0.78%	**1.06%**
Local nature sites							
E8	Dee Rifle LWS	1.79%	1.80%	1.19%	1.66%	0.40%	2.98%

Table 57: Impact at Ecological Sites - Change - µg/m³

ID	Site	Oxides of nitrogen (µg/m³)		Sulphur dioxide (µg/m³)	Hydrogen fluoride (µg/m³)		Ammonia (µg/m³)
		Annual mean	Daily mean	Annual mean	Weekly mean	Daily mean	Annual mean
European and UK designated sites							
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	0.21	1.86	0.046	0.006	0.010	0.011
E2	Deeside and Buckley Newt Sites SAC	0.02	1.07	0.005	0.002	0.006	0.001
E3	Halkyn Mountain SAC	0.0005	0.22	0.0001	0.0001	0.001	0.00003
E4	River Dee and Bala Lake SAC, LWS	0.06	1.82	0.013	0.005	0.010	0.003
E5	Inner Marsh Farm SSSI	0.06	0.14	0.014	0.001	0.001	0.004
E6	River Dee SSSI	0.06	1.82	0.013	0.005	0.010	0.003
E7	Shotton Lagoons and Reedbeds SSSI/LWS	0.10	2.93	0.022	0.006	0.016	0.006
Local nature sites							
E8	Dee Rifle LWS	0.12	0.41	0.027	0.001	0.002	0.007

Table 58: Impact at Ecological Sites - Change - % of Critical Level

ID	Site	Oxides of nitrogen (µg/m³)		Sulphur dioxide (µg/m³)	Hydrogen fluoride (µg/m³)		Ammonia (µg/m³)
		Annual mean	Daily mean	Annual mean	Weekly mean	Daily mean	Annual mean
Critical level (µg/m³)		**30**	**200**	**10**	**0.5**	**5**	**1**
European and UK designated sites							
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	0.69%	0.93%	0.46%	1.26%	0.21%	**1.15%**
E2	Deeside and Buckley Newt Sites SAC	0.07%	0.53%	0.05%	0.45%	0.12%	0.12%
E3	Halkyn Mountain SAC	0.002%	0.11%	0.001%	0.02%	0.02%	0.003%
E4	River Dee and Bala Lake SAC, LWS	0.19%	0.91%	0.13%	0.96%	0.20%	0.32%
E5	Inner Marsh Farm SSSI						Not sensitive
E6	River Dee SSSI	0.19%	0.91%	0.13%	0.96%	0.20%	0.32%
E7	Shotton Lagoons and Reedbeds SSSI/LWS	0.34%	1.46%	0.22%	1.27%	0.33%	0.56%
Local nature sites							
E8	Dee Rifle LWS	0.40%	0.21%	0.27%	0.19%	0.05%	0.67%

Table 59: Annual Mean PC used for Deposition Analysis - Permitted Facility

ID	Site	Annual mean PC (ng/m^3)			
		Nitrogen dioxide	Sulphur dioxide	Hydrogen chloride	Ammonia
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	383.8	121.8	24.4	30.5
E2	Deeside and Buckley Newt Sites SAC	30.6	9.7	1.9	2.4
E3	Halkyn Mountain SAC	8.8	2.8	0.6	0.7
E4	River Dee and Bala Lake SAC, LWS	135.1	42.9	8.6	10.7
E5	Inner Marsh Farm SSSI	234.2	74.3	14.9	18.6
E6	River Dee SSSI	135.1	42.9	8.6	10.7
E7	Shotton Lagoons and Reedbeds SSSI/LWS	63.0	20.0	4.0	5.0
E8	Dee Rifle LWS	290.9	92.3	18.5	23.1

Note:

Assumes continuous operation of the ERF at the daily ELVs.

Table 60: Annual Mean PC used for Deposition Analysis - CC Facility

ID	Site	Annual mean PC (ng/m^3)						
		Nitrogen dioxide	Sulphur dioxide	Hydrogen chloride	Ammonia	MEA	DEA	DMA
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	528.5	167.8	33.5	42.0	21.0	1.05	1.05
E2	Deeside and Buckley Newt Sites SAC	45.7	14.5	2.9	3.6	1.8	0.09	0.09
E3	Halkyn Mountain SAC	9.1	2.9	0.6	0.7	0.4	0.02	0.02
E4	River Dee and Bala Lake SAC, LWS	175.1	55.6	11.1	13.9	7.0	0.35	0.35
E5	Inner Marsh Farm SSSI	278.5	88.4	17.7	22.1	11.1	0.55	0.55
E6	River Dee SSSI	175.1	55.6	11.1	13.9	7.0	0.35	0.35
E7	Shotton Lagoons and Reedbeds SSSI/LWS	133.8	42.5	8.5	10.6	5.3	0.27	0.27
E8	Dee Rifle LWS	375.6	119.2	23.8	29.8	14.9	0.75	0.75

Note:
Assumes continuous operation of the ERF at the daily ELVs and emitting via the CC facility.

Table 61: Deposition Calculation - Permitted Facility

ID	Site	Deposition (kg/ha/yr)				Total N Deposition (kgN/ha/yr)	Acid Deposition (keq/ha/yr)	
		Nitrogen dioxide	Sulphur dioxide	Hydrogen chloride	Ammonia		N	S
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	0.055	0.231	0.374	0.158	0.214	0.015	0.025
E2	Deeside and Buckley Newt Sites SAC (woodland)	0.009	0.037	0.071	0.019	0.028	0.002	0.004
E3	Halkyn Mountain SAC	0.001	0.005	0.009	0.004	0.005	0.000	0.001
	Halkyn Mountain SAC (woodland)	0.003	0.011	0.021	0.005	0.008	0.001	0.001
E4	River Dee and Bala Lake SAC, LWS	0.019	0.081	0.131	0.056	0.075	0.005	0.009
	River Dee and Bala Lake SAC, LWS (woodland)	0.039	0.162	0.315	0.084	0.122	0.009	0.019
E5	Inner Marsh Farm SSSI	0.034	0.141	0.228	0.097	0.130	0.009	0.015
E6	River Dee SSSI	0.019	0.081	0.131	0.056	0.075	0.005	0.009
E7	Shotton Lagoons and Reedbeds SSSI/LWS	0.009	0.038	0.061	0.026	0.035	0.003	0.004
E8	Dee Rifle LWS	0.042	0.175	0.283	0.120	0.162	0.012	0.019

Notes:
Assumes continuous operation of the ERF at the daily ELVs.
All deposition calculated using the grassland deposition velocities except where stated.

Table 62: Deposition Calculation - CC Facility

ID	Site	Deposition (kg/ha/yr)							Total N Deposition (kgN/ha/yr)	Acid Deposition (keq/ha/yr)	
		Nitrogen dioxide	Sulphur dioxide	Hydrogen chloride	Ammonia	MEA	DEA	DMA		N	S
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	0.076	0.317	0.514	0.218	0.030	0.0009	0.0021	0.327	0.021	0.034
E2	Deeside and Buckley Newt Sites SAC (woodland)	0.013	0.055	0.107	0.028	0.004	0.0001	0.0003	0.041	0.003	0.006
E3	Halkyn Mountain SAC	0.001	0.005	0.009	0.004	0.001	0.00002	0.00004	0.006	0.0004	0.001
	Halkyn Mountain SAC (woodland)	0.003	0.011	0.021	0.006	0.001	0.00002	0.0001	0.008	0.001	0.001
E4	River Dee and Bala Lake SAC, LWS	0.025	0.105	0.170	0.072	0.010	0.0003	0.0007	0.108	0.007	0.011
	River Dee and Bala Lake SAC, LWS (woodland)	0.050	0.210	0.409	0.108	0.015	0.0004	0.0010	0.159	0.011	0.025
E5	Inner Marsh Farm SSSI	0.040	0.167	0.271	0.115	0.016	0.0005	0.0011	0.172	0.011	0.018
E6	River Dee SSSI	0.025	0.105	0.170	0.072	0.010	0.0003	0.0007	0.108	0.007	0.011
E7	Shotton Lagoons and Reedbeds SSSI/LWS	0.019	0.080	0.130	0.055	0.008	0.0002	0.0005	0.083	0.005	0.009
E8	Dee Rifle LWS	0.054	0.226	0.366	0.155	0.022	0.0006	0.0015	0.233	0.015	0.024

Note:
Assumes continuous operation of the ERF at the daily ELVs and emitting via the CC facility.
All deposition calculated using the grassland deposition velocities except where stated.

