COG MOORS WWTW – PROPOSED ADVANCED ANAEROBIC DIGESTION (AAD) PLANT

Odour Assessment

NOVEMBER 2017

Incorporating

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VERSION CONTROL

Version	Date	Author	Changes
01	June 17	P Manktelow	
02	July 23	S Slater	Dispersion Modelling Added
03	August 02	S Slater	Updated following LW review
04	August 18	S Slater	Updated Red Line Boundary
05	November	P Manktelow	Update following comments
06	November	S Slater	Updated dispersion modelling to address final design

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Non-Technical Summary

An odour assessment has been carried out to assess odour associated with the proposed advanced anaerobic digestion (AAD) plant at Cog Moors Wastewater Treatment Work (WwTW). The proposed Scheme involves the addition of an AAD plant to treat sewage sludge arising from the waste water treatment process. Biogas produced by the proposed AAD would be used, via a combined heat and power (CHP) plant, to generate heat and renewable electricity for use at the site or for export to the electricity grid. The scheme will include two odour control units which will service the plant to reduce the odour from the sludge treatment process.

A detailed dispersion model has been used together with manufacturer odour emission limits for the odour control units and hourly weather observations, to predict odour levels at nearby residential locations with the scheme in operation. The assessment followed guidance set by the Institute of Air Quality Management. Results from the odour model show that the receptors closest to the site are expected to experience negligible changes in odour as a result of the AAD plant, and the overall effects are therefore expected to be not significant.

1 Introduction

This report considers the potential odour effects associated with the proposed Advanced Anaerobic Digestion (AAD) plant at Cog Moors Wastewater Treatment Works (WwTW) (known as proposed Scheme from herein). The proposed Scheme will treat sewage sludge arising from wastewater treatment processes. The odour assessment has been undertaken by Arcadis Consulting (UK) Ltd working as part of Dŵr Cymru Welsh Water (DCWW) Capital Delivery Alliance (CDA).

The proposed Scheme would be located on the eastern side of the existing Cog Moors WwTW, adjacent to the existing sewage sludge treatment infrastructure. The proposed Scheme would operate in conjunction with the existing facilities, supplementing the operation of the existing digesters, which would be refurbished. The biogas produced by the proposed AAD plant would be used, via a combined heat and power (CHP) plant and boiler, to generate heat and renewable electricity, for use on site or for export to the electricity grid.

The proposed Scheme comprises several new process and storage tanks and buildings, together with the demolition of and modification to some existing items of plant and equipment. The changes to the sludge handling and processing areas of the site have the potential to affect odour emissions from the WwTW.

The odour assessment has considered how the Scheme is likely to affect odorous emissions and associated odour exposure from the sludge handling and processing areas of the site. As the proposed Scheme only affects specific elements of the operations that relate to sludge processing, it is expected that the odorous emissions from the rest of the works operations will not change.

The objectives of the assessment are:

1. To review the current sludge treatment processes to identify odour sources and estimate the current magnitude of odour emissions from these sources under baseline conditions;

2. To review the proposed design to identify the new sources of odour that will be introduced, estimate odour emissions, and clarify how the odour emissions from the site are likely to change due to the proposed upgrade; and

3. To assess the change in off-site odour exposure around the site for the proposed Scheme and evaluate the effect of these upgrades on offsite impact risk and potential adverse impact on the amenity of the area around the site.

2 Background

2.1 Location

Cog Moors WwTW is situated to the east of the A4055 Cardiff Road, approximately 2km east of Barry and 1km south of Dinas Powys, as shown in Figure 1 below.

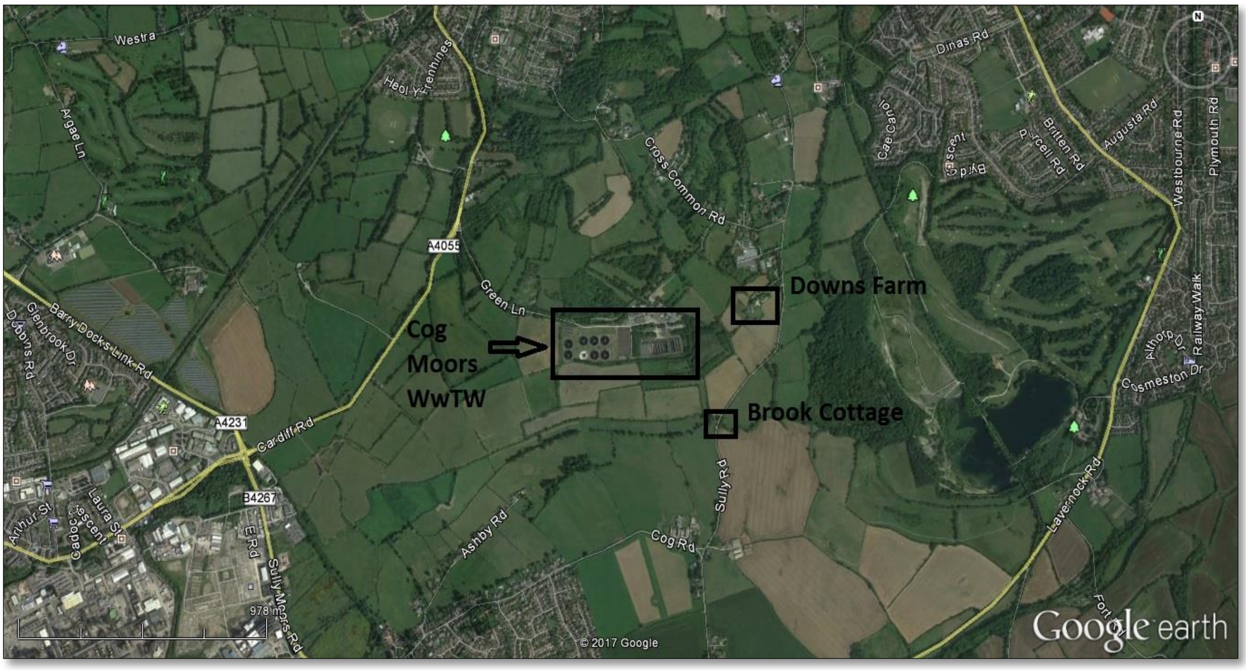


Figure 1 - Cog Moors WwTW Facility (Imagery from 2016 Google Earth)

The closest sensitive receptors to the proposed development site are Downs Farm and cottage, located approximately 230m to the east, and Brook Cottage, located approximately 290m to the south, both properties are off Sully Road. Other residential properties are located at distances in excess of 0.5km from the site on Ashby Road to the south of the site; along Cross Common Road to the north east and along Sully Road and Cog Road to the east and south, respectively.

2.2 Existing WwTW

The population equivalent served by the works is 206,000. There is very little industrial input. The catchment area for the works is Cardiff West, Penarth, Dinas Powys, Sully, Barry and Barry West/Rhoose. The current works at the site consist of the processes detailed below.

Inlet Works:

The Inlet Works receives all the flows of crude sewage into the works as well as process supernatant liquors and works surface water. The combined flow enters the Inlet Sump and gravitates to the Drum Screening system. The screened flow common reception tank catches grit as well as the retained materials from the drum screens. Screened materials are dewatered and compressed, and deposited to skips which are taken off site for appropriate disposal to landfill site. The screened flow is then admitted into the full flow to treatment line or to storm as appropriate.

Primary Treatment:

From the preliminary stage flow passes to Primary Settlement Tanks for primary settlement. There is a total of 14 No. operational tanks designed for primary and storm treatment. Primary Settled Sludge is pumped to 2 No. Primary Sludge Storage Tanks to await digestion treatment.

Secondary Treatment:

Following Primary treatment, the effluent flow is pumped to aeration tanks and combined with Return Activated Sludge. Effluent from the aeration tanks then passes to a total of 8 No. circular Final Settlement Tanks. Sludge from the Final Settlement Tanks is then pumped to the aeration tanks (RAS – Returned Activated Sludge) and to 2 No. Surplus Activated Sludge Storage Tanks (SAS). The effluent flow from the Settlement Tanks combines and gravitates to the Final Effluent and Storm Water Pumping Station located behind the Inlet Works. Final treated effluent is pumped off site and is finally discharged via the Lavernock Long Sea Outfall to the Severn Estuary.

Sludge Treatment:
Sludge discharged from the Primary Settlement process and from the Final Settlement Tanks (SAS) is pumped to dedicated Storage Tanks prior to treatment. Both sludges are thickened prior to anaerobic digestion. The digested sludge is dewatered by centrifuges to a cake and transferred to skips before being recycled to arable land.

Supernatant liquor from the Sludge Thickeners and Centrifuges and washdown water is held in the Supernatant Storage Tank from where it is returned to the Works Inlet for treatment through the works.

Odour Control:
The current facility has odour control units installed to reduce odour from the sludge treatment and inlet works. There are four odour control units at the facility which service the following areas:

- Inlet works (OCU 4);
- Raw Sludge Holding (OCU 1);
- Digested Sludge Tanks (OCU 2); and
- Thickener and Centrifuge Buildings (OCU 3).

The site plant for the facility location including the current sludge handling sources and associated odour control units are shown below in Figure 2.

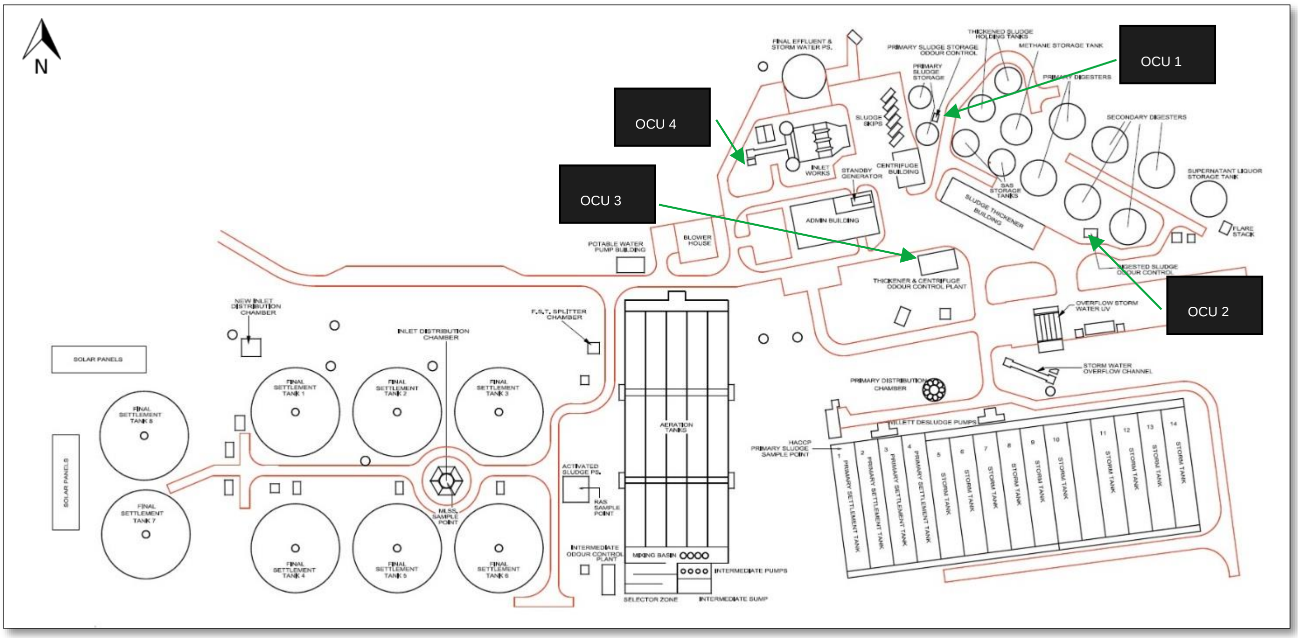


Figure 2 - Current Facility Site Plan (From Facility Operating Manual)

