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ATTACHMENT-7-1-3-2-AIR EMISSIONS IMPACT ASSESSMENT ADSIL DROGHEDA BUSINESS & TECHNOLOGY PARK, CO. LOUTH

Technical Report Prepared For

Amazon Data Services Ireland Limited

Prepared By

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EXECUTIVE SUMMARY

This report presents the assessment of air quality impacts as a result of the operation of the Amazon Data Services Ireland Ltd. ("ADSIL" or 'the applicant') data storage facility (the subject 'installation' under this licence application) located at Drogheda Business & Technology Park, Drogheda, Co. Louth. The site is occupied by one no. data storage installation building, termed Building A, along with ancillary elements.

The installation requires a continuous supply of electricity to operate. During normal operations, the facility is supplied electricity from the national grid. Outside of normal operations, the facility is first supplied electricity by some or all of the onsite battery installations and then by some or all of the onsite backup generators. Outside of routine testing and maintenance, the operation of these back-up generators is typically only required under the following emergency circumstances:

- A loss, reduction or instability of grid power supply,
- Critical maintenance to power systems,
- A request from the utility supplier (or third party acting on its behalf) to reduce grid electricity load

The air dispersion modelling has been carried out using the United States Environmental Protection Agency's regulated model AERMOD. The AERMOD model has USEPA regulatory status and is one of the advanced models recommended within the air modelling guidance document 'Air Dispersion Modelling from Industrial Installations Guidance Note (AG4)' published by the EPA in Ireland. The modelling of air emissions is carried out to assess concentrations of nitrogen dioxide (NO_2) at a variety of locations beyond the site boundary. The modelling assessment also included the cumulative impact of additional facilities with NO_X emissions in the vicinity of the site.

The assessment has been undertaken for the installation which includes Building A. The installation has 26 no. 6.49 MW_{th} diesel powered back-up generators, 1 no. 2.19 MW_{th} diesel powered generator and 2 no. fire pump generators (0.52 MW_{th}). The 2 no. 0.52 MW_{th} diesel powered emergency back-up fire pumps have been scoped out of this air modelling assessment as it is not expected that they would cause any significant impacts on ambient air quality considering their smaller scale (compared to the data hall back-up generators and admin back-up generator) and the low number required for use at any one time.

The assessment has determined the ambient air quality impact of the site and any air quality constraints that may be present. The diesel generators will be used solely for emergency operation (i.e. less than 500 hours per year) and thus the emission limit values outlined in the Medium Combustion Plant Directive are not applicable to the diesel generators on site.

A number of modelling scenarios are investigated for the purposes of this assessment. Both normal day-to-day testing operations are considered as well as emergency operations. Normal testing operations involve the diesel generators operating for up to 30 minutes on a weekly basis at 25% load with no more than one generator tested at the same time. Quarterly maintenance testing of the generators at 90% load for 1-hour individually was also included in the modelling assessment. Emergency operation is based on 100 emergency hours modelled according to the USEPA methodology.

Cumulative Air Emissions

A cumulative impact assessment of the installation and nearby sites with NO_X emissions within a 1km radius was also conducted. Sites which hold an IED licence from the EPA are usually assessed for relevant air emissions, however, there are no IED licenced sites within 1 km of the subject site. The closest IED licenced site is over 2 km to the south of the installation. At a distance of between 2 - 3 km are two licenced facilities, Irish Cement (P0030-06) and Indaver Ireland Carranstown WTE facility (P0167-03). These two facilities have been included in the cumulative assessment.

Assessment of the Facility

The NO_2 modelling results at the worst-case location at and beyond the site boundary are based on the operation of 24 of the 26 no. 6.49 MW_{th} back-up diesel generations and 1 no. 2.19MW_{th} back-up diesel generator for 100 hours per year using the USEPA methodology outlined within the guidance document titled '*Additional Clarification Regarding Application of Appendix W Modelling Guidance for the 1-Hour National Ambient Air Quality Standard*' as well as considering scheduled weekly testing and quarterly maintenance testing of all 27 no. back-up generators from the installation.

The results indicate that the ambient ground level concentrations are in compliance with the relevant air quality standards for NO_2. For the worst-case year, emissions from the site lead to an ambient NO_2 concentration (including background) which is 48% of the maximum ambient 1-hour limit value (measured as a 99.8^{th} percentile) and 56% of the annual limit value at the worst-case off-site receptor.

The UK EA assessment methodology determined that in any year, the diesel generators can run for 238 hours before there is a likelihood of an exceedance at the nearest residential receptor (at a 98^{th} percentile confidence level).

Cumulative Assessment

The NO_2 cumulative modelling results at the worst-case location at and beyond the site boundary are based on the operation of 24 of the 26 no. 6.49 MW_{th} back-up diesel generations and 1 no. 2.19 MW_{th} back-up diesel generator for 100 hours per year using the USEPA methodology as well as considering scheduled weekly testing and quarterly maintenance testing of all 27 no. back-up generators from the installation in addition to the continuous operation of the four emission points from Irish Cement and main emission point from Indaver Ireland.

The results indicate that the ambient ground level concentrations are within the relevant air quality standards for NO_2. For the worst-case year modelled, emissions from the site and nearby facilities lead to an ambient NO_2 concentration (including background) which is 48% of the maximum ambient 1-hour limit value (measured as a 99.8^{th} percentile) and 58% of the annual limit value at the worst-case off-site receptor. Concentrations decrease with distance from the site boundary.

The cumulative UK EA assessment methodology determined that in any year, the diesel generators can run for 238 hours before there is a likelihood of an exceedance at the nearest residential receptor (at a 98^{th} percentile confidence level).

Conclusion

In summary, emissions to atmosphere of NO_2, as the main polluting substance (as defined in the Schedule of EPA (Industrial Emissions) (Licensing) Regulations 2013, S.I. No. 137 of 2013) from the standby generators, will be in compliance with the ambient air quality standards which are based on the protection of the environment and human health. Therefore, no significant impacts to the ambient air quality environment are predicted.

In terms of impacts at nearby ecologically sensitive areas, the closest sensitive ecological area is the River Boyne And River Blackwater SAC (Site Code 002299) located over 1 km to the north of the subject site. Dispersion modelling of NO_X emissions from the installation at this distance is not required as there is no potential for significant impacts to vegetation as a result of emissions from the installation at such a distance. Emissions from the back-up generators on site peak at the site boundary and fall off rapidly with increasing distance from the installation.

CONTENTS

1.0 INTRODUCTION 7

2.0 ASSESSMENT CRITERIA 10

2.1 Ambient Air Quality Standards 10

2.2 Industrial Emissions Directive and Medium Combustion Plant Directive 10

2.3 Sensitive areas or areas of special interest 11

3.0 ASSESSMENT METHODOLOGY 12

3.1 Air Dispersion Modelling Methodology 12

3.2 Terrain 13

3.3 Meteorological Data 13

3.4 Geophysical Considerations 16

3.5 Building Downwash 16

4.0 BACKGROUND CONCENTRATIONS OF POLLUTANTS 18

5.0 PROCESS EMISSIONS 20

5.1 Emergency Operations 21

6.0 RESULTS 23

6.1 Emergency Operations (USEPA Methodology) 23

6.2 Emergency Operations (UK EA Methodology) 23

6.3 Cumulative Operations (USEPA Methodology) 29

6.4 Cumulative Emergency Operations (UK EA Methodology) 29

7.0 ASSESSMENT SUMMARY 29

8.0 REFERENCES 35

1.0 INTRODUCTION

This report presents the assessment of air quality impacts as a result of the operation of the Amazon Data Services Ireland Ltd. ("ADSIL" or 'the applicant') data storage facility (the subject 'installation' under this licence application) located at Drogheda Business & Technology Park, Drogheda, Co. Louth. The site is occupied by one no. data storage installation building, termed Building A, along with ancillary elements.

The installation requires a continuous supply of electricity to operate. During normal operations, the facility is supplied electricity from the national grid. Outside of normal operations, the facility is first supplied electricity by some or all of the onsite battery installations and then by some or all of the onsite backup generators. Outside of routine testing and maintenance, the operation of these back-up generators is typically only required under the following emergency circumstances:

- A loss, reduction or instability of grid power supply,
- Critical maintenance to power systems,
- A request from the utility supplier (or third party acting on its behalf) to reduce grid electricity load.

The air dispersion modelling has been carried out using the United States Environmental Protection Agency's regulated model AERMOD(1). The AERMOD model has USEPA regulatory status and is one of the advanced models recommended within the air modelling guidance document 'Air Dispersion Modelling from Industrial Installations Guidance Note (AG4)' published by the EPA in Ireland(2). The modelling of air emissions is carried out to assess concentrations of nitrogen dioxide (NO_2) at a variety of locations beyond the site boundary. The assessment has been undertaken for Building A which has 26 no. 6.49 MW back-up generators and 1 no. 2.19 MW back-up generator.

The assessment has determined the ambient air quality impact of the site and any air quality constraints that may be present. The diesel generators will be used solely for emergency operation (i.e. less than 500 hours per year) and thus the emission limit values outlined in the Medium Combustion Plant Directive are not applicable to the diesel generators on site.

A number of modelling scenarios are investigated for the purposes of this assessment. Both normal day-to-day testing operations are considered as well as emergency operations. Normal testing operations involve the diesel generators operating for 30 minutes on a weekly basis at 25% load with no more than one generator tested at the same time. Quarterly maintenance testing of the generators at 90% load for 1-hour individually was also included in the modelling assessment. Emergency operation is based on 100 emergency hours modelled according to the USEPA methodology.

