The Tecpro Building,
Clonshaugh Business & Technology Park,
Dublin 17, Ireland.

T: + 353 1 847 4220
F: + 353 1 847 4257
E: info@awnconsulting.com
W: www.awnconsulting.com

DETERMINATION OF AIR EMISSIONS TO ATMOSPHERE FROM THE NESTLE FACILITY, ASKEATON, COUNTY LIMERICK

Technical Report Prepared For

Nestle Askeaton
Coolrahnee
Askeaton
County Limerick

Technical Report Prepared By

Dr. Edward Porter C Chem MRSC MIAQM

Our Reference

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Cork Office
Unit 5, ATS Building,
Carrigaline Industrial Estate,
Carrigaline, Co. Cork.
T: +353 21 438 7400
F: +353 21 483 4606

AWN Consulting Limited
Registered in Ireland No. 319812
Directors: F Callaghan, C Dilworth,
T Donnelly, E Porter
Associate Director: D Kelly

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EXECUTIVE SUMMARY

AWN Consulting Ltd were commissioned to carry out an air dispersion modelling study of emissions from the Nestle Askeaton facility in Askeaton, Co. Limerick based on the current design details. The modelling assessment will form part of the Technical Amendment application process which will be required due, in part, to the installation of one new emission points on-site (A2-8) and the decommissioning of two emission points (A2-2 and A2-5).

The air dispersion modelling compared the ambient air quality impact of the current licensed main emission points (A2-1, A2-2, A2-3, A2-4, A2-5 and A2-6) and the proposed scenario based on five emission points (A2-1, A2-3, A2-4, A2-6 and A2-8).

Air dispersion modelling was carried out using the United States Environmental Protection Agency's regulatory model AERMOD (Version 16128r). The aim of the study was to assess both the existing scenario and secondly the contribution of one new emission point and all remaining existing emission points from the facility to off-site levels of release substances and to identify the location and maximum of the worst-case ground level concentrations for each compound assessed. The dispersion model study consisted of the following components:

- Review of new and existing emission data and other relevant information needed for the modelling study;
- Summary of background for the pollutants of concern (PM_{10} / $PM_{2.5}$ levels);
- Dispersion modelling of released substances under the current and proposed emission scenarios;
- Presentation of predicted ground level concentrations of released substances;
- Evaluation of the significance of these predicted concentrations, including consideration of whether these ground level concentrations are likely to exceed the relevant ambient air quality limit values.

Assessment Summary

The results indicate that the ambient ground level concentrations are below the relevant air quality standards for PM_{10} / $PM_{2.5}$ for the existing scenario. Emissions from the facility lead to an ambient PM_{10} concentration (including background) which is 86% of the maximum ambient 24-hour limit value at the worst-case receptor. In relation to the annual mean concentration, ambient PM_{10} / $PM_{2.5}$ concentration (including background) are at most 58% of the annual mean limit values at the worst-case receptor.

The results also indicate that the ambient ground level concentrations are below the relevant air quality standards for PM_{10} / $PM_{2.5}$ for the proposed scenario. Emissions from the facility lead to an ambient PM_{10} concentration (including background) which is 73% of the maximum ambient 24-hour limit value at the worst-case receptor. In relation to the annual mean concentration, ambient PM_{10} / $PM_{2.5}$ concentration (including background) are at most 50% of the annual mean limit values at the worst-case receptor.

Comparing the results of the existing and proposed modelling scenarios shows that the impact of the proposed removal of main emission points A2-2 and A2-5 and the introduction of main emission point A2-8 is to decrease the predicted ambient air concentrations for all averaging periods and for both PM_{10} and $PM_{2.5}$. The benefit of the proposed changes to licenced emission points is to decrease ambient levels of PM_{10} by as much as 13% of the ambient limit value whilst $PM_{2.5}$ ambient levels will decrease by up 10% of the ambient limit value.

In summary, all emissions from the facility under normal operations of the facility will be in compliance with the ambient air quality standards whilst the proposed changes to the licenced emission points will further reduced environmental concentrations.

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1.0 INTRODUCTION

AWN Consulting Ltd were commissioned to carry out an air dispersion modelling study of emissions from the Nestle Askeaton facility in Askeaton, Co. Limerick based on the current and proposed design details. The modelling assessment will form part of the Technical Amendment application process which will be required due, in part, to the installation of one new emission points on-site (A2-8) and the decommissioning of two emission points (A2-2 and A2-5).

The air dispersion modelling will compare the ambient air quality impact of the current licensed main emission points (A2-1, A2-2, A2-3, A2-4, A2-5 and A-2-6) and the proposed scenario based on five emission points (A2-1, A2-3, A2-4, A-2-6 and A2-8). The current Industrial Emission Directive (IED) Licence for the facility is P0395-03.

The site, consisting of approximately 13 hectares, is located approximately 25km west of Limerick City and 1km north of Askeaton. In the immediate region of the facility, the land-use is dominated by agriculture and one-off housing as shown in Figure 1 with Askeaton village located approximately 1 km south of the facility. Several residential units are also located in the vicinity of the facility with various commercial units located within 500m of the site. The River Shannon & River Fergus SPA is also located immediately east of the facility with the Lower Shannon SAC located within 1km north of the site.

Air dispersion modelling was carried out using the United States Environmental Protection Agency's regulatory model AERMOD (Version 16128r). The aim of the study was to assess both the existing scenario and secondly the contribution of one new emission point and all remaining existing emission points from the facility to off-site levels of release substances and to identify the location and maximum of the worst-case ground level concentrations for each compound assessed. The dispersion model study consisted of the following components:

- Review of emission data and other relevant information needed for the modelling study;
- Summary of background PM_{10} / $PM_{2.5}$ levels;
- Dispersion modelling of PM_{10} / $PM_{2.5}$ under the current and proposed emission scenarios;
- Presentation of predicted ground level concentrations of released substances;
- Evaluation of the significance of these predicted concentrations, including consideration of whether these ground level concentrations are likely to exceed the relevant ambient air quality limit values.

Information supporting the conclusions has been detailed in the following sections. The assessment methodology and study inputs are presented in Section 2. The dispersion modelling results and assessment summaries are presented in Section 3. The model formulation is detailed in Appendix I, a review of the meteorological data used is detailed in Appendix II whilst detailed meteorological data is presented in Appendix III.

Site Location
Residential Areas
Industry / Warehousing
Commercial

Scale
1:16,000
N

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Figure 1
Map Of Land-Use In The Vicinity Of Nestle Askeaton, Askeaton, County Limerick

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T: +353 1 847 4220 F: +353 1 847 4257

2.0 ASSESSMENT METHODOLOGY

Emissions from the facility have been modelled using the AERMOD dispersion model (Version 16216r) 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(3) as the regulatory model by the USEPA for modelling emissions from industrial sources in both flat and rolling terrain(4-6). The model has more advanced algorithms and gives better agreement with monitoring data in extensive validation studies(7-10). 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 was then added to the background concentration to give the worst-case predicted environmental concentration (PEC). The PEC was then compared with the relevant ambient air quality standard to assess the significance of the releases from the site.

