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DETERMINATION OF ODOUR EMISSIONS TO ATMOSPHERE AT PROPOSED SPENCER PLACE NORTH DEVELOPMENT, DUBLIN 1.

Technical Report Prepared For

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EXECUTIVE SUMMARY

The purpose of this odour modelling assessment is to assess the impact on sensitive receptors from the discharge of odour emissions from an Irish Water Pumping Station Flue. The flue of the Irish Water pumping station is proposed to be moved from its current location as part of the Proposed Spencer Place North Development. The contribution of odour emissions from the pumping station flue to odour concentrations at sensitive receptors in the Proposed Spencer Place North Development were evaluated in this assessment.

Odour dispersion modelling results have been compared with the odour detection threshold at the relevant sensitive receptors including the proposed development. The modelling results have predicted that the 98^{th}%ile of 1-hour mean odour concentrations over a five-year period will peak at 0.15 OU_E/m^3, with the highest concentrations occurring at a location modelled to represent the upper floors window height. This is 10% of the relevant odour criterion of 1.5 OU_E/m^3 measured as a 98^{th}%ile of mean hourly odour concentrations at the worst-case receptor.

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1.0 INTRODUCTION

AWN Consulting has been instructed to conduct an odour modelling study to assess the impact on sensitive receptors from the discharge of odour emissions from the Irish Water Pumping Station Flue. The flue of the Irish Water pumping station is proposed to be moved from its current location as part of the Proposed Spencer Place North Development. The contribution of odour emissions from the pumping station flue to odour concentrations at sensitive receptors in the Proposed Spencer Place North Development were evaluated in this assessment.

This report describes the outcome of this study. The study consists of the following components:

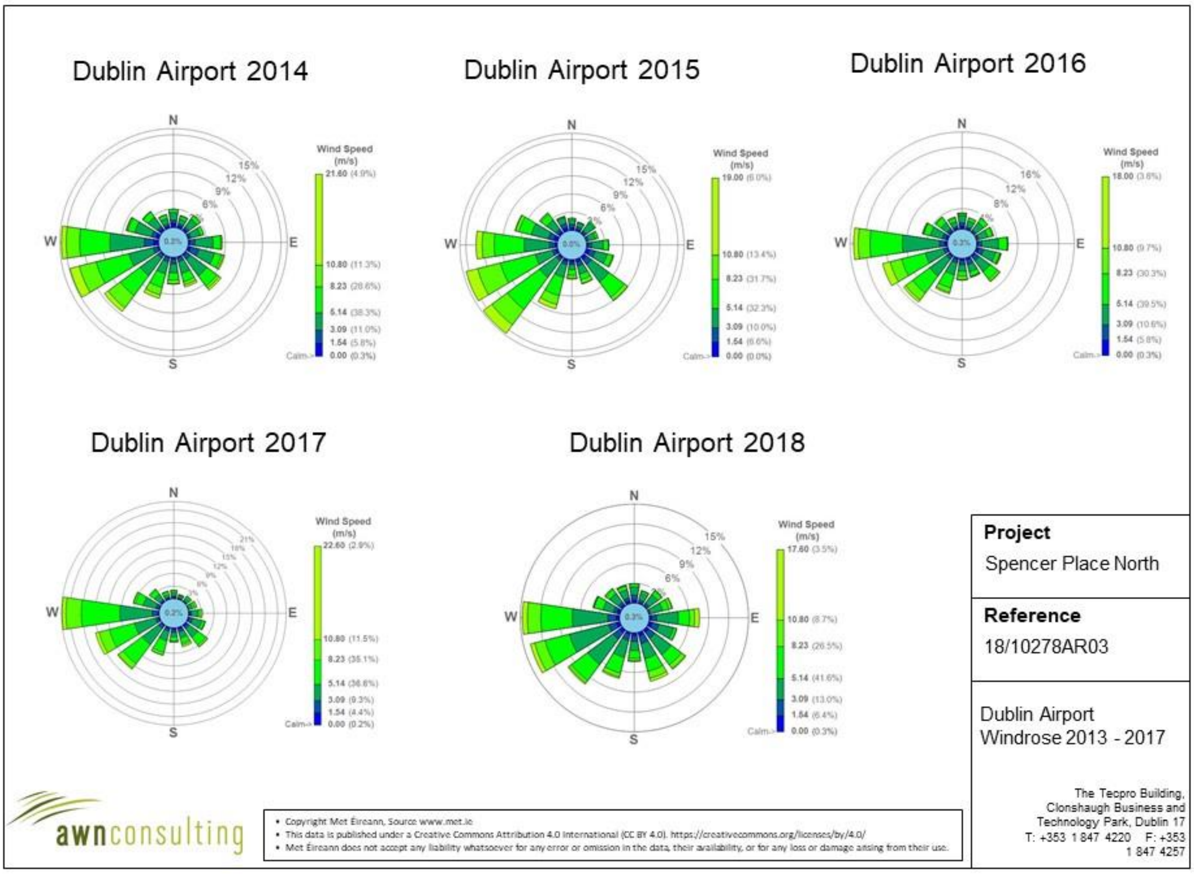
- Review of odour emission data and other relevant information needed for the modelling study;
- Dispersion modelling of odour under the emission scenario based on a proposed flue height (2 m above roof height of Block 1);
- Presentation of predicted concentrations of released odours at the Block 2 AHUs, windows on Block 1 and Block 2 and the residential receptors to the south east of Block 2;
- Evaluation of the significance of these predicted concentrations, including consideration of whether these ground level concentrations are likely to exceed the relevant ambient Odour Guidelines 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 and the monitoring which the odour emission rates are based on is detailed in Appendix III.

