ODOURNET
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Report

Odour impact assessment study for land adjacent to sewage treatment works in Foxton, Cambridgeshire

Client: [redacted]

[redacted]

Date: 3rd September 2019 (September 2019)

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Executive Summary

Odournet UK Ltd were commissioned by [redacted] to undertake an odour impact assessment for proposed development land which is located adjacent to an Anglian Water sewage treatment works (STW) in Foxton, Cambridgeshire. The overall aim of the study was to determine the extent to which odours from the STW are likely to pose a risk of odour impact on the proposed development land.

The specific scope of the study was as follows:

1. To liaise with Anglian Water and review the current STW configuration and operations and define the scope of the odour survey.
2. To undertake an odour survey and define odour emission estimates for each element of the treatment process at the STW.
3. To undertake odour dispersion modelling of the STW under the current operational conditions and assess the extent of potential odour impact risk across the development land.

An odour impact assessment was undertaken using an approach based on assessment techniques that are presented within guidance published by the Environment Agency[1] and the Institute of Air Quality Management (IAQM)[2]. On-site measurement data was collected in July 2019 and this was supplemented with data collected by Odournet at works of a similar size and configuration to Foxton STW, and with information provided by Anglian Water. Dispersion modelling was used to assess how odours from the works are likely to disperse and to predict odour exposure levels across the development site.

The study was undertaken by specialist consultants drawn from Odournet's UK consultancy team which has extensive experience (in excess of 20 No. years) in assessing the odour impact of sewage treatment operations, including those of a comparable size and configuration to Foxton STW.

The key findings of the study are summarised as follows:

1. A range of activities were identified at Foxton STW that have the potential to generate odorous emissions. These include processes within the preliminary treatment, primary treatment, secondary treatment and sludge handling stages of the works.
2. Under the current operational conditions at the works the estimated total time weighted summer odour emission is approximately 5,500 ou_E/s. Of these emissions approximately 53% are released from the sludge handling operations, 30% from the preliminary treatment stage, 10% from the secondary treatment, 6 % from primary treatment, 1% from the humus tanks and the remaining 1% from the non-operational storm tank. The two largest individual contributors to emissions from the works are the new sludge holding tank and the sludge transfer well (both assumed to be in constant use for this assessment), which together account for approximately 49% of the total time weighted emissions.
3. Emissions from Foxton STW are predicted to result in odour exposure levels across the proposed development land that range from below $C_{98,\ 1\text{-hour}} = 3\ ou_E/m^3$ to greater than $C_{98,\ 1\text{-hour}} = 5\ ou_E/m^3$. The highest exposure levels are predicted in locations adjacent to the STW boundaries. The areas of the proposed development land where exposure levels are predicted to exceed $C_{98,\ 1\text{-hour}} = 3\ ou_E/m^3$ are at risk of odour impact.

[1] IPPC H4 Technical Guidance Note "H4 Odour Management", published by the Environment Agency, March 2011.

[2] Guidance on the assessment of odour for planning, published by IAQM: April 2014, reissued July 2018.

A reduction in odour emissions from the STW, and impact risk across the development site, could in principal be achieved through the application of cover and treat odour mitigation measures to the open sludge holding tank and transfer well. Site operational staff have however indicated that the transfer well may be taken out of use in the future however.

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1 Introduction and scope

1.1 Introduction

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The specific objectives of the study were as follows:

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An odour impact assessment was undertaken using an approach based on assessment techniques that are presented within guidance published by the Environment Agency[3] and the Institute of Air Quality Management (IAQM)[4]. The on-site measurement data was supplemented with data collected by Odournet at works of a similar size and configuration to Foxton STW, and with information provided by Anglian Water.

This report provides the findings of this assessment.

1.2 Structure of report

The report is structured as follows:

- Section 1 outlines the scope of the assessment.
- Section 2 describes the methodology undertaken to conduct the assessment.
- Section 3 provides an overview of current site operations and the proposed development site
- Section 4 identifies the odour sources associated within Foxton STW under the current operational conditions.
- Section 5 presents the results of the odour survey.
- Section 6 summarises the assumptions applied to define emissions from the odour sources at the works.
- Section 7 reviews the odour impact of Foxton STW on the proposed development land.
- Section 8 summarises the findings of the study.

Supporting information is provided in the Annex.

[3] IPPC H4 Technical Guidance Note "H4 Odour Management", published by the Environment Agency, March 2011.

[4] Guidance on the assessment of odour for planning, published by IAQM: April 2014, reissued July 2018.

1.3 Quality Control and Assurance

Odournet's odour measurement, assessment and consultancy services are conducted to the highest possible quality criteria by highly trained and experienced specialist staff. All activities are conducted in accordance with quality management procedures that are certified to ISO9001 (Certificate No. A13725).

All sensory odour analysis and odour sampling services are undertaken using UKAS accredited procedures (UKAS Testing Laboratory No. 2430) which comply fully with the requirements of the international quality standard ISO 17025: 2005 and the European standard for olfactometry EN13725: 2003. Where required, Odournet are accredited to conduct odour sampling from stacks and ducts in accordance to ISO 17025: 2005 and EN13725: 2003 under the MCERTS scheme. Odournet is the only company in the UK to have secured UKAS accreditation for all elements of the odour measurement and analysis procedure. Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.

The Odournet laboratory is recognised as one of the foremost laboratories in Europe, consistently out performing the requirements of the British Standard for Olfactometry in terms of accuracy and repeatability of analysis results.

2 Description of approach

2.1 Site review

A site visit was undertaken to the sewage treatment works on 8th May 2019, in the company of Anglian Water's odour specialist. The aim of the visit was to establish the current STW configuration and operations and identify all potential sources of odour.

2.2 Odour survey

An odour sampling program was conducted at the works on 17th July 2019 using Odournet's UKAS accredited procedures which comply fully with the requirements of the international quality standard ISO 17025: 2005[5] and the European standard for olfactometry BS EN 13725: 2003[6].

Samples were collected in triplicate from the locations defined in table 1 below.

