Aldwarke Secondary Containment Assessment

September 2022

Sign-Off Sheet

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1 Introduction

As part of the Industrial Emissions Directive (IED) permit application for Aldwarke Sludge Treatment Facility (STF), Yorkshire Water (YW) has undertaken an assessment of the potential environmental risks associated with a loss of containment of process vessels. YW has also reviewed existing provisions and potential improvement options against Best Available Techniques (BAT) principles, in alignment with CIRIA 736[1].

Aldwarke STF falls under the IED as a Part A(1) installation by virtue of exceeding the 100t/d throughput limit for anaerobic digestion (AD). The permit will cover raw sludge storage, handling and thickening, digested sludge storage, handling and dewatering, sludge cake secondary treatment and storage, biogas storage, utilisation and flaring. This document focuses on the secondary containment aspects of the permit requirements, in particular the application of BAT, and should be viewed in parallel with the main permit application document, in particular Section II: Technical Description, Section III: Accident Risk Assessment and Appendix 4: Site Condition Report.

1.1 Site details

Aldwarke Wastewater Treatment Works (WwTW) is located within an industrial area in South Yorkshire, approximately 3 km north-east of Rotherham town centre. The River Don is located to the south and the STF installation is bordered primarily by open land and commercial properties to the east and west, and scrubland to the north. Aldwarke STF treats indigenous sludge from the co-located WwTW and liquid sludge imported from other YW WwTW.

An aerial view of Aldwarke STF along with its installation boundary is shown in Figure 1. The key activities at Aldwarke STF are illustrated via a process flow diagram in Figure 2. Key activities include sludge import; sludge thickening; anaerobic digestion; biogas handling and combustion; sludge dewatering and associated routes of gaseous, liquid, and solid materials. These processes are further discussed in Section 3.2.1.

Figure 1. Aldwarke STF aerial view, installation boundary in green. © Google, 2021

[1] CIRIA (2014) Containment systems for the prevention of pollution: Secondary, tertiary, and other measures for industrial and commercial premises (C736; 2014)