A cumulative impact assessment of the installation and nearby sites with NO_X emissions within a 1km radius was also conducted. Sites which hold an IED licence from the EPA are usually assessed for relevant air emissions, however, there are no IED licenced sites within 1 km of the subject site. The closest IED licenced site is over 2 km to the south of the installation. At a distance of between 2 - 3 km are two licenced facilities, Irish Cement (P0030-06) and Indaver Ireland Carranstown WTE facility (P0167-03). These two facilities have been included in the cumulative assessment. The location of the subject site is shown below in Figure 1.

Information supporting the conclusions of this assessment is detailed in the following sections. The assessment methodology and study inputs are presented in Section 2 and Section 3. Background pollutant concentrations are summarised in Section 4. The process emissions and modelling inputs for on-site plant are presented in Section 5. The dispersion modelling results are presented in Section 6 and the assessment summaries are presented in Section 7. The model formulation is detailed in Appendix I and a review of the meteorological data used is detailed in Appendix II.

Site Location

Project
ADSIL Drogheda Data Centre IE Licence

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Figure 1
Land use in the vicinity of ADSIL Drogheda site

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2.0 ASSESSMENT CRITERIA

2.1 Ambient Air Quality Standards

In order to reduce the risk to health from poor air quality, national and European statutory bodies have set limit values in ambient air for a range of air pollutants. These limit values or "Air Quality Standards" are health or environmental-based levels for which additional factors may be considered. The applicable standards in Ireland include the Air Quality Standards Regulations 2022, implement the obligations under Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (see Table 1). The ambient air quality standards applicable for NO_2 are outlined in this Directive. Directive 2008/50/EC has also set limit values for other pollutants including SO_2. Levels of SO_2 emitted from the installation will be insignificant and have been screened out of the assessment.

Air quality significance criteria are assessed on the basis of compliance with the appropriate standards or limit values. The standards outlined in Table 1 have been used in the current assessment to determine the potential impact of NO_2 emissions from the installation on ambient air quality.

Table 1 *Ambient Air Quality Standards*

Pollutant	Regulation Note 1	Limit Type	Value
Nitrogen Dioxide (NO_2)	2008/50/EC	Hourly limit for protection of human health - not to be exceeded more than 18 times/year	200 $\mu g/m^3$
		Annual limit for protection of human health	40 $\mu g/m^3$
Nitrogen Oxides (NO_X)	2008/50/EC	Critical level for protection of vegetation (Annual)	30 $\mu g/m^3$ NO + NO_2
Sulphur Dioxide (SO_2)	2008/50/EC	Critical level for protection of vegetation (Annual & Winter)	20 $\mu g/m^3$ SO_2

Note 1 EU 2008/50/EC – Clean Air For Europe (CAFÉ) Directive replaces the previous Air Framework Directive (1996/30/EC) and daughter directives 1999/30/EC and 2000/69/EC

2.2 Industrial Emissions Directive and Medium Combustion Plant Directive

The Industrial Emissions Directive (IED) (Directive 2010/75/EU) was adopted on 7 January 2013 and is the key European Directive which covers the regulation of the majority of processes in the EU. As part of the IED Article 15, paragraph 2, requires that Emissions Limit Values (ELVs) are based on best available techniques (BAT) and the relevant sector Reference Document of Best Available Techniques (BREF documents).

The most relevant BAT sector document for the activities at the installation is the Best Available Techniques (BAT) Reference Document for Large Combustion Plants LCP. There are no ELVs set out in the LCP BAT that are applicable to the individual emergency back-up generators.

The individual emergency back-up generators considered in this assessment are 6.49 MW_{th} for Building A therefore the Medium Combustion Plant (MCP) Regulations (S.I No. 595 of 2017), which transposed the Medium Combustion Plant Directive ((EU) 2015/2193) is a relevant consideration in respect of the individual plant.

The installation requires a continuous supply of electricity to operate. During normal operations, the facility is supplied electricity from the national grid. Outside of normal operations, the facility is first supplied electricity by some or all of the onsite battery installations and then by some or all of the onsite backup generators. Outside of routine testing and maintenance, the operation of these back-up generators is typically only required under the following emergency circumstances:

- A loss, reduction or instability of grid power supply,
- Critical maintenance to power systems,
- A request from the utility supplier (or third party acting on its behalf) to reduce grid electricity load.

The diesel generators are for emergency back-up only and are not anticipated to operate in excess of 500 hours per annum. Therefore, the emergency generators as proposed are exempt from complying with the relevant ELVs set out in the MCP Directive subject to Section 13(3) of the Medium Combustion Plant (MCP) Regulations.

The UK Environment Agency assessment methodology in Section 6.2 below determined that the standby generators could operate for 238 hours before there is a likelihood of an exceedance of the ambient air quality standard (at a 98^{th} percentile confidence level). However, the UK guidance recommends that there should be no running time restrictions placed on standby generators which provide power on site only during an emergency power outage.

2.3 Sensitive areas or areas of special interest

An Appropriate Assessment (AA) Screening Report (Attachment-6-3-4-AA Screening-Planning-Mar-20204) has previously been prepared by Moore Group for the planning application MCC Reg. Ref.: LB191735 and has been submitted as part of the licence application for the site.

The AA Screening identifies that the lands in which the installation is located have no formal designations, and that the nearest European site to the Installation is the River Boyne And River Blackwater SAC (Site Code 002299) located over 1 km to the north.

Emissions of NO_X have the potential to impact vegetation and sensitive plant species. Directive 2008/50/EC has set limit values for vegetation effects as per Table 1. As such it is typical to assess the impact of NO_X emissions from a facility on any nearby sensitive ecological areas in close proximity to the site. There are no European sites within 1 km of the subject site as noted above. The closest sensitive ecological area is the River Boyne And River Blackwater SAC (Site Code 002299)which is located c. 1.1 km north of the subject site. Dispersion modelling of NO_X emissions from the installation at this distance is not required as there is no potential for significant impacts to vegetation as a result of emissions from the installation at such a distance. Emissions from the back-up generators on site peak at the site boundary and fall off rapidly with increasing distance from the installation.

3.0 ASSESSMENT METHODOLOGY

Emissions from the facility are modelled using the AERMOD dispersion model (Version 22112) which has been developed by the U.S. Environmental Protection Agency (USEPA)(1) and following guidance issued by the EPA(2). The model is a steady-state Gaussian plume model used to assess pollutant concentrations associated with industrial sources and has replaced ISCST3(4) as the regulatory model by the USEPA for modelling emissions from industrial sources in both flat and rolling terrain(5-7). The model has more advanced algorithms and gives better agreement with monitoring data in extensive validation studies(8-11). An overview of the AERMOD dispersion model is outlined in Appendix I.

The air dispersion modelling input data consisted of information on the physical environment (including building dimensions and terrain features), design details from all emission points on-site and five years of appropriate hourly meteorological data. Using this input data the model predicted ambient ground level concentrations beyond the site boundary for each hour of the modelled meteorological years. The model post-processed the data to identify the location and maximum of the worst-case ground level concentration. This worst-case concentration is then added to the background concentration to give the worst-case predicted environmental concentration (PEC). The PEC is then compared with the relevant ambient air quality standard to assess the significance of the releases from the site.

The modelling aims to achieve compliance with the guidance outlined within the EPA *AG4 Guidance for Air Dispersion Modelling*(2). Throughout this study a worst-case approach was taken. This will most likely lead to an over-estimation of the levels that will arise in practice. The worst-case assumptions are outlined below:

- Maximum predicted concentrations are reported in this study, even if no residential receptors are near the location of this maximum;
- Conservative background concentrations are used in the assessment;
- The effects of building downwash, due to on-site buildings, are included in the model;
- Emergency operations were assumed to occur for a maximum of 100 hours per year calculated according to USEPA methodology, in reality generators are likely to be used for maintenance and testing purposes only.

3.1 Air Dispersion Modelling Methodology

The United States Environmental Protection Agency (USEPA) approved AERMOD dispersion model has been used to predict the ground level concentrations (GLC) of compounds emitted from the principal emission sources on-site.

The modelling incorporated the following features:

- Two receptor grids are included at which concentrations are modelled. Receptors are mapped with sufficient resolution to ensure all localised “hot-spots” are identified without adding unduly to processing time. The receptor grids are based on Cartesian grids with the site at the centre. The outer grid measures 5 x 5 km with the site at the centre and with concentrations calculated at 250m intervals. The inner grid measures 2 x 2 km with the site at the centre and with concentrations calculated at 50m intervals. Boundary receptor locations are also placed along the boundary of the site, at 25m intervals, giving a total of 2,230 calculation points for the model.

- Discrete receptors are also added to the model to represent nearby residential receptors. Receptors were modelled at a height of 1.8m to represent breathing height.
- All on-site buildings and significant process structures are mapped into the computer to create a three dimensional visualisation of the site and its emission points. Buildings and process structures can influence the passage of airflow over the emission stacks and draw plumes down towards the ground (termed building downwash). The stacks themselves can influence airflow in the same way as buildings by causing low pressure regions behind them (termed stack tip downwash). Both building and stack tip downwash are incorporated into the modelling.
- Detailed terrain has been mapped into the model using SRTM data with 30m resolution. The site is located in an area of complex terrain. All terrain features have been mapped in detail into the model using the terrain pre-processor AERMAP(12).
- Hourly-sequenced meteorological information has been used in the model. Meteorological data over a five year period (Dublin Airport 2017 – 2021) is used in the model (see Figure 2 and Appendix II).
- The source and emissions data, including stack dimensions, gas volumes and emission temperatures have been incorporated into the model.

3.2 Terrain

The AERMOD air dispersion model has a terrain pre-processor AERMAP(12) which is used to map the physical environment in detail over the receptor grid. The digital terrain input data used in the AERMAP pre-processor is obtained from SRTM. This data is run to obtain for each receptor point the terrain height and the terrain height scale. The terrain height scale is used in AERMOD to calculate the critical dividing streamline height, H_{crit}, for each receptor. The terrain height scale is derived from the Digital Elevation Model (DEM) files in AERMAP by computing the relief height of the DEM point relative to the height of the receptor and determining the slope. If the slope is less than 10%, the program goes to the next DEM point. If the slope is 10% or greater, the controlling hill height is updated if it is higher than the stored hill height.