2.0 MODELLING METHODOLOGY

Emissions from the proposed relocated flue of the Irish Water pumping station will be modelled using the AERMOD dispersion model (Version 18081) 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[(7-11)].

The odour 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.



2.1 Characteristics of Odour

Odours are sensations resulting from the reception of a stimulus by the olfactory sensory system, which consists of two separate subsystems: the olfactory epithelium and the trigeminal nerve. The olfactory epithelium, located in the nose, is capable of detecting and discriminating between many thousands of different odours and can detect some of them in concentrations lower than those detectable by currently available analytical instruments(12). The function of the trigeminal nerve is to trigger a reflex action that produces a painful sensation. It can initiate protective reflexes such as sneezing to interrupt inhalation. The olfactory system is extremely complex and peoples' responses to odours can be variable. This variability is the result of differences in the ability to detect odour; subjective acceptance or rejection of an odour due to past experience; circumstances under which the odour is detected and the age, health and attitudes of the human receptor.

Odour Intensity and Threshold

Odour intensity is a measure of the strength of the odour sensation and is related to the odour concentration. The odour threshold refers to the minimum concentration of an odorant that produces an olfactory response or sensation. This threshold is normally determined by an odour panel consisting of a specified number of people, and the numerical result is typically expressed as occurring when 50% of the panel correctly detect the odour. This odour threshold is given a value of one odour unit and is expressed as 1 OU_E/m^3. The odour threshold is not a precisely determined value but depends on the sensitivity of the odour panellists and the method of presenting the odour stimulus to the panellists. An odour detection threshold relates to the minimum odorant concentration required to perceive the existence of the stimulus, whereas an odour recognition threshold relates to the minimum odorant concentration required to recognise the character of the stimulus. Typically, the recognition threshold exceeds the detection threshold by a factor of 2 to 10[12-13].

Odour Character

The character of an odour distinguishes it from another odour of equal intensity. Odours are characterised on the basis of odour descriptor terms (e.g. putrid, fishy, fruity etc.). Odour character is evaluated by comparison with other odours, either directly or through the use of descriptor words.

Hedonic Tone

The hedonic tone of an odour relates to its pleasantness or unpleasantness. When an odour is evaluated in the laboratory for its hedonic tone in the neutral context of an olfactometric presentation, the panellist is exposed to a stimulus of controlled intensity and duration. The degree of pleasantness or unpleasantness is determined by each panellist's experience and emotional associations. The responses among panellists may vary depending on odour character; an odour pleasant to many may be declared highly unpleasant by some.