2.3 Proposed Facility Upgrade

The proposed Scheme facility upgrade involves the addition of an AAD Plant to treat sewage sludge arising from the waste water treatment process. The proposed Scheme will be situated at the east area of the site where the current sludge treatment is located and would provide the following:

- Additional digestion capacity;

- Conditioning of the sludge generated on site (i.e. dewatering and removal of contaminating rags and plastic);
- Reception facilities for sludge imported to the site;
- Blending of the indigenous sludge and imported sludge;
- A thermal hydrolysis plant (THP), which uses steam to increase the temperature and pressure in a reaction vessel to pre-heat the sludge;
- Boilers to generate the steam for thermal hydrolysis;
- A siloxane plant to remove contaminants from the biogas generated;
- A combined heat and power (CHP) plant to generate useable heat and electricity, which can be used on site, exported to the grid, or both;
- UV plant to treat some of the final effluent water from the WwTW, to provide better quality process water, for the sludge downstream of thermal hydrolysis;
- Tanks to hold sludge and liquor, resulting from the thickening and dewatering process;
- A cake storage silo;
- Odour control equipment (Plant A and Plant C);
- New internal site access roads and drainage;
- Site clearance, earthworks, and new fencing;
- New MCC equipment and control kiosks; and,
- Appropriate mitigation planting and ecological mitigation measures.

As the new plant would operate in conjunction with the existing facilities and supplement the operation of the existing digesters, the plant would operate as described in Section 2.2, apart from the sludge treatment process. The proposed changes to the works are described below.

Raw Sludge Handling:

Prior to digestion, raw sludge from the Primary and SAS storage tanks would be filtered through strainpresses, where screenings such as leaves, sticks and other inert material would be separated and discharged to a skip. A total of four strainpresses are proposed to be fitted on a raised steel platform, with a maximum of two to service each area. Each press will have an associated skip which is to be contained within plastic enclosures located under the strainpress platform. A maximum of two strainpresses will operate at any one time, one at each location. The strainpresses servicing the primary sludge tanks will be located adjacent to the Primary Sludge storage tanks and Centrifuge Building. The SAS strainpress will be located between the existing Thickening Building and the SAS storage tanks.

Sludge Processing and Storage:

Following filtering with the strainpresses, the sludge will be moved from the presses to the 2 No. Blending Tanks through a contained pipeline. Prior to dewatering, the sludge is transported to the 2 No. Centrifuge Feed Tanks. At this stage, the indigenous sludge will be dewatered using the centrifuge prior to mixing with imported sludge in the THP Feed Silos (2 No.). Upon arrival to site, imported sludge will be transferred to the Import Cake Facility where it will be pumped to the THP Silos and mixed with indigenous sludge. The imported sludge will have been run through a strainpress and will be dewatered to ca. 25% prior to arrival onsite.

THP and Digestion:

The dewatered indigenous sludge and imported sludge mix will feed from the THP silos to the THP unit where the sludge will be heated to approximately 165 degrees Celsius and pressurised to 6 barg for 20 to 30 minutes before undergoing anaerobic digestion. The biogas produced by the proposed AAD plant will be used by a combined heat and power (CHP) plant and boiler, to generate heat and renewable electricity, for use on site or for export to the electricity grid.

Sludge Disposal:
Following sludge digestion, the process is similar to the current facility whereby the digested sludge will be stored in a Post Digestion Tank, undergo a final dewatering and will be stored as cake in the proposed 2 No. Cake Silos until it can be recycled off-site to arable land. The supernatant from the dewatering processes will be returned to the Works Inlet for treatment through the works.

Odour Control:

Other than the strainpress skips, odorous air from the proposed sludge handing process will be controlled by passing through an odour control unit. The proposed Scheme would replace the three existing odour control units for sludge handling (OCU 1, OCU 2, OCU 3) with two odour control units (OCU Plant A and OCU Plant C). The new units would service the Sludge Storage Tanks, Blending Tanks, and Post Digestion Tanks (Plant A) as well as the Centrifuge Feed Tank, Cake Import Facility, Cake Export Silos, and Pre/Post Digestion Centrifuges (Plant C). The proposed locations for the new units are shown in Figure 3.

Figure 3 – Planning Application Boundary (Imagery from 2016 Google Earth)

2.4 Understanding Odour

Odour Exposure

Most odours are mixtures of many chemicals that interact to produce what we detect as a smell (Institute of Air Quality Management (IAQM), 2014). There must be odour exposure for an adverse effect (such as disamenity, annoyance or nuisance) to occur. IAQM note that for odour exposure to occur all three links in the source-pathway receptor chain must be present:

1) an odour emission source;

2) a pathway - for the odour to travel through the air away from the odour source; and

3) receptors (i.e. people).

When considering whether an odour is likely to result in an adverse effect it is important to consider several parameters collectively known as FIDOL factors (Frequency, Intensity, Duration, Offensiveness and Location), which are described below:

Frequency – How often an individual is exposed to odour.

Intensity – The perceived strength of the odour.

Duration – The length of an odour event or episode.

Offensiveness – The type of odour (whether pleasant, neutral or unpleasant).

Location - The type of land use and nature of human activities in the vicinity of an odour source. The tolerance and expectation of the receptor.

Odour Detection Thresholds

The sensitivity of a person to detecting odour and the perception of whether those odours are acceptable, objectionable or offensive varies between individuals.

For a simple, single odorous compound (e.g. hydrogen sulphide), the "amount" of odour present in a sample of air can be expressed in terms of ppm, ppb or in mg/m^3 of air. More usually, odours are very complex mixtures of compounds and the concentration of the mixture can be expressed in European odour units per cubic metre (OU_E m^{-3}) (Environment Agency (EA), 2010). The concentration at which an odour is just detectable to a "typical" human nose is referred to as the "threshold" concentration (EA, 2010). This is determined by presenting a sample to an odour panel made up of a number of trained observers in a laboratory setting. The sample is diluted a number of times and the threshold concentration is the concentration at which 50% of the panel of observers can first detect the odour (this point is equivalent to one odour unit). The number of dilutions of the original sample required to reach the threshold concentration, is used to represent the odour concentration of the sample (where each dilution represents one odour unit i.e. if five dilutions were required to reach the threshold concentration, then the original sample would have an odour concentration of 5 odour units).

In very general terms:

- 1 odour unit is the threshold of detection (in the laboratory);
- 5 odour units is noticeable (faint); and
- 10 odour units is a distinct smell which can be intrusive.

2.5 Odour Benchmarks

Environment Agency H4

An odour benchmark can be used to describe the concentration of odour which would be likely to result in an adverse effect for those exposed. More offensive odours have a lower odour benchmark than those considered to be more pleasant. EA (2011) 'H4 Odour Management' guidance recommends that the odour benchmark be based on the 98th percentile of hourly average concentrations of odour over a year. This equates to the 175th highest hourly average odour concentration across the year, which accounts for the fact that odour is likely to be detected on several occasions before being considered a nuisance.

Table 1 shows the recommended benchmarks in EA (2011) H4 guidance, which vary depending on the offensiveness of the odour.

Table 1 - EA H4 Odour Benchmark Criteria

Criteria ($OU_E\ m^{-3}$) as 98th Percentile	Offensiveness	Odour Emission Sources
1.5	Most Offensive	Biological landfill odours Processes involving septic effluent or sludge Processes involving decaying animal or fish remains
3.0	Moderately Offensive	Intensive livestock rearing Well aerated green waste composting Fat frying (food processing)
6.0	Least Offensive	Bakery Coffee roasting Confectionery

Wastewater Industry Research

The wastewater industry investigated the relationship between odour exposure and complaints from a number of case studies where odour emissions from WwTWs were measured and used to estimate exposure through dispersion modelling (UKWIR, 2001). The exposure was then related to the location of registered complaints for that site. The findings of this research indicated the following relationship between frequency of complaint and odour (expressed as the 98% percentile of the hourly mean odour concentration):

- At modelled odour concentrations below 5 OU_E/m^3, complaints are relatively rare, at only 3% of the total registered;
- At modelled odour concentrations between 5 OU_E/m^3 and 10 OU_E/m^3, a significant proportion of total registered complaints occur; 38% of the total; and,
- The majority of complaints occur in areas of modelled odour concentrations is excess of 10 OU_E/m^3, 59% of the total.

Chartered Institution of Water and Environmental Management

The Chartered Institution of Water and Environmental Management (CIWEM) issued the following position statement on odour from WwTWs in 2012

"*CIWEM considers 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:*

• $C_{98,\ 1\text{-hour}}$ >10OU_E/m^3 - complaints are highly likely and odour exposure at these levels represents an actionable nuisance;
• $C_{98,\ 1\text{-hour}}$ >5OU_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; and
• $C_{98,\ 1\text{-hour}}$ <3OU_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."

Institute of Air Quality Management

IAQM (2014) guidance states that it is incumbent on the responsible practitioner to exercise good professional judgement in selecting an appropriate odour assessment criterion for any particular case and providing justification for that selection. The guidance states that:

"In the absence of comprehensive dose-response information to allow the derivation of exact C_{98} concentration metrics for different types of odour, IAQM is of the opinion that the practitioner should observe, from the various scientific studies, case law and practical examples of the investigation of odour annoyance cases, that in any specific case, an appropriate criterion could lie somewhere in the range of 1 to 10 ou_E/m^3 as a 98th percentile of hourly mean odour concentrations".

Planning Case Law

A 5 OU_E/m^3 odour criteria has been considered an appropriate threshold for avoidance of unacceptable odour effects in several WwTWs planning appeal judgements including Newbiggin, Mogden and Bloor Homes, Leighton Linslade.

3 Legislation and Standards

Environmental Protection Act 1990

Section 79(1)(d) of the Environmental Protection Act 1990 defines one type of 'statutory nuisance' as "*any dust, steam, smell or other effluvia arising on industrial, trade or business premises and being prejudicial to health or a nuisance*".

