Appendix 5B

Odour Report

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ODOUR IMPACT ASSESSMENT OF THE PROPOSED CORK HARBOUR MAIN DRAINAGE SCHEME, CORK CITY AND ENVIRONS.

PERFORMED BY ODOUR MONITORING IRELAND ON BEHALF OF MOTT MACDONNELL PETTIT CONSULTING ENGINEERS

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1. Executive Summary

Odour Monitoring Ireland was commissioned by Mott MacDonnell Pettit Consulting Engineers to carry out an odour impact assessment of the proposed Cork Harbour Main Drainage Scheme Waste Water Treatment Plant (WWTP) specimen design and five major Pumping stations (4 proposed and 1 existing) to be located in Cork City and environs. The purpose of this assessment was to determine the potential for the generation of odour impact on the surrounding population from the proposed wastewater treatment plant and five pumping stations specimen design. The WWTP will have a Population Equivalent (PE) of 80,000 PE.

Potential odour sources were identified and were used to construct the basis of the modelling assessment. Odour emission rates/fluxes were calculated from library olfactometry data. Odour dispersion modelling was used to perform an impact assessment of the proposed WWTP specimen design and five major pumping stations to be located in Raffeen, West Beach, Monkstown, Church Road (existing) and Carrigaloe. Minor pumping stations were not assessed as it was anticipated that impacts predicted for the major pumping stations would be greater than that for minor pumping stations.

Following measurement and development of odour emission rates/fluxes, two data sets for odour emission rates were calculated to determine the potential odour impact of the Cork Harbour Main Drainage Scheme WWTP specimen design and five pumping stations during their proposed operation.

These included:

Ref Scenario 1: Predicted overall odour emission rate from proposed Cork Harbour Main Drainage Scheme WWTP specimen design with the incorporation of odour mitigation protocols (*see Table 4.1*).

Ref Scenario 2: Predicted overall odour emission rate from proposed five pumping stations with the incorporation of odour management systems (e.g. good design in terms of odour minimisation, tight fitting covers, etc.) (*see Table 4.2*).

Aermod Prime was used to determine the overall odour impact of the proposed Cork Harbour Main Drainage Scheme WWTP and five pumping stations operation located in Cork Harbour Main Drainage Scheme as set out in odour impact criteria presented in *Table 2.1* and *2.2*. The output data was analysed to calculate:

Ref Scenario 1:

- Predicted odour emission contribution of overall proposed Cork Harbour Main Drainage Scheme WWTP operation to surrounding population (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.50 Ou_E m^{-3} (*see Figure 8.1*).
- Predicted odour emission contribution of overall proposed Cork Harbour Main Drainage Scheme WWTP operation to surrounding population (*see Table 4.1*), to odour plume dispersal at the 99.5th percentile for an odour concentration of less than or equal to 3.0 Ou_E m^{-3} (*see Figure 8.2*).
- Predicted odour emissions contribution of individual grouped Odour control units 1 to 5 to surrounding population (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 0.30 Ou_E/m^3 (*see Figure 8.3*).
- Predicted odour emissions contribution of individual grouped Aeration, Secondary settlement and Storm water tankage sources to surrounding population (*see Table 4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.50 Ou_E/m^3 (*see Figure 8.4*).

These odour impact criterions were chosen for the existing WWTP in order to ascertain the level of proposed impact to the surrounding residential and industrial population in the vicinity of the proposed WWTP.

Ref Scenario 2:

- Predicted odour emission contribution of overall proposed Raffeen Pumping Station operation to surrounding population (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.50 Ou_E m^{-3} (*see Figure 8.5*).
- Predicted odour emission contribution of overall proposed West Beach Pumping Station operation to surrounding population (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.50 Ou_E m^{-3} (*see Figure 8.6*).
- Predicted odour emission contribution of overall proposed Monkstown Pumping Station operation to surrounding population (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.50 Ou_E m^{-3} (*see Figure 8.7*).
- Predicted odour emission contribution of overall proposed Church Road Pumping Station (existing) operation to surrounding population (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.50 Ou_E m^{-3} (*see Figure 8.8*).
- Predicted odour emission contribution of overall proposed Carrigaloe Pumping Station operation to surrounding population (*see Table 4.2*), to odour plume dispersal at the 98th percentile for an odour concentration of less than or equal to 1.50 Ou_E m^{-3} (*see Figure 8.9*).

Since the predicted odour emission rate from the pumping stations is low following the implementation of odour management systems (e.g. tight fitting covers, etc.), odour isopleths suitable for reporting clarity were chosen (i.e. those isopleths presented were lower than the 1.50 Ou_E/m^3 isopleths since the overall odour emission rate from the pumping stations were low due to the nature of the odour source and hence the subsequent odour impact was low). All odour impact criterions chosen were in accordance with the guideline value presented in *Section 3.3.4.*.

These computations give the odour concentration at each Cartesian grid receptor location that is predicted to be exceeded for 0.5% (44 hours) and 2% (175 hours) of five years of meteorological data. Additionally, individual sensitive receptors and 20 five metre spaced boundary receptors were established within the modelling assessment.

It was concluded that:

Cork Harbour Main Drainage Scheme WWTP

- In accordance with odour impact criterion in *Table 2.2*, and in keeping with current recommended odour impact criterion in this country, no odour impact will be perceived by sensitive receptors in the vicinity of the proposed Cork Harbour Main Drainage Scheme WWTP following the installation of proposed odour management, minimisation and mitigation protocols assuming specimen design. As can be observed, the overall odour emission rate from the new proposed Cork Harbour Main Drainage Scheme WWTP will be no greater than 6,611 Ou_E/s based on the specimen design.
- All residents/industrial neighbours in the vicinity of the proposed Cork Harbour Main Drainage Scheme WWTP will perceive an odour concentration at or less than 1.50 Ou_E m^{-3} for the 98th percentile and less than 3.0 Ou_E/m^3 for the 99.5th percentile for five years of meteorological data (*see Figures 8.1 and 8.2*). Those odour sources considered most offensive (inlet works, primary treatment and holding tanks, centrate, filtrate, sludge, RAS/WAS pump sumps, flow splitting chambers and all sludge handling processes including tankage will be effectively contained and ventilated to an odour control system

and therefore the overall risk of any resident/industrial neighbours detecting odour will be negligible since the major odour sources contributing to the remaining odour plume are considered low risk in term of odour. These sources include the aeration tankage, secondary settlement tankage and storm water tankage (*see Figures 8.3 and 8.4*).

