Appendix 4A

Geophysical Survey

Mott MacDonald

Cork Lower Harbour Main Drainage Scheme

Water Treatment Plant, Shanbally, County Cork

Geophysical Survey

Report Status: Draft

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Confidential Report To:

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EXECUTIVE SUMMARY

1. Minerex Geophysics Ltd. (MGX) carried out a geophysical survey consisting of EM31 Ground Conductivity, 2D-Resistivity and Seismic Refraction measurements for a proposed water treatment works development at a Cork County Council site in Shanbally, Co. Cork.
2. The main objectives of the survey were to determine ground conditions, the depth to rock, the existence of karst features and to reduce the risk of encountering difficult subsurface conditions and possible subsidence for proposed developments on the site.
3. The results of the geophysical survey show a thick overburden and possible fractured rock layer overlying clean strong limestone at a depth between 8 and in excess of 20m below ground level. Where the top of strong bedrock is approx. 20m and more deep it is at the penetration limit of the seismic setup.
4. The data describes a four layer earth model. The top three layers represent a transition from topsoil to stiff to very dense overburden and possible broken/fractured mudstone to clean limestone. The limestone bedrock has a typical depth of > 20m below ground level.
5. Overburden conductivities are quite low (unless influenced by metal objects) and indicate gravelly soil and sub soil types. There are no indications for soft ground layers on the site.
6. The overburden is interpreted as gravelly clay, sand and gravel and is expected to be well drained.
7. The shallowest rock is in the SE corner of the site (at R1) and the rock head dips to the north at the centre of the profile R1.
8. Generally the top of rock is so deep that no indicating for karstification of the bedrock can be found.
9. In the south east corner of the site where limestone bedrock is interpreted a 25m wide zone of possible faulting, fracturing or karstification is present and a borehole is recommended at this location.
10. Borehole locations for a possible drilling programme are recommended to further investigate areas of possible thickening of the overburden and shallowing bedrock as they may be related to the proposed constructions on the site.

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List of Tables, Maps and Figures:

1. INTRODUCTION

1.1 Background

Minerex Geophysics Ltd. (MGX) carried out a geophysical survey for a proposed development by Cork County Council at a site in Shanbally, Co. Cork. The survey consisted of mapping the site with EM31 Ground Conductivity Measurements followed by 2D-Resistivity and Seismic Refraction Profiles.

1.2 Objectives

The main objectives of the geophysical survey were:

- To determine the ground conditions under the site
- To determine the depth to rock
- To estimate the strength/stiffness/quality of overburden and rock
- To detect lateral changes within the geological layers
- To determine the presence of possible faults, fracture zones and karstified rock
- To reduce the risk of encountering difficult subsurface conditions during construction
- To reduce the risk of possible subsidence of future buildings and structures

1.3 Site Description

The site has a size of approximately 12 ha and consists of two open fields of pastureland. There is an elevation difference of about 2m from the northern to southern side of the site. An ESB station lies 200m to the west of the area and a number of pylons and high powered overhead cables are present. There is a BGE installation in the southwest. Underground pipelines (possible foul sewer and surface water drain) run west – east across the southern part of the site.

1.4 Geology

The site is underlain by Carboniferous lithologies, Waulsortian limestones and rocks of the latest Devonian and Carboniferous Cork Group, the Kinsale Formation. The Waulsortian Limestones consist of massive unbedded fine grained limestone. To the north near Cloyne the Waulsortian is known to be over 400m thick. The Kinsale Formation consists of grey mudstone with sandstone. South Cork consists of a series of west – east trending synclines and anticlines. The site lies between the Ringaskiddy Anticline and the more southerly Church Bay Anticline. These fold belts are cross-cut by a series of NNW – SSE trending faults (GSI, 1995).

1.5 Report

This report includes the draft results and interpretation of the geophysical survey. Maps, figures and tables are included to illustrate the survey and the results. More detailed descriptions of geophysical methods and measurements can be found in GSEG (2002), Milsom (1989) and Reynolds (1997).

The client provided a digital map of the site and ground investigation data from boreholes and trial pits in an area just north of the survey site. The map was used as the background for the maps in this report.

The interpretative nature and the non-intrusive survey methods must be taken into account when considering the results of this survey and Minerex Geophysics Limited, while using appropriate practice to execute, interpret and present the data give no guarantees in relation to the existing subsurface.

2. GEOPHYSICAL SURVEY

2.1 Methodology

The methodology consisted of using EM31 Ground Conductivity measurements to map the whole accessible area within the site. The results were reviewed and followed by 2D-Resistivity profiles and seismic refraction profiles.

The conductivity survey was carried out on lines nominally 10 m apart using a Geonics EM31. Along each line a reading of ground conductivity was taken every second, thereby resulting in a survey grid of about 10 x 2 m. Base station readings were taken and no instrument drift was noted. The ground conductivity contour map is shown on Map 2. The locations were measured with a DGPS system attached to the EM31 and all data was jointly stored in a data logger for later office based processing and analysis.

The 2D-Resistivity profiles were located to give good coverage of the site. The specifications for the 2D-Resistivity survey were: Multi-electrode switching system Tigre Resistivity Meter, laptop computer, power supply, 32 electrodes under computer control per array, 5 m electrode spacing, profile length of 155m, Imager 5 cable, stainless steel electrodes, contact resistances < 2000 Ωm, Wenner electrode configuration and 3 cycles per reading to reduce background noise. A total of 8 locations were surveyed (R1 – R8, see Map1).

Along each 2D-Resistivity profile a seismic profile with 12 geophones and 5 m geophone spacing, resulting in a profile length of 55m, was surveyed. The recording equipment was 6 DMT Summit 2in1 remote units with 10 Hz vertical geophones. The seismic energy source was a hammer and plate. A zero delay trigger was used to start the recording.

The resolution of the geophysical methods used depends on a large number of factors, but the following can be used to estimate the performance and detection ability of layers and features:

The EM31 method determines bulk ground conductivities to an approximate depth of 6m below ground level.

2D-Resistivity profiles determine the subsurface resistivity on a cross section. With a five meter electrode spacing and profile length of 155m as used in this project it is possible to detect lateral changes with an extent of 3-5 m and more and get depth penetration of 30m.

Seismic Refraction generally determines the depth to layers where the compaction/strength/rock quality changes with an accuracy of 10 – 20% of depth to that layer. The depth of penetration for the setup used on this site is approx. 20m.

The field observers ensured that good data quality was gathered and recognised on site if sudden changes in ground conditions occurred.

2.2 Site Work

The geophysical survey was carried out between the 5th and 7th of November 2007 in good weather conditions. The locations are indicated on the following table.

Table 1: Geophysical Survey Locations.

Profile Name	ING Northing Start	ING Easting Start	ING Northing End	ING Easting End
R1	175299	63630	175313	63784
R2	175140	63709	175295	63704
R3	175003	63853	175157	63838
R4	175092	63637	175122	63789
R5	175003	63723	175034	63875
R6	174856	63706	175007	63672
R7	174870	63645	174899	63797
R8	174916	63782	175068	63754
S1	175305	63679	175310	63734
S2	175200	63706	175255	63704
S3	175080	63843	175134	63839
S4	175103	63686	175114	63740
S5	175014	63772	175025	63826
S6	174905	63694	174958	63682
S7	174881	63694	174891	63748
S8	174965	63772	175019	63762

3. RESULTS AND INTERPRETATION

The interpretation of geophysical data was carried out utilising the known response of geophysical measurements, typical physical parameters for subsurface features that may underlay the site and the experience of the authors.

3.1 EM31 Ground Conductivity

The EM31 ground conductivity values were merged into one data file and contoured and gridded with the SURFER contouring package. The colour contour map with ground conductivities is displayed on Map 2 overlaid over the site base map. The contours are created by gridding and interpolation and care must be taken when using the data. The values in milliSiemens/metre (mS/m) are colour coded and the colour scale is shown on the map.

Low (blue contours) conductivities would indicate shallow bedrock and higher (green to red contours) conductivities would indicate deeper bedrock and thicker overburden. Very high conductivities (orange) indicate noise from man made metal objects. High interference occurs along the route of the pipelines in the south of the area as indicated by the long linear and bulls eye anomalies. The pipelines show as a different pattern in the EM31 data as the walking direction differed between the two fields. In some parts of the site small scale interference from a number of fences can be seen in the conductivity data. Such anomalies are seen close to the north – south field boundary running down the middle of the site and also in the western field boundary.

The ground conductivity values are generally quite small (where not disturbed by metal objects). This would indicate soils and subsoil with a gravelly nature. The range of values would indicate gravely clay and sand and gravel. The values would also indicate a well drained overburden. The conductivities do not show strong geological anomalies within the depth range of 6m. More detail within the overburden will be shown below by the other methods.

3.2 2D-Resistivity and Seismic Refraction

The 2D-Resistivity data was inverted with the RES2DINV inversion package. The programme uses a smoothness constrained least-squares inversion method to produce a 2D model of the subsurface model resistivities from the recorded apparent resistivity values. Three variations of the least squares method are available but it was determined that for this project the Jacobian Matrix would be recalculated for the first two iterations then a Quasi-Newton approximation would be used for subsequent iterations. This is deemed sufficient for this project as the largest changes in the Jacobian matrix normally occur in the early iterations, where a more robust Gauss – Newton method was used, and as large resistivity contrasts over small areas are not significant here. Each dataset was inverted using five iterations resulting in a maximum RMS error of < 2.5%. The resulting models are displayed as colour contoured sections in Figures 1 - 3 (left hand section) in the report. Interpretations of the data are shown on the right hand sections in Figures 1 - 3. The colour scale is the same for all profiles.

The seismic refraction data was processed with the SEISIMAGER software package to give a layered model of the subsurface. The number of layers has been determined by analysing the seismic traces and 4 layers were used in the models. All seismic profiles have been ray-traced, and residual deviations of typically 0.6 to 2.8 msec RMS have been obtained for each profile. The resulting layer boundaries are shown as thick lines on the cross sections (Fig. 1 – 3).

The interpretations for the site were based on all available geophysical data and supplied ground investigation data for a nearby site. The layer boundaries were determined by the seismic velocities and interpretation of lateral variation within the layers was based on the 2D-Resistivity datasets.

Table 2 summarises the interpretation of the geophysical data. The compaction/strength/rock quality has been estimated from the seismic velocity. An estimation of the excavatability for the bedrock has been made according to the caterpillar chart published in Reynolds (1997). A full estimation of excavatability should take borehole data and core descriptions into account.

Table 2: Summary of Results and Interpretation

Layer	General Seismic Velocity Range (km/sec)	General Resistivity Range (Ohmm)	Compaction/ Strength/ Rock Quality	Interpretation	Estimated Excavation Method
1	0.3	any	Loose/Soft	**Overburden/Topsoil**	Diggable
2a	0.9	< 566	Loose/Soft	**Gravelly Clay Overburden**	Diggable
2b	0.9	> 566	Loose	**Sand and Gravel Overburden**	Diggable
3a	1.9 – 2.0	< 566	Stiff – Very Stiff	**Gravelly Clay** (Or Fractured Rock/Mudstone)	Diggable
3b	1.9 – 2.0	> 566	Very Dense	**Sand and Gravel** (Or fractured Rock/Limestone)	Diggable
4	2.7 – 2.8	> 400	Good Rock	**Clean Limestone**	Breaking/Blasting

3.3 Summary Interpretation

The combined geophysical datasets collected at Shanbally describe a four layered earth model below the site with very thick overburden overlying clean limestone and mudstone bedrock lithologies. Layer 1 consists of a thin loose/soft overburden/topsoil deposit which is no more than about 3m thick.

Layer 2, which is < 3m - ~22m thick, has seismic velocities of 0.9 Km/S and is interpreted as overburden rather than rock. This layer has a very wide range of model resistivity values, 200 Ωm - > 1600 Ωm, and this variation is used to subdivide the layer into two. Layer 2a which has resistivity values < 566 Ωm is described as a gravelly clay. Resistivity values between 200 and 566 Ohmm are typical for gravelly clay. There are no model resistivity values less than 200 Ohmm recorded under the site. Such smaller values would be typical for soft clay and cohesive soils with high water content. Therefore it is concluded that there are no soft clays or organic mud in the overburden layer under the site. No soft ground conditions are likely to exist under the site. Layer 2b has model resistivity values > 566 Ωm, suggesting a decrease in clay content and an increase in sand and gravel. Within this layer there are pockets of very high values > 1131 Ωm. It is likely that these areas, mainly found in the eastern part of the site, are unsaturated sand and gravel deposits. These areas are seen at the north end of profile R1, the eastern end of R2 and R3 and centred around 60m on R4 (Figures 1 & 2). In the east of the site, at a distance of ~ 40 m – 80 m on R1, very high resistivity values suggest the gravel here may be rock derived in nature. It is possible that weathering, fracturing and breaking of the bedrock created a gravel deposit close to the surface and at the top of the strong rock.

The boundary between Layer 2 and Layer 3 is at a maximum depth of ~ 24m. It is important to note that given such significant depth values an accurate depth estimation of the deeper boundaries is difficult with small scale seismic refraction methodologies. Layer 3 has a significant seismic velocity of 1.9 – 2.0 Km/s and is therefore described as a very dense/very stiff lithology. This layer is also subdivided based on model resistivity values and is similar to layer 2 but is more indurated. It has a thickness range of < 2.0m - ~15m and reaches its maximum in the far west. It is likely this layer is made up of gravelly clay and sand and gravel deposits but given the determined velocity it may in places be a fractured or broken mudstone or limestone.

Layer 4 which has high seismic velocities and model resistivity values is a clean limestone. The top of this layer is at depths > 8m but is normally > 20m. In the SE corner of the site the rock is shallowest with values of 8m at the start of S1. Generally the strong rock is deep and at the depth penetration limit of the seismic refraction setup.

In addition to the above descriptions it should be noted that strong lateral variation in the model resistivity values on Profile R1 (see Figure 1) at depths of over 15 – 20 m may be due to faulting or fracturing of the rock. It is also possible that this zone represents karstification of the Waulsortian Limestone.

4. Conclusions and Recommendations

The following conclusions and recommendations are made:

- A geophysical survey consisting of EM31 Ground Conductivity, 2D-Resistivity and Seismic Refraction measurements was undertaken at the site of a proposed water treatment works at a site in Shanbally County Cork.

- The results of each of the geophysical methodologies indicated thick overburden overlying limestone and mudstone geology at a depth of 20m and more below ground level.

- The data describes a four layer earth model. Layer 1 is about 3m thick and is overburden and topsoil.

- Layer 2 is 3 – 22m of thick overburden. This layer shows significant lateral variation and consists mainly of gravelly clay (low resistivities) and sand and gravel (high resistivities). In places, particularly in the east, the gravels are likely unsaturated to depths of 10 – 15m bgl.

- Layer 3 is subdivided into stiff – very stiff gravelly clay and very dense sand and gravel. This layer is more consolidated than layer 2 and may in places contain fractured mudstone or limestone. This layer is ~2m - ~15m thick.

- Layer 4 is a clean limestone and has a depth which is normally 20m b.g.l. This layer is shallowest in the southeast corner of the site with a depth to the top of rock of 8m.

- In the east of the area there is a small area at the centre of R1 which may represent faulting/fracturing of the rock or karstification of the limestone (see Figure 1).

- In general ground conductivities are low and resistivities are larger than 200Ohmm. This would indicate gravelly and very gravelly clay as well as Sand and Gravel. This overburden type would provide for good drainage on the site and would indicate an absence of ground water to within 10 – 15 m under the site.

- For a possible drilling programme a number of boreholes are recommended at the following locations (Map 1). These target possible thickening of the overburden and areas of shallower bedrock. These should be considered based on the design of proposed constructions:

Borehole Number	ING Northing Coordinate	ING Easting Coordinate
BH1	175304	63689
BH2	175309	63723
BH3	175136	63840
BH4	175105	63707
BH5	174930	63689
BH6	174884	63719

5. REFERENCES

1. **CIRIA 2002.** Geophysics in Engineering Investigations, 2002. Geological Society Engineering Geology Special Publication 19, London, 2002.

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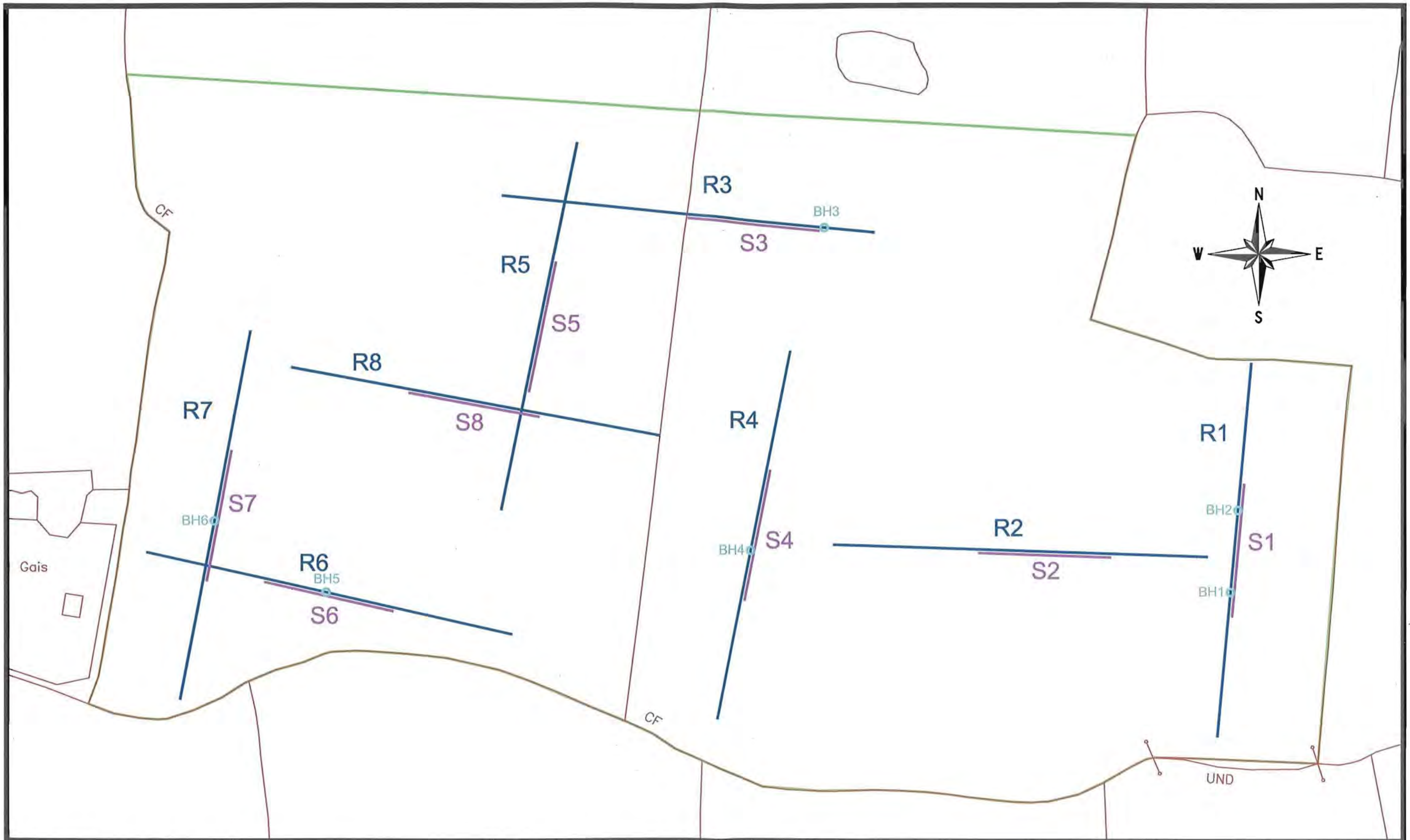
3. **Milsom, 2003.** Field Geophysics. Third Edition. John Wiley and Sons.

4. **Reynolds, 1997.** An Introduction to Applied and Environmental Geophysics. John Wiley and Son.



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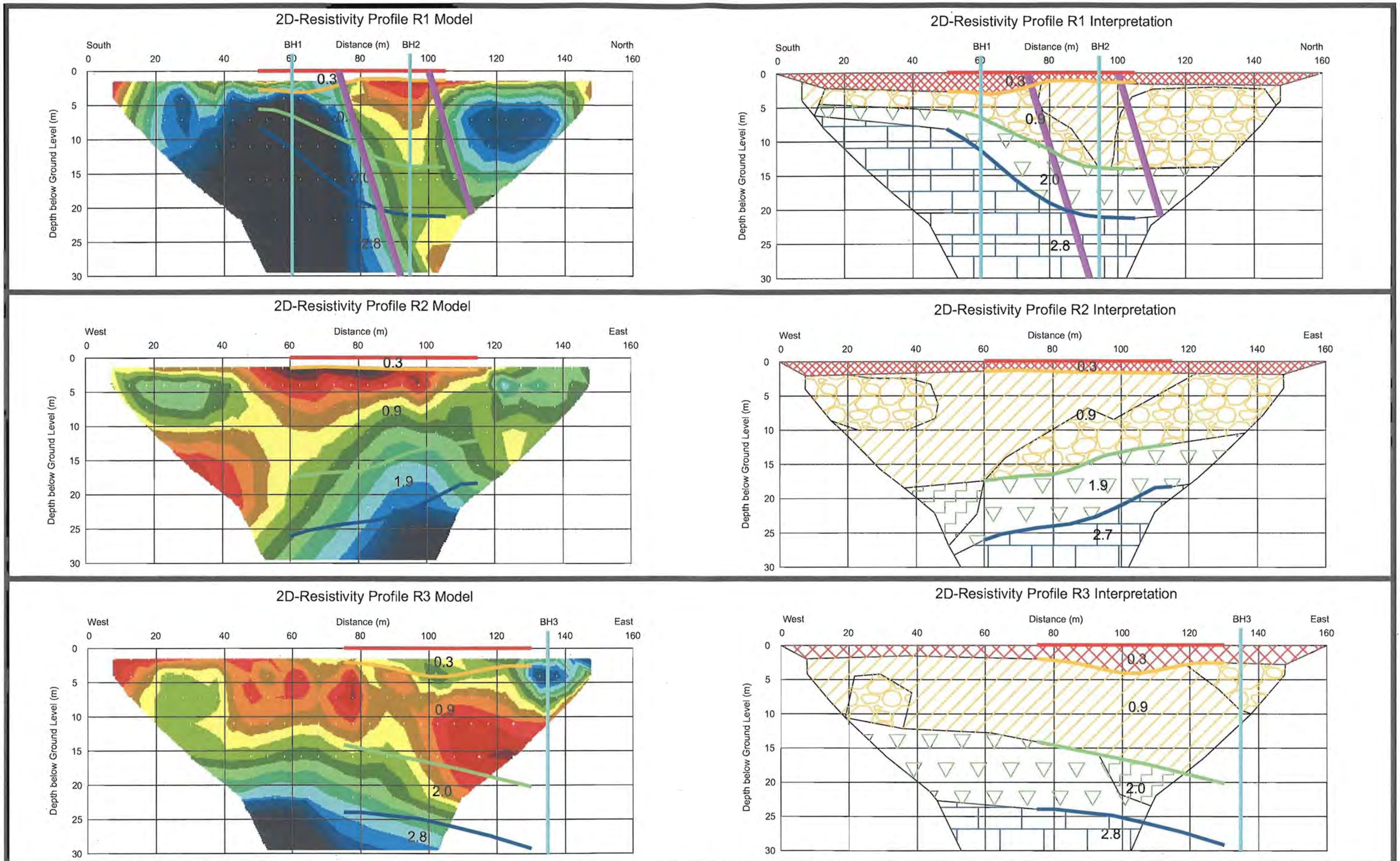
CLIENT	Mott MacDonald Pettit Cork County Council
PROJECT	Water Treatment Plant, Shanbally, Co. Cork, Geophysical Survey
TITLE	Map 1: Location Map of Geophysical Survey

SCALE:	1:1500 at A3
PROJECT:	5213
DRAWN:	TL
DATE:	13/11/07
MGX FILE:	5213d_Maps.dwg
STATUS:	Draft

LEGEND: (Refer to Report)

- Site and EM31 Survey Boundary
- 2D-Resistivity Profile
- Seismic Profile
- BH1 Proposed Borehole Location

Minerex Geophysics Limited	CLIENT	Mott MacDonald Pettit Cork County Council	SCALE:	1:1500 at A3	LEGEND: (Refer to Report)
Unit F4, Maynooth Business Campus Maynooth, Co. Kildare Tel. (01) 6510030 Fax. (01) 6510033 Email: info@mgx.ie Web: www.mgx.ie	PROJECT	Water Treatment Plant, Shanbally, Co. Cork, Geophysical Survey	PROJECT:	5213	Site and EM31 Survey Boundary
			DRAWN:	TL	2D-Resistivity Profile
			DATE:	13/11/07	Seismic Profile
	TITLE	Map 2: EM31 Ground Conductivity Contour Map	MGX FILE:	5213d_Maps.dwg	Colour Contours show conductivities in mS/m
			STATUS:	Draft	BH1 Proposed Borehole Location



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CLIENT	Mott MacDonald Pettit Cork County Council
PROJECT	Water Treatment Plant, Shanbally, Co. Cork Geophysical Survey
TITLE	Figure 1: Results and Interpretation of 2D-Resistivity & Seismic Profiles R1 - R3

