REPORT

Odour assessment of Queensferry WwTW

Client:
Dwr Cymru Welsh Water

Report Number:
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Executive Summary

Dŵr Cymru Welsh Water (DCWW) commissioned Olfasense UK Ltd to undertake an odour impact assessment of Queensferry Wastewater Treatment Works (WwTW), located In Queensferry, Deeside.

The scope of the study was as follows:

1. To review the current works operations undertaken at the WwTW and identify the activities which are likely to generate odour emissions.
2. To undertake an odour sampling survey of the WwTW to quantify existing odour emissions and assess the effectiveness of existing odour control plant.
3. To undertake odour dispersion modelling of the WwTW to assess the current level of odour impact risk to nearby sensitive receptors.
4. To identify measures that could be applied by DCWW to reduce any odour impact identified.

The study involved the use of 'at-source' odour sampling and analysis techniques to measure odour emissions from the site, followed using dispersion modelling techniques to estimate offsite exposure and provide a basis to assess odour impact risk. All odour sampling and analysis was conducted using procedures that were fully compliant with the British Standard for Olfactometry BS EN 13725: 2003 and accredited by the UK Accreditation Service (UKAS). Assessment of impact risk was performed using techniques and criteria outlined in odour guidance published by the Environment Agency[1], and where relevant, the Institute of Air Quality Management (IAQM)[2].

The findings of the study are summarised as follows:

1. A range of activities were identified at Queensferry WwTW that have the potential to generate odorous emissions. These include processes within the preliminary treatment, stormwater storage, primary treatment, secondary treatment and sludge handling and treatment stages of the works.
2. Under current operational conditions, the total time-weighted odour emission rate from the works under summer conditions is estimated at 109,256 ou_E/s. The main contributors to these emissions are the inlet works which accounts for ~23% of emissions; the primary treatment operations (29%); storm water handling (16%), and sludge handling and treatment operations (29%).
3. The relatively high contribution of odour emissions from the preliminary, storm water handling and primary treatment operations is predominantly due to the high odour potential of the influent received by the works, which is in turn is likely to be due to the influence of odorous trade effluents and tankered septic imports. The fact that much of the inlet works and primary distribution channels are open, and the storm tank cleaning

[1] Environmental Permitting: H4 Odour Management, published by the Environment Agency, April 2011.

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

systems are ineffective are also important factors. The high contribution of odours from sludge handling area can be attributed to the fact that the odour control treatment system is no longer operational and that hatches on the tank covers are left open for operational reasons.

4. Odour dispersion modelling indicates that under current operational conditions, odours from the works pose a potential risk of impact on the neighbouring residential areas to the north and east up to 0.9 km from the works. However, since the odour potential of the sewage entering the site varies, it is quite plausible that odours may travel further than predicted by the model under certain conditions when particularly odorous inflows / imported sludge are received. The model impact profile can therefore be considered to reflect the average rather than worst case view and hence odour complaints may be experienced further afield. This appears to be supported by the complaints record for the site, which suggests that odour can impact up to 1.6 km from the site boundary. It is also plausible that other odour sources in the area influence complaints and may have led to the site being mistakenly identified as the cause of odour impact in some circumstances.

5. However, since the odour potential of the sewage entering the site varies, it is quite plausible that odours may travel further than predicted by the model which considered 'average' odour emission rates, and hence complaints may be experienced further afield. This appears to be supported by the complaints which have been linked to the site, which occur up to 1.6 km from the site boundary.

6. To reduce the risk of impact of the site, the following enhancements to odour control are recommended:

    a) Cover the inlet works including the discharge chamber, detritor, inlet channels, inlet pumping station and primary settlement tank distribution chambers and extract to a suitable odour treatment system or systems.

    b) Install an effective automised cleaning systems in the storm tanks, to ensure that sediment is not retained on the base of the storm tanks following storm events.

    c) Minimise the use of the storm tanks as far as possible.

    d) Refurbish the covers on consolidation tanks 1 & 2 covers and modify the sludge delievery systems so that the hatches can be closed during norml operating conditions.

    e) Re-furbish or replace the sludge odour control unit to eliminate fugitive emissions of potentially high concentration odours from the indigenous raw sludge tank, sludge imports tank, digestor feed tank and sludge thickening building. This will require a review of the adequacy of the extraction systems to ensure effective control of fugitive emissions is achieved and reassesment of the adequacy and design of the current odour treatment system.

f) Ensure that the hatches on the Sludge import wells are kept closed. It may be necessary to connect the sludge wells to an extractive odour treatment system if odours persist in this area.

g) Review whether it is possible to use a pump to empty out the imported sludge and septic tankers rather than use of the tanker vacuum systems.

h) Prepare an odour management plan for the site to ensure operations are conducted in a manner that minimises odour generation where possible.

If such measures are not effective in reducing complaints, more expensive capital odour control measures may be required.

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1 Introduction and Scope

1.1 Scope

Dŵr Cymru Welsh Water (DCWW) commissioned Olfasense UK Ltd to undertake an odour impact assessment of Queensferry Wastewater Treatment Works (WwTW), located In Queensferry, Deeside.

The objective of the study is to assess the risk of odour impact posed by the works operations in terms of offsite odour nuisance and assess the adequacy of the odour control measures in place to minimise this risk.

The scope of the study was as follows:

1. To review the current works operations undertaken at the WwTW and identify the activities which are likely to generate odour emissions.
2. To undertake an odour sampling survey of the WwTW to quantify existing odour emissions and assess the effectiveness of existing odour control plant.
3. To undertake odour dispersion modelling of the WwTW to assess the current level of odour impact risk to nearby sensitive receptors.
4. To identify measures that could be applied by DCWW to reduce any odour impact identified.