- Those management and mitigation strategies discussed through this document should be considered and implemented in the design of the proposed Cork Harbour Main Drainage Scheme WWTP. Any deviations from the proposed mitigation strategies will require reassessment in order to ensure no odour impact in the vicinity of the proposed facility.

Pumping Stations

- In accordance with odour impact criterion in *Section 3.3.4*, and in keeping with current recommended odour impact criterion in this country, no odour impact will be perceived by sensitive receptors in the vicinity of the major Pumping stations Raffeen, West Beach, Monkstown, Church Road and Carrigaloe following the implementation of good design in terms of odour management (e.g. tight fitting covers, etc.).
- All residents/industrial neighbours in the vicinity of the proposed pumping stations will perceive an odour concentration at or less than 1.50 $Ou_E\ m^{-3}$ for the 98^{th} percentile for five years of meteorological data (*see Figures 8.5 to 8.9*). All pumping station (both minor and major) will incorporate the use of an odour management system (e.g. good design in terms of odour, tight fitting covers etc.) to ensure no fugitive release of odours from each pumping station. In addition, each pumping station will be regularly visited so as to ensure efficient operation of the odour management system.
- It is acknowledged that many of the pumping stations are located in populous areas. For this reason the design of the collection system will include best practice and adequate odour management systems to prevent odour complaint and impact.
- The pumping stations will be covered/sealed to allow for containment of odours. The implementation of odour management systems within each pumping station (both minor and major) will minimise the uncontrolled release of fugitive odour emissions.
- Pumping stations will be subject to Part 8 Planning *(Planning and Development Regulations 2001)* at detailed design. It will be the responsibility of the designer and contractor to review the PS location and the odour management systems proposed to prevent odour complaints and impact.

The following recommendations were developed during the study:

1. Odour management, minimisation and mitigation procedures as discussed within this document in general will be implemented at the proposed Cork Harbour Main Drainage Scheme wastewater treatment plant and each Pumping Station in order to prevent any odour impact in the surrounding vicinity.
2. The maximum allowable odour emission rate from the overall proposed WWTP should not be greater than 6,611$Ou_E\ s^{-1}$ (*see Table 4.1*) inclusive of the odour emission contribution from the abatement systems installed on the primary treatment, pumping and sludge handling processes. The maximum overall odour emission rate from the odour control units shall be no greater than 2,314 $Ou_E\ s^{-1}$ and an exhaust stack concentration of less than 300 Ou_E/m^3 for OCU 1, 2, 4 and 5 and less than 500 Ou_E/m^3 for OCU 3, respectively. The specimen design suggests the use of three OCU's. As long as the total odour emission rate for the WWTP (i.e. 6,611$Ou_E\ s^{-1}$) is achieved along with the total minimum odour treatment volume (i.e. 6.20 m^3/s) and a total odour emission rate from the OCU's of less than or equal to 2,314 $Ou_E\ s^{-1}$ is similar, then the number of OCU's utilised onsite is not important. The hedonic tone of this odour should not be considered unpleasant (Scale greater than –2) as assessed in accordance with VDI 3882:1997, part 2; ('Determination of Hedonic) for all emission points.
3. The odour management systems to be installed upon Raffeen, Carrigaloe, West Beach, Monkstown and Church road should be sufficient to prevent any uncontrolled fugitive odours escaping from the system. In addition any odour management system

incorporated into the design and upgrade of the pumping station should be capable of achieving less than 1.5 Ou_E/m^3 at the 98^{th} percentile and less than 3.0 Ou_E/m^3 at the 99.5^{th} percentile of hourly averages.

4. Maintain good housekeeping practices (i.e. keep yard area clean, etc.), closed-door management strategy (i.e. to eliminate puff odour emissions from sludge dewatering building), maintain sludge storage within sealed airtight containers and to implement an odour management plan for the operators of the WWTP and all Pumping station. All odourous processes such as inlet works, primary treatment, and thickening will be carried out indoors/enclosed tankage.
5. Avoid accumulation of floating debris and persistent sediments in channels and holding tanks by design (i.e. flow splitters and secondary sedimentation tanks, etc.). Techniques to eliminate such circumstances shall be employed.
6. Enclose and seal all primary treatment, wet wells and sludge handling processes.
7. Operate the proposed WWTP within specifications to eliminate overloading and under loading, which may increase septic conditions within the processes.
8. Odour scrubbing technologies employing will be implemented within the proposed Cork Harbour Main Drainage Scheme WWTP. An odour management system (e.g. tight fitting covers, etc.) will be implemented upon each pumping station (both minor and major). All other odour management, minimisation and mitigation strategies contained within this document where necessary will be implemented within the overall design.
9. When operational, it is recommended that the contractor should provide evidence through the use of dispersion modelling (Aermod Prime) and olfactometry measurement (in accordance with EN13725:2003), that the as built WWTP and Pumping stations are achieving the overall mass emission rate of odour and emission limit values for the installed odour management systems.

2. Introduction

Odour Monitoring Ireland was commissioned by Mott MacDonald Consulting Engineers to perform a desktop odour impact assessment of the proposed Cork Harbour Main Drainage Scheme Waste Water Treatment Plant (WWTP) and five major Pumping stations (4 proposed and one existing) utilising dispersion modelling software Aermod Prime. Like the majority of industries, the operation of the proposed WWTP and pumping stations in Cork Harbour Main Drainage Scheme is faced with the issue of preventing odours causing impact to the public at large.