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 were reported in this study, even if no residential receptors were near the location of this maximum;
- Worst-case background concentrations were used to assess the baseline levels of substances released from the site;
- The effects of building downwash, due to on-site and any nearby off-site buildings, has been included in the model;
- Worst-case operations for PM_{10} / $PM_{2.5}$ emissions assumes all emission points were running continuously for a full year;
- Hours of operation were based on the highest recorded level over the last five years for each emission point. It was also assumed that all emission points overlap for a significant period each day that the emission points were in operation;
- Modelling assumed that all emission points were running at the IED emission concentration and maximum volume flow for each hour modelled.

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 2011, which incorporate EU Directive 2008/50/EC (see Table 1). The ambient air quality standards applicable for PM_{10} / $PM_{2.5}$ are outlined in this Directive.

These standards have been used in the current assessment to determine the potential impact of PM_{10} / $PM_{2.5}$ emissions from the proposed facility on air quality.

Pollutant	Regulation Note 1	Limit Type	Value
Particulate Matter (as PM_{10})	2008/50/EC	24-hour limit for protection of human health - not to be exceeded more than 35 times/year	50 µg/m³ PM_{10}
		Annual limit for protection of human health	40 µg/m³ PM_{10}
$PM_{2.5}$	2008/50/EC	Annual limit for protection of human health	25 µg/m³ $PM_{2.5}$

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

Table 1 Air Quality Standards 2011 (Based on Directive 2008/50/EC)

2.2 Background Concentrations Of Pollutants

Air quality monitoring programs have been undertaken in recent years by the EPA and Local Authorities(11,12). The most recent annual report on air quality "Air Quality Monitoring Annual Report 2015"(11), 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(11). 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, Askeaton is categorised as Zone D(11).

PM_{10}

Long-term PM_{10} monitoring was carried out at the Zone D locations of Castlebar, Claremorris, Enniscorthy and Kilkitt in 2015. The PM_{10} annual averages for these four locations in 2015 ranged from 9.2 to 18 µg/m³(11). The PM_{10} annual average in 2015 for the rural Zone D location of Kilkitt was 9.2 µg/m³(11). In addition, data from the Phoenix Park provides a good indication of urban background levels, with an annual average in 2015 of 12 µg/m³(11). Based on the above information, a conservative estimate of the background PM_{10} concentration for Askeaton of 10 µg/m³ has been used. In relation to the maximum 24-hour averaging period, real monitoring data for Kilkitt for 2015 (90th%ile of 18.0 µg/m³) was employed using the methodology outlined in Appendix E of AG4(2). A summary of the average short-term and annual mean PM_{10} concentrations at Zone D locations is shown in Tables 2 and 3.

In relation to the annual averages, the ambient background concentration was added directly to the process concentration. However, in relation to the short-term peak concentration, concentrations due to emissions from elevated sources cannot be combined in the same way. Guidance from the UK DEFRA(13) and EPA(2) advises that for PM_{10} an estimate of the maximum combined pollutant concentration can be obtained as shown on the following page:

PM_{10} - The 90.4th%ile of total 24-hour mean PM_{10} is equal to the maximum of either A or B below:

a) 90.4th%ile of 24-hour mean background PM_{10} + annual mean process contribution PM_{10}

b) 90.4th%ile 24-hour mean process contribution PM_{10} + annual mean background PM_{10}

$PM_{2.5}$

The results of $PM_{2.5}$ monitoring at the Zone D location of Claremorris in 2015[11] indicated an average $PM_{2.5}/PM_{10}$ ratio of 0.6. Based on this information, a conservative ratio of 0.65 was used to generate a background $PM_{2.5}$ concentration of 6.5 µg/m^3.

Year	Claremorris	Kilkitt	Shannon Town	Castlebar
2012	17.7	15.9	23.1	19.8
2013	21	18.6	-	26.9
2014	9.5	15.4	-	21.4
2015	10.2	18.0	-	22.7
Average	**14.6**	**17.0**	**23.1**	**22.7**

Table 2 90th%ile of 24-Hour PM_{10} Concentrations In Zone D Locations 2012 - 2015 (µg/m^3)

Year	Claremorris	Kilkitt	Shannon Town	Castlebar
2012	10	9	11	12
2013	13	11	-	15
2014	15.4	8.9	-	12.4
2015	16.6	9.2	-	12.9
Average	**13.8**	**9.5**	**11.0**	**13.1**

Table 3 Annual Mean PM_{10} Concentrations In Zone D Locations 2010 - 2013 (µg/m^3)

2.3 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:

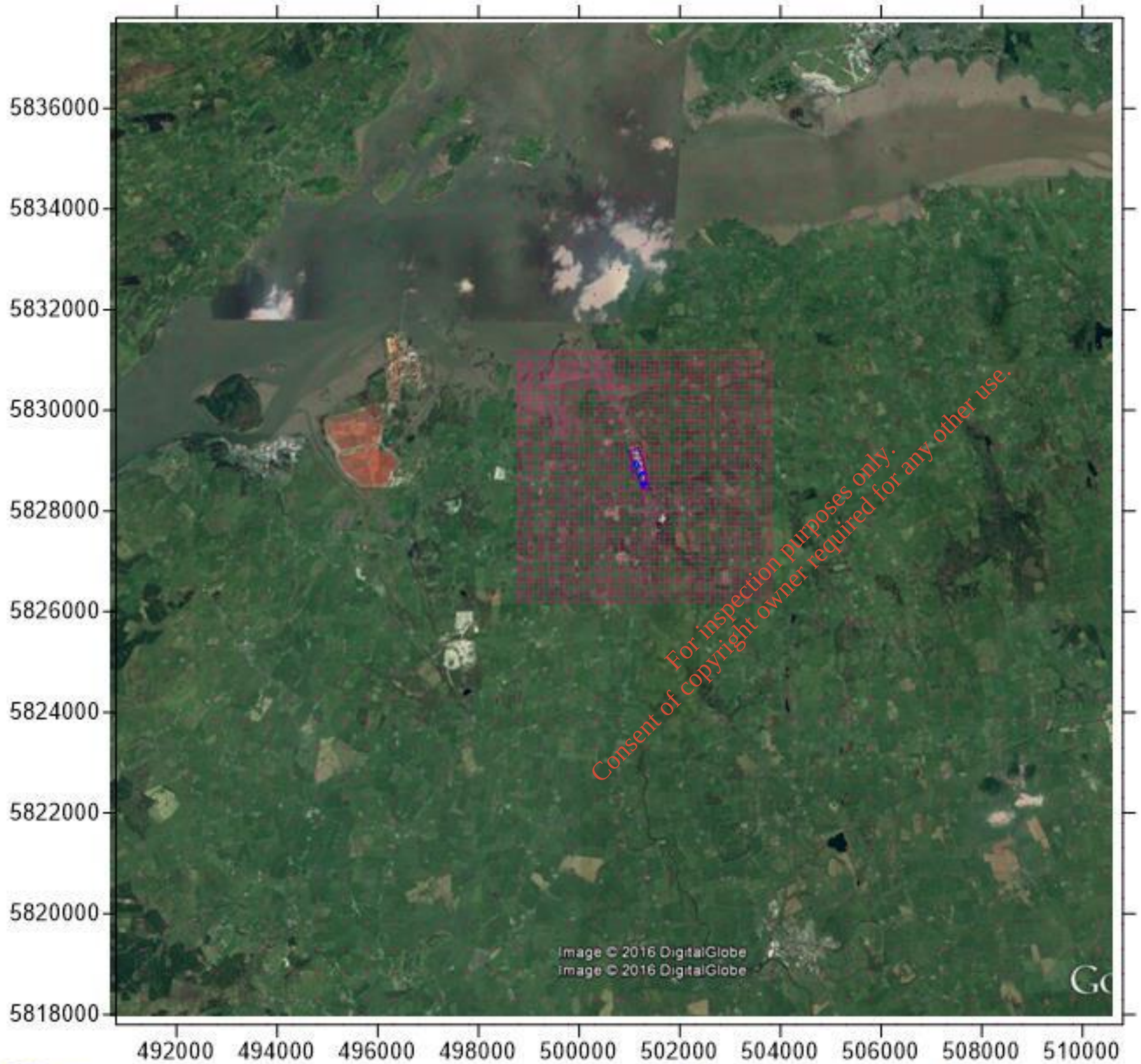
- Three receptor grids were created at which concentrations would be modelled. Receptors were mapped with sufficient resolution to ensure all localised "hot-spots" were identified without adding unduly to processing time. The receptor grids were based on Cartesian grids with the site at the centre. An outer grid extended to 20,000m^2 with the site at the centre and with concentrations calculated at 500m intervals. A middle grid extended to 5,000m^2 with the site at the centre and with concentrations calculated at 100m intervals. A smaller denser grid extended to 1250m from the site with concentrations calculated at 25m intervals. Boundary receptor locations were also placed along the boundary of the site, at 20m intervals, giving a total of 14,368 calculation points for the model as shown in Figure 2 (outer, middle and boundary receptors shown for ease of viewing).