Adaptation

Adaptation, or Olfactory Fatigue, is a phenomenon that occurs when people with a normal sense of smell experience a decrease in perceived intensity of an odour if the stimulus is received continually. Adaptation to a specific odorant typically does not interfere with the ability of a person to detect other odours. Another phenomenon known as habituation or occupational anosmia occurs when a worker in an industrial situation experiences a long-term exposure and develops a higher threshold tolerance to the odour.

2.2 Odour Guidelines

The exposure of the population to a particular odour consists of two factors; the concentration and the length of time that the population may perceive the odour. By definition, 1 OU_E/m^3 is the detection threshold of 50% of a qualified panel of observers working in an odour-free laboratory using odour-free air as the zero reference (the selection criteria result in the qualified panel being more sensitive to a particular odorant than the general population). The recognition threshold is generally about five times this concentration (5 OU_E/m^3) and the concentration at which the odour may be considered a nuisance is between 5 and 10 OU_E/m^3 based on hydrogen sulphide (H_2S)[14]. Clarkson and Misslebrook[15] proposed that a "faint odour" was an acceptable threshold criterion for the assessment of odour as a nuisance. Historically, it has been generally accepted that odour concentrations of between 5 and 10 OU_E/m^3 would give rise to a faint odour only, and that only a distinct odour (concentration of >10 OU_E/m^3) could give rise to a nuisance[16]. However, this criterion has generally been based on waste water treatment plants where the source of the odour is generally hydrogen sulphide. In 1990, a survey of the populations surrounding 200 industrial odour sources in the Netherlands showed that there were no justifiable complaints when 98%[ile] compliance with an odour exposure standard of a "faint odour" (5-10 OU_E/m^3) was achieved[17].

DEFRA[18,19] in the UK has published detailed guidance on appropriate odour threshold levels based in part on the offensiveness of the odour. The potential odour source is related to an Irish Water pumping station flue which could be classed as a worst-case scenario as a WwTP which is included in Table 1. As shown in Table 1, a WwTP is listed with a ranking of 16.1 (medium) and 15.3 (mean) in terms of pleasantness.

DEFRA has also detailed installation-specific exposure criteria based on the "annoyance potential"[18] which is defined as "the likelihood that a specific odorous mixture will give reasonable cause for annoyance in an exposed population". Industrial sources have been ranked into three categories based on their relative offensiveness which are "low", "medium" and "high" and exposure criteria assigned to each category (as shown in Table 2). The relevant exposure criteria vary from 1.5 OU_E/m^3 for highly odorous sources to 6.0 OU_E/m^3 for the least offensive odours. Due to the potential offensiveness of the onsite pumping station odours to the proposed Spencer Place North development, the worst-case exposure criteria for the facility is used. This is an odour exposure criteria of 1.5 OU_E/m^3 which is expressed as a 98^{th}%ile and based on one hour means over a one-year period.

Environmental Odour Industrial Source	Ranking UK Median	Ranking UK Mean	Ranking Dutch Mean
Bread Factory	1	2.5	1.7
Coffee Roaster	2	3.9	4.6
Chocolate Factory	3	4.6	5.1
Beer Brewery	6	7.7	8.1
Fragrance & Flavour Factory	8	8.5	9.8
Charcoal Production	8	9.2	9.4
Green Fraction composting	9	10.3	14
Fish smoking	9	10.5	9.8
Frozen Chips production	10	11	9.6
Sugar Factory	11	11.3	9.8
Car Paint Shop	12	11.7	9.8
Livestock odours	12	12.6	12.8
Asphalt	13	12.7	11.2
Livestock Feed Factory	15	14.2	13.2
Oil Refinery	14	14.3	13.2
Car Park Bldg	15	14.4	8.3
Wastewater Treatment	**17**	**16.1**	**12.9**
Fat & Grease Processing	18	17.3	15.7
Creamery/milk products	10	17.7	-
Pet Food Manufacture	19	17.7	-
Brickworks (burning rubber)	18	17.8	-
Slaughter House	19	18.3	17.0
Landfill	20	18.5	14.1