In areas of complex terrain, AERMOD models the impact of terrain using the concept of the dividing streamline (H_c). As outlined in the AERMOD model formulation(1) a plume embedded in the flow below H_c tends to remain horizontal; it might go around the hill or impact on it. A plume above H_c will ride over the hill. Associated with this is a tendency for the plume to be depressed toward the terrain surface, for the flow to speed up, and for vertical turbulent intensities to increase.

AERMOD model formulation states that the model "captures the effect of flow above and below the dividing streamline by weighting the plume concentration associated with two possible extreme states of the boundary layer (horizontal plume and terrain-following). The relative weighting of the two states depends on: 1) the degree of atmospheric stability; 2) the wind speed; and 3) the plume height relative to terrain. In stable conditions, the horizontal plume "dominates" and is given greater weight while in neutral and unstable conditions, the plume traveling over the terrain is more heavily weighted"(1).

3.3 Meteorological Data

The selection of the appropriate meteorological data has followed the guidance issued by the USEPA(1). A primary requirement is that the data used should have a data capture of greater than 90% for all parameters. Dublin Airport meteorological station, which is located approximately 31 km south of the site, collects data in the correct format and has a data collection of greater than 90%. Long-term hourly observations at Dublin Airport meteorological station provide an indication of the prevailing wind conditions for the region (see Figure 2 and Appendix II)[13]. Results indicate that the prevailing wind direction is westerly to south-westerly in direction over the period 2017 – 2021. The mean wind speed is approximately 5.3 m/s over the period 2017 - 2021.

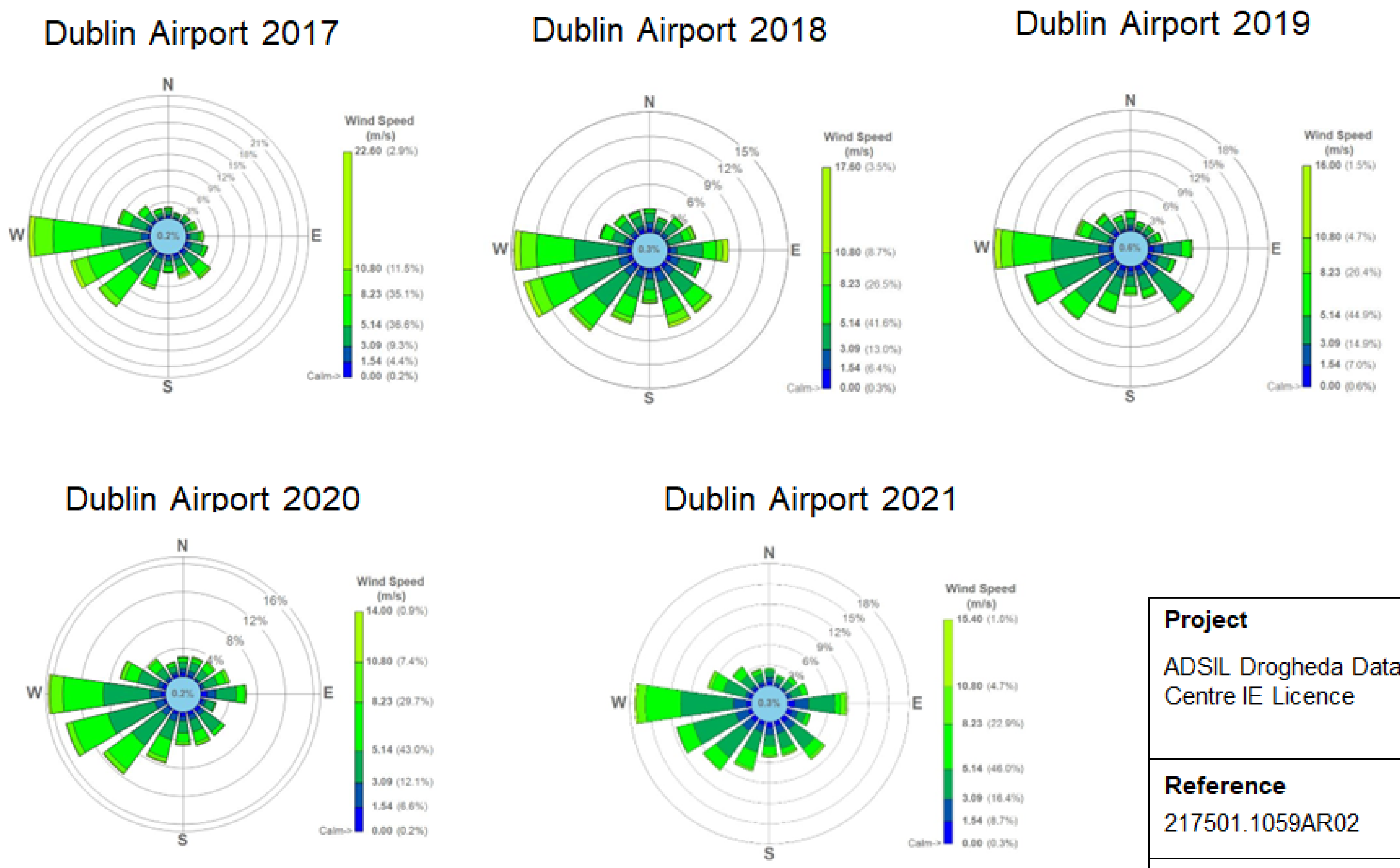

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Figure 2

Dublin Airport Windrose 2017 - 2021

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3.4 Geophysical Considerations

AERMOD simulates the dispersion process using planetary boundary layer (PBL) scaling theory[1]. PBL depth and the dispersion of pollutants within this layer are influenced by specific surface characteristics such as surface roughness, albedo and the availability of surface moisture. Surface roughness is a measure of the aerodynamic roughness of the surface and is related to the height of the roughness element. Albedo is a measure of the reflectivity of the surface whilst the Bowen ratio is a measure of the availability of surface moisture.

AERMOD incorporates a meteorological pre-processor AERMET[14] to enable the calculation of the appropriate parameters. The AERMET meteorological preprocessor requires the input of surface characteristics, including surface roughness (z_0), Bowen Ratio and albedo by sector and season, as well as hourly observations of wind speed, wind direction, cloud cover, and temperature. The values of albedo, Bowen Ratio and surface roughness depend on land-use type (e.g., urban, cultivated land etc) and vary with seasons and wind direction. The assessment of appropriate land-use type is carried out to a distance of 10km from the meteorological station for Bowen Ratio and albedo and to a distance of 1km for surface roughness in line with USEPA recommendations[14,15] as outlined in Appendix II.

In relation to AERMOD, detailed guidance for calculating the relevant surface parameters has been published[15]. The most pertinent features are:

- The surface characteristics should be those of the meteorological site (Dublin Airport) rather than the installation;
- Surface roughness should use a default 1km radius upwind of the meteorological tower and should be based on an inverse-distance weighted geometric mean. If land use varies around the site, the land use should be sub-divided by sectors with a minimum sector size of 30º;
- Bowen ratio and albedo should be based on a 10km grid. The Bowen ratio should be based on an un-weighted geometric mean. The albedo should be based on a simple un-weighted arithmetic mean.

AERMOD has an associated pre-processor, AERSURFACE[15] which has representative values for these parameters depending on land use type. The AERSURFACE pre-processor currently only accepts NLCD92 land use data which covers the USA. Thus, manual input of surface parameters is necessary when modelling in Ireland. Ordnance survey discovery maps (1:50,000) and digital maps such as those provided by the EPA, National Parks and Wildlife Service (NPWS) and Google Earth® are useful in determining the relevant land use in the region of the meteorological station. The Alaska Department of Environmental Conservation has issued a guidance note for the manual calculation of geometric mean for surface roughness and Bowen ratio for use in AERMET[16]. This approach has been applied to the current site with full details provided in Appendix II.

3.5 Building Downwash

When modelling emissions from an industrial installation, stacks which are relatively short can be subjected to additional turbulence due to the presence of nearby buildings. Buildings are considered nearby if they are within five times the lesser of the building height or maximum projected building width (but not greater than 800m).

The USEPA has defined the “Good Engineering Practice” (GEP) stack height as the building height plus 1.5 times the lesser of the building height or maximum projected building width. It is generally considered unlikely that building downwash will occur when stacks are at or greater than GEP[17].

When stacks are less than this height, building downwash will tend to occur. As the wind approaches a building it is forced upwards and around the building leading to the formation of turbulent eddies. In the lee of the building these eddies will lead to downward mixing (reduced plume centreline and reduced plume rise) and the creation of a cavity zone (near wake) where re-circulation of the air can occur. Plumes released from short stacks may be entrained in this airflow leading to higher ground level concentrations than in the absence of the building.

The Plume Rise Model Enhancements (PRIME)[9,10] plume rise and building downwash algorithms, which calculates the impact of buildings on plume rise and dispersion, have been incorporated into AERMOD. The building input processor BPIP-PRIME produces the parameters which are required in order to run PRIME. The model takes into account the position of each stack relative to each relevant building and the projected shape of each building for 36 wind directions (at 10º intervals). The model determines the change in plume centreline location with downwind distance based on the slope of the mean streamlines and coupled to a numerical plume rise model[10].

Given that the stacks are less than 2.5 times the lesser of the building height or maximum projected building width, building downwash was taken into account and the PRIME algorithm run prior to modelling with AERMOD. The dominant building for each relevant stack will vary as a function of wind direction and relative building heights.