In order to obtain odour emission data for the site, library based odour data collected in accordance with EN13725:2003 European Standard on olfactometry was used to construct the basis of the dispersion modelling scenarios. Utilising the indicative design and site library odour emission data; dispersion-modelling techniques were used to establish maximum allowable odour emission rates from the proposed sites in order to limit any odour impact on the surrounding population.

Two odour emission scenarios were developed to take account of the specimen design of the Cork Harbour Main Drainage Scheme WWTP and pumping station operations with the implementation of odour mitigation strategies. These odour emission rates and specified source characteristics were input into Aermod Prime in order to determine any overall odour impact from the proposed Cork Harbour Main Drainage Scheme WWTP and five pumping stations.

It was concluded from the study, it is predicted all residential/commercial neighbours in the vicinity of the proposed Cork Harbour Main Drainage Scheme WWTP will perceive an odour concentration less than or equal to 1.50 Ou_E m^{-3} at the 98th percentile and less than or equal to 3.0 Ou_E m^{-3} at the 99.5th percentile, respectively for five years of meteorological data (*see Figures 8.1 and 8.2*). The overall remaining odour plume spread from the proposed WWTP will be predominately made up from odours from the aeration tankage, secondary settlement tankage and storm water tankage. Emissions from such processes are generally not offensive and based on experience do not cause odour impact if operated correctly (*see Figures 8.3 and 8.4*). The overall odour emission rate from the proposed specimen design Cork Harbour Main Drainage Scheme WWTP will be approximately 6,611 Ou_E/s following the implementation of odour mitigation strategies. The ability of process upset to cause odour impact is greatly reduced as those sources generally responsible for such process upset will be enclosed and negatively extracted to an odour control unit. Two stages of odour treatment (only if biological is first stage) have been recommended to provide confidence in the treatment options for the WWTP and to achieve the strict odour concentration levels from the odour control unit stacks 1 to 5. Three odour control units were included in the specimen design. Five odour control units were assessed in the impact assessment. In terms of the number of odour treatment units, the contractor will be required to ensure that odour emission rates does not exceed 2,314 Ou_E s^{-1} whether 3, 4 or 5 OCU's are utilised within the design (i.e. must achieve the total odour emission from the WWTP (i.e. 6,611 Ou_E/s) and also at minimum the total treatment volume 6.20 m^3/s and a total odour emission rate of less than or equal to 2,314 Ou_E s^{-1} from the odour control units.

In terms of odour impact from the five major pumping stations to be located at Raffeen, West beach, Monkstown, Church Road (existing) and Carrigaloe, the predicted odour impact will be less than or equal to 1.50 Ou_E/m^3 at the 98th percentile odour impact criterion (*see Figures 8.5 to 8.9*). An odour management system (e.g. tight fitting covers, etc.) will be provided on both minor and major pumping stations to ensure there is no uncontrolled escape of fugitive odour emissions.

This assessment was performed in accordance with currently recommended international guidance for the assessment of odour impact criterion to limit odour complaint.

3. Materials and Methods

This section will describe the materials and methods used throughout the study period.