Table 1: Odour sampling locations

Stage of treatment process	Process/odour source
Preliminary	Inlet balance tank
Primary	Primary settlement tank
Secondary	Filter bed
	Filter distribution chamber
	Humus tank
Sludge	Sludge storage tank

The collected samples were transported to the Odournet UK laboratory in Bristol for the following analysis:

- Determination of the odour concentration in terms of European odour units in accordance with the British Standard for Olfactometry BS EN 13725: 2003. The analysis was conducted using Odournet's internal quality management procedures which are accredited by the UK accreditation services (UKAS) under certificate No. 2430.
- Determination of the hydrogen sulphide concentration using a calibrated Jerome gold film analyser.

During the survey the ambient temperature and weather conditions were recorded. All sources were sampled following a period of dry weather conditions (3 days prior with less than 5mm of rainfall).

2.3 Estimation of emissions

The results of the odour survey were used alongside information obtained during the site audit and reference odour emissions data held within Odournet's data library (and additional information provided by Anglian Water), to define odour emission rates for each stage of the sewage treatment process. Odournet's odour emissions data has been collected at UK sewage treatment works (including those of a comparable size and design to Foxton STW) over a period in excess of 20 years and allows robust and defensible odour emission rates to be defined.

In defining emissions from each area of the works, the following factors were considered:

[5] ISO/IEC 17025:2005, General requirements for the competence of testing and calibration laboratories.

[6] BS EN 13725:2003, Air quality - Determination of odour concentration by dynamic olfactometry.

- The dimensions and release height of each odour source.
- The frequency of use of each aspect of the plant.
- The potential effects of sludge/sewage turbulence.

2.4 Odour dispersion modelling

2.4.1 Assessment of odour impact

On the basis that odour annoyance or 'nuisance' is a symptom that develops through intermittent exposure to odours over extended time periods (see Section 2.4.2 below), the study focused on assessing the long-term odour exposure levels which may occur across the proposed development land under the current operational conditions.

This assessment was performed using mathematical atmospheric dispersion modelling techniques which provided a statistical analysis of the odour exposure levels that are likely to occur around the site. The model was run using five separate years of meteorological data (2012 - 2016), and the worst case results for each specific receptor from across the five years were used to create an overall worst case model output.

Meteorological data from Cambridge International Airport was used following a review of the available data. The output of the model was presented as isopleths of equal odour concentration and plotted on a plan of the area surrounding the STW.

The dispersion modelling was conducted using the US Environmental Protection Agency (US EPA) AERMOD dispersion model (version 8.1). The model was run in accordance with guidance issued by the US EPA and the Environment Agency. Suitable meteorological data was used by the model to simulate the dispersion and dilution effects generated by the atmosphere. Data describing the topography of the local area was obtained from Ordnance Survey. The locations of the odour sources at the STW were defined from maps of the site obtained from aerial imagery, as well as notes and photographs from the site audit.

The model was run to investigate the odour exposure levels in the potential development land surrounding the STW which are predicted to be generated from the STW under the current operational regime.

2.4.2 Odour exposure criteria

In general terms, odour annoyance is recognised as a symptom that develops as a result of intermittent but regular exposure to odours that are recognisable and have an offensive character. The key factors that contribute to the development of odour annoyance can be usefully summarised by the acronym FIDOL:

- Frequency of exposure.
- Intensity or strength of exposure.
- Duration of exposure.
- Offensiveness.
- Location sensitivity.

In acknowledgement of these factors, a number of odour impact criteria have been developed that enable the odour impact risk of facilities to be predicted using dispersion modelling techniques. These criteria are generally defined in terms of a minimum concentration of odour (reflecting the intensity/strength element of FIDOL) that occurs for a defined minimum period of time (reflecting duration and frequency element of FIDOL) over a typical meteorological year. The concentration element of these criteria can be increased or lowered to reflect variations in the offensiveness of the odours released from a specific type of facility, and the sensitivity of nearby sensitive locations.

There are currently a range of odour criteria applied in the UK to attempt to gain an insight into the probability of odour annoyance developing at a given location. However, there is no firm consensus on which odour impact criteria should be applied for sewage treatment works and the issue is currently a matter of debate.

In the UK, odour impact criteria are generally expressed in terms of a European odour unit concentration that occurs for more than 2% of the hours of a typical meteorological year and have been designed for application to permanent residential properties, which are considered to be the most sensitive from an impact risk perspective.

Historically, the most commonly applied criterion from this perspective is the 'Newbiggin criterion'. This criterion was originally introduced into a public inquiry for a new sewage works at Newbiggin-by-the-sea in 1993, and equates to an odour exposure level of 5 European odour units per cubic meter ($C_{98,\ 1\text{-hour}} > 5\ ou_E/m^3$). The Newbiggin criterion has been successfully applied during numerous planning and odour nuisance assessment studies since 1993 for sewage, waste, food and a range of other industrial and agricultural activities.

Since 2002, a range of indicative odour annoyance criteria have also been applied to assess odour impact risk from residential properties, which have supplemented the use of the Newbiggin criterion. These criteria were introduced in the Horizontal Guidance Note for Odour Management H4 issued by the Environment Agency[7] and define three different levels of exposure at which odour impact or annoyance could potentially be expected to occur, for odours with high, moderate and low offensiveness. The indicative criteria are presented in the table below:

Table 2: Odour impact criteria

Relative offensiveness	Indicative criterion	Typical processes
Most offensive	1.5 ou_E/m^3 98th percentile (hourly average)	Processes involving decaying animals or fish remains; septic effluent or sludge; biological landfill odours
Moderately offensive	3 ou_E/m^3 98th percentile (hourly average)	Intensive livestock rearing; sugar beet processing; fat frying (food processing); well aerated green waste composting
Less offensive	6 ou_E/m^3 98th percentile (hourly average)	Brewery; coffee roasting; confectionary; bakery

Odour guidance published by DEFRA in March 2010[8] also refers to these criteria but in less specific terms. The guidance does not state which criterion should be applied for assessing impact but does suggest that typical criteria fall within the range of $C_{98,\ 1\text{-hour}} = 3\ ou_E/m^3$ to $C_{98,\ 1\text{-hour}} = 5\ ou_E/m^3$. Similarly, guidance published by the Institute of Air Quality Management (IAQM)[9] in May 2014 and reissued in July 2018 also refers to these criteria. This guidance does however state that odour impact may occur between $C_{98,\ 1\text{-hour}} = 1\ ou_E/m^3$ and $C_{98,\ 1\text{-hour}} = 10\ ou_E/m^3$ and that professional judgement should be applied to determine criteria on a case by case basis by considering the underlying science, sensitivity of local receptors and developing case law.