1.2 Quality Control and Assurance

Olfasense'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 ISO 9001 (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 17025:2017[3] and the European standard for olfactometry BS EN 13725:2003[4]. Where required, Olfasense are accredited to conduct odour sampling from stacks and ducts in accordance with ISO 17025:2017 and BS EN 13725:2003 under the MCERTS scheme. Olfasense 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 Olfasense laboratory is recognised as one of the foremost laboratories in Europe, consistently outperforming the requirements of the British Standard for Olfactometry in terms of accuracy and repeatability of analysis results.

[3] ISO 17025:2017 – General requirements for the competence of testing and calibration laboratories.
[4] BS EN 13725:2003 – Air quality. Determination of odour concentration by dynamic olfactometry.

2 Description of approach

2.1 Identification of odour sources & odour survey

The odour sources associated with the site were defined on the basis of a detailed review of the existing site operations, which included a site audit and consultation with site staff conducted in August 2020.

An odour survey was then undertaken, utilising a combination of UKAS-accredited 'at source' odour sampling and containment testing. The survey was conducted on the 7th, 8th, 14th, and 28th October 2020. The scope of the survey is outlined in Table 1 below:

Table 1: Scope of 2020 odour survey

Sampling location	Type of sample	Analysis type / # of samples			
		Olfactometry	Trace gas	Hedonic tone	Smoke test
Storm tanks	Retained sediment	3	3	-	-
Preliminary treatment	Open channel downstream of detritor	3	3	-	-
	Screenings skip	3	3	-	-
Primary treatment	Surface of primary settlement tank	3	3	-	-
Secondary & final treatment	High rate filter	3	3	1	-
	Filter bed	3	3	-	-
	Humus tank	6	6	-	-
Sludge treatment	Headspace of imported sludge well	3	3	-	1
	Headspace of centrate well	3	3	-	-
	Headspace of consolidation tank 1	3	3	-	1
	Headspace of consolidation tank 2	3	3	-	1
	Headspace of consolidation tank 3	3	3	-	1
	Sludge thickener building	3	3	-	-
	Digestion tanks	6	6	-	-
	Sludge cake	3	3	1	-
Total		51	51	2	4

Odour sampling was conducted using Olfasense's UKAS-accredited source sampling procedures (UKAS Laboratory Number 2430), which comply fully with the requirements of the British Standard for Olfactometry B13725.

The collected odour samples were be transported back to Olfasense's odour laboratory in Northwich for the following analysis:

- Olfactometry analysis in accordance with BS EN 13725 and Olfasense's UKAS-accredited analysis procedures (UKAS Laboratory Number 2430).
- Trace gas analysis (hydrogen sulphide, dimethyl sulphide, mercaptans, ammonia) using a calibrated Jerome hydrogen sulphide analyser and colorimetric detector tubes (non-accredited analysis).
- Hedonic tone analysis in accordance with Olfasense's in-house procedure based on NVN 2818 (non-accredited analysis).

In addition, smoke testing was conducted to estimate the containment and leakage rate of tanks that contain odorous processes.

Relevant operational parameters of each process were recorded at the time of the survey. Sampling of sewage-related sources was conducted during dry weather conditions (<5mm rainfall 3 days prior).

2.2 Quantification of site emissions

Odour emissions estimates for each source were derived from measurements collected during the odour survey, in combination with relevant operational data provided by Dŵr Cymru Welsh Water (DCWW) and data from Olfasense's extensive odour emission library. Olfasense's library of odour emissions data has been collected at UK sewage treatment works over a period more than 20 years and allows robust and defensible odour emission rates to be defined.

Consideration was also given to the influence of the following factors to derive representative and comparable emission values:

- Turbulence of aspects of the process handling odorous liquid and solid material.
- The effect of seasonal changes in the influent quality and rate of biological generation of odours within the process.
- The frequency and duration of release of intermittent activities.

2.3 Odour impact assessment

The data collected during the survey was used to estimate the magnitude of odour emissions generated from each aspect of the treatment process and prepare a site odour emission inventory. Adjustments were applied in accordance with Olfasense's in-house procedures to simulate the changes to emissions that may have occurred due to seasonal variations in temperature and source turbulence.

The emission inventory was then input into an odour dispersion model and used to assess the odour exposure levels which may occur around the site under the current operational conditions.

The model used for the study was the US EPA BREEZE AERMOD dispersion model (version 9.1.0.18), which was established in accordance with relevant guidance issued by the US Environmental Protection Agency (EPA) and other relevant authorities. The model was run using 5

No. years of recent meteorological data from Hawarden meteorological station to simulate the dispersion of odours.

The results of the modelling were presented in the forms of maps identifying the areas around the site that are exposed to odour levels that correspond to existing UK impact criteria.

2.3.1 Odour impact criteria

In general terms, odour annoyance is recognised as a symptom that develops because 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:

- **F**requency of exposure.
- **I**ntensity or strength of exposure.
- **D**uration of exposure.
- **O**ffensiveness.
- **L**ocation sensitivity.

In acknowledgement of these factors, several 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 odour concentration expressed in odour units, and a minimum exposure period, which is typically 2% of the time or the 98th percentile of hourly average concentrations in a given year. E.g. $C_{98,\ 1\text{-hour}} > 5\ ou_E/m^3$.

The most commonly applied impact criteria in the UK are drawn from guidance published by the Environment Agency[5] , which defines three benchmark exposure levels for odours of high, moderate and low offensiveness, above which odour may be viewed as unacceptable and may lead to odour complaints when applied to highly sensitive receptors (e.g. residential properties).

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

Whilst these benchmarks were originally intended for application to industrial facilities permitted by the Environment Agency under EPR[6], they are now applied more broadly for assessments of

[5] H4 Odour Management. How to comply with your environmental permit.April 2011.