Table 63: Nitrogen Deposition

ID	Site	NCL Class	Lower CL (kgN/ha/yr)	Upper CL (kgN/ha/yr)	Permitted Facility PC			CC Facility PC			Change		
					kgN/ha/yr	% of Lower CL	% of Upper CL	kgN/ha/yr	% of Lower CL	% of Upper CL	kgN/ha/yr	% of Lower CL	% of Upper CL
European and UK designated sites													
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	Moist and wet dune slacks - acid type	5	10	0.21	4.27%	2.14%	0.33	6.55%	3.27%	0.114	**2.27%**	**1.14%**
		Atlantic upper-mid & mid-low salt marshes	10	20	0.21	2.14%	1.07%	0.33	3.27%	1.64%	0.114	**1.14%**	0.57%
E2	Deeside and Buckley Newt Sites SAC	Acidophilous Quercus forest	10	15	0.03	0.28%	0.18%	0.04	0.41%	0.28%	0.014	0.14%	0.09%
E3	Halkyn Mountain SAC	Arctic-alpine calcareous grassland	5	10	0.00	0.10%	0.05%	0.01	0.11%	0.06%	0.001	0.01%	0.01%
		Carpinus and Quercus mesic deciduous forest	15	20	0.01	0.05%	0.04%	0.01	0.06%	0.04%	0.0003	0.002%	0.001%
E4	River Dee and Bala Lake SAC, LWS	Permanent oligotrophic lakes, ponds and pools (including softwater lakes)	2	10	0.08	3.76%	0.75%	0.11	5.42%	1.08%	0.033	**1.66%**	0.33%
		Acidophilous Quercus forest	10	15	0.12	1.22%	0.82%	0.16	1.59%	1.06%	0.036	0.36%	0.24%
E5	Inner Marsh Farm SSSI	Atlantic upper-mid & mid-low salt marshes	10	20	0.13	1.30%	0.65%	0.17	1.72%	0.86%	0.042	0.42%	0.21%
E6	River Dee SSSI	Permanent oligotrophic lakes, ponds and pools (including softwater lakes)	2	10	0.08	3.76%	0.75%	0.11	5.42%	1.08%	0.033	**1.66%**	0.33%
		Atlantic upper-mid & mid-low salt marshes	10	20	0.08	0.75%	0.38%	0.11	1.08%	0.54%	0.033	0.33%	0.17%
E7	Shotton Lagoons and Reedbeds SSSI/LWS	Coastal dune grasslands (grey dunes)	5	15	0.04	0.70%	0.23%	0.08	1.66%	0.55%	0.048	0.96%	0.32%
Local nature sites													
E8	Dee Rifle LWS	Atlantic upper-mid & mid-low salt marshes	10	20	0.16	1.62%	0.81%	0.23	2.33%	1.16%	0.071	0.71%	0.35%

Note:

Other habitats with the same or less stringent Critical Loads are present at some ecological sites. The most sensitive habitats for which the grassland and woodland deposition velocities are appropriate have been assessed in the first instance as a screening assessment, except at the Dee Estuary designated site where is it clear that the maximum impact occurs on salt marsh habitat, so this has been included in the screening assessment.

Consideration given to baseline deposition in section 9.4 as required.

Table 64: Acid Deposition

ID	Site	Acidity Class	Min CLmax (keq/ha/yr)[(1)]	Permitted Facility PC		CC Facility PC		Change	
				keq/ha/yr[(2)]	% of CL	kgN/ha/yr[(2)]	% of CL	kgN/ha/yr[(2)]	% of CL
European and UK designated sites									
E1	Dee Estuary SAC, Ramsar, SPA, SSSI	Dwarf shrub heath	1.329	0.0402	5.54%	0.0553	7.63%	0.0151	**2.09%**
		Atlantic upper-mid & mid-low salt marshes (not sensitive)	-	-	-	-	-	-	-
E2	Deeside and Buckley Newt Sites SAC	Unmanaged Broadleafed/Coniferous Woodland	2.999	0.0063	0.16%	0.0094	0.24%	0.0031	0.08%
E3	Halkyn Mountain SAC	Dwarf shrub heath	1.245	0.0009	0.27%	0.0010	0.28%	0.00003	0.01%
		Unmanaged Broadleafed/Coniferous Woodland	1.006	0.0018	0.17%	0.0019	0.18%	0.0001	0.01%
E4	River Dee and Bala Lake SAC, LWS	Unmanaged Broadleafed/Coniferous Woodland	1.075	0.0278	2.56%	0.0360	3.32%	0.0082	0.76%
E5	Inner Marsh Farm SSSI	No sensitive features	-	-	-	-	-	-	-
E6	River Dee SSSI	No Critical Loads defined	-	-	-	-	-	-	-
E7	Shotton Lagoons and Reedbeds SSSI/LWS	Calcareous grassland (using base cation)	4.000	0.0066	0.10%	0.0087	0.22%	0.0046	0.12%
Local nature sites									
E8	Dee Rifle LWS	No sensitive features	-	-	-	-	-	-	-

Note:

(1) CLmax is CLmaxN for comparison with PC N+S, except at E7 where PEC nitrogen acid deposition is less than CLminN; at this site PC S has been compared to CLmaxS.

(2) PC is N + S except at E7, where PEC nitrogen acid deposition is less than CLminN – as such only sulphur contributes to acidification and S acid deposition has been compared to CLmaxS.

Other habitats with the same or less stringent Critical Loads are present at some ecological sites. The most sensitive habitats for which the grassland and woodland deposition velocities are appropriate have been assessed in the first instance as a screening assessment, except at the Dee Estuary designated site where is it clear that the maximum impact occurs on salt marsh habitat, so this has been included in the screening assessment.

Consideration given to baseline deposition in section 9.4 as required.

E Model inputs for cumulative sources

Table 65: Cumulative Schemes Stack Source Data

Item	Unit	Connah's Quay CC(1)	Shotton Paper Mill(3)
Stack Height	m	150	65
Internal diameter (each flue)	m	7.0	2.2
Stack location(s)	m, m	327355, 371479 327310, 371413	330401, 371479 330427, 371484 330449, 371488
Temperature	°C	60	65
Flue gas exit velocity	m/s	19.3	18.5
NOx emission conc.	mg/Nm³	30(2)	30
NOx emission rate (each flue)	g/s	33.9(2)	2.187
Ammonia emission conc.	mg/Nm³	0.75	-
Ammonia emission rate (each flue)	g/s	0.75	-

Note:

(1) Worst-case data from each of the FEED contractor datasets taken from the Supporting Information Report for the Connah's Quay Development.

(2) NOx concentration for the HRSG, as FEED contractor data for CC absorber emissions were lower. We have conservatively assumed that all NOx generated by the CCGT passes unabated through the CC system, as do not know of any mechanism by which the CC process would abate NOx emissions.

(3) Emissions from the three CHP units included only; back-up boiler will not operate long-term, and the NOx release rate from the drier is ~5% of the total from the CHP units so will be inconsequential.

Table 66: Cumulative Schemes Building Details

Buildings	Centre Point		Height (m)	Width (m)	Length (m)	Angle (°)
	X (m)	Y (m)				
Connah's Quay Abs 1	327310	371413	120	56	24	34
Connah's Quay Abs 2	327355	371479	120	56	24	34
Connah's Quay HRSG	327475	371341	60	175	193	34

Note: Shotton Paper Mill buildings not tall enough to influence dispersion from the stacks, so have been excluded from the model.