Enforcement of the Act, in regard to nuisance, is currently under the jurisdiction of the local Environmental Health Department, whose officers are deemed to provide an independent evaluation of nuisance. If the local authority is satisfied that a statutory nuisance exists, or is likely to occur or happen again, it must serve an Abatement Notice under Part III of the Environmental Protection Act (1990). The only defence is to show that the process to which the nuisance has been attributed and its operation are being controlled according to best practice measures.

Planning Policy Wales 2016

The Planning Policy Wales Edition 9 was published on November 2016 and sets out the Government's core policies with respect to land use planning. The document includes the following in Chapter 13 – Minimising and Managing Environmental Risks and Pollution, which is relevant to the proposed development:

"The potential for pollution affecting the use of land will be a material consideration in deciding whether to grant planning permission. Material considerations in determining applications for potentially polluting development are likely to include:

- *location, taking into account such considerations as the reasons for selecting the chosen site itself;*
- *impact on health and amenity;*
- *the risk and impact of potential pollution from the development, insofar as this might have an effect on the use of other land and the surrounding environment (the environmental regulatory regime may well have an interest in these issues, particularly if the development would impact on an Air Quality Management Area or a SAC);*
- *prevention of nuisance;*
- *impact on the road and other transport networks, and in particular on traffic generation; and*
- *the need, where relevant, and feasibility of restoring the land (and water resources) to standards sufficient for an appropriate after use. (Powers under the Pollution Prevention and Control Act 1999 require an operator to return a site to a satisfactory state on surrender of an Integrated Pollution Prevention and Control Permit"*

4 Methodology

4.1 Overview

The odour assessment has been undertaken in line with the following guidance documents:

- Environment Agency (EA) (2010) 'Odour Guidance for Local Authorities'
- Environment Agency (EA) (2011) 'H4 Odour Management'
- Institute of Air Quality Management (2014) 'Guidance on the assessment of odour for planning'

4.2 Consultation

The approach to the odour assessment for the proposed development was discussed and agreed between Sarah Naylor (Senior Air Quality Consultant, Arcadis) and Rebecca Athay (Neighbourhood Services Officer, SGC) on 20 June 2017 and between Sarah Slater (Air Quality Consultant, Arcadis) and Rebecca Athay on August 02, 2017.

An assessment of odour emissions from the Cog Moors facility has previously been undertaken for a planning application in 2008 which was for the upgrade to the current odour control units on the site. As the proposed development only affects specific elements of the operations relating to sludge processing, it is likely that the odorous emissions from the rest of the works operations will not change. It was therefore proposed that all odour sources will be considered in the assessment but the dispersion modelling would focus on those current and future sludge processes at the facility affected by the proposed Scheme.

4.3 Methodology

Identification of Odour Sources

Baseline Conditions - Current Site:

A summary of odour sources for the current facility are listed in Table 2 along with their associated odour emission rate. The odour potential is based on 'Typical' works odour emissions listed in Table 2 of the UKWIR document (2006). The UKWIR report has provided a general categorisation of wastewater treatment sources. For the odour control units, the manufacturer odour emission guarantee was applied to determine maximum odour emissions.

Table 2 - Current Facility Odour Sources

Source ID	Odour Emission Rate (OU_E/s)*	% of Total Facility Odour Emissions	Controlled/ Uncontrolled Odour	Changing with Proposed Upgrade	Included in Dispersion Model
Primary Distribution Chamber	23	0.0%	Uncontrolled	No	No
Primary Tanks 4 No.	3973	2.6%	Uncontrolled	No	No
Primary De-sludge PS	34640	22.5%	Uncontrolled	No	No
Storm Tanks 10 No.	3973	2.6%	Uncontrolled	No	No
Storm Channel	1161	0.8%	Uncontrolled	No	No
Storm UV channel	475	0.3%	Uncontrolled	No	No
Storm tank De-sludge	34640	22.5%	Uncontrolled	No	No

Source ID	Odour Emission Rate (OU_E/s)*	% of Total Facility Odour Emissions	Controlled/ Uncontrolled Odour	Changing with Proposed Upgrade	Included in Dispersion Model
Intermediate Pump Station	628	0.4%	Uncontrolled	No	No
Anoxic Zone	19640	12.7%	Uncontrolled	No	No
Aeration Lanes	42300	27.4%	Uncontrolled	No	No
RAS/SAS pumping Station	440	0.3%	Uncontrolled	No	No
Final Settlement Tank (FST) Splitter Chamber	78	0.05%	Uncontrolled	No	No
Final Settlement Tanks	5250	3.4%	Uncontrolled	No	No
Final Effluent / Storm Water Pump Station	199	0.13%	Uncontrolled	No	No
Cake Skips**	62 (0)	0%	Controlled (enclosed)	Yes	No
***Inlet Works (Inlet Screen Chamber/Screen Skip, Screen Chamber, Grit Trap, Flow to Full Treatment (FFT) Channel, FTT outlet))	903	0.59%	Controlled (OCU 4)	No	No
***Raw Sludge Handling (SAS Tanks, Primary Sludge Tank, Thickened Sludge Blending Tanks)	582	0.38%	Controlled (OCU 1)	Yes	Yes
***Digested Sludge Tanks (Primary Digester Tanks 2 No., Secondary Digester Tank 2 No., Supernatant Tank)	2418	1.57%	Controlled (OCU 2)	Yes	Yes
***Thickener and Centrifuge Buildings (Thickened Sludge, Centrifuges)	2833	1.84%	Controlled (OCU 3)	Yes	Yes

*Odour emission rate based on 'Typical' process Table 2 in UKWIR Odour Control in Water Treatment document

** Cake skips are completely enclosed; therefore, although they have an associated odour emission potential the skips were considered a negligible source of odour and were not included in the dispersion modelling assessment.

***Odour Emission Rate based on Manufacturer Specifications

The main sources of odour at the current site are the uncontrolled inlet works and sludge processing and handling, as such at the current site these processes are controlled by four odour control units. The sludge operations have three associated odour control units. OCU 1 services the Primary Sludge Tanks, Blending Sludge Tanks and Thickened Sludge Tanks. The tanks are all covered and under force extraction with odour treatment being undertaken via the two-stage lava rock/carbon OCU. The system is designed to provide 95%

removal of inlet hydrogen sulphide (average concentration 40ppm, maximum concentration 100ppm) and 98.5% of inlet mercaptan concentrations (average concentration 4ppm, maximum concentration 10ppm).

OCU 2 services the Digester and Supernatant Tanks which are covered and under force extraction via a shell media OCU. The system is designed to provide 99.9% removal of inlet hydrogen sulphide (average concentration 50ppm) and 90% of inlet mercaptan concentrations (average concentration 5ppm).

OCU 3 services the Sludge Thickener and Centrifuge Buildings. Belt presses are covered with source extraction and general building extraction via shell media OCU. The system is designed to provide 95% removal of inlet hydrogen sulphide (average concentration 50ppm) and 90% of inlet mercaptan concentrations (average concentration 5ppm).

The inlet works OCU services the Screen Skip, Screen Chamber, Screen Outlet Chamber, Grit Trap, FFT Channel, and FFT Outlet. The system is designed to provide 99% removal of inlet hydrogen sulphide (average concentration 30ppm, maximum concentration 150ppm) and 98% of inlet mercaptan concentrations (average concentration 3ppm, maximum concentration 15ppm). A summary of OCU extraction rates is shown in Table 3. It should be noted the inlet works OCU will not be affected by the proposals.

Proposed Scheme - Future Site:

With the proposed Scheme upgrade, two odour control plants will replace the existing sludge treatment OCUs (OCU 1, OCU 2, OCU 3). Odour Control Plant A will service the Primary Sludge Holding Tanks, SAS Tanks, Blending Tanks and Post Digestion Tanks. Odour Control Plant C will service the Centrifuge Feed Tank, Pre-digestion Centrifuges, Cake Import Facility, THP Feed Silos, Cake Export Facility, and Post-digestion Centrifuges. The associated flows are shown below in Table 3. For both OCUs, a manufacturer guarantee of 1000 OU_E/m^3 will be required and the minimum removal efficiency of Hydrogen Sulphide and Mercaptans will be 99% and 98% of the inlet concentration. The new OCUs will use a biological filter (plastic or mineral) followed with a dry scrubber (activated carbon media).

Uncontrolled Odour Sources:
The only new uncontrolled odour source in the proposed Scheme will be from the strainpress enclosures due to the skips storing inert strainpress material which may have adhered raw sludge. The skips are to be enclosed with plastic sheets to reduce odour emissions; however, events such as gusts of wind may result in occasional odour releases. Two presses are anticipated to operate at a time, one at each location. The expected emissions from this area are discussed in the Emission Estimates section and can be seen in Table 3.

Odour Contribution Current Site versus Proposed Scheme:

The percent contribution of each source to total facility odour emissions is listed in Table 2. Although the sludge processing and handling areas are highly odorous, due to the control units, the sludge sources only contribute approximately 3.78% of the total odour emissions at the current site. The three odour control units at the current site will be replaced by two odour control units at the proposed Scheme site. The proposed odour control units would make up approximately 3.95% of the total facility odour emissions, and the uncontrolled strainpress skips would contribute approximately 0.58%. This equates to an increase in contribution of sludge processing/handling sources to the total facility odour emission of approximately 0.74%. Although the source contributions are similar in both scenarios, the exhaust parameters and locations of sources will differ; therefore, a dispersion modelling assessment was undertaken in order to determine the effects of the proposed Scheme in comparison to the existing baseline scenario.

Dispersion Modelling

A dispersion modelling assessment was undertaken for the works as per guidance outlined in the IAQMs Odour Guidance document (2014). AERMOD version 14134 was used for the assessment. AERMOD is recognised by the Environment Agency, Natural Resources Wales, UK Met Office and the US Environmental Protection Agency and is accepted by the EA and DEFRA for predicting pollutant concentrations.

Modelling Scenarios:

A dispersion modelling assessment has been undertaken to understand how the change in odour emissions from the proposed Scheme will affect odour concentrations at off-site receptors. To determine the effects from the current facility, the current sludge handling works altered by the proposed Scheme were modelled to establish baseline odour concentrations associated with the affected sources. The proposed Scheme sludge sources were then modelled to compare predicted concentrations to the existing baseline conditions. The modelling inputs and assumptions for both operating scenarios are described in the following sections.

Emission Estimates

Odour Control Units:

Where available, emission rates for the odour control units were based on manufacturer guarantees. Where the odour extraction process was not anticipated to have a polishing stage of treatment in the current facility WwTW , a maximum odour output of 2000 OU_E/m^3 was assumed as a conservative estimate. All odour control units for the future proposed Scheme will have a maximum odour outlet concentration of 1000 OU_E/m^3.