[7] IPPC H4 Technical Guidance Note "H4 Odour Management", published by the Environment Agency, March 2011.

[8] Odour Guidance for Local Authorities, published by DEFRA, March 2010 (now revoked)

[9] Guidance on the assessment of odour for planning, published by IAQM: April 2014, reissued July 2018.

There is currently some debate as to which odour criteria is the most appropriate for assessing the risk of impact of odorous industries such as sewage treatment, and to what extent the criteria are able to predict the occurrence of odour annoyance for different odour types. Whilst there appears to be a substantial body of evidence to support the Newbiggin-by-the-Sea impact criterion for assessing the development of odour annoyance from the sewage sector, the availability of such evidence for the EA criteria is currently somewhat lacking. There is therefore a developing view within the UK odour community that the most stringent EA criteria (i.e. $C_{98,\ 1\text{-hour}}$ = 1.5 ou_E/m^3) may represent an overly cautious standard in many cases even for highly offensive odours.

Odournet's general experience based on assessment of odours which could generally be classified as moderate to highly offensive (e.g. odours from waste water and sludge handling operations) generally supports this view, and indicates that odour annoyance is a symptom that is less likely to develop at exposure levels below $C_{98,\ 1\text{-hour}}$ = 3 ou_E/m^3, and is more likely to develop at levels between $C_{98,\ 1\text{-hour}}$ = 3 and 5 ou_E/m^3, with the risk of annoyance increasing at higher exposure levels. However, the possibility of occurrence of adverse odour impact and complaints at odour exposure levels below $C_{98,\ 1\text{-hour}}$ = 3 ou_E/m^3 cannot be completely excluded.

This observation is supported to some extent by the findings of recent legal cases relating to odours from sewage treatment works (and a policy statement issued by the Chartered Institute of Water and Environmental Management) as indicated below, although from review of these it is clear that the use of the most stringent criteria EA cannot necessarily be discounted.

- **Appeal by Sherborne School, CRUK, CLIC Sargent, Mencap and British Heart Foundation against North Dorset District Council (January 2016).** The District Council originally refused outline planning permission for the erection of homes on land in proximity to Gillingham sewage treatment works on the basis that the proposed development would have an adverse impact on the general amenity of the future occupants due to odours from the sewage treatment works. Odour dispersion modelling was undertaken on behalf of the appellant, and the inspector concluded that "the appropriate parameter to apply in this case is the 3 ou_E/m^3 contour line".

- **Appeal by Abbey Homes against St Edmundsbury Borough Council (March 2012).** The Borough Council originally refused planning permission for the erection of 101 dwellings on land between Upthorne Road and Hepworth Road, Stanton, Suffolk, for reasons including the proximity of the site to an existing small rural sewage treatment works and the potential effects on the living conditions of future residents of the dwellings. On the basis of odour dispersion modelling submitted by experts acting for both parties, the inspector considered $C_{98,\ 1\text{-hour}}$ 3 - 5 ou_E/m^3 an appropriate threshold, allowed the appeal and planning permission was granted.

- **Appeal against Corby Borough Council (2012).** This appeal concerned land at Ashley Road, Middleton, Leicestershire. The inspector concluded in this case "I believe that it is reasonable to take account of the 1.5 ou_E/m^3 contour map in determining odour impact. In my view areas subject to such concentrations are unlikely to provide a reasonable permanent living environment."

- **Appeal by Lakeland Leisure Ltd. against Allerdale Borough Council, 2012.** This appeal concerned the development of dwellings in Cockermouth, Cumbria in the vicinity of a sewage treatment works. The inspector concluded that development within the area predicted to experience odour exposure levels of $C_{98,\ 1\text{-hour}}$ = 3 ou_E/m^3 or less would be appropriate due to the anticipated medium offensive nature of the odours from the sewage works.

- **Thames Water vrs Dobson 2011.** This nuisance action was brought against Thames Water Mogden Sewage Treatment Works by a group of residents claiming odour nuisance caused by this large municipal sewage works in London. The inspector concluded that he would be reluctant to find nuisance if the modelled odour concentration was only $C_{98,\ 1\text{-hour}} > 1.5\ ou_E/m^3$ but as the odour concentration rises to $C_{98,\ 1\text{-hour}} = 5\ ou_E/m^3$ he considered that this was the area where nuisance from the works would start and that by the time that $C_{98,\ 1\text{-hour}} > 5\ ou_E/m^3$ or above is reached nuisance would certainly be established.

- **Appeal by JS Bloor (Northampton) Ltd 2010.** This appeal concerned a proposed residential development on land near an existing sewage treatment works in Leighton Linslade. The inspector noted that the water company used a standard of $C_{98,\ 1\text{-hour}} > 5\ ou_E/m^3$ which they indicated would be a "concentration level above which odour might be a potential nuisance", and stated that the approach seemed reasonable and had been accepted at a previous appeal.
- **Extract from CIWEM policy statement.** CIWEM issued a position statement on odour in 2012 stating that the following framework is the most reliable that can be defined on the basis of the limited research undertaken in the UK at the time of writing:
  - $C_{98,\ 1\text{-hour}} > 10\ ou_E/m^3$ - complaints are highly likely and odour exposure at these levels represents an actionable nuisance;
  - $C_{98,\ 1\text{-hour}} > 5\ ou_E/m^3$, - complaints may occur and depending on the sensitivity of the locality and nature of the odour this level may constitute a nuisance;
  - $C_{98,\ 1\text{-hour}} < 3\ ou_E/m^3$, - complaints are unlikely to occur and exposure below this level are unlikely to constitute significant pollution or significant detriment to amenity unless the locality is highly sensitive or the odour highly unpleasant in nature.