3.1. Site

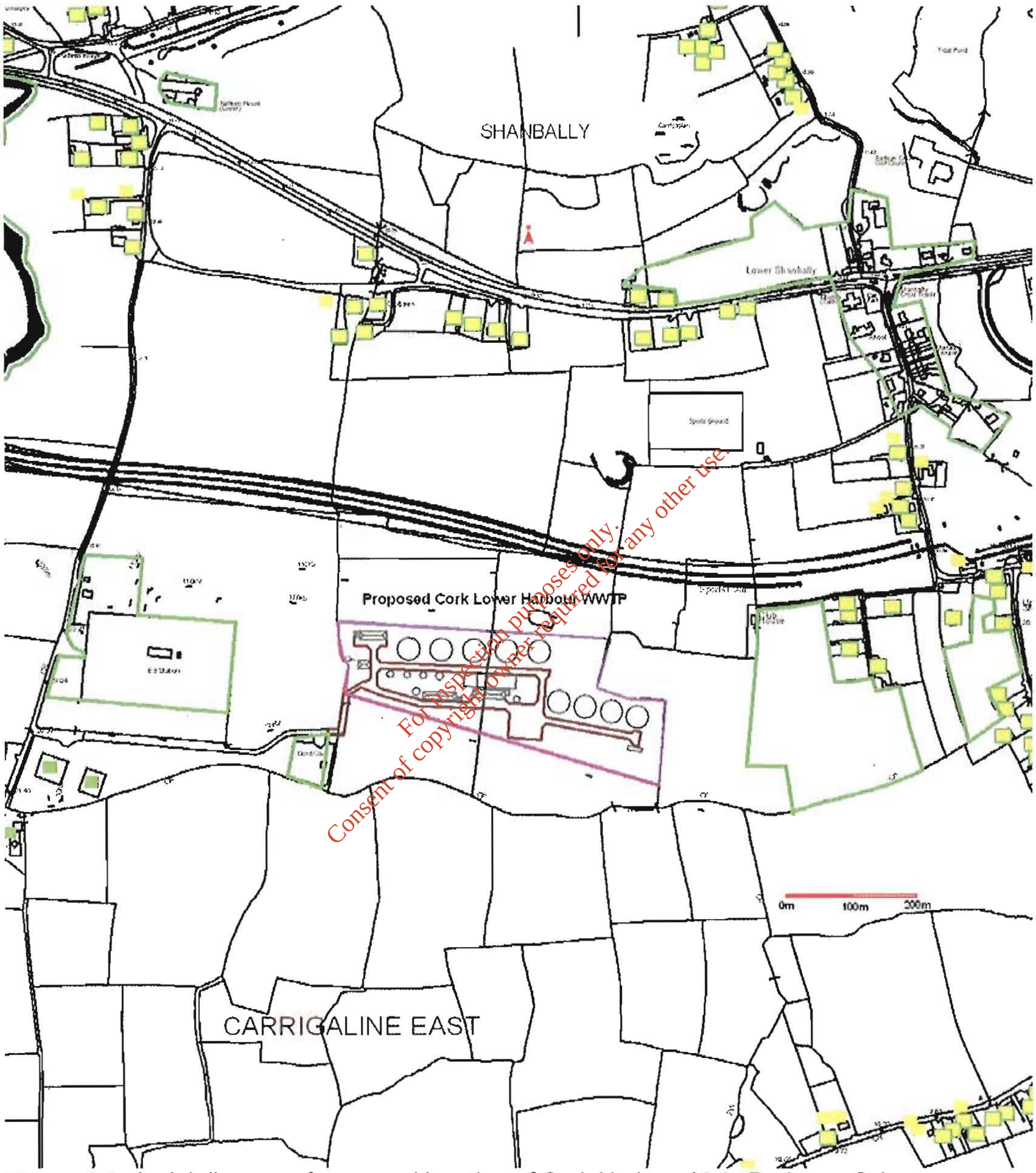

Figure 3.1. Aerial diagram of proposed location of Cork Harbour Main Drainage Scheme WWTP, boundary (—) and sensitive receptor locations (—).

The different distances and directions that the proposed Cork Harbour Main Drainage Scheme WWTP is located from the neighbouring sensitive receptors are presented in *Figure 3.1*. As can be observed, a number or commercial and residential receptors are in close proximity to the proposed WWTP. This includes a proposed new development to be located approximately 134 metres from the eastern boundary of the WWTP. Existing sensitive receptors include the ESB substation located approximately 200 metres to the west, a sports field located approximately 100 metres to the northeast and a number of residential properties located from a minimum distance of 250 metres from the boundary.

3.2. Odour emission rate calculation.

The measurement of the strength of a sample of odourous air is, however, only part of the problem of quantifying odour. Just as pollution from a stack is best quantified by a mass emission rate, the rate of production of an odour is best quantified by the odour emission rate. For a chimney or ventilation stack, this is equal to the odour threshold concentration ($Ou_E\ m^{-3}$) of the discharge air multiplied by its flow-rate ($m^3\ s^{-1}$). It is equal to the volume of air contaminated every second to the threshold odour limit ($Ou_E\ s^{-1}$). The odour emission rate can be used in conjunction with dispersion modelling in order to estimate the approximate radius of impact or complaint (Hobson et al, 1995).

Area source mass emission rates/flux were calculated as either $Ou_E\ m^{-2}\ s^{-1}$ or $Ou_E\ s^{-1}$ depending if they are being represented as discrete point sources or area sources in the atmospheric dispersion model.

3.3. Dispersion modelling overview

3.3.1. Atmospheric dispersion modelling of odours: What is dispersion modelling?

Any material discharged into the atmosphere is carried along by the wind and diluted by wind turbulence, which is always present in the atmosphere. This process has the effect of producing a plume of air that is roughly cone shaped with the apex towards the source and can be mathematically described by the Gaussian equation. Atmospheric dispersion modelling has been applied to the assessment and control of odours for many years, originally using Gaussian form ISCST 3 and more recently utilising advanced boundary-layer physics models such as ADMS and AERMOD (Keddie et al. 1992). Once the odour emission rate from the source is known, ($Ou_E\ s^{-1}$), the impact on the vicinity can be estimated. These models can effectively be used in three different ways: firstly, to assess the dispersion of odours and to correlate with complaints; secondly, in a "reverse" mode, to estimate the maximum odour emissions which can be permitted from a site in order to prevent odour complaints occurring; and thirdly, to determine which process is contributing greatest to the odour impact and estimate the amount of required abatement to reduce this impact within acceptable levels (McIntyre et al. 2000). In this latter mode, models have been employed for imposing emission limits on industrial processes, odour control systems and intensive agricultural processes (Sheridan et al., 2002).

3.3.2. AERMOD Prime

The AERMOD model was developed through a formal collaboration between the American Meteorological Society (AMS) and U.S. Environmental Protection Agency (U.S. EPA). AERMOD is a Gaussian plume model and replaced the ISC3 model in demonstrating compliance with the National Ambient Air Quality Standards (Porter et al., 2003) AERMIC (USEPA and AMS working group) is emphasizing development of a platform that includes air turbulence structure, scaling, and concepts; treatment of both surface and elevated sources; and simple and complex terrain. The modelling platform system has three main components: AERMOD, which is the air dispersion model; AERMET, a meteorological data pre-processor; and AERMAP, a terrain data pre-processor (Cora and Hung, 2003).

AERMOD is a Gaussian steady-state model which was developed with the main intention of superseding ISCST3 (NZME, 2002). The AERMOD modeling system is a significant departure from ISCST3 in that it is based on a theoretical understanding of the atmosphere rather than depend on empirical derived values. The dispersion environment is characterized by turbulence theory that defines convective (daytime) and stable (nocturnal) boundary layers instead of the stability categories in ISCST3. Dispersion coefficients derived from turbulence theories are not based on sampling data or a specific averaging period. AERMOD was especially designed to support the U.S. EPA's regulatory modeling programs (Porter at al., 2003)

Special features of AERMOD include its ability to treat the vertical in-homogeneity of the planetary boundary layer, special treatment of surface releases, irregularly-shaped area sources, a three plume model for the convective boundary layer, limitation of vertical mixing in the stable boundary layer, and fixing the reflecting surface at the stack base (Curran et al., 2006). A treatment of dispersion in the presence of intermediate and complex terrain is used that improves on that currently in use in ISCST3 and other models, yet without the complexity of the Complex Terrain Dispersion Model-Plus (CTDMPLUS) (Diosey et al., 2002).