An example of odour emission calculated using manufacturer specifications is shown below for Source OCU 1 (current facility):

$$OCU\ 1\ Emission\ Rate\ \left(\frac{OUE}{s}\right) = \ Manufacturer\ Outlet\ Guarantee\ \left(\frac{OUE}{m3}\right) x\ Flow\ Rate\ \left(\frac{m3}{s}\right)$$
$$OCU\ 1\ Emission\ Rate\ \left(\frac{OUE}{s}\right) = \ 1000\frac{OUE}{m3} x\ 0.582\frac{m3}{s}$$
$$OCU\ 1\ Emission\ Rate\ \left(\frac{OUE}{s}\right) = \ 582$$

Uncontrolled Odour Sources:

All sources assessed in the dispersion model were vented through with an associated OCU with the exception of the proposed Scheme strainpress skip enclosure area. Emissions from the stainpress skips were based on the UKWIR Odour Control in Wastewater Treatment document (2006) using the 'typical' odour emission rates multiplied by the area of the source. As the sludge would be in the early stages of processing, it was assumed the odour would be similar to that of the inlet works; therefore, an emission factor of 50 $OU_E/s/m^2$ was applied. There will be a maximum of four skips (two in each strainpress area) with a total area of approximately 9 m^2 per area. For the purposes of this assessment a worst-case scenario was applied to the dispersion model, whereby 100% of the odour emissions generated by the strainpress skips were assumed to be continually emitted from the plastic enclosure and an operating scenario of all strainpresses working simultaneously was applied.

The emission estimates for the strainpress skips are conservative as it is expected only two skips will be used (rather than four, as assumed here) and the plastic enclosure would provide some odour control as it would inhibit the odour mixing with ambient air. An example calculation for the strainpress skip enclosure emission rate (proposed Scheme) is shown below:

$$Skip\ Enclosure\ \ Emission\ Rate\ \left(\frac{OUE}{s}\right) = \ UKWIR\ Emission\ Factor\ \left(\frac{OUE}{s/\ m2}\right) x\ Area\ (m2)$$
$$Skip\ Enclosure\ \ Emission\ Rate\ \left(\frac{OUE}{s}\right) = \ 50\frac{OUE}{s\ /m2} x\ 9\ m2$$
$$Skip\ Enclosure\ Emission\ Rate\ \left(\frac{OUE}{s}\right) = \ 450$$

The emission summary for all odour sources modelled in the assessment is shown in Table 3.

Table 3 - Emission Summary Table

Odour Source	Outlet Odour Concentration (OU_E/m^3)	Flow Rate (m^3/s)	Emission Rate (OU_E/s)	Current or Future Facility	Summary of Total Sludge Source Odour Emission Rates (OU_E/s)	% of Total Facility Odour Emissions
OCU 1 – Raw Sludge Holding	1000	0.582	582	Current		
OCU 2 – Digested Sludge Tanks	2000	1.209	2418	Current	5834	3.8
OCU 3 – Thickener and Centrifuge	2000	1.417	2833	Current		
OCU Plant A	1000	1.358	1358	Future		4.0
OCU Plant C	1000	4.779	4779	Future		
Sludge Skips Primary Sludge Storage	n/a	n/a	450	Future	7037	0.6
Sludge Skips SAS Storage	n/a	n/a	450	Future		

Meteorological Conditions

As per guidance in IAQMs Odour Guideline document (2014), five years of sequential hourly meteorological data from 2012 to 2016 was obtained from Rhoose/Cardiff Airport for use in the dispersion model. The area surrounding the site is primarily ‘rural’ and this was taken into consideration when the data was adjusted through the pre-processor AERMET prior to use in the AERMOD dispersion model (in accordance with the guidance issued in the AERMOD Implementation Guide (US EPA)). DEFRA guidance LAQM.TG(16) recommends meteorological stations within 30km of an assessment area as being suitable for detailed modelling and Rhoose/Cardiff Airport is located approximately 9.2 km from the site. The wind roses are shown below for the five years modelled (Figure 4) and indicate the site and surrounding area experience predominant winds from the west.

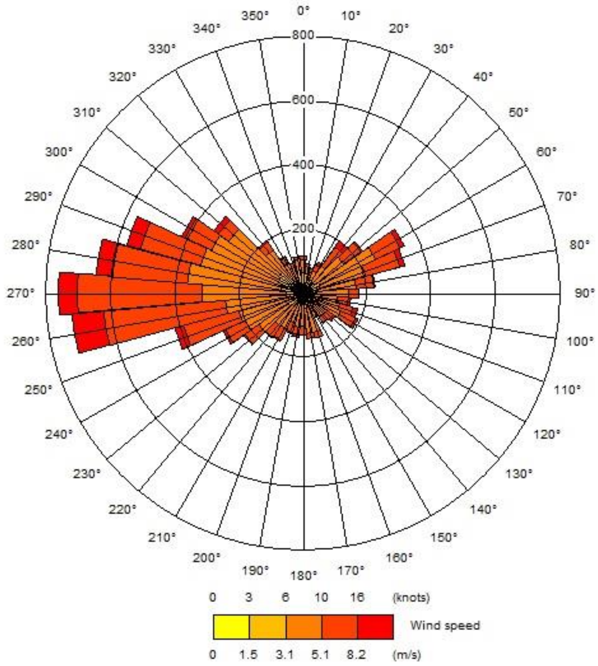


Figure 4a - Wind Rose for Rhoose (Cardiff Airport) 2012

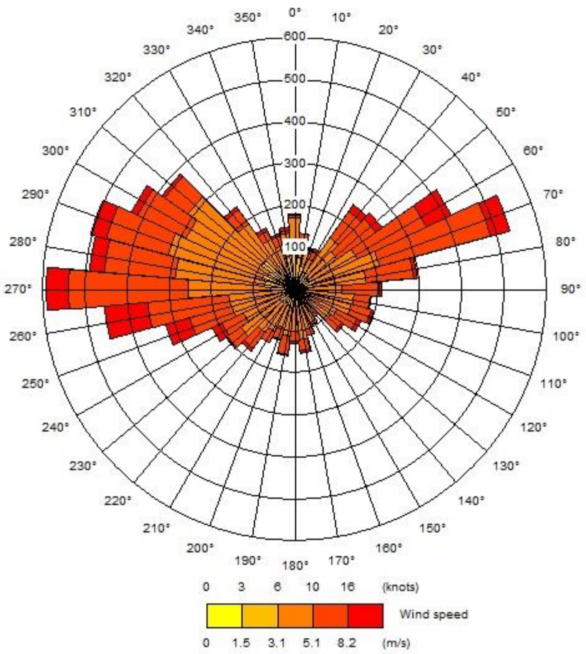


Figure 4b - Wind Rose for Rhoose (Cardiff Airport) 2013

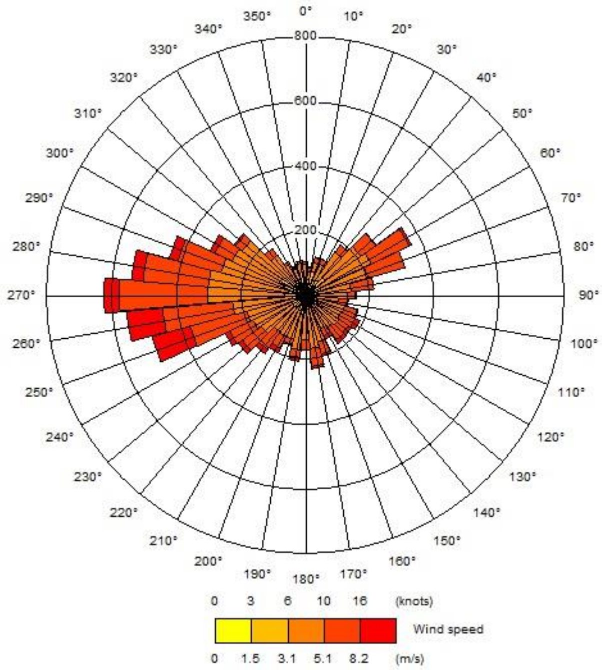


Figure 4c - Wind Rose for Rhoose (Cardiff Airport) 2014

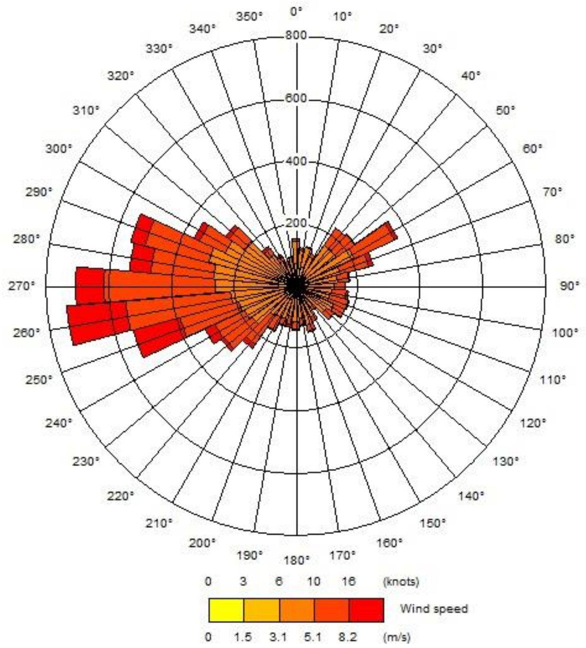


Figure 4d - Wind Rose for Rhoose (Cardiff Airport) 2015

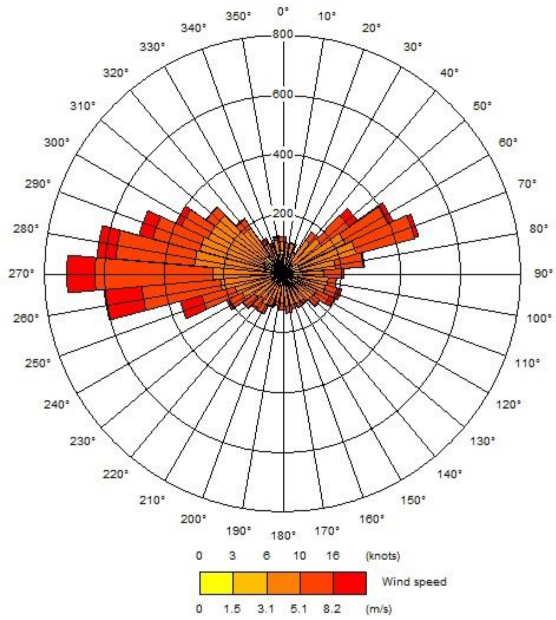


Figure 4e - Wind Rose for Rhoose (Cardiff Airport) 2016

Area of Model Coverage

To assess odour impacts, discrete sensitive receptors (mainly residential properties) were included in the model at worst-case locations in the vicinity of the site. The nearest receptors to the Scheme were selected, since odour impacts would be expected to reduce with increasing distance from the source (due to dispersion). The list of the discrete receptors considered is provided in Appendix A. In addition, a multitiered receptor grid based on guidance in the IAQM odour guidance document (2014) was applied using the spacing shown in Table 4 - Receptor Grid Spacing for distances up to a distance of 2km from the site. All receptors were modelled at a flag pole height of 1.5 metres above ground.