4.0 BACKGROUND CONCENTRATIONS OF POLLUTANTS

Air quality monitoring programs have been undertaken in recent years by the EPA and Local Authorities[18,19]. The most recent annual report on air quality "*Air Quality in Ireland 2021"*[19], details the range and scope of monitoring undertaken throughout Ireland. As part of the implementation of the Framework Directive on Air Quality (1996/62/EC), four air quality zones have been defined in Ireland for air quality management and assessment purposes[18]. Dublin is defined as Zone A and Cork as Zone B. Zone C is composed of 23 towns with a population of greater than 15,000. The remainder of the country, which represents rural Ireland but also includes all towns with a population of less than 15,000 is defined as Zone D. In terms of air monitoring, Drogheda is categorized as Zone C[18].

In 2020 the EPA reported[19] that Ireland was compliant with EU legal air quality limits at all locations, however this was largely due to the reduction in traffic due to Covid-19 restrictions. The EPA report details the effect that the Covid-19 restrictions had on air monitoring stations, which included reductions of up to 50% at some monitoring stations which have traffic as a dominant source. The report also notes that CSO figures show that while traffic volumes are still slightly below 2019 levels, they have significantly increased since 2020 levels. 2020 concentrations are therefore predicted to be an exceptional year and not consistent with long-term trends. For this reason, they have been included in the baseline section for representative purposes only and previous data has been used to determine the baseline air quality in the region of the site.

With regard to NO_2, continuous monitoring data from the EPA[18,19] at the Zone C locations of Dundalk, Kilkenny and Portlaoise in 2021 show that levels of NO_2 are below both the annual and 1-hour limit values (see Table 2). Average long-term concentrations at Kilkenny and Portlaoise range from 4 - 11 $\mu g/m^3$ for the period 2017 – 2021; suggesting an upper average over the five-year period of no more than 11 $\mu g/m^3$. There were no exceedances of the maximum 1-hour limit of 200 $\mu g/m^3$ in any year albeit 18 exceedances are allowed per year. Data for Dundalk indicates that annual mean concentrations ranged from 10 – 14 $\mu g/m^3$. Based on the above results an estimate of the background NO_2 concentration in the region of the subject site is 15 $\mu g/m^3$.

In relation to the annual average background, the ambient background concentration is added directly to the process concentration with the short-term peaks assumed to have an ambient background concentration of twice the annual mean background concentration.

The methodology for converting NO_X to NO_2 is based on the ozone limiting method (OLM) approach based on an initial NO_2/NO_X ratio of 0.1 and a background ozone level of 58 $\mu g/m^3$ based on a review of EPA data for similar Zone C locations[19].

Table 2 *Annual Mean and 99.8th Percentile 1-Hour NO_2 Concentrations In Zone C Locations (µg/m³)*

Station	Averaging Period	Year				
		2017	2018	2019	2020	2021
Kilkenny	Annual Mean NO_2 (µg/m³)	5	6	5	4	4
	99.8th%ile 1-hr NO_2 (µg/m³)	41	45	42	40	35
Portlaoise	Annual Mean NO_2 (µg/m³)	11	11	11	11	8
	99.8th%ile 1-hr NO_2 (µg/m³)	60	68	60	52	49
Dundalk	Annual Mean NO_2 (µg/m³)	-	14	12	10	11
	99.8th%ile 1-hr NO_2 (µg/m³)	-	-	69	73	67

5.0 PROCESS EMISSIONS

The installation has no major emissions to air and only has potential emissions (emergency generators) that will generate quantities of air pollutants listed as a Principal Pollution Substance (*S.I. No. 137/2013 - Environmental Protection Agency (Industrial Emissions) (Licensing) Regulations 2013*).

The data storage facility has 26 no. 6.49 MW_{th} back-up generators and 1 no. 2.19 MW_{th} back-up generator which were considered in this assessment. Each generator has an associated stack the heights of which were designed in an iterative fashion to provide for adequate dispersion of pollutants. All stacks are vertical and are 25m above ground level.

Two of the 6.49 MW_{th} back-up diesel generators associated with Building A have been modelled as "catcher" generators to provide redundancy to the remaining generators on site. Therefore, in the event of a power failure at the site 24 of the 26 no.6.49 MW_{th} back-up generators will be operational.

Modelling for NO_2 was undertaken in detail. In relation to CO, PM_{10} and $PM_{2.5}$ no detailed modelling was undertaken. Emissions of these pollutants are significantly lower than the NO_X emissions from the generators relative to their ambient air quality standards and thus ensuring compliance with the NO_2 ambient limit value will ensure compliance for all other pollutants. For example, the emission of CO from the generators is at least eight times lower than NO_X whilst the CO ambient air quality standard is 10,000 $\mu g/m^3$ compared to the 1-hour NO_2 standard of 200 $\mu g/m^3$. Similarly, levels of $PM_{10}/PM_{2.5}$ emitted from the generators will be significantly lower than NO_X emissions whilst the ambient air quality standards are comparable.

In addition to the 26 no. 6.49 MW_{th} and 1 no. 2.19 MW_{th} emergency back-up generators which will power the site in the event of a power failure, the site also includes 2 no. fire sprinkler pump generators (0.52 MW_{th}). The diesel powered fire sprinkler pump generators have been scoped out of this air modelling assessment as it is not expected that they would cause any significant impacts on ambient air quality considering their smaller scale (compared to the stationary data hall back-up generators) and the low number required for use at any one time.

Two testing regimes for the back-up generators have also been included in the model as outlined below, all testing was assumed to occur from 8am to 5pm, Monday to Friday only.

- **Test 1:** Testing once per week of all 27 no. back-up generators on the campus at 25% load for a maximum of 30 minutes each, one generator at a time, sequentially.
- **Test 2:** All 27 no. back-up generators will be periodically tested individually at 90% load for a maximum of four hours per year. This is incorporated into the dispersion model as one generator operating, at 90% load, for one full hour, once per week during every quarter (assumed to be January, April, June and October for the purpose of this assessment).

The modelling has considered maintenance testing of the back-up generators once per week during four months of the year, however, in reality maintenance testing will occur for a maximum of 4 hours per year or only once every quarter for each back-up generator. Thus, the worst-case approach used in this study will lead to an over-estimation of the actual levels that will arise.

5.1 Emergency Operations

The diesel generators will operate in an emergency scenario as per the criteria in Section 2.2. In addition, testing of the generators will be required as outlined above.

There are two methodologies used to determine the impact from the operation of the diesel generators on ambient air quality. Both methodologies from the USEPA and UK Environment Agency have been used in this assessment, this follows the guidance outlined in Appendix K of the Irish EPA document AG4(2). Emission details can be seen in Table 3.

USEPA Guidance suggests that for emergency operations, an average hourly emission rate should be used rather than the maximum hourly rate(3). As a result, the maximum hourly emission rates from the diesel generators are reduced by $\frac{100}{8760}$ and the diesel generators are modelled over a period of one full year.

A second methodology has been published by the UK Environment Agency. The consultation document is entitled "*Diesel Generator Short-Term NO_2 Impact Assessment*"(20). The methodology is based on considering the statistical likelihood of an exceedance of the NO_2 hourly limit value (18 exceedances are allowable per year before the air standard is deemed to have been exceeded). The assessment assumes a hypergeometric distribution to assess the likelihood of exceedance hours coinciding with the emergency operational hours of the diesel generators. The cumulative hypergeometric distribution of 19 and more hours per year is computed and the probability of an exceedance determined. The guidance suggests that the 95^{th} percentile confidence level should be used to indicate if an exceedance is likely. More recent guidance(21) has recommended this probability should be multiplied by a factor of 2.5 and therefore the 98^{th} percentile confidence level should be used to indicate if an exceedance is likely. The guidance suggests that the assessment should be conducted at the nearest residential receptor or at locations where people are likely to be exposed and that there should be no running time restrictions on these generators when providing power on site during an emergency.

Both the methodology advised in the USEPA guidance as well as the approach described in the UK EA guidance have been applied for the emergency scenario modelled in this study to ensure a robust assessment of predicted air quality impacts from the diesel generators. This also follows the guidance outlined in Appendix K of the EPA AG4 guidance(2).

The modelling is undertaken to assess the impact to ambient air quality from the following two emergency operations scenarios:

The Facility: This includes the emergency operation of 24 no. of the 26 no. 6.49 MW_{th} diesel generators (the remaining 2 no. generators serving as a "catcher" generator for Building A) and emergency operation of the 1 no. 2.19 MW_{th} generator. The scenario also included testing of all 27 no. generators as described above. The process emissions are outlined in Table 3;

Cumulative Assessment: A review of sites with NO_X emissions within a 1 km radius of the subject site was conducted to determine the potential for cumulative impacts. Sites which hold an IED licence from the EPA were assessed for relevant air emissions. There are no IED licenced sites within 1 km of the subject site. At a distance of between 2 - 3 km are two licenced facilities, Irish Cement (P0030-06) and Indaver Ireland Carranstown WTE facility (P0167-03). These two facilities have been included in the cumulative assessment as outlined in Table 3.