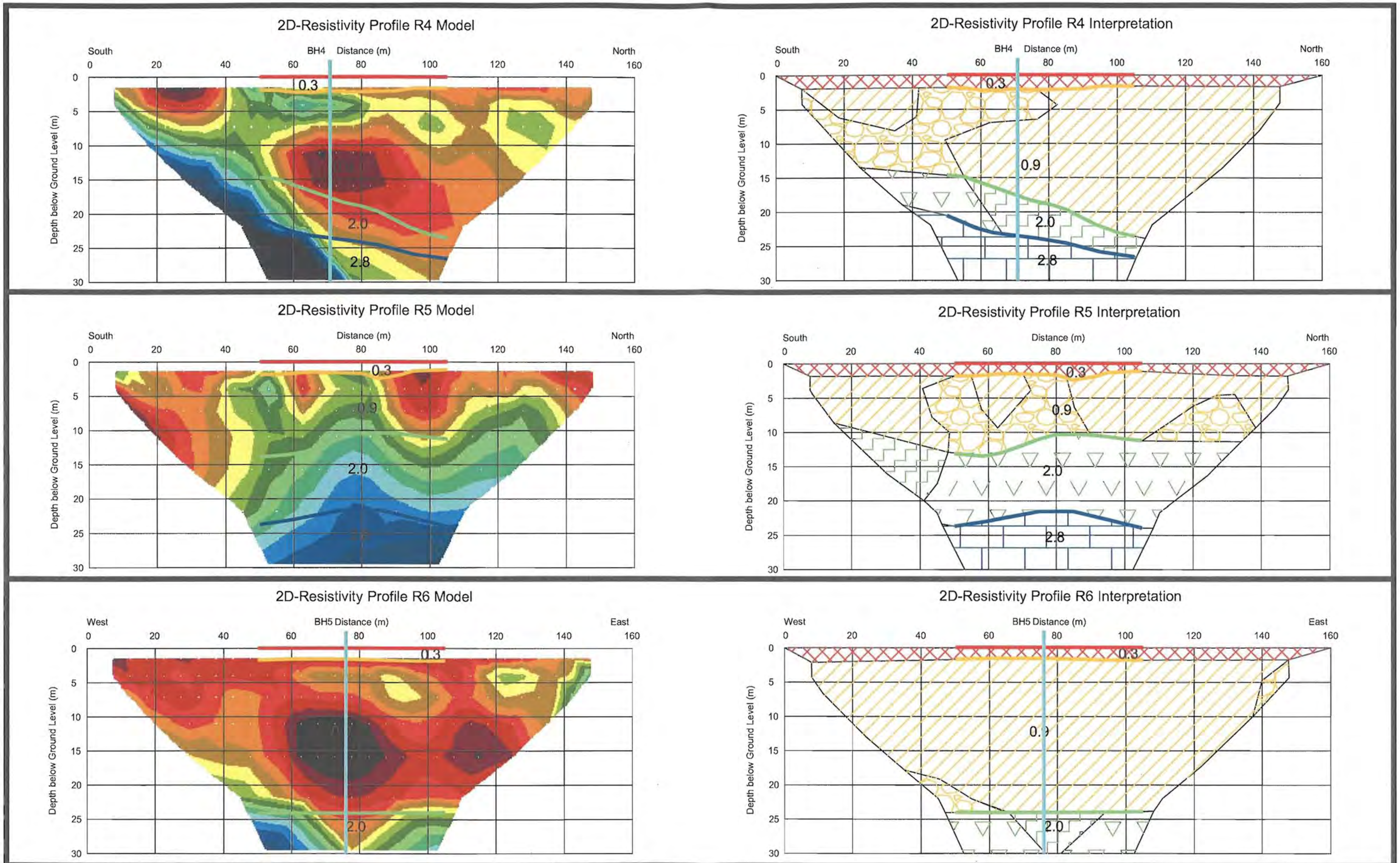
SCALE:	NTS, 2 x VE
PROJECT:	5213
DRAWN:	TL
DATE:	13/11/07
MGX FILE:	5213d_Figs.dwg
STATUS:	Draft

LEGEND: Integrated Interpretation

- Top of Layer 1 from Seismic Data
- Top of Layer 2 from Seismic Data
- Top of Layer 3 from Seismic Data
- Top of Layer 4 from Seismic Data
- 0.9 Seismic Velocity in Km/S
- 1 - Overburden/Soil
- 2A - Gravelly Clay
- 2B - Sand and Gravel
- 3A - Stiff -Very Stiff Gravelly Clay or Fractured Mudstone
- 3B - Very Dense Sand and Gravel or Fractured Limestone
- 4 - Clean Limestone
- Possible Fault, Fracture or Karst Zone
- BH1 Recommended Borehole Location

Model Resistivities Ohm.m

200 283 400 566 800 1131 1600 2263



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CLIENT: Mott MacDonald Pettit
Cork County Council

PROJECT: Water Treatment Plant, Shanbally, Co. Cork
Geophysical Survey

TITLE: Figure 2: Results and Interpretation of 2D-Resistivity & Seismic Profiles R4 - R6

SCALE:	NTS, 2 x VE
PROJECT:	5213
DRAWN:	TL
DATE:	13/11/07
MGX FILE:	5213d_Figs.dwg
STATUS:	Draft

LEGEND: Integrated Interpretation

- Top of Layer 1 from Seismic Data
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- Top of Layer 4 from Seismic Data
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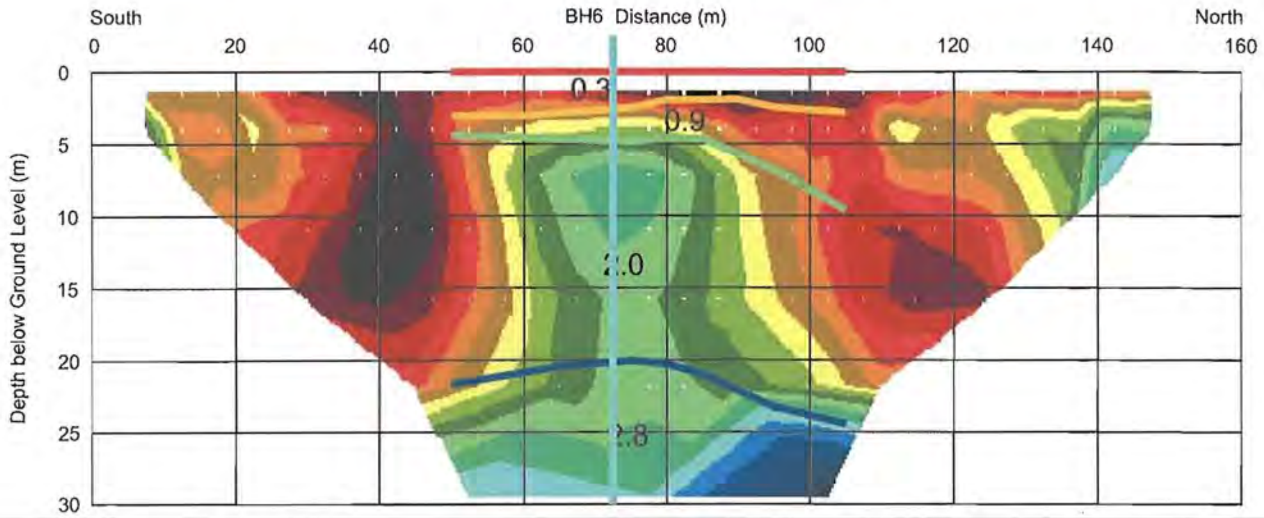
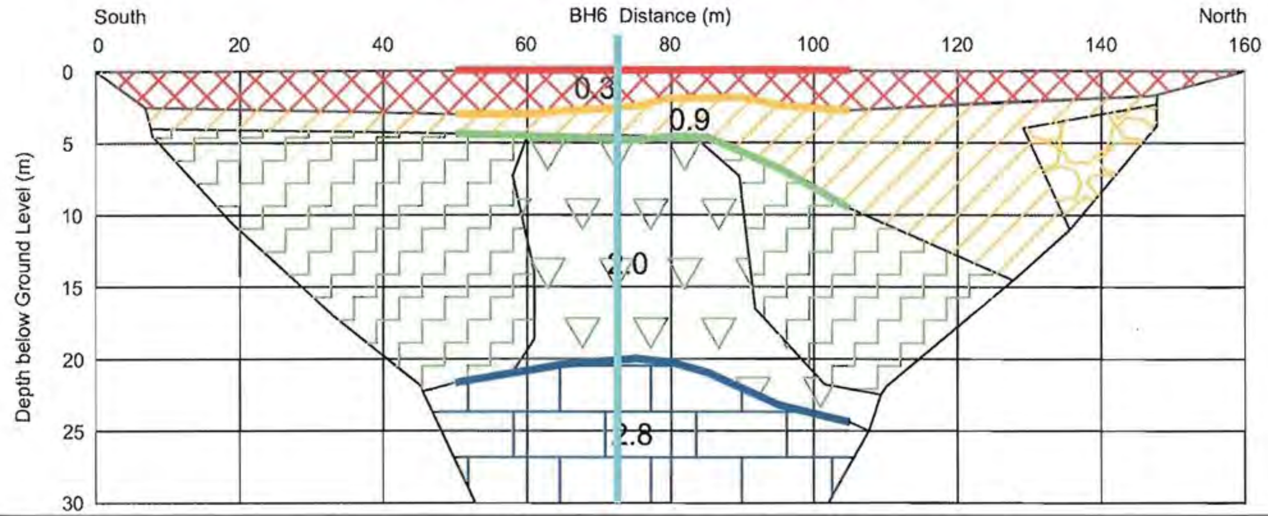
Model Resistivities Ohm.m

200 283 400 566 800 1131 1600 2263

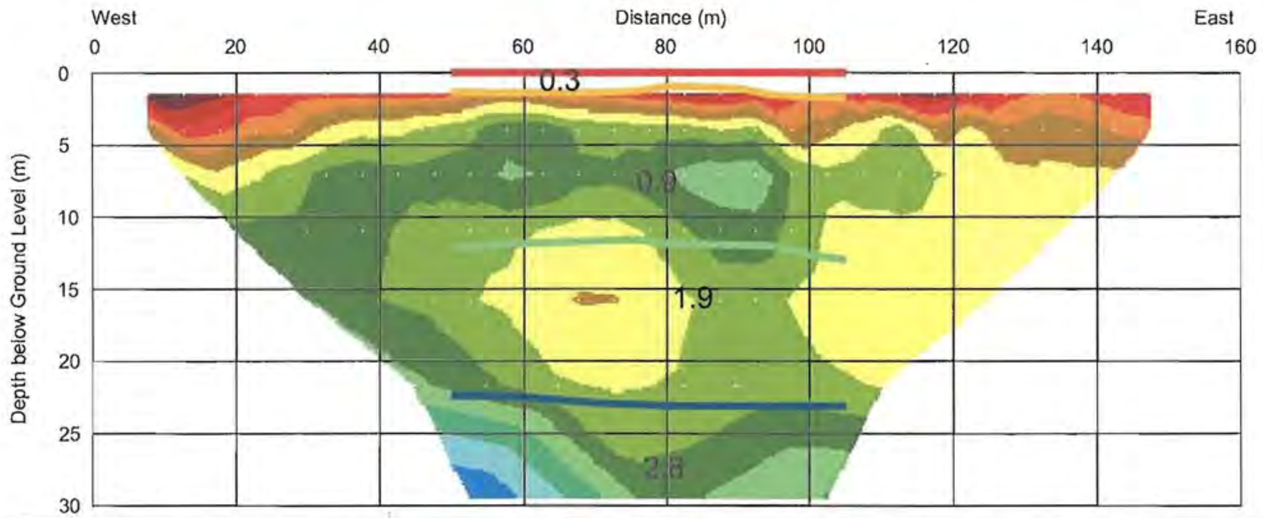
2D-Resistivity Profile R7 Model



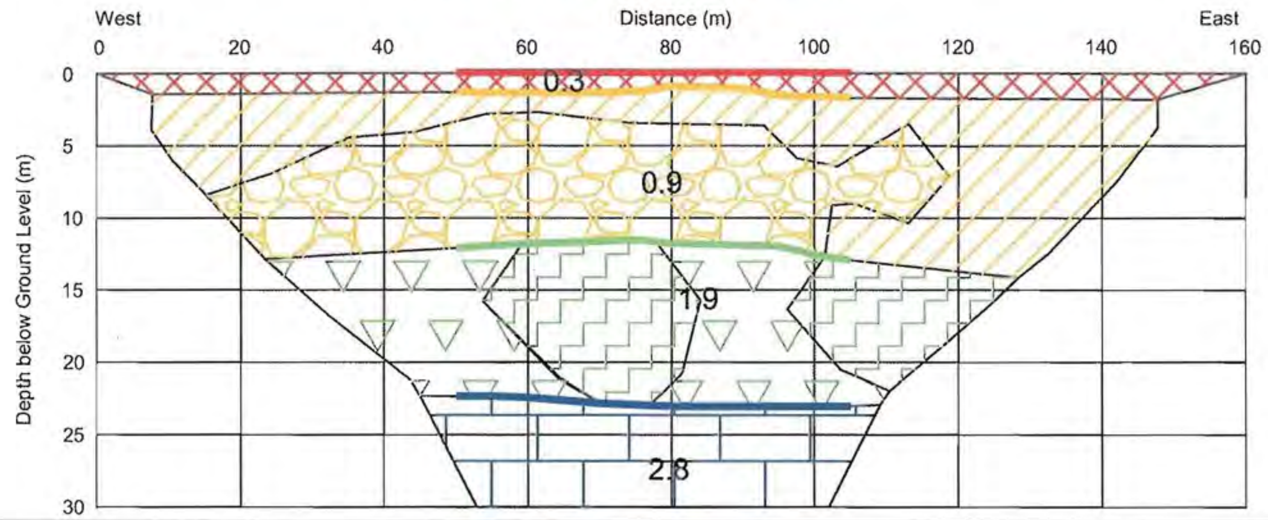
2D-Resistivity Profile R7 Interpretation



2D-Resistivity Profile R8 Model



2D-Resistivity Profile R8 Interpretation



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CLIENT	Mott MacDonald Pettit Cork County Council
PROJECT	Water Treatment Plant, Shanbally, Co. Cork Geophysical Survey
TITLE	Figure 3: Results and Interpretation of 2D-Resistivity & Seismic Profiles R7 - R8

SCALE:	NTS, 2 x VE
PROJECT:	5213
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DATE:	13/11/07
MGX FILE:	5213d_Figs.dwg
STATUS:	Draft

LEGEND: Integrated Interpretation

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- BH1 Recommended Borehole Location

Model Resistivities Ohm.m

200 283 400 566 800 1131 1600 2263

Appendix 4B

Bedrock Geology Summary

Mott MacDonald

GEOLOGY OF SOUTH CORK

A GEOLOGICAL DESCRIPTION OF SOUTH CORK
AND ADJOINING PARTS OF WATERFORD
TO ACCOMPANY THE BEDROCK GEOLOGY
1:100,000 SCALE MAP SERIES, SHEET 25, SOUTH CORK.

A.G. Sleeman, M. Pracht

E. P. Daly, A.M. Flegg,
P. J. O'Connor, and W.P. Warren.

Published under the authority of the
Director of the Geological Survey of Ireland.

The lack of heterolithic lithologies and bipolar current structures suggest that the environment was fluviatile. The succession is interpreted to be the deposit of meandering rivers with **levees** in a coastal plain environment. There is a total absence of marine faunas.

THE DEVONIAN STRATIGRAPHY IN THE CENTRAL AND EASTERN PART OF THE MUNSTER BASIN

Apart from the Gortanimill Fm. which extends into East Cork (to the south of Ballynoe at grid ref. 19500 08700), no other formations recognised in West Cork have been mapped. In general, only the higher parts of the Old Red Sandstone facies are exposed in East Cork.

Ballytrasna Formation

The type section of the Ballytrasna Formation (MacCarthy *et al.* 1978, here raised to formation status) is at Ballytrasna near Ballycotton (grid ref. 19830 06320). The thickness ranges from 360m up to 1500m. In the type area some 90% of the formation is composed of dusky-red mudstone while the remainder comprises pale-red fine-medium grained sandstone. The sandstones are occasionally large scale trough cross-laminated with planar or irregular lower surfaces (MacCarthy *et al.* 1978). Correlation of the Ballytrasna Formation with the Caha Mountain, Gun Point and Castlehaven Formations on broad lithological grounds is possible.

The Gyleen Formation

The Gyleen Formation (Gyleen Member, MacCarthy 1974; raised to formation status by Sleeman 1991) is characterised by alternating mudstones and sandstones. The type section is situated to the northwest of Cotters Point (grid ref. 18480 06030).

At the type section the Gyleen Formation comprises about 20% of medium-grained sandstone with large and small-scale cross lamination and about 80% mudstones. Fining up sequences are characteristic throughout the formation. Intraformational breccias, where present, occur in the basal parts of the sandstone units (MacCarthy *et al.* 1978).

The formation shows various colours from green to grey and purple but there is a general decrease of the purple colouration in relation to the underlying units. The base of the formation is at the lowermost thick (greater than 1.5m) sandstone unit, the top at the incoming of the first heterolithic sediments. Stratigraphically it has a similar transitional position as the Toe Head Formation further to the southwest.

Ballyknock Member

The type section is north west of Cotters Point, Co. Cork(grid Ref: 18500 06020). The member varies from 0-365m thick and comprises rapidly alternating thin green siltstone and sandstones with red mudstones. Thick fining upwards sequences, as found in the rest of the Gyleen Formation are rare. The red mudstones (2-30m thick) occur as sheets separated by thin red sandstones. The green siltstones and sandstones (2-20m thick) contain ubiquitous small-scale cross- lamination. About 50% of these sandstones are cross-stratified and arranged in lenticular units. Thin pale green and grey mudstones occur towards the top of the member (MacCarthy *et al.* 1978).

Ballyquinn Member

The type section is in the cliffs at Ballyquinn, Co. Waterford (grid Ref: 22130 08020) where it is approximately 390m thick. The base of the member is transitional from the Ballytrasna Formation and the top passes up transitionall to the Ardmore Member. The member comprises, alternating thick, grey and red medium-grained sandstones with thick red mudstones. The sandstones erosively cut into earlier mudstones and are large-scale, tabular and trough cross-stratified and parallel laminated. They frequently show **epsilon cross-stratification** and **fining upwards cycles**. Intraformational mudstone-flake conglomerates occur at several levels (MacCarthy *et al.* 1978).

Ardmore Member

The type section is located on the coast to the north of Ardmore Village, Co.Waterford (grid Ref: 21970 07740) where it is approximately 107-154m thick. It overlies the Ballyquinn Member conformably and passes up to the Castle Slate Member of the Kinsale Formation at the type section. The member is distinguished by regular alternations of grey and pale red sandstones (2-9m thick) (38%), with grey-yellow siltstones up to 6m thick (62%) (MacCarthy *et al.* 1978). Red beds are isolated and discontinuous where present.

The formations of the Cork Group are defined at the Old Head of Kinsale where they form a sequence more than 2km thick (Naylor 1966; Naylor *et al.* 1985; Kuijpers 1972). This Old Head sequence compares with a thickness near the geographical centre of the South Munster Basin (George *et al.* 1976) of 2.5km recorded in the Ringabella area (Naylor 1969). Further to the north, however, in Cork Harbour, the succession thins markedly (Sleeman et al 1978; Naylor *et al.* 1989) as the North Munster shelf is reached[6]. Further northeast at Ardmore, in County Waterford, the Cork Group is only represented by the 8m thick (MacCarthy et al 1978) Castle Slate Member of the Kinsale Formation.

OLD HEAD SANDSTONE FORMATION

The Old Head Sandstone Formation comprises a thick succession of grey sandstones and heterolithic bedded sandstones and mudstones. The type section is at the Old Head of Kinsale where the sequence has been divided into two members, the Bream Rock Member (550m thick) and the overlying Holeopen Bay Member (290m thick) (Naylor 1966; Kuijpers 1972). Individual members within the formation have generally only been recognised on well exposed coastal sections, so these are not distinguished separately on this mapsheet. The base of the formation is not seen at the type section, but where it can be seen (e.g. Curraghbinny to the north of Crosshaven), it is generally taken "at the entry of significant amounts of lens bedding and flaser bedding into the sequence" (Naylor 1975; Sleeman *et al.* 1978).

The lowest 60m of the Bream Rock Member are mud dominant and bioturbated heterolithic beds (Kuijpers 1972). Above this the heterolithic beds are less bioturbated and the sand dominant heterolithic beds are more common though still subordinate. From 170m above the lowest bed, sand dominant heterolithics predominate. From 355m - 410m above the base the section is inaccessible, but above this sandstone facies constitutes 40% of the succession and the remainder are sand dominant heterolithics (Kuijpers 1972).

The lowest 100m of the Holeopen Bay Member is dominated by sandstone facies. In the remainder of the member, sandstone bodies and mudstone complexes are both common whereas heterolithic facies rocks are less common (Kuijpers 1972).

Kuijpers (1972) interprets the Old Head Sandstone Formation as a tidally influenced depositional environment. The base of the Bream Rock Formation he interprets partly as intertidal mudflat deposits while the remainder of the member is considered to represent a sub tidal environment governed by low energy tidal currents. The Holeopen Bay Member Kuijpers interprets as a tidally influenced environment in which high energy tidal currents prevailed with some strata presumably deposited in a shallow lagoon or (interdistributary) bay lacking evidence of appreciable tidal current action.

The formation is well exposed (in part) at Coolmain (southwest of Ballinspittle) and further west at Seven Heads where Naylor (1964) recognised both the Bream Rock and Holeopen Bay Members. Here the succession is thinner (450m - Kuijpers 1972).Eastwards the formation is well exposed along the coastline from the Old Head of Kinsale, through Reanies Bay, Flat Head to Man of War Cove and Carrigada Bay and on to Cork Harbour (Naylor and Higgs 1980). In the latter area it is well exposed north of Roches Point at Whitebay (MacCarthy *et al.* 1978 - as the Coomhola Formation, Whitebay and Glanagow Members) and is also well exposed at Curraghbinny, Ringaskiddy, Cuskinny (Grid. Ref. 18097 06657) and Marino Point (Grid. Ref. 17716 06955) (Sleeman *et al.* 1978). The latter exposures in Cork Harbour are much thinner (92m - 42m) than further south into the main basin (Sleeman *et al.* 1978).

Inland, the formation is generally rather poorly exposed. Further thinning has been demonstrated northwards (Sleeman *et al.* 1978, Sleeman 1991) into the Cork Syncline where a 10m thick exposure can be seen at the entrance to St. Joseph's Hospital (grid ref: 16295 07201), beyond Sundays Wells, Cork City (MacCarthy 1987). East of Midleton the formation feathers out and is replaced **diachronously** by the topmost red beds of the Gyleen Formation (Sleeman 1991). The formation is also well exposed in Killeady Quarry (Crossbarry, north of Inishannon, grid ref: 15675 06170), where the apparent outcrop width is increased by subsidiary folding (Sleeman 1991).

[6] The top of the "Old Red Sandstone facies", on which the Cork Group rests conformably, is, however, diachronous. This has been demonstrated within the confines of this map sheet (Sleeman et al 1978).

The age of the formation, based on miospores is summarised by Higgs *et al.* (1988) who show that the formation encompases the LL, LE and LN miospore Biozones and is thus of Strunian age. The northward thinning of the formation is paralleled by the later age of the base of the formation demonstrated by the presence of LN Biozone miospores at or near the base of the formation at various localities between North Ringabella and Marino Point (Higgs 1975; Higgs *et al.* 1988; Sleeman *et al.* 1978).

KINSALE FORMATION

The Kinsale Formation, 762m thick at the Old Head of Kinsale (Naylor 1966), is defined, overall, as a mud-dominant succession. The formation is divided into three members on the Old Head: the Castle Slate, Narrow Cove and Pig's Cove Members

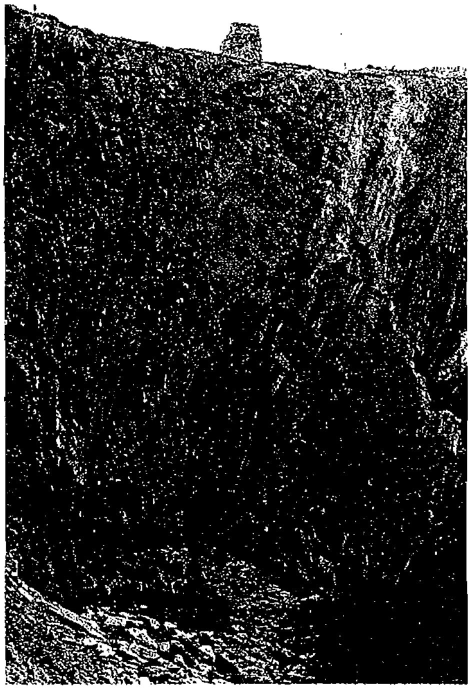

Plate 3. The topmost beds of the Uppermost Devonian Old Head Sandstone Formation on the right pass up to the dark-grey mudstones of the Carboniferous Kinsale Formation (Castle Slate Member) at the Old Head of Kinsale. This locality is the Courceyan Stratotype and approximates to the international Devonian-Carboniferous boundary (photo. by A.G.Sleeman).

(Naylor 1966; see also Naylor *et al.* 1977). They are not always shown separately on the mapsheet because inland, west of Kinsale, it has not yet proved possible to map them out in detail, for the most part. The individual members however are mapped out in the Cork City and Harbour district as shown here and on the recent Geological Survey 1:25,000 maps (Sleeman 1991). Approximately east and north of Belgooly and the Carrigada Fault, the overall mud dominant but sandy Narrow Cove Member, is represented by the sand dominant Cuskinny Member (MacCarthy *et al.* 1978; *Sleeman 1987*).

The Old Head of Kinsale is the stratotype for the base of the Courceyan Stage, the lowest of six regional stages in the Dinantian proposed for Great Britain and Ireland (George *et al.* 1976). It is named after the local Barony of de Courceys. The base of the stage corresponds to the Old Head Sandstone/ Kinsale Formation boundary located in Holeopen Bay West (plate 3). The base of the Courceyan Stage corresponds with the boundary between the LN and VI miospore Zones, (Clayton *et al.* 1974; George *et al.* 1976), which, in the absence of **goniatites** of the *Gattendorfia subinvoluta* Zone of Germany, approximates to the Devonian/ Carboniferous boundary.