On this basis, the assessment of risk to the development land has been conducted by consideration of the $C_{98,\ 1\text{-hour}} = 3\ ou_E/m^3$ and $5\ ou_E/m^3$ criteria.

It is however very important to note that the choice of criteria for planning and development purposes would ultimately be defined on the basis of the risk appetite of the parties involved.

3 Overview of operations and proposed development

3.1 Locations of works and development site

Foxton sewage treatment works is located in the rural town of Foxton, bordering the towns of Barrington and Shepreth, to the south of Cambridge.

Figure 1 below shows the STW situated within the development land (extents supplied by [redacted]. The STW is outlined in red and the potential development land is outlined in blue.

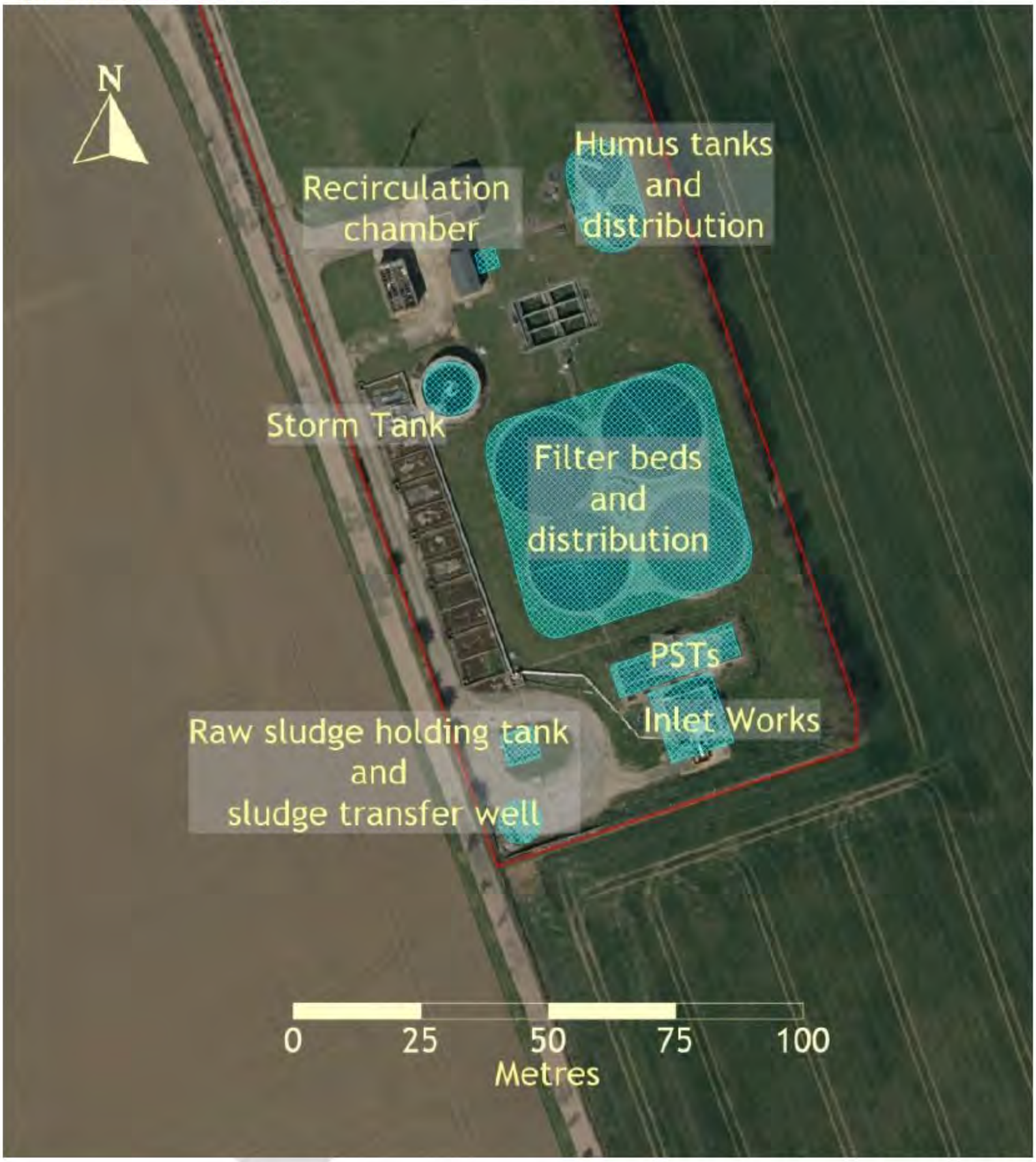
Figure 1: Map of the STW and development land

3.2 Overview of current sewage treatment works operation

Foxton sewage treatment works serves a population equivalent of approximately 5,800 with an average incoming flow rate of 14 l/s with a maximum discharge recorded in the past year (2018) of 50 l/s. The works comprises of preliminary treatment (for screenings removal), primary treatment (for sludge settlement), secondary treatment and sludge storage assets.

The layout of the STW is shown in Figure 2.

Figure 2: Assets at Foxton STW



3.2.1 Sewage treatment

Incoming sewage received at the works discharges into the inlet reception chamber where (operationality permitting) it is fed through an enclosed screening chamber for the removal of screenings/rags before being passed through 4 No. balance tanks. Removed screenings are deposited into a skip prior to removal from site for disposal.

A non-operational storm tank was previously used during times of high influent flows, however discussions with Anglian Water staff during the audit indicated that this tank is no longer in operational use. However due to the retention of material within the disused tank (aged storm materials and rainwater) it is still believed to contribute to site odours to some extent.