Table 3 *Summary of Process Emission Information for all Buildings Associated with the Facility & Nearby Facilities*

Stack Reference	Stack Height Above Ground Level (m)	Exit Diameter (m)	Cross-Sectional Area (m^2)	Temp (K)	Volume Flow (Nm^3/hr at 15% Ref. O_2)	Exit Velocity (m/sec actual)	NO_x	
							Concentration (mg/Nm^3 at 15% Ref. O_2)	Mass Emission (g/s)
Emergency Operation and Testing of 6.49 MWth Back-up Diesel Generators (90% load)	25	0.58	0.26	760.75	19,966	32.8	651	0.041 Note 1 / 3.61 Note 2
Testing of 6.49 MWth Diesel Generators (25% load)				716.75	6,116	10.5	815	0.693 Note 3
Emergency Operation and Testing of 2.19 MWth Back-up Diesel Generators (90% load)	25	0.30	0.07	770.15	1,683	10.1	814	0.0043 Note 1 / 0.38 Note 2
Testing of 2.19 MWth Diesel Generators (25% load)	25	0.30	0.07	632.15	696	5.2	661	0.13 Note 3
Indaver Ireland – A1-1	65	2.2	3.8	423.15	183,700	29.1	400 / 200 Note 4	20.4 / 10.2 Note 4
Irish Cement – Kiln 2 (A2-02)	103.04	3.7	10.7	394.15	650,000	27.0	500	90.3
Irish Cement – Kiln 3 (A2-08)	123	3.75	11.0	381.15	650,000	30.7	500	90.3
Irish Cement – A2-01	98.01	2.38	4.4	360.15	49,000	5.9	500	6.8
Irish Cement – A2-03	48.1	1.0	0.8	354.15	31,000	18.9	500	4.3

Note 1 Reduced emission rates based on USEPA protocol (assuming 100 hours / annum) used to model emissions during emergency operation of generators (90% load)
Note 2 Maximum emission rates for diesel generators (based on 90% load) used to model emissions during emergency operation of generators for UK EA assessment methodology and for quarterly testing for USEPA assessment methodology
Note 3 Emission rates used to model emissions during scheduled testing at 25% load conducted once per week.
Note 4 An emission rate of 20.4 g/s for the 1-hour scenario and an emission rate of 10.2 g/s for the annual mean scenario was used in the cumulative assessment.

6.0 RESULTS

6.1 Emergency Operations (USEPA Methodology)

The NO_2 modelling results at the worst-case location at and beyond the site boundary are detailed in Table 4 based on the operation of 24 of the 26 no. 6.49 MW_{th} back-up diesel generations and 1 no. 2.19 MW_{th} back-up diesel generator for 100 hours per year using the USEPA methodology outlined within the guidance document titled '*Additional Clarification Regarding Application of Appendix W Modelling Guidance for the 1-Hour National Ambient Air Quality Standard*'[(3)] as well as considering scheduled weekly testing and quarterly maintenance testing of all 27 no. back-up generators from the installation.

The results indicate that the ambient ground level concentrations are within the relevant air quality standards for NO_2. For the worst-case year modelled, emissions from the site lead to an ambient NO_2 concentration (including background) which is 48% of the maximum ambient 1-hour limit value (measured as a 99.8th percentile) and 56% of the annual limit value at the worst-case off-site receptor. Concentrations decrease with distance from the site boundary. The geographical variations in the 1-hour mean (99.8th percentile) and annual mean NO_2 ground level concentrations for the Facility Scenario are illustrated as concentration contours in Figures 3 and 4. The locations of the maximum concentrations for NO_2 are close to the boundary of the site with concentrations decreasing with distance from the facility.

Table 4 *Dispersion Model Results for Nitrogen Dioxide (NO_2) – Emergency Operations & Scheduled Testing*

Pollutant / Year	Background (µg/m^3)	Averaging Period	Process Contribution (µg/m^3)	Predicted Environmental Concentration (µg/m^3)	Standard (µg/m^3) Note 1	% of Ambient Standard
NO_2 / 2017	30	99.8th%ile of 1-Hr Means	64.2	63.8	93.8	47%
	15	Annual mean	8.0	7.4	22.4	56%
NO_2 / 2018	30	99.8th%ile of 1-Hr Means	64.3	64.0	94.0	47%
	15	Annual mean	6.4	5.7	20.7	52%
NO_2 / 2019	30	99.8th%ile of 1-Hr Means	65.2	65.2	95.2	48%
	15	Annual mean	7.3	6.5	21.5	54%
NO_2 / 2020	30	99.8th%ile of 1-Hr Means	64.0	63.9	93.9	47%
	15	Annual mean	7.1	6.5	21.5	54%
NO_2 / 2021	30	99.8th%ile of 1-Hr Means	64.8	64.7	94.7	47%
	15	Annual mean	7.0	6.2	21.2	53%

Note 1 *Air Quality Standards 2022 (from EU Directive 2008/50/EC and S.I. 739 of 2022)*

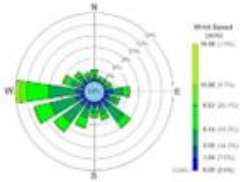
6.2 Emergency Operations (UK EA Methodology)

Emissions from 24 of the 26 no. 6.49 MW_{th} standby generators and 1 no. 2.19 MW_{th} back-up generator were assessed using the UK Environment Agency methodology. The methodology, based on considering the statistical likelihood of an exceedance of the NO_2 hourly limit value assuming a hypergeometric distribution, has been undertaken at the worst-case residential receptor for the Facility Scenario. The cumulative hypergeometric distribution of 19 and more hours per year is computed and the probability of an exceedance determined. The results have been compared to the 98th percentile confidence level to indicate if an exceedance is likely at various operational hours for the diesel generators. The results (Table 5 and Figure 5) indicate that in the worst-case year, the diesel generators can operate for the 238 hours per year before there is a likelihood of an exceedance of the ambient air quality standard (at a 98th percentile confidence level).

Table 5 *Hypergeometric Statistical Results at Worst-case Residential Receptor – Emergency Operations Scenario*

Pollutant / Year / Scenario	Hours of operation (Hours) (98th%ile) Allowed Prior To Exceedance Of Limit Value	UK Guidance – Probability Value = 0.02 (98th%ile)$^{Note\ 1}$
NO_2 / 2017	332	0.02
NO_2 / 2018	308	
NO_2 / 2019	238	
NO_2 / 2020	252	
NO_2 / 2021	251	

Note 1 Guidance Outlined In UK Environment Agency (2019) Emissions from specified generators - Guidance on dispersion modelling for oxides of nitrogen assessment from specified generators



Site boundary

Maximum concentration: 95.2µg/m³

N

Background mapping from Google Earth

Project
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Reference
217501.1059AR02

Figure 3
Max 1-Hour NO_2 Concentrations 2019 (as 99.8%ile) (µg/m³) (including background concentrations)

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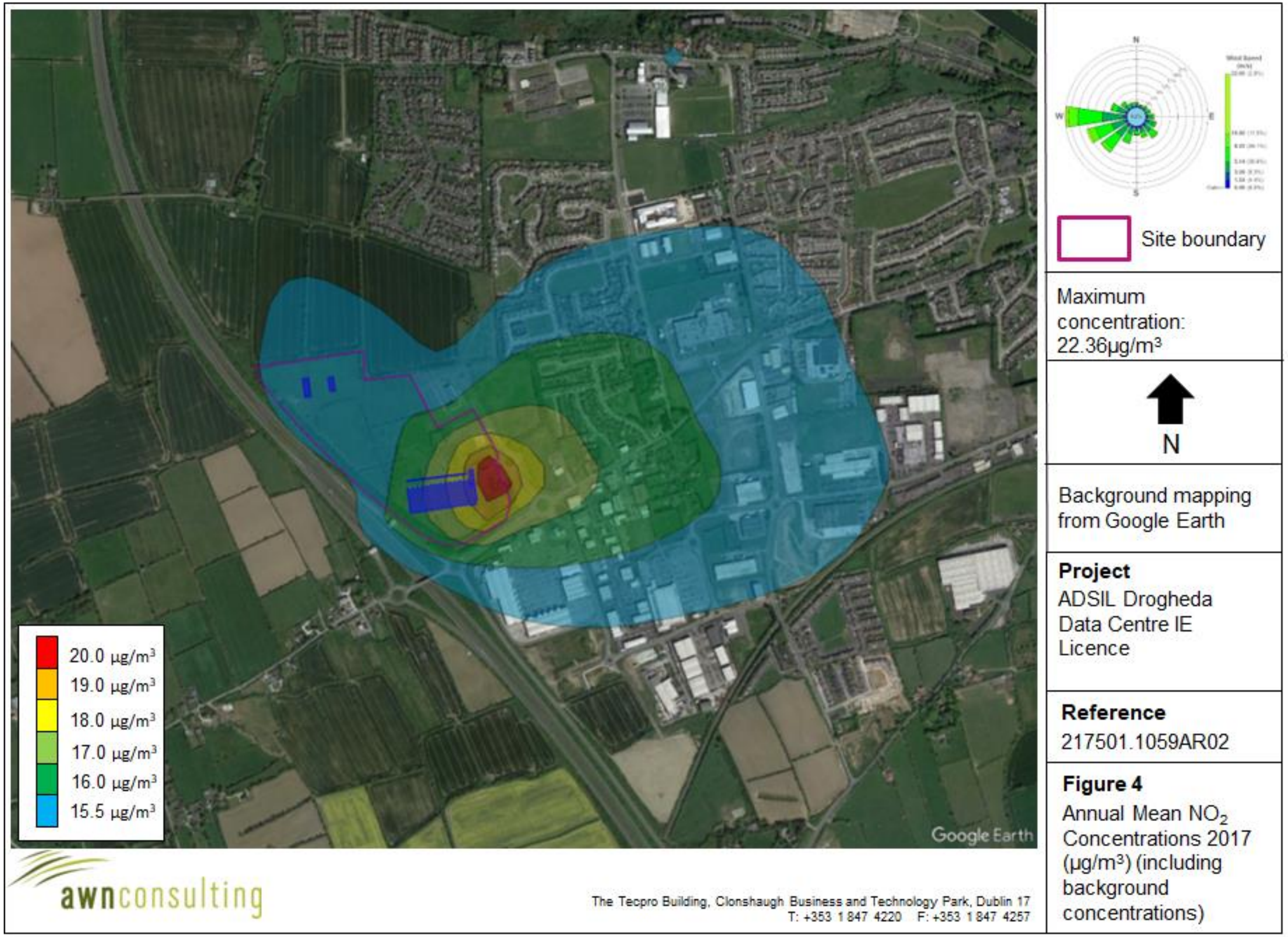
20.0 µg/m³
19.0 µg/m³
18.0 µg/m³
17.0 µg/m³
16.0 µg/m³
15.5 µg/m³
Google Earth
awnconsulting
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Site boundary
Maximum concentration: 22.36µg/m³
N
Background mapping from Google Earth
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Reference
217501.1059AR02
Figure 4
Annual Mean NO_2 Concentrations 2017 (µg/m³) (including background concentrations)