Table 4 - Receptor Grid Spacing

Distance from Source (m)	Receptor Grid Spacing (m)	Receptor Height (mag)
200	20	1.5
1000	50	1.5
2000	100	1.5

Receptor Sensitivity

Receptors vary in their sensitivity to odour, and the sensitivity of receptors surrounding the site has been defined according to IAQM odour guidance (2014). Table 5 shows the receptor sensitivity criteria adopted.

Table 5 - Receptor Sensitivity to Odours

Sensitivity	Description
High	Surrounding land where: • Users can reasonably expect enjoyment of a high level of amenity; and, • People would reasonably be expected to be present here continuously, or at least regularly for extended periods, as part of the normal pattern of use of the land Examples may include residential dwellings, hospitals, schools/education and tourist/cultural
Medium	Surrounding land where: • Users would expect to enjoy a reasonable level of amenity, but would not reasonably expect to enjoy the same level of amenity as in their home; or, • People would not reasonably be expected to be present here continuously or regularly for extended periods as part of the normal pattern of use of the land Examples may include places of work, commercial/retail premises and playing/recreation fields
Low	Surrounding land where: • The enjoyment of amenity would not reasonably be expected; or, • There is transient exposure, where the people would reasonably be expected to present only for limited periods of time as part of the normal pattern of use of the land. Examples may include industrial use, farms, footpaths and roads

The discrete receptors identified within 2km of the site are mainly of residential use, and based on Table 5 can be described as being of high sensitivity.

Terrain Data

Terrain data describing the topography of the site and surrounding area was obtained from Ordinance Survey to take into account variations in ground height throughout the area of model coverage. The data was converted to DEM format for use in the dispersion model and the pre-processor AERMAP was used to assign the appropriate elevations to each model input.

Building Downwash Calculations

The integrated Building Profile Input Programme (BPIP) module within AERMOD was used to assess the potential impact of building downwash upon predicted dispersion characteristics. Building downwash occurs when turbulence that is induced by nearby structures, causes pollutants emitted from an elevated source such as a stack, to be displaced and dispersed rapidly towards the ground, resulting in elevated concentrations.

Building heights and dimensions were obtained from plans and drawings of the site including the proposed AAD facility. The buildings included in the model are listed in Appendix A.

Significance of Effects

The significance of odour effects was assessed through consideration of the 98th percentile of hourly mean odour concentrations and receptor sensitivity, as outlined in IAQM odour guidance (2014). The change in odour concentrations predicted between the baseline and Scheme scenario were derived and compared against the criteria in Table 6. The criteria were developed by IAQM on the assumption that the odour in question is at the offensive end of the spectrum, which is considered applicable to the odour considered here.

Table 6 – Odour Effect Descriptors

Change in Odour Exposure as hourly 98th %ile (OU_E/m^3)	Receptor Sensitivity		
	Low	Medium	High
≥ 10	Moderate	Substantial	Substantial
5 - < 10	Moderate	Moderate	Substantial
3 - < 5	Slight	Moderate	Moderate
1.5 - < 3	Negligible	Slight	Moderate
0.5 - < 1.5	Negligible	Negligible	Slight
< 0.5	Negligible	Negligible	Negligible

The overall odour effects across all receptors have been used to determine the likely significance. IAQM odour guidance recommends that where the overall effect is greater than slight adverse, the effect is likely to be considered significant, and this should be a binary judgement: either it is significant or not significant.

Model Uncertainty

Uncertainty in dispersion modelling predictions can be associated with a number of different factors, including:

- Model uncertainty-due to model limitations;
- Data uncertainty-due to errors in input data, including emissions estimates, background estimates and meteorology; and
- Variability-randomness of measurements used.

Potential uncertainties in model results have been minimised as practicable and worst-case inputs used in the absence of definitive information. This encompassed the following:

- Choice of model- AERMOD is a commonly used atmospheric dispersion model and results have been verified through a number of studies to ensure predictions are as accurate as possible;
- Meteorological data-Modelling was undertaken using five meteorological datasets from the closest observation site from the proposed development to take account of the worst-case conditions;
- Receptor locations- A Cartesian grid and discrete receptors were included in the model to calculate maximum predicted concentrations throughout the assessment extents;
- Variability- All model inputs are as accurate as possible and worst-case conditions have been considered where necessary to ensure a robust assessment of potential pollutant concentrations; and

5 Baseline Conditions

With the exception of Cog Moors WwTW, there are no other notable sources of odour located within the assessment study area (i.e. within 2km of the proposed Scheme). According to complaints records from within 1.2km of the site, there have been two odour complaints associated with the WwTW since June 2011, and these arose in October 2015 and June 2016.

6 Dispersion Modelling Results

6.1 Baseline - Current Site

The odour concentrations associated with the current sludge works (specifically those affected by the proposed upgrade; i.e. OCU 1, OCU 2 and OCU 3) have been predicted for the meteorological years 2012 to 2016. The year 2015 was found to give rise to the highest odour concentrations, and the results for this particular year are discussed in this section.

Figure 5 shows the 98th percentile hourly average odour concentrations predicted from the current sludge OCUs. The maximum predicted off-site odour concentrations are predicted to be less than 2.5 OU_E/m^3 and occur in an area to the north east of the site boundary, where there are no sensitive receptors present.

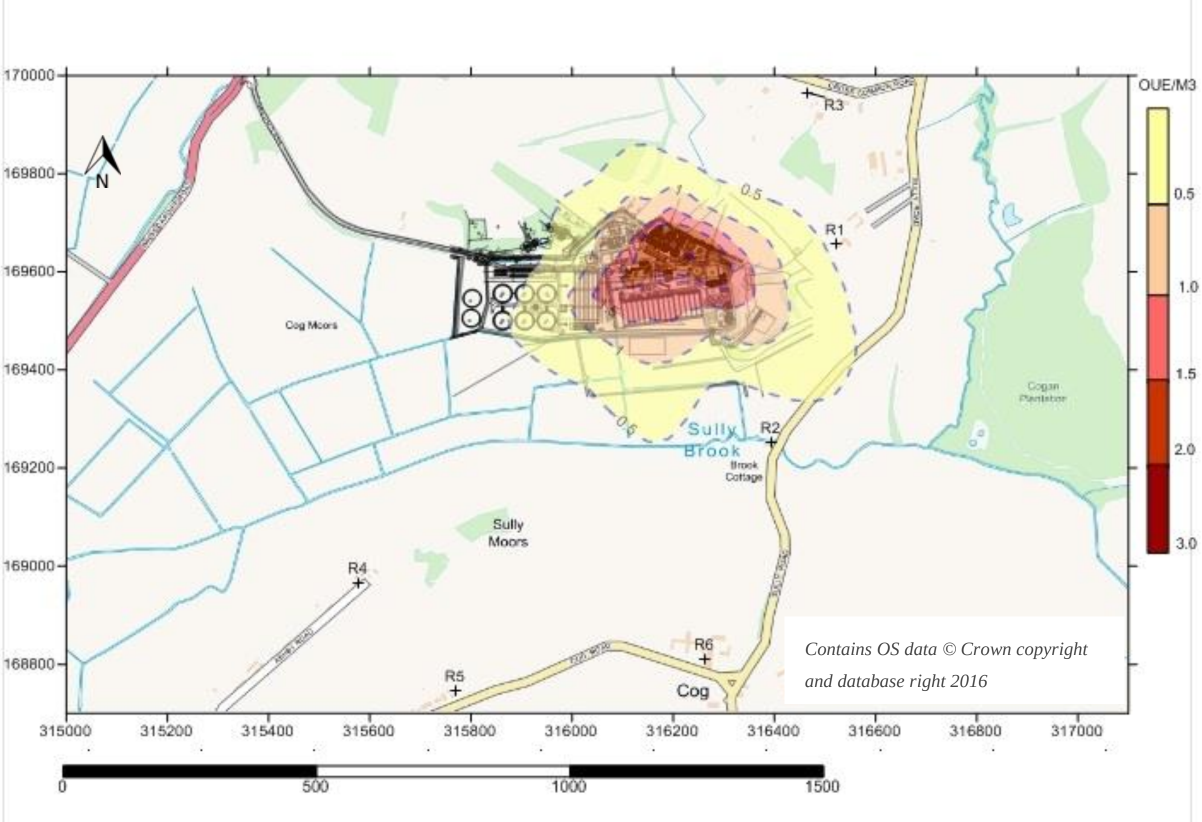


Figure 5 - Current Sludge Works 98%ile Hourly Mean Odour Concentrations (2015)

The greatest odour concentration predicted at a discrete sensitive receptor is 0.46 OU_E/m^3, which occurs at receptor R1. Predicted odour concentrations at all sensitive receptors are shown in Table 7.

Table 7 - Predicted Odour Concentrations from Current Facility Sludge Works at Sensitive Receptors

			Predicted 98th Percentile of 1-hour Mean Odour Concentration (OU_E/m^3)				
Receptor ID	X	Y	2012	2013	2014	2015	2016
R1	316522	169656	0.46	0.39	0.46	0.42	0.39
R2	316394	169252	0.31	0.33	0.33	0.21	0.36
R3	316465	169965	0.07	0.07	0.08	0.07	0.07
R4	315578	168966	0.07	0.08	0.11	0.08	0.08
R5	315770	168746	0.01	0.02	0.02	0.02	0.01
R6	316263	168811	0.03	0.07	0.03	0.04	0.04

6.2 Proposed Scheme – Future Site

The worst-case meteorological year modelled for the proposed Scheme was found to be 2016. The worst-case year differs from the baseline scenario as the source locations and exhaust parameters are different and thereby have different dispersion characteristics. The results in this section are discussed for the year 2016.

Figure 6 shows the 98th percentile hourly average odour concentrations predicted from the proposed Scheme sludge works. The maximum predicted off-site odour concentrations are predicted to be less than 1.0 OU_E/m^3. The odour contour plots for the other modelled years are presented in Appendix A.