The formation spans the VI, HD and BP miospore Biozones. Higgs *et al.* (1988) summarise the available data for localities within the mapsheet. The Castle Slate Member contains miospores of the VI Biozone. The Narrow Cove and Cuskinny Members contain VI Biozone miospores near the base but most of the sequence is in the HD Biozone. The base of the Pig's Cove Member contains upper HD biozone miospores and the top generally contains BP miospores[7]. These miospores show that the formation is of earliest to mid Courceyan age (Tn1b - Tn2b/c in Belgian terms).

Other stratigraphically useful fossils are scarce. Matthews and Naylor (1973), however, have recorded **conodonts** from the Castle Slate Member at the Old Head and Matthews (1983), has recorded an interesting goniatite fauna from the same member at Nohaval Cove (east of Kinsale).

Castle Slate Member

The Castle Slate Member, as defined in Holeopen Bay West, is 61.5m thick. The base of the member

[7] At one locality PC Biozone miospores were obtained from the topmost few metres suggesting that elsewhere the top of the member was eroded before deposition of the overlying Courtmacsherry Formation.

is the base of the Courceyan Stage as described above. The member consists of uniform, dark-grey, well cleaved massive mudstones (Naylor 1966) and is in marked contrast to the sandstones of the underlying Old Head Formation. Phosphatic **cryptocrystalline** quartz nodules are common, and especially near the base of the member, comminuted crinoid debris is found, sometimes in bioclastic lenses which also contain **ostracods** and small indeterminate bivalves (Naylor 1966).

The member is an excellent marker horizon across the whole South Munster Basin. It is found as far west as the Beara Peninsula (Gardiner and Horne 1976) and as far east as Ardmore (MacCarthy *et al.* 1978; Clayton *et al.* 1982). Within the area of Sheet 25 it can be seen in many other coastal sites including Dunnycove Bay (Galley Head), Lions Cove (Dunworly Bay) (Graham and Reilly 1976; Naylor and Reilly 1981, MacCarthy 1987), Nohaval Cove and Flat Head (Naylor and Higgs 1980), Ringabella Bay (Naylor 1969), Curraghbinny, Marino Point and Cuskinny, (Sleeman *et al.* 1978; MacCarthy *et al.* 1978), Whitebay, Inch, Ballycotton and Knockadoon (MacCarthy *et al.* 1978).

Plate 4. Vertically bedded sand-lensed (linsen) and sand-streaked mudstones of the Courceyan (Lower Carboniferous) Kinsale Formation (Narrow Cove Member) at Duneen Bay near Clonakilty (photo by A.G. Sleeman).

The member is found in many stream sections and quarries inland (the latter often worked in the past for roofing slate), but is difficult to map inland west of Belgooly.

The base of the member represents a sudden but slight deepening of the sea (Naylor *et al.* 1983), immediately succeeding the topmost sandstones of the Old Head Formation which, in some places, are probably shore face deposits (Graham 1975a).

Narrow Cove Member

The type section at Narrow Cove, on the west coast of the Old Head is 303m thick (Naylor 1966). The dominant lithology is sand-lensed (linsen) mudstone (plate 4); although a wide range of lithologies are found including parallel and cross-bedded sandstone, flaser-bedded sandstones and laminated mudstones. There is a general increase in the proportion of sand up sequence so that the top few metres are sand-dominant (Naylor 1966).

The member is well exposed between the Old Head of Kinsale and Kinsale Harbour (de Raaf *et al.* 1977; Naylor and Higgs 1980). Further east the cliff sections are inaccessible. Westwards, there is a good section at Dunworly Bay (Graham and Reilly 1976) and the member thins towards Galley Head (Keegan 1977). Inland it is exposed along the Cork - Bandon road west of Inishannon, where it is very sandy. However, at present it has not been mapped out inland west of Belgooly.

The member, while mudstone dominant, is relatively sandy. The proportion of sandstone gradually increases north and east from the Old Head until north of the Carrigada Fault at Robert's Cove (Robert's Cove Sandstone Formation of Naylor 1969) its equivalent is sandstone dominant (Van Gelder and Clayton 1978). In consequence Sleeman (1987) proposed that the name Cuskinny Member (MacCarthy *et al.* 1978) should be used north of the Carrigada Fault.

De Raaf *et al*. (1977) concluded that the depositional environment was a muddy shallow marine platform on which sandy shoals were formed under the influence of wave action and, overall, represents a regressive phase.

Cuskinny Member

The Cuskinny Member (MacCarthy *et al.* 1978) is the lateral equivalent of the Narrow Cove Member, north and east of the Carrigada Fault (Sleeman 1987). The type section at Cuskinny, east of Cobh (Grid. Ref. 18097 06651), is more than 235m thick wheras the section at South Ringabella (the Robert's Cove Sandstone Formation of Naylor *et al.* 1969; Naylor 1969), records 243m in total.

The Cuskinny Member is distinguished from the equivalent Narrow Cove Member in the higher proportion of sandstone and sand-dominant heterolithic bedded facies. MacCarthy *et al.* (1978) describe the member as composed of relatively thick (0 - 2.65m) sometimes conglomeratic sandstone units (54%), alternating with thin sandstone laminated mudstones (3%), massive claystone (8%) and heterolithic sediments (35%).

North and east of the type section it is difficult to map due to poor outcrop. The member dies out in the region of Knockadoon Head north of which it is laterally replaced by the Crows Point Formation.

MacCarthy *et al.* (1978) and Cotter (1985) describe the member as a regressional phase representing a shallow coastal marine environment with storm generated offshore gravel-topped barrier bar and beach facies.

Pig's Cove Member

The member is distinguished from the underlying Narrow Cove Member by a general lack of sandstones. At the type section (397m thick, Grid. Ref. 16200 04005) the lowermost 66m are characterised by silt and fine sand lenses (linsen) within a parallel laminated mud-siltstone sequence. The next 68m of the member consists of undifferentiated highly cleaved massive mudstones and the following 70m are similar to the basal 66m (Naylor 1966). The uppermost 195m, originally designated as the Coosduff Member (Naylor 1966), is sandier than the underlying beds. There is a high proportion of sand-lensed mudstones and thin (less than 0.15m) sandstone beds with rare thick sandstones. Small discoid silicophosphatic nodules are common throughout the mudstones (Naylor 1966; Naylor and Reilly 1981).

The member reaches a maximum thickness in the Kinsale - Ringabella area where Naylor (1969) recorded 709m (Doonavanig Formation) and Sleeman (1987) recorded a similar thickness in Tracton Wood. Further north, however, the member rapidly thins (340m - Paulgorm Formation of Naylor (1969) at North Ringabella) and is probably laterally replaced by the upper part of the Cuskinny Member north of the Cloyne Syncline (Sleeman 1987). In the Cork Harbour area the member is recorded by MacCarthy *et al.* (1978) from the core of the syncline at Whitebay and from the Inch and Ballyshane (east of Gyleen) area (see also MacCarthy 1988 -map). A section at Halfway (between Cork and Bandon), at the western end of the Cloyne Syncline, exposes about 200m through the member, but this sequence appears to thin rapidly eastwards towards Ballea Gorge (north of Carrigaline), where only 75m is recorded (Sleeman 1987). At Raffeen, where the member is no more than 50m thick, it is seen to pass up to the Courtmacsherry Formation. The member has not been found further north and east of Raffeen. While available evidence points to eastward thinning of the member, post Kinsale Formation erosion, suggested by the absence of the BP Miospore Biozone in the Ballea area (Sleeman *et al.* 1986), and strike parallel faulting may both have contributed to the apparent thinning and absence of the member through much of the Cloyne Syncline (Sleeman 1987).

MacCarthy and Gardiner (1987) suggest that the member represents deposition on an offshore wave influenced muddy shelf.

Courtmacsherry Formation

Naylor (1966) recorded a thickness of about 343m from the type section on the west side of the Old Head of Kinsale, between Ringalurisky Point and Well Cove. The formation is informally divided into four units at the type section (Naylor 1966; Matthews and Naylor 1973; Naylor *et al.* 1985), the base of which is taken at the incoming of the first calcareous mudstone. The first unit is characterised by crinoidal debris in beds and lenses inserted into a sequence of calcareous and non-calcareous grey nodular mudstones. Above this the second member is composed of non calcareous siltstones with fine-sand cross-laminae. The third unit comprises interbedded calcareous and non-calcareous mudstones with fewer thicklimestone beds than the basal unit. The topmost unit contains dark-grey mudstones with up to 20% ferroan carbonate as rhombs or concretions[8].

While this description suffices for the formation in the Old Head - Seven Heads area, at Ringabella and Inishannon there is a significant increase in limestone incorporated into the formation (equivalent to member 2).

[8] Away from the Old Head, the boundary between the Courtmacsherry and Lispatrick Formations is rather difficult to define (Naylor *et al* 1987 - Seven Heads).

Elsewhere only member 1 appears to be present. The formation on the basin margin is much less calcareous and less fossiliferous than the equivalent formation on the North Munster Shelf, at Whiting Bay and Mallow for instance (i.e. the Ringmoylan Formation - Campbell 1988; Sevastopulo and Sleeman, unpublished).

The most notable locality is Ringabella Bay where the lower part of the formation (The Fountainstown Member) is succeeded by the limestone rich Ringabella Limestone Member (Naylor 1969; Sleeman 1987). Here the member comprises alternations of 0.1-0.2m thick crinoidal biomicritic limestones and black siliceous and in some cases calcareous, and commonly phosphatic, mudstones. The limestones also contain quartz sand whose origin is difficult to establish. The presence of reworked conodonts in these limestones, however, lends support to the argument that the carbonates found in the Ringabella Limestone Member are derived by removal of material from an intrabasinal uplifted fault block to the north as a result of local intra Courceyan slumping and erosion (Naylor *et al.* 1983).

The Ringabella Limestone Member cannot be mapped away from the coast. Inland adjacent to the old National School at Minane Bridge the Geological Survey drilled a short hole which encountered calcareous mudstones (Sleeman 1987).

The second area where limestones are a significant proportion of the Courtmacsherry sequence is at Rag Bridge east of Inishannon. Here boreholes drilled by Riofinex penetrated a succession comparable to that at Ringabella, but about 1/10th the thickness: the succession is still poorly known and is referred to here informally as the "Inishannon Limestone" (Naylor *et al.* 1983). Again, thin limestones present in the sequence contain quartz sand and reworked conodonts.

The Courtmacsherry Formation has been mapped by one of us (AGS) recently in the area between Upton, Kilpatrick and to the west of Mishells House. A particularly interesting section has been noted in the old Bandon and South Coast Railway cutting at Rockfort House, Brinny (see Key Localities), where the formation as measured is about 200m thick (true thickness) and passes up to the Lispatrick Formation. The section exposes silty and variably calcareous mudstones with thin crinoidal **bioclastic** limestones and dolomitised calcisiltites. The upper part of the sequence is dominated by blocky, nodular, cherty, dolomitised, calcisiltites and **argillaceous** decalcified and cleaved mudstones (Sleeman unpublished). This passes up gradationally to bedded cherts assigned here to the Lispatrick Formation (cf the Minane Chert Member - Naylor 1969; Sleeman 1987).

Further east in the Cloyne Syncline, the formation thins rapidly and passes northwards laterally into the Ringmoylan Formation. The 24m thick sequence exposed between faults at Golden Rock, Ringaskiddy (Sleeman *et al.* 1978, 1986) is transitional to the Ringmoylan Formation; it resembles the Fountainstown Member at Ringabella but is considerably more fossiliferous and was probably more calcareous originally (the mudstones are all weathered and decalcified). At Ballygarvan and Kilnahone Mill the formation is only 3 - 5m thick.

At Broadstrand (Seven Heads), the formation can be divided into four members as at the Old Head but is only 208m thick. The basal beds contain conodonts of the *Siphonodella* Biozone while in member 4 specimens of *Gnathodus cuneiformis*, similar to those recovered from the Ringabella Limestone, have been found. At Ringabella these are known to be of earliest *Polygnathus communis carina* Biozonal age (Naylor *et al.* 1988). Thus the Courceyan age for the top of the Courtmacsherry Formation, as at Ringabella is confirmed at Seven Heads.

At Ballinglanna, on the west side of Seven Heads, the formation is only 7 - 17m thick and lithologically is only slightly different from the underlying Kinsale Formation. It comprises silty mudstones with thin linsen laminae and siliceous and pyritic bullions up to 0.5m across (Naylor *et al.* 1988). The formation here is of early Courceyan (PC Biozone) age.

At Galley Head, only 10km further west, the Courtmacsherry Formation is equivalent to, at most, 8.25m of chert and mudstone (but assigned by Naylor *et al.* (1985) to the Lispatrick Formation). Alternatively and more probably, equivalents of the Courtmacsherry are not present, or are to be found within the 2.15m of cherty mudstone just above the Kinsale Formation (Naylor *et al.* 1985).

Lispatrick Formation
The Lispatrick Formation, 67m thick at the Old Head (Naylor *et al.* 1985), comprises a sequence of fissile and blocky dark-grey to black mudstones, often extremely pyritic, with interbedded bands of

ferroan dolomite. The mudstones often weather to a pale ash-grey colour. Bands of black chert are common.

The distinction between the upper part of the Courtmacsherry Formation and the Lispatrick Formation is subtle; while the base of the Lispatrick Formation in Well Cove (Old Head of Kinsale) is satisfactory, the overall nature of the transition between the two formations presents problems in regional correlation (Naylor *et al.* 1985).

The Brigantian bivalve *Posidonia becheri* is found between 13 - 21m above the base of the formation and goniatites of the Brigantian P1d Subzone occur higher up (Naylor *et al.* 1985). However, conodonts (Naylor *et al.* 1985) suggest a late Courceyan to Arundian age for the base of the formation, although reworking from older levels (as for example is known from the Ringabella Limestone Member) cannot be discounted yet.

At Seven Heads the formation is exposed in a small cove east of Meelmane (Naylor *et al.* 1988) where it is 40m thick. At Ballinglanna it is 32.8m thick and **palynological** data (VF Biozone) and conodont data (*Gnathodus girtyi*) confirm the Brigantian age here (Naylor *et al.* 1988). At Galley Head the base of the formation rests on the Kinsale Formation. Here a 2.15m thick sequence of cherty mudstone is present. Its basal 0.2m contains abundant, angular granules and moulds of crinoid ossicles. It is lithologically distinct from typical mudstone of the Lispatrick but is included in the formation by Naylor *et al.* (1988) to avoid introducing another stratigraphical term unique to the locality. Mudstones containing P1c subzonal goniatites (Brigantian) occur 8.25m above the base.

In the Cloyne Syncline the formation is poorly exposed. It has been recorded, however, in boreholes at Meadstown House (Grid. Ref. 16781 06280, Sleeman 1987). Here the sequence comprises very dark-grey pyritic mudstones interdigitating with brecciated **calcilutites** and dolomitised **calcarenites** of Asbian age (Little Island Formation). This is considered to reflect a position on the basin slope margin. Elsewhere the formation appears to pass up to the Namurian White Strand Formation.

Further south, in the Ringabella Syncline, bedded cherts and dark-grey phosphatic and pyritic mudstones at Minane Bridge (plate 5) are assigned to the formation (Minane Chert Member - Naylor 1969; Sleeman 1987). The discovery of a goniatite (*Ammonellipsites*) from Minane Quarry (Naylor *et al.* 1983) suggest a Courceyan age for the base of the Lispatrick Formation here. The possibility of a similar age for the base of the formation at the Old Head has already been noted.

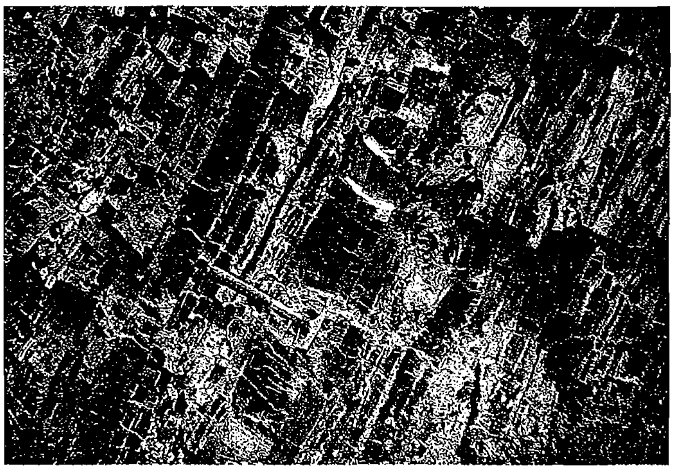

Plate 5. Bedded cherts from Minane Quarry (at Minane Bridge), Lispatrick Formation. These rocks are the basinal down-slope equivalents of the cherty Loughbeg Formation on the shelf edge (photo by A.G. Sleeman).

At Rag Bridge, southeast of Innishannon, the Lispatrick Formation has been drilled fairly extensively by Riofinex. Here black cherty shales interbedded with limestone breccias (similar to those at Meadstown) rest on limestones and calcareous shales of the "Innishannon Limestones" (Courtmacsherry Formation)[9]. Only about 4km further eastwards, however, the Lispatrick Formation mudstones are in juxtaposition with the Kinsale Formation due to strike parallel faulting.

White Strand Formation

The Namurian White Strand Formation is 44m thick at the Old Head of Kinsale, where the top is not reached. At Ballinglanna, however, Naylor *et al.* (1988) record a thickness of 346m. The outcrop of

[9] Work in progress (Naylor, Sevastopulo and Sleeman). Northwest of Inishannon itself, in the Kilpatrick Syncline, the Lispatrick Formation may occupy the centre of the syncline (Sleeman unpublished).

the formation in the Cloyne Syncline (between Meadstown and Inishannon) is probably of the same order of thickness.

This formation is the youngest formation present on the South Cork mapsheet and is of Pendleian or Arnsbergian age (E1 - ?H goniatite subzone).

At the type section the formation consists of sandstones up to 0.7m thick, interbedded with brittle, commonly pyritic, grey mudstones. The ratio of sandstone to mudstone is approximately 1:3. Much of the lower part of the formation is strongly slumped. Its base istaken at the abrupt entry of sandstones on the southern side of White Strand Point.

In the Cloyne Syncline, the formation is poorly exposed, but comprises a mixed sequence of grey silty mudstones and dark-grey to khaki or greeny-grey medium to coarse grained sandstones; it is easily mistaken in the field for the Cuskinny Member of the Kinsale Formation (Sleeman 1987). Outcrops at Ballyheady Church west of Ballinhassig have yielded Namurian miospores of the NC Biozone (Sleeman 1987) and Coelacanth fish remains (Huxley 1866).

At Ballinglanna miospores belonging to the NC Biozone have been found 41m above the base and miospores of the SO Biozone at the top of the formation as exposed (Naylor *et al.* 1988).

Carboniferous Limestones

"THE LOWER LIMESTONE SHALE"

The standard succession through the "Lower Limestone Shales" on the North Munster Shelf to the north of this mapsheet comprises the Mellon House, Ringmoylan and Ballyvergin Shale Formations respectively (table 2). The northern half of mapsheet 25 is geographically in a transitional position between the basinal succession of the South Munster Basin and the shallow water North Munster Shelf succession outlined above. Consequently aspects of both sequences can be seen in juxtaposition in the Cork, Riverstown, Ardmore and Clashmore Synclines. The shelf succession is also laterally very variable, so a series of laterally equivalent units have been proposed in different areas (e.g. Sleeman *et al.* 1978; MacCarthy *et al.* 1978; Campbell 1988; Tietzsch-Tyler *et al.* 1994).

Crows Point Formation

The Crows Point Formation, restricted to the Youghal, Ardmore and Helvick Head areas of East Cork and Waterford, is the lateral equivalent on the southern edge of the North Munster Shelf of the Cuskinny and Pig's Cove Members (Kinsale Formation) further south. The formation differs from the Kinsale Formation in being sandstone dominant (92% at the type section - MacCarthy *et al.* 1978). It probably equates with part of the Mellon House Formation further north on the shelf.

At the type section, at Helvick Head just northeast of this mapsheet, the formation is 73m thick (although the bottom contact is faulted and the top is not seen). The formation here comprises mainly thick, parallel-sided, massive and epsilon cross-stratified grey sandstones, interbedded with minor thin cross-stratified grey sandstones, grey mudstones and heterolithic lithologies (MacCarthy *et al.* 1978; MacCarthy 1979).

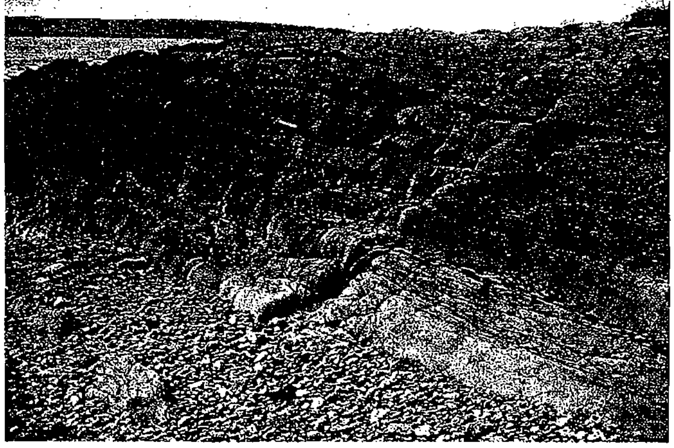

Plate 6. Megaripples developed on a bedding surface of grey sandstones in the Crows Point Formation, Whiting Bay, Co. Waterford (photo by A.G. Sleeman).

At Crushea (Ballyquinn, north of Ardmore) and Whiting Bay, however, where only the presumed top of the formation is exposed, sandstones with interbedded burrowed weathered mudstones and decalcified sandstones occur. These sequences also contain appreciable quantities of quartz-pebble conglomerates lining the bases of sandstones

Appendix 4C

Geological Heritage Correspondence

Mott MacDonald

From: Sarah Gatley [Sarah.Gatley@gsi.ie]
Sent: 09 July 2007 15:34
To: Freyne, Orla
Subject: RE: 234541 (A5670 Cork Lower Harbour WWTP EIS) - Geological Heritage

Dear Orla,

With reference to your enquiry on geological heritage sites in the Cork Harbour region, I have attached an xls. showing 3 sites of geological heritage interest in the area. I do not see any potential impacts from your proposed Waste Water Treatment Plant development; this is mostly for your information. As you can see from the 'Cork Harbour' entry, details of the extent of the raised beach feature have not been resolved, but I see that few of your proposed pipes are mapped for the foreshore areas.

I am sure that you are already aware of the biodiversity NHAs in this area; namely Loughbeg, Monkstown Creek and Owenboy River (?proposed foreshore pipe runs along the north bank).

If development does proceed (all other factors considered), GSI would much appreciate a copy of reports detailing site investigations undertaken. The data would be added to GSI's national database of site investigation boreholes, implemented to provide a better service to the civil engineering sector.

We would also appreciate notification of any ground excavations etc. carried out that might provide good geological exposures for our examination and enhance our understanding of the area. This would allow recording, fossil or rock sample collecting and gathering of new data.

Should any significant bedrock cuttings be created, we would request that they be designed to remain available as rock exposure rather than covered with soil and vegetated.

I hope that these comments will be of assistance, and if the GSI can be of any further help, please contact me.

Kind regards

Sarah

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Latest GSI Newsletter: www.gsi.ie/newsletters/

Theme Site No.	Site Name	County	Sheet No. 6 inch	Sheet No. 1:50,000	Easting	Northing	Principal characteristics Critical feature(s) key words	Townland(s)/district	Grid Ref.	Nominated by or ex-ASI site?	Summary description	definite NHA	NHA?	Definite CGS	Key references	IGH Theme - Primary	IGH Theme - Secondary	IGH Theme- Tertiary	Comments	Possible site report author bold red means agreed to do it	Age/Type	Colour Code
IGH8	Lough Beg Section	Cork		87	178000	063000		Loughbeg, Curraghbinny	W 78 63		Coastal section, Armour stone		NHA?		Sleeman, A.G., Thornbury, B. and Sevastopulo, G.D. The Stratigraphy of the Courceyan (Carboniferous; Dinantian) Rocks of the Cloyne Syncline, West of Cork Harbour. *Irish Jnl. Earth Sci.* **6**, 1986, 21-40.	IGH8 Lower Carboniferous					Carboniferous	
IGH8	Ringaskiddy, Golden Rock	Cork	87	87	179000	064000		Ringaskiddy	W 79 64					CGS		IGH8 Lower Carboniferous					Carboniferous	
IGH13	Cork Harbour	Cork		87, 81	181000	061000	ORS, structural features, raised beaches		N/A		On the western side of Cork Harbour is the Crosshaven Peninsula, where the Old Red Sandstone comes up in a Southern Anticline trending east-west, exposed on Weaver's Point, flanked by Carboniferous Limestone to the north. An emerged ("raised") beach can be traced around the shores of Cork Harbour, but there are discrepancies in the levels of Late Quaternary sediment sequence levels on either side of the harbour which could result from Holocene warping (Devoy). Near Rostellan on the eastern side of the bay a dolmen (megalithic tomb) a dolmen built 3000-4000 years ago is submerged at high tide.				Farrington, A. 1966 The early glacial raised beach in County Cork. Sci Proc Roy Dublin Soc A, 2: 197-219.	IGH13 Coastal Geomorphology			grs refer to Weaver's Point, W.Cork harbour -se			

Appendix 4D

Well Search Results

Mott MacDonald

GEOLOGICAL SURVEY OF IRELAND

GROUNDWATER DATABASE

List of abbreviations

GSIHolename. 1:25,000 sheet Number and number of the well on that sheet

EASTING (E) & NORTHING (N) Grid Reference of the well

Grid Acc or Acc Accuracy level, refers to the accuracy of the grid reference.

1 = 10m	5 = 200m	9 = 5km
2 = 20m	6 = 500m	10 = 10km
3 = 50m	7 = 1km	
4 = 100m	8 = 2km	

Schemename Name of the person or organisation who own the well.