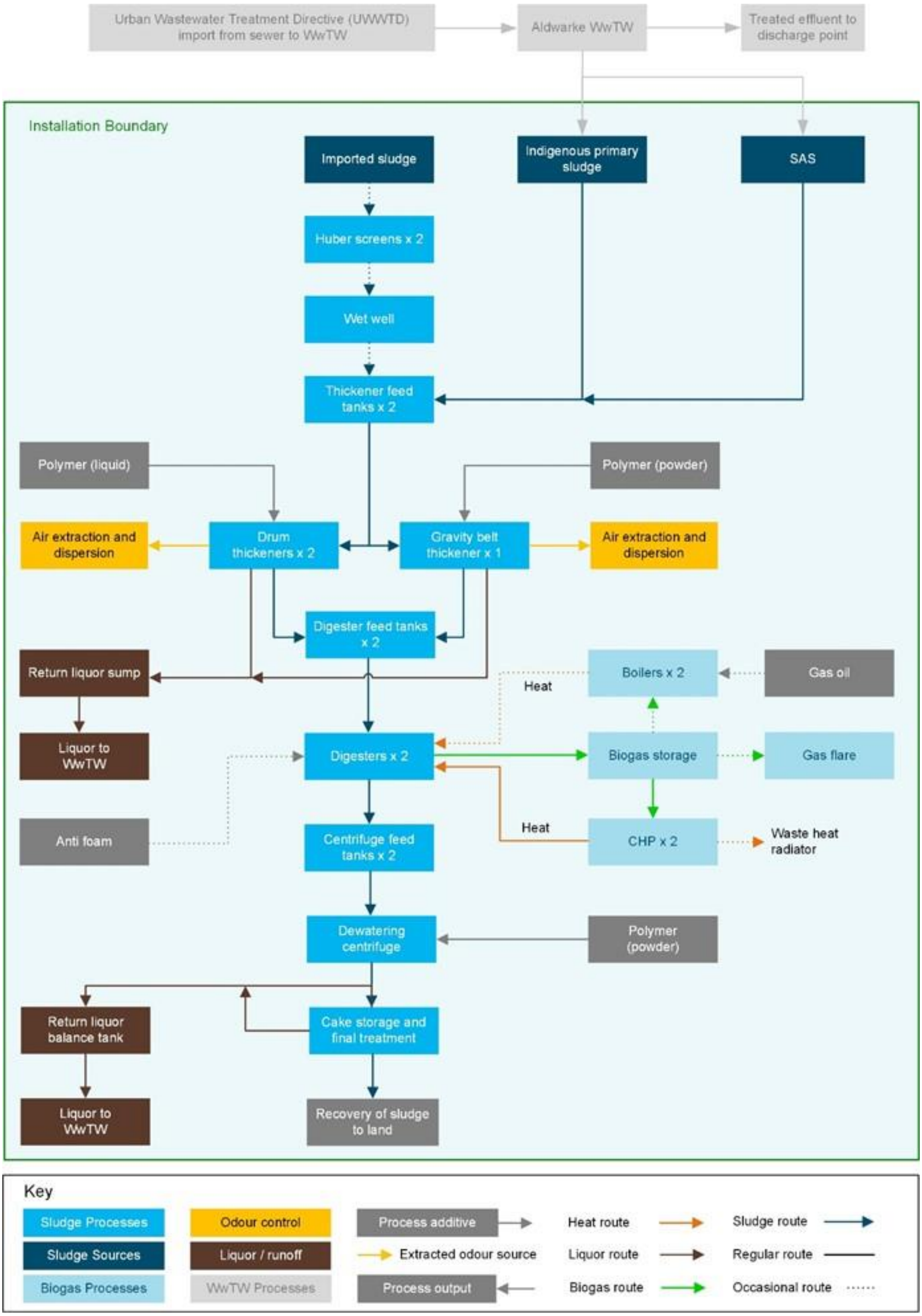


Figure 2. Aldwarke STF process flow diagram.

1.2 Overview

YW commissioned Stantec to assess existing provisions and, where necessary, improvement options for secondary containment at the site. Stantec have provided risk-based supporting evidence to accompany the permit application, which demonstrates the most appropriate solution(s) for BAT compliance using CIRIA 736 standards. To fully understand the requirement for secondary containment and to provide environmental protection at Aldwarke, two industry standard tools have been used, these are shown within the flow chart in Figure 3.

Firstly, the Anaerobic Digestion and Biogas Association (ADBA) secondary containment risk assessment tool has been applied to assets at Aldwarke. The ADBA assessment tool provides a methodology for determining the specific design of secondary containment systems at a site, based on an assessment of sources, pathways and receptors which are at highest risk, and the types of control options which would provide protection. However, as an existing installation in continuous operation, retrospectively applying a standard secondary containment bund to all sludge tanks and containers presents significant technical, operational, safety and logistical challenges. It is also noted that the location of Aldwarke STF within a wider wastewater treatment works (WwTW) presents opportunities in terms of utilising other existing YW assets as part of the pollution containment and prevention solution, and the ADBA tool does not have the flexibility to reflect this in the solutions it recommends.

Recognising this limitation, a bespoke source, pathway, receptor approach has been developed by Stantec and applied to identify and risk assess bunding solutions favoured by the ADBA approach, as well as additional site-specific options for secondary containment.

Whilst these tools are discrete pieces of work, they come together to provide a robust evidence base for assessment of secondary containment requirements at Aldwarke.

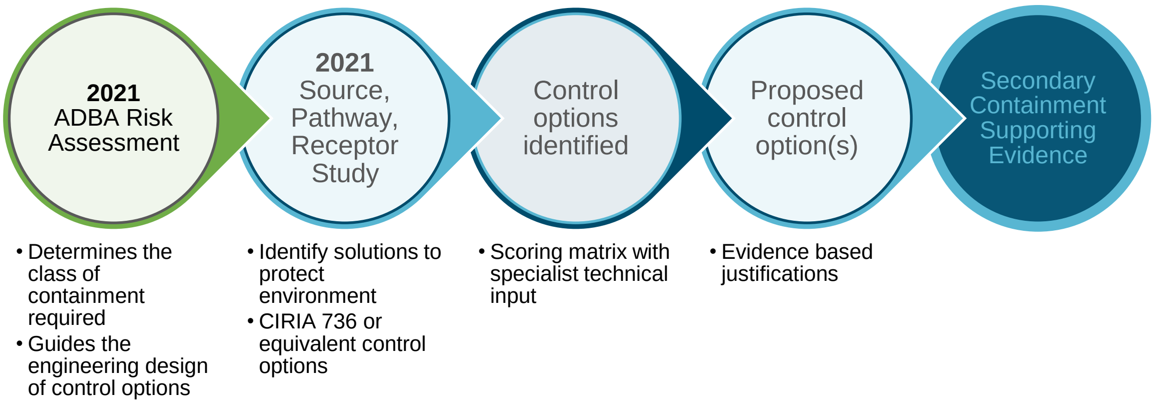


Figure 3. Flow chart showing the approach taken to provide secondary containment supporting evidence.

2 ADBA risk assessment tool findings

The ADBA Risk Assessment Tool is based on CIRIA C736 requirements for the prevention of pollution: including secondary and tertiary containment, and other measures for industrial and commercial premises. An assessment is presented in Appendix 1 and the findings are summarised in this chapter.

2.1 Class of required secondary containment for Aldwarke

To identify the class of containment deemed to provide sufficient environmental protection in the ADBA Risk Assessment, the tool uses a source, pathway, receptor model. This identifies hazards posed to the environment and assigns a class of containment based on the site hazard rating and likelihood of loss of primary containment. The approach is summarised in Figure 4 below.

Figure 4. ADBA risk assessment classification flowchart.