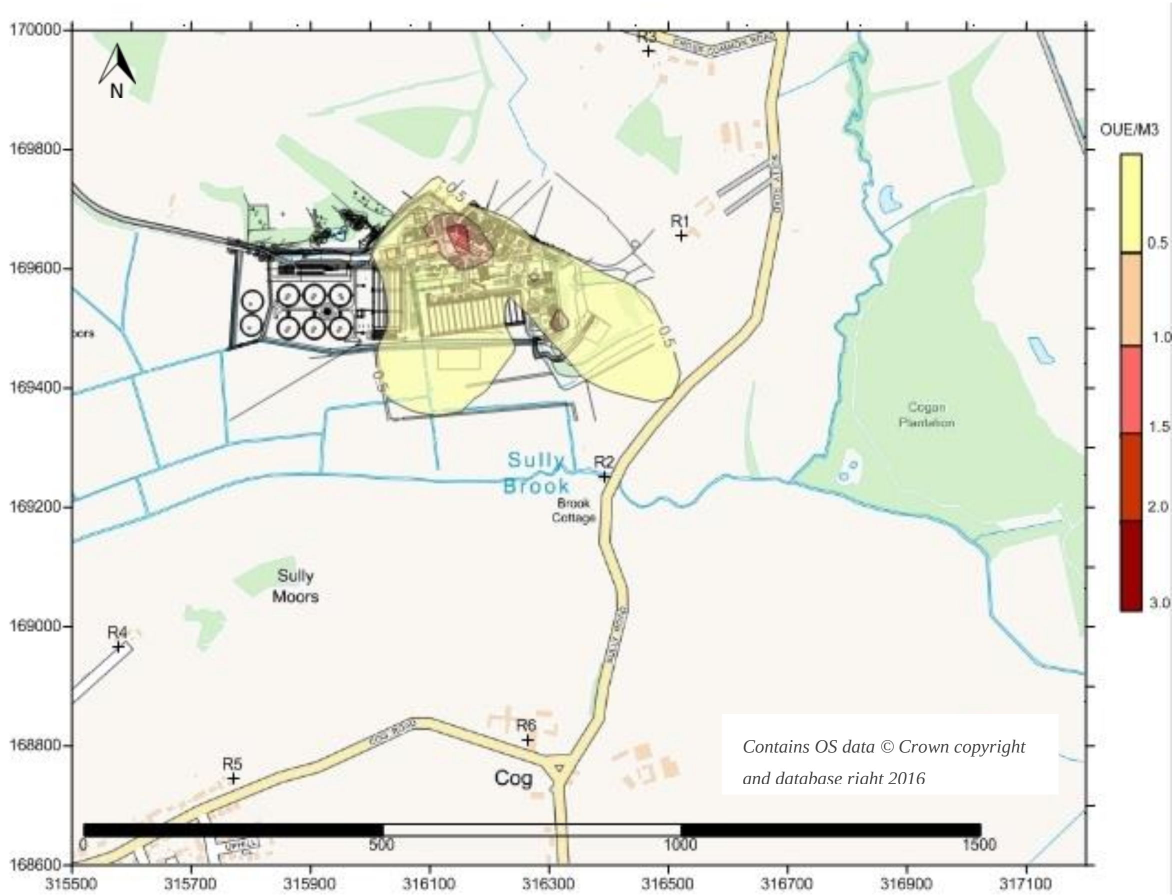


Figure 6 - Proposed Scheme Sludge Works 98%ile Hourly Mean Odour Contour Plot (2016)

The greatest odour concentration predicted at sensitive receptors is 0.25 OU_E/m^3, and this is predicted at receptor R2. The predicted odour concentrations for all sensitive receptors assessed in the dispersion model are shown in Table 8.

Table 8 - Predicted Odour Concentrations from Proposed Scheme Sludge AAD Plant at Sensitive Receptors

Receptor ID	X	Y	Predicted 98th Percentile of 1-hour Mean Odour Concentration (OU_E/m^3)				
			2012	2013	2014	2015	2016
R1	316522	169656	0.24	0.19	0.22	0.22	0.20
R2	316394	169252	0.22	0.25	0.21	0.17	0.23
R3	316465	169965	0.05	0.05	0.07	0.06	0.05

Receptor ID	X	Y	Predicted 98th Percentile of 1-hour Mean Odour Concentration (OU_E/m^3)				
			2012	2013	2014	2015	2016
R4	315578	168966	0.09	0.08	0.12	0.08	0.10
R5	315770	168746	0.03	0.04	0.05	0.04	0.04
R6	316263	168811	0.06	0.13	0.05	0.09	0.07

A comparison of the odour concentrations predicted at sensitive receptors under baseline conditions and with the proposed Scheme in operation is shown in Table 9. With the proposed Scheme, R1 and R2 are anticipated to experience an overall decrease in odour. The reduction in odour is likely to be due to the more effective odour control measures being implemented and an exhaust design which will facilitate greater dispersion than the current works. All of the receptors are described as high sensitivity and are predicted to experience a change in odour concentration of less than 0.5 OU_E/m^3, which according to Table 6 can be described as negligible.

Table 9 - Predicted Difference in Odour Concentrations at Sensitive Receptors Between Current and Proposed Scheme Works

Receptor ID	X	Y	Difference in Predicted 98th Percentile of 1-hour Mean Odour Concentration between Proposed Scheme* and Current Site (OU_E/m^3)				
			2012	2013	2014	2015	2016
R1	316522	169656	-0.22	-0.20	-0.24	-0.20	-0.19
R2	316394	169252	-0.09	-0.08	-0.12	-0.04	-0.13
R3	316465	169965	-0.02	-0.02	-0.01	-0.01	-0.02
R4	315578	168966	0.02	0.00	0.01	0.00	0.02
R5	315770	168746	0.02	0.02	0.03	0.02	0.03
R6	316263	168811	0.03	0.06	0.02	0.05	0.03

Since the odour effects predicted at sensitive receptors are expected to be negligible, the overall odour effects associated with the Scheme are expected to be not significant.

7 Conclusion

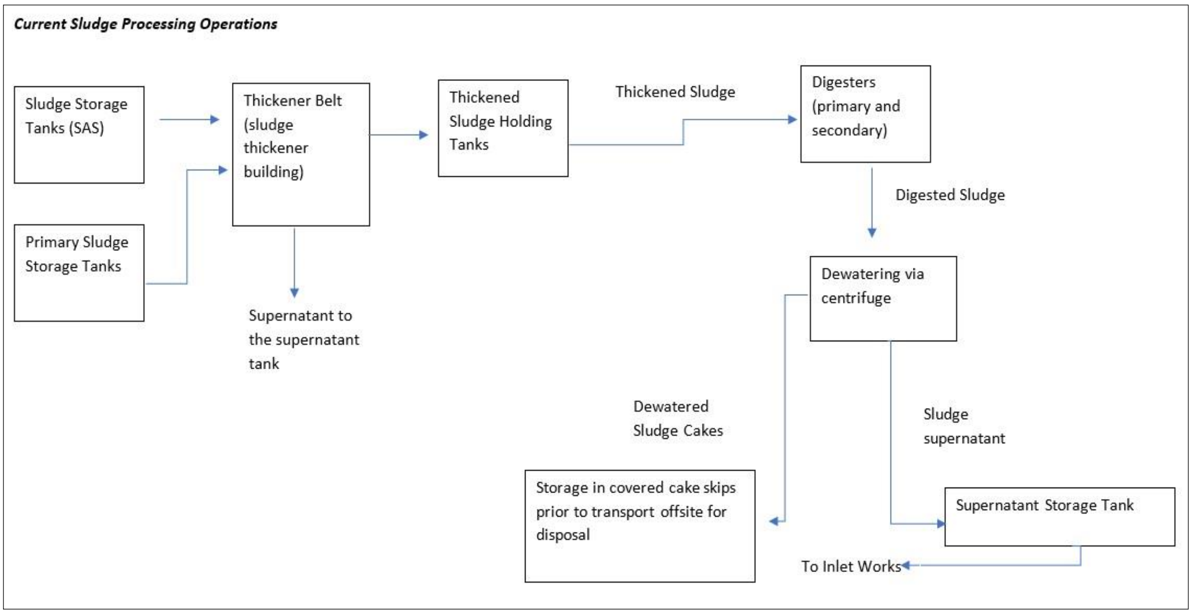
The proposed Scheme involves the addition of an AAD Plant at Cog Moors WwTW. An odour assessment has been carried out to assess odour associated with the proposed AAD Plant. The Scheme will include two odour control units which will service the Plant to reduce the odour from the sludge treatment process.

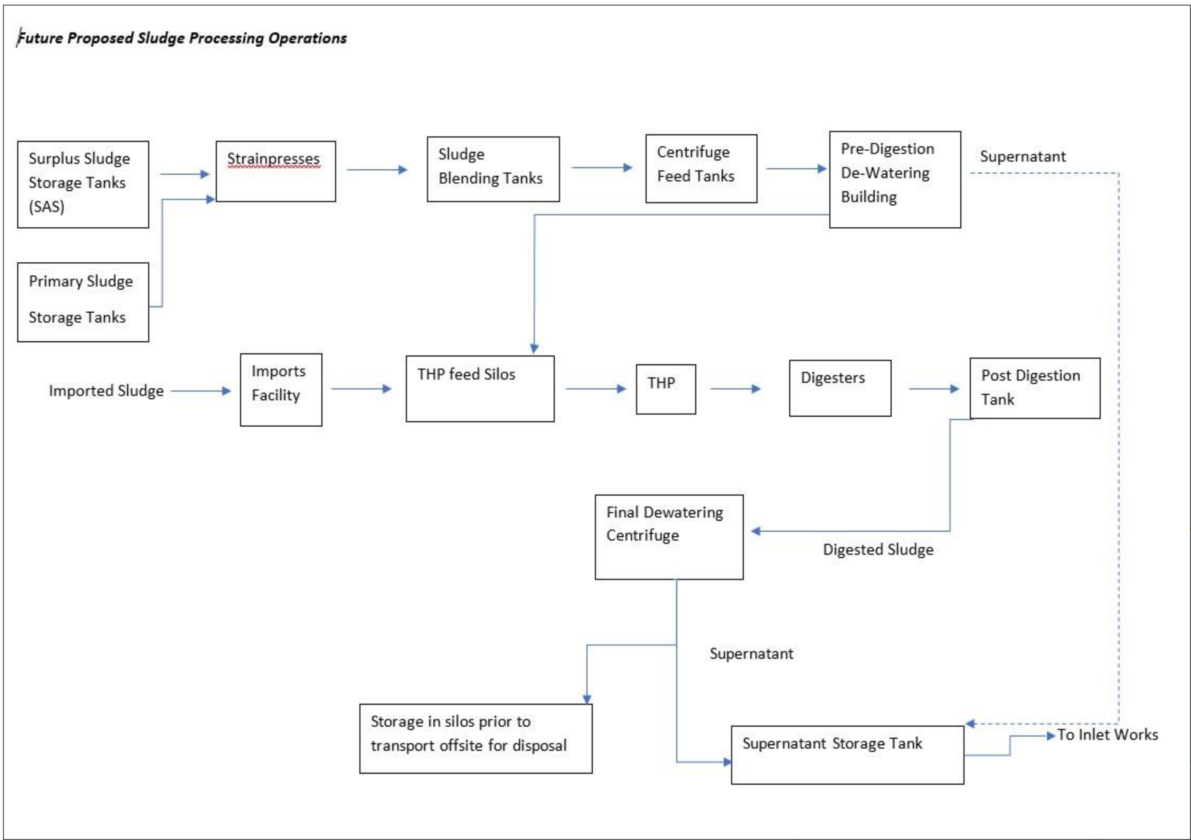
A detailed dispersion model has been used, together with manufacturers odour emission limits for the odour control units and hourly weather observations to predict odour levels at nearby residential locations with the Scheme in operation. The results of the modelling show that receptors closest to the site are expected to experience negligible changes in odour. Three sensitive receptors are anticipated to experience an overall decrease in odour, likely to be due to the more effective odour control measures being implemented and the exhaust design which will facilitate better dispersion than the current units. Odour effects are therefore expected to be not significant.