Table 1: Ranking Table For Various Industrial Sources [(15)]

Industrial Sectors	Relative Offensiveness of Odour	Indicative Criterion
Rendering Fish Processing Oil Refining Creamery WWTP Fat & Grease Processing	**High**	1.5 OU_E/m^3 as a 98^{th}%ile of hourly averages at the worst-case sensitive receptor
Intensive Livestock Rearing Food Processing (Fat Frying) Paint-spraying Operations Asphalt Manufacture	Medium	3.0 OU_E/m^3 as a 98^{th}%ile of hourly averages at the worst-case sensitive receptor
Brewery Coffee Roasting Bakery Chocolate Manufacturing Fragrance & Flavouring	Low	6.0 OU_E/m^3 as a 98^{th}%ile of hourly averages at the worst-case sensitive receptor

Table 2: Indicative Odour Standards Based On Offensiveness Of Odour [(15)]

2.3 Odour Dispersion Modelling Methodology

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

The modelling incorporated the following features:

- A ground level (1.8m) receptor grid was 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 grid was based on a Cartesian grid with the site at the centre. A dense grid extended to 1,000 m from the site with concentrations calculated at 50 m intervals.

- An additional over 5,000 sensitive receptors were modelled at various heights along the outer walls of Block 1 and 2. These were designed to represent windows which residents may choose to open and therefore can be classed as odour sensitive locations.

- 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. This takes account of all significant features of the terrain. All terrain features have been mapped in detail into the model using the terrain pre-processor AERMAP[20].

- Hourly-sequenced meteorological information has been used in the model. Meteorological data over a five-year period (Dublin Airport, 2014 – 2018) was used in the model (see Figure 1).

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

2.4 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. Dublin Airport meteorological station, which is located approximately 7.5 km north-east of the site, collects data in the correct format. Long-term hourly observations at Dublin Airport meteorological station provide an indication of the prevailing wind conditions for the region (see Figure 4 and Appendix III). For data collated during five representative years (2014-2018), the predominant wind direction is south-westerly. The average wind speed over the period 1981 – 2010 is approximately 5.3 m/s.

2.5 Process Emissions

The source information for the modelled emission points from the Irish Water facilities' flues has been summarised in Table 3. Odour Monitoring Ireland carried out odour monitoring at the flues current location on 09/07/2018 (for details see Appendix III). These process emissions from the current Irish Water Pumping Station Flue are predicted to be the same for the proposed scenario as no changes will occur at the new station. The new location, stack diameter and height were integrated in the dispersion model. The relocated flue is proposed to be 2 m above the roof height.

Sensitive receptors were modelled at varying heights along the outer walls of Block 1 and 2 at regular intervals horizontally. These were designed to represent windows which residents may choose to open and therefore can be classed as odour sensitive locations. The worst-case emissions were predicted to occur close to the roof level nearby the odour emission points.

Stack Reference	Exit Diameter (m)	Cross-Sectional Area (m^2)	Temp (K)	Max Volume Flow (Nm^3/hr) Note 1	Exit Velocity (m/sec actual)	Odour	
						Emission Concentration (OU_E/m^3) Note 1	Mass Emission (OU_E/s)
RHS wet well	0.6	0.2826	291.45	9,554	10.0	168	446
LHS dry well	0.6	0.2826	294.85	1,477	1.6	155	64

Note 1: Based on Odour Monitoring Ireland Monitoring Results (09/07/2018)

Table 3 Summary Of Source Information for Modelling Scenario.

3.0 RESULTS & DISCUSSION

3.1 Odour Emissions

Details of the 98th%ile of 1-hour mean odour concentrations at the worst case off site location are given in Table 4 over a five-year period based on the USEPA approved AERMOD model (version 18081). The worst-case scenario occurs in 2018, where the maximum off-site concentrations is 10% of the 98th%ile one-hour guideline value at the boundary of the site. The impact of the worst-case scenario is shown in Figure 2.