F Amine Chemistry Modelling

F.1 Introduction

The proposed CC facility would use an amine-based solution to capture carbon dioxide from the flue gas. Amines are nitrogen-based compounds which are structurally similar to ammonia (NH_3), with one or more of the hydrogen atoms substituted by a substituent which is typically a functional group such as a methyl or alcohol group. Amines are categorised as primary, secondary or tertiary, depending on whether one, two, or three of the hydrogen atoms are substituted.

Amines are highly effective at absorbing carbon dioxide, which is the process that takes place in the absorber column. The 'rich' amine, combined with the carbon dioxide, is transported to the stripper column where the mixture is heated to release the carbon dioxide to be taken for storage, while the 'lean' amine is returned to the absorber column to repeat the process. Full details of the process are provided in the supporting information submitted with the application to vary the EP.

Amines can react with oxides of nitrogen either in the absorber column or the atmosphere. The reaction with nitric oxide (NO) forms nitrosamines, and the reaction with nitrogen dioxide (NO_2) forms nitramines. The most toxic nitrosamine, NDMA, is categorised by the International Agency for Research on Cancer as a group 2A carcinogen, meaning it is "probably carcinogenic to humans". NDMA is a known carcinogen in animals. Other nitrosamines and nitramines are also toxic and/or carcinogenic, albeit to a lesser degree or with greater uncertainty than is known for NDMA. NDMA is the only nitrosamine or nitramine for which an AQAL has been set.

As shown in Table 1 this assessment has applied the EA's EAL of 0.2 ng/m³ for NDMA as the AQAL, which is a highly conservative approach.

Although the process will be designed to minimise emissions of amines, nitrosamines, and nitramines, there will be small quantities released. An MEA solvent is to be used in the CC facility and as such it has been assumed that all emissions of the primary amine are of MEA. It is also likely that much smaller quantities of secondary amines would be released. For the purpose of this assessment it has been assumed to be equally proportioned between DMA and DEA. DMA is the precursor to NDMA.

F.2 Amine chemistry reaction scheme

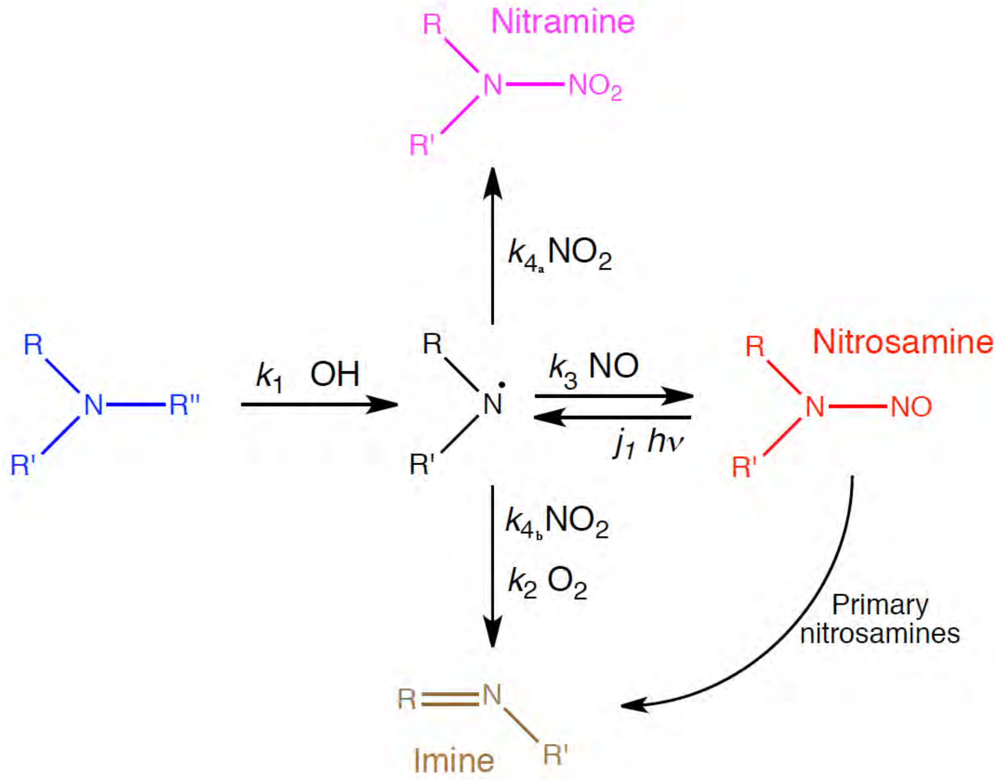
ADMS 6 includes an amine chemistry reaction scheme which models the chemical reactions which occur once amines, nitrosamines and nitramines are released into the atmosphere. The reaction scheme does not account for reactions that occur prior to release, which are accounted for in the release rate of direct emissions of nitrosamines and nitramines.

The amine chemistry reaction scheme accounts for reactions that occur in the atmosphere that cause amines and amine degradation products to react and form different compounds. The first reaction that occurs is between the amine and the hydroxyl radical (OH), labelled k1. The OH radical attacks the amine at either an N-H bond, which results in the formation of an amino radical, or at a C-H bond, forming other compounds which are not significantly harmful to human health and are therefore not relevant to this assessment. The ratio of the attack on the N-H bond and C-H bond is called the branching ratio. Similar reactions occur with nitrate ions (NO_3), but these reactions are much slower than the OH radical reactions[15] and are not considered further in this assessment. The amino radical can then react with nitric oxide (NO) to form a nitrosamine (k3), nitrogen dioxide

[15] CERC, Atmospheric Chemistry Modelling Executive Summary, May 2012

(NO_2) to form a nitramine (k4a) or an imine (k4b), or oxygen (O_2) to form an imine (k2). Nitrosamines do not have a long atmospheric lifetime and undergo photolysis (i.e., are broken down to the amino radical by sunlight). Furthermore, nitrosamines formed from primary amines are unstable and rapidly change structure to form imines within around 1 second of formation. Imines are not significantly harmful to human health and therefore are not relevant to this assessment. A schematic of the reactions included in the scheme is shown in Figure 23.

Figure 23: Reactions included in ADMS Chemistry Reaction Scheme



Source: Adapted from Nielsen et al (2012)[16]

The ADMS amine chemistry module requires the user to input values for the kinetic parameters (i.e. reaction rates) for these reactions, along with the branching ratio for the k1 reaction, the ratio between the photolysis rate (J) of nitrosamine compared to the photolysis rate of nitrogen dioxide, and a constant to determine the OH radical concentration, which is based on estimated annual average background OH, ozone and NOx concentrations, and incoming solar radiation.

A number of studies have been published in literature which attempt to determine the values for these parameters, either theoretically or experimentally. For some parameters there is broad agreement, while for others there is a wide range of published values. In September 2022 the CCSA published an updated position paper which was most recently updated in January 2023 (referenced in section 5.6.1), co-authored by Claus Nielsen who is a recognised authority on the atmospheric chemistry of amines, which "seeks to provide one consolidated set of amines chemistry data for use in modelling of amine emissions". In May 2024, CERC published the paper "Improving Post-Combustion Carbon Capture Air Quality Risk Assessment Techniques"[17] which was commissioned by the EA. As part of this work CERC collated and summarised data on the rection rate parameters

[16] Nielsen et al, Atmospheric Degradation of Amines – Summary report from atmospheric chemistry studies of amines, nitrosamines, nitramines and amides, February 2012

[17] CERC, Improving Post-Combustion Carbon Capture Air Quality Risk Assessment Techniques, May 2024

from literature. For MEA and DMA the values recommended in the CCSA paper are close to the central values collated by CERC. There is no data for DEA provided in the CCSA paper.

The values for MEA and DMA presented in the CCSA paper and reproduced in Table 26 in section 5.6.1 have been used in the main model runs. The values for DEA have been taken from the references listed in CERC's paper. Where values specific to DEA are unknown, the values have been assumed to be the same as for DMA.