APPENDIX A

Sludge Treatment Process

The sludge process flow diagrams for the current (baseline) and future proposed Scheme facility are below:





Dispersion Modelling Inputs

The inputs listed below were used in the odour dispersion modelling assessment.

Sources:

Table A1 - Current Facility Source Summary Table

Source ID	Exhaust Flow Rate (m^3/s)	Stack Height (mag)	Stack Diameter (m)	Exhaust Temperature (ºC)	X	Y	Odour Emission Rate (OU/s)
OCU 1	0.582	4.3	0.3	ambient	316138	169690	582
OCU 2	1.21	3.2	0.4	ambient	316209	169628	2418
OCU 3	1.42	5.1	0.4	ambient	316144	169618	2833

Table A2 - Future Proposed Scheme Source Summary Table

Source ID	Exhaust Flow Rate (m^3/s)	Stack Height (mag)	Stack Diameter (m)	Exhaust Temperature (ºC)	X	Y	Odour Emission Rate (OU/s)
OCU Plant A	1.36	15.1	0.4	ambient	316210	169630	1358
OCU Plant C	4.78	11.4	0.7	ambient	316282	169515	4779
SP_A (Primary Sludge Strainpress area)	n/a	n/a	n/a	ambient	316137	169658	450
SP_B * (SAS Strainpress area)	n/a	n/a	n/a	ambient	316158	169651	450

*SP_A and SP_B were modelled as volume sources with initial vertical dimensions of 5.7m (SP_A) and 5.63 (SP_B), initial lateral dimensions of 2.21m, and release heights of 6.1m.

Receptors:
The following discrete sensitive receptor locations were assessed in the dispersion modelling assessment:

Table A3 – Sensitive Receptor Locations

Receptor ID	X	Y	Height (mag)
R1 (Downs Farm)	316522	169656	1.5
R2 (Brook Cottage)	316394	169252	1.5
R3 (Cross Common Road Residence)	316465	169965	1.5
R4 (Sully Moors Residence)	315578	168966	1.5
R5 (Cog Road Residence)	315770	168746	1.5
R6 (Cog Farm)	316263	168811	1.5

Buildings:
The following buildings were included in the dispersion modelling assessment:

Table A4 - Building Properties for Dispersion Model

Building Description	X	Y	Height (mag)	Current or Future Facility
THP Plant	316264	169594	8.8	Future
Boiler House	316237	169608	8	Future
CHP Plant	316239	169588	2.8	Future
MCC1 Kiosk	316178	169609	4.5	Future
Transformer 7 & 8	316234	169591	2.9	Future
Indigenous Dewatering Building	316260	169566	12.7	Future
Cooling Plant	316262	169603	3.1	Future
Siloxane Plant	316239	169620	3.2	Future
Gas Holder	316221	169625	14	Future
Digester C	316204	169641	12.5	Future
Digester D	316215	169663	12.5	Future
Post Digestion Tank	316235	169653	5.7	Future
Digester A	316185	169650	10.72	Future

Building Description	X	Y	Height (mag)	Current or Future Facility
Digester B	316196	169673	10.72	Future
Final Effluent Holding Tank	316253	169644	12.2	Future
Sludge Control Building	316187	169630	10	Future
Blending Tank A	316160	169678	12.25	Future
Blending Tank B	316172	169689	12.25	Future
Centrifuge Building	316121	169660	7.3	Future
Inlet Works	316056	169658	3.3	Future and Current
Mains Building	316077	169639	7.1	Future and Current
Odour Control Plant C	316272	169495	4.8	Future
Odour Control Plant A	316194	169622	5.1	Future
Overflow Storm Water UV	316183	169601	1.34	Future and Current
Primary Sludge Storage Tank A	316134	169686	9	Future
Primary Sludge Storage Tank B	316136	169672	9	Future
Final Dewatering Building	316288	169499	12.7	Future
Polymer Building	316285	169523	12.7	Future
Polymer Silo A	316276	169534	6.5	Future
Polymer Silo B	316276	169529	6.5	Future
Polymer Silo C	316271	169528	6.5	Future
Polymer Silo D	316270	169534	6.5	Future
Potable Wash water Tank	316292	169495	8.3	Future
Export Silo A	316307	169506	14.9	Future
Export Silo B	316305	169529	14.9	Future
THP Feed Silo Building	316266	169579	15.4	Future
Cake Imports Facility	316293	169581	5.2	Future
CHP Plant	316239	169588	2.8	Future

Building Description	X	Y	Height (mag)	Current or Future Facility
Centrifuge Feed Tank A	316277	169544	13.2	Future
Centrifuge Feed Tank B	316302	169548	13.2	Future
SAS Tank A	316153	169665	11.3	Future
SAS Tank B	316169	169656	11.3	Future
Primary Strain Press	316134	169662	12.3	Future
SAS Strainpress	316153	169651	12.1	Future
Disinfected Fe Building	316275	169627	5.0	Future
Disinfected Fe Storage Tank	316299	169622	12.5	Future
HV Switchgear Building	316223	169583	6.7	Future
LVDB and MCC3 Building	316231	169590	6.7	Future
Natural Gas Metre Kiosk	316216	169601	2.4	Future
Wash Water Booster Kiosk	316292	169491	2.3	Future
Wheel Wash Control Kiosk	316282	169614	2.9	Future
Storm and Settlement Tanks	316096	169543	1.1	Future and Current
Pump Building A	316202	169586	1.96	Future and Current
Pump Main Building	316207	169588	2.64	Future and Current
Pump Building B	316221	169588	1.96	Future and Current
OCU4_Inlet Odour Control Large Unit	316056	169653	4.2	Future and Current
OCU4_Inlet Odour Control Small Unit	316056	169649	2	Future and Current
Centrifuge Building	316121	169660	7.3	Current
CakeSkip1	316116	169685	1.5	Current
CakeSkip2	316117	169681	1.5	Current
CakeSkip3	316117	169677	1.5	Current
CakeSkip4	316118	169673	1.5	Current
CakeSkip5	316119	169669	1.5	Current

Building Description	X	Y	Height (mag)	Current or Future Facility
CakeSkip6	316120	169666	1.5	Current
Methane Storage Tank	316176	169670	8.8	Current
OCU1_sludge tanks large unit	316144	169685	4.5	Current
OCU1_sludge tanks small unit	316139	169690	2	Current
OCU2_digested sludge control	316201	169631	3.8	Current
OCU3_Thickener and Centrifuge	316134	169618	2.5	Current
Primary Digester A	316184	169650	8.5	Current
Primary Digester B	316196	169673	8.4	Current
Primary Sludge Storage Tank A	316134	169681	9	Current
Primary Sludge Storage Tank B	316136	169668	9	Current
SAS Tank A	316153	169665	7.2	Current
SAS Tank B	316169	169656	7.2	Current
Sludge Control Building	316187	169630	10	Current
Secondary Digester A	316203	169640	7.2	Current
Secondary Digester B	316215	169663	7.2	Current
Secondary Digester C	316224	169632	7.2	Current
Secondary Digester D	316235	169654	7.2	Current
Supernatant Storage Tank	316253	169644	7.2	Current
Thickened Sludge Holding Tank A	316160	169678	9.1	Current
Thickened Sludge Holding Tank B	316172	169689	9.2	Current

Dispersion Modelling Outputs

The proposed Scheme 98th Percentile of 1-hour Mean Odour Concentration Contour Plots are shown below:

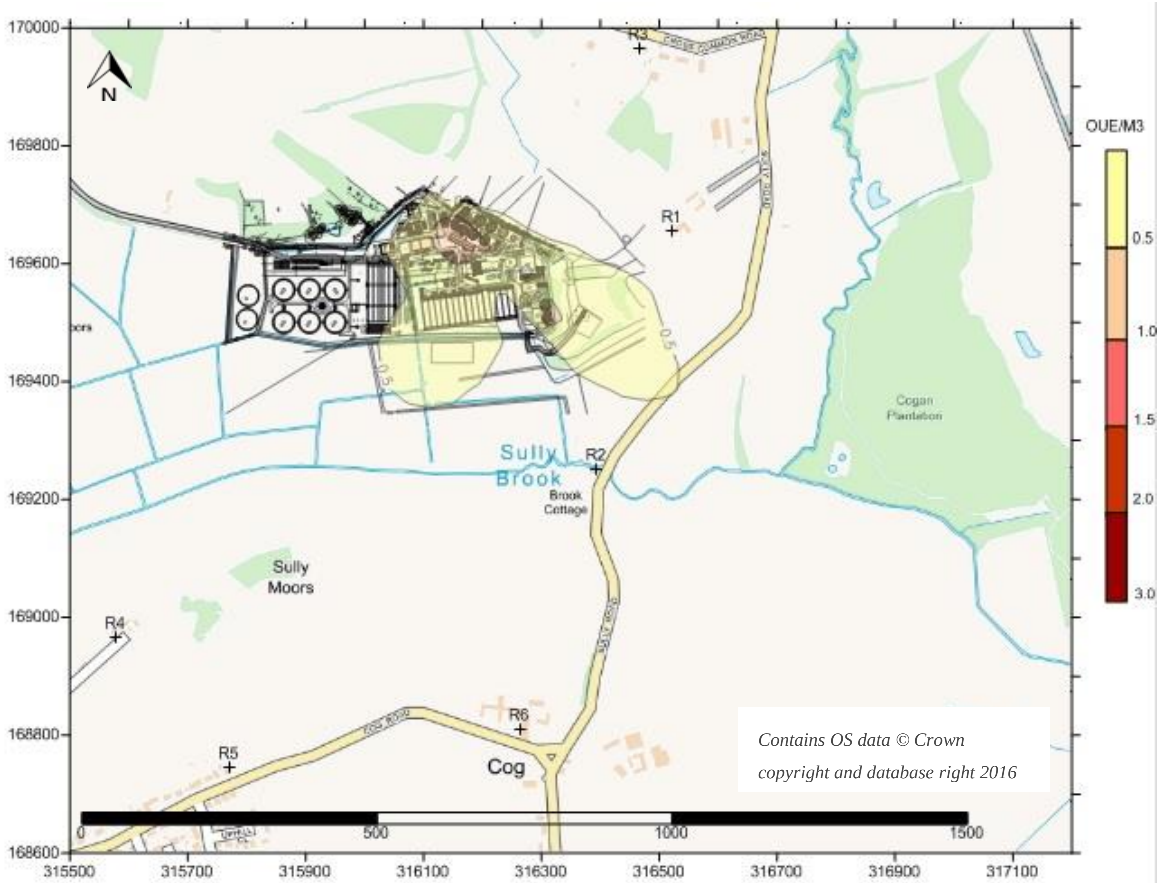


Figure A1 – Proposed Scheme Sludge Works 98%ile Hourly Mean Odour Contour Plot (2012)