Townland Name of the area where the well is located

Co. County i.e. DO = County Donegal

Six or Six" 1:10,560 sheet number (6" sheet number)

InvType Well Type:

WD = Dug Well	WB = Bored Well
WS = Spring	WU = Unknown

U Usage:

A = Agricultural use only	B = Agricultural & Domestic use
D = Domestic use only	G = Group Scheme
I = Industrial use	P = Public Supply
O = Other	

Y or Yield Class Yield:

F = Failure	P = Poor (<40m^3/d)
M = Moderate (40 – 100m^3/d)	G = Good (100 – 400m^3/d)
E = Excellent (>400m^3/d)	U = Unknown

Depth Total depth of the well in metres

DTB Depth to bedrock in metres

Yield Usually yield obtained during initial well testing in m^3/day

SpeCap_Abstract Discharge/ Drawdown m^3/day/ m (from yield test or abstraction data)

MainAquifer Lith. General description of the geological unit supplying water to the well.

AveDailyAbstract m^3/day

WaterStrike Metres below dipping reference – ground level unless stated otherwise

BHOLENAME	EASTING	NORTHING	GRID_ACCURACY	TOWNLAND	TOWN	SIXINCH	INVTYPE	USAGE	STARTDATE	DTB	DEPTH	DTB_CONFID	COMPANYHOLENAME	SCHEMENAME	CASING1DIAMETER	YIELD	YIELDCLASS
5SWW047	17393	6305	8	BALLINDEASIG		113	WB	U	01/04/1963	3.7	15.2	Bedrock Met				28	P
1705NWW077	17627	6468	3	BALLINTAGGART		87	WB	U	01/10/1995	17	25	Bedrock Met	C2				
1705NWW078	17628	6463	3	BALLINTAGGART		87	WB	M	01/10/1995	14	23	Bedrock Met	C1				
1705NWW079	17629	6459	3	BALLINTAGGART		87	WB	M	01/10/1995	18.5	23.5	Bedrock Met	C3				
1705NWW006	18213	6835	8	BALLYDANIEL MORE		74	WB	U	01/07/1967	3.7	30.5	Bedrock Met		WTB/CK 2372		32.7	P
1705NWW017	18106	6819	6	BALLYDULEA		87	WB	U	01/06/1973	4.3	30.5	Bedrock Met				32.7	P
1705NWW100	17924	6817	1	BALLYLEARY		87	WB		28/08/2001	6	6	Bedrock Met	1705NW D12				
1705NWW021	18238	6763	7	BALLYMORE		88	WB	U	01/06/1970	3	23.5	Bedrock Met		WTB/CK 5971		32.7	P
1705NWW018	18238	6769	7	BALLYMORE		87	WB	U	01/10/1971	5.5	27.4	Bedrock Met				32.7	P
1705NWW116	18264	6791	3	BALLYMORE	Cobh	87	WB	B		3.7	56.4	Bedrock Met	DWG 1918		165	16.4	P
1705NWW005	18002	6880	7	BALLYNACRUSHA		74	WB	U	01/04/1971	3.7	24.7	Bedrock Met				38.2	P
1705NWW040	18032	6855	2	BALLYNACRUSHA		87	WB	D	03/07/1998	4.3	46.6	Bedrock Met				43.6	M
1705NWW115	18231	6273	4	CARLISLE FORT	Whitegate	87	WB	B	03/08/2001	6	44.2	Bedrock Met	DWG 2653		165	43.6	M
1705NWW020	17345	6321	9	CARRIGALINE		87	WB	U	01/01/1966	3.1	45.7	Bedrock Met				28	P
1705NWW032	17532	6328	3	CARRIGALINE EAST		87	WB	B	01/11/1983		45.7	Bedrock Not Met				300	G
1705NWW029	17380	6170	7	COMMEEN		99	WB	U	01/05/1971	3.4	25.6	Bedrock Met				32.7	P
1705NWW028	17382	6169	7	COMMEEN		99	WB	U	01/05/1971	3.7	19.5	Bedrock Met				32.7	P
1705NWW087	17740	6257	5	CURRAGHBINNY		87	WB	I	12/12/1999	1	20	Bedrock Met	1979/TW-2		150	272.5	G
1705NWW086	17846	6261	5	CURRAGHBINNY		87	WB	I	09/12/2000	1.5	15	Bedrock Met	1979/TW-1		150		
1705NWW016	18155	6743	6	CUSKINNY		87	WB	U	01/05/1971	2.1	22.9	Bedrock Met				32.7	P
1705NWW004	18063	6902	7	FANICK		74	WB	U	01/07/1961	1.8	19.2	Bedrock Met				10.9	P
05NWW007	17827	6935	8	MARINO		74	WB	U	01/05/1970		27.4	DTB Unknown				21.8	P
5NWW019	17356	6793	7	OLD COURT		87	WB	U	01/10/1970	2.4	35.1	Bedrock Met				43.6	M
05NWW068	17431	6552	4	RAFFEEN		87	WB	D	19/05/1998	6.1	50.3	Bedrock Met				49.1	M
1705NWW082	17442	6472	8	RAFFEEN		87	WB	O	22/05/1986	10	30	Bedrock Met	BH3	CORK CO CO			
1705NWW083	17442	6477	8	RAFFEEN		87	WB	O	20/05/1986	0	13.5	Bedrock Met	BH2	CORK CO CO			
1705NWW081	17443	6482	8	RAFFEEN		87	WB	O	19/05/1986	1	10	Bedrock Met	BH1	CORK CO CO			
1705NWW080	17443	6485	8	RAFFEEN		87	WB	O	01/05/1986	2	36.5	Bedrock Met	BH4	CORK CO CO			
1705NWW015	17444	6490	7	RAFFEEN		87	WB	U	01/08/1973	2.4	54.9	Bedrock Met				43.6	M
1705NWW098	17453	6367	1	RAFFEEN		87	WB		03/09/2001	5	5	Bedrock Met	1705NW D10				
1705NWW036	17521	6542	3	RAFFEEN		87	WB	O	21/11/1997	0	26	Bedrock Met	B3	CORK CO CO	150		
1705NWW038	17522	6539	3	RAFFEEN		87	WB	O	20/01/1998	0	13.9	Bedrock Met	F3	CORK CO CO			
1705NWW037	17527	6529	3	RAFFEEN		87	WB	O	20/11/1997	0	26	Bedrock Met	B4	CORK CO CO	150		
1705NWW039	17538	6526	3	RAFFEEN		87	WB	O	23/01/1998	0	18	Bedrock Met	F4	CORK CO CO			
1705NWW072	17670	6310	4	RAHEENS EAST		87	WB	I	01/11/1985	2.5	91	Bedrock Met		WHEAT INDUSTRIES			U
1705NWW092	17617	6732	1	RATHANKER		87	WB		08/08/2001	2	2	Bedrock Met	1705NW D4				
1705NWW048	17877	6305	5	RINGASKIDDY		87	WB	O	01/07/1997	11.8	15.3	Bedrock Met		G/T WARNER LAMBERT			
1705NWW047	17877	6312	5	RINGASKIDDY		87	WB	O	01/02/1998	7.3	10.5	Bedrock Met	WD3A	G/T WARNER LAMBERT			
1705NWW049	17879	6302	5	RINGASKIDDY		87	WB	O	01/07/1997	9.5	14.5	Bedrock Met		G/T WARNER LAMBERT			
1705NWW045	17879	6303	2	RINGASKIDDY		87	WB	O	01/02/1998	1.5	7	Bedrock Met	WD1	G/T WARNER LAMBERT			
1705NWW046	17880	6316	5	RINGASKIDDY		87	WB	O	01/02/1998	2	6	Bedrock Met	WD2	G/T WARNER LAMBERT			
1705NWW050	17883	6298	5	RINGASKIDDY		87	WB	O	01/07/1997	6	9	Bedrock Met	WD3	G/T WARNER LAMBERT			
05NWW041	17883	6304	2	RINGASKIDDY		87	WB	O	01/07/1997	15	21	Bedrock Met	RC1	G/T WARNER LAMBERT			
5NWW042	17883	6306	2	RINGASKIDDY		87	WB	O	01/07/1997	4	10.5	Bedrock Met	RC2	G/T WARNER LAMBERT			
05NWW051	17885	6293	5	RINGASKIDDY		87	WB	O	01/07/1997	1.5	4.5	Bedrock Met	WD11	G/T WARNER LAMBERT			
1705NWW044	17888	6315	2	RINGASKIDDY		87	WB	O	01/07/1997	12.5	17.5	Bedrock Met	RC9	G/T WARNER LAMBERT			
1705NWW052	17889	6319	5	RINGASKIDDY		87	WB	O	01/07/1997	4.5	7.5	Bedrock Met	WD34	G/T WARNER LAMBERT			
1705NWW053	17892	6315	5	RINGASKIDDY		87	WB	O	01/07/1997	1.5	5	Bedrock Met	WD35	G/T WARNER LAMBERT			
1705NWW056	17893	6303	5	RINGASKIDDY		87	WB	O	01/07/1997	12.3	15.5	Bedrock Met	WD41	G/T WARNER LAMBERT			
1705NWW055	17894	6306	5	RINGASKIDDY		87	WB	O	01/07/1997	4.5	8	Bedrock Met	WD40	G/T WARNER LAMBERT			
1705NWW054	17894	6311	5	RINGASKIDDY		87	WB	O	01/07/1997		19	Bedrock Not Met	WD39	G/T WARNER LAMBERT			
1705NWW043	17895	6305	2	RINGASKIDDY		87	WB	O	01/07/1997	5.1	11	Bedrock Met	RC5	G/T WARNER LAMBERT			
1705NWW058	17897	6296	5	RINGASKIDDY		87	WB	O	01/07/1997	4.5	7.5	Bedrock Met		G/T WARNER LAMBERT			
1705NWW057	17898	6299	5	RINGASKIDDY		87	WB	O	01/07/1997	5.5	10	Bedrock Met	WD42	G/T WARNER LAMBERT			
1705NWW113	17526	6938	3	ROCHESTOWN	Passage West	75	WB	B		1.5	68.6	Bedrock Met	DWG 2498		162.5	10.9	P
1705NWW097	18095	6978	1	ROSSLAGUE		75	WB		16/08/2001		10.3	Bedrock Not Met	1705NW D9				
1705NWW096	18121	6991	1	ROSSLAGUE		75	WB		16/08/2001		10	Bedrock Not Met	1705NW D8				
1705NWW095	18126	6913	1	ROSSLAGUE		75	WB		16/08/2001	0.5	0.5	Bedrock Met	1705NW D7				
1705NWW111	18126	6965	3	ROSSLAGUE	Cobh	75	WB	B			13.1	Bedrock Not Met	DWG 2385		165	65.5	M
1705NWW076	17493	6458	3	SHANBALLY		87	WB	I	01/01/1973	6.1	61	Bedrock Met		PFIZERS CHEMICALS (WELL 5A)		802	E
1705NWW067	17530	6390	5	SHANBALLY		87	WB	O	01/10/1997		12.8	Bedrock Not Met	BH8	IDA NEPTUNE PROJECT (SEAGATE)			
1705NWW066	17530	6396	5	SHANBALLY		87	WB	O	01/10/1997		9.7	Bedrock Not Met	BH7	IDA NEPTUNE PROJECT (SEAGATE)			
1705NWW065	17530	6402	5	SHANBALLY		87	WB	O	01/10/1997	6.5	6.5	Bedrock Presumed	BH6	IDA NEPTUNE PROJECT (SEAGATE)			
1705NWW060	17530	6418	5	SHANBALLY		87	WB	O	01/10/1997	14	14.1	Bedrock Met	BH1	IDA NEPTUNE PROJECT (SEAGATE)			
1705NWW061	17530	6423	5	SHANBALLY		87	WB	O	01/10/1997		7.2	Bedrock Not Met	BH2	IDA NEPTUNE PROJECT (SEAGATE)			
5NWW062	17530	6428	5	SHANBALLY		87	WB	O	01/10/1997		14.3	Bedrock Not Met	BH3	IDA NEPTUNE PROJECT (SEAGATE			
5NWW064	17531	6406	5	SHANBALLY		87	WB	O	01/10/1997		7.6	Bedrock Not Met	BH5	IDA NEPTUNE PROJECT (SEAGATE)			
1705NWW063	17531	6412	5	SHANBALLY		87	WB	O	01/10/1997		14.1	Bedrock Not Met	BH4	IDA NEPTUNE PROJECT (SEAGATE)			
1705NWW075	17535	6450	3	SHANBALLY		87	WB	I	01/01/1973	7	56.4	Bedrock Met		PFIZERS CHEMICALS (WELL 14A)		632	E
1705NWW014	17548	6458	3	SHANBALLY		87	WB	I	01/03/1980	5.5	49.7	Bedrock Met	Well 15B	PFIZER LTD		1374.7	E

GSIHOLENAME	PROD_CLASS	ABSTRACTDDOWN	WATERSTRIKE_1	MAINAQUIFER_MLITH	WATERSTRIKE_2	WATERSTRIKE_3	SPECAP_ABSTRACTION	COMMENTS	COMMENTS	CWCOMMENTS
5SWW047				ORS				w/ck 7209		
1705NWW077								b/hole c2		
1705NWW078				GRAVEL/SILT/LIMESTONE				b/hole c1		
1705NWW079								b/hole c3		
1705NWW006				RED SANDSTONE						
1705NWW017				BROWN SANDSTONE				wtb/ck 10487		
1705NWW100										
1705NWW021				BROWN SANDSTONE						
1705NWW018				BROWN SANDSTONE				wtb/ck 9644		
1705NWW116	V	45.7	9.1	SANDSTONE	19.8	45.7	0.36	Drilled by Southern Pumps Ltd□□Chemical data available	Rotary.□□Location from site r	Clear and good quality
1705NWW005										
1705NWW040								Drilled by Dominick Harte		
1705NWW115	IV	11.3	13.7		36.6		3.87	DtB inferred from casing□□Drilled by Southern Pumps Ltd	Rotary.□□Location from site r	Clear
1705NWW020								wtb/ck 3394		
1705NWW032				SAND				another well on site drilled to 27m, no other info		
1705NWW029				BROWN SANDSTONE						
1705NWW028				SANDSTONE				wtb/ck 8997		
1705NWW087			18	LIMESTONE	26					
1705NWW086			12	LIMESTONE						
1705NWW016				BROWN SANDSTONE				wtb/ck 9337		
1705NWW004				ORS				w/ck 1668		
705NWW007				SANDSTONE				lined 9.14m		
5NWW019								wtb/ck 8696		
705NWW068								Drilled by Southern Pumps Ltd		
1705NWW082								drilled by dunnes/bhole no3		
1705NWW083				MUDSTONE				drilled by dunnes/b/hole no 2		
1705NWW081								drilled by dunnes b/hole no1		
1705NWW080				MUD & SANDSTONE				drilled by dunnes/b/hole no.4		
1705NWW015				BROWN SANDSTONE				wtb/ck 10271		
1705NWW098										
1705NWW036								site invest & monitoring @ raffeen landfill bh-b3	Raffeen Landfill Site	casing surrounded by pea gravel from 2.5 to 26m□
1705NWW038				SHALE				site invest & monit @ raffeen landfill bh-f3	Raffeen Landfill Site	
1705NWW037								site invest & monitor @ raffeen landfill Site bh-b4	Raffeen Landfill Site	Pea gravel 2.5 to 26m
1705NWW039				SHALE				site invest & monit @raffeen landfill bh-f4	Raffeen Landfill Site	
1705NWW072			5.5	LIMESTONE				see file 3.1.4 v. little water		
1705NWW092										
1705NWW048				LIMESTONE				site invest petits rotary percussive bhole wd1		
1705NWW047								site invest petits rotary percussive bhole wd3a (bh3 on map)		
1705NWW049				LIMESTONE				site invest petits rotary percussive bhole wd2		
1705NWW045				LIMESTONE				site invest by Pettits rotary percussive b/hole wd1 (bh1)		
1705NWW046				LIMESTONE				site invest by petits rotary percussive b/hole wd2 (bh2)		
1705NWW050				LIMESTONE				site invest by petits rotary percussive bhole wd3		
705NWW041				LIMESTONE				site invest report by Pettits rotary coring b/hole c1		
5NWW042				LIMESTONE				site invest by Pettits rotary coring- bhole c2		
05NWW051				LIMESTONE				site invest by petits rotary percussive bhole wd11		
1705NWW044				LIMESTONE				site investigation by Pettits rotary coring b-hole c9		
1705NWW052				LIMESTONE				site invest by petits rotary percussive bhole wd34		
1705NWW053								site invest by petits rotary percussive bhole wd35		
1705NWW056								site invest by petits rotary percussive bhole wd41		
1705NWW055								site invest by petits rotary percussive bhole wd40		
1705NWW054								site invest by petits rotary percussive bhole wd39 (skipped 38)		
1705NWW043				LIMESTONE				site invest by Pettits rotary coring b/hole c5		
1705NWW058				LIMESTONE				site invest by petits rotary percussive bhole wd_		
1705NWW057								site invest by petit's rotary percussive b/hole wd42		
1705NWW113	V		48.77	MUDSTONE	60.96		0.22	unknown□□Drilled in Sept 2001□□Chemical data available	Rotary.□□Location from site r	Ok quality
1705NWW097										
1705NWW096										
1705NWW095										
1705NWW111			13.1	GRAVEL				Chemical data available	Rotary.□□Location from site r	OK quality; 72 hr test
1705NWW076	I	8.5		LIMESTONE			94.35	from files in Core room -log and Q and ddwn		
1705NWW067								SITE INVEST BY GEOTECH SHELL & AUGER BH8		
1705NWW066								SITE INVEST BY GEOTECH SHELL & AUGER BH7		
1705NWW065								SITE INVEST BY GEOTECH SHELL & AUGER BH6		
1705NWW060								site invest by geotech shell & auger BH-1		
1705NWW061								site investigation by geotech shell & auger bh2		
5NWW062								site invest by geotech shell & auger bh3		
5NWW064								SITE INVEST BY GEOTECH SHELL & AUGER BH5		
1705NWW063								site invest by geotech shell & auger bh4		
1705NWW075	II	13.7		LIMESTONE			46.13	from files in Core room-logs including Q and ddwn		
1705NWW014	I	7.3					188.32	new" well located on map from reg of abs AB/9/81"		

Appendix 5A

Air Quality Report

Mott MacDonald

ODOUR monitoring IRELAND

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AIR QUALITY CHAPTER FOR THE PROPOSED CORK HARBOUR MAIN DRAINAGE SCHEME TO BE LOCATED IN CORK CITY AND ENVIRONS.

PREPARED BY ODOUR MONITORING IRELAND ON BEHALF OF MOTT MACDONALD CONSULTING ENGINEERS,

PREPARED BY:	Dr. Brian Sheridan,
ATTENTION:	Ms. Orla Freyne
DATE:	16th Jan 2007
REPORT NUMBER:	2007.A393(4)
DOCUMENT VERSION:	Document Ver. 004
REVIEWERS:	Ms. Orla Freyne & Mr. Paul Kelly

TABLE OF CONTENTS

Document Amendment Record

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Project Number: 2007.A393(4)			**Document Reference:** Air quality environmental impact assessment of proposed Cork Harbour Main Drainage Scheme Cork Harbour Main Drainage Scheme to be located in Cork city and Environs.		
2007A393(1)	Document for review	BAS	JWC	BAS	13/11/2007
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Revision	**Purpose/Description**	**Originated**	**Checked**	**Authorised**	**Date**
ODOUR Monitoring IRELAND					

11.1. Air quality environmental assessment

11.1.1 Introduction

Odour Monitoring Ireland were commissioned to undertake a baseline air quality survey in order to assess the potential impact to air quality from the proposed Cork Harbour Main Drainage Scheme to be located in Cork city and Environs. This study will identify, describe and assess the impact of the development in terms of its impact on air quality.

The objective of the Cork Harbour Main Drainage Scheme is to provide wastewater treatment for the towns and villages in the lower Cork Harbour area. The main population centres to be served by the scheme include Cobh, Passage West/Glenbrook, Monkstown, Ringaskiddy (including Shanbally and Coolmore), Carrigaline and Crosshaven.

A baseline air quality assessment has been carried out in the area between the time periods July to August 2007 in the vicinity of the proposed WWTP development. In addition, baseline speciated Volatile organic compound survey was performed in the vicinity of five major pumping stations located along the drainage network. These included Raffeen, West Beach, Monkstown, Church road and Carraigaloe Pumping stations. The purpose of this survey was to identify existing pollutant trends in the vicinity of the proposed development(s), and to assess the potential impact of the proposed development(s). This will establish sufficient spatial information in order to determine compliance with relevant ambient air quality legislation. Additionally, comparison with longer period limit values can be used to establish trends and are important in defining baseline air quality.

This section should be read in conjunction with the site layout plans for the site.

11.1.2 Study methodology-Assessment Criteria

The EU has introduced several measures to address the issue of air quality management. In 1996, Environmental Ministers agreed a Framework Directive on ambient air quality assessment and management (Council Directive 96/62/EC). As part of the measures to improve air quality, the European Commission has adopted proposals for daughter legislation under Directive 96/62/EC. The first of these directives to be enacted, 1999/30/EC, has set limit values which replaced existing limit values under Directives 80/779/EEC, 82/884/EEC and 85/203/EEC in April 2001. The new directive, as relating to limit values for sulphur dioxide, lead, PM_{10} and nitrogen dioxide, is detailed in *Table 11.1.1* EU Council Directive 2000/69/EC defines limit values for both carbon monoxide and benzene in ambient air and is presented in *Table 11.1.2.*

The National Air Quality Standards Regulations 2002 (S.I. No. 271 of 2002) transpose those parts of the "Framework" Directive 92/30/EC on ambient air quality assessment and management not transposed by Environment Protection Agency Act 1992 (Ambient Air Quality Assessment and Management) Regulations 1999 (S.I. No. 33 of 1999). The 2002 Regulations also transpose, in full, the 1st two "Daughter" Directives 1999/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air and 2000/69/EC relating to limit values for benzene and carbon monoxide in ambient air.

Table 11.1.1. Irish and EU Ambient Air Standard (SI 271 of 2002 and 1999/30/EC).

Pollutant	Regulation	Limit Type	Margin of Tolerance	VALUE
Nitrogen Dioxide	1999/30/EC SI 271 of 2002	Hourly limit for protection of human health - not to be exceeded more than 18 times/year-1 hour average	50% until 2001 reducing linearly to 0% by 2010 for 199/30/EC 40% from the date of entry into force of these Regulations, reducing on 1 January 2003 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2010 for SI 271 2002	200 µg/m³ NO_2
		Annual limit for protection of human health-Annual	50% until 2001 reducing linearly to 0% by 2010 for 1999/30/EC 40% from the date of entry into force of these Regulations, reducing on 1 January 2003 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2010 for SI 271 2002	40 µg/m³ NO_2
		Annual limit for protection of vegetation-Annual	None	30 µg/m³ NO + NO_2
Lead	1999/30/EC	Annual limit for protection of human health-Annual average	100% until 2001 reducing linearly to 0% by 2005	0.5 µg/m³
Sulphur Dioxide	1999/30/EC SI 271 of 2002	Hourly limit for protection of human health – not to be exceeded more than 24 times/year-1 hour average	43% until 2001 reducing linearly until 0% by 2005 for 199/30/EC 90 µg/m³ from the date of entry into force of these Regulations, reducing on 1 January 2003 and every 12 months thereafter by 30 µg/m³ to reach 0 µg/m³ by 1 January 2005 for SI 271 of 2002	350 µg/m³
		Daily limit for protection of human health – not to be exceeded more than 3 times/year-24hr average	None	125 µg/m³
		Annual & Winter limit for the protection of ecosystems-Annual	None	20 µg/m³

Table 11.1.1 continued. Irish and EU Ambient Air Standard (SI 271 of 2002 and 1999/30/EC).

Particulate Matter Stage 1	1999/30/EC SI 271 of 2002	24-hour limit for protection of human health - not to be exceeded more than 35 times/year-24 hour average	50% until 2001 reducing linearly to 0% by 2005 for 1999/30/EC 30% from the date of entry into force of these Regulations, reducing on 1 January 2003 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2005 for SI 271 of 2002	50 µg/m³ PM_{10}
		Annual limit for protection of human health-Annual	20% until 2001 reducing linearly to 0% by 2005 for 1999/30/EC 12% from the date of entry into force of these Regulations, reducing on 1 January 2003 and every 12 moths thereafter by equal annual percentages to reach 0% by 1 January 2005	40 µg/m³ PM_{10}
Particulate Matter Stage 2	1999/30/EC SI 271 of 2002	24-hour limit for protection of human health - not to be exceeded more than 7 times/year-24 hour average	To be derived from data and to be equivalent to Stage 1 limit value for 1999/30/EC Not to be exceeded more than 28 times by 1 January 2006, 21 times by 1 January 2007, 14 times by 1 January 2008, 7 times by 1 January 2009 and zero times by 1 January 2010 for SI 271 of 2002	50 µg/m³ PM_{10}
		Annual limit for protection of human health-Annual	50% until 2005 reducing linearly to 0% by 2010 for 1999/30/EC and SI 271 of 2002	20 µg/m³ PM_{10}

Table 11.1.2. Irish and EU Ambient Air Standard (SI 271 of 2002 and 2000/69/EC).

Pollutant	Regulation	Limit Type	Margin of Tolerance	VALUE
Benzene	2000/69/EC SI 271 of 2002	Annual limit for protection of human health	100% until 2003 reducing linearly to 0% by 2010 for 2000/69/EC 100% from the date of entry into force of these Regulations, reducing on 1st January 2006 and every 12 months thereafter by 1 $\mu g/m^3$ to reach 0 $\mu g/m^3$ by 1st January 2010	5 $\mu g/m^3$
Carbon Monoxide	2000/69/EC SI 271 of 2002	8-hour limit (on a rolling basis) for protection of human health	50% until 2003 reducing linearly to 0% by 2005 for 2000/69/EC 6 mg/m^3 from the date of entry into force of these Regulations, reducing on 1st January 2003 and every 12 months thereafter by 2 mg/m^3 to reach 0 mg/m^3 by 1st January 2005	10 mg/m^3

11.2. Receiving environment-Air

11.2.1 General

The objective of the Cork Harbour Main Drainage Scheme is to provide wastewater treatment for the towns and villages in the lower Cork Harbour area. The main population centres to be served by the scheme include Cobh, Passage West/Glenbrook, Monkstown, Ringaskiddy (including Shanbally and Coolmore), Carrigaline and Crosshaven.