[6] Environmental Permitting Regulations

nuisance risk and harm to amenity during planning. In order to reflect potential variations in sensitivity of the receiving environment, adjustments can be made to the concentration level at the discretion of the odour practitioner.

More recent guidance published by the Institute of Air Quality Management (IAQM)[7] provides further insight into this issue, by classifying receptors as low, moderate or highly sensitive.

Table 1: IAQM receptor sensitivity

Relative receptor sensitivity	Typical land use
High sensitivity receptor	Land where: - Users can reasonably expect enjoyment of a high level of amenity; and- - People would reasonably expect to be present here continuously, or at least regularly. Examples may include residential dwellings, hospitals, schools/education and tourist/cultural
Medium sensitivity receptor	Land where: - Users would expect to enjoy a reasonable level of amenity, but wouldn't reasonably expect to enjoy the same level of amenity as in their home; or - People wouldn't 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 sensitivity receptor	Land where: - The enjoyment of amenity would not reasonably be expected; or - There is transient exposure, where the people would reasonably be expected to be 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.

Impact benchmarks can then be selected which reflect these variations for odours of which are classified as 'moderately' or 'most' offensive using the matrices presented below. Under this system, the starting point of unacceptable odour under EPR and risk of odour nuisance broadly corresponds to a moderate odour effect under planning.

Table 1: IAQM odour effect descriptors for impacts predicted by modelling: 'moderately offensive' odours.

Odour exposure level	Receptor Sensitivity		
[$C_{98, 1\text{-hour}}$ x ou_E/m^3]	Low	Medium	High
≥10	**Moderate**	**Substantial**	**Substantial**
5 - <10	Slight	**Moderate**	**Moderate**
3 - <5	Negligible	Slight	**Moderate**
1.5 - <3	Negligible	Negligible	Slight
0.5 - <1.5	Negligible	Negligible	Negligible
<0.5	Negligible	Negligible	Negligible

Table 2: IAQM odour effect descriptors for impacts predicted by modelling: 'most offensive' odours.

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

Odour exposure level [$C_{98, 1\text{-hour}}$ x 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

In Olfasense's experience, the potential for adverse odour impact typically starts to occur at odour exposure levels of $C_{98, 1\text{-hour}}$ = 3 to 5 ou_E/m^3 for highly sensitive receptors, at well operated sewage works where the most odorous elements of the process (e.g. inlet works and raw sludge handling operations) are well contained and odour controlled.

However, impact risk can develop at lower exposure levels (e.g. 1.5 ou_E/m^3) at sites that receive septic sewage inflows, highly odorous trade discharges or septic sludge, and where containment and control measures are not working effectively.

This experience is generally supported by recent planning enquires and case law.

3 Description of works operations

3.1 Site location

Queensferry WwTW is in Queensferry, Flintshire, to the south of the River Dee and approximately 8 km west of Chester.

The land adjacent to the works is mainly occupied by industrial premises which arguably have a low level of sensitivity to odour exposure. However, there are residential receptors approximately 100 m to the west of the site and 300 m to the north and south of the site which are generally classified as highly sensitive to odour.

Figure 1 below presents the location of the works. The site boundary is outlined in dark blue and residential receptors are shaded in light blue.