- All on-site buildings and significant process structures were 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 were incorporated into the modelling.

- Detailed terrain has been mapped into the model using SRTM data with 30m resolution. The site is located in gentle terrain. All terrain features have been mapped in detail into the model using the terrain pre-processor AERMAP[14] as shown in Figure 3.

- Hourly-sequenced meteorological information has been used in the model. Meteorological data over a five year period (Shannon Airport, 2012 – 2016) was used in the model (see Figure 4 and Appendix III).

- The source and emission data, including stack dimensions, gas volumes and emission temperatures have been incorporated into the model.



Background Mapping from Google Earth

Receptor

Scale

1:25,000

N

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Figure 2

AERMOD

3-Tier Receptor Grid

14,368 Calculation points

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2.4 Terrain

The AERMOD air dispersion model has a terrain pre-processor AERMAP[14] which was used to map the physical environment in detail over the receptor grid. The digital terrain input data used in the AERMAP pre-processor was obtained from SRTM. This data was 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.

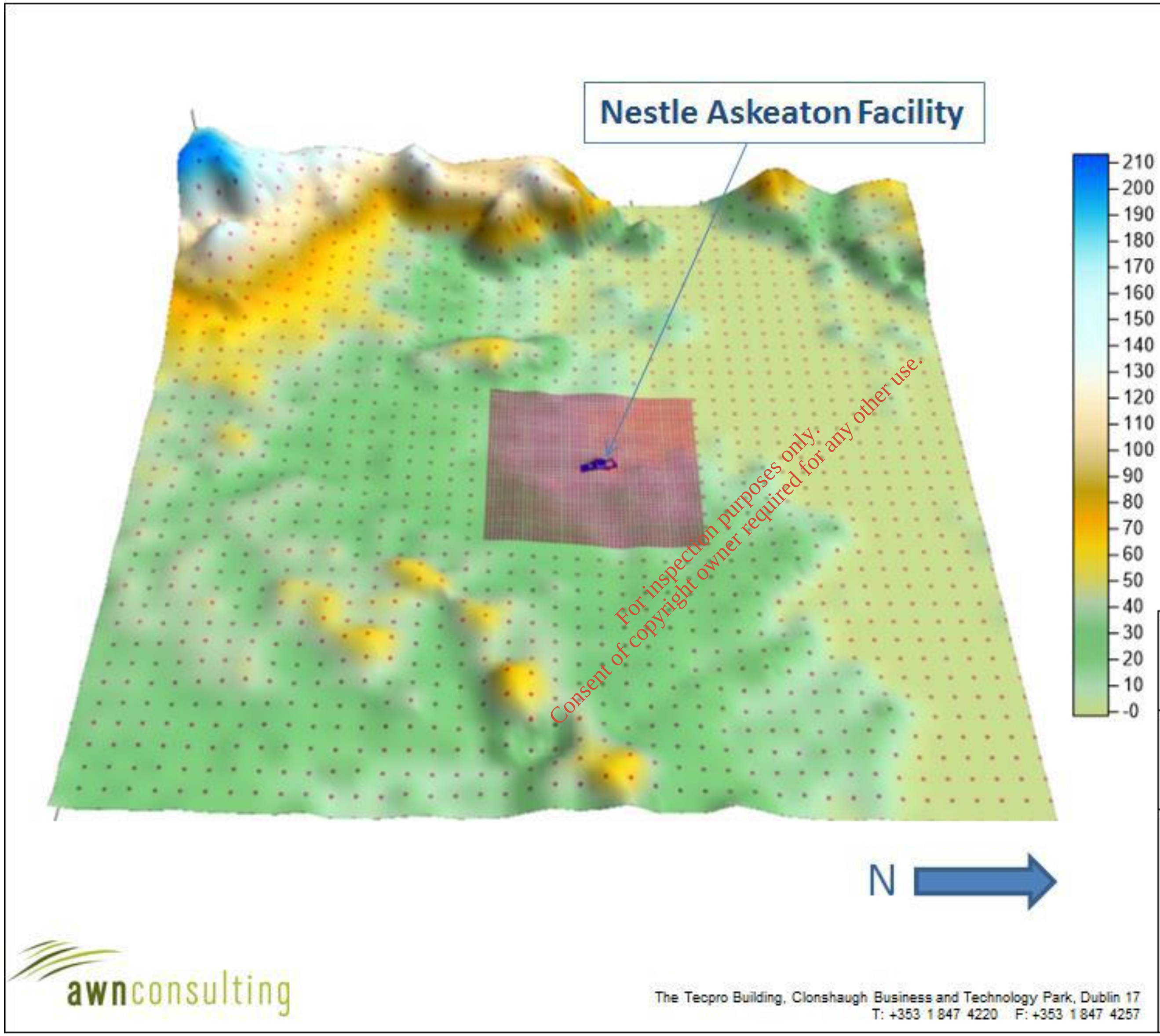
In areas of complex terrain, AERMOD models the impact of terrain using the concept of the dividing streamline (H_c). As outlined in the AERMOD model formulation[1] a plume embedded in the flow below H_c tends to remain horizontal; it might go around the hill or impact on it. A plume above H_c will ride 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"[2].