The proposed development includes for the construction of a wastewater treatment plant, which will include for sludge treatment, and a collection system to convey the waste water to the new plant. The proposed scheme also includes for upgrading the existing drainage network to modern standards and expanding the network in order to cater for the future needs of the area. The Scheme will be designed to meet the needs of the Cork Harbour Area to the year 2030. This section describes the existing drainage system, and the characteristics of the proposed development.

The proposed wastewater treatment plant is likely to be constructed using the Design/Build/Operate (DBO) procurement system. A Contractor will be appointed to Design, Build and Operate the wastewater treatment plant for a period of 20 years to achieve the required standards within defined design constraints. Therefore the exact details of the proposed development are not available at this stage.

Nevertheless, it is possible to describe the necessary level of treatment to be provided to achieve the required effluent treatment standards. The treatment requirements and treatment options are discussed in *Section 2.5.* In order to assess the environmental impact of the development indicative designs of the proposed Cork Harbour Waste Water Treatment Plant have also been undertaken. The indicative designs achieve the required discharge standards and described in detail in *Section 2.5.5.*

The proposed site consists of portions of two large agricultural fields located on sloping ground and currently used for pasture. The land has been zoned for industrial development (South Cork County Development Plan, 2005). The site has an area of approximately 7.35 hectares.

With the exception of a small Bord Gais substation, which adjoins the south-west corner of the site, the site is bordered on all sides by adjoining agricultural fields. The boundaries of the two fields consist primarily of managed, immature to semi-mature hedgerow. A large ESB substation is situated circa 200 metres west of the site and a sports field is located circa 100 metres to the northeast of the site.

According to the South County Cork Development Plan (2005), the site has been zoned for industrial development. It is also noted that there are proposals to construct a branch of the National Primary Route N28 to by-pass the villages of Shanbally and Ringaskiddy on lands immediately north of the site.

There are no existing site services. Access to the site will be provided via an existing access road to the Bord Gais substation currently bordering the site. The proposed site is located approximately 380 metres east of the minor road (locally known as Cogan's Road), which links to the N28 National Primary Route just east of Raffeen Bridge.

The proposed new route for the upgraded N28 from Cork to Ringaskiddy, which will run directly north of the site, will provide a buffer between the site and industrial lands to the north.

There is an area zoned for residential use ~140m east of the proposed WWTP site boundary. Planning applications for residential development have been granted in this area.

11.2.2 Baseline air quality

A total of ten sample locations were chosen to represent the baseline air quality for named parameters in the vicinity of the proposed development(s). These locations are listed in *Table 11.2.1* and presented in *Figure 11.7.1*.

Table 11.2.1. Description of air monitoring locations.

Reference	X cord (Irish National Grid)	Y cord (Irish National Grid)	Description of monitoring
A1-WWTP	174861	63796	NO2, SO2, BTEX, PM10, Total depositional dust, H2S-Monitored using passive diffusion tubes, Partisol PM10 analyser, Jerome analyser and Bergerhoff gauges.
A2-WWTP	175341	63619	NO2, SO2, BTEX, Total depositional dust, H2S-Monitored using passive diffusion tubes, Jerome analyser and Bergerhoff gauges.
A3-WWTP	175267	63938	NO2, SO2, BTEX, Total depositional dust, H2S-Monitored using passive diffusion tubes, Jerome analyser and Bergerhoff gauges.
A4-WWTP	175071	63891	NO2, SO2, BTEX, Total depositional dust, H2S-Monitored using passive diffusion tubes, Jerome analyser and Bergerhoff gauges.
A5-WWTP	174850	63999	NO2, SO2, BTEX, Total depositional dust, H2S-Monitored using passive diffusion tubes, Jerome analyser and Bergerhoff gauges.
A6-WWTP	174907	63837	Speciated VOC's and H2S-Monitored using pumped sorbent tube and Jerome analyser.
A7-WWTP	175257	63805	Speciated VOC's and H2S-Monitored using pumped sorbent tube and Jerome analyser.
A8-Raffeen PS	175442	65188	Monitored using pumped active sorbent tube. Monitoring of H2S using Jerome metre at 5 locations around the Pumping station.
A9-West beach PS	179799	66426	Monitored using pumped active sorbent tube. Monitoring of H2S using Jerome metre at 5 locations around the Pumping station.
A10-Monksland PS	176977	66081	Monitored using pumped active sorbent tube. Monitoring of H2S using Jerome metre at 5 locations around the Pumping station.
A11-Carrigaloe PS	177607	67511	Monitored using pumped active sorbent tube. Monitoring of H2S using Jerome metre at 5 locations around the Pumping station.
A12-Church Rd PS	174405	62628	Monitored using pumped active sorbent tube. Monitoring of H2S using Jerome metre at 5 locations around the Pumping station.

As a result of the existing site conditions and the potential for traffic, residential and amenity-derived pollution, the following parameters were monitored:

11.2.2.1 Benzene, Toluene, Ethyl benzene and ortho and para Xylene (BTEX)

Benzene, Toluene, Ethyl benzene, p/o xylene (BTEX) and other aromatic/alkanes are most likely derived from petrol driven vehicle exhausts. Heavier semi-volatile organic compounds are frequently derived from diesel-powered engines. Benzene is a known carcinogen, poisonous by inhalation and a severe eye and moderate skin irritant.

At each of the five monitoring locations (A1 to A5) (*see Figure 11.7.1 and Table 11.2.1*), the air quality was monitored for BTEX, over a 29-day period, using BTEX diffusion tubes. The sample tubes were analysed for BTEX at a UKAS accredited laboratory (ISO 17025) using gas chromatography flame ionisation detector. The results are presented in *Table 11.2.2*.

Table 11.2.2. Average BTEX concentrations at each location as measured by passive diffusion tubes.

Location	Benzene ($\mu g/m^3$) [1, 3]	Toluene ($\mu g/m^3$) [1,3]	Ethyl benzene ($\mu g/m^3$) [1,3]	p-Xylene ($\mu g/m^3$) [1,3]	o-Xylene ($\mu g/m^3$) [1,3]
A1[2]	0.695	0.256	0.183	0.256	0.121
A2[2]	0.143	0.361	0.428	0.312	0.224
A3[2]	0.270	0.233	0.418	0.249	0.186
A4[2, 7]	-	-	-	-	-
A5[2]	0.329	0.282	0.471	0.576	0.248
EPA value-Old station rd hourly median value[6]	0.20	-	-	-	-
Limit Value	**5[4]**	**4700[5]**	**10,875[5]**	**5525[5]**	**5525[5]**

Notes: [1] *denotes the lower limit of detection was 5.91 ηg of sorbed compound per tube;*
[2] *denotes sampling period July to August 2007;*
[3] *denotes Lower limit of detection 2.88 ng;*
[4] *denotes Irish and EU Ambient Air Standard (SI 271 of 2002 and 1999/30/EC);*
[5] *denotes No specific ambient air limits. Rule of thumb is using 1/40th of the 8-hour Occupational Exposure Limit as stated in the National Authority for Occupational Safety and Health 2002 "Code of Practice for the Safety, Health and Welfare at Work (Chemical Agents) Regulations".*
[6] *denotes Air Quality Monitoring Report, 2006-Old station Rd monitoring site;*
[7] *denotes location lost to vandalism.*

The results illustrated in *Table 11.2.2* for BTEX at A1 to A5 are all in compliance with Irish and EU limit values (i.e. SI 271 of 2002 and EU Directive 2000/69/EC) for Benzene. Average Benzene concentrations were up to 93% lower than the Irish and EU directive limit values. The rule of thumb for guidelines for ambient air quality of volatile organic compounds without legislative limit values is using 1/40th of the 8-hour Occupational Exposure Limit as stated in the National Authority for Occupational Safety and Health 2002 "Code of Practice for the Safety, Health and Welfare at Work (Chemical Agents) Regulations". Toluene, Ethyl benzene and Xylene isomers are well within their respective fractional exposure limit values.

11.2.2.2 Nitrogen dioxides (NO_2)

Nitrogen is a constituent of both the natural atmosphere and of the biosphere. When industrial metabolism releases nitrogen to the environment it is considered a "pollutant" because of its chemical form: NO, NO_2, and N_2O. These oxides of nitrogen can be toxic to humans, to biota, and they also perturb the chemistry of the global atmosphere. In the transportation sector, the NOx emissions result from internal combustion engines. In power plants and industrial sources, NOx is produced in boilers. The overwhelming fraction of nitrogen oxide emissions arises from the high temperature combustion of fossil fuels; emissions from metal-processing plants and open-air burning of biomass are insignificant.

Nitrogen dioxide is classed as both a primary pollutant and a secondary pollutant. As a primary pollutant NO_2 is emitted from all combustion processes (such as a gas/oil fired boiler or a car engine). Potentially, the main sources of primary NO_2 for the proposed development will be from vehicle exhausts.

As a secondary pollutant NO_2 is derived from atmospheric reactions of pollutants that are themselves, derived mainly from traffic sources (e.g. volatile organic compounds). Secondary pollution is usually derived from regional sources and may be used as an indicator of general air quality in the region. Nitrogen dioxide has been shown to reduce the pulmonary function of the lungs. Long-term exposure to high concentrations of NO_2 can cause a range of effects, primarily in the lungs, but also in the liver and blood.

At each of the five monitoring locations (A1 to A5) (*see Figure 11.7.1 and Table 11.2.1*), levels of NO_2 were measured using diffusion tubes, which were left on site for a 29-day period. The tubes were then analysed using UV spectrophotometer, at a UKAS accredited laboratory (ISO 17025), giving an average concentration over the 29-day period. The results are presented in *Table 11.2.3.*

Table 11.2.3. Average NO_2 concentrations at each location as measured by passive diffusion tubes.

Location	Sampling Period	Average NO_2 conc. ($\mu g/m^3$)[2]
A1	July to Aug 2007	6.00
A2	July to Aug 2007	4.82
A3	July to Aug 2007	4.86
A4	July to Aug 2007	6.06
A5	July to Aug 2007	6.76
EPA value-Old station Rd hourly max value[2]	2006	111
EPA value-Old station Rd Annual mean value[2]	2006	26
Limit value-Annual average	-	**40**
Limit value 1 hour average	-	**200**

Notes:[1] *denotes Lower limit of detection 0.003 μgNO_2;*
[2] *denotes Air Quality Monitoring Report, 2006-Wexford station;*

The dominant source of NO_2 in the area appears to be from motor vehicle exhausts and the burners/boiler of space heating of local light industry and business units. The measured concentrations of NO_2 at all monitoring locations are within the Irish and EU Ambient Air Standards. Monitoring locations A1 to A5 are an average 83% lower than currently established Irish and European ambient air regulatory levels for annual averages.

11.2.2.3 Sulphur dioxide (SO_2)

Sulphur dioxide is a colourless gas, about 2.50 times as heavy as air, with a suffocating faint sweet odour. Sulphur dioxide occurs in volcanic gases and thus traces of sulphur dioxide are present in the atmosphere. Other sources of sulphur dioxide include smelters and utilities, electrical generation, iron and steel mills, petroleum refineries, pulp and paper mills, metallurgical processes, chemical processes and the combustion of the iron pyrites, which are contained in coal. Small sources include residential, commercial and industrial space heating.

SO_2 can be oxidised to sulphur trioxide, which in the presence of water vapour is readily transformed to sulphuric acid mist. SO_2 is a precursor to sulphates, which are one of the main components of respirable particles in the atmosphere. Health effects caused by exposure to high levels of SO_2 include breathing problems, respiratory illness, changes in the lung's defences, and worsening respiratory and cardiovascular disease. People with asthma or chronic lung or heart disease are the most sensitive to SO_2. It also damages trees and crops. SO_2, along with nitrogen oxides, are the main precursors of acid rain. This contributes to the acidification of lakes and streams, accelerated corrosion of buildings and reduced visibility. SO_2 also causes formation of microscopic acid aerosols, which have serious health implications as well as contributing to climate change.

At each of the five monitoring locations (A1 to A5) (*see Figure 11.7.1 and Table 11.2.1*), levels of SO_2 were measured using diffusion tubes, which were left on site for a 29-day period. The tubes were then analysed using Ion chromatography, at a UKAS accredited laboratory (ISO 17025), giving an average concentration over the 29-day period. The results are presented in *Table 11.2.4*.

Table 11.2.4. Average SO_2 concentrations at each location as measured by passive diffusion tubes.

Location	Sampling Period	Average SO_2 conc. ($\mu g/m^3$)[1]
A1	July to Aug 2007	1.64
A2	July to Aug 2007	1.75
A3	July to Aug 2007	1.32
A4	July to Aug 2007	1.60
A5	July to Aug 2007	1.18
EPA value-Old station Rd hourly max value[2]	2006	58
EPA value-Old station Rd daily max value[2]	2006	24
EPA value-Old station Rd Annual mean value[2]	2006	4
Limit value-Annual average	-	**20**
Limit value-Daily average		**125**
Limit value-Hourly average		**350**

Notes:[1] *denotes lower limit of detection 0.060 μgSO_4;*
[2] *denotes Air Quality Monitoring Report, 2006-Old station Rd,*

The dominant source of SO_2 in the area appears to be from motor vehicle exhausts and the burners/boiler/solid fuel heating local single residences and industrial units. The measured concentrations of SO_2 at all monitoring locations are within the Irish and EU Ambient Air Standards. Monitoring locations A1 to A5 are an average 91% lower than currently established Irish and European ambient air regulatory annual levels.

11.2.2.4 Carbon monoxide (CO)

Carbon monoxide is produced as a result of incomplete burning of carbon-containing fuels including coal, wood, charcoal, natural gas, and fuel oil. It can be emitted by combustion sources such as un-vented kerosene and gas heaters, furnaces, woodstoves, gas stoves, fireplaces and water heaters, automobile exhaust from attached garages, and tobacco smoke. Carbon monoxide interferes with the distribution of oxygen in the blood to the rest of the body. Depending on the amount inhaled, this gas can impede coordination, worsen cardiovascular conditions, and produce fatigue, headache, weakness, confusion, disorientation, nausea, and dizziness. Very high levels can cause death. The symptoms are sometimes confused with the flu or food poisoning. Foetuses, infants, elderly, and people with heart and respiratory illnesses are particularly at high risk for the adverse health effects of carbon monoxide.

Due to power and equipment safety issues existing baseline monitoring data from EPA monitoring sites was used for assessment of baseline Carbon monoxide air quality. The EPA monitoring location and results are presented in *Table 11.2.5.*

Table 11.2.5. Average ambient baseline CO concentrations for the proposed site development.

Location	Sampling Period	Ambient CO conc. (mg/m^3)
EPA - Annual mean - Old station Rd[1]	2006	0.50
EPA - 8 hour median value - Old station Rd[1]	2006	0.40
EPA-Maximum 8 hourly value - Old station Rd[1]	2006	2.80
Limit value-8 hour average[2]	-	**10**

Notes: *[1] denotes Air Quality Monitoring Report, 2006-Old station Rd,*
[2] denotes Irish and EU ambient air standard (SI 271 of 2002 and 2000/69/EC) as an 8 hour running average;

CO monitoring is also very limited in Ireland. Data sets developed by the EPA indicate 8 hour running average CO levels of between 0.10 and 0.80mg m^{-3} for 8 hour rolling averages, respectively for urban areas in Ireland. The dominant source of CO in this area would appear to be vehicle emissions, boilers (i.e. Home heating and Industrial heating), industrial processes and construction activities. The CO emissions measured in Old Station Road would be considered worst case in comparison to the proposed site location. CO emissions are on average 78% lower than Irish and EU ambient air limit values, which would be considered worst case in terms of exposure for the area (*see Table 11.2.5*).

11.2.2.5 Particulate matter (PM_{10})

Major sources of particulates include industrial/residential combustion and processing, energy generation, vehicular emissions and construction projects. The particulate matter created by these processes is responsible for many adverse environmental conditions including reduced visibility, contamination and soiling, but also recognised as a contributory factor to many respiratory medical conditions such as asthma, bronchitis and lung cancer. PM_{10} (Particulate Matter 10) refers to particulate matter with an aerodynamically diameter of 10 µm. Generally, such particulate matter remains in the air due to low deposition rates. It is the main particulate matter of concern in Europe and has existing air quality limits. In order to obtain a baseline PM_{10} for the proposed work area, a PM_{10} analyser was used to monitor the PM_{10} ambient concentration levels at one location (A1) within the vicinity of the proposed works. Continuous monitoring was performed over a 2-day period. The monitoring location is presented in *Figure 11.7.1 and Table 11.2.1.* Results are presented in *Table 11.2.6.*

Table 11.2.6. Average ambient PM_{10} concentrations in the vicinity of the proposed development.

Location	Sampling Period	Ambient PM_{10} conc. ($\mu g/m^3$)
A1-24 hour average	July 2007	22
A1-24 hour average	July 2007	31
EPA measured conc. – Old Station Rd, annual mean value [4]	2006	16
Limit Value at 98.07th percentile	-	50[1, 2]
Limit Value-annual mean Stage 1		40
Limit value-annual mean Stage 2		20[3]

Notes: *[1] denotes Irish and EU ambient air standard (SI 271 of 2002 and 1999/30/EC) as a 24-hour average;*
[2] denotes maximum number of exceedence 7 times in a one-year period;
[3] denotes annual limit value for Stage 2 implementation 2010;

[4] *denotes Air quality Monitoring Report, 2006-Old Station Rd.*

PM_{10} monitoring in Ireland is limited to continuous monitoring stations operated by the Local Authorities and the Irish EPA, mainly in large urban centres. Average 24-hour ambient air concentrations monitored at Old Station Rd, Cork would be considered worst case in this area. The EPA measured an annual mean of 16 $\mu g\ m^{-3}$ at this monitoring station. The dominant source of PM_{10} in the area appears to be vehicle emissions, boilers (i.e. Home heating and Industrial heating), industrial processes and construction activities. The average ambient PM_{10} concentrations are higher to those monitored by the EPA. Maximum-recorded ambient PM_{10} concentrations were on average 38% lower than the Irish and EU 24 hour ambient air quality limit value.

11.2.2.6 Total Depositional Dust

Total dust deposition was measured at the site using Bergerhoff gauges specified in the German Engineering Institute VDI 2119 entitled "Measurement of Dustfall Using the Bergerhoff Instrument (Standard Method)." Samples were collected at five locations (i.e. A1 to A5) over a 30-day period, as shown in *Figure 11.7.1.* The purpose of these monitors is to assess the baseline total depositional dust impact in the vicinity of the current site. The glass jars containing the dust were submitted to an accredited test house for analyses. The results are presented in *Table 11.2.7.*

Table 11.2.7. Total depositional dust levels at each monitoring location.

Sample Reference	Sampling period	Total Dust Deposition (Summer sampling period) (mg/m^2day)
A1	July to Aug 2007	66
A2	July to Aug 2007	78
A3	July to Aug 2007	94
A4	July to Aug 2007	62
A5	July to Aug 2007	87
EPA recommended Limit value	-	350

Currently in Ireland there are no statutory limits for dust deposition, however, EPA guidance suggest, "a soiling of 10mg/m^2/hour is generally considered to pose a soiling nuisance" (TA Luft 2002). This equates to 240mg/m^2/day of Total Depositional Dust. The EPA recommend a maximum level of 350mg/m^{2}day of dust deposition when measured according to TA Luft standard, which includes both soluble and insoluble matter (i.e. EPA compliance monitoring is based on the TA Luft Method). This value was not exceeded at any of the sample locations with all measured values at least 73% lower than the maximum recommended limit value.

11.2.2.7 Hydrogen sulphide

H_2S is commonly associated with wastewater handling operations. It is used as an indicator gas for the assessment of significant odour nuisance in the vicinity of waste water facilities. The current California Ambient Air Quality standard for hydrogen sulphide, based on a 1-hour averaging time, is 42 $\mu g\ m^{-3}$ (30 ppb). On this basis, the proposed REL of 10 $\mu g\ m^{-3}$ (8 ppb) is likely to be detectable by many people under ideal laboratory conditions, but it is unlikely to be recognized or found annoying by more than a few. It is therefore expected to provide reasonable protection from odour annoyance in practice. Based on a review of 26 studies, the average odour detection threshold ranged from 0.00007 to 1.4 ppm (Amoore, 1985). Hydrogen sulphide is noted for its strong and offensive odour. The geometric mean of these studies is 0.008 ppm. In general, olfactory sensitivities decrease by a factor of 2 for each 22 years of age above 20 (Venstrom and Amoore, 1968); the above geometric mean is based on the average age of 40. Laboratory experiments performed by Sheridan (2003) in California measured H_2S detection threshold at 2 $\mu g\ m^{-3}$ while the recognition odour threshold was 22 $\mu g\ m^{-3}$. At the current California Ambient Air Quality Standard (CAAQS) of 30 ppb, the level would be detectable by 83% of the population and would be discomforting to 40% of the population. These estimates have been substantiated by odour complaints and reports of nausea and headache (Reynolds and Kauper 1985) at 0.030 ppm H2S exposures from geyser emissions. The World Health Organization (WHO) recommends that in order to avoid substantial complaints about odour annoyance among the exposed population, hydrogen sulphide concentrations should not be allowed to exceed 0.005 ppm (5 ppb; 7 $\mu g\ m^{-3}$), with a 30-minute averaging time. The OEHHA (2000) adopted a level of 8 ppb (10 $\mu g\ m^{-3}$) as the chronic Reference Exposure Level (cREL) for use in evaluating long-term emissions from hot spots facilities. The only instrument capable of providing comparison with such reference levels is a Jerome meter analyser. These are real time data-logging H_2S analyser for the measurement of ambient hydrogen sulphide concentration levels (Sheridan, 2003).

An ambient H_2S profile monitoring exercise was carried out in the vicinity of the proposed WWTP site and five pumping stations using a pre-calibrated H_2S analyser (Jerome metre). Samples were taken approximately 1.2 meter above ground level. The analyser is a real time analyser with a range of detection from 3 ppb to 50 ppm. Samples were collected at twelve locations (i.e. A1, to A12). *Figures 11.7.1, to 11.7.6 and Table 11.2.1* illustrate each monitoring location. In order to maintain clarity within the document all 5 individual monitoring locations in the vicinity of the pumping stations are presented as one value as the ambient H_2S concentration were below instrumental limits of detection. The purpose of this monitoring is to assess the baseline H_2S in the vicinity of the sites. The results are presented in *Table 11.2.8.*

Table 11.2.8. Hydrogen sulphide levels at each monitoring location.

Monitoring location	Sampling period	Ambient air conc (µg/m3)
A1-WWTP	July 2007	<4.50
A2-WWTP	July 2007	6.0
A3-WWTP	July 2007	6.0
A4-WWTP	July 2007	7.50
A5-WWTP	July 2007	<4.50
A6-WWTP	July 2007	<4.50
A7-WWTP	July 2007	<4.50
A8-Raffeen PS	July 2007	<4.50
A9-West beach PS	July 2007	<4.50
A10-Monksland PS	July 2007	<4.50
A11-Carrigaloe PS	July 2007	<4.50
A12-Church Rd PS	July 2007	<4.50
Recommended limit	-	**7.50**

Currently in Ireland, there are no statutory limits for hydrogen sulphide concentrations in ambient air, however, guidance from the California Air Resources Board suggest an ambient air concentration level of less than 7.50 $\mu g/m^3$ to limit odour nuisance. This value was not exceeded at any of the sample locations. Elevated ambient concentrations above the lower limits of detection of the instrument method were detected at location A2, A3 and A4. There were no scheduled point emissions of Hydrogen sulphide in the vicinity of the site although; concentrations could be attributed to traffic movement on the nearby main road. Hydrogen sulphide is generated from side product reactions of exhaust emissions with the catalytic converter on diesel engines.

11.2.2.8 Speciated Volatile organic compounds (VOC's)

Speciated VOC's to include alkanes, Mercaptans, organic acids, aromatics and nitrogen containing organics in ambient air at elevated concentrations can lead to the formation of odours. In order to ascertain the baseline levels of speciated VOC's in the vicinity of the proposed site location, ambient pumped sampling of VOC's was performed in order to ascertain the baseline profile of such compounds in order to generate a baseline profile during no operation of the WWTP.

In order to pre-concentrate speciated VOC upon each sorbent, a pre-calibrated controlled volume of sample air was drawn through each tube by a pre-calibrated SKC constant flow sampling pump for a period range of 180 minutes (i.e. Active sampling/pumped sampling). Each SKC pump was pre-calibrated with their specific sorbent using a Bios Primary flow calibrator (NIST traceable certified) with calibration flow checked following the completion of the sample run. Each pump was calibrated to a flow rate of between 71 and 200 ml min^{-1} depending on the sample, sample pump and sorbent tube as recommended by the sorbent manufacturer, analysing laboratory and sampling/test methodology. When sampling was completed all tubes were sealed and stored in flexible air tight containers and transported to the gas chromatography laboratory and analysed by means of thermal desorption GCFID/GCMS in a UKAS accredited laboratory.

Samples were taken approximately 1.20 meter above ground level using two-bed silcosteel packed sorbent tubes on the 12th July 2007. Samples were collected at two locations across the proposed WWTP site (i.e. A6 and A7), and at one location in the vicinity of each of the five pumping stations (i.e. A8 to A12) as shown in *Figures 11.7.1 to 11.7.6 and Table 11.2.1.* The purpose of this monitoring is to assess the baseline speciated VOC concentration level and profile in the vicinity of the proposed site. The results are presented in *Tables 11.2.9 to 11.2.15.*

Table 11.2.9. Speciated VOC profile and concentrations in the vicinity of the proposed site location at monitoring location A6-WWTP.