Table 4 shows the worst-case sensitive receptor result for each year, which occurs at the sensitive receptor modelled to represent the top floor window to the north side of the development. Concentrations decrease in value as the odour disperses away and downwards from the emission point. The maximum 1-hour 98th%ile odour concentration at a sensitive receptor is 0.15 OU_E/m^3. This is equivalent to 10% of the relevant odour criterion of 1.5 OU_E/m^3 measured as a 98th%ile of mean hourly odour concentrations at the worst-case receptor. Table 5 shows the four highest receptors for each of the modelled metrological years. Similar to the worst-case location, all of these are located at a height representing the upper floors of the building, with concentrations falling off as the height of the receptor decreases.

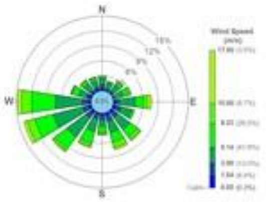
It should be noted that concentrations less than 0.07 Ou_E/m^3 are not shown on the map because it was not considered necessary as they are significantly below the ambient odour criterion of 1.5 Ou_E/m^3 and the normal limits of odour detection.

Model Scenario / Meteorological Year	Averaging Period	Maximum 1-Hour 98th%ile Predicted Odour Concentration (OU_E/m^3)	Guideline (OU_E/m^3)
			EPA AG4 (2010)
Ambient Odour Concentration / 2014	Maximum 1-Hour (as a 98th%ile)	0.142	1.5 (UK Guidance)
Ambient Odour Concentration / 2015		0.141	
Ambient Odour Concentration / 2016		0.146	
Ambient Odour Concentration / 2017		0.138	
Ambient Odour Concentration / 2018		0.150	

Table 4: Predicted Odour Concentration At Worst-Case Offsite Receptors (OU_E/m^3)

Sensitive Receptor Grid Co-ordinates		Maximum 1-Hour 98th%ile Predicted Odour Conc. (OU_E/m^3)				
UTM (Zone 29 N)		2014	2015	2016	2017	2018
683970.88	5914764	0.14	0.14	0.15	0.14	0.15
683971.13	5914766	0.14	0.14	0.15	0.13	0.15
683971.81	5914771.5	0.12	0.12	0.12	0.11	0.12
683972.13	5914773.5	0.11	0.11	0.11	0.10	0.11

Table 5: Predicted Odour Concentration At Sensitive Receptors With Greatest Impact (OU_E/m^3)



Background Mapping from Google Earth

98th%ile of 1-Hour Odour Concentrations (including background) = 0.1498 OU_Em^{-3}

Proposed Block 1 and Block 2

Project

Spencer Place North

Reference

18/10278AR03

Figure 2

98th%ile of 1-Hour Odour Concentrations (OU_Em^{-3}) (Year 2018)

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4.0 CONCLUSION

The purpose of this odour modelling assessment is to assess the impact on sensitive receptors from the discharge of odour emissions from an Irish Water pumping station flue. The flue of the Irish Water pumping station is proposed to be moved from its current location as part of the Proposed Spencer Place North Development. The contribution of odour emissions from the pumping station flue to odour concentrations at sensitive receptors in the Proposed Spencer Place North Development were evaluated in this assessment.

Odour dispersion modelling results have been compared with the odour detection threshold at the relevant receptor. The modelling results have predicted that the 98^{th}%ile of 1-hour mean odour concentrations over a five-year period will peak at 0.15 OU_E/m^3, with the highest concentrations occurring at a location modelled to represent the upper floor window height. This is 10% of the relevant odour criterion of 1.5 OU_E/m^3 measured as a 98^{th}%ile of mean hourly odour concentrations at the worst-case receptor.

In summary, the odour dispersion modelling concludes that concentrations of odour due to the Irish Water pumping station flue will be significantly below the detectible concentration at the worst-case sensitive receptor as shown in Table 5.

Assessment	Impact Significance at Worst Case Sensitive Receptor	Percentage of Guideline Value	Duration of Impact Assessed
Odour Impact	Imperceptible	10%	Long Term

Table 5: Predicted Odour Impact Analysis

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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)[1,3]. 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[6].