The ADBA Risk Assessment Tool scored the source element as ‘High risk’, pathway elements as ‘Medium risk’ and the receptor element as ‘Medium risk’ at Aldwarke owing to the significant volumes of sewage sludge stored on site. In summary, this assessment approach indicates that Aldwarke STF has an overall site hazard rating of ‘High Risk’. The likelihood of failure was ‘Low Risk’ due to the type of infrastructure involved and the mitigations at the site e.g., regular tank inspections and level sensors.

According to Table 4 within the ADBA tool (box 2.2 CIRIA 736), reproduced in Figure 5 below, the combination of a high site hazard rating and a low likelihood rating, gives the overall site risk as medium. The indicated class of secondary containment for **Aldwarke STF was therefore deemed as being Class 2.**

Table 4: Overall site risk rating as defined by combining ratings of site hazard and probability of containment failure *(Box 2.2 CIRIA 736)*

Possible combination	**Overall Risk Rating**	**Indicated class of secondary containment**
HH, HM, OR MH	**HIGH**	**Class 3**
MM, HL, OR LH	**MEDIUM**	**Class 2**
LL, ML, OR LM	**LOW**	**Class 1**

Figure 5. ADBA classification matrix.

The ‘Aldwarke STF ADBA Secondary Containment Risk Assessment’ outlines the information and data utilised in greater detail, as well as the assumptions applied to undertake a secondary containment risk assessment. The requirement for ‘Class 2’ type secondary containment within Aldwarke STF will be used to inform the next stage of secondary containment assessment, carried out by Stantec to support the permit application process (See Chapter 3).

3 Solution appraisal

3.1 Objectives

The purpose of this stage of the assessment is to determine the significance and potential environmental risks associated with a loss of containment from sludge vessels within the Aldwarke STF, and to review existing provisions and a potential improvement solution against BAT principles, including CIRIA C736. As described previously, this stage of the process is informed by the outputs of the ADBA tool, but also considers options which are outside the scope of the ADBA scoring system utilising a bespoke methodology which adopts source-pathway-receptor principles in a qualitative risk-based framework.

3.2 Sources at Aldwarke STF

The sources of risk which have been identified at Aldwarke as shown in Figure 6. These STF operational assets comprise of sludge import sludge thickening, digestion, dewatering and cake storage areas.

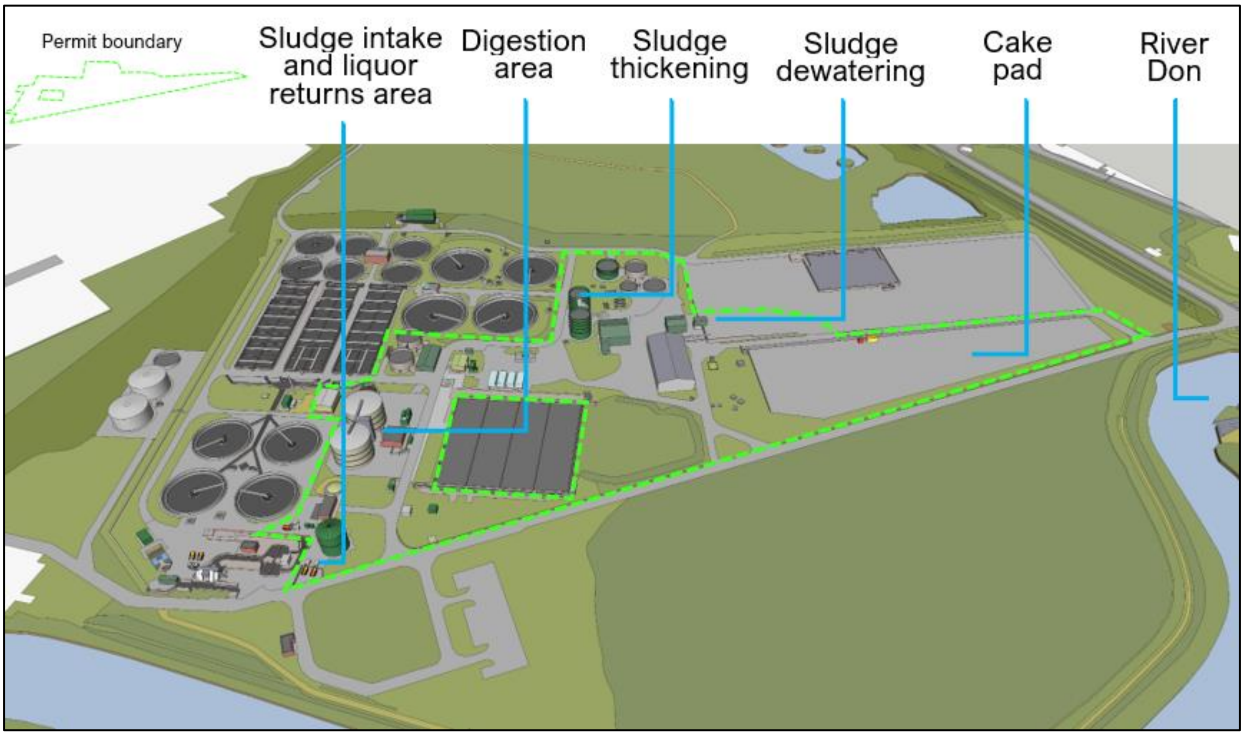


Figure 6. Aldwarke sources of risk and site areas.