Compound identity	Ambient air conc. (μg/m³)
3-Butyn-1-ol	1.75
Benzaldehyde	0.58
Acetophenone	0.63
Nonanal	0.38
Decanal	0.40
Cyclododecane	0.56
Hexadecanal	0.99
Cyclohexadecane	13.20
Total VOC's	**26.02**

Table 11.2.10. Speciated VOC profile and concentrations in the vicinity of the proposed site location at monitoring location A7-WWTP.

Compound identity	Ambient air conc. (μg/m³)
Benzaldehyde	0.65
Acetophenone	0.65
Nonanal	0.84
Decanal	0.66
Tetradecane	0.65
1-Hexadecene	0.57
Oxirane, tetradecyl-	1.49
Cyclohexadecane	4.09
Total VOC's	**25.64**

Table 11.2.11. Speciated VOC profile and concentrations in the vicinity of the proposed site location at monitoring location A8-Raffeen PS.

Compound identity	Ambient air conc. (μg/m^3)
2,5-Furandione, dihydro-3-methylene-	7.43
3(2H)-Thiophenone, dihydro-2-methyl-	1.02
2,2-Dichlorocyclopropanecarboxamide	6.05
Cyclohexan-1,4,5-triol-3-one-1-carboxylic acid	1.61
2,4-Diethyl-6-methyl-1,3,5-trioxane	12.20
1-Tetradecene	2.03
Cyclohexadecane	5.54
Oxirane, heptadecyl-	1.45
1-Nonadecene	16.90
Total VOC's	**74.03**

Table 11.2.12. Speciated VOC profile and concentrations in the vicinity of the proposed site location at monitoring location A9-West beach PS.

Compound identity	Ambient air conc. (μg/m^3)
2,5-Furandione, dihydro-3-methylene-	5.62
Formamide, N,N-dimethyl-	2.54
Ethanol, 2-butoxy-	2.19
Benzaldehyde	1.26
Acetophenone	0.82
Cyclotetradecane	1.03
1-Decanol, 2-hexyl-	19.44
1-Hexacosene	1.11
1-Heptadecanol	4.93
Total VOC's	**64.95**

Table 11.2.13. Speciated VOC profile and concentrations in the vicinity of the proposed site location at monitoring location A10-Monkstown PS.

Compound identity	Ambient air conc. (μg/m^3)
2,5-Furandione, dihydro-3-methylene-	4.23
Nonanal	3.32
Ethanol, 2-butoxy-	1.19
2-Propanol, 1-[2-(2-methoxy-1-methylethoxy)-1-methylethoxy]-	1.16
Acetophenone	1.25
Cyclotetradecane	1.20
1-Decanol, 2-hexyl-	6.89
2,4-Diethyl-6-methyl-1,3,5-trioxane	5.42
1-Heptadecanol	2.23
Total VOC's	**54.23**

Table 11.2.14. Speciated VOC profile and concentrations in the vicinity of the proposed site location at monitoring location A11-Carrigaloe PS.

Compound identity	Ambient air conc. (μg/m³)
2,5-Furandione, dihydro-3-methylene-	5.42
2-Octanamine	0.66
Benzaldehyde	1.42
Acetophenone	1.22
2-Propanol, 1-[2-(2-methoxy-1-methylethoxy)-1-methylethoxy]-	1.17
2,4-Diethyl-6-methyl-1,3,5-trioxane	2.43
Cyclohexadecane	5.05
1-Hexadecanol	2.38
Total VOC's	**36.78**

Table 11.2.15. Speciated VOC profile and concentrations in the vicinity of the proposed site location at monitoring location A12-Church Road PS.

Compound identity	Ambient air conc. (μg/m³)
Propane, 1-(ethenylthio)-	0.72
Benzaldehyde	1.03
Acetophenone	0.84
Nonanal	1.11
Decanal	1.18
Cyclohexadecane	6.20
Hexadecanal	3.39
Cyclohexadecane	6.45
Eicosane	0.52
Total VOC's	**49.37**

Currently in Ireland, there are no statutory limits for total volatile organic compound concentrations in ambient air, however, research data gathered by Odour Monitoring Ireland suggest an ambient air concentration level of less than 250 μg/m³ to limit odour impact. The compounds detected in ambient air would be typical of emissions detected close to busy roadways and in agricultural locations. No background concentrations of Mercaptans or Sulphur containing organics were detected and the absence of such compounds suggests in general that odour air quality is good in the vicinity of the site. The profiles can be compared with any additional profiles measured when the facilities are operational in order to ascertain any increases in ambient air concentrations of speciated VOC's. The overall background level of speciated VOC's as total VOC's is generally low in the vicinity of all site locations.

11.3. Characteristics of the proposal

The proposed development consists principally of the construction of a large sized urban wastewater treatment plant to serve the population centres of Cork Lower Harbour and its' environs. The proposed wastewater treatment plant is an essential element of the Cork Lower Harbour Main Drainage Scheme. Associated works, which will be carried out as part of the proposed development, include:

- The widening of sections of the minor road to the west of the site
- The widening and upgrading of the site access road
- Marine crossing
- New wastewater pumping stations

- The laying of rising mains, surface water sewers and gravity wastewater sewers to direct the wastewater to the new treatment works
- New wastewater treatment works-

The treated wastewater will be discharged to Cork Lower Harbour via the existing IDA outfall. The overall area of the two fields on which this proposed wastewater treatment plant will be constructed is approximately 17.5 hectares. However, the fields are traversed by overhead high voltage electrical cables. By providing sufficient clearance from these power lines a suitable area of approx. 7.35 ha is available between the power lines. This area is considered adequate for the construction of the proposed wastewater treatment plant, including facilities for organic-material removal, nutrient removal, basic sludge treatment (if required) and appropriate landscaping measures.

The principal elements of a treatment plant of the type and scale proposed include preliminary, primary and secondary treatment of the wastewater stream with further provision for treatment of surplus sludge arising from the primary and biological stages of the treatment process. The specific details of each process are contained elsewhere within the EIS.

11.4. Potential Impacts of the Proposal

11.4.1 Construction Phase

There is the potential for a number of emissions to atmosphere during the construction of the development with wind blown dust been most significant. Wind blown dust emissions may arise during the construction phase of the proposed development, which may impact upon the surrounding environment. The deposition of dust and mud on the local roads is both unsightly and dangerous. Dust may be a particular problem during periods of dry windy weather.

Potential sources of dust from construction and operation include the following:

- Vehicles carrying dust on their wheels,
- Un-vegetated stockpiles of construction materials,
- The handling of construction materials for the construction phase of the development,
- The generation of dust from the recycling activities to be carried out indoors within the facility.

The construction and operation vehicles, generators, etc., will also give rise to petrol and diesel exhausts emissions, although this is of minor significance compared to dust.

11.4.2 Operation Phase

11.4.2.1 Scheduled Emissions

Regarding operations at the proposed development, the activities to be located in the development are waste water treatment activities. All equipment generating dust emissions will contain localised dust abatement equipment where necessary in order to prevent the release of dust to atmosphere. Scheduled emission point from odour control units will occur to atmosphere from the WWTP and pumping stations. Emissions of odour will be dealt with in detail in *Section 12.*

11.4.2.2 Climate

There is a potential for impacts to climate as a result of any development that requires fuel and energy. These impacts are the generation of greenhouse gas emissions (principally carbon dioxide and oxides of nitrogen) from traffic and electrical supply.

The potential effects of climate change on a global scale have been investigated by the Intergovernmental Panel on Climate Change (IPCC). The resulting impacts in Ireland are outlined in the National Climate Change Strategy and recently by the EPA and include the following:

- Significant increases in winter rainfall, of the order of 10% in the southeast, with a corresponding increase in the water levels in rivers, lakes and soils. Serious flooding more frequent than at present.
- Lower summer rainfall, of the order of 10% in the southern half of the country. Less recharge of reservoirs in the summer leading to more regular and prolonged water shortages than at present. Loss of bog land due to regular water deficits.
- Increased agricultural production, with new crops becoming more viable and potentially reduced agricultural costs. Grass growth could enjoy beneficial effects with an increase in 20% possible with higher temperatures and changes in rainfall patterns.
- The development will be designed to take account of changes in rainfall intensity and mean sea level rise.

These figure for climate change refer to year 2100. The specimen design is for up to 2030.

It is recognised that Ireland cannot, on its own, prevent or ameliorate the impacts of climate change. However, the National Climate Change Strategy states that Ireland must meet its responsibilities with regard to reducing CO_2 emissions in partnership with the EU and the global community. In terms of this specimen design, the generation of biogas and utilisation of generated biogas in a gas utilisation engine/boiler will offset CO_2 eq. emissions generated by the WWTP.

11.4.3"Do-nothing" Scenario

The baseline survey results suggest that air quality in the vicinity of the proposed development is average/good and shows typical levels for a rural and suburban area with all pollutants within the relevant Irish and EU limits. The air quality may improve slightly in future years due to improvements in engine technology and greater controls on petrol, diesel, coal and gas composition and purity. If the proposed development were not to take place, the current air pollutant concentrations will remain unchanged followed by potential decreases in future years for the reasons outlined above. In relation to dust, non-development of the site would result in no movement of soils/sands and no construction activity and therefore no dust creation as a result of construction works. Impacts associated with odours as demonstrated in *Section 12* are considered negligible as a result of the mitigation measures to be used at the proposed WWTP and Pumping stations. This will be discussed in more detail in *Section 12*.

11.4.4 Remedial or Reductive Measures

11.4.4.1 Construction Phase

Construction activities are likely to generate some dust emissions. The potential for dust to be emitted depends on the type of construction activity being carried out in conjunction with environmental factors including levels of rainfall, wind speed and wind direction. In order to ensure that no dust nuisance occurs, a series of measures will be implemented. Site roads shall be regularly cleaned and maintained as appropriate. Hard surface roads shall be swept to remove mud and aggregate materials from their surface as a result of the development. Any un-surfaced roads shall be restricted to essential site traffic only. Furthermore, any road in the vicinity of the development that has the potential to give rise to dust may be regularly watered, as appropriate, during extended dry and/or windy conditions.

A full traffic management plan and dust management plan will be implemented into the Construction Environmental Management Plan (CEMP) in order to minimise such emission as a result of the construction phase of the development. This will be generated specifically for the development when detailed design is completed.

Vehicles using site roads shall have their speed restricted, and this speed restriction must be enforced rigidly. On any un-surfaced site road and on hard surfaced roads that site management dictates speed shall be restricted to 20 km per hour.

Material handling systems and site stockpiling of materials shall be designed and laid out to minimise exposure to wind. Water misting or sprays shall be used as required if particularly dusty activities are necessary during dry or windy periods.

In relation to the completion of the proposed development, the hard standing surface, and all roads will be tarmacadamed/concreted. In periods of dry weather when dust emission would be greatest, a road sweeper, which would also dampen the road, may be employed in order to prevent the generation of dust.

11.4.4.2 Operation Phase

It is not anticipated that dust will be a significant problem during the operation of the development. All sources generating dust will operate dust management equipment as required.

Emissions of pollutants from road traffic can be controlled by either controlling the number of road users or by controlling the flow of traffic. For the majority of vehicle-generated pollutants, emissions rise as speed drops. Emissions are also higher under stop-start conditions when compared with steady speed driving. Since the development will generate only small volumes of traffic, emissions from such activities were predicted to be minimal.

It is envisaged that the proposed development will not have a significant impact on the surrounding air quality. However, as discussed previously a number of mitigation measures have been suggested. Moreover, dust monitoring could be carried out during the construction phase of the development if deemed necessary by the planning authority. If the level of dust is found to exceed 350 mg/m^2/day in the vicinity of the site, further mitigation measures will be incorporated into the construction and operation of the proposed development. Odour control techniques for the proposed development are discussed in more detail in *Section 12*.

11.4.4.3 Climate

Road traffic and power usage would be expected to be the dominant sources of greenhouse gas emissions as a result of the proposed development. Vehicles and power used to operate the plant will give rise to CO_2 and N_2O emissions as a result of the proposed development. It is expected that the number of vehicles accessing the site when operational will be a weekly maximum of 12 vehicles for truck movements and approximately 60 vehicle movements per week for small vehicles such as passenger cars. This will lead to the emission of 139 tonnes of CO_2 per annum, which is equivalent to 0.00000175% of the National Emissions in Ireland in 2008 to 2012 assuming a driving radius of 30 Km from the facility and a payload of 13 tonnes.

With reference to relevant evaluation criteria such as the Kyoto Protocol, which has set objectives to be achieved by 2008 – 2012, GHG emissions as a result of this proposal will be imperceptible.

11.5. Predicted Residual Impacts of the development

11.5.1.1 Construction Phase

The effect of construction of the facility on air quality will not be significant following the implementation of the proposed mitigation measures. The main environmental nuisance associated with construction activities is dust. However, it is proposed to adhere to good working practices and dust mitigation measures to ensure that the levels of dust generated will be minimal and are unlikely to cause an environmental nuisance. A series of such good working practices and mitigation measures are outlined earlier in this chapter (*see Section 11.4.4.1*).

11.5.1.2 Operation Phase

Traffic

The predicted increases in traffic volumes as a result of the development along the existing road network are expected to be very low. The information on traffic provided in the traffic section of the Statement has been used to identify whether any significant impact on sensitive receptors will occur. The traffic information has been input into the Design Manual for Roads and Bridges (DMRB), Volume 11 (February 2003) model. This model was prepared by the United Kingdom Department of Transport, the Scottish Office of Industrial Development, the Welsh Office and the Department of Environment for Northern Ireland as a screening tool to assess worst-case air quality impact associated with roads developments.

The screening model uses a worst-case scenario in calculating emissions. The emission factors used for each pollutant are intentionally biased to overestimate the actual emission rate. Also, wind speeds are assumed to be 2 m s^{-1} (approximately 3.9 knots compared to a mean wind speed of between 4 to 5 m s^{-1} from nearest Met stations (Cork met station). In addition to this, the background concentrations incorporated into the model are worst-case scenario concentrations. For these reasons, it can be assumed with confidence that a project will not produce air pollution from traffic if this model identifies none.

Traffic figures have been assessed using the Annual Average Daily Traffic (AADT) figures. The overall predicted increase in air pollutants as a result of the development was assessed utilising the predicted traffic generation figures for the facility when in operation. The predicted impact of traffic on air quality during the construction phase of the development are more difficult to predict since this is only a specimen design and the actual DBO plant could be a little different. The overall emissions as a result of traffic during the construction phase of the project will be short term. In terms of emissions, as the average speed of vehicles has a significant effect on the generation of pollutants, calculations are carried out for two different traffic speed scenarios. The speeds are 20 km hr^{-1}, to represent gridlock conditions and 50 km hr^{-1}, to represent free-flowing traffic conditions in the area. The growth rate per annum assumed for the area is based on NRA future traffic forecasts for non-national roads.

The DMRB only assesses the potential impacts from traffic up to and including the year 2023. Even though the development design period goes beyond this date, this is not considered significant since impacts are expected to be even lower beyond this date due to improvements in engine technology etc. The impacts associated with the proposed development are well within the ground level impact concentrations in year 2023 (as predicted by the model). Using the model, concentrations of Carbon Monoxide, Benzene, Oxides of Nitrogen and PM_{10} (particulate matter with an average 10 μm aerodynamic diameter), have been determined for a receptor point road along the road L2490 (Fernhill Rd). The results of these calculations are presented in *Tables 11.5.1* (J1). It is assumed that a total of 4 ADDT movements per day for HGV's and a maximum 12 ADDT movements per day for LGV/cars (i.e. to and from the site).

Table 11.5.1. Screening Air Quality Assessment, Cork Harbour Main Drainage Scheme WWTP operation phase for WWTP traffic.

Scenarios	Traffic Speed Km hr^{-1}	Carbon Monoxide (mg/m^3)	Benzene ($\mu g/m^3$)	Oxides of Nitrogen ($\mu g/m^3$)	Particulates (PM_{10}) ($\mu g/m^3$)
	-	**Annual Average-Traffic component**	**Annual Average-Traffic component**	**Annual Average NO_2-Traffic component**	**Annual Average-Traffic component**
2010 "Do something Scenario"	20	0.01	0.01	0.08	0.01
	50	0.01	0.01	0.06	0.01
2023 "Do Something" Scenario	20	0.01	0.01	0.05	0.01
	50	0.01	0.01	0.03	0.01
Irish and EU Standards	-	-	**5**	**40**	**40**

For carbon monoxide (CO) under all traffic scenarios at both speeds, the predictions indicate that even under worst-case scenario conditions the maximum CO level combined with the baseline figures will not breach the EU limit as a result of traffic movements to and from the WWTP during operation.

The predicted results for benzene at the two speed scenarios indicate that the concentrations are below the relevant Irish and EU limit at both locations. Again, the predicted levels drop with increases in speed. As with the CO results, the predicted levels actual remain relative equal over the development years. When added to baseline the overall ambient air concentrations of Benzene are well within the Irish and EU limit values during the operation phase of the development.

The predicted levels of nitrogen dioxide (NO_2) at the two speed scenarios for the operation phase of the development will cause negligible increases NO_2 on the surrounding area. There is a general overall improvement in the NO_2 levels as the development proceeds from 2010 to 2023 due to improvements in engine technology. When added to baseline the overall ambient air concentrations of NO_2 are well within the Irish and EU limit values for the operation phase of the development.

For particulate matter (PM_{10}) the predictions indicate that even under worst-case scenario conditions the annual average will not breach the Irish and EU limit as a result of traffic movement during the operation phase of the WWTP. The predictions show a variation with speed resulting in lower levels of particulates produced under normal traffic conditions (50 km/hr). There is no significant difference on air quality impact whether the development proceeds or not.

The computer model predictions indicate the following findings:

- Ambient concentrations will, in general, decrease due to legislation driven improvements in engine technology and fuel content. Any increases will be slight.
- There will be negligible increases in NO_2 and PM_{10} concentrations as the development phase is implemented.
- The net impact of the proposed development will be a slight negative for NO_2 and PM_{10} but will remain well within the Irish and EU legislative limit values.

11.5.1.3 Climate

The effect of the proposed WWTP is not considered to be significant in term of air quality impact from traffic emissions.

All space heating and energy requirements for the proposed development should be designed in accordance with best practice. The Building Regulations 2002 "Technical Guidance Document Part L – Conservation of Fuel an Energy Dwellings" should be used as a reference for best practice in order to reduce the impact of the proposed development on greenhouse gas emissions.

11.5.1.4 "Worst Case" Scenario

For traffic-derived pollutants, the "worst-case" scenario consists of gridlock conditions with large volumes of traffic on the road, simultaneously. This has been accounted for within the model whereby it is predicted that traffic movements will occur simultaneously on the road network. In addition gridlock is also assessed.

The DMRB predictive model employed is a screening model that is used to generate worst-case scenario predictions for air quality. If this model indicates that pollutant levels will not breach the Irish and EU limits, then it can be assumed with some confidence that a project will not produce air pollution problems if none are identified by this method. There are no predicted breaches of Irish and EU legislation for design year and 2023. As a result of these model predictions it may be concluded that the worst-case impact of the traffic alterations associated with the proposed development are predicted to be a slight negative.

11.5.2 Monitoring

11.5.2.1 Construction Phase

It is envisaged that the proposed development will not have a significant impact on the surrounding air quality. However, as discussed previously a number of dust mitigation measures have been suggested. Moreover, dust monitoring could be carried out during the construction phase of the development if deemed necessary by the planning authority. If the level of dust is found to exceed 350mg/m^2day in the vicinity of the site (using Bergerhoff gauges), further mitigation measures will be incorporated into the construction of the proposed site.

11.5.2.2 Operational phase

In terms of odours, the exhaust emission point of the odour control systems will be monitored for odours using both onsite subjective assessment and biannual monitoring, if this is deemed necessary. Greater detail on the assessment of odours can be found in *Section 12*.

Process equipment responsible for dust generation will be fitted with dust abatement equipment and monitored continuously in accordance with EN14181.

Depositional dust monitoring will be carried out during the operation phase of the development if deemed necessary by the regulatory authority. If the level of dust is found to exceed 350mg/m^2day in the vicinity of the site, further mitigation measures will be incorporated into the operation of the proposed site.

11.5.3 Reinstatement

Not Applicable

11.6. Non-Technical Summary

A baseline ambient air quality survey was carried out in the vicinity of the proposed Cork Lower Harbour. Currently the air quality is average to good with levels of criteria and baseline odour pollutants for traffic, industrial and residential derived pollution (BTEX, NO_2, NO, CO, PM_{10}, H_2S and Speciated VOC's) below the relevant Irish and European Union limits. The main source of air pollution in the area is from motor vehicle exhausts, construction and industrial activities, and associated suburban emissions. There is the risk that emissions from dust could result in air quality impacts in the vicinity of the proposed WWTP site location. Since focused dust extraction and abatement will be applied to the dust generation equipment as necessary, then it is anticipated that no associated impacts will occur with the proposed development.

11.7. Appendix I-Monitoring and predictive traffic emission modelling location

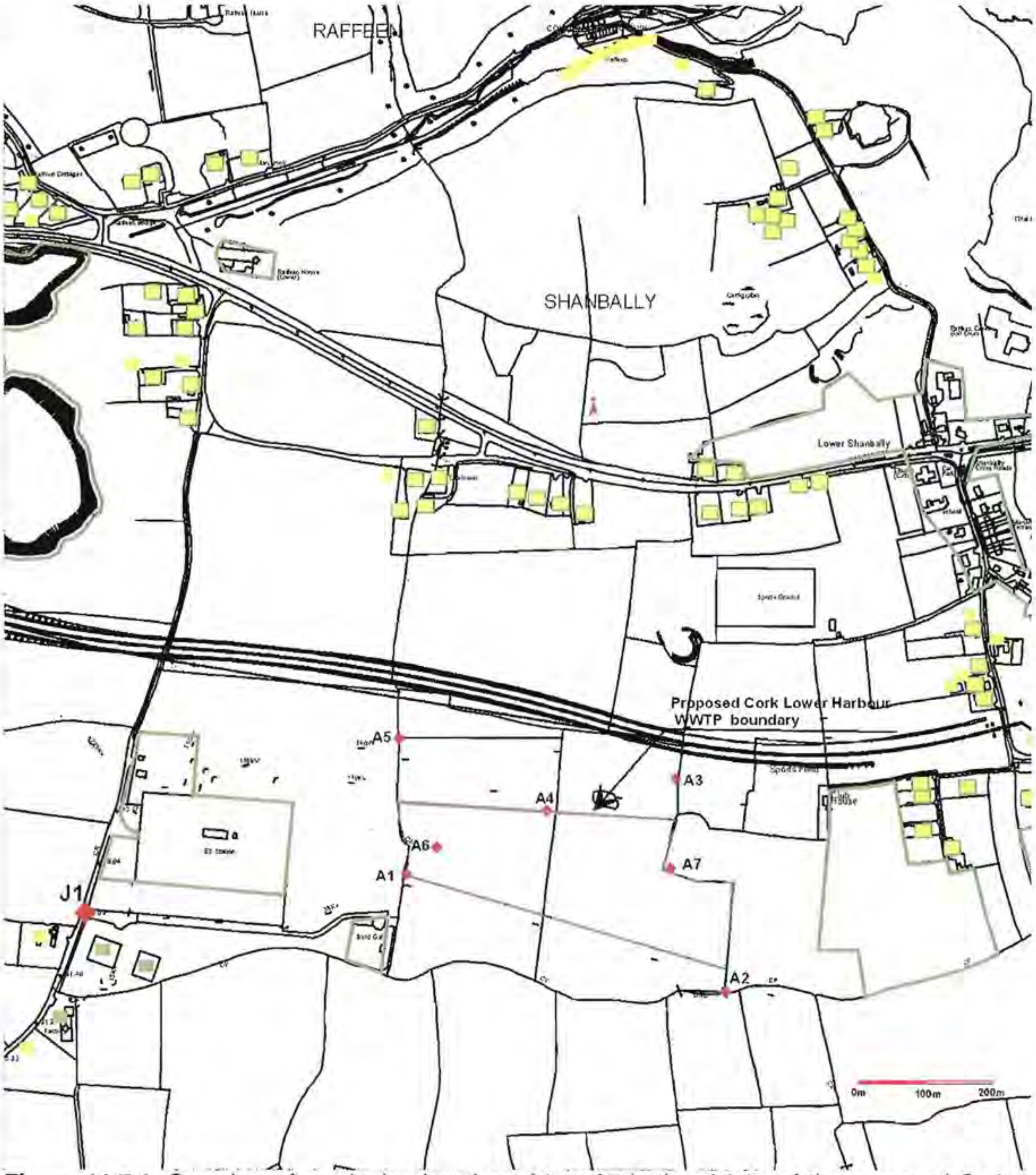

Figure 11.7.1. Overview of monitoring locations A1 to A7 in the vicinity of the proposed Cork Harbour Main Drainage Scheme WWTP and receptor location J1 (used for assessing the maximum predicted emissions associated with traffic generation as a result of the WWTP operation phase).