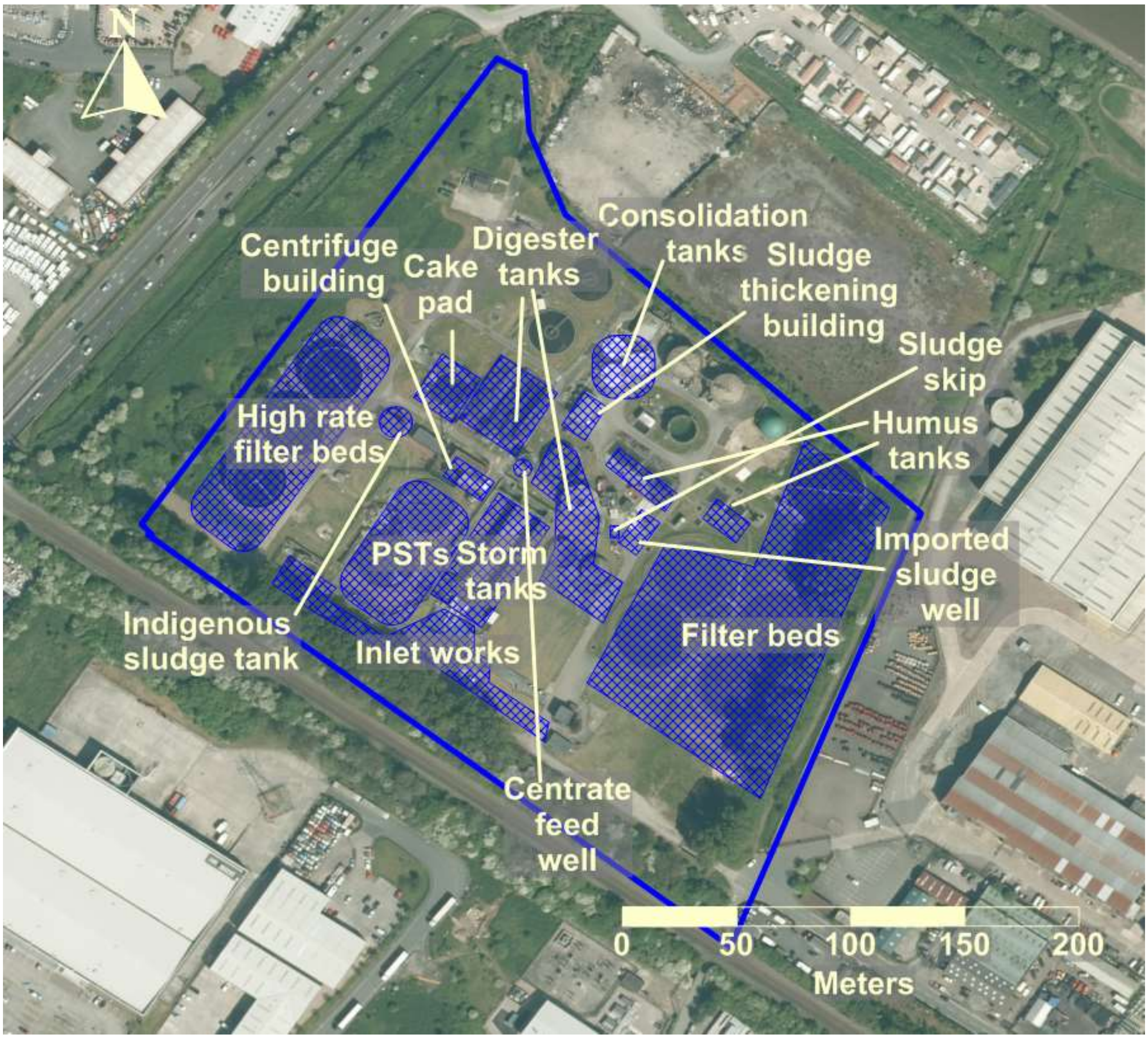
Figure 1: Location of Queensferry WwTW

3.2 Description of site operations

Queensferry WwTW receives a combination of domestic sewage and trade effluent. Incoming dry weather flows are approximately 100 l/s and full flow to treatment capacity is approximately 272 l/s.

The layout of the treatment assets at Queensferry WwTW is shown in Figure 2 below.

Figure 2: Queensferry WwTW site layout



3.2.1 Effluent treatment stream

Incoming sewage is received at the head of the inlet works at the southern edge of the site, via 7 No. bell mouths which serve the following pumping stations:

- Deeside industrial park.
- Pentre.
- Sandicroft.
- Mancott and Hawarden.
- Sealand.
- Queensferry.
- Site returned liquor PS.

A septic tanker discharge point is also provided in this area and received approximately 15-20 No. tankers per week.

Following receipt, the combined sewage flows through an open channel to 2 No. screens (duty/assist), which extract retained rag and discharge it to 1 no. open skip. The screened sewage is then split between 2 no. covered detritors (neither of which are currently operational), after which it recombines and is conveyed via an open channel to the inlet pumping station. There is also a detritor bypass channel running from prior to the entrance to the first detritor to the start of the post detritor channel. This channel is used as part of normal operations (since the detritors are not operational). The inlet pumping station also receives centrate from the sludge centrifuges when it is operational.

A storm weir is located just up-stream of the inlet pumping station which enables flows more than 272 l/s to be diverted to 2 No. sequentially filling rectangular storm tanks. Although these tanks are fitted with a scraper, they are not effective.

From the inlet pumping station, flows are pumped underground to an open distribution channel and onto a partially covered PST distribution chamber, which splits the flow equally between 2 No. open circular PSTs. Following settlement, the settled sewage is then split between 3 No. high rate filters beds & 2 No. circular humus tanks (2/3's of the flow) and 5 No. filter beds & 6 No. rectangular humus tanks (the remaining 1/3 of the flow). The treated effluent flows are then recombined, treated in an UV disinfection system, and discharged to the River Dee.

3.2.2 Sludge treatment

The sludge treatment assets at the site are as follows:

- An indigenous sludge storage tank.
- 3 no. sludge consolidation tanks.
- An import facility comprising an import reception tank, rotamat screen and post-screening import tank.
- 2 no. anaerobic digestors
- 7 no. secondary digestors (2 no. covered and the rest open).
- A sludge thickener
- Sludge centrifuge
- Sludge cake pad and liming facility.

The sludge process is as follows:

- Indigenous sludge from the 2 No. PSTs is conveyed via 2 No. open de-sludge wells to a partially covered sludge holding tank, from which it is periodically transferred to Consolidation tank No. 1 & 2.
- Imported sludge is tankered onto site and discharges into a covered sludge import tank from which it is screened and returned to the post-screening import tank. The sludge is

then conveyed to consolidation tank no. 1 & 2 where it is mixed with indigenous sludge. There are currently approximately 25 sludge imports per week.

- The mixed sludge from consolidation tank 1 & 2 are thickened and discharged into Consolidation tank No. 3 which feeds the 2 No. anaerobic digestors. Following digestion, the sludge is discharged into the 7 no. secondary digestion tanks (4 No. circular tanks and 3 No. rectangular tanks) for storage for between 11 and 14 days.
- Digested sludge is pumped to a centrifuge feed tank centrifuged to produce sludge cake which is stored on a pad until it is conveyed offsite for disposal.

It is understood that the following sludge treatment assets were originally extracted to a central odour treatment system. However, this system is no longer working:

- Indigenous raw sludge tank.
- Sludge imports tank.
- Digester feed tank.
- Sludge thickener building.

3.3 Odour complaints history

It is understood that Queensferry WwTW has received 115 complaints between 2018 – February 2021, 27 of which were within a 1-mile radius of the works (see Figure 4 below). No abnormalities were noted by the client.

Figure 3: Complaint locations (light blue stars) 2018 – Feb 2021

4 Review of odour sources

4.1 Overview of the mechanisms that lead to odour generation

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

In general, the elements of sewage treatment process which pose the highest risk in terms of odour generation are those which involve handling of the raw sewage in sludge, under anoxic or anaerobic conditions, e.g the preliminary and primary sewage treatment operations and raw sludge storage handling and treatment.