The terrain in the region of the facility is complex in the sense that the maximum terrain in the modelling domain peaks at 230m which is above the stack top of all emission points onsite. However, in general, as shown in Figure 3, the region of the site has gently sloping terrain particularly in the immediate vicinity of the facility.

2.5 Meteorological Data

The selection of the appropriate meteorological data has followed the guidance issued by the USEPA[4]. A primary requirement is that the data used should have a data capture of greater than 90% for all parameters. Shannon Airport meteorological station, which is located approximately 11 km north-east of the site, collects data in the correct format and has a data collection of greater than 90%. Long-term hourly observations at Shannon Airport meteorological station provide an indication of the prevailing wind conditions for the region (see Figure 4 and Appendix III). Results indicate that the prevailing wind direction is from south-easterly to westerly in direction over the period 2012 - 2016. The mean wind speed is approximately 4.7 m/s over the period 1981-2010. Calm conditions account for only a small fraction of the time in any one year peaking at 80 hours in 2014 (0.9% of the time). There are also no missing hours over the period 2012 – 2016.



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Nestle Askeaton Air Modelling Assessment

Reference

17/9407AR01

Figure 3

Terrain (in metres) In The Vicinity Of Nestle Askeaton, County Limerick With Modelled Grid Also Shown

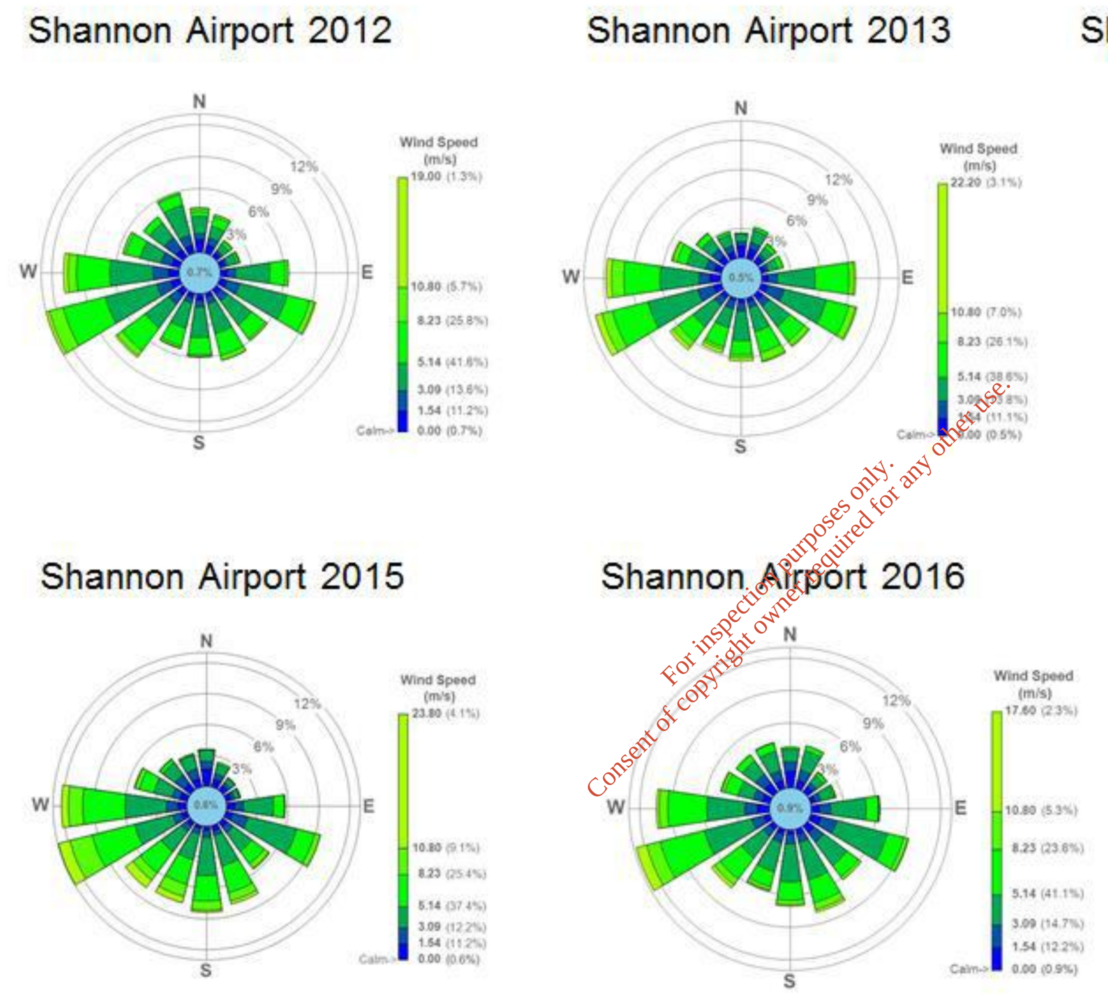

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Figure 4
Shannon Airport
Windrose
2012 - 2016

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2.6 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[15] 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 was 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[15,16] as outlined in Appendix II.

In relation to AERMOD, detailed guidance for calculating the relevant surface parameters has been published[17]. The most pertinent features are:

- The surface characteristics should be those of the meteorological site (Shannon 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[16], 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[17]. This approach has been applied to the current site with full details provided in Appendix II.

2.7 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[18].

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)[8,9] 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[9].

Given that most stacks onsite are less than 2.5 times the lesser of the building height or maximum projected building width, building downwash will need to be taken into account and the PRIME algorithm run prior to modelling with AERMOD. Shown in Figure 5 is an example of the dominant building (in blue) which is influencing the building downwash for stack A2-3. The dominant building may change as the wind direction changes for each of the 36 wind directions. The dominant building for each relevant stack will vary as a function of wind direction and relative building heights.