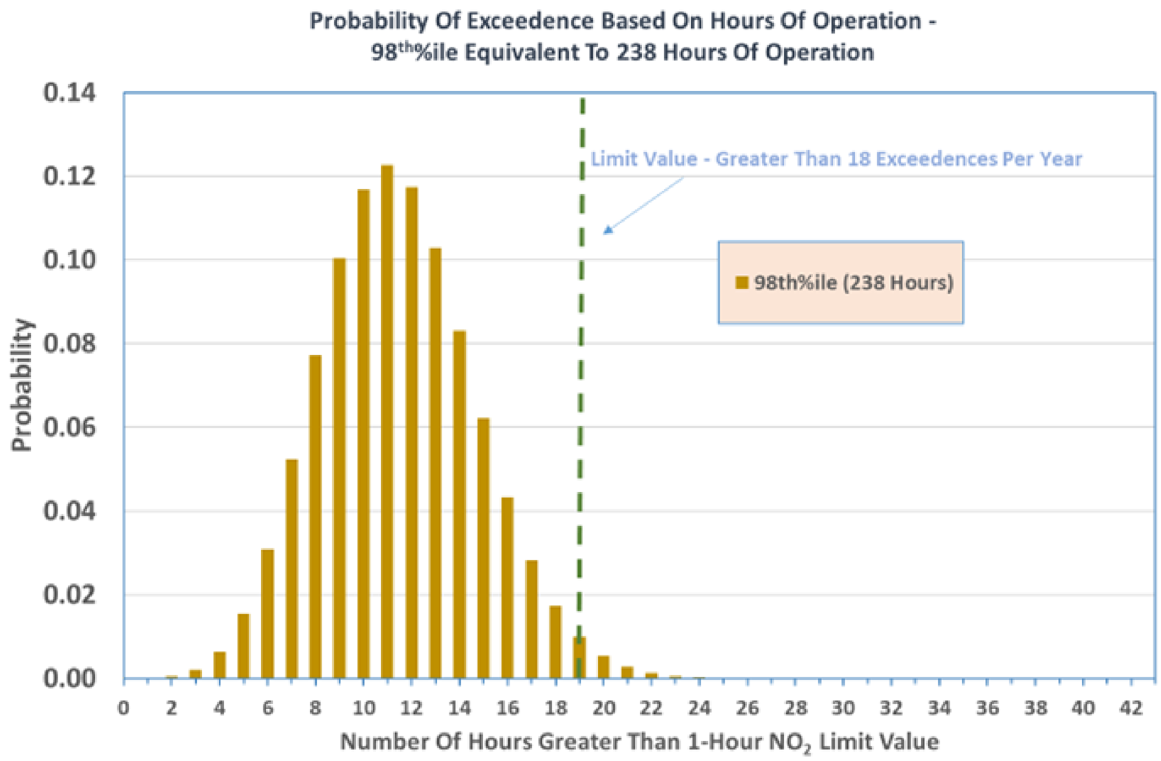

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Figure 5
Probability of Exceedance of 1-Hour NO_2 Ambient Air Quality Limit Value based on Hours of Operation for Emergency Generators

6.3 Cumulative Operations (USEPA Methodology)

The NO_2 cumulative modelling results at the worst-case location at and beyond the site boundary are detailed in Table 6 based on the operation of 24 of the 26 no. 6.49 MW_{th} back-up diesel generations and 1 no. 2.19 MW_{th} back-up diesel generator for 100 hours per year using the USEPA methodology outlined within the guidance document titled '*Additional Clarification Regarding Application of Appendix W Modelling Guidance for the 1-Hour National Ambient Air Quality Standard'*[(3)] as well as considering scheduled weekly testing and quarterly maintenance testing of all 27 no. back-up generators from the installation in addition to the continuous operation of the four emission points from Irish Cement and main emission point from Indaver Ireland.

The results indicate that the ambient ground level concentrations are within the relevant air quality standards for NO_2. For the worst-case year modelled, emissions from the site and nearby facilities lead to an ambient NO_2 concentration (including background) which is 48% of the maximum ambient 1-hour limit value (measured as a 99.8th percentile) and 58% of the annual limit value at the worst-case off-site receptor. Concentrations decrease with distance from the site boundary. The geographical variations in the 1-hour mean (99.8th percentile) and annual mean NO_2 ground level concentrations for the Cumulative Operations Scenario are illustrated as concentration contours in Figures 6 and 7. The locations of the maximum concentrations for NO_2 are close to the boundary of the site with concentrations decreasing with distance from the facility.

Table 6 *Dispersion Model Results for Nitrogen Dioxide (NO_2) – Cumulative Operations Scenario*

Pollutant / Year	Background ($\mu g/m^3$)	Averaging Period	Process Contribution ($\mu g/m^3$)	Predicted Environmental Concentration ($\mu g/m^3$)	Standard ($\mu g/m^3$) Note 1	% of Ambient Standard
NO_2 / 2017	30	99.8th%ile of 1-Hr Means	64.2	94.2	200	47%
	15	Annual mean	8.0	23.0	40	58%
NO_2 / 2018	30	99.8th%ile of 1-Hr Means	64.3	94.3	200	47%
	15	Annual mean	6.4	21.4	40	54%
NO_2 / 2019	30	99.8th%ile of 1-Hr Means	65.2	95.2	200	48%
	15	Annual mean	7.3	22.3	40	56%
NO_2 / 2020	30	99.8th%ile of 1-Hr Means	64.0	94.0	200	47%
	15	Annual mean	7.1	22.1	40	55%
NO_2 / 2021	30	99.8th%ile of 1-Hr Means	64.8	94.8	200	47%
	15	Annual mean	7.0	22.0	40	55%

Note 1 Air Quality Standards 2022 (from EU Directive 2008/50/EC and S.I. 739 of 2022)

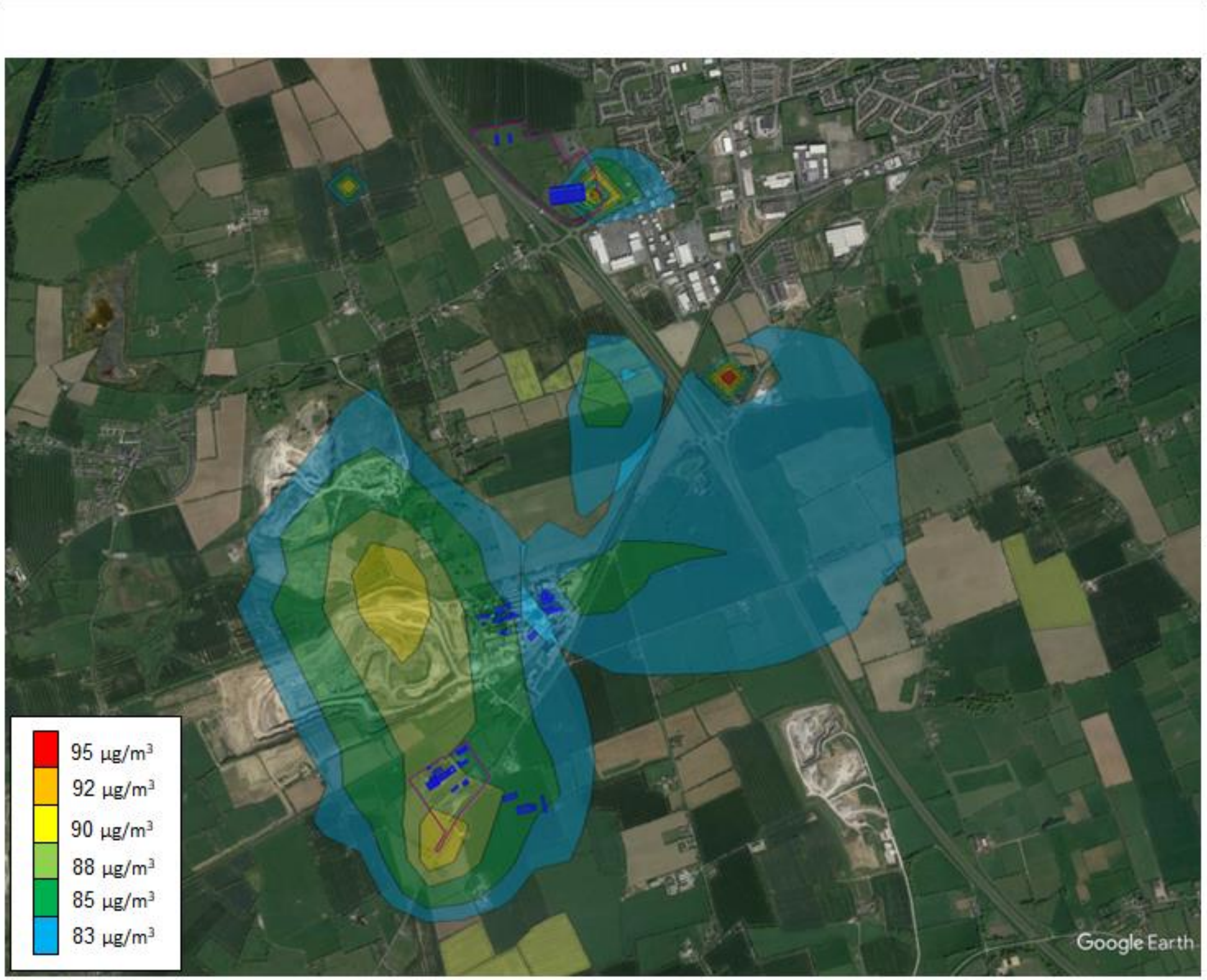
6.4 Cumulative Emergency Operations (UK EA Methodology)

Emissions from 24 of the 26 no. 6.49 MW_{th} standby generators and 1 no. 2.19 MW_{th} back-up generator were assessed using the UK Environment Agency methodology in addition to the continuous operation of the four emission points from Irish Cement and main emission point from Indaver Ireland. The methodology, based on considering the statistical likelihood of an exceedance of the NO_2 hourly limit value assuming a hypergeometric distribution, has been undertaken at the worst-case residential receptor for the Cumulative Scenario. The cumulative hypergeometric distribution of 19 and more hours per year is computed and the probability of an exceedance determined. The results have been compared to the 98^{th} percentile confidence level to indicate if an exceedance is likely at various operational hours for the diesel generators. The results (Table 7) indicate that in the worst-case year, the diesel generators can operate for the 238 hours per year before there is a likelihood of an exceedance of the ambient air quality standard (at a 98^{th} percentile confidence level).