The ADMS amine chemistry module requires the user to input the amine, nitrosamine and nitramine species modelled. As noted above, the nitrosamine formed from a primary amine rapidly forms an imine. Therefore, the direct emissions of nitrosamines have been split equally between NDMA (formed from DMA) and NDELA (formed from DEA). The direct emissions of nitramines have been apportioned to those formed from MEA, DMA, and DEA in the same proportions as the emissions of their parent amines.

The amine chemistry module treats these direct releases of nitrosamines the same as those formed in atmospheric chemical reactions, so that the nitrosamines undergo photolysis and the resultant amino radical can react with atmospheric NO, NO_2 and O_2. A sensitivity analysis has been undertaken assuming that the nitrosamines do not undergo chemical reactions after release, and a further sensitivity analysis undertaken with no direct emissions of nitrosamines and nitramines, to determine the quantity formed indirectly via atmospheric reactions compared to those directly emitted from the stack (refer to section F.3).

The amine chemistry scheme allows the user to select the option 'low concentration dilution and entrainment' which improves the way the model accounts for dilution of pollutant species and the entrainment of background pollutants into the plume. CERC strongly recommends that this option is selected when running the amine chemistry module, so this option has been selected.

The amine chemistry scheme also allows the user to model aqueous partitioning of amines, nitrosamines, and nitramines. As many amines and their degradation products are soluble, they will dissolve in any liquid water contained within the plume. This reduces their concentration in ambient air, and their availability for atmospheric reactions. A sensitivity analysis has been run to determine the effect of including aqueous partitioning (refer to section F.3).

F.3 Sensitivity analysis

A series of sensitivity analyses have been undertaken the kinetic parameters and other inputs to the amine chemistry modules, using a range of values from available published literature. The values used and their sources are presented in Table 67. Where it has not been possible to determine alterative values that are higher or lower than the mid-range value, the relevant cells have been left blank.

Table 67: Amine Chemistry Module Inputs

Parameter	Units	Value	MEA	DEA	DMA
k1 - Amine/OH reaction rate constant	$ppb^{-1}s^{-1}$	Low	0.895(B)	2.318(E)	1.30(D)
		Mid	1.900	2.525(F)	1.625
		High	2.328(C)	-	1.775(D)
k2 - Amino radical/O_2 reaction rate constant	$ppb^{-1}s^{-1}$	Low	$2.39x10^{-9}$(B)	-	$4.73x10^{-10}$(C)
		Mid	$3.10x10^{-9}$	$4.45x10^{-10}$(G)	$3.10x10^{-9}$
		High	$9.20x10^{-8}$	-	$9.10x10^{-8}$(C)
k3 - Rate constant for formation of nitrosamine	$ppb^{-1}s^{-1}$	Low	$1.41x10^{-3}$(C)	-	$2.09x10^{-3}$(C)
		Mid	$2.13x10^{-3}$	$1.78x10^{-2}$(G)	$2.13x10^{-3}$
		High	1.75(I)	-	$5.55x10^{-2}$(G)
k4a - Rate constant for formation of nitramine	$ppb^{-1}s^{-1}$	Low	$2.10x10^{-4}$(C)	-	$7.88x10^{-3}$(C)
		Mid	$7.95x10^{-3}$(A)	$7.95x10^{-3}$	$7.95x10^{-3}$
		High	-	-	-
k4 - Amino radical/NO_2 reaction rate constant	$ppb^{-1}s^{-1}$	Low	$3.14x10^{-4}$(C)	$8.20x10^{-3}$(C)	$8.20x10^{-3}$(C)
		Mid	$9.70x10^{-3}$	$9.70x10^{-3}$	$9.70x10^{-3}$
		High	-	-	-
k1 branching ratio	Unitless	Low	0.05(C)	0.34(J)	0.34(J)
		Mid	0.08	0.41	0.41
		High	0.47(H)	0.98(K)	0.98(K)

Parameter	Units	Value	MEA	DEA	DMA
Ratio of J(nitrosamine) to J(NO_2)	Unitless	Low	-	-	0.13(L)
		Mid	-	0.15	0.34
		High	-	-	0.53(M)

References:

A – CCSA, Carbon Capture Chemistry Parameters, N-Amines Chemistry, January 2023. Refer to CCSA paper for original source of each value. All 'mid' values taken from CCSA paper.

B – Nielsen et al., Atmospheric Degradation of Amines Summary Report, February 2012, as used by CERC in "Atmospheric Chemistry Modelling Executive Summary". May 2012.

C – Manzoor et al., Atmospheric chemistry modelling of amine emissions from post combustion CO2 capture technology, 2014.

D – Lee & Wexler, Atmospheric amines - Part III: Photochemistry and toxicity, 2013.

E – Carter, Reactivity Estimates for Selected Consumer Product Compounds, 2008.

F – da Silva et al., Protocol for evaluation of solvents – process and atmospheric chemistry, 2010.

G – Liu et al, Mechanism and predictive model development of reaction rate constants for N-center radicals with O_2, 2019.

H – Onel et al., Branching ratios for the reactions of OH with ethanol amines used in carbon capture and the potential impact on carcinogen formation in the emission plume from a carbon capture plant, 2015.

I – Xie et al., Quantum Chemical Study on Cl-Initiated Atmospheric Degradation of Monoethanolamine, 2015.

J – Butkovskaya and Setser, Branching Ratios and Vibrational Distributions in Water-Forming Reactions of OH and OD Radicals with Methylamines, 2016.

K – Borduas et al., Gas-Phase Mechanisms of the Reactions of Reduced Organic Nitrogen Compounds with OH Radicals, 2016.

L – Larsen, Atmospheric Chemistry – Nitrosamine Photolysis, 2011.

M – Tuazon et al., Atmospheric reactions of N-nitrosodimethylamine and dimethylnitramine, 1984.

The effect of varying each of the parameters on concentrations of nitramines and nitrosamines is summarised in Table 68.

Table 68: Effect of Increasing Amine Chemistry Parameters

Parameter	Effect of Increase on Nitrosamines	Effect of Increase on Nitramines
k1 amine/OH reaction rate constant	Increase – faster reaction rate results in more amino radical, the precursor to both nitrosamines and nitramines	
k2 amino radical/O_2 reaction rate constant	Decrease – this reaction forms an imine, which is a sink for the amino radical	
k3 rate constant for formation of nitrosamine	Increase	Decrease – less amino radical available to form nitramine
k4a rate constant for formation of nitramine	Decrease – less amino radical available to form nitrosamine	Increase.
k4 Amino radical/NO_2 reaction rate constant	Decrease – less amino radical available to form nitrosamine	Increase – some reactions from this path form nitramine (via k4a)
Branching ratio for amine/OH reaction	Increase – higher values result in more amino radical formation	
Ratio of J(nitrosamine)to J(NO_2)	Decrease – as this increases the rate of photolysis of the nitrosamine back to the amino radical	Increase – more radical available to form nitramine

Based on the relationships detailed in Table 68 the model has been run with the parameters that produce the maximum and minimum concentrations of nitramines and nitrosamines. The results are presented in Table 71.

The sensitivity of the model results to other parameters used in the amine chemistry scheme has been tested. The model is sensitive to the total NOx emission concentration and the percentage of the NOx release which is NO_2, as these values affect the amount of NO and NO_2 available to react with the amino radical, as well as the constant 'c' used to determine the concentration of the OH radical. This constant is directly proportional to the annual mean OH concentration. Advice from CERC and published literature[18] is that OH concentrations are typically $1x10^6$ molecules/cm³ at UK latitudes, but values are up to 3 times higher at equatorial latitudes. Therefore, a 2x multiplier has been applied to the OH radical constant as a reasonable assumption for the sensitivity analysis.

The parameters tested and their modelled values are presented in Table 69.

Table 69: Additional Sensitivity Analysis Parameters

Parameter	Units	Minimum	Main Runs	Maximum
NOx emission concentration	mg/Nm³	50[(1)]	180	**180**
% of primary NOx as NO_2	%	1.5%	1.5%	**10%**
Constant 'c' for OH concentration	s	0.001111	0.001111	**0.002222**
Note: *(1) NOx concentration of 50 mg/Nm³ represents use of selective catalytic reduction (SCR)*				

The proportion of nitrosamines and nitramines formed from atmospheric chemical reactions (indirect emissions) has also been compared to those emitted from the stack (direct emissions). A further sensitivity analysis has been undertaken assuming that directly emitted nitrosamines and nitramines do not undergo any chemical reactions following release.