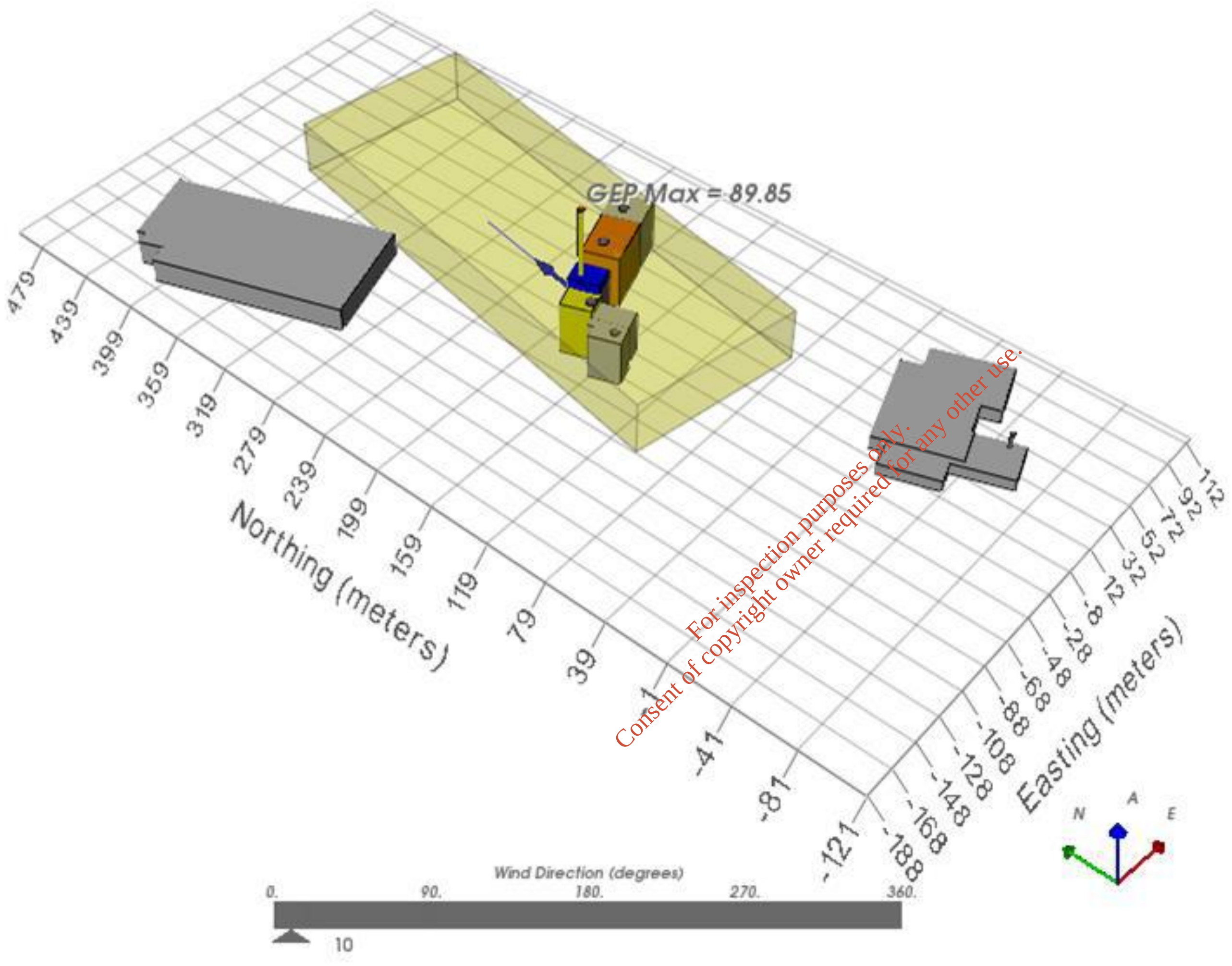

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Figure 5
Example Of Building Downwash Calculations (Example Shown For A2-3)

2.8 Process Emissions

Nestle Askeaton are currently licensed (IED Licence number P0395-03) to operate 11 major emission points (A1-1, A1-2, A1-3, A1-4, A2-7, A2-1, A2-2, A2-3, A2-4, A2-5 and A2-6). Of these, six emission points (A2-1, A2-2, A2-3, A2-4, A2-5 and A2-6) are licenced to emit Total Particulates.

Nestle Askeaton intend to apply for a Technical Amendment which will be required due, in part, to the installation of one new emission points on-site (A2-8) and the decommissioning of two emission points (A2-2 and A2-5). Thus, the future relevant Total Particulate emission points will be A2-1, A2-3, A2-4, A2-6 and A2-8.

The information used in the dispersion model for the existing and proposed emission points is shown in Tables 4 and 5.

Stack Reference	Irish Grid (IG) Stack Location	Height Above Ground Level (m)	Height Above Ordnance Datum (m)
A2-1	E133512, N151217	37.7	51.1
A2-2	E133518, N15196	25.5	38.8
A2-3	E133522, N151232	25.5	39.0
A2-4	E133556, N151244	37.3	50.8
A2-5	E133506, N151195	32.0	45.5
A2-6	E133588, N151255	35.8	49.3
A2-8	E133591, N150990	19.2	32.5

Table 4 Stack Release Points Used In The Air Modelling

The facility currently operates the six existing particulate emission points for differing frequencies over the course of the year. As shown in Table 6, the hours of operation for each of the six existing emission point has varied from a minimum of 677 hours per year for A2-1 in 2016 to a maximum of 5,743 hours per year for A2-4 in 2015. As shown in Table 6, conservative hours of operation have been selected for each emission point which reflects the maximum hours of operation that has been experienced over the last five years.

Stack Reference	Exit Diameter (m)	Cross-Sectional Area (m^2)	Temperature (K)	Max Volume Flow (Nm^3/hr)	Exit Velocity (m/sec actual)	PM_{10} / $PM_{2.5}$ Concentration[Note 1] (mg/Nm^3)	PM_{10} / $PM_{2.5}$ Mass Emission[Note 1] (g/s)
A2-1	0.90	0.636	361.15	46,992	27.1	50	0.65
A2-2	1.49	1.744	364.15	38,132	8.1	50	0.53
A2-3	1.07	0.899	357.15	83,267	33.6	50	1.16
A2-4	1.43	1.606	350.15	104,084	23.1	50	1.45
A2-5	0.85	0.567	331.15	29,267	17.4	50	0.41
A2-6	1.43	1.606	350.15	104,084	23.1	50	1.44
A2-8	0.447	0.157	348.15	6,600	14.9	15	0.028

Note 1 Concentrations and mass emissions are licenced as Total Particulates. As a worst-case it is assumed that all particulate matter released from the facility is firstly less than 10 microns when comparing to the PM_{10} ambient limit values and secondly less then 2.5 microns when comparing to the $PM_{2.5}$ ambient limit value.

Table 5 Nestle Askeaton Facility, Askeaton, Co. Limerick. Stack Emission Details for PM_{10} / $PM_{2.5}$.

Stack Reference	2016 (Hours / year)	2015 (Hours / year)	2014 (Hours / year)	2013 (Hours / year)	2012 (Hours / year)	Maximum Frequency (%)	Max (Days) / Week	Modelled[Note 2]
A2-1	677	912	811	1532	2042	23%	1.63	8 hrs (5 days/week)
A2-2	3000	3000	3000	3000	3000	34%	3.00	8 hrs (7 days/week)
A2-3	3694	3373	2632	2097	2887	42%	2.95	10 hrs (7 days/week)
A2-4	5260	5743	5604	5655	5049	66%	4.59	16 hrs (7 days/week)
A2-5	3000	3000	3000	3000	3000	34%	3.00	8 hrs (7 days/week)
A2-6	4685	4043	4679	3602	4635	53%	3.74	13 hrs (7 days/week)
A2-8	n/a							Continuously

Note 1 A2-2 and A2-5 hours of operation are historical averages.

Note 2 Each emission point was modelled such that all emissions occurred as a minimum between the hours of 08:00 – 16:00 with additional hours added to the emission points which operated greater than this period.