3.2.1 Bulk storage vessels

The bulk storage vessel locations are shown and labelled in Figure 7 and Figure 8. Further description of how these vessels are utilised, the sources of risk, existing controls and mitigations associated with the STF is provided in the discussion.

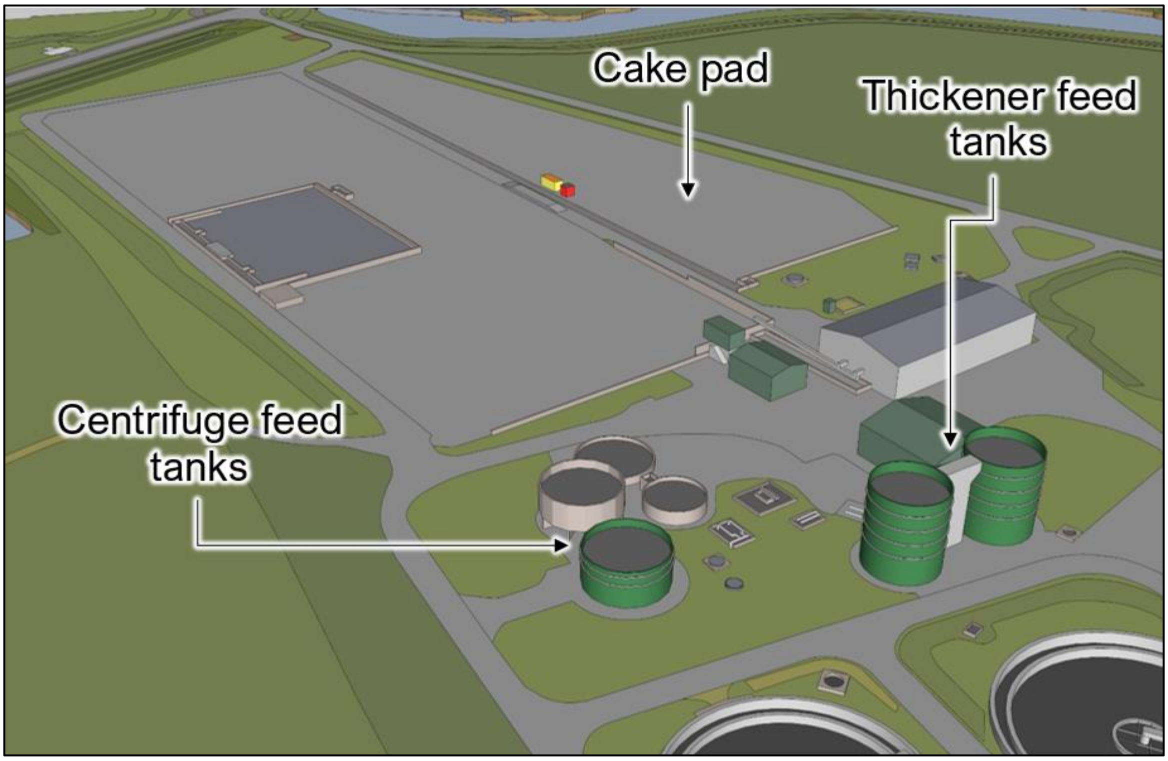


Figure 7. Sludge vessels located in the central north section of the site (view 1).