Finally, a sensitivity analysis has been run using the aqueous partitioning scheme included in the ADMS 6 amine chemistry module. As amines, nitrosamines and nitramines are soluble in water, when there is liquid water in the atmosphere or the plume, some of these substances dissolve, decreasing the concentration of pollutants in the gaseous phase and reducing their availability for gaseous phase reactions. This option requires the user to input Henry's Law constants for each amine modelled and their resultant nitrosamine and nitramine species. The values used are presented in Table 70.

18 Stevenson et al, Trends in global tropospheric hydroxyl radical and methane lifetime since 1850 from AerChemMIP, 2020

Table 70: Henry's Law Constants Used in Aqueous Partitioning Scheme

Parent Amine Species	Henry's Law Solubility Constant (mol/L atm)		
	Amine	Nitrosamine	Nitramine
MEA	6.08×10^{6} (1)	-	6.08×10^{7} (5)
DEA	2.53×10^{7} (2)	2.03×10^{8} (2)	2.03×10^{8} (5)
DMA	56.7 (3)	618 (4)	618 (5)

Notes:

(1) Bone et al., Solvent effects on equilibria of addition of nucleophiles to acetaldehyde and the hydrophilic character of diols, 1983

(2) HSDB: Hazardous Substances Data Bank, TOXicology data NETwork (TOXNET), National Library of Medicine (US), 2015

(3) Christie & Crisp, Activity coefficients on the n-primary, secondary and tertiary aliphatic amines in aqueous solution, 1967

(4) Klein, Calculations and measurements on the volatility of N-nitrosamines and their aqueous solutions, 1982.

(5)No published values available for nitramines. Tan et al., Experimental and Theoretical Study of the OH-Initiated Degradation of Piperazine under Simulated Atmospheric Conditions, 2020, states "There are no data for the Henry's law solubility constants for nitramines, but to a first approximation, they are expected to be the same as those of the nitrosamines." Nielsen et al., Atmospheric chemistry and environmental impact of the use of amines in carbon capture and storage (CCS), 2012, states "In general, the Henry's Law constants for nitrosamines are an order of magnitude smaller than that of the corresponding amine".

Therefore, where there is a published value for a certain nitrosamine, the same value has been assumed for the corresponding nitramine. As the Nielsen et al. reference reports the Henry's Law constants in reciprocal units to those required as an input for ADMS, where there are no values available for the nitrosamine or nitramine, these have been assumed to be an order of magnitude greater *than for the corresponding amine.*

The sensitivity analysis runs have been run for a single year (2023) and the maximum results for nitrosamine and nitramine concentrations at the point of maximum impact are presented in Table 71. The maximum amine, nitrosamine and nitramine concentrations and the percentage change from the main model run has been presented.

Table 71: Sensitivity Analysis Results – Amine Chemistry Parameters

Scenario	Annual mean concentration							
	Max amines		Max nitrosamines		Max nitramines		Max nitrosamines + nitramines	
	ng/m^3	As % of main run	pg/m^3	As % of main run	pg/m^3	As % of main run	pg/m^3	As % of main run
Main model run	17.65	-	14.83	-	17.80	-	31.67	-
Minimum nitramine formation	17.96	101.8%	13.31	89.7%	5.46	30.7%	18.35	57.9%
Maximum nitramine formation	17.53	99.3%	29.12	196.3%	135.15	759.3%	162.17	512.1%
Minimum nitrosamine formation	17.96	101.7%	11.82	79.7%	5.58	31.4%	16.83	53.2%
Maximum nitrosamine formation	17.54	99.4%	55.46	373.9%	24.94	140.1%	79.29	250.4%
NOx emission at 50 mg/Nm^3	17.49	99.1%	14.03	94.6%	19.01	106.8%	32.07	101.3%
Primary NO_2 = 10%	17.62	99.9%	14.80	99.8%	19.67	110.5%	33.67	106.3%
2x increase in OH conc.	17.09	96.9%	23.24	156.7%	32.93	185.0%	54.89	173.3%
Aqueous partitioning	16.40	92.9%	13.85	93.4%	17.02	95.6%	29.94	94.6%
No direct NS + NA emissions	17.65	100.0%	9.06	61.1%	17.29	97.2%	25.80	81.5%
No direct amine emissions (NS+NA only)	-	-	5.89	39.7%	0.55	3.1%	6.41	20.2%
No amine chemistry (direct emissions only)	-	-	5.98	40.3%	0.30	1.7%	6.28	19.8%

.

The following conclusions can be drawn from these results:

- The concentration of amines is not highly sensitive to any of the parameters. This is because the large majority of the amine remains unreacted (by the time the plume reaches the point of maximum impact) in all scenarios.
- Varying the amine chemistry reaction parameters leads to a range of 90% - 374% of the main model result for nitrosamines and 31% - 759% of the main model result for nitramines. The nitramine results are more sensitive because the majority are formed from MEA; there is a large range of parameters relating to nitramine formation from MEA (see Table 67).
- The concentrations of nitrosamines and nitramines are not highly sensitive to either the NOx emission concentration or the percentage of NOx emission that is primary NO_2.
- Increasing the OH concentration by a factor of 2 results in a near doubling of the concentrations of nitramines, but a more somewhat more modest increase of 57% in the concentrations of nitrosamines.
- Including aqueous partitioning results in only a slight decrease in concentrations of amines, nitrosamines and nitramines. This is likely due to the reheat of the flue gas to 80°C which prevents the formation of liquid water droplets in the plume.
- When there are no direct emissions of nitrosamines and nitramines (i.e. they are all formed from atmospheric reactions) the concentrations are reduced by almost 40% for nitrosamines, but only around 3% for nitramines. The directly-emitted nitrosamines and nitramines will tend to increase concentrations closer to the source, while those formed by atmospheric chemical reactions will tend to increase concentrations further from the source.
- When there are no emissions of amines and amine chemistry is enabled the peak concentrations of nitrosamines are reduced by around 60% and nitramines by almost 97%. When chemistry is not enabled the concentration of nitramines is slightly lower still, while the concentration of nitrosamines is slightly higher. This indicates that a portion of the directly-emitted nitrosamine would undergo photolysis.

The use of a 2x multiplier for the OH concentration constant would be overly conservative, as there is no evidence that OH concentrations are this high at UK latitudes.

The main model scenario, in which there are direct emission of amines, nitrosamines and nitramines, and amine chemistry is enabled, is considered to be the most realistic scenario.

Under the scenario that the worst-case amine reaction parameters for the formation of nitramines and nitrosamines are correct, and the total concentration of nitrosamines and nitramines is 512% of the value predicted in the main model run, the maximum concentration of nitrosamines and nitramines combined would be 162.17 pg/m³, which is 81% of the AQAL of 0.2 ng/m³ (200 pg/m³) set for NDMA. As such, even under these-worst case assumptions, the PEC of total nitrosamines and nitramines would remain below the AQAL.

G Environmental Assessment Level for DMA

FICHTNER
Consulting Engineers Limited

Fichtner

Carbon Capture

Derivation of environmental assessment levels for dimethylamine (DMA)

1 Dimethylamine (CAS Number 124-40-3)

Dimethylamine (DMA) is a water-soluble, basic secondary aliphatic amine which produces an odour similar to that of ammonia and/or rotting fish (US EPA, 2008). DMA is a flammable gas and forms explosive mixtures with air in the range 2.8% to 14.4% volume in air (NIPH, 2011). DMA is present in many foods, including cabbage and fish, and is also formed endogenously from DMA precursors by bacteria in the gut. It is widely used in industry as a precursor and is a raw material in the production of agrichemicals and pharmaceuticals. DMA is rapidly biodegradable in the environment and has an estimated phototransformation half-life in air of about two hours (ECHA dossier).