Table 6 Nestle Askeaton Facility, Askeaton, Co. Limerick. Modelled and Actual Hours Of Operation

3.0 RESULTS & DISCUSSION

3.1 Process Contributions - Existing Scenario

Ambient Ground Level Concentrations (GLCs) of PM_{10} / $PM_{2.5}$ have been predicted below in Tables 7 – 8 for the existing scenario.

PM_{10} / $PM_{2.5}$ Emissions

The PM_{10} / $PM_{2.5}$ modelling results are detailed in Table 7 and Table 8. The results indicate that the ambient ground level concentration is below the relevant air quality standard for PM_{10} / $PM_{2.5}$. Emissions from the facility lead to an ambient PM_{10} concentration (including background) which is 86% of the maximum ambient 24-hour limit value at the worst-case receptor (see Table 7 and Figure 6). In relation to the annual mean concentration, ambient PM_{10} / $PM_{2.5}$ concentration (including background) are at most 58% of the annual mean limit values at the worst-case receptor (Figure 7 and Tables 7 and 8).

Pollutant / Scenario	Background (μg/m³)	Averaging Period	Process Contribution (μg/m³)	Predicted Environmental Concentration (μg/Nm³)	Standard (μg/Nm³) Note 1
PM_{10} / 2012	18.0	Maximum 24-hr mean (as a 90th%ile) Note 2	28.4	37.6	50
PM_{10} / 2012	9.2	Annual mean	8.5	17.7	40
PM_{10} / 2013	18.0	Maximum 24-hr mean (as a 90th%ile) Note 2	33.9	43.1	50
PM_{10} / 2013	9.2	Annual mean	8.4	17.6	40
PM_{10} / 2014	18.0	Maximum 24-hr mean (as a 90th%ile) Note 2	28.5	37.7	50
PM_{10} / 2014	9.2	Annual mean	8.2	17.4	40
PM_{10} / 2015	18.0	Maximum 24-hr mean (as a 90th%ile) Note 2	24.7	33.9	50
PM_{10} / 2014	9.2	Annual mean	8.2	17.4	40
PM_{10} / 2016	18.0	Maximum 24-hr mean (as a 90th%ile) Note 2	26.4	35.6	50
PM_{10} / 2016	9.2	Annual mean	8.2	17.5	40

Note 1 Air Quality Standards 2011 (from EU Directive 2008/50/EC)
Note 2 Short-term Environmental Concentrations calculated according to UK DEFRA guidance(17) based on the maximum background 24-hr mean (as a 90th%ile) of 18.0 μg/m³ (based on Kilkitt)

Table 7 Dispersion Model Results – PM_{10} (Existing Scenario)

Pollutant / Scenario	Annual Mean Background (µg/m^3)	Averaging Period	Process Contribution (µg/m^3)	Predicted Environmental Concentration (µg/Nm^3)	Standard (µg/Nm^3)Note 1
$PM_{2.5}$ / 2012	6.0	Annual mean	8.5	14.5	25
$PM_{2.5}$ / 2013	6.0	Annual mean	8.4	14.4	25
$PM_{2.5}$ / 2014	6.0	Annual mean	8.2	14.2	25
$PM_{2.5}$ / 2015	6.0	Annual mean	8.2	14.2	25
$PM_{2.5}$ / 2016	6.0	Annual mean	8.3	14.3	25

Note 1 Air Quality Standards 2011 (from EU Directive 2008/50/EC)

Table 8 Dispersion Model Results – $PM_{2.5}$ (Existing Scenario)

3.2 Process Contributions - Proposed Scenario

Ambient Ground Level Concentrations (GLCs) of PM_{10} / $PM_{2.5}$ have been predicted below in Tables 9 – 10 for the proposed scenario.

<u>PM_{10} / $PM_{2.5}$ Emissions</u>

The PM_{10} / $PM_{2.5}$ modelling results are detailed in Table 9 and Table 10. The results indicate that the ambient ground level concentration is below the relevant air quality standard for PM_{10} / $PM_{2.5}$. Emissions from the facility lead to an ambient PM_{10} concentration (including background) which is 73% of the maximum ambient 24-hour limit value at the worst-case receptor (see Table 9 and Figure 8). In relation to the annual mean concentration, ambient PM_{10} / $PM_{2.5}$ concentration (including background) are at most 50% of the annual mean limit values at the worst-case receptor (Figure 9 and Tables 9 and 10).

Pollutant / Scenario	Background ($\mu g/m^3$)	Averaging Period	Process Contribution ($\mu g/m^3$)	Predicted Environmental Concentration ($\mu g/Nm^3$)	Standard ($\mu g/Nm^3$) Note 1
PM_{10} / 2012	18.0	Maximum 24-hr mean (as a 90th%ile)Note 2	22.2	31.4	50
PM_{10} / 2012	9.2	Annual mean	6.0	15.2	40
PM_{10} / 2013	18.0	Maximum 24-hr mean (as a 90th%ile)Note 2	27.2	36.4	50
PM_{10} / 2013	9.2	Annual mean	6.6	15.8	40
PM_{10} / 2014	18.0	Maximum 24-hr mean (as a 90th%ile)Note 2	22.6	31.8	50
PM_{10} / 2014	9.2	Annual mean	6.0	15.2	40
PM_{10} / 2015	18.0	Maximum 24-hr mean (as a 90th%ile)Note 2	19.8	29.0	50
PM_{10} / 2014	9.2	Annual mean	6.0	15.2	40
PM_{10} / 2016	18.0	Maximum 24-hr mean (as a 90th%ile)Note 2	19.9	29.1	50
PM_{10} / 2016	9.2	Annual mean	6.0	15.2	40

Note 1 Air Quality Standards 2011 (from EU Directive 2008/50/EC)
Note 2 Short-term Environmental Concentrations calculated according to UK DEFRA guidance(17) based on the maximum background 24-hr mean (as a 90th%ile) of 18.0 $\mu g/m^3$ (based on Kilkitt)

Table 9 Dispersion Model Results – PM_{10} (Proposed Scenario)

Pollutant / Scenario	Annual Mean Background ($\mu g/m^3$)	Averaging Period	Process Contribution ($\mu g/m^3$)	Predicted Environmental Concentration ($\mu g/Nm^3$)	Standard ($\mu g/Nm^3$)Note 1
$PM_{2.5}$ / 2012	6.0	Annual mean	6.0	12.0	25
$PM_{2.5}$ / 2013	6.0	Annual mean	6.6	12.6	25
$PM_{2.5}$ / 2014	6.0	Annual mean	6.0	12.0	25
$PM_{2.5}$ / 2015	6.0	Annual mean	6.0	12.0	25
$PM_{2.5}$ / 2016	6.0	Annual mean	6.0	12.0	25

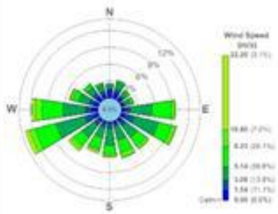
Note 1 Air Quality Standards 2011 (from EU Directive 2008/50/EC)

Table 10 Dispersion Model Results – $PM_{2.5}$ (Proposed Scenario)

3.3 Process Contributions - Comparison Of Existing & Proposed Scenarios

Comparing the results of the existing and proposed modelling scenarios shows that the impact of the proposed removal of main emission points A2-2 and A2-5 and the introduction of main emission point A2-8 is to decrease the predicted ambient air quality for all averaging periods and for both PM_{10} and $PM_{2.5}$.