From the inlet works balance tanks the influent is gravity fed to into 4 No. rectangular PSTs which cause sludge to be removed from the flow and settled in the tank bases.

Following primary treatment, the settled sewage combines within a filter bed distribution chamber where flows are split and conveyed to 4 No. filter beds where biological treatment takes place.

The flows from the filter beds then recombine and pass through 2 No. humus tanks before the treated effluent is discharged to the River Rhee.

3.2.2 Sludge treatment

Sludge settled within the PSTs is transferred via 5 No. de-sludge pumps into an open raw sludge holding tank via enclosed pipework. An open sludge transfer well is also in use, although site operators indicated that this may be taken out of use in the future.

Solid materials which accumulate in the base of the inlet balance tanks is periodically removed via 2 No. open desludging chambers and pumped to the raw sludge holding tank.

Indigenous raw sludge from the humus tanks is recirculated (via an open recirculation chamber and underground pipework) for settlement within the PSTs.

Sludge from the site is periodically removed from the site by tankers.

4 Identification of odour sources

4.1 Overview of the mechanisms for odour generation from sewage treatment operations

The generation of odour from the processing of sewage is primarily associated with the release of odorous Volatile Organic Compounds (VOCs) that are generated as a result of the anaerobic breakdown of organic matter by micro-organisms. Anaerobic breakdown starts within the human bowel and may continue within the sewerage network and treatment works if conditions (i.e. a lack of oxygen) allow.

The key objectives of the sewage treatment process are to remove solid organic matter which is responsible for the generation of the majority of sewage odours and to provide treatment to remove any residual contaminants from the wastewater so that it can be returned back into the environment.

Since the main source of odour and VOCs is the solid organic matter, the most intense and offensive odours tend to be generated from the operations involving the handling of sludge i.e. the processes applied to dewater, treat and store raw sludge. These processes are generally considered to present the greatest risk of odour impact offsite, unless adequate controls are put in place. Depending upon the quality of the sewage presented to the works, the aspects of the treatment process involved in the handling of raw sewage (e.g. preliminary and primary treatment stages) may also generate significant levels of offensive odours.

The rate of odour release from sewage and sludge sources is primarily dependent upon temperature of the material, and the surface area exposed to the atmosphere. As a result, odorous emissions from sewage treatment operations tend to be highest during the summer months. Furthermore, activities that lead to increase in the surface area of odorous material exposed to the atmosphere (e.g. due to turbulence generated by sewage handling processes and agitation of sludge) will inevitably lead to an increase in the magnitude of odour released.

4.2 Identification of sources of odour emission.

On the basis of the findings of the site audit and information provided by Anglian Water, a range of odour sources were identified at Foxton STW. These sources are summarised in Table 3 below.

Table 3: Identification of odour sources

Stage of treatment	Source	Nature of odorous material/level of enclosure	Frequency and duration of release
Preliminary treatment	Inlet reception chamber	Raw sewage - open chamber	Continuous
	Inlet screen chamber	Raw screening - enclosed chamber	Continuous
	Inlet balance tanks (4)	Raw sewage - open tanks	Continuous
	Screening skip	Screenings/rag - open skip	Continuous
Storm water handling	Storm tank (non-operational)	Storm material/rain water - open tank	Continuous
Primary treatment	Primary settlement tanks (4)	Raw sewage - open tanks	Continuous
Secondary treatment	Filter distribution chamber	Settled sewage - open chamber	Continuous
	Filter beds (4)	Partially treated sewage - open beds	Continuous
	Filter effluent channel	Partially treated sewage - open channel	Continuous
	Humus tank distribution chamber	Partially treated sewage - open chamber	Continuous
	Humus tanks (2)	Partially treated sewage - open tanks	Continuous

Sludge handling and treatment	Inlet balance tanks desludge chamber (2)	Raw sludge - open chambers	Intermittent - only 1 in operation at a time for 2 hours per day
	Raw sludge holding tank	Raw sludge - open tank	Continuous
	Sludge transfer well	Raw sludge - open well	Continuous
	Humus tank desludging chamber	Secondary treatment sludge - open tank	Continuous
	Recirculation chamber	Secondary treatment sludge	Continuous
	Sludge tanker	Raw sludge - enclosed tanker (emissions from displaced air)	Intermittent - operational for 1 hour 20 minutes/ week - 3-4 tanker/ week

5 Odour survey results

5.1 Olfactometry and hydrogen sulphide measurement results

The data obtained from the odour survey conducted on the 16th July 2019 is summarised in Table 4 below. The results are presented in full in Annex B.

Table 4: Emission measurements from open sources

Source	Measured geomean odour emission rate ($ou_E/m^2/s$)	Measured average H_2S emission rate ($\mu g/m^2/s$)
Inlet balance tank	16.0	<LLOD
Primary settlement tank	1.0	<LLOD
Filter distribution chamber	0.9	<LLOD
Filter bed	0.4	<LLOD
Humus tank	0.3	<LLOD
Sludge transfer well	50.5	0.010

LLOD = $\leq 0.005\ \mu g/m^3$

5.2 Discussion

Review of the odour measurement results presented in the table above prompts the following observations:

- The odour emission rate measured from the influent at the inlet works is indicative of a relatively low odour influent, which can be typically expected from a sewage treatment works of this size. The low hydrogen sulphide emission rates measured across the sewage treatment assets is likely to be associated with the anticipated relatively fresh (non-septic) nature of influent received.
- The odour emission rates measured from the PSTs, filter distribution chamber, filter bed and humus tanks fall at the middle to lower end of the normal range of emissions which are typically observed from PSTs, filter effluent and humus tanks at STWs of a similar size and configuration.
- The odour emission rate measured from the surface of the sludge transfer well was elevated in comparison to the other sources onsite, as were the hydrogen sulphide measurements. This is an expected result as odour and hydrogen sulphide emissions from sludge operations tend to be greater than those from the processes which handle raw or treated sewage.