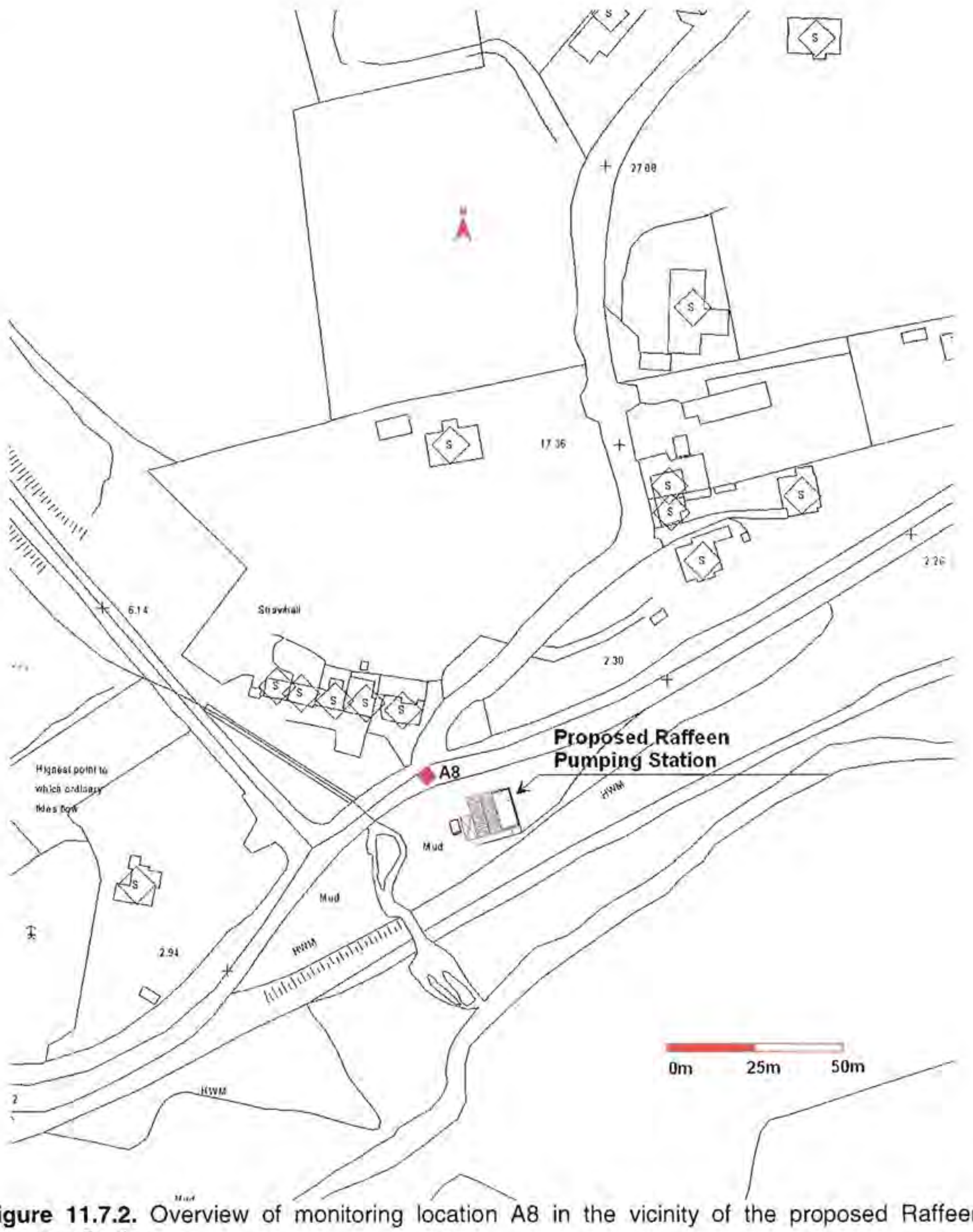

Figure 11.7.2. Overview of monitoring location A8 in the vicinity of the proposed Raffeen Pumping Station.

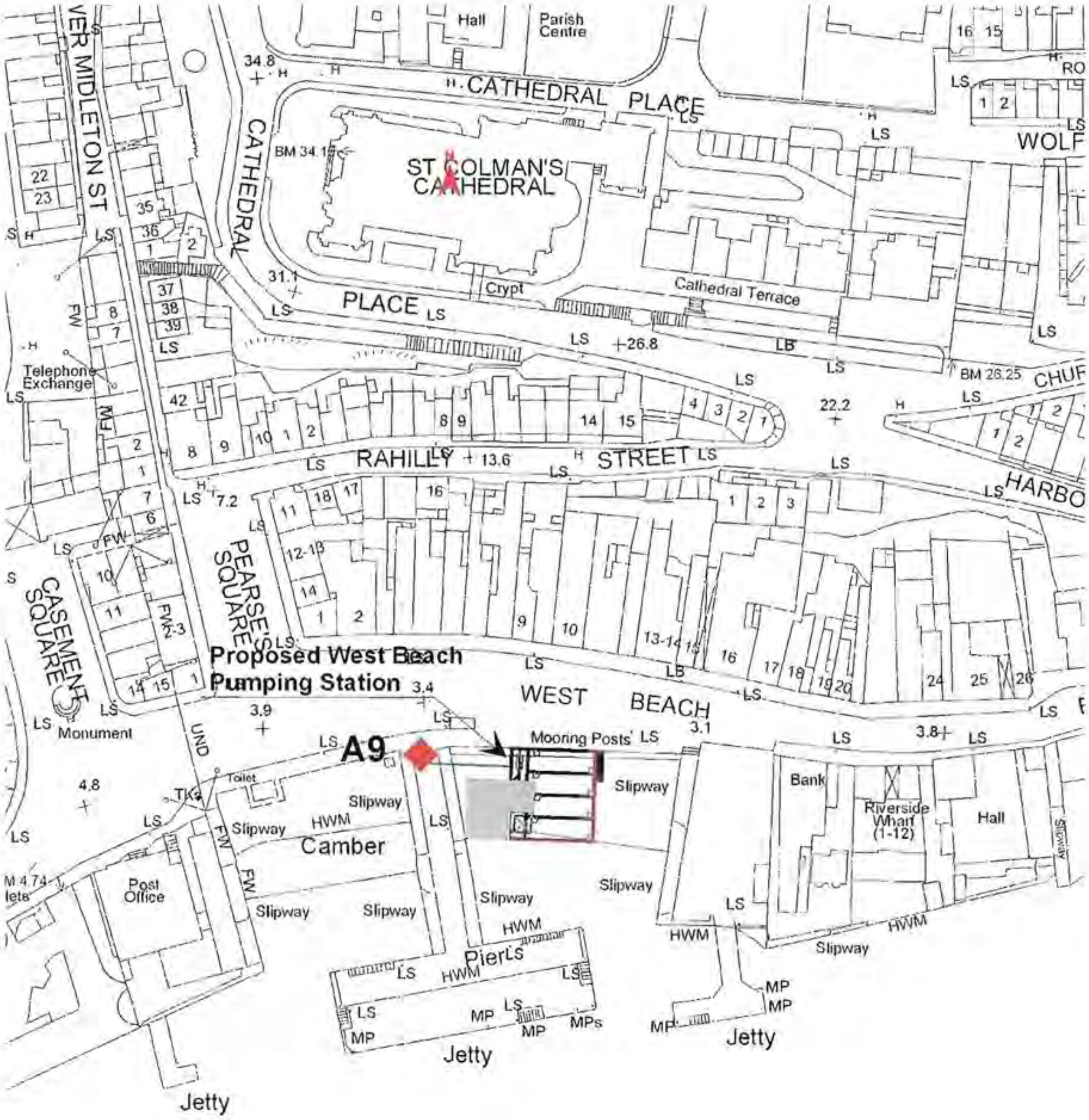

Figure 11.7.3. Overview of monitoring location A9 in the vicinity of the proposed West beach Pumping Station.

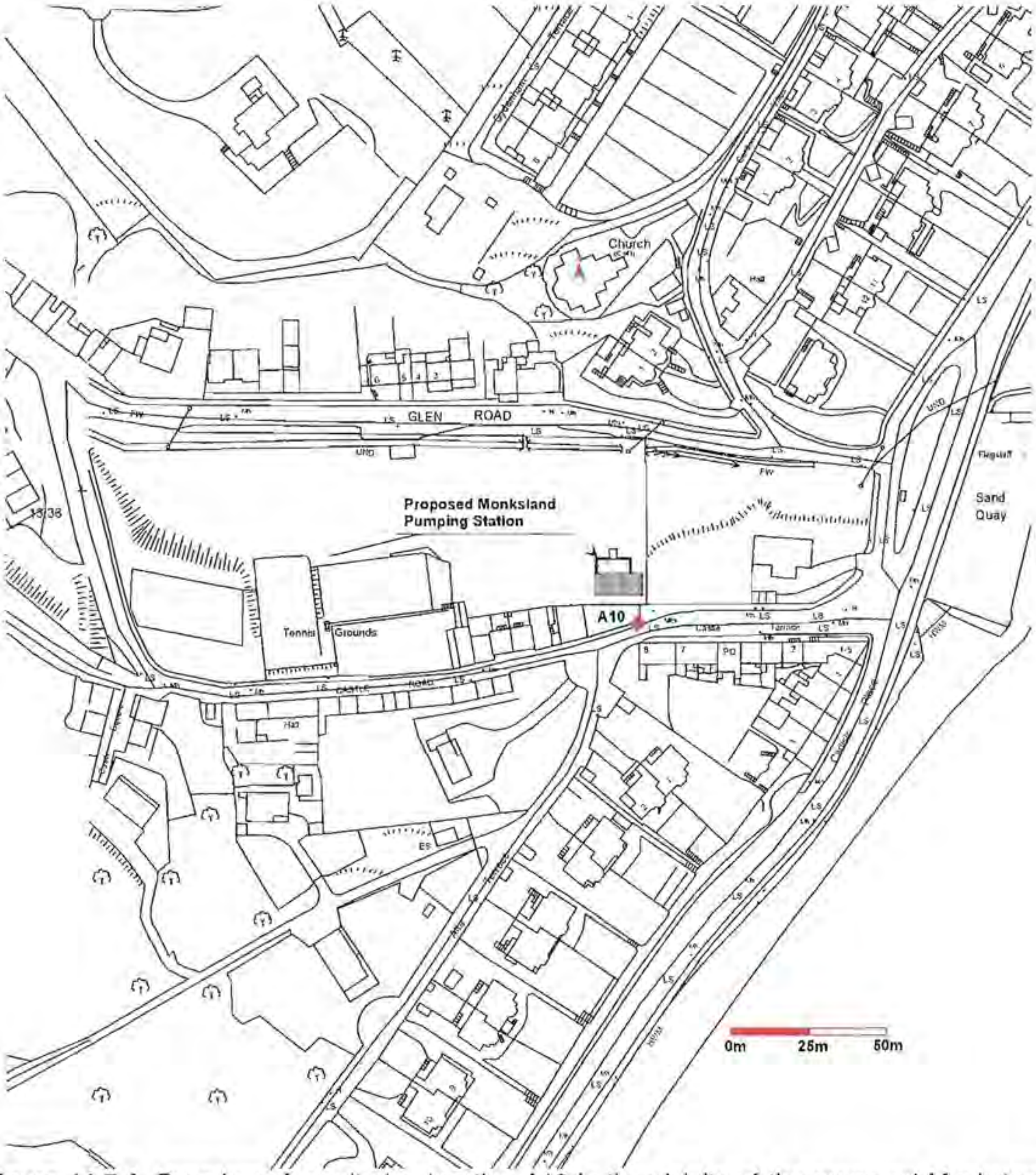

Figure 11.7.4. Overview of monitoring location A10 in the vicinity of the proposed Monkstown Pumping Station.

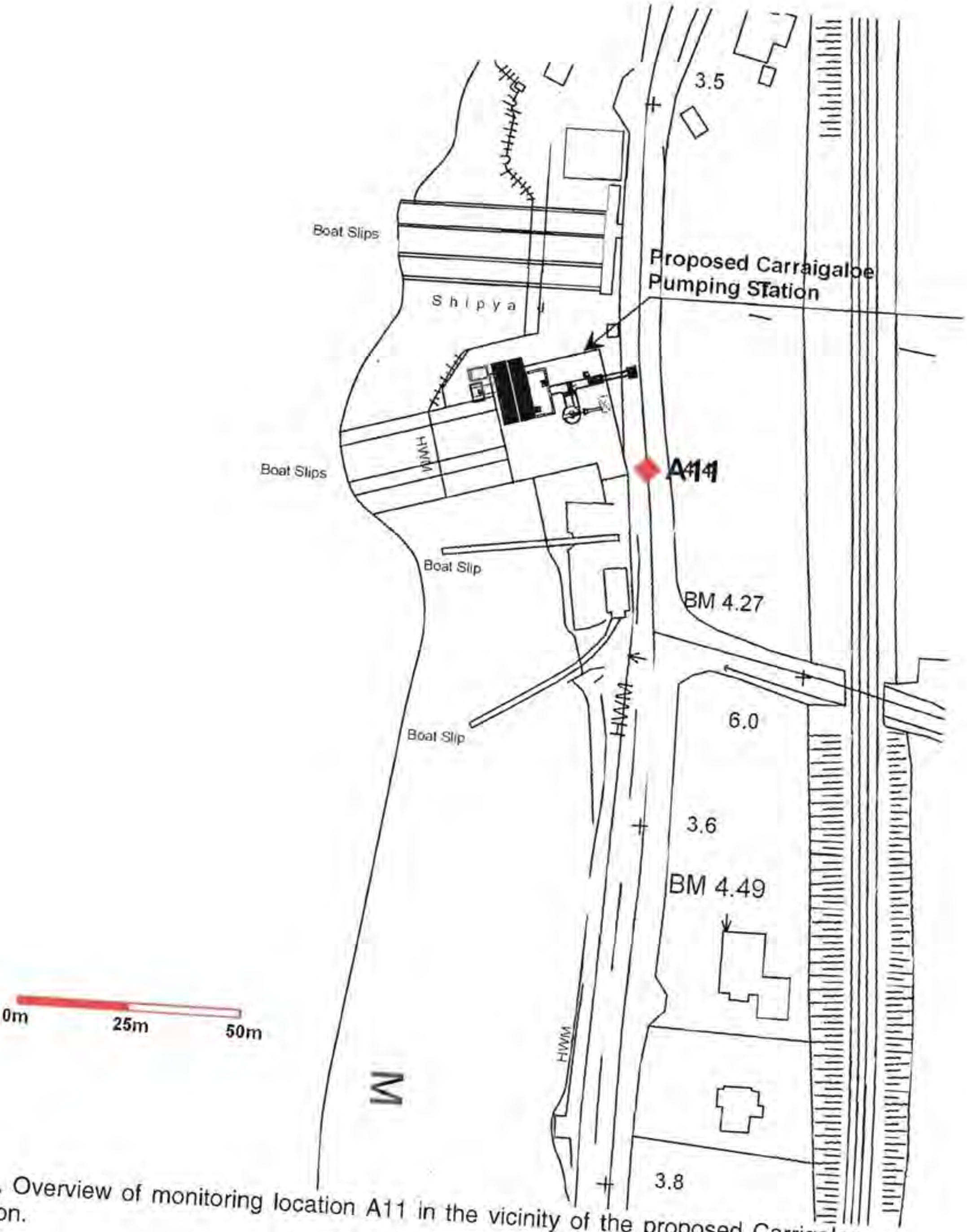

Figure 11.7.5. Overview of monitoring location A11 in the vicinity of the proposed Carrigaloe Pumping Station.

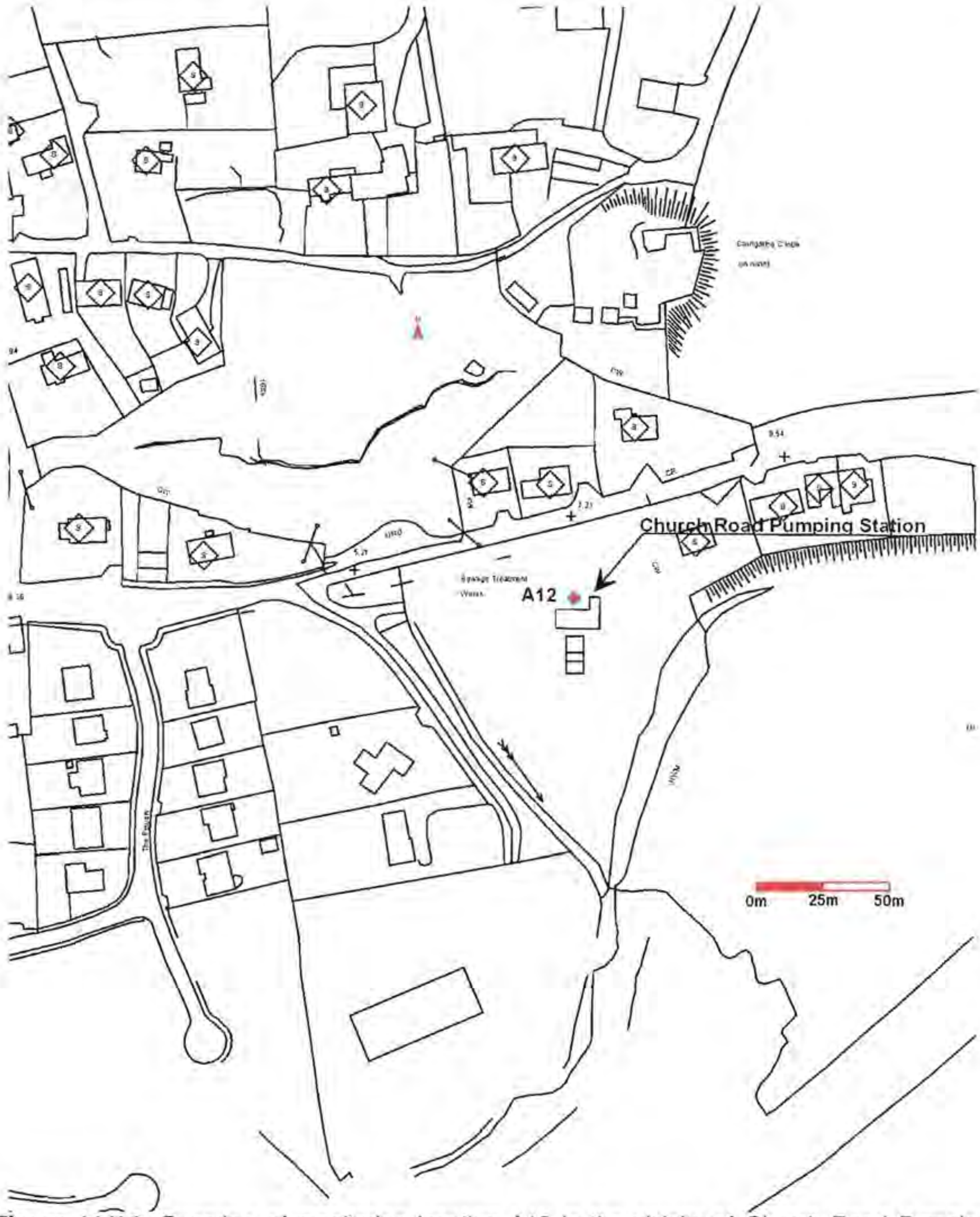

Figure 11.7.6. Overview of monitoring location A12 in the vicinity of Church Road Pumping Station.

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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

PREPARED BY: Dr. Brian Sheridan
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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:

<u>Cork Harbour Main Drainage Scheme WWTP</u>

- 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 6,611Ou_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. 6,611Ou_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 98th percentile and less than 3.0 Ou_E/m^3 at the 99.5th 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 98^{th} percentile and less than or equal to 3.0 Ou_E m^{-3} at the 99.5^{th} 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 98^{th} 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 98^{th} 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.).

4.3. Results of odour dispersion modelling for the proposed Cork Harbour Main Drainage Scheme WWTP and Pumping stations operation and design

Aermod Prime was used to determine the overall odour impact of the proposed Cork Harbour Main Drainage Scheme WWTP and Pumping stations operation at as set out in odour impact criteria *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 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: These contours are selected in order to allow for representation of the results obtained from the dispersion modelling. The limit value in terms of odour impact criterion is less than 1.50 Ou_E/m^3 at the 98th percentile and less than 3.0 Ou_E/m^3 at the 99.5th percentile of hourly averages. Since the overall predicted odour emission rate from the five major pumping stations is low (due to the small nature and characteristics of the odour source), these odour contours were selected for illustrative purposes only to demonstrate the absence of odour impact and in addition, the contours for the 99.5th percentile are not presented.

- 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 0.10 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 0.30 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 0.20 Ou_E m^{-3} (*see Figure 8.7*).
- Predicted odour emission contribution of overall proposed Church Road 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 0.14 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 0.10 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. good design in terms of odour management, tight fitting covers, etc.), odour isopleths suitable for reporting clarity were chosen (i.e. actual impact criterion is less than or equal to 1.50 Ou_E/m^3 at the 98^{th} percentile of hourly averages over 5 years of meteorological data). All odour impact criterions chosen were in accordance with best international practice (*see Section 3.3.4*). Taking this low impact into account, there is no requirement to perform risk analysis using the 99.5^{th} percentile assessment criterion, as the predicted odour impact criterion will always be below this level.

These computations give the odour concentration at each Cartesian grid receptor location that is predicted to be exceeded for 0.50% (44 hours) and 2% (175 hours) of a standard meteorological year.

This will allow for the predictive analysis of any potential impact on the neighbouring sensitive locations while the WWTP and Pumping stations are in operation. It will also allow the operators of the WWTP and Pumping station site to assess the effectiveness of their suggested odour abatement/minimisation strategies. The intensity of the odour from two or more sources of the WWTP operation will depend on the strength of the initial odour threshold concentration from the sources and the distance downwind at which the prediction and/or measurement is being made. Where the odour emission plumes from a number of sources combine downwind, then the predicted odour concentrations may be higher than that resulting from an individual emission source. It is important to note that various odour sources have different odour characters. This is important when assessing those odour sources to minimise and/or abate. Although an odour source may have a high odour emission rate, the corresponding odour intensity (strength) may be low and therefore it is easily diluted. Those sources that express the same odour character, as an odour impact should be investigated first for abatement/minimisation before other sources are examined as these sources are the driving force behind the character of the perceived odour.

5. Discussion of results

This section will discuss the results obtained during the desktop study.

5.1. Odour plume dispersal for proposed Cork Harbour Main Drainage Scheme WWTP specimen design with the incorporation of odour mitigation protocols

The plotted odour concentrations of ≤ 1.50 Ou_E m^{-3} for the 98[th] percentile and ≤ 3.0 Ou_E m^{-3} for the 99.5[th] percentile for the proposed Cork Harbour Main Drainage Scheme WWTP specimen design operation are illustrated in *Figure 8.1 and Figure 8.2*, respectively. As can be observed for the 98[th] percentile contour, it is predicted that odour plume spread is small with a radial spread of 80 metres from the boundary of the facility in a northerly direction. In accordance with odour impact criterion in *Section 3.6.4*, and in keeping with currently recommended odour impact criterion in this country, no long-term odour impacts will be generated by receptors in the vicinity of the future proposed WWTP.

In terms of the 99.5[th] percentile of hourly averages over five years of meteorological data, the overall odour plume spread is similar with a radial spread of 75 metres in a northerly and easterly direction. In accordance with odour impact criterion in *Section 3.6.4*, and in keeping with currently recommended odour impact criterion in this country, no short-term odour impacts will be generated by receptors in the vicinity of the future proposed WWTP.

Figures 8.4 and 8.5 illustrates the odour plume spread for individual grouped odour sources to include odour control units (OCU's) 1 to 5 and tankage odour sources Aeration, Secondary settlement and Storm water tankage. As can be observed, the main contributor of odour to the actual plume spread is the aeration, secondary settlement and storm water tankage. All other offensive odour sources will be covered, sealed and negatively ventilated and odourous air directed to two stages of odour control if biological treatment is chosen as first stage. The maximum predicted ground level concentration for odour control units 1 to 5 will be less than 0.41 Ou_E/m^3 at the 98 percentile of hourly averages over 5 years of meteorological data. This is a result of a guaranteed odour threshold concentration of less than 300 Ou_E/m^3 for OCU's 1, 2, 4, and 5 and less than 500 Ou_E/m^3 for OCU 3. The overall stack heights of each OCU is 12 m high from ground level with an efflux velocity greater than 15 m/s.

5.2. Odour plume dispersal for five Pumping stations with the incorporation of good design and odour management systems

The plotted odour concentrations of ≤ 0.10 Ou_E m^{-3} for the 98^{th} of hourly averages for five years of meteorological data for the proposed Raffeen Pumping station is illustrated in *Figure 8.5*. The maximum ground level concentration of odour in the vicinity of the facility will be 0.19 Ou_E/m^3 for the 98^{th} percentile following the implementation of standard design elements for odour management (e.g. tight fitting covers, etc.). In accordance with odour impact criterion presented in *Section 3.3.4*, no long-term odour impacts will be perceived in the vicinity of the Pumping station. This is up to 87% lower than the odour impact criterion presented in *Section 3.3.4*.

The plotted odour concentrations of ≤ 0.30 Ou_E m^{-3} for the 98^{th} of hourly averages for five years of meteorological data for the proposed West beach Pumping station is illustrated in *Figure 8.6*. The maximum ground level concentration of odour in the vicinity of the facility will be 0.34 Ou_E/m^3 for the 98^{th} percentile following the implementation of standard design elements for odour management (e.g. tight fitting covers, etc.). In accordance with odour impact criterion presented in *Section 3.3.4*, no long-term odour impacts will be perceived in the vicinity of the Pumping station. This is up to 77% lower than the odour impact criterion presented in *Section 3.3.4*.

The plotted odour concentrations of ≤ 0.20 Ou_E m^{-3} for the 98^{th} of hourly averages for five years of meteorological data for the proposed Monkstown Pumping station is illustrated in *Figure 8.7*. The maximum ground level concentration of odour in the vicinity of the facility will be 0.23 Ou_E/m^3 for the 98^{th} percentile following the implementation of standard design elements for odour management (e.g. tight fitting covers, etc.). In accordance with odour impact criterion presented in *Section 3.3.4*, no long-term odour impacts will be perceived in the vicinity of the Pumping station. This is up to 84% lower than the odour impact criterion presented in *Section 3.3.4*.

The plotted odour concentrations of ≤ 0.14 Ou_E m^{-3} for the 98^{th} of hourly averages for five years of meteorological data for the existing Church Road Pumping station is illustrated in *Figure 8.8*. The maximum ground level concentration of odour in the vicinity of the facility will be 0.18 Ou_E/m^3 for the 98^{th} percentile following the implementation of standard design elements for odour management (e.g. tight fitting covers, etc.). In accordance with odour impact criterion presented in *Section 3.3.4*, no long-term odour impacts will be perceived in the vicinity of the Pumping station. This is up to 88% lower than the odour impact criterion presented in *Section 3.3.4*.