Odours can also be generated from operations that involving handling of digested sludges, sludge that is amended with lime and secondary treatment operations, although the later tend to be relatively low risk since they are generally conducted under aerobic conditions which quickly oxidise any odorous chemicals and inhibit formation of any new ones.

The rate of odour release from sewage and sludge sources is primarily dependent upon the quality of the material, temperature, and the surface area exposed to the atmosphere. As a result, odour emissions tend to be highest during the spring and summer months. Furthermore, activities that lead to increases 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 increase emissions from that activity.

4.2 Potential odour sources identified during the odour survey

The following specific odour sources were identified at Queensferry WwTW:

Table 3: Summary of principal odour sources identified at Queensferry WwTW

Stage of treatment	Odour Source	Nature of odorous material	Frequency and duration of release
Preliminary treatment	Septic tanker imports to inlet works	Septic waste	20 times per week
	Inlet channels	Sewage	Continuous
	Screen	Sewage	Continuous
	Detritors	Sewage	Continuous
	Rag storage skips	Screenings	Continuous
Storm water handling	Storm tank distribution channels	Storm water	2 days per week in summer 4 days per week in winter
	Storm tank 1	Storm water	In use 2 days per week summer & continuous in winter
	Storm tank 2:	Storm water	4 days per week in winter.
	Storm tank 1 & 2	Sediment	When not in use
	Open PST distribution channels	Screened sewage	Continuous

Primary treatment	Covered PST distribution chamber	Screened sewage	Continuous
	Primary Settlement Tanks	Open tanks	Continuous
Secondary treatment	High rate filter bed distrib. chamber	Screened sewage	Continuous
	High rate filter beds	Screened sewage	Continuous
	High rate filter outflow chambers	Treated sewage	Continuous
	Filter bed distribution chambers	Screened sewage	Continuous
	Filter beds	Screened sewage	Continuous
	Humus tanks	Treated sewage	Continuous
Sludge handling and treatment	PST de-sludge wells	Raw sludge	Continuous
	Indigenous raw sludge tank*	Raw sludge	Continuous
	Sludge import	Raw sludge	25 times per week
	Covered sludge import wells	Imported sludge	Continuous
	Sludge imports screen	Imported sludge	Continuous
	Sludge screenings skip	Imported sludge rags	Continuous
	Consolidation tank 1 (covered) *	Imported sludge	Continuous
	Consolidation tank 2 (covered) *	Indigenous sludge	Continuous
	Consolidation tank 3 (covered) *	Mixed sludge	Continuous
	Sludge thickening building*	Digested sludge	Continuous[8]
	Digested sludge tanks	Digested sludge	Continuous
	Centrifuge feed tank	Open tank	Continuous
	Centrifuge building*	Sludge	Continuous[8]
	Sludge cake pad	Digested sludge	Continuous. Active transfer 3 hours/day
	Sludge export	Tanker	Approximately one hour per week

* These sources are covered; however, it is noted that there will still be fugitive odour emissions released from these sources as the covers do not provide full containment.

5 Estimation of current site odour emissions

5.1 Emission assumptions

Based on the observations made during the site audit and review of results of the survey and historic survey data for the site, the following assumptions were made:

- The incoming influent has a moderate to high odour potential which is likely to vary depending upon timing of discharge of the various pumping stations, discharge of septic imports, and the nature and quality of influent received. The emissions from the inlet chamber and downstream channels are therefore likely to highly variable.
- The variability in emissions measured from the treatment processes decreases as the sewage moves through the process, which is likely to be due to the averaging effects of retention in the primary settlement tanks. The emission rates measured form the secondary treatment processes fell towards the lower end of the expected range based on data collected at other Welsh Water sites.
- Other than the inlet works, the highest emissions from the site were measured from the elements of the plant which handle raw sludges. The odour emission potential of the imported sludge was approximately an order of magnitude higher than indigenous sludge. Although these elements of the process are designed to be contained an extracted to an odour treatment system, this system is not currently working and many of the access hatches on the tanks are left open, which leads to avoidable fugitive emissions from these areas.

The emission estimate applied to determine current site emissions are summarised in the tables below. Further details of the assumptions from which these are derived are presented in Annex B.

Table 4: Emission rate assumptions for open sources

Stage	Source	Summer odour emission rate $[ou_E/m^2/s]$	Turbulence factor
Preliminary treatment	Inlet works	83	1-20
	Screening's skip	35.7	-
Storm water handling	Storm tank feed channels and tanks in use	17	-
	Storm Tank sediment	30	-
Primary treatment	Primary Settlement Tank	20	3 for weirs
	Settled sewage?	0.7	
	Desludge wells	30	-
Secondary treatment	High-rate filter bed	0.7	-
	Filter bed	0.7	-
	Humus tank	0.3	1-12
Sludge treatment	Indigenous sludge holding tank	31	-
	Imported sludge screen skip	50	-

	Digested sludge tanks**[9]	3.1-4.3	-
	Centrate well	2	-
	Centrifuge feed tank	4.3	-
	Stored sludge cake	5.2	-

*Open grated well source. Headspace was created for sampling using polyethene roll.

**Emission rate dependent upon age of digested sludge

Table 5:Emission assumptions for enclosed sources

Source	Average odour concentration [ou_E/m^3]	Estimated air change per hour	Estimated odour emission rate [ou_E/s]
Detritor*	29,418	3	259 - 988
Indigenous raw sludge tank (Consolidation tank 1)	37,203	3	2,946
Imported sludge well	4,566	3	482
Imported sludge tank (Consolidation tank 2)	234,407	3	18,564
Digester feed tank (Consolidation tank 3)	32,924	2	1,738
Sludge thickening building	234	5	124
Centrifuge building	69	3	22

*Source modelled in different stages – multiple airflow rates assumed based on varying volumes.