As shown in Figure 10, the benefit of the proposed changes to licenced emission points is to decrease ambient levels of PM_{10} by as mcuh as 13% of the ambient limit value whilst $PM_{2.5}$ ambient levels will decrease by up 10% of the ambient limit value.



Background Mapping from Google Earth

90th%ile of 24-Hour Mean PM_{10} Concentrations (excluding background) Maximum Concentration = 33.9 µg/m³

Boundary Of Facility

Scale

1:15,000

N

Project

Nestle Askeaton Air Modelling Assessment

Reference

17/9407AR01

Figure 6

Existing 90th%ile of 24-Hour PM_{10} Concentrations (µg/m³) (Year 2013)

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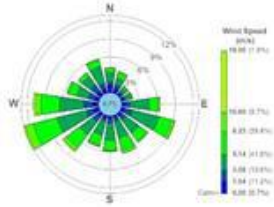

Background Mapping from Google Earth

Annual Mean PM_{10} Concentrations (excluding background)
Maximum Concentration = 8.5 µg/m^3

Boundary Of Facility

Scale	
1:12,000	N

Project

Nestle Askeaton Air Modelling Assessment

Reference

17/9407AR01

Figure 7

Existing Annual Mean PM_{10} Concentrations (µg/m^3) (Year 2012) (excluding background concentration).

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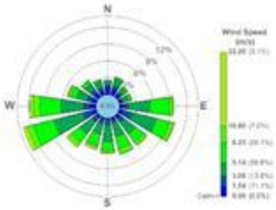

Background Mapping from Google Earth

90^{th}%ile of 24-Hour Mean PM_{10} Concentrations (excluding background) Maximum Concentration = 27.2 $\mu g/m^3$

Boundary Of Facility

Scale

1:15,000

N

Project

Nestle Askeaton Air Modelling Assessment

Reference

17/9407AR01

Figure 8

Proposed 90^{th}%ile of 24-Hour PM_{10} Concentrations ($\mu g/m^3$) (Year 2013)

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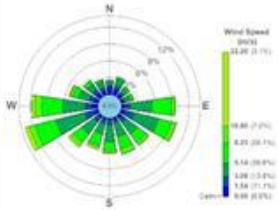

Background Mapping from Google Earth

Annual Mean PM_{10} Concentrations (excluding background)
Maximum Concentration = 6.6 $\mu g/m^3$

Boundary Of Facility

Scale

1:12,000

N

Project

Nestle Askeaton Air Modelling Assessment

Reference

17/9407AR01

Figure 9

Proposed Annual Mean PM_{10} Concentrations ($\mu g/m^3$) (Year 2013) (excluding background concentration).

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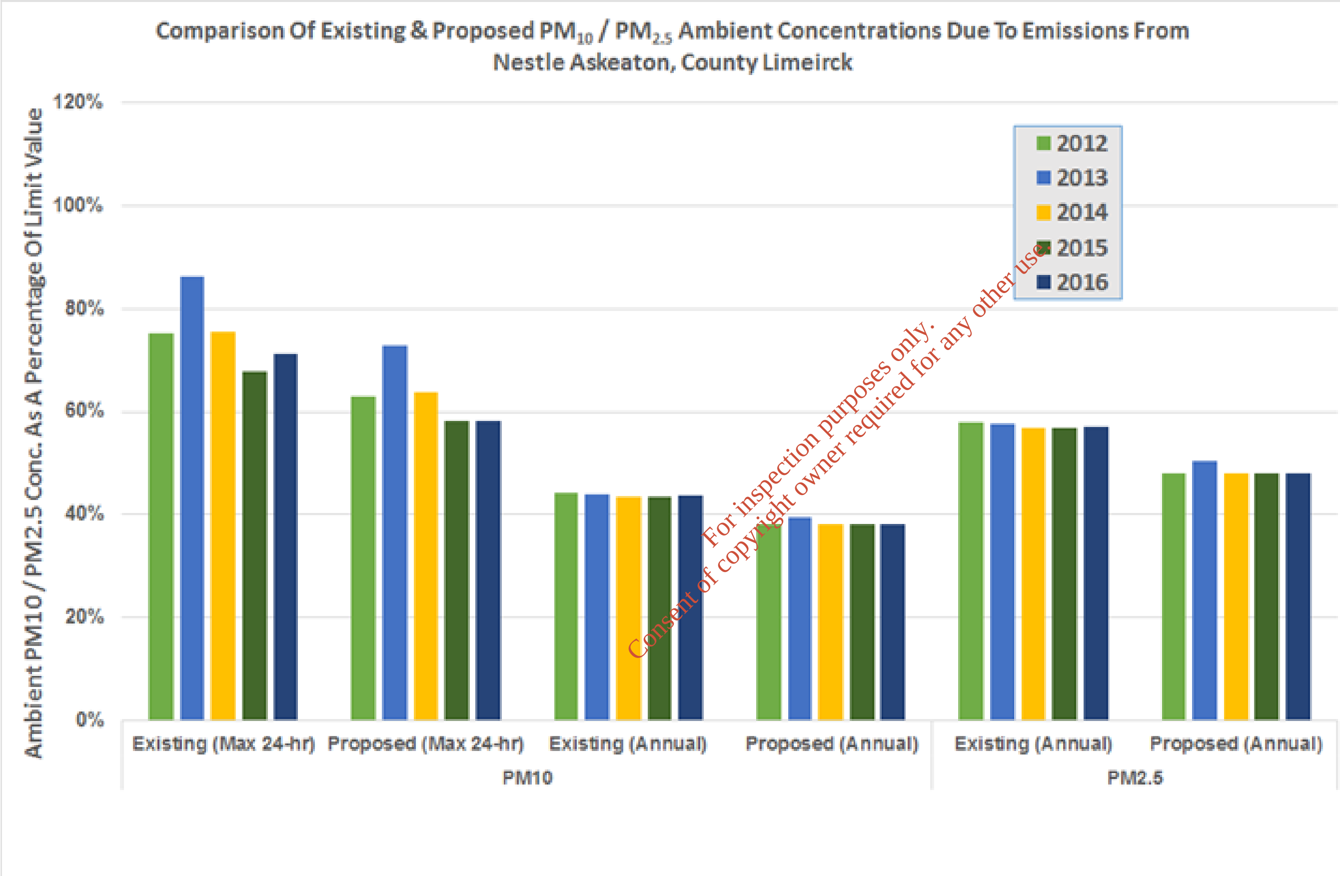

Project
Nestle Askeaton Air Modelling Assessment

Reference
17/9407AR01

Figure 10
Comparison Of The Existing & Proposed PM_{10} / $PM_{2.5}$ Ambient Concentrations For Each Year 2012 - 2016

awnconsulting
The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17
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3.4 Assessment Summary

The results indicate that the ambient ground level concentrations are below the relevant air quality standards for PM_{10} / $PM_{2.5}$ for the existing scenario. Emissions from the facility lead to an ambient PM_{10} concentration (including background) which is 86% of the maximum ambient 24-hour limit value at the worst-case receptor. In relation to the annual mean concentration, ambient PM_{10} / $PM_{2.5}$ concentration (including background) are at most 58% of the annual mean limit values at the worst-case receptor.