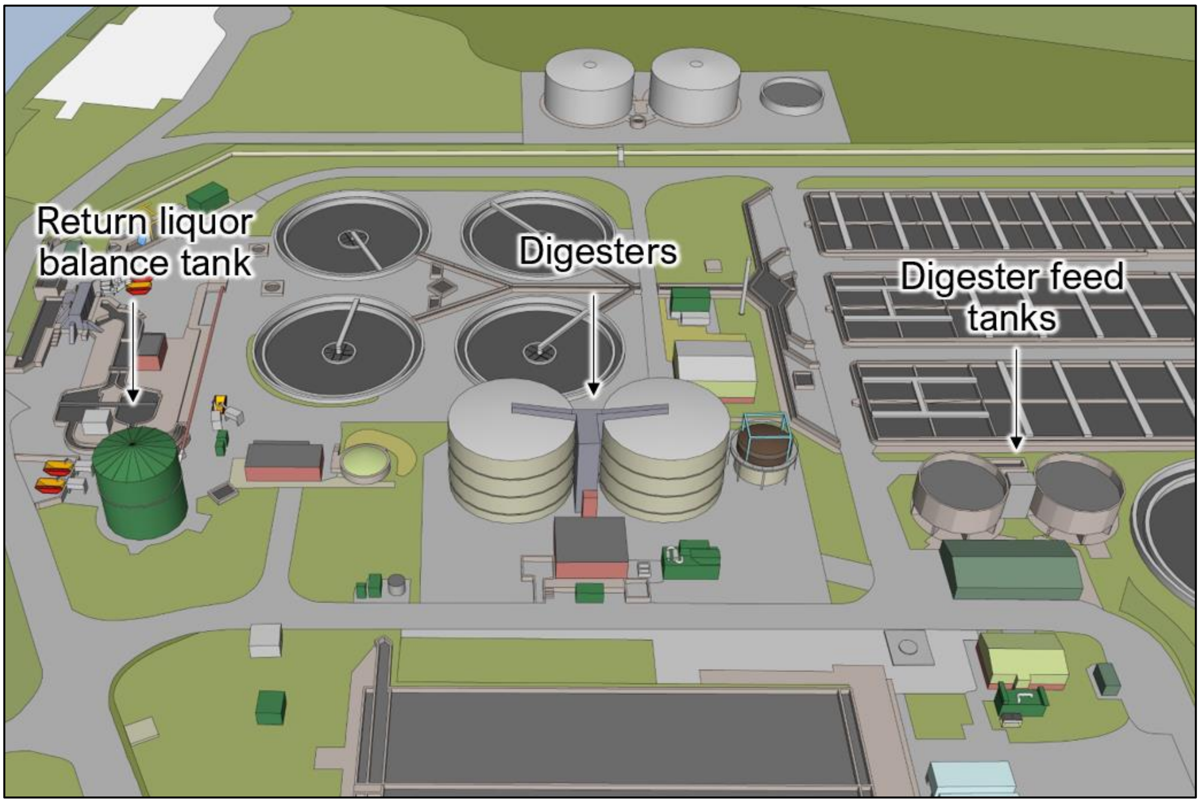


Figure 8. Sludge vessels located in the central west section of the site (view 2).

3.2.1.1 Sludge reception, treatment, and handling

Aldwarke STF treats the following sewage sludges:

- Indigenous primary sludges and surplus activated sludge (SAS) arising from sewage treatment processes operating within the wider Aldwarke WwTW that are piped directly to the STF.
- Liquid sludges generated by other YW Wastewater Treatment Works (WwTW) (with lower capacity or capability for treating sludges on-site) that are imported to Aldwarke STF for additional treatment.

Imported liquid sludge is delivered to site by tanker, which would normally unload at the sludge import area. The maximum load is typically 28 tonnes with unloading taking up to 30 minutes. Only appropriately authorised vehicles can discharge at the site. This is controlled using a 'WaSP' logger; valves on the discharge pipework will only open when a driver presents appropriate authentication to the system. The WaSP logger records the source of the sludge, the time and date of delivery, the total volume discharged and average percentage dry solids of the load.

The existing (but currently unused) sludge import facility comprises two Huber ROTAMAT enclosed rotating screens to screen the sludge prior to transfer to a covered, below ground concrete sump of approximately 80 m^3. Screenings drop into a skip and are disposed of off-site (see Part III: Form B3, Question 6e for more details of waste streams). Imported sludge is then passed forward to the thickener feed tanks (see below for more details).

There is a programme of works planned to upgrade the existing STF import facility, either via refurbishment of the existing facility or replacement with a new sludge import facility. The new facility would perform the same function as the existing and would comprise a new sludge screen feed tank with connections for imported and indigenous primary sludge, pipework to bring indigenous primary sludge to this tank, a new import discharge facility with WaSP system, flow meter and other monitoring equipment and pipework. The existing ROTAMAT sludge screens would be refurbished and retained.

Indigenous primary sludge and surplus SAS from the wider Aldwarke WwTW is pumped via below ground pipework into the thickener feeds tanks (2 no. 1,493 m^3 open topped steel tanks, shown in Figure 9). The liquid sludge is mechanically mixed; the tanks operate in parallel fill mode or operate in fill / draw mode i.e., one fills whilst the other empties.

Figure 9. Thickener feed tanks

Liquid sludge from the thickener feed tanks is then transferred to either the gravity belt thickener (GBT) building or drum thickener building via below ground pipeline. Forward feed of sludge to the drum thickeners and GBT is controlled via SCADA and each thickener unit can operate either individually or in any combination.

Gravity Belt Thickener

Within the GBT building, potable water is mixed with powdered polymer (stored in 25 kg bags) within the polymer make up tank (approximate capacity 1.5 m^3 steel tank), before transfer to a dosing tank (approximate capacity 1.5 m^3 steel tank), as shown in Figure 10. Both polymer tanks are located on a metal grid above a secondary containment sump within the GBT building. The polymer solution is dosed into the sludge stream and fed into the GBT (1 no.). From here the sludge migrates down the moving, porous belt where excess liquid is able to drain away, leaving the thickened sludge on the belt. Thickened sludge is then scraped from the belt and collected in the thickened sludge hopper. Sludge is typically thickened to 5-7% solids.