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 [21]. 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 [1,22].

APPENDIX III

Odour Monitoring Report

Odour Test Certificate

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Project:	Spensor Dock Odour & Flow
Project number	SPDOTL10090718
Lead technician	Dr. John Casey

Investigated item:

Odour concentration Ou_E/m^3, determined by sensory measurement of odour concentration of an odour sample supplied in a sampling bag.

Identification:

The odour sample bags were labelled individually and supplied with a chain of custody. The label showed the identification of the bag. This identification is referenced within the results table.

Method

The odour concentration measurements were performed according to the European Standard EN13725:2003 '*Air quality – Determination of odour concentration by dynamic olfactometry*', and according to those parts as described in the internal procedure SOP2042: ' *Procedure for olfactometry based on EN13725:2003*'. The odour perception characteristic of the panel within the presentation series for the samples was analogous to that for the butanol calibration. The yes/no method of presentation was used and at least three rounds are presented to determine the panel threshold. Sample bags are manufactured from Nalophane and are not re-used.

Measuring range

The measuring range of the olfactometer is $2^4 \leq x \leq 2^{16}$ ou_E/m^3. When the sample concentration is outside the measuring range the odour sample may have been pre-diluted. If samples are pre-diluted in the laboratory, this is specified under the column *Pre-dilution factor Z* in Table 1.

Laboratory Environment

The measurements were performed in an air- and odour conditioned room, at a temperature of T ≤25 °C and with a fluctuation of less than ±3 °C. The CO_2 concentration is ≤0.1 %. The relative humidity is ≤55%. The laboratory is stationary and permanent.

Measurement dates and times

The measuring dates and times are specified together with the results in Table 1.

Results

The measurement results for odour threshold concentration as determined by dynamic dilution olfactometry in accordance with EN13725:2003 are presented in Table 1.

Uncertainty

The confidence limits for a value x for one measurement according to EN13725:2003, with a cover factor $k = 2$ are: $x \cdot 2.21^{-1} \leq x \leq x \cdot 2.21$. Based on repeated measurements of n-butanol reference gas the actual confidence limits at the OMI Lab are more favourable: for one measurement, including pre-dilution, the confidence limits are: $x \cdot 1.80^{-1} \leq x \leq x \cdot 1.80$ ($k = 2$). It is assumed that this uncertainty, based on verification with reference gases, is transferable to environmental samples. The most recent inter-laboratory comparison result is A = 0.14.

Traceability

The measurements have been performed using standards for which the traceability to (inter)national standards has been demonstrated. The assessors are individually selected to comply with fixed criteria and are monitored in time to keep within the limits set. The results from the assessors are traceable to primary standards (PSM's) of n-butanol in nitrogen.

For and on behalf of Odour Monitoring Ireland Ltd,

Brian Sheridan Ph.D Eng.

Laboratory Director

CERTIFICATE OF ANALYSIS

Certificate number SPDOTL10090718

Table 1 – Odour Results

Analysis file	Sample ID	Client reference	Analysis results (Ou_E/m^3)	Pre-dilution factor Z	Odour concentration (Ou_E/m^3)	Date and time of sampling	Date and time of analysis	Number of valid panel members	Number of valid ITE's	Remarks
2018381SPDOTL10090718	1	1. RHS Wet Well	168	--	168	09/07/2018 10:31	09/07/2018 14:00	6	9	Dynamic dilution olfactometry to EN13725:2003
2018381SPDOTL10090718	2	2. LHS Dry Well	155	--	155	09/07/2018 10:24	09/07/2018 14:50	6	9	Dynamic dilution olfactometry to EN13725:2003

Table 2 – Flow Results

Analysis file	Sample ID	Client reference	Dia. (mm)	Temp. (Deg. C)	Vol. Flow Rate (m_3/hr	Stack Gas Velocity (m/s_{-1})
2018381SPDOTL10090718	1	1. RHS Wet Well	700	18.3	9,554	7.53
2018381SPDOTL10090718	2	2. LHS Dry Well	500	21.7	1,477	2.31