Table 6:Emission assumptions for agitated sludge cake sources

Source	Duration/week (hours)	Kg sludge/second	Odour units/kg (ou_E/kg)	Odour emission rate (ou_E/s)
Fresh sludge cake drops to pad	12	5	35	175
Sludge cake export (1 week)	1	14.2	12	170

5.2 Site odour emission hierarchy

A breakdown of the estimated odour emission rates under summer conditions from each aspect of the sewage treatment process under current operating conditions are 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 hence 'time-weighted'.

Table 11: Contribution of time weighted emissions from each aspect of the treatment process (summer conditions).

Stage of works	Odour source	Emission rate [ou_E/s]	% of site emissions
Preliminary treatment	Inlet works	25,506	23
	Screens and grit storage	139	<1
Storm water handling	Storm water storage and handling	3,540	3
	Storm sediment	14,657	13

[9] It is assumed that of the 7 digested sludge tanks, at any one time, 4 tanks are empty or have older, retained sludge, while 3 tanks have fresher digested sludge.

Primary treatment	PST distribution	9,696	9
	Primary Settlement tanks	20,810	19
Secondary treatment	Filter bed distribution	131	<1
	High-rate filters	1,115	1
	Filter beds	2,815	3
	High-rate filter outflow chambers	4	<1
Sludge handling and treatment	PST desludge chambers	540	<1
	Indigenous raw sludge tank	832	1
	Consolidation tank 1	2,946	3
	Sludge imports well	1,148	1
	Consolidation tank 2	18,564	17
	Sludge thickening building	124	<1
	Consolidation tank 3	1,738	2
	Humus tank	350	<1
	Digested sludge storage tanks	3,446	3
	Centrifuge feed tank	165	<1
	Centrate well	5	<1
	Centrifuge building	22	<1
	Sludge cake handling and storage	769	1
	Sludge skip	195	<1
Total		109,256	100

Review of the table above indicates that the total estimated time-weighted odour emission rate from the works under summer conditions is 109,256 ou_E/s.

The main contributors to these emissions are the inlet works which accounts for ~23% of emissions; the primary treatment operations (29%); storm water handling (16%), and sludge handling (29%).

The relatively high contribution of odour emissions from the preliminary, storm water handling and primary treatment operations is predominantly due to the high odour potential of the influent received by the works, which is in turn is likely to be due to the influence of odorous trade effluents and tankered septic imports. The fact that much of the inlet works and the primary tank distribution channels are open, and the storm tank cleaning systems are ineffective are also important contributary factors.

The high contribution of odours from sludge handling area can be attributed to the fact that the odour control treatment system is no longer operational and that hatches on the tank covers are left open for operational reasons.

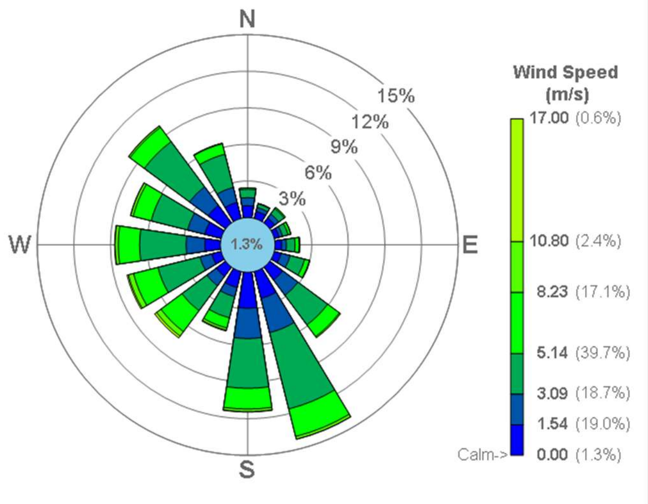
6 Dispersion modelling

6.1 Assumptions

The following assumptions have been applied to the dispersion modelling study.

- The emission rate of odour from the preliminary and primary operations involved in handling liquid sewage (e.g. inlet channels, PSTs, settled sewage and storm water) were reduced by a factor of 5 between summer and winter (with incremental reductions for spring and autumn) to reflect the seasonal changes in emissions due to lower sewage/ambient temperature and dilution effects of rainwater
- Meteorological data utilised within the study was derived from 5 years of recent sequential hourly average data obtained from Hawarden meteorological station for the years 2015 to 2019. This meteorological recording station is located approximately 4 km to the south west of the works. The meteorological data was adjusted to reflect the surface characteristics of the meteorological site in accordance with the guidelines issued in the AERMOD Implementation Guide[10] issued by the US EPA. The wind rose for the meteorological data utilised in the study is presented below.

Figure 4: Wind rose for Hawarden meteorological station for 2015-19



- The model was run without considering any urban heat effects. A review of land use in the vicinity of Queensferry WwTW, in line with procedures detailed in the AERMOD Implementation Guide, indicated that the site is in a predominantly rural setting.
- A 30 ring, 36 radial receptor circular grid was defined for the study area with a 50 m spacing. All receptors were assigned a 1.5 m flagpole height.
- Data describing the topography of the area surrounding the works was obtained from Ordnance Survey in Landform Panorama™ format.