3.3.3. Establishment of odour impact criterion for WWTP and pumping station odours

Odours from WWTP's / Pumping station operations arise mainly from the volatilisation of odourous gases from:

- The surfaces of non-quiescence processes including overflow weirs, returned pumped centrate/liquor above the working height of the tank/channel, etc,
- Positive displacement of odours from tankage as a result of inlet waste water flow and pressure effects induced by wind flows,
- Anaerobic decay of floating organic debris upon quiescence surfaces including organic matter attached to grit and rags, organic matter carryover to secondary tanks, etc,
- Sludge handling operations including dewatering, thickening, digestion, drying, storage and transport of raw/processed sludge's offsite,
- Anaerobic digestion processes and emissions of sour gas,
- Turbulent processes within the inlet works and storage of screens (i.e. grit and rags removal),
- Inefficient odour control/abatement equipment operation and design including loose fitting covers, inefficient extraction and odour control unit failure.

Some of the compounds emitted are characterised by their high odour intensity and low odour detection threshold (*see Section 9.5*). A sample of a report carried out in the Netherlands, United Kingdom and USA ranking generic and environmental odours according to the like or dislike by a group of people professionally involved in odour management is illustrated in *Table 2.1* (EPA, 2001, Environment Agency, 2002). Although not scientifically based, it is interesting to observe the results of such studies.

Table 2.1. Ranking of environmental odours according to like and dislike (i.e. similar odour hedonic tone).

Generic odours	Hedonic score[1] Dravnieks, 1994	Ranking[2]	Ranking[2]	Ranking[2]	Environmental odours	Ranking[2]	Ranking[2]	Ranking[2]
Descriptor	**USA**	**UK median**	**UK mean**	**NL mean**	**Descriptor**	**NL mean**	**UK mean**	**UK Median**
Roses	3.08	4	4.4	3.4	*Bread Factory*	**1.7**	**2.5**	**1**
Coffee	2.33	3	4.5	4.6	Coffee Roaster	4.6	3.9	2
Cinnamon	2.54	4	4.9	6	Chocolate Factory	5.1	4.6	3
Mowed lawn	2.14	4	4.9	6.4	Beer Brewery	8.1	7.7	6
Orange	2.86	4	5.2	5.8	Fragrance & Flavour Factory	9.8	8.5	8
Hay	1.31	7	6.9	7.5	Charcoal Production	9.4	9.2	8
Soap	0.96	8	7.8	7.3	**Green Fraction composting**	**14**	**10.3**	**9**
Brandy		9	8.8	7.8	Fish smoking	9.8	10.5	9
Raisins	1.56	8	8.8	7.9	Frozen Chips production	9.6	11	10
Beer	0.14	9	9.5	9.3	Sugar Factory	9.8	11.3	11
Cork	0.19	10	10	10.5	Car Paint Shop	9.8	11.7	12
Peanut Butter	1.99	10	10.4	11.1	**Livestock odours**	**12.8**	**12.6**	**12**
Vinegar	-1.26	14	13.3	14.8	Asphalt	11.2	12.7	13
Wet Wool	-2.28	14	14	14.1	**Livestock Feed Factory**	**13.2**	**14.2**	**15**
Paint	-0.75	15	14	14.4	**Oil Refinery**	**13.2**	**14.3**	**14**
Sauerkraut	**-0.6**	**15**	**14.6**	**12.8**	Car Park Bldg	8.3	14.4	15
Cleaning Agent	**-1.69**	**15**	**14.7**	**12.1**	**Wastewater Treatment**	**12.9**	**16.1**	**17**
Sweat	-2.53	18	16.6	17.2	Fat & Grease Processing	15.7	17.3	18
Sour Milk	-2.91	19	18	17.5	Creamery/milk products		17.7	10
Cat's Pee	-3.64	19	18.8	19.4	Pet Food Manufacture		17.7	19
Sewer odour	**-3.68**	-		-	Brickworks (burning rubber)		17.8	18
-	-	-	-	-	**Slaughter House**	**17**	**18.3**	**19**
-	-	-	-	-	**Landfill**	**14.1**	**18.5**	**20**

Notes: *Source: Draft Odour H4-Part 1, Integrated Pollution Prevention and Control (IPPC). (2004). Environment Agency, Bristol, UK.*

[1] The higher the positive "value", the more pleasant the odour descriptor and similarly below, the greater the negative value, the more unpleasant the odour descriptor

[2] Ranking in order of dislike ability.

As can be observed from *Table 2.1*, and using the Dutch based ranking system, Wastewater treatment plants (WWTP) have a mean raking of 12.90 in terms of dislike. Other odours with similar mean dislike ranking include Oil Refinery, Livestock Feed Factory, Livestock odour (i.e. intensive pig/poultry production). Generic odours such as Sauerkraut and Cleaning agents have also similar dislike abilities to WWTP odours. Dravnieks *et al.*, 1994 performed hedonic tone ranking of generic odours including Sauerkraut, Cleaning agents and Sewer odour and obtained a mean hedonic score of –0.60, –1.69 and –3.68, respectively. There is a clear trend in these studies whereby both mean ranking of dislike ability and hedonic scoring provide subjective ranking of odours and their respective ability to cause offensive/complaint. It would appear that when the hedonic tone of the odour reached a specific level, the odour hedonic tone decreases rapidly to small increases in odour threshold concentration (i.e. small increases in odour threshold concentrations will cause a large change in the perceived odour offensiveness). Such trends have been observed by Odour Monitoring Ireland in a laboratory-based environment. It has been suggested that when an odour reached an odour intensity level of 3 (distinct) and a mean hedonic score of –2 (unpleasant), an odour will become offensive and cause odour complaint. This scoring level can be assessed through the use of olfactometric techniques in a laboratory based environment whereby the odour concentration level corresponding to an odour intensity level of 3 and a hedonic tone of –2 can be determined. This methodology of analysis is very important in spot-checking odour abatement systems. By implementing hedonic tone assessment techniques on source odour samples, the odour threshold concentration responsible for causing on odour complaint following dynamic dilution can be determined. VDI Guidelines 3882 Part 2 – Determination of odour Hedonic tone specifies a methodology for such an assessment.