2 Regulatory standards

- None

3 Recommended environmental assessment level (EAL) in air

- Long-term EAL – 0.0033 mg/m^3 as a 24-hour mean.
- Short-term EAL – none (constrained by compliance with long-term EAL).

4 Overview

There are a few authoritative reviews on the adverse effects from exposure to DMA (US EPA (2008), NIPH (2011) and the industry registration, evaluation, authorisation and restriction of chemicals (REACH) dossier). It is a strong respiratory, ocular and skin irritant, which induces adverse effects when inhaled or ingested.

5 Toxicokinetics

There is limited information available on the metabolism and disposition of DMA by humans. Pharmacokinetic studies indicate that DMA is absorbed from the gastrointestinal tract rapidly ($t_{1/2}$ = 8 min) and extensively (bioavailability = 82%) (US EPA, 2008). The industry REACH dossier indicates that systemic uptake of DMA can occur via inhalation or dermal routes, in addition to the oral route (ECHA dossier). Following uptake, it can be found in human saliva, gastric juices, blood, urine and faeces (Tricker et al., 1992). Investigations of workers in a factory processing DMA showed excretion of the substance in urine when workers were exposed to the amine in air (Bittersohl and Heberer, 1980).

In a study on the metabolism of DMA in mammals McNulty and Heck (1983) studied the disposition and metabolism of DMA in male rats following inhalation of ^{14}C-DMA in concentrations of either 10 or 175 ppm for six hours. 72 hours after the end of exposure, the disposition of recovered radioactivity was similar for each concentration of DMA. The vast majority of the DMA was excreted (predominately in urine) without being metabolised, whilst 7-8% of radioactivity was distributed around the body in internal organs and other tissues, including the nasal mucosa, olfactory mucosa, kidneys, liver and lungs. In vitro studies also carried out by McNulty and Heck (1983) showed that DMA is metabolised by microsomes from rat liver and nasal and tracheal mucosa.

6 Short- and long-term exposures

DMA is a strong irritant to the eyes, skin and mucous membranes (NIPH, 2011). Exposure to the vapour can also result in temporary hazy vision (glaucopsy) which has been reported for amine production workers on several occasions (Mellerio, 1966). Direct contact between DMA vapor or aqueous solutions and skin can cause concentration-dependant damage, particularly in the eyes. Several ocular adverse effects are induced when a 1% DMA solution is applied to the rabbit eye including photophobia, blepharospasm and conjunctivitis, whilst solutions of 5% DMA or more caused severe damage such as vascularisation and clouding of the cornea (MAK Value Documentation, 2012).

Repeated inhalation toxicity of DMA was investigated in F344 rats and B6C3F1 mice[1] who showed significant lesions in the nasal passages when repeatedly exposed to 175 ppm of DMA for six hours a day, five days a week for 12 months (Buckley, 1985). More extensive olfactory lesions were developed in the rats compared to mice, and even when exposed to a concentration of 10 ppm, the animals developed minor lesions. In an investigation of the lethal concentration of DMA, Steinhagen et al. (1982) observed ulceration, necrosis, tracheitis and emphysema, resulting in mortality with a lethal concentration 50 (LC_{50}) value of 4,540 ml/m^3 for rats which had inhaled DMA for six hours.

Darad et al. (1985) investigated the effects of repeated dose oral exposure of DMA on rats by administering 0.2% DMA through drinking water over nine months. The results indicate that DMA may induce free radical-mediated damage to the cellular and subcellular membranes, thus disturbing the protective function of the skin. Ingested DMA has been shown to cause a number of effects in rats, such as coordination disorders, severe irritation of mucous membranes and bleeding of stomach walls, resulting in death. An oral lower dose 50 (LD_{50}) for rats was found to be 689 mg/kg body weight (MAK Value Documentation, 2012).

Guinea pigs exposed to a 0.5 M solution of DMA through a patch test of Magnusson and Kligman produced positive allergenic reactions to the solution. However, no sensitisation of humans handling DMA has been observed to date (MAK Value Documentation, 2012).

Evidence for neurobehavioural effects in humans from DMA inhalation exposure has not been reported (US EPA, 2008). However, a study by Simenhoff et al. (1977) found a correlation between serum levels of DMA and two neurophysiological parameters in uremic dialysis patients: choice reaction time (CRT) and abnormal electroencephalograms (EEG), noting that uremic patients have elevated levels of DMA in the blood, cerebrospinal fluid and brain.

[1] These are common inbred rats and hybrid strains of mice which are available commercially for use in toxicological studies.

There is very limited research on the reproductive and developmental toxicity of DMA. A study involving intraperitoneal injection of DMA, in doses of up to 137.7 mg/kg, into pregnant Swiss mice observed no toxic effects on dams of foetuses (Varma et al., 1990). However, in vitro experiments performed in the same study found that DMA causes a concentration-dependant reduction in embryo ribonucleic acid (RNA), deoxyribonucleic acid (DNA) and proteins.

6.1 Genotoxicity and carcinogenicity

Green (1978) found DMA to be a weak mutagen in the Ames test of mutagenicity with liver metabolic activation. However, other studies (e.g., Zeiger et al., 1987) have not been able to confirm this result and have concluded that DMA does not cause cytotoxic or genotoxic effects. DMA has not been found to be carcinogenic in rats or mice after exposure via inhalation for 24 months (ECHA dossier) and there has been no evidence to indicate carcinogenic effects in humans.

However, there is the potential for DMA to react with nitrosating agents in the body, to produce N-nitrosodimethylamine (NDMA), which is a potent carcinogen that reacts with DNA to form adducts (NIPH, 2011). This has been shown to occur in vitro, but to date no studies have shown that DMA is carcinogenic in vivo. Fay et al. (1997) investigated whether consuming frozen fish with very high DMA levels, with ingested nitrate, would result in elevated urinary adducts as a result of NDMA formation, but no genetic damage was found. NDMA is also mutagenic and clastogenic. The effects of NDMA and its associated EALs has been reported by the Environmental Agency.[2]

6.2 Pivotal studies

The US EPA (2008) summarised the Mitchell et al. (1982) 90-day inhalation toxicology study in F344 rats which was used as the basis for their derivation of acute exposure guidance levels (AEGL-1). In this study, 10 rats per sex per dose group (80 total) were exposed to DMA for six hours a day, five days a week, for 90 days at concentrations ranging from 0 to 100 ppm.

In the 10 ppm group, no treatment related effects were observed. A slightly lower weight gain was observed in the first two-week period in males and/or females at 30 ppm and 100 ppm, but over the total 13-weeks, weight gain for all groups was similar to that observed for the control groups.

After 13-weeks, all rats were necropsied. In three of the ten females exposed to 100 ppm, gross lesions of the liver red areas were observed with an increased incidence. This was not observed in any other group. Otherwise, no histopathological differences in tissue between the control and test groups were observed in microscopic analysis.

For males at 100 ppm and females at 30 ppm there was an increase in lung weight (approximately 20%). Females at 30 ppm and or 100 ppm also showed increased weight of heart, liver and kidneys (6-11%). The significance of this was unclear.

In a chronic inhalation study cited as the key source by the industry REACH dossier for DMA, male and female F344 rats and B6C3F1 mice were subjected to inhalation exposure of 0, 10, 50, or 175 ppm DMA for six hours a day, five days a week, for 12 months. Groups of 9-10 male and female rats and mice underwent necropsy after six and 12 months of exposure. Notably, no male mice were sacrificed at 12 months due to a high rate of premature deaths in that group, but this was attributed to fighting.

[2] https://www.gov.uk/government/consultations/environmental-assessment-levels-eals-used-in-air-emissions-risk-assessments/public-feedback/appendix-c-summary-of-toxicological-evidence-for-mea-and-ndma#fnref:1

Rats and mice exposed to 175 ppm DMA experienced a decrease in mean body weight gain to approximately 90% of the control after 3 weeks of exposure. This continued throughout the 12-month period.