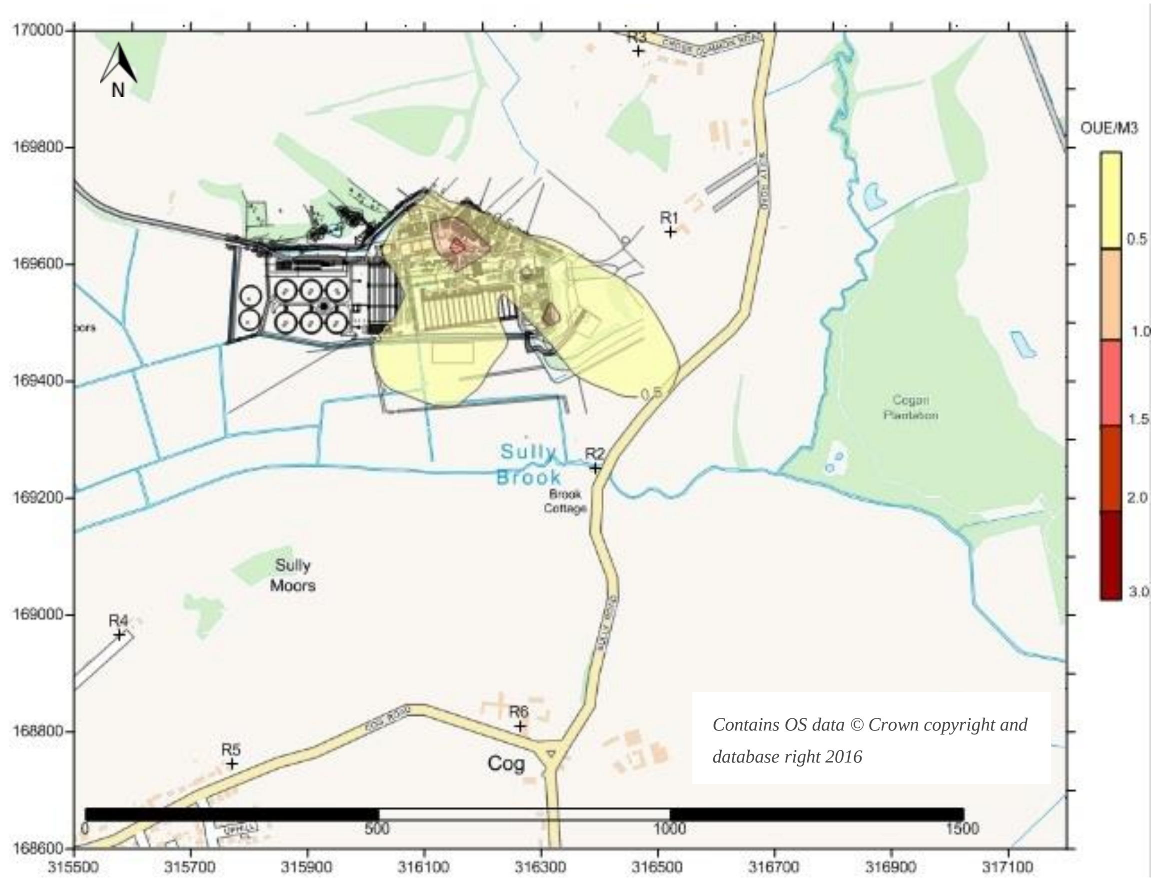


Figure A2 - Proposed Scheme Sludge Works 98%ile Hourly Mean Odour Contour Plot (2013)

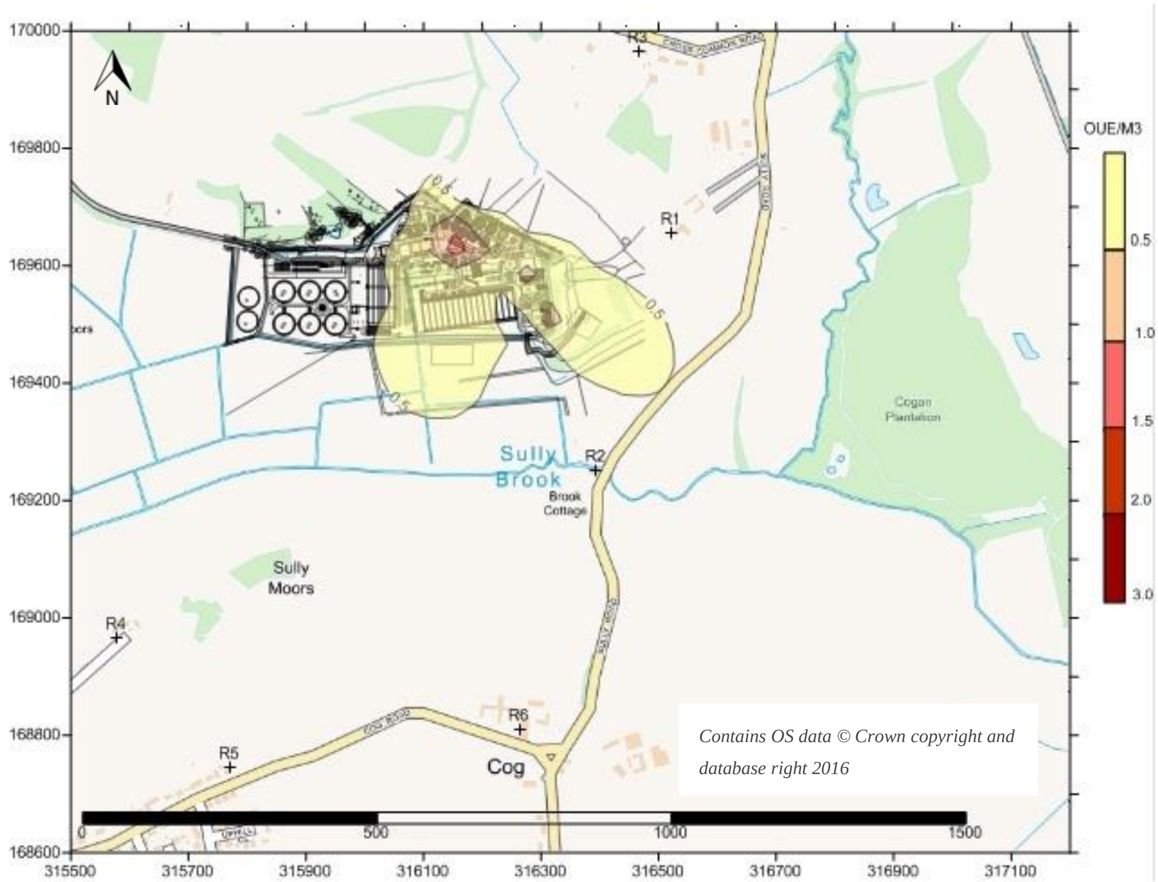


Figure A3- Proposed Scheme Sludge Works 98%ile Hourly Mean Odour Contour Plot (2014)

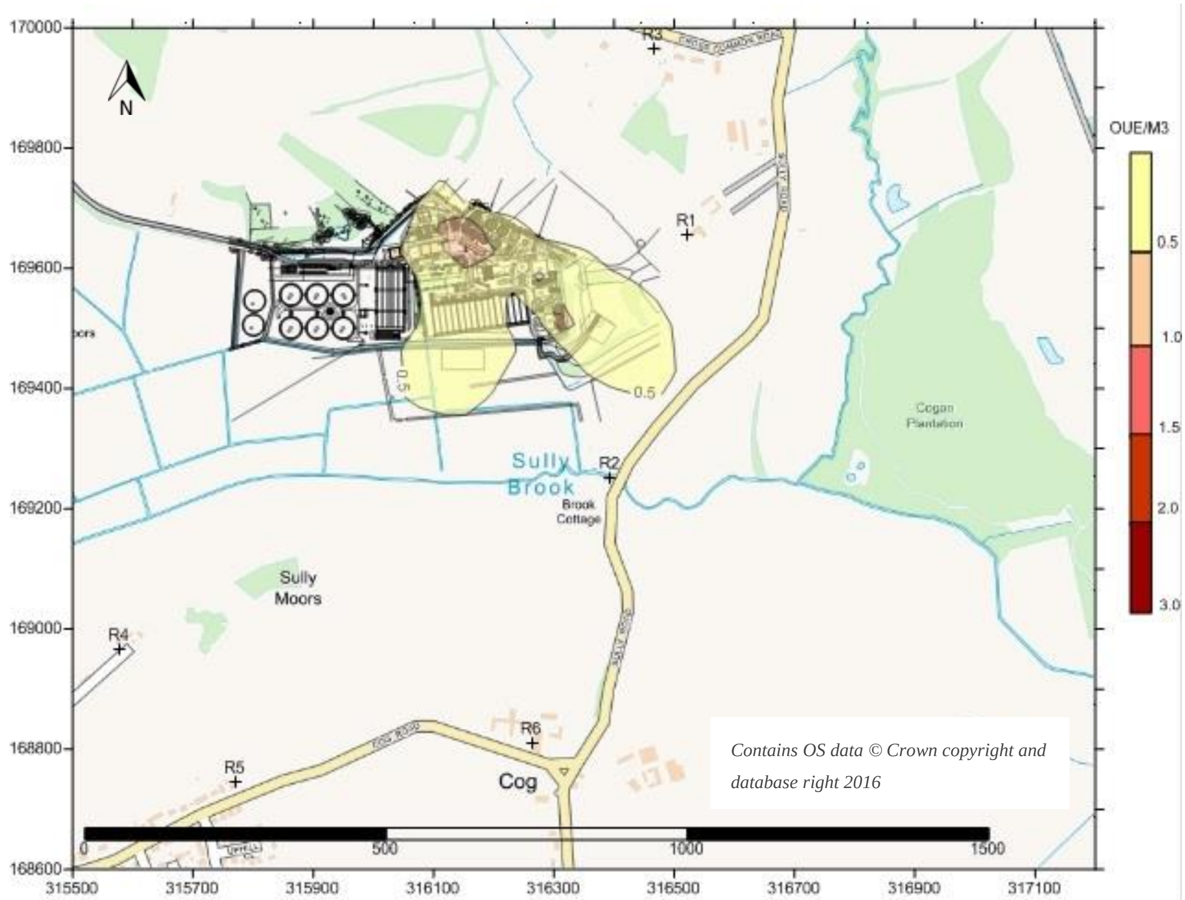


Figure A4 - Proposed Scheme Sludge Works 98%ile Hourly Mean Odour Contour Plot (2015)

7 References

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