6 Estimation of odour emissions

6.1 Assumptions applied to odour emissions

A summary of the key assumptions applied to derive emission estimates are presented below:

- The odour emission rate for the majority of open odour sources for summer conditions were calculated by multiplying the plan area of the treatment process by the estimated odour emission rate. Emission rates for sources not sampled by Odournet were estimated using information obtained during the site audit as well as reference odour emissions data held within Odournet's data library and information provided by Anglian Water.

Table 5: Identification of odour sources.

Stage of treatment	Source	Estimated odour emission rate ($ou_E/m^2/s$)	Turbulence factors applied
Preliminary treatment	Inlet - reception chamber	16	6
	Inlet - screen chamber	*8	3
	Inlet - balance tanks (4)	16	1-6
	Inlet - screening skip	35	1
Storm water handling	Storm tank (non-operational)	0.5	1
Primary treatment	Primary settlement tanks (4)	3	1
Secondary treatment	Filter distribution chamber	0.9	1
	Filter beds (4)	0.4	1
	Filter effluent channel	1	1
	Humus tank distribution chamber	0.4	12
	Humus tanks (2)	0.3	1
Sludge handling and treatment	Inlet - balance tank desludge chamber (1)	50.5	12
	Raw sludge holding tank	50.5	1
	Sludge transfer well	50.5	1
	Humus tank desludging chamber	8	1
	Recirculation chamber	8	1

*includes 50% abatement provided by non-extracted covers

- For turbulent sources, a multiplier was applied to the emission rate to reflect the elevation in emissions that occurs due to the increase in surface area exposed to the atmosphere. The following turbulence factors were used which are based on Odournet's broader experience in the wastewater sector and the findings of research:

Table 6: Turbulence factors

Level of turbulence	Turbulence multiplier
Low	3
Medium	6
High	12
Extreme	20

- Of the two inlet balance tank desludge chambers at the works, only one chamber is assumed to be operational for 2 hours each day.
- The enclosure on the inlet works screen chamber is assumed to provide a 50% abatement of odorous emissions.
- It is assumed that the storm tank continuously contains low odorous material (aged storm materials and rainwater)
- It is assumed that the sludge transfer well is in continuous use.
- The emission rates from filling of sludge tankers were estimated assuming an outlet odour concentration of 200,000 ou_E/m^3. 3 No. tankers were assumed to be filled per week, with each 30 m^3 tanker taking approximately 20 minutes to fill.

6.2 Breakdown of estimated emissions

A breakdown of the summer odour emissions generated from each aspect of the sewage treatment process under the current operational conditions is presented in the table below. The emission rates presented in the table have been adjusted to reflect the frequency of occurrence of each odour source, and are thus time weighted.

Table 7: Time weighted emissions from each aspect of the treatment process (summer conditions).

Stage of treatment	Source	Time weighted odour units ($ou_E/m^2/s$)	Time weighted percentage of total emissions (%)	Time weighted percentage of total emissions by treatment stage (%)
Preliminary Treatment	Inlet reception chamber	192	3.5	30.2
	Inlet screen chamber	180	3.3	
	Inlet balance tanks	1130	20.5	
	Screening skip	158	2.9	
Storm water handling	Storm tank (non-operational)	39	0.7	0.7
Primary treatment	Primary settlement tanks	337	6.1	6.1
Secondary treatment	Filter distribution chamber	23	0.4	9.6
	Filter beds	503	9.1	
	Filter effluent channel	8	0.1	
	Humus tank distribution chamber	10	0.2	0.9
	Humus tanks	38	0.7	
Sludge handling and treatment	Inlet balance tanks desludge chambers	114	2.1	52.5

	Raw sludge holding tank	1428	26.0	
	Sludge transfer well	1263	23.0	
	Humus tank desludging chamber	25	0.5	
	Recirculation chamber	24	0.4	
	Sludge tanker	30	0.5	
Total		5,500	100	100

Review of Table 7 above indicates that the total time weighted summer odour emissions from the works are approximately 5,500 ou_E/s.

The emission breakdown indicates that approximately 30% of emissions are generated by the preliminary treatment stage, 1% by the non-operational storm tank, 6% by primary treatment, 10% by the trickling filter stage, 1% by the humus tanks and the remainder (approximately 53%) by the sludge handling processes.

The single largest contributor to site emissions is the new sludge holding tank which accounts for approximately 26% of total time weighted emissions. This is due to the relatively high odour emission rate of the material which is stored within the open tank when in use. Emissions from the sludge transfer well account for approximately 23% of emissions (again due to the odorous nature of the material) and the balance tanks account for approximately 21%, although this is predominantly due to the large surface area and high levels of turbulence within two of the tanks, rather than the odour emission rate of the material in the tank which is relatively low for an inlet works.