3.3.4. Commonly used odour annoyance criteria utilised in dispersion models

An odour impact criterion defines the odour threshold concentration limit value above baseline in ambient air, which will result in an odour stimulus capable of causing an odour complaint. There are a number of interlinked factor, which causes a nearby receptor (i.e. resident) to complain. These include:

- Odour threshold concentration, odour intensity and hedonic tone-defined measurable parameters at odour source,
- Frequency of odour-how frequently the odour is present at the receptor location,
- Duration of odour-how long the odour persists at the receptor location,
- Physiological-previous experiences encountered by receptor, etc.

By assessing these combined interlinked factors, the ability for a facility to cause odour complaint can be determined. As odour is not measurable in ambient air due to issues in sampling techniques, limit of detections for olfactometers and the inability to monitor continuously, therefore dispersion models become useful tools in odour impact assessments and odour risk analysis. Dispersion modelling also allows for the assessment of proposed changes in processes within the WWTP without actually having to wait for the processes to be changed (i.e. predictive analysis).

When utilising dispersion models for impact assessment, specific impact criterion (odour concentrations) need to be established at receptors. For odour assessment in general terms, this is called an odour impact criterion, which defines the maximum allowable ground level concentration (GLC) of odour at a receptor location for a particular exposure period (i.e. $\leq$ 1.50 Ou_E m^{-3} at the 98th percentile of hourly averages). Commonly used odour annoyance criteria in Ireland, UK, Netherlands and other world wide countries are illustrated in *Table 2.2*. The odour concentration, % odour exposure at this odour concentration, the dislike ability, the dispersion model and industry it applies are presented (*see Table 2.2*).

Table 2.2. Odour annoyance criterion used for environmental odours.

Country	Odour conc. limit ($Ou_E\ m^3$)	Percentile value (%)	Average time (minutes)	Industry type	Dispersion model	Type area it applies	Dislike ability (*see Table 1.2*)	Application of criterion
Ireland	≤6.0[1]	98th	60	Intensive pig production	Complex 1	Limit value for existing pig production units	12.80	For all pig production units in Ireland
Ireland	≤3.0[1]	98th	60	Intensive pig production	Complex 1	Limit value for existing pig production units	12.80	For all pig production units in Ireland
Ireland	≤1.50[2]	98th	60	Slaughter house	Complex 1/ISC ST3	Limit value for new slaughter house facilities	17.0	Limit value for new slaughter house facilities
Ireland	≤1.50[3]	98th	60	Balbriggan WWTP	ISC Prime/ISC ST3	Limit value at sensitive receptor locations	12.90	Limit value for existing facility at sensitive receptor locations.
UK	≤1.50[4]	98th	60	WWTP	ADMS/ AERMOD	Indicative odour exposure criterion for licensing	12.90	IPPC H4 Guidance Notes Part 1-Regulation and Permitting, Environment Agency
Ireland	≤3.0[3]	98th	60	Enniscorthy WWTP	ISC Prime/ISC ST3	Limit value at sensitive receptor locations	12.90	Limit value for existing facility at sensitive receptor locations.
UK	≤5.0[4]	98th	60	WWTP-Newbiggin by the Sea Planning	ADMS	Used as a limit value prevent odour impact associated with WWTP	12.90	Planning application-Newbiggin by the Sea
UK	≤1.50[4]	98th	60	Livestock feed factory	ADMS/ AERMOD	Indicative odour exposure criterion for licensing	13.20	IPPC H4 Guidance Notes Part 1-Regulation and Permitting, Environment Agency
UK	≤1.50[4]	98th	60	Oil refinery	ADMS/ AERMOD	Indicative odour exposure criterion for licensing	13.20	IPPC H4 Guidance Notes Part 1-Regulation and Permitting, Environment Agency
UK	≤3.0[5]	98th	60	Landfill activities	Complex 1	Odour exposure criterion developed through laboratory based odour intensity studies and complaint correlation	14.10	Longhurst et al 1998 for Landfill planning application
NL	≤3.50[6]	98th	60	WWTP	Complex 1	Limit value to prevent odour nuisance existing plant	12.90	Industry sector specific air quality criterion for odours in Netherlands
NL	≤1.50[6]	98th	60	WWTP	Complex 1	Limit value to prevent odour nuisance new plant	12.90	Industry sector specific air quality criterion for odours in Netherlands

Notes: [1] denotes reference BAT Note development for intensive agriculture sector & EPA, 2001. Odour Impacts and Odour emissions control for Intensive Agriculture. R&D Report Series no. 14. EPA, Johnston Castle, Wexford.

[2] denotes EPA, (2004). BAT Notes for the Slaughterhouse sector, EPA, Johnston Castle, Wexford.

[3] denotes Odour limit values used during EIA application for WWTP's.

[4] denotes Environment Agency, (2002). Technical Guidance Notes IPPC H4-IPPC, Horizontal Guidance for Odour, Part 1-Regulation and Permitting. Environment Agency, Bristol, UK.

[5] denotes Magette, W., Curran, T., Provolo, G., Dodd, V., Grace, P., and Sheridan, B., (2002). BAT Note for the Pig and Poultry Sector. EPA, Johnston Castle, Wexford.

[6] denotes EPA, 2001. Odour Impacts and Odour emissions control for Intensive Agriculture. R&D Report Series no. 14. EPA, Johnston Castle, Wexford