The GBT is continually cleaned using automatic spray bars. In addition, cold water cleaning using a pressure washer is undertaken as required. This system operates using potable water and wash water leaves via the liquor route.

The resulting thickener liquor is transferred to the return liquor sump (covered, underground sump approximately 80 m^3 capacity located adjacent to the sludge import facility). From this sump, liquors are pumped back to the WwTW for full treatment.

Figure 10. Polymer tanks in GBT building.

Drum Thickeners

From the thickener feed tanks sludge is pumped via underground pipework to the drum thickener building. Liquid polymer is normally delivered to the thickener building in 1,000 litre IBCs, or alternatively may be delivered in bulk. The polymer intake point is located outside the thickener building; polymer is transferred for storage to a bulk storage tank (approximately 5 m^3 capacity), is mixed with final effluent and transferred to the adjacent holding tank (approximately 2.5 m^3 capacity), as shown in Figure 11. Both tanks are GRP and located on a metal grid over a secondary containment concrete sump inside the building. The polymer solution is injected into the sludge stream before being introduced to the thickener drums (2 No.). The polymer encourages separation of water from the sludge as the sludge is rotated in the drum to remove excess liquid. The thickener liquor is transferred to the liquor return sump where it is mixed with the GBT thickener liquor (underground sump approximate 80 m^3 capacity located adjacent to the sludge import facility) prior to transfer back to the WwTW for full treatment.

The drum thickeners are equipped with automatic spray bars which provide frequent short cleans. The automatic spray bars operate using treated final effluent. A manual jet wash is also available for additional cleaning requirements; this system utilises potable water and has a dedicated extraction system for the diesel engine fumes which are vented outside the building.

Figure 11. Polymer tanks in drum thickener building.

Containment Best Available Techniques (BAT) for sludge reception, treatment & handling includes:

- In-line dosing of polymer ensures levels are controlled and raw materials used efficiently.
- Tank mixing using air injection to avoid settlement, blockage or gas production.
- PLC controlled plant and largely automated. PLC includes level sensors to reduce risk of tank overtopping, resulting in contamination and potential odour generation.

3.2.1.2 Sludge digestion

The thickened sludge is transferred from the GBT and drum thickener buildings via above and below ground pipework into two digester feed tanks (Figure 12, 2 no. open topped 500 m^3 concrete tanks). Sludge within the digester feed tanks is mechanically mixed. The tanks operate in alternate fill and draw mode.

Sludge is pumped from the digester feed tanks to the anaerobic digesters (Figure 13, 2 no. 3,167 m^3 concrete tanks, approximately 347 m^3 of each tank's storage capacity is below ground). The anaerobic digesters operate as a continuous process with sludge being added at the bottom, with one tank feeding on the hour every hour and the other on the half hour every hour. Treated sludge is displaced out of the top of the digester, via the outlet pipe, by sludge being fed into the bottom of the digester. The digesters are capable of feeding at up to 475 m^3/day combined at 6% dry solids giving a 12-day retention time as required by Hazard Analysis and Critical Control Points (HACCP) controls. The digesters are mechanically mixed.

Figure 12. Digester feed tanks (2.no)

Figure 13. Digesters (2 no.).

A water circuit filled with potable water is heated to around 70°C by the CHPs and/or boilers; this heats the digesters using tube-in-tube, counter-current heat exchangers ensuring optimum conditions for digester microbial activity. Sludge from the digesters is continually recirculated around the heat exchangers using 2 no. (duty/standby) recirculation pumps per digester. Valves are manually balanced to moderate the amount of hot water that passes into the heat exchanger, depending on the heat demand of the digesters.

Grit build up within digesters is a normal feature of operation; the digesters are cleaned out (including accumulated grit) approximately every 10 years as part of the planned periodic inspection which also includes an internal and external inspection of tank integrity and replacement of instrumentation and gas mixing equipment as required.

An automatic anti-foam dosing system is in place to control digester foaming. This system uses a radar level probe in the digester headspace and compares this to the pressure level sensor at the bottom of the digester to determine the depth of foam. Upon detection of foam, antifoam is automatically dosed into the sludge mixing pumps. This system includes operator-adjustable dosing setpoints; if the foam level continues to increase the digester feed will be inhibited. Antifoam is stored in an IBC within a dedicated cabinet with two dosing pumps to dose into the digesters as required.

Sludge extracted from the digesters is transferred via below ground pipeline and the interceptor pump station to the centrifuge feed tanks (see below for further information).

The digesters are due to undergo a major refurbishment by 2024 including improvements to the recirculation system and heat exchangers as well as installing impermeable surfacing to the area around the digesters. It is also proposed that a new sludge transfer tank will be installed adjacent to the digesters to receive sludge and a new transfer pumping station will be installed to transfer sludge to the centrifuge feed tanks.