Table 7 *Hypergeometric Statistical Results at Worst-case Residential Receptor – Cumulative Operations Scenario*

Pollutant / Year / Scenario	Hours of operation (Hours) (98^{th}%ile) Allowed Prior To Exceedance Of Limit Value	UK Guidance – Probability Value = 0.02 (98^{th}%ile)[Note 1]
NO_2 / 2017	332	0.02
NO_2 / 2018	308	
NO_2 / 2019	238	
NO_2 / 2020	252	
NO_2 / 2021	251	

Note 1 Guidance Outlined In UK Environment Agency (2019) Emissions from specified generators - Guidance on dispersion modelling for oxides of nitrogen assessment from specified generators



Maximum concentration: 95.2µg/m³

Background mapping from Google Earth

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Figure 6
Cumulative Max 1-Hour NO_2 Concentrations 2019 (as 99.8%ile) (µg/m³) (including background concentrations)

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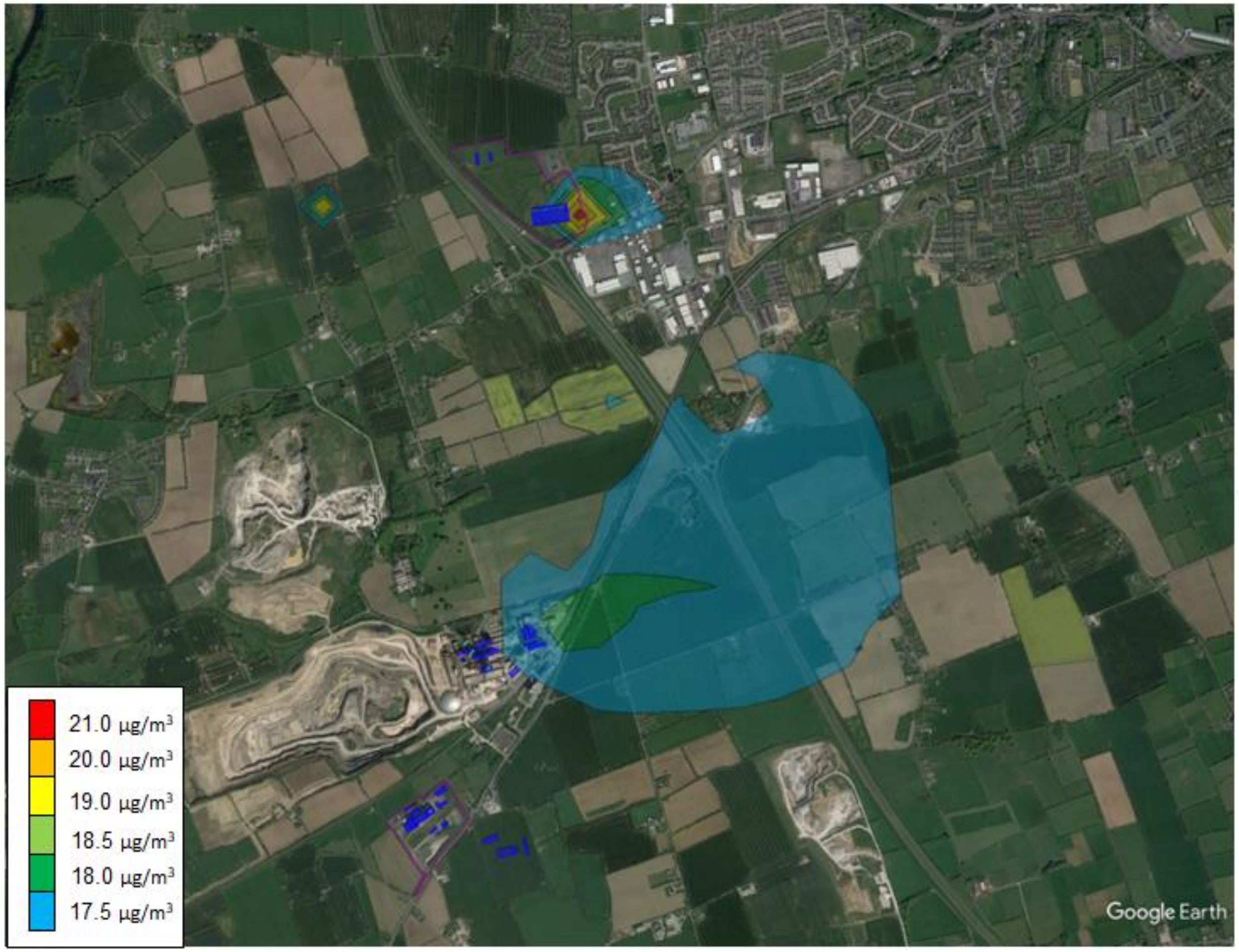

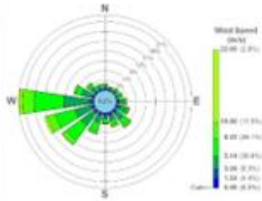

Site boundary

Maximum concentration: 23.0µg/m³

N

Background mapping from Google Earth

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Figure 7
Annual Mean NO_2 Concentrations 2017 (µg/m³) (including background concentrations)

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7.0 ASSESSMENT SUMMARY

The assessment was carried out the determine the ambient air quality impact of the site. As the diesel generators will be used solely for emergency operation (i.e. less than 500 hours per year) thus the emission limit values outlined in the Medium Combustion Plant Directive are not applicable to the diesel generators on site.

The Facility

The NO_2 modelling results at the worst-case location at and beyond the site boundary are based on the operation of 24 of the 26 no. 6.49 MW_{th} back-up diesel generations and 1 no. 2.19 MW_{th} back-up generator for 100 hours per year using the USEPA methodology outlined within the guidance document titled '*Additional Clarification Regarding Application of Appendix W Modelling Guidance for the 1-Hour National Ambient Air Quality Standard*' as well as considering scheduled weekly testing and quarterly maintenance testing of all 27 no. back-up generators from the installation.

The results indicate that the ambient ground level concentrations are in compliance with the relevant air quality standards for NO_2. For the worst-case year, emissions from the site lead to an ambient NO_2 concentration (including background) which is 48% of the maximum ambient 1-hour limit value (measured as a 99.8th percentile) and 56% of the annual limit value at the worst-case off-site receptor.

The UK EA assessment methodology determined that in any year, the diesel generators can run for 238 hours before there is a likelihood of an exceedance at the nearest residential receptor (at a 98th percentile confidence level).

Cumulative Assessment

The NO_2 cumulative modelling results at the worst-case location at and beyond the site boundary are based on the operation of 24 of the 26 no. 6.49 MW_{th} back-up diesel generations and 1 no. 2.19 MW_{th} back-up diesel generator for 100 hours per year using the USEPA methodology as well as considering scheduled weekly testing and quarterly maintenance testing of all 27 no. back-up generators from the installation in addition to the continuous operation of the four emission points from Irish Cement and main emission point from Indaver Ireland.

The results indicate that the ambient ground level concentrations are within the relevant air quality standards for NO_2. For the worst-case year modelled, emissions from the site and nearby facilities lead to an ambient NO_2 concentration (including background) which is 48% of the maximum ambient 1-hour limit value (measured as a 99.8th percentile) and 58% of the annual limit value at the worst-case off-site receptor. Concentrations decrease with distance from the site boundary.

The cumulative UK EA assessment methodology determined that in any year, the diesel generators can run for 238 hours before there is a likelihood of an exceedance at the nearest residential receptor (at a 98th percentile confidence level).

Conclusion

In summary, emissions to atmosphere of NO_2, as the main polluting substance (as defined in the Schedule of EPA (Industrial Emissions) (Licensing) Regulations 2013, S.I. No. 137 of 2013) from the standby generators, will be in compliance with the ambient air quality standards which are based on the protection of the environment and human health. Therefore, no significant impacts to the ambient air quality environment are predicted.

In terms of impacts at nearby ecologically sensitive areas, the closest sensitive ecological area is the River Boyne And River Blackwater SAC (Site Code 002299) located over 1 km to the north of the subject site. Dispersion modelling of NO_X emissions from the installation at this distance is not required as there is no potential for significant impacts to vegetation as a result of emissions from the installation at such a distance. Emissions from the back-up generators on site peak at the site boundary and fall off rapidly with increasing distance from the installation.

8.0 REFERENCES

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APPENDIX I

Description of the AERMOD Model

The AERMOD dispersion model has been developed in part by the U.S. Environmental Protection Agency (USEPA)[1,5]. The model is a steady-state Gaussian model used to assess pollutant concentrations associated with industrial sources. The model is an enhancement on the Industrial Source Complex-Short Term 3 (ISCST3) model which has been widely used for emissions from industrial sources.