Table 2.2. illustrates the range of odour impact criterion used in Ireland, UK, Netherlands, and other worldwide communities. The impact criterion accepted in Ireland and UK are based on research performed in Netherlands over the mid 80's and early 90's. In the late 90's the UK Environment Agency performed some research on validating those standards developed in Netherlands through studies performed in the UK. The main aims of these studies were for the developing of guidance notes on odour for licensing procedures under the EPA Act 1992. Over the last decade, these impact criterions have been providing protection to the community at large in the vicinity of such facilities. There is a general trend in odour impact criterion and dislike ability presented in *Table 2.1*. As can be observed in *Table 2.1 and 2.2*, the more offensive the odour is perceived, the lower the acceptable ambient odour concentration above baseline. Odours such as bakery odours are considered less offensive than pig production facilities and this is observed through the relative dislike ability and also the odour impact criterion established to limit nuisance. Wastewater treatment plants have similar dislike ability to intensive pig production facilities and therefore it would be rational to suggest a similar odour impact criterion to intensive pig production facilities. Other factors that require consideration include, the location of the WWTP / pumping station, the surrounding sensitive receptors, and amount of odour mitigation to be implemented into the overall design. For example in Ireland, pig production facilities are generally located in rural environments, whereby sensitive receptors in the vicinity of the facility are working in similar livestock operations and therefore do not consider the perceived odour as offensive as say a person not familiar with the odour. WWTP's / Pumping stations on the other hand in recent times are located close to the source of effluent and in the vicinity of sensitive receptors (population encroachment of residences and industrial estates). In addition, in recent times WWTP's and pumping stations have installed odour control technologies to limit the risk of odour complaint (e.g. Sutton Pumping station, Limerick Main Drain Pumping station, Ringsend Pumping station, etc.). By abating the sources of offensive odours within the WWTP and Pumping station, the odour limit value becomes less conservative as the odour emitted from the odour abatement technology is considered less offensive and therefore has a markedly lower potential risk of causing complaint. Taking into account these factors for the WWTP's and Pumping stations, it is proposed that:

- All sensitive locations and areas of amenity should be located outside the 1.50 $Ou_E\ m^{-3}$ at the 98th percentile of hourly averages over a meteorological year.
- All sensitive locations and areas of amenity should be located outside the 3.0 $Ou_E\ m^{-3}$ at the 99.5th percentile of hourly averages over a meteorological year.

These proposed odour impact criterion is sufficiently conservative to provide protection to the community at large taking into account latest suggested odour impact criterion by environmental agencies in Ireland, UK and Netherlands. In the case of the proposed Cork Harbour Main Drainage Scheme WWTP, all significant odour sources (wastewater handling and sludge handling operations) capable of generating offensive odours will be enclosed, sealed and negatively ventilated to an odour control system. Only the Aeration tankage, secondary settlement tankage and storm water tankage within the proposed WWTP will be open to atmosphere. All other odour sources will be enclosed, sealed and abated using odour treatment system (two stages of treatment for biological treatment unit as first stage).

For all pumping stations, an odour management system will be implemented to ensure that no uncontrolled release of fugitive odours occur.

For the WWTP odour impact assessment, the 99.5th percentile of hourly averages is used to complement the 98th percentile of hourly averages to take account of predicted downwind odour concentrations during short time worst-case meteorological conditions thereby providing added protection to the public at large. This was not performed upon the pumping station odour impact assessment as the predicted plume spread as assessed using the 98th percentile assessment criterion concluded negligible odour impact due to the overall low odour emissions due to odour source characteristics (i.e. odour emission rate from pumping stations is predicted to be low).

3.4. Meteorological data.

Cork airport meteorological station Year 1993 to 1997 inclusive was used for the operation of Aermod Prime. This allowed for the determination of the worst-case meteorological year for the determination of overall odour impact from the proposed Cork Harbour Main Drainage Scheme WWTP and each of the five Pumping stations on the surrounding population.

3.5. Terrain data.

Topography affects in the vicinity of the WWTP site were accounted for within the dispersion modelling assessment using a topography file. All significant deviations in terrain are examined in modelling computations through terrain incorporation using AerMap software.

All building wake effects within the propose WWTP and Pumping stations were accounted for in the modelling scenarios (i.e. building effects on point sources) as this can have a major effect on the odour plume dispersion at short distances.

4. Results

This section will present the results obtained from the study.

4.1. Odour emission data

Two data sets for odour emission rates were calculated to determine the potential odour impact of the proposed WWTP operation and design utilising site specific and library individual source odour emission data gathered onsite. These scenarios included:

Ref Scenario 1: Predicted overall odour emission rate from proposed Cork Harbour Main Drainage Scheme WWTP specimen design with the incorporation of odour mitigation protocols (*see Table 4.1*).

Ref Scenario 2: Predicted overall odour emission rate from major pumping stations with the incorporation of odour management systems (i.e. tight fitting covers, etc.) (*see Table 4.2*).

A worst-case odour-modelling scenario was chosen to estimate worst-case odour impact from the proposed Cork Harbour Main Drainage Scheme WWTP and five pumping stations following the incorporation of odour management systems (i.e. five years of met data, predicted odour emission rate, etc.).

4.2. Odour emission rates from Cork Harbour Main Drainage Scheme specimen design WWTP and Pumping stations operations for atmospheric dispersion modelling Scenario 1 and 2

Table 4.1 and *Table 4.2* illustrate the overall odour emission rate from the proposed Cork Harbour Main Drainage Scheme WWTP and five pumping stations (i.e. with installed odour management systems implemented).

As can be observed in *Table 4.1*, the overall odour emission rate from the proposed Cork Harbour Main Drainage Scheme WWTP specimen design will be at or less than 6,611 Ou_E/s. This overall source odour emission rate is based on worst case estimated of maximum emissions that could occur from the site with odour mitigation strategies implemented.

Table 4.2 illustrates the overall odour emission rate from the five pumping stations to be located in Raffeen, West Beach, Monkstown, Church Road (existing) and Carrigaloe Pumping Stations following implementation of odour management systems.

Odour emission rates are based on a number of mitigation assumptions that will require to be implemented into the Cork Harbour Main Drainage Scheme WWTP while odour emissions rates for the five pumping stations design are based on the implementation of good design and implementation of standard odour management systems (i.e. tight fitting covers).

Table 4.1. Predicted overall odour emission rate from proposed Cork Harbour Main Drainage Scheme WWTP specimen design with the incorporation of odour mitigation protocols (ref Scenario 1).