Containment Best Available Techniques (BAT) for sludge digestion includes:

- The plant operates under PLC (programmable logic controller) and is largely automated.
- Monitoring is undertaken to check that the digestion process is healthy and stable. This includes temperature, solids, volatiles, fatty acids and pH, as well as biogas quality.
- Monitoring instrumentation including high level probes and pressure sensors linked to automatic PLC controlled pumps and other equipment to avoid potential loss of containment.
- An inspection and testing programme for above and below ground vessels, pipes and valves is in place. This incorporates a combination of visual examinations and non-destructive testing (e.g., ultrasonic thickness measurements).

3.2.1.3 Digested sludge treatment, handling and disposal

Digested sludge is transferred via below ground pipes and the interceptor pumping station to two centrifuge feed tanks (1 x uncovered 700 m^3 steel/GRP tank (No. 2) and 1 x uncovered 700 m^3concrete tank (No. 1), as shown in Figure 14). In these tanks the digestate is mechanically mixed, to prevent settlement. The tanks operate as a fill/draw pair. From these tanks the digestate is piped to the centrifuge building, which contains one centrifuge.

Figure 14. Centrifuge feed tank (no. 1 on the right, no. 2 on the left).

Within the adjacent polymer room, powdered polymer is dropped from a 700 kg bag into a hopper and then mixed with potable water in a *c.* 5 m³ polymer blend tank prior to being pumped to an adjacent *c.* 5 m³ polymer transfer tank where the polymer solution is held prior to use, as shown in Figure 15. The digested sludge is mixed with the polymer solution and then passed to the dewatering centrifuge where the sludge coagulates and supernatant liquor is removed by centrifugal forces. The liquor drops from the centrifuge into a wet well and is then pumped to the return liquor balance tank (Figure 16, steel, covered, 1,186 m³ capacity) located near the WwTW inlet. From here liquors are transferred to the WwTW for full treatment.

Figure 15. Polymer tanks within centrifuge building.

Figure 16. Return liquor balance tank

Sludge cake handling arrangements are currently being altered; the final digested and dewatered sludge cake will be dropped directly from the centrifuge onto a trailer prior to being transferred by tractor/trailer to the sludge cake pad. The cake pad is an engineered impermeable surface, with water runoff collected in drains running along edges of the pad. These liquids are pumped back to the WwTW (via the return liquor wet well (adjacent to the cake pad) and liquor balance tank) for full treatment.

Sludge cake is moved by mechanical loaders into storage rows on the cake pad area. There is no lime addition at Aldwarke; instead, cake is stored in piles according to age and is left for further pathogen reduction according to the Critical Limit in the HACCP plan. The maximum storage capacity of the cake pads is approximately 2,800 m^3; although less than this is stored under normal operating conditions (normally up to approximately 1,500 m^3). Once treatment is complete, sludge cake is removed from site and landspread in accordance with legislative requirements. Samples of digested, matured cake are taken every 3 months and analysed for metals and pathogens to ensure HACCP standards are being met.

A project is currently being developed to upgrade the digested sludge dewatering facilities including installation of a new raised dewatering system sized on the basis of peak digester throughput. The new facility would drop sludge cake directly on to the engineered cake pad. The existing centrifuge would be retained to provide back-up dewatering capacity.

The cake pad also serves certain contingency functions, for both operations at Aldwarke and to wider strategic regional sewage infrastructure operated by YW. The cake pad may, under exceptional circumstances (such as the failure of assets or non-availability of normal disposal routes on a temporary basis) be used for storage of treated digestate produced at other YW sites, before being recycled to agriculture. Similarly, other contingency measures could require, under exceptional circumstances such as failure of assets, the interim storage of thickened or dewatered sludge on the cake pad, where that sludge originates from another YW site (or from Aldwarke operations), before that material then undergoes AD treatment in the STF at Aldwarke, or if necessary is removed for further treatment at an alternative AD facility. It is recognised that such operations are abnormal and would require initiation of site contingency operating procedures, with the intention of minimising any potential short term adverse environmental effects and returning to normal operations as soon as practicable.

Containment Best Available Techniques (BAT) for sludge digestion includes:

- Engineered cake pad with leachate collected for treatment at the WwTW.
- An inspection and testing programme for pipes and valves is in place. This includes periodic surveys using in-pipe crack detection technology.

3.2.2 Tank volumes

The storage volumes, age and construction materials of the sludge and non-sludge tanks within the STF are summarised in Table 1.

Table 1. Aldwarke STF tanks and sumps, capacities, age, and construction materials.

Tank/ Sump	Size m^3 (each tank)	Year built	Construction material
2 no. thickener feed tanks	1,493	2013	Steel
2 no. digester feed tanks	500	1988	Concrete
2 no. digesters[a]	3,167 (2,820 above ground)	1968	Concrete
2 no. centrifuge feed tanks	700	1994 2009	Concrete Steel / GRP
1 no. return liquors balance tank	1,186	2013	Steel
2 no. drum thickener polymer tanks (bulk and solution)	5 2.5	2013	GRP
2 no. GBT polymer tanks (make-up and dosing)	1.5	2008	Steel
GBT thickener liquor underground sump	80	2008	Concrete
2 no. centrifuge polymer tanks (blend and transfer)	5	2009	Steel
1 no. gas-oil boiler back-up fuel tank	9.7	2005	Steel (integrally bunded)

[a] subsurface installation.