The sole other changes linked to treatment were lesions in the nasal passages, which were dose dependent. These lesions occurred in two distinct nasal locations: the respiratory epithelium in the anterior nasal passages and the olfactory epithelium, particularly in the anterior dorsal meatus. In rats, the severity of lesions progressed between six to 12 months in the olfactory epithelium, but there was no progression observed in mice.

Rats exhibited more extensive olfactory lesions compared to mice at the 175 ppm exposure level, showing hyperplasia of small basophilic cells adjacent to the basement membrane. Even at 10 ppm, a 12-month exposure led to a small degree of loss of olfactory sensory cells and their axons in the nasal passages of a few rats and mice. These findings suggested a high sensitivity of olfactory sensory cells to DMA's toxic effects.

The comprehensive two-year study conducted by the Chemical Industry Institute of Toxicology (CIIT, 1990), of which Buckley et al. (1985) reported the first-year portion, served as the foundation for the Scientific Committee of Occupational Exposure Limits (SCOEL, 1991) occupational exposure limit (OEL) recommendation to the Health and Safety Executive (HSE). The study was summarised by the US EPA in their 2008 document where they derived the AEGLs. As described above, female and male F344 rats and B6C3F1 mice were subjected to inhalation exposure of 0, 10, 50, or 175 ppm DMA for six hours a day, five days a week. The total duration of the study was two years. The rats were observed twice a day and weighed weekly or biweekly.

In addition to the six- and 12-month interim sacrifices previously described a further interim sacrifice at 18 months of 9-10 animals per species was undertaken. This only applied to females, as excessive fighting in males lead to high mortality (which also prevented male sacrifice at the 12-month mark).

Decreased gain in body weight persisted throughout the study compared to the control group. Additionally, severity of nasal lesions increased after 18 months. At 10 ppm, minimal lesions were observed in the respiratory epithelium of rats and in the olfactory epithelium in both species. When exposed to 50 ppm, both species showed minimal alterations in the respiratory epithelium and moderate changes in the olfactory epithelium, coupled with mild chronic inflammation. Exposure to 175 ppm resulted in rats developing mild goblet cell hyperplasia, while both species experienced moderate chronic inflammation. Additionally, severe lesions were found in both the respiratory and olfactory epithelium, with these lesions being slightly more extensive in rats than in mice.

7 HBGV for short-term exposure

The industry REACH dossier, HSE (2020) and US EPA (2008) have proposed health based guidance values (HBGVs) for short-term exposure of DMA. The World Health Organisation (WHO) have not recommended any assessment levels for short-term exposure.

7.1 REACH chemical dossier

The industry REACH dossier for DMA on the ECHA dissemination portal derived a derived no effect level (DNEL) of 21.33 mg/m^3 to protect the general population from systemic effects from acute exposure via inhalation (REACH chemical dossier). It was based on a NOAEC of 184.85 mg/m^3

(100 ppm). ECHA applied modified Haber's law[3] using an exponent of 3 to the NOAEC to adjust the NOAEC from a six-hour exposure period to a 15-minute exposure period. The REACH chemical dossier then applied an uncertainty factor[4] (UF) of 25 (a factor of 2.5 for interspecies variation and a factor of 10 for intraspecies variation). ECHA didn't state from which source the NOAEC was taken. However, it is assumed that it was Mitchell et al. (1982) on the basis that they observed the same NOAEC, and their study was also used as the pivotal study for the AEGL-1 derivation by the US EPA.

7.2 United States Environmental Protection Agency

To assess the observed effects of inhalation of DMA, the US EPA reviewed various studies and derived acute exposure guideline levels (AEGLs) for different classifications of exposure levels, averaged over a number of different time frames, as shown in Table 1.

Table 1: Summary of AEGL Values for Dimethylamine

Classification	10-min	30-min	1-h	4-h	8-h
AEGL-1 (Non-disabling)	10 ppm (18 mg/m^3)	10 ppm (18 mg/m^3)	10 ppm (18 mg/m^3)	10 ppm (18 mg/m^3)	10 ppm (18 mg/m^3)
AEGL-2 (Disabling)	130 ppm (240 mg/m^3)	85 ppm (160 mg/m^3)	66 ppm (120 mg/m^3)	40 ppm (74 mg/m^3)	32 ppm (59 mg/m^3)
AEGL-3 (Lethal)	480 ppm (880 mg/m^3)	320 ppm (590 mg/m^3)	250 ppm (460 mg/m^3)	150 ppm (280 mg/m^3)	120 ppm (220 mg/m^3)

Source: US EPA (2008)

The AEGL-1 (non-disabling exposure level) was based on NOAEL for histopathological lesions of the nasal passages of rats following exposure to 100 ppm for six hours/day over 13 weeks, where no nasal lesions were observed (Mitchell et al., 1982). Inter- and intraspecies uncertainty factors of 3 each were applied for a total UF of 10, in accordance with the NRC (2001). The value of 10 ppm was not time-scaled as there is an adaptation to the mild irritation that defines the AEGL-1.

The AEGL-2 (disabling exposure level) was based on a study by Gross et al. (1987), in which rats were exposed to 175 ppm DMA for six hours/day and showed extensive nasal lesions. A total UF of 10 was applied, with UFs of 3 for the inter- and intraspecies uncertainty. Additionally, an adjustment value of 0.5 was applied as the effect was considered mild and below the definition of an AEGL-2 effect. Time-scaling was performed using the relationship $C^n \times t = k$ (ten Berge et al., 1986), where n = 2.8 as derived from a linear regression of LC_{50} studies.

The AEGL-3 (lethal exposure level) was based on a 2-hour $BMCL_{05}$ of 1978 ppm for mice, where internal organ haemorrhages were observed. A total UF of 10, with an UF of 3 for species variability and 3 for human variability was applied, and time-scaling was performed as per ten Berge et al. (1986).

[3] Modified Haber's law is used by REACH for time extrapolation when the exposure period for the point of departure is different to the desired HGBV exposure period. The law is $c^n * t = k$ where c is concentration, n is an exponent (n = 1 for extrapolating from shorter to longer exposure durations, n=3 for longer to shorter durations), t is the exposure time and k is a constant. The calculation by REACH to derive the adjusted NOAEC was as follows: $184.85\ ^3\ mg/m^3 \times 6\ hours\ = 37897417.4\ ;\ \sqrt[3]{\frac{37897417.4}{0.25\ hours}} = 533.2\ mg/m^3$

[4] Uncertainty factors (UFs), also known as safety factors or assessment factors, are numerical factors used to account for uncertainty when extrapolating data to derive HBGVs. When setting an UF, consideration is usually given to interspecies variability, intraspecies variability, point of departure used to derive the HBGV, completeness of the database, and steepness of the dose response curve. See Appendix A for further detail.

7.3 Health and Safety Executive

The HSE (2020) state a 15-minute short term exposure limit (STEL) of 11 mg/m^3 in their latest workplace exposure limits guidance. This has been highlighted since it is UK authoritative guidance. However, it is unclear how this was derived and the study on which it was based.

8 HBGVs for long-term exposure

The sections below outline the HBGVs which have been proposed for long-term exposure of DMA by the industry REACH dossier and the HSE.

8.1 REACH chemical dossier

ECHA derived 2 long-term REACH DNELs for inhalation for the general population, one systemic and one local. Both derivations were obtained from the findings of Buckley et al. (1985) study. Buckley et al. observed a LOAEC of 18.5 mg/m^3 (10 ppm) based on exposure six hours per day, five days per week for one year. Lesions in the nasal passageways of the rats and mice were the only effect observed at this concentration.

ECHA applied the UF of 30 to the LOAEC (10 for intraspecies differences and 3 for the use of LOAEC) to derive the local DNEL of 0.615 mg/m^3. ECHA did not correct for continuous exposure when calculating the local DNEL but it is unknown why.

The derived systemic REACH DNEL of 0.33 mg/m^3 is based on the NOAEC for systemic effects of 92.26 mg/m^3 (presumed to be from Mitchell et al. 1982). The NOAEC is corrected for continuous exposure, and an uncertainty factor of 50 is used (2 for extrapolation of subchronic to chronic exposure duration, 2.5 for interspecies differences, and 10 for intraspecies differences).