Source identity	Area (m^2)	Odour emission flux ($Ou_E/m^2/s$)	Volumetric airflow rate (m^3/s)	Odour threshold conc (Ou_E/m^3)	Odour emission rate (Ou/s)	% Contribution
Inlet works-Primary treatment building[1]	0	See OCU emission rate		-	0	0
Primary settlement tank 1[2]	0	See OCU emission rate	-	-	0	0
Primary settlement tank 2[2]	0	See OCU emission rate	-	-	0	0
Primary settlement tank 3[2]	0	See OCU emission rate	-	-	0	0
Storm water tank 1[3]	952.47	0.50		-	476	7.20
Storm water tank 2[3]	952.47	0.50		-	476	7.20
Aeration tank[4]	1200	1.20		-	1440	21.78
Secondary settlement tank 1[5]	952.47	0.50		-	476	7.20
Secondary settlement tank 2[5]	952.47	0.50		-	476	7.20
Secondary settlement tank 3[5]	952.47	0.50		-	476	7.20
Secondary settlement tank 4[5]	952.47	0.50		-	476	7.20
OCU 1 - Inlet works building OCU[6]	-	-	1.0	300	300	4.54
OCU 2 - Primary settlement tanks/Flow splitting chambers OCU[7]	-	-	0.93	300	279	4.22
OCU 3 - Sludge holding tanks/Digesters/Sludge drier OCU[8]	-	-	2.27	500	1135	17.17
OCU 4 - Primary sludge storage OCU[9]	-	-	1	300	300	4.54
OCU 5 - Secondary sludge treatment OCU[10]	-	-	1	300	300	4.54
Total odour emission rate[11, 12, 13]	**-**	**-**	**-**	**-**	**6,611**	**100**

Notes:

[1, 6] denotes all inlet works processes (screening and grit removal) will be double contained (to achieve legislative requirements of odourants in work space environment) and up to 6 to 10 AC/hr applied within enclosed process. All odourous air will be treated in an odour control unit. The double containment principle will apply here to ensure no emissions of odours escape to the headspace of the building. At all times the legislative concentrations of odourant will be required to be below their respective occupational exposure concentration level in all buildings.

[2] denotes the Primary settlement tanks will be covered with tight fitting covers and negatively ventilated to an odour control system.

[3] denotes the storm water tanks will be fitted with automated washing facilities to ensure each tank is free of organic debris following emptying. This will minimise any odour emissions associated with such process.

[4] denotes the odour emission rate from aeration process is based on library data assuming efficient oxygen transfer through the wastewater liquor (absence of anaerobicity). Advancements in the oxygen transfer equipment market have facilitated faster aerobic digestion of wastewater and efficient transfer of oxygen into the wastewater therefore reducing odour emission rates in comparison to older based techniques (OMI database on WWTP's in Ireland)

[5] denotes that secondary settlement tanks will be operated in accordance with standard practices and the build-up of scum will be prevented.

[7] denotes all sludge drying operations will be performed indoors. The sludge drying operation will be effectively sealed and negatively ventilated to prevent odour release to the headspace of the building. All odours generated as a result of drying and storage of undried/drier sludge cake will be negatively extracted to an odour control unit.

[8] denotes all sludge thickening process including Gravity belt thickeners and centrifuges will be double contained within their respective building and negatively ventilated to an odour control unit. All associated sumps and tankage will be sealed with tight fitting covers and negatively ventilated to an odour control unit.

[9] denotes all tankage associated with the handling and processing of primary sludge will be sealed with tight fitting covers and negatively ventilated to an odour control unit. All primary sludge treatment processes will be enclosed and negatively ventilated to an odour control unit.

[10] denotes all tankage associated with the handling and processing of secondary sludge will be sealed with tight fitting covers and negatively ventilated to an odour control unit. All secondary sludge treatment processes will be enclosed and negatively ventilated to an odour control unit.

[11] denotes the overall odour emission rate of 6,611 Ou/s is based on the facts of effective containment and extraction of odours from odour generating processes. The odour emission rate associated with odour treatment is assumed to be residual odour from the odour treatment process itself and aeration, secondary settlement and storm water tank processes.

[12] denotes it is anticipated that 5 odour control system will be installed providing an estimated treatment volume of 6.20 m^3/s to an exhaust odour concentration of less than or equal to 300 Ou_E/m^3 for OCU's 1, 2, 4, 5 and less than of equal to 500 Ou_E/m^3 for OCU 3 . This equated to an overall odour emission rate of 2,314 Ou_E/s from the treatment technologies. This treatment volume airflow rate should be sufficient to capture and maintain each process under slight negative pressure if effective enclosure, double containment and sealing of tankage/processes occur. In accordance with good engineering practice, the overall stack height will be at least 12 metres high. The overall effective efflux velocity will be 15 m/s at stack tip. This will aid in the dispersion of residual odours. The hedonic tone of this odour exhaust from the odour control units should not be considered unpleasant (Scale greater than –2) as assessed in accordance with VDI 3882:1997, part 2; ('Determination of Hedonic). The specimen design suggests the use of three OCU's. The following should be achieved at minimum: total odour emission rate of 6,611 Ou/s is achieved for the entire WWTP; the total minimum odour treatment volume of 6.20 m^3/s is treated within the OCU's, and a total odour emission rate of less than or equal to 2,314 Ou_E/s is achieved for the OCU's, then the number of OCU's utilised onsite is not important from an odour treatment viewpoint.

[13] denotes the overall odour treatment extraction rate is assumed and may need revision depending on process layout and final engineering design. This can only be changed if the DBO contractor can provide evidence that the selected design is sufficient to contain minimise and prevent fugitive odour emission to atmosphere. The overall containment process will be process proved independently using traditional smoke generation techniques so as to demonstrate containment of odours.

Table *4.2.* Predicted overall odour emission rate from five Pumping stations specimen design with the implementation of good design and odour management system operation (i.e. tight fitting covers, etc.) (ref Scenario 2).

Source identity	Odour emission rate (Ou_E/s)
Raffeen PS OCU[1]	90
West beach PS OCU[1]	360
Monkstown PS OCU[1]	120
Church Rd PS OCU[1]	81
Carrigaloe PS OCU[1]	51

Notes:

[1] denotes the overall odour emission rate will be dependent on the implementation of good design and odour management systems (e.g. good design in term of odour, tight fitting covers, etc.).