The plotted odour concentrations of ≤ 0.10 Ou_E m^{-3} for the 98^{th} of hourly averages for five years of meteorological data for the proposed Carrigaloe Pumping station is illustrated in *Figure 8.9*. The maximum ground level concentration of odour in the vicinity of the facility will be 0.15 Ou_E/m^3 for the 98^{th} percentile following the implementation of standard design elements for odour management (e.g. tight fitting covers, etc.). In accordance with odour impact criterion presented in *Section 3.3.4*, no long-term odour impacts will be perceived in the vicinity of the Pumping station. This is up to 90% lower than the odour impact criterion presented in *Section 3.3.4*.

The implementation of good design and odour management systems (e.g. standard design for odour minimisation, tight fitting covers, etc.) within each pumping station (both minor and major) will minimise the uncontrolled release of fugitive odour emissions and prevent complaints from the public at large.

6. Conclusions

A worst-case odour emission scenario was modelled using the atmospheric dispersion model Aermod Prime with meteorology data representative of the study area. A worst-case odour emission data set was used to predict any potential odour impact in the vicinity of the proposed Cork Harbour Main Drainage Scheme WWTP and five Pumping stations. Odour impact potential was discussed for proposed operations with the implementation of management and mitigation protocols. 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 98^{th} percentile and less than 3.0 Ou_E/m^3 for the 99.5^{th} 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 Pumping Stations 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 minimisation, 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 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.

7. Recommendations

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 6,611Ou_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} (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 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. The specimen design suggests the use of three OCU's. As long as the total odour emission rate for the WWTP (i.e. 6,611Ou_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.
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 1.50 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 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.

8. Appendix I-Odour dispersion modelling contour results for Cork Harbour Main Drainage Scheme

8.1 Predicted odour emission contribution of proposed overall Cork Harbour Main Drainage Scheme WWTP operation with odour abatement protocols implemented (ref Scenario 1) (see Table 4.1), to odour plume dispersal at the 98th percentile for an odour concentration of ≤ 1.50 Ou$_E$ m^3 for five years of meteorological data.

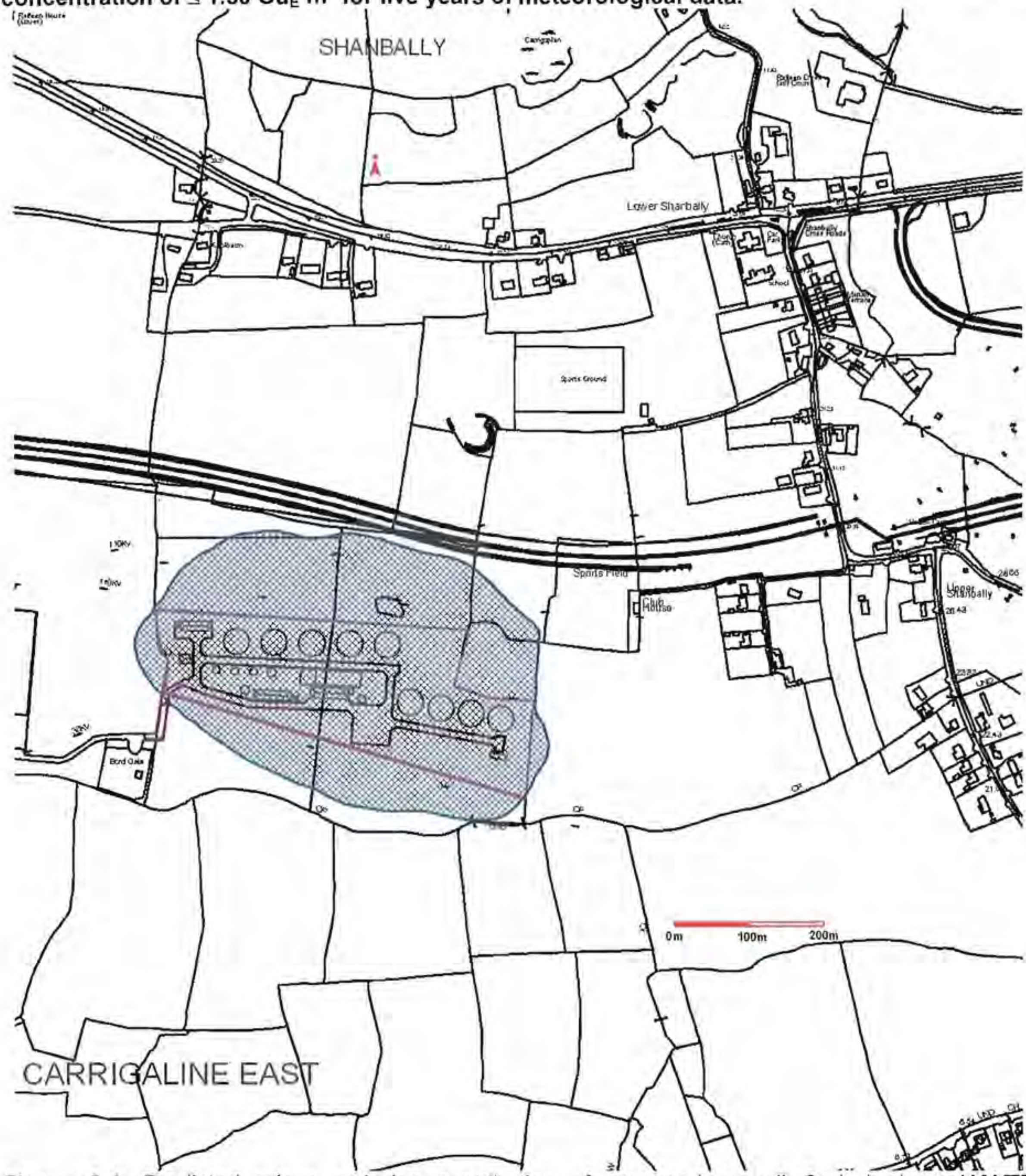

Figure 8.1. Predicted odour emission contribution of proposed overall Cork harbour WWTP operation with odour abatement protocols implemented to odour plume dispersal for Scenario 1 at the 98th percentile for odour concentrations ≤ 1.5 Ou$_E$ m^{-3} (▬) for five years of meteorological data.

8.2 Predicted odour emission contribution of proposed overall Cork Harbour Main Drainage Scheme WWTP operation with odour abatement protocols implemented (ref Scenario 1) (see Table 4.1), to odour plume dispersal at the 99.5th percentile for an odour concentration of ≤ 3.0 Ou_E m^3 for 5 years of meteorological data.

Figure 8.2. Predicted odour emission contribution of proposed overall Cork harbour WWTP operation with odour abatement protocols implemented to odour plume dispersal for Scenario 1 at the 99.5th percentile for odour concentrations ≤ 3.0 Ou_E m^{-3} ( ) for 5 years of meteorological data.

8.3 Predicted odour emission contribution of individual grouped odour control unit sources for proposed overall Cork Harbour Main Drainage Scheme WWTP operation (ref Scenario 1) (see Table *4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of ≤ 0.30 Ou_E m^3 for five years of meteorological data.

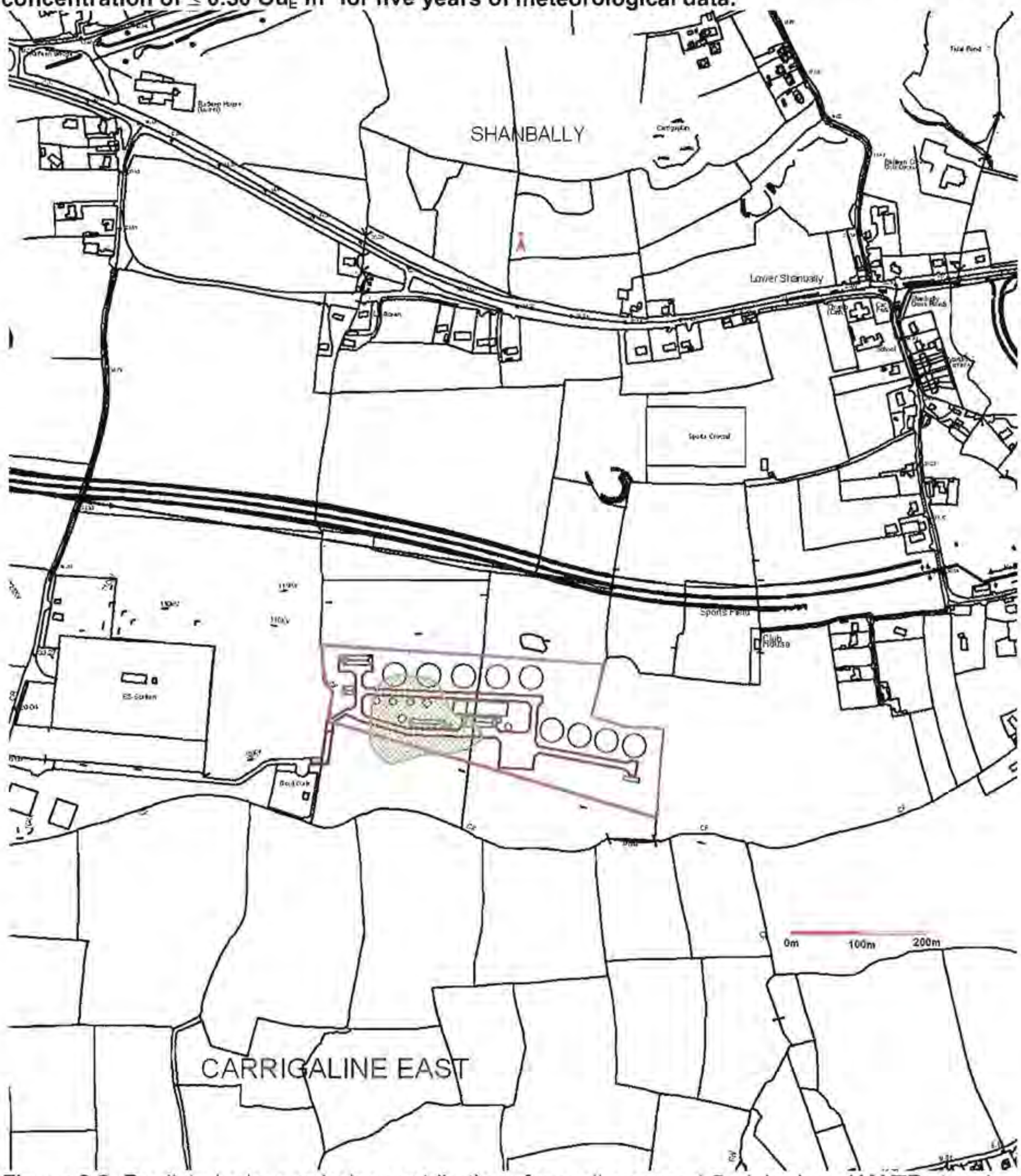

Figure 8.3. Predicted odour emission contribution of overall proposed Cork harbour WWTP to odour plume dispersal for grouped sources Odour control units 1, 2, 3, 4 and 5 for an odour concentration of less than or equal to 0.30 Ou_E m^{-3} (——)at the 98th percentile of hourly averages for 5 years of meteorological data.

8.4 Predicted odour emission contribution of individual grouped aeration tankage, secondary settlement tankage and storm water tankage sources for proposed overall Cork Harbour Main Drainage Scheme WWTP operation (ref Scenario 1) (see Table *4.1*), to odour plume dispersal at the 98th percentile for an odour concentration of ≤ 1.50 Ou_E m^3 for five years of meteorological data.

Figure 8.4. Predicted odour emission contribution of overall proposed WWTP to odour plume dispersal for grouped odour sources aeration tankage, Secondary settlement tankage and Storm water tankage for an odour concentration of less than or equal to 1.50 Ou_E m^{-3} (▬▬)at the 98th percentile of hourly averages for 5 years of meteorological data.

8.5 Predicted odour emission contribution of proposed Raffeen Pumping station operation with odour abatement protocols implemented (ref Scenario 2) (see Table 4.2), to odour plume dispersal at the 98th percentile for an odour concentration of ≤ 0.10 Ou_E m^3 for five years of meteorological data.

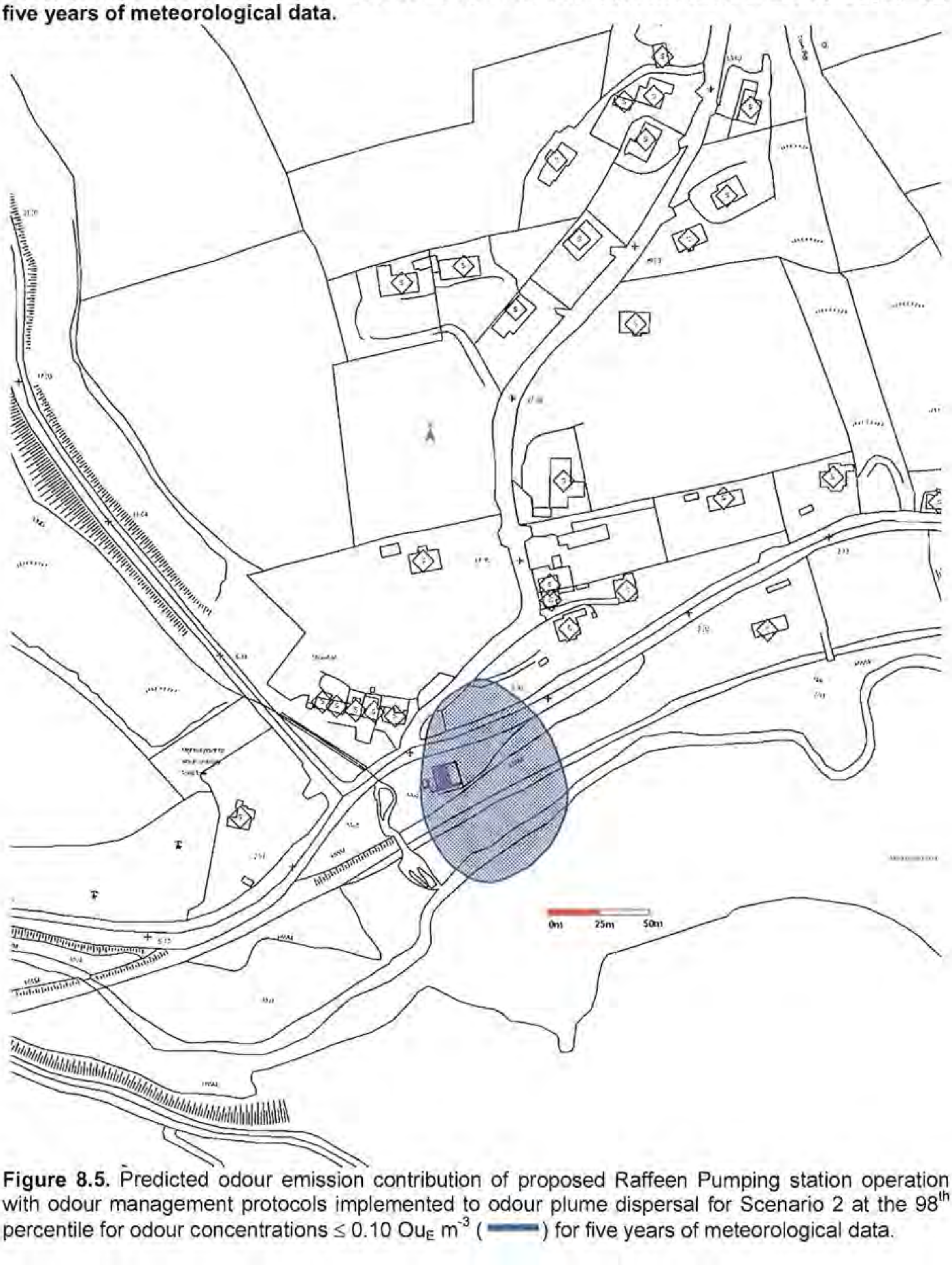

Figure 8.5. Predicted odour emission contribution of proposed Raffeen Pumping station operation with odour management protocols implemented to odour plume dispersal for Scenario 2 at the 98th percentile for odour concentrations ≤ 0.10 Ou_E m^{-3} (▬) for five years of meteorological data.

8.6 Predicted odour emission contribution of proposed West beach Pumping station operation with odour abatement protocols implemented (ref Scenario 2) (see Table 4.2), to odour plume dispersal at the 98th percentile for an odour concentration of ≤ 0.30 Ou_E m^3 for five years of meteorological data.

Figure 8.6. Predicted odour emission contribution of proposed West beach Pumping station operation with odour management protocols implemented to odour plume dispersal for Scenario 2 at the 98th percentile for odour concentrations ≤ 0.30 Ou_E m^{-3} (▬) for five years of meteorological data.

8.7 Predicted odour emission contribution of proposed Monkstown Pumping station operation with odour abatement protocols implemented (ref Scenario 2) (see Table 4.2), to odour plume dispersal at the 98th percentile for an odour concentration of ≤ 0.20 Ou_E m^3 for five years of meteorological data.

Figure 8.7. Predicted odour emission contribution of proposed Monkstown Pumping station operation with odour management protocols implemented to odour plume dispersal for Scenario 2 at the 98th percentile for odour concentrations ≤ 0.20 Ou_E m^{-3} (▬) for five years of meteorological data.

8.8 Predicted odour emission contribution of proposed Church Road Pumping station operation with odour abatement protocols implemented (ref Scenario 2) (see Table 4.2), to odour plume dispersal at the 98th percentile for an odour concentration of ≤ 0.14 Ou_E m^3 for five years of meteorological data.

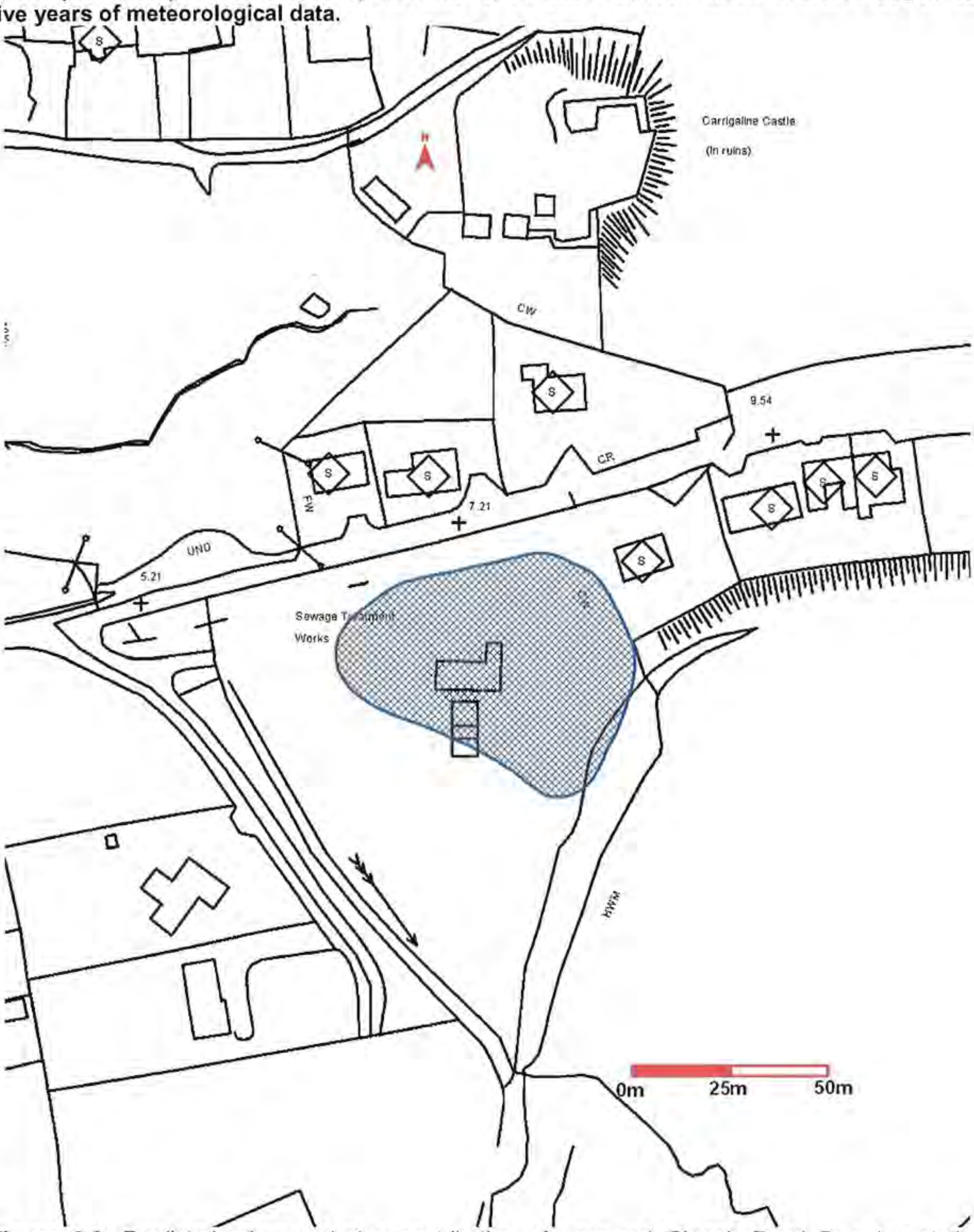

Figure 8.8. Predicted odour emission contribution of proposed Church Road Pumping station operation with odour management protocols implemented to odour plume dispersal for Scenario 2 at the 98th percentile for odour concentrations ≤ 0.14 Ou_E m^{-3} (▬▬) for five years of meteorological data.

8.9 Predicted odour emission contribution of proposed Carraigaloe Pumping station operation with odour abatement protocols implemented (ref Scenario 2) (see Table 4.2), to odour plume dispersal at the 98th percentile for an odour concentration of ≤ 0.10 Ou_E m^3 for five years of meteorological data.

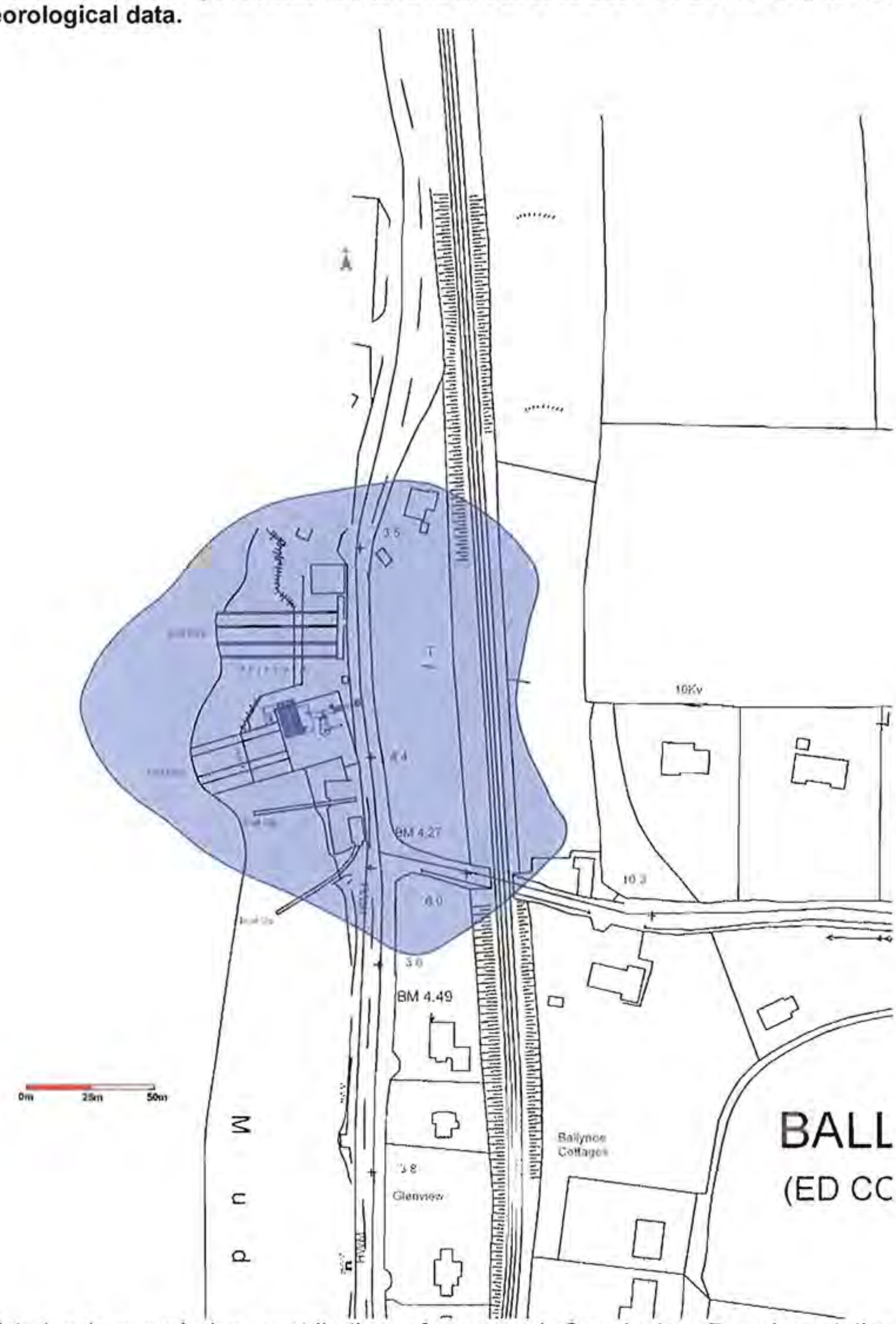

Figure 8.9. Predicted odour emission contribution of proposed Carraigaloe Pumping station operation with odour management protocols implemented to odour plume dispersal for Scenario 2 at the 98th percentile for odour concentrations ≤ 0.10 Ou_E m^{-3} (▬) for five years of meteorological data.