The results also indicate that the ambient ground level concentrations are below the relevant air quality standards for PM_{10} / $PM_{2.5}$ for the proposed scenario. Emissions from the facility lead to an ambient PM_{10} concentration (including background) which is 73% of the maximum ambient 24-hour limit value at the worst-case receptor. In relation to the annual mean concentration, ambient PM_{10} / $PM_{2.5}$ concentration (including background) are at most 50% of the annual mean limit values at the worst-case receptor.

Comparing the results of the existing and proposed modelling scenarios shows that the impact of the proposed removal of main emission points A2-2 and A2-5 and the introduction of main emission point A2-8 is to decrease the predicted ambient air concentrations for all averaging periods and for both PM_{10} and $PM_{2.5}$. The benefit of the proposed changes to licenced emission points is to decrease ambient levels of PM_{10} by as much as 13% of the ambient limit value whilst $PM_{2.5}$ ambient levels will decrease by up 10% of the ambient limit value.

In summary, all emissions from the facility under normal operations of the facility will be in compliance with the ambient air quality standards whilst the proposed changes to the licenced emission points will further reduced environmental concentrations.

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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)[1,4]. 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[8].

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[1,3]. 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[1,3]. 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 (version 16216)[15]. 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 was carried out in line with USEPA recommendations[4] and using the detailed methodology outlined by the Alaska Department of Environmental Conservation[17]. 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.

<u>Surface roughness</u>

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 Shannon Airport Meteorological Station is shown in Table A1.

Sector	Area Weighted Land Use Classification	Spring	Summer	Autumn	Winter Note 1
270-180	100% Grassland	0.05	0.10	0.01	0.01
180-270	100% Urban	1	1	1	1

(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))[19]. Thus for the current location autumn more accurately defines "winter" conditions in Ireland.

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

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 Shannon Airport Meteorological Station is shown in Table A2.

Area Weighted Land Use Classification	Spring	Summer	Autumn	Winter Note 1
6% Urban, 49% Grassland, 45% Water	0.151	0.143	0.172	0.172

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

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

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 Shannon Airport Meteorological Station is shown in Table A3.

Area Weighted Land Use Classification	Spring	Summer	Autumn	Winter Note 1
19% Urban, 81% Grassland	0.301	0.557	0.655	0.655

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

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

APPENDIX III

Detailed Meteorological Data – Shannon Airport 2012 - 2016

Shannon Airport 2012

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	106	51	141	40	27	4	369
22.5	70	59	100	76	21	2	328
45.0	42	22	65	29	9	0	167
67.5	40	24	79	23	8	0	174
90.0	57	68	284	130	25	2	566
112.5	60	110	404	194	40	12	820
135.0	47	71	244	141	19	1	523
157.5	34	57	253	188	39	3	574
180.0	54	58	251	138	16	5	522
202.5	38	47	214	148	20	6	473
225.0	62	89	241	237	52	17	698
247.5	79	117	440	360	118	27	1,141
270.0	86	130	357	277	72	36	958
292.5	68	91	178	126	23	1	487
315.0	76	119	150	63	1	0	409
337.5	66	85	256	92	15	0	514
Total	985	1,198	3,657	2,262	505	116	8,723
Calms							61
Missing							0
Total							8,784

Shannon Airport 2013

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	106	42	65	9	0	0	222
22.5	91	57	111	27	2	0	288
45.0	57	33	74	33	9	1	207
67.5	38	30	88	48	2	0	206
90.0	56	83	339	305	42	18	843
112.5	64	148	390	209	61	14	886
135.0	58	74	223	164	50	10	579
157.5	36	52	221	193	75	12	589
180.0	32	77	265	128	27	28	557
202.5	23	77	170	179	26	32	507
225.0	42	77	237	161	60	36	613
247.5	72	146	461	330	96	59	1,164
270.0	97	99	349	324	112	47	1,028
292.5	68	79	173	91	41	10	462
315.0	69	77	112	58	5	1	322
337.5	61	58	99	27	2	0	247
Total	970	1,209	3,377	2,286	610	268	8,720
Calms							40
Missing							0
Total							8,760

Shannon Airport 2014

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	118	84	112	12	2	0	328
22.5	66	80	98	25	0	0	269
45.0	56	21	44	9	0	0	130
67.5	44	23	53	14	0	1	135
90.0	102	111	332	132	18	2	697
112.5	96	181	418	81	26	5	807
135.0	65	77	250	135	34	15	576
157.5	56	71	257	222	64	27	697
180.0	58	68	229	159	62	22	598
202.5	60	52	203	207	61	10	593
225.0	62	100	250	211	64	39	726
247.5	68	126	402	335	133	74	1,138
270.0	91	113	352	271	49	45	921
292.5	58	61	166	67	6	0	358
315.0	61	92	118	35	1	0	307
337.5	87	100	153	60	0	0	400
Total	1,148	1,360	3,437	1,975	520	240	8,680
Calms							80
Missing							0
Total							8,760

Shannon Airport 2015

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	146	66	93	10	0	0	315
22.5	68	49	79	19	0	0	215
45.0	52	33	45	5	0	0	135
67.5	48	29	43	8	0	0	128
90.0	70	73	256	96	4	0	499
112.5	64	130	426	159	49	2	830
135.0	48	64	198	130	49	9	498
157.5	47	40	268	233	72	29	689
180.0	36	58	327	216	79	18	734
202.5	25	51	223	216	107	55	677
225.0	39	61	212	224	77	81	694
247.5	50	77	337	372	195	102	1,133
270.0	76	94	355	361	123	59	1,068
292.5	66	67	162	127	38	6	466
315.0	71	94	129	34	4	0	332
337.5	74	85	120	13	0	0	292
Total	980	1,071	3,273	2,223	797	361	8,705
Calms							55
Missing							0
Total							8,760

Shannon Airport 2016

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	137	75	100	18	0	0	330
22.5	68	86	162	42	0	0	358
45.0	57	38	76	27	4	1	203
67.5	40	43	106	17	5	1	212
90.0	65	93	288	102	6	4	558
112.5	89	131	423	138	35	5	821
135.0	70	97	236	115	27	1	546
157.5	47	64	313	191	57	23	695
180.0	38	76	308	150	35	13	620
202.5	43	68	245	126	27	11	520
225.0	43	65	219	213	57	31	628
247.5	50	104	397	371	113	87	1,122
270.0	97	102	309	319	70	22	919
292.5	64	75	128	113	27	7	414
315.0	90	93	132	61	2	0	378
337.5	70	79	164	67	4	0	384
Total	1,068	1,289	3,606	2,070	469	206	8,708
Calms							76
Missing							0
Total							8,784