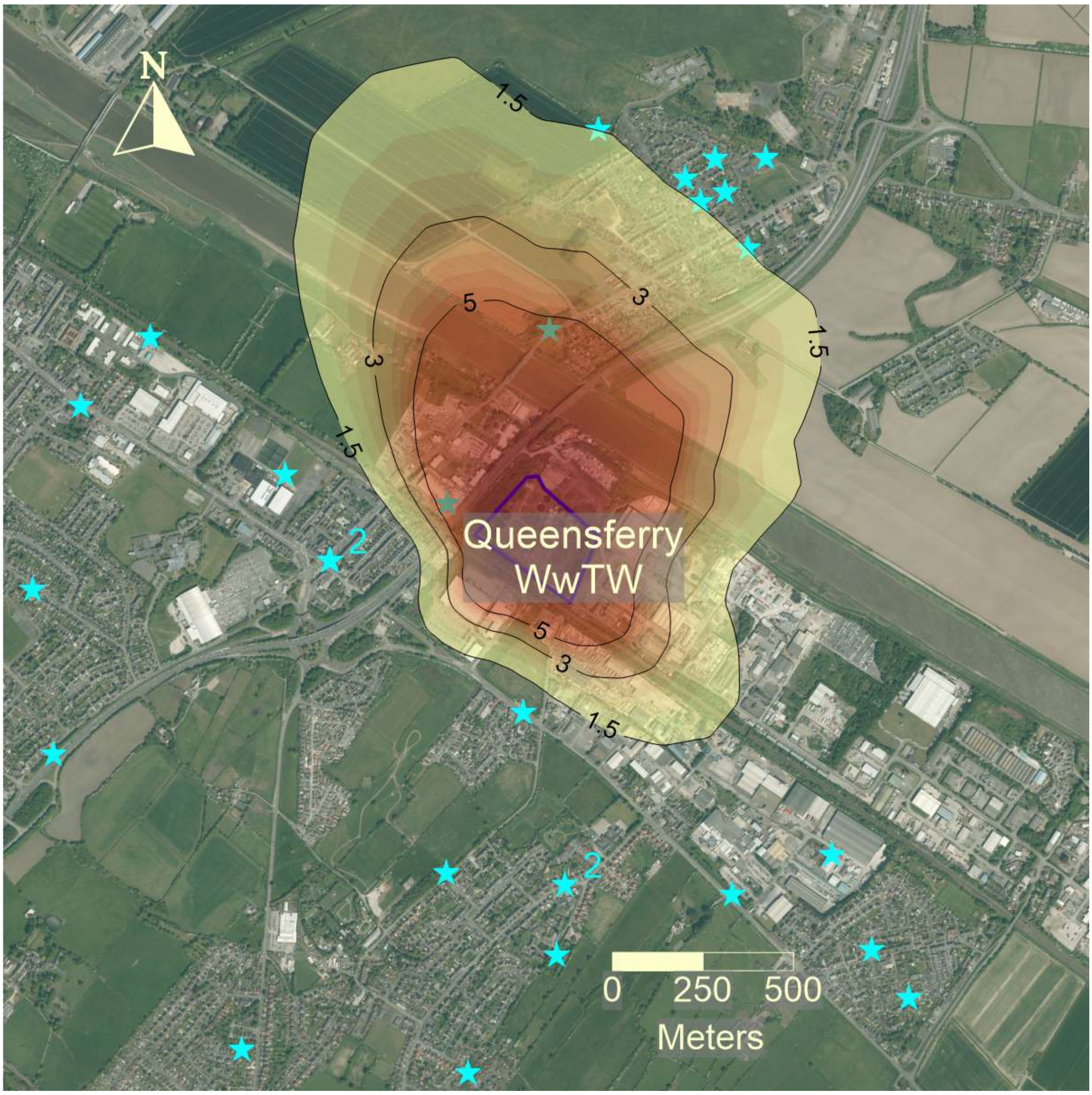
[10] AERMOD Implementation Guide, Published by the US EPA, Last Revised: March 19, 2009

- The model only considers normal operational occurrences. 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. Short term emission events such as sludge liming may not be accurately represented by long term dispersion models.

6.2 Model output for baseline conditions

The results of the dispersion modelling are presented in Figure below. The figure presents isopleths encompassing the area where odour exposure levels are predicted to exceed 1.5, 3, 5 ou_E/m^3 for greater than 2% of the hours in the year, for the meteorological 2015-2019 (Hawarden airport met station) for the current works operations.

Figure 5: Results of odour dispersion modelling under normal operational conditions (2015-19) with complaints



Odour dispersion modelling indicates that under current operational conditions, odours from the works pose a potential risk of impact on residential areas to the north and east up to 0.9 km from the works, and at commercial premises up to 0.6 km.

However, since the odour potential of the sewage entering the site varies, it is quite plausible that odours may travel further than predicted by the model under certain conditions when particularly odorous inflows / imported sludge are received. The model impact profile can therefore be considered to reflect the average rather than worst case view and hence odour complaints may be experienced further afield. This appears to be supported by the complaints record for the site, which suggests that odour can impact up to 1.6 km from the site boundary. It is also plausible that other odour sources in the area influence complaints and may have led to the site being mistakenly identified as the cause of odour impact in some circumstances.

6.3 Opportunities for enhancing odour control and reducing impact risk

The following opportunities have been identified to enhance odour control and reduce odour impact risk:

1. Cover the inlet works including the discharge chamber, detritor, inlet channels, inlet pumping station and primary settlement tank distribution chambers and extract to a suitable odour treatment system or systems.
2. Install an effective automised cleaning systems in the storm tanks, to ensure that sediment is not retained on the base of the storm tanks following storm events.
3. Minimise the use of the storm tanks as far as possible.
4. Refurbish the covers on consolidation tanks 1 & 2 covers and modify the sludge delievery systems so that the hatches can be closed during norml operating conditions.
5. Re-furbish or replace the sludge odour control unit to eliminate fugitive emissions of potentially high concentration odours from the indigenous raw sludge tank, sludge imports tank, digestor feed tank and sludge thickening building. This will require a review of the adequacy of the extraction systems to ensure effective control of fugitive emissions is achieved and reassesement of the adequacy and design of the current odour treatment system.
6. Ensure that the hatches on the Sludge import wells are kept closed. It may be necessary to connect the sludge wells to an extractive odour treatment system if odours persist in this area.
7. Review whether it is possible to use a pump to empty out the imported sludge and septic tankers rather than use of the tanker vacuum systems.
8. Prepare an odour management plan for the site to ensure operations are conducted in a manner that minimises odour generation where possible.