Improvements over the ISCST3 model include the treatment of the vertical distribution of concentration within the plume. ISCST3 assumes a Gaussian distribution in both the horizontal and vertical direction under all weather conditions. AERMOD with PRIME, however, treats the vertical distribution as non-Gaussian under convective (unstable) conditions while maintaining a Gaussian distribution in both the horizontal and vertical direction during stable conditions. This treatment reflects the fact that the plume is skewed upwards under convective conditions due to the greater intensity of turbulence above the plume than below. The result is a more accurate portrayal of actual conditions using the AERMOD model. AERMOD also enhances the turbulence of night-time urban boundary layers thus simulating the influence of the urban heat island.

In contrast to ISCST3, AERMOD is widely applicable in all types of terrain. Differentiation of the simple versus complex terrain is unnecessary with AERMOD. In complex terrain, AERMOD employs the dividing-streamline concept in a simplified simulation of the effects of plume-terrain interactions. In the dividing-streamline concept, flow below this height remains horizontal, and flow above this height tends to rise up and over terrain. Extensive validation studies have found that AERMOD (precursor to AERMOD with PRIME) performs better than ISCST3 for many applications and as well or better than CTDMPLUS for several complex terrain data sets[7].

Due to the proximity to surrounding buildings, the PRIME (Plume Rise Model Enhancements) building downwash algorithm has been incorporated into the model to determine the influence (wake effects) of these buildings on dispersion in each direction considered. The PRIME algorithm takes into account the position of the stack relative to the building in calculating building downwash. In the absence of the building, the plume from the stack will rise due to momentum and/or buoyancy forces. Wind streamlines act on the plume leads to the bending over of the plume as it disperses. However, due to the presence of the building, wind streamlines are disrupted leading to a lowering of the plume centreline.

When there are multiple buildings, the building tier leading to the largest cavity height is used to determine building downwash. The cavity height calculation is an empirical formula based on building height, the length scale (which is a factor of building height & width) and the cavity length (which is based on building width, length and height). As the direction of the wind will lead to the identification of differing dominant tiers, calculations are carried out in intervals of 10 degrees.

In PRIME, the nature of the wind streamline disruption as it passes over the dominant building tier is a function of the exact dimensions of the building and the angle at which the wind approaches the building. Once the streamline encounters the zone of influence of the building, two forces act on the plume. Firstly, the disruption caused by the building leads to increased turbulence and enhances horizontal and vertical dispersion. Secondly, the streamline descends in the lee of the building due to the reduced pressure and drags the plume (or part of) nearer to the ground, leading to higher ground level concentrations. The model calculates the descent of the plume as a function of the building shape and, using a numerical plume rise model, calculates the change in the plume centreline location with distance downwind.

The immediate zone in the lee of the building is termed the cavity or near wake and is characterised by high intensity turbulence and an area of uniform low pressure. Plume mass captured by the cavity region is re-emitted to the far wake as a ground-level volume source. The volume source is located at the base of the lee wall of the building, but is only evaluated near the end of the near wake and beyond. In this region, the disruption caused by the building downwash gradually fades with distance to ambient values downwind of the building.

AERMOD has made substantial improvements in the area of plume growth rates in comparison to ISCST3[4,8]. ISCST3 approximates turbulence using six Pasquill-Gifford-Turner Stability Classes and bases the resulting dispersion curves upon surface release experiments. This treatment, however, cannot explicitly account for turbulence in the formulation. AERMOD is based on the more realistic modern planetary boundary layer (PBL) theory which allows turbulence to vary with height. This use of turbulence-based plume growth with height leads to a substantial advancement over the ISCST3 treatment.

Improvements have also been made in relation to mixing height[4,8]. The treatment of mixing height by ISCST3 is based on a single morning upper air sounding each day. AERMOD, however, calculates mixing height on an hourly basis based on the morning upper air sounding and the surface energy balance, accounting for the solar radiation, cloud cover, reflectivity of the ground and the latent heat due to evaporation from the ground cover. This more advanced formulation provides a more realistic sequence of the diurnal mixing height changes.

AERMOD also has the capability of modelling both unstable (convective) conditions and stable (inversion) conditions. The stability of the atmosphere is defined by the sign of the sensible heat flux. Where the sensible heat flux is positive, the atmosphere is unstable whereas when the sensible heat flux is negative the atmosphere is defined as stable. The sensible heat flux is dependent on the net radiation and the available surface moisture (Bowen Ratio). Under stable (inversion) conditions, AERMOD has specific algorithms to account for plume rise under stable conditions, mechanical mixing heights under stable conditions and vertical and lateral dispersion in the stable boundary layer.

AERMOD also contains improved algorithms for dealing with low wind speed (near calm) conditions. As a result, AERMOD can produce model estimates for conditions when the wind speed may be less than 1 m/s, but still greater than the instrument threshold.

APPENDIX II
Meteorological Data - AERMET

AERMOD incorporates a meteorological pre-processor AERMET(14). AERMET allows AERMOD to account for changes in the plume behaviour with height. AERMET calculates hourly boundary layer parameters for use by AERMOD, including friction velocity, Monin-Obukhov length, convective velocity scale, convective (CBL) and stable boundary layer (SBL) height and surface heat flux. AERMOD uses this information to calculate concentrations in a manner that accounts for changes in dispersion rate with height, allows for a non-Gaussian plume in convective conditions, and accounts for a dispersion rate that is a continuous function of meteorology.

The AERMET meteorological preprocessor requires the input of surface characteristics, including surface roughness (z_0), Bowen Ratio and albedo by sector and season, as well as hourly observations of wind speed, wind direction, cloud cover, and temperature. A morning sounding from a representative upper air station, latitude, longitude, time zone, and wind speed threshold are also required.

Two files are produced by AERMET for input to the AERMOD dispersion model. The surface file contains observed and calculated surface variables, one record per hour. The profile file contains the observations made at each level of a meteorological tower, if available, or the one-level observations taken from other representative data, one record level per hour.

From the surface characteristics (i.e. surface roughness, albedo and amount of moisture available (Bowen Ratio)) AERMET calculates several boundary layer parameters that are important in the evolution of the boundary layer, which, in turn, influences the dispersion of pollutants. These parameters include the surface friction velocity, which is a measure of the vertical transport of horizontal momentum; the sensible heat flux, which is the vertical transport of heat to/from the surface; the Monin-Obukhov length which is a stability parameter relating the surface friction velocity to the sensible heat flux; the daytime mixed layer height; the nocturnal surface layer height and the convective velocity scale which combines the daytime mixed layer height and the sensible heat flux. These parameters all depend on the underlying surface.

The values of albedo, Bowen Ratio and surface roughness depend on land-use type (e.g., urban, cultivated land etc) and vary with seasons and wind direction. The assessment of appropriate land-use types is carried out in line with USEPA recommendations(5) and using the detailed methodology outlined by the Alaska Department of Environmental Conservation(16). AERMET has also been updated to allow for an adjustment of the surface friction velocity (u*) for low wind speed stable conditions based on the work of Qian and Venkatram (BLM, 2011). Previously, the model had a tendency to over-predict concentrations produced by near-ground sources in stable conditions.

Surface roughness

Surface roughness length is the height above the ground at which the wind speed goes to zero. Surface roughness length is defined by the individual elements on the landscape such as trees and buildings. In order to determine surface roughness length, the USEPA recommends that a representative length be defined for each sector, based on an upwind area-weighted average of the land use within the sector, by using the eight land use categories outlined by the USEPA. The inverse-distance weighted surface roughness length derived from the land use classification within a radius of 1km from Dublin Airport Meteorological Station is shown in Table A1.

Table A1 Surface Roughness based on an inverse distance weighted average of the land use within a 1km radius of Dublin Airport Meteorological Station.

Sector	Area Weighted Land Use Classification	Spring	Summer	Autumn	Winter[Note 1]
0-360	100% Grassland	0.050	0.100	0.010	0.010

Note 1: Winter defined as periods when surfaces covered permanently by snow whereas autumn is defined as periods when freezing conditions are common, deciduous trees are leafless and no snow is present (Iqbal, 1983). Thus for the current location autumn more accurately defines "winter" conditions at the facility.

Albedo

Noon-time albedo is the fraction of the incoming solar radiation that is reflected from the ground when the sun is directly overhead. Albedo is used in calculating the hourly net heat balance at the surface for calculating hourly values of Monin-Obuklov length. A 10km x 10km square area is drawn around the meteorological station to determine the albedo based on a simple average for the land use types within the area independent of both distance from the station and the near-field sector. The classification within 10km from Dublin Airport Meteorological Station is shown in Table A2.

Table A2 Albedo based on a simple average of the land use within a 10km × 10km grid centred on Dublin Airport Meteorological Station.

Area-weighted Land Use Classification	Spring	Summer	Autumn	Winter[1]
0.5% Water, 30% Urban, 0.5% Coniferous Forest 38% Grassland, 19% Cultivated Land	0.155	0.180	0.187	0.187

(1) For the current location autumn more accurately defines "winter" conditions in Ireland.

Bowen Ratio

The Bowen ratio is a measure of the amount of moisture at the surface of the earth. The presence of moisture affects the heat balance resulting from evaporative cooling which, in turn, affects the Monin-Obukhov length which is used in the formulation of the boundary layer. A 10km x 10km square area is drawn around the meteorological station to determine the Bowen Ratio based on geometric mean of the land use types within the area independent of both distance from the station and the near-field sector. The classification within 10km from Dublin Airport Meteorological Station is shown in Table A3.

Table A3 Bowen Ratio based on a geometric mean of the land use within a 10km × 10km grid centred on Dublin Airport Meteorological Station.

Geometric Mean Land Use Classification	Spring	Summer	Autumn	Winter[1]
0.5% Water, 30% Urban, 0.5% Coniferous Forest 38% Grassland, 19% Cultivated Land	0.549	1.06	1.202	1.202

(1) For the current location autumn more accurately defines "winter" conditions in Ireland.