7 Dispersion modelling

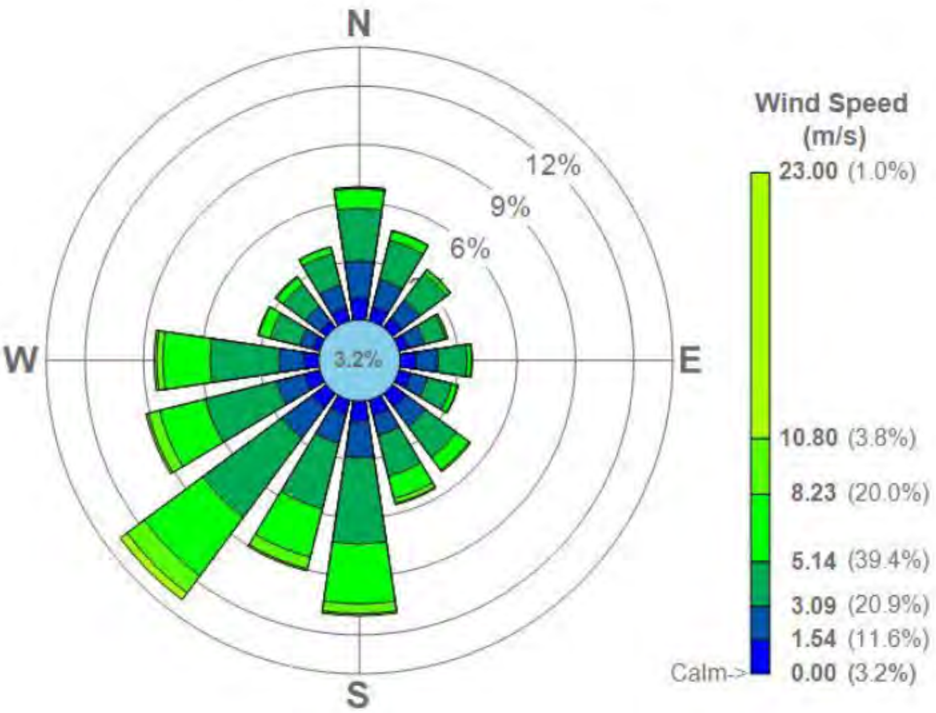
7.1 Dispersion modelling assumptions

The model was applied to visualise the likely extent of impact from the existing site operations in relation to the development site.

The following assumptions have been applied for the dispersion modelling study;

- A review was undertaken of available meteorological data that could potentially be used by the model to simulate the dispersion and dilution effects generated by the atmosphere. It is normal practice to use the most representative meteorological dataset available, and this will be influenced by proximity of the measurement location to the study site, the quality of the data and the representativeness of the surface characteristics of the area surrounding the meteorological station in comparison to the study site (in this case a largely rural location near to a small town).
- On the basis of review of the available meteorological stations, sequential hourly average meteorological data from Cambridge airport meteorological station was utilised for the years 2012, 2013, 2014, 2015 and 2016. Cambridge International Airport is located approximately 13 km to the North East of Foxton STW and is considered to be the most suitable source of data for the study site. The meteorological data was adjusted to reflect the surface characteristics of the study site in accordance with the guidelines issued in the AERMOD User Guide issued by the US EPA. The wind rose for the meteorological data is presented below.

Figure 3: Wind rose of Cambridge International Airport meteorological data 2012-2016



- Data describing the topography of the area surrounding the works was obtained from Ordnance Survey in Landform Panorama™ format.

- A 1km by 1km uniform Cartesian receptor grid was defined for the study area with a receptor spacing of 20m and a receptor height of 1.5m.
- The model was run assuming rural dispersion characteristics.
- The model only considers normal operational occurrences (as discussed with Anglian Water). Short term events such as plant breakdown, maintenance and repair may impact considerably on the odorous emissions from time to time. Such short term variations have not been considered within the model.

7.2 Modelling results

7.2.1 Output of dispersion model

The dispersion model output is presented below. The model was run using five separate years of meteorological data (2012 - 2016), and the worst case results for each specific receptor from across the five years were used to create an overall worst case model output. The model outputs for each of the individual years are presented in Annex C.

The figure presents the isopleths (i.e. lines of equal odour exposure) which correspond to the impact criterion of $C_{98,\ 1\text{-hour}} \geq 3\ ou_E/m^3$ and $C_{98,\ 1\text{-hour}} \geq 5\ ou_E/m^3$. The STW site boundary is shown in red and the extents of the development land are presented in blue.

Figure 4: Output of current baseline dispersion model (worst case output)

7.2.2 Discussion of results

From review of the figure above it is apparent that under the current operational conditions, emissions from Foxton STW are predicted to result in odour exposure levels across the proposed development land that range from below $C_{98,\ 1\text{-hour}} = 3\ ou_E/m^3$ to greater than $C_{98,\ 1\text{-hour}} = 5\ ou_E/m^3$. The highest exposure levels are predicted in locations adjacent to the STW boundaries.

Taking into account the above model output and the discussion of suitable odour impact criteria presented in section 2.4.2 of this report, it can be concluded that the areas of the proposed development land where exposure levels are predicted to exceed $C_{98,\ 1\text{-hour}} = 3\ ou_E/m^3$ are at risk of odour impact.

When reviewing the model output, it should be noted that odour emissions associated with the loading of sludge tankers for offsite export is unlikely to be reflected in the model output due to the very infrequent occurrence (approximately 3 No. tankers per week lasting approximately 20 minutes per tanker) of the operation. On the basis of Odournet's experience, the emissions from the tanker during these times are likely to be high in magnitude and detectable at locations some distance from the STW. However due to the short duration and very infrequent nature of these events the long term odour impact risk associated with this operation is anticipated to be low.

A reduction in odour emissions from the STW could in principal be achieved by the application of cover and treat odour mitigation measures to the open sludge holding tank and transfer well (although site operational staff have indicated that the transfer well may be taken out of use).

8 Summary of findings

The key findings of the study are summarised as follows:

1. A range of activities were identified at Foxton STW that have the potential to generate odorous emissions. These include processes within the preliminary treatment, primary treatment, secondary treatment and sludge handling stages of the works.

2. Under the current operational conditions at the works the estimated total time weighted summer odour emission is approximately 5,500 ou_E/s. Of these emissions approximately 53% are released from the sludge handling operations, 30% from the preliminary treatment stage, 10% from the secondary treatment, 6 % from primary treatment, 1% from the humus tanks and the remaining 1% from the non-operational storm tank. The two largest individual contributors to emissions from the works are the new sludge holding tank and the sludge transfer well (both assumed to be in constant use for this assessment), which together account for approximately 49% of the total time weighted emissions.

3. Emissions from Foxton STW are predicted to result in odour exposure levels across the proposed development land that range from below $C_{98, 1\text{-hour}} = 3\ ou_E/m^3$ to greater than $C_{98, 1\text{-hour}} = 5\ ou_E/m^3$. The highest exposure levels are predicted in locations adjacent to the STW boundaries. The areas of the proposed development land where exposure levels are predicted to exceed $C_{98, 1\text{-hour}} = 3\ ou_E/m^3$ are at risk of odour impact.