8.2 The HSE

In 2020, the HSE outlined a long-term exposure limit (8-hour TWA ref period) of 3.8 mg/m^3. This value was based on a SCOEL recommendation (SCOEL, 1991) which was derived from a CIIT study (CIIT, 1990), where a LOAEC of 10 ppm (18.5 mg/m^3) was observed. The CIIT (1990) study was the continuation of the Buckley et al. (1985) study for a further year. Therefore, the LOAEC was based on exposure for six hours per day, five days per week for two years. An UF of 5 was applied to calculate the workplace exposure limit (WEL) to account for absence of human data and use of LOAEC.

9 Summary

Although the overall toxicological database is small, several authoritative organisations have proposed HBGVs for DMA.

Short-term exposure guidelines have been proposed by the industry REACH dossier and US EPA (2008) based on nasal irritation observed in rats. Table 2 shows a summary of these guidance values.

Table 2: Summary of health-based guidance values for short-term exposures

Guideline	Value (mg/m^3)	Duration	Critical effect	Pivotal reference(s)
Current EAL	None	-	-	-
REACH DNEL	21.33	15 minutes	Irritation	Mitchell et al. 1982 (assumed)
AEGL-1	18	10 mins to 8 hours	Irritation	Mitchell et al. 1982
HSE STEL	11	15 minutes	Unknown	Unknown

Long-term chronic exposure guidelines have been proposed by the industry REACH dossier and HSE (2020) based on nasal irritation and depressed weight gain observed in rats. Table 3 shows a summary of these guidance values.

Table 3: Summary of health-based guidance values for long-term exposures

Guideline	Value (mg/m^3)	Duration	Critical effect	Pivotal reference(s)
Current EAL	None	-	-	-
REACH DNEL (systemic)	0.33	24 hours	Decreased body weight gain	Buckley et al. 1985
REACH DNEL (local)	0.615	24 hours	Irritation	Buckley et al. 1985
SCOEL/HSE LTEL	3.8	8 hours, 5 days a week	Irritation	CIIT 1990

10 Recommendations

10.1 Short-term EAL

The primary acute effect from short-term inhalation exposure of DMA is considered to be upper respiratory tract irritation. The HSE (2020) HBGV was not considered in determining the appropriate EAL value due to insufficient detail on the pivotal reference. The ECHA REACH DNEL and the US EPA AEGL-1 both used the same pivotal study: Mitchell et al. (1982). In this study, the rats were exposed to DMA for six hours a day, five days a week, for 90 days. The test concentrations were 0, 10, 30, or 100 ppm DMA, and there were 10 rats per sex per dose group.

Both ECHA and US EPA used the NOAEC of 100 ppm as the point of departure. However, the HBGVs are slightly different as a result of different UFs being applied, and ECHA's use of modified Haber's law to the NOAEC to adjust for a 15-minute exposure period. The US EPA did not adjust for time scale due to irritation being a concentration dependent effect over shorter periods. To be consistent with the Environment Agency's (EA's) 2009 guidance on assessment of contaminants in soil, it is proposed that the UF of 100 (10 for interspecies variation, 10 for intraspecies variation) is instead applied to the NOAEC with no adjustment for time scale For more detail about UFs, see Appendix A. This would provide the short term EAL of 1.8 mg/m^3. However, this is significantly higher than 24 * the long term EAL. Therefore, in accordance with the EA guidance (2020) on compliance constraints for threshold effects, a short term EAL is not recommended.

10.2 Long-term EAL

The critical health effects from long-term inhalation exposure of DMA are considered to be upper respiratory tract irritation and depressed weight gain. The proposed EAL of 0.0033 mg/m^3 is derived from the LOAEC that was used to derive the HSE (2020) WEL, since this was used by a UK authoritative body. The pivotal study used to derive the REACH DNEL, Buckley et al. (1985) is the first-year portion of the two-year CIIT (1990) study that was used to derive the HSE (2020) WEL. In these studies, male and female F344 rats and B6C3F1 mice were subjected to inhalation exposure of 0, 10, 50, or 175 ppm dimethylamine (DMA) for six hours a day, five days a week. Groups of 9-10 male and female rats and mice underwent necropsy after 6, 12, 18 and 24 months of exposure.

The point of departure used by ECHA to derive the REACH DNEL and the HSE to derive the WEL was the same. Differences in the HGBVs are the result of different UFs being used and the values applying to different time periods. To derive the long term EAL of 0.0033 mg/m^3, it is proposed that an UF of 1000 is used after correcting the LOAEC of 18.5 mg/m^3 for continuous exposure ($LOAEC \times \frac{6\ hours}{24\ hours} \times \frac{5\ days}{7\ days} = 3.33\ mg/m^3$). The UF accounts for the following uncertainties: 10 for interspecies variation, 10 for intraspecies variation, and 10 for use of a LOAEC. This uncertainty factor was chosen in line with the EA 2009 guidance on assessment of contaminants in soil. For more detail about UFs, see Appendix A.

10.3 Summary

Table 4 summarises the recommended EALs as described in sections 10.1 and 10.2.

Table 4: Recommended EALs for DMA

Short-term EAL	None - (constrained by compliance with the long-term EAL)
Long-term EAL	0.0033 mg/m^3 as a 24-hour mean

Source: Fichtner

Appendices

A Uncertainty factors

Uncertainty factors, also known as safety factors or assessment factors, are numerical factors used to account for uncertainty when extrapolating data to derive health-based guidance values (HBGVs). There are differences in the approach to the application of the uncertainty factors among groups that derive HBGVs.

Table 5 provides examples of the typical uncertainty factors used in chemical risk assessment, highlighted in the EA's 2009 guidance on assessment of contaminants in soil (EA, 2009).

Table 5: Examples of uncertainty factors used in chemical risk assessment

Consideration	Typical uncertainty factor applied
Interspecies variability	A 10-fold factor is normally used to account for variability in species susceptibility between humans and the animal species in which the chemical was tested.
Intraspecies variability	A 10-fold factor is normally used to account for variability of responses in human populations which may not be present in the inbred strains of animals used for toxicity testing.
LOAEL to NOAEL	A 10-fold factor may be used when a LOAEL instead of a NOAEL is used in the derivation. For a minimal LOAEL, an intermediate factor of three may be used. It is inappropriate to use a LOAEL if the NOAEL is likely to be more than 10 times less than the NOAEL.
Data gaps	A factor, usually 3- to 10-fold, may be used for "incomplete" databases (with missing studies, such as no chronic bioassays or no reproductive toxicity data). It accounts for the inability of any study to consider all toxic endpoints.
Steep dose-response curve	Where the dose-response curve is steep and a small error in the extrapolation would have dramatic consequences, an additional factor may be applied.

Source: Environment Agency (2009)

B Abbreviations and definitions

AEGL - Acute exposure guideline level

AEGL-1

The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2

The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL-3

The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

$BMCL_{05}$ - Benchmark concentration, 95% lower confidence limit with 5% response

CIIT - Chemical Industry Institute of Toxicology

CRT - Choice reaction time

DMA - Dimethylamine

DNA -Deoxyribonucleic acid

DNEL - Derived no-effect level

EAL - Environmental assessment level

ECHA - European Chemicals Agency

EEG - Electroencephalogram

HBGV - Health-based guidance value

HSE - Health and Safety Executive

LC_{50} - Lethal concentration 50

LD_{50} - Lethal dose 50

LOAEL/C - Lowest observed adverse effect level / concentration

LTEL - Long term exposure limit

MAK - Maximale Arbeitsplatz-Konzentration (maximum workplace concentration)

NDMA - N-nitrosodimethylamine

NIOSH - National Institute for Occupational Safety and Health

NIPH - Norwegian Institute of Public Health

NOAEL/C - No observed adverse effect level / concentration **UF - Uncertainty factor**

US EPA - United States Environmental Protection Agency

WEL - Workplace exposure limit

WHO - World Health Organisation

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