3.2.3 Current Engineering and maintenance standards

YW technical standards define the types of assets that meet the requirements of the business, including how they should be built and then maintained. In relation to Aldwarke, this covers:

- Design and construction of all assets, including selection of appropriately qualified design and build contractors.
- Procedures for inspection and testing of storage vessels, including internal and external inspections, thickness assessment and non-destructive testing.
- Regular inspections of above ground assets and associated pipework at defined intervals.
- Documented log of any actions arising because of these inspections.

YW's asset standards have been developed over many years and where relevant comply with Civil Engineering Specification for the Water Industry (CESWI) Seventh Edition March 2011 and the Water Industry Mechanical and Electrical Specifications (WIMES 9.02).

Contractors involved in the design/build of the Aldwarke scheme were YW framework contractors, appointed following a rigorous EU tender process; this process involved an assessment of experience, technical competency, design capability and quality procedures.

The combination of all these measures significantly reduces the risk of a catastrophic tank failure, thus reducing the likelihood of secondary containment being required. Nonetheless, it is recognised that the risk of a catastrophic tank failure cannot be eliminated, and external factors could always arise leading to very low likelihood, high consequence events (such as missile generation arising from other plant failure, domino effects or *force majeure*, for example an aircraft impact or terrorist attack).

3.3 Existing site surfaces

Most of the active process areas within the installation are covered by buildings, hardstanding and soft landscaping (grass and gravel cover). Surfacing was generally observed to be in good condition across the site. Site surfacing for Aldwarke STF is illustrated in Figure 17.

Figure 17. Aldwarke STF existing site surfaces.

3.4 Pathways

Pathways are the routes by which pollutants could travel from a source to the point where they could cause damage, the receptor. The potential pathways in this assessment were determined using computational flow modelling based on defined source spillage volumes. The modelling approach, limitations and spill volumes are outlined in the following sections, allowing the principal pathways to be identified.

3.4.1 Spill modelling

To model the potential impact of spills to the environment from the various sludge treatment assets at Aldwarke STF and defined credible pathways, YW has used PondSIM, a computational overland flow modelling tool. PondSIM can represent the flow of a liquid spill across an area of ground, taking account of local topography and flow restrictions (such as barriers). Applying this to the Aldwarke site has allowed visualisation of the likely effects of a spill occurring within each of the key areas of the permitted installation.

3.4.1.1 Modelling limitations and uncertainties

As with any computational modelling tool, there are several assumptions required and associated modelling limitations and uncertainties:

- PondSIM is designed to model the overland flow of water; as such it is not able to account for the typically higher viscosities associated with sludge, which results in a larger modelled inundation extent than would be expected.
- The model cannot allow for flow to drains and other subsurface features.
- Surge is not accounted for within the model. Instead, this will be allowed for by ensuring final designs consider CIRIA736 recommendations, while recognising the loss of kinetic energy as viscous sludge travels over flat ground.
- The model assumes that no mitigation measures are put in place following an incident to curtail flow.
- The model assumes that the full modelled volume spills from a single point.
- Assets are treated as simple flow barriers in the model, which may result in deflections being observed where flow would spread out.

Therefore, the modelled outputs are a worst-case inundation scenario resulting from sludge spills at Aldwarke. Notwithstanding these limitations, the use of PondSIM is considered appropriate as an initial screening tool for this study.

3.4.2 Spill volumes

YW has followed CIRIA C736 guidance on spill volumes to be modelled i.e., values equivalent to the containment provided by bunded tanks have been used. For a single tank the volume should be calculated based on 110 per cent of the capacity of that tank. For multi-tank installations, the containment volume is calculated based on 25 per cent of the total capacity of all the tanks in a common area (which assumes that it is unlikely that more than 25 per cent of tanks will fail simultaneously), or 110 per cent of the largest tank, whichever is greatest. Tanks which are hydraulically linked are treated as if they were a single tank.

The Aldwarke sludge storage tanks and treatment processes are installed as either multi-tank or single tank installations, as shown in Figure 18, where blue is a single tank installation and numbered yellow areas are multi-tank installation areas. Non-sludge vessels (i.e., polymer, water, and gas oil tanks etc.) have not been included within the PondSIM modelling. This is due to the site already having appropriate secondary containment measures in place, in accordance with YW's asset standards.

The digester tanks at Aldwarke are located partially below ground, therefore any volumes below ground can be considered contained, evidence of this can be seen in Appendix Figure 2. Consequently, only above ground volumes were used in the calculation of modelling volumes. The CIRIA C736 rule spill modelling scenario and associated containment volumes is listed in Table 2, whilst full calculations can be viewed in Appendix Figure 3.