4. A reduction in odour emissions from the STW, and impact risk across the development site, could in principal be achieved through the application of cover and treat odour mitigation measures to the open sludge holding tank and transfer well. Site operational staff have however indicated that the transfer well may be taken out of use in the future however.

Annex A Odour sampling and analysis

A.1 Collection of odour samples from sources with no measurable flow

Collection of samples from area sources where there is no measurable flow such as open liquid tanks or channels and piles of sludge cake was conducted using a ventilated canopy known as a 'Lindvall hood'. The canopy was placed on the odorous material and ventilated at a known rate with clean odourless air. A sample of odour was collected from the outlet port of the hood using the 'Lung' principle.

The rate of air blown into the hood was monitored for each sample and used to calculate a specific odour emission rate per unit area per second (E_{sp}) as follows:

- Odour emission rates for sources where a Lindvall sampling hood was used were calculated in odour units per square metre per second ($ou_E/m^2/s$) using the following equation:

  E_{sp} ($ou_E/m^2/s$) = C_{hood} x L x V

  Where:

  C_{hood} is the concentration result from the laboratory analysis.

  V is the flow presented to the hood.

  L is the $\frac{\text{flow path cross section of the hood } (m^2)}{\text{Covered area } (m^2)}$

- Odour emission rates for sources where a sampling sheet was used were calculated in odour units per square metre per second ($ou_E/m^2/s$) by multiplying the geometric mean odour concentration of the samples (from the laboratory analysis) by the air volume flow rate of air from the fan presented under the sheet, and dividing this figure by the area of the sheeted section of material.

A.2 Measurement of odour concentration using olfactometry

Odour measurement is aimed at characterising environmental odours, relevant to human beings. As no methods exist at present that simulates and predicts the responses of our sense of smell satisfactorily, the human nose is the most suitable 'sensor'. Objective methods have been developed to establish odour concentration, using human assessors. A British standard applies to odour concentration measurement:

- BSEN 13725:2003, *Air quality - Determination of odour concentration by dynamic olfactometry.*

The odour concentration of a gaseous sample of odorants is determined by presenting a panel of selected and screened human subjects with that sample, in varying dilutions with neutral gas, in order to determine the dilution factor at the 50% detection threshold (D_{50}). The odour concentration of the examined sample is then expressed as multiples of one European Odour Unit per cubic meter [ou_E/m^3] at standard conditions.

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Annex B Odour measurement results

Odour and H_2S measurement results

Table 8: Odour emission measurements from open sources

Source	Measured odour emission rate [$ou_E/m^2/s$]			
	Geomean	S.1	S.2	S.3
Inlet balance tank	16.0	28.8	14.7	9.6
Primary settlement tank	1.0	1.0	1.1	1.1
Filter distribution chamber	0.9	0.8	0.9	1.1
Filter bed	0.4	0.3	0.4	0.4
Humus tank	0.3	0.7	0.2	0.2
Sludge transfer well	50.5	69.5	49.1	37.6

Table 9: Hydrogen sulphide emission measurements from open sources

Source	Measured hydrogen sulphide [$\mu g/m^2/s$]			
	Average	S.1	S.2	S.3
Inlet balance tank	0.003	0.006	0.001	0.001
Primary settlement tank	<LLOD	<LLOD	<LLOD	<LLOD
Filter distribution chamber	<LLOD	<LLOD	<LLOD	<LLOD
Filter bed	<LLOD	<LLOD	<LLOD	<LLOD
Humus tank	<LLOD	<LLOD	<LLOD	<LLOD
Sludge transfer well	0.010	0.016	0.007	0.006

LLOD = $\leq 0.005\ \mu g/m^3$

Annex C Description of AERMOD dispersion modelling software

AERMOD is a steady-state Gaussian plume model which is designed to assess short-range (up to 50 kilometres) dispersion of air pollutant emissions. The model was developed by the US Environment Protection Agency and the American Meteorological Society. Algorithms within the model consider a number of elements when assessing how pollutants will disperse, including the following:

- Dispersion in both the convective and stable boundary layers;
- Plume rise and buoyancy;
- Plume penetration into elevated inversions;
- Computation of vertical profiles of wind, turbulence, and temperature;
- The urban night-time boundary layer;
- The treatment of building wake effects;
- The treatment of plume meander.

The model has 2 No. important pre-processors, AERMET and BPIPPRIME. AERMET is a meteorological data pre-processor that calculates the atmospheric parameters needed by the dispersion model, such as atmospheric turbulence characteristics, mixing heights, friction velocity, Monin-Obukov length and surface heat flux. Unlike with earlier, more basic dispersion models, vertical profiles of wind, turbulence and temperature are created. BPIPPRIME is a dispersion algorithm used in AERMOD to factor in the effect of turbulence in the wake regions of buildings. BPIPPRIME calculates turbulence intensity and wind fields as a function of the building dimension, these are then used in AERMOD to alter the downwind plume.

Annex D Dispersion model outputs for individual years

Figure 5: Dispersion model output for current operations, 2012 meteorological data

Contours of the areas are presented in which odour concentrations of 3 ou_E/m^3, and 5 ou_E/m^3 are exceeded for more than 175 hours per year.

Figure 6: Dispersion model output for current operations, 2013 meteorological data

Contours of the areas are presented in which odour concentrations of 3 ou_E/m^3, and 5 ou_E/m^3 are exceeded for more than 175 hours per year.

Figure 7: Dispersion model output for current operations, 2014 meteorological data

Contours of the areas are presented in which odour concentrations of 1.5 ou_E/m^3, 3 ou_E/m^3, and 5 ou_E/m^3 are exceeded for more than 175 hours per year.

Figure 8: Dispersion model output for current operations, 2015 meteorological data

Contours of the areas are presented in which odour concentrations of 3 ou_E/m^3, and 5 ou_E/m^3 are exceeded for more than 175 hours per year.

Figure 9: Dispersion model output for current operations, 2016 meteorological data

Contours of the areas are presented in which odour concentrations of 3 ou_E/m^3, and 5 ou_E/m^3 are exceeded for more than 175 hours per year.