Annex A Odour sampling and analysis

A.1 Collection of odour samples from buildings.

Collection of samples from ducts or stacks was conducted using the ‘Lung’ principle of sample collection. A 60 l Nalophan sample bag was placed in a rigid container and connected to the duct/stack containing odorous gas using a PTFE sample line. Air was withdrawn from this container using a pump which caused a sample of the odorous air to be drawn through the sample line into the bag.

Where necessary, samples were pre-diluted with nitrogen at the point of collection to prevent condensation from forming in the sampling lines and odour bag, which may influence the odour concentration prior to analysis. Pre-dilution is conducted using Olfasense’s Sample Master stack sampling system.

The temperature and velocity of the airflow at each point was also determined where possible using suitable monitoring techniques.

The emission rate of odour was then calculated by multiplying the measured odour concentration by the volume flow rate (m^3/s) as measured in the duct/stack.

Samples of odorous air from buildings were collected within the building in question using the ‘Lung’ principal of sample collection as described above.

A.2 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 as described above.

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

- 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.3 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.

Annex B Odour survey data & emission assumptions

B.1 Emission measurement results for open sources

Table 12: Odour emission results for open sources – 2016, 2018, & 2020

Source	Average Odour emission rate [$ou_E/m^2/s$]		
	2020	2018	2016
Inlet channel	231.4	213.6	34.4
Screen skip	35.7	-	-
Storm Tank	121.8	0.4-7.3*	-
Primary settlement tanks	1.4	19.5	-
High-rate filter bed	0.5	-	-
Filter bed	0.7	0.7	-
Humus tank	0.3	-	-
Digested sludge tank (Fresh)	1.7	4.1	-
Fresh Sludge cake	5.2	3.0	-
Aged sludge cake	0.3	3.3	-

*Storm sediment sampled.

Table 13: Hydrogen sulphide results for open sources – 2016, 2018, & 2020

Source	Average H_2S emission rate [μg/m²/s]		
	2020	2018	2016
Inlet channel	79.477	0.045	34.4
Screen skip	<0.003	-	-
Storm Tank	48.305	<0.003*	-
Primary settlement tanks	1.538	<0.003	-
High rate filter bed	0.021	-	-
Filter bed	<0.003	<0.003	-
Humus tank	<0.003	-	-
Digested sludge tank (Fresh)	<0.003	<0.003	-
Fresh Sludge cake	0.031	0.005	-
Aged sludge cake	<0.003	<0.003	-

*Storm sediment sampled.

B.2 Emission measurement results for enclosed sources

Table 17: Olfactometry results for headspace sources – 2020.

Source	Odour concentration [ou_E/m^3]			
	Geomean	Sample 1	Sample 2	Sample 3
Indigenous raw sludge tank (Consolidation tank 1)	35,226	34,378	33,236	38,257
Imported sludge well	1,524	1,179	2,260	1,328

Imported sludge tank (Consolidation tank 2)	234,407	139,610	364,102	253,381
Digester feed tank (Consolidation tank 3)	37,092	38,850	35,096	37,429
Sludge thickening building	52	110	43	30
Centrate well	70	56	78	79

Table 18: Hydrogen sulphide results for headspace samples – 2020

Source	Date of sampling	Hydrogen sulphide concentration [mg/m^3]			
		Mean	Sample 1	Sample 2	Sample 3
Indigenous raw sludge tank (Consolidation tank 1)	7/10/20	1.26	1.67	1.00	1.11
Imported sludge well	7/10/20	0.034	0.042	0.033	0.028
Imported sludge tank (Consolidation tank 2)	8/10/20	21.756	27.321	22.768	15.179
Digester feed tank (Consolidation tank 3)	8/10/20	3.466	3.871	3.415	3.112
Sludge thickening building	8/10/20	0.003	0.005	0.003	0.002
Centrate well*	8/10/20	<0.003	<0.003	<0.003	0.005

B.3 Emission assumptions

The following assumptions were applied to define emissions to from the site:

Table 18: Emission assumptions

Stage of process	Source	Assumption
Preliminary treatment	Inlet works	Average of measurements from the 2016, 2018 and 2020 surveys. Turbulence factors were then applied based on observations made during the 2020 audit.
Storm water handling	Storm tanks and channels when in use	Surface emission rate from the inlet works divided by 5
	Storm tanks when not in use	Average of the data collected from storm sediment in 2018 and 2020.
Primary treatment	Primary settlement tanks	2018 dataset and library data.
	Desludge wells	Library data
Secondary treatment	High-rate filters	2020 survey data
	Filter beds	2020 survey data
	Humus tanks	2020 survey data
Sludge treatment	Indigenous sludge holding tank	Surface emission rate determined from Consolidation tank No. 1
	Consolidation tank 1	Average of 2018 and 2020 data
	Consolidation tank 2	Average of 2018 and 2020 data
	Consolidation tank 3	2020 data
	Imported sludge wells	Average of 2018 and 2020 data
	Imported sludge screenings skip	Library data

	Digested sludge tanks	Average of data collected during 2018 and 2020 surveys
	Centrifuge feed tanks	As digested sludge tanks
	Sludge cake	2020 data for fresh sludge
	Centrifuge building	2018 data as the building was not operational during the 2020 survey
	Sludge thickening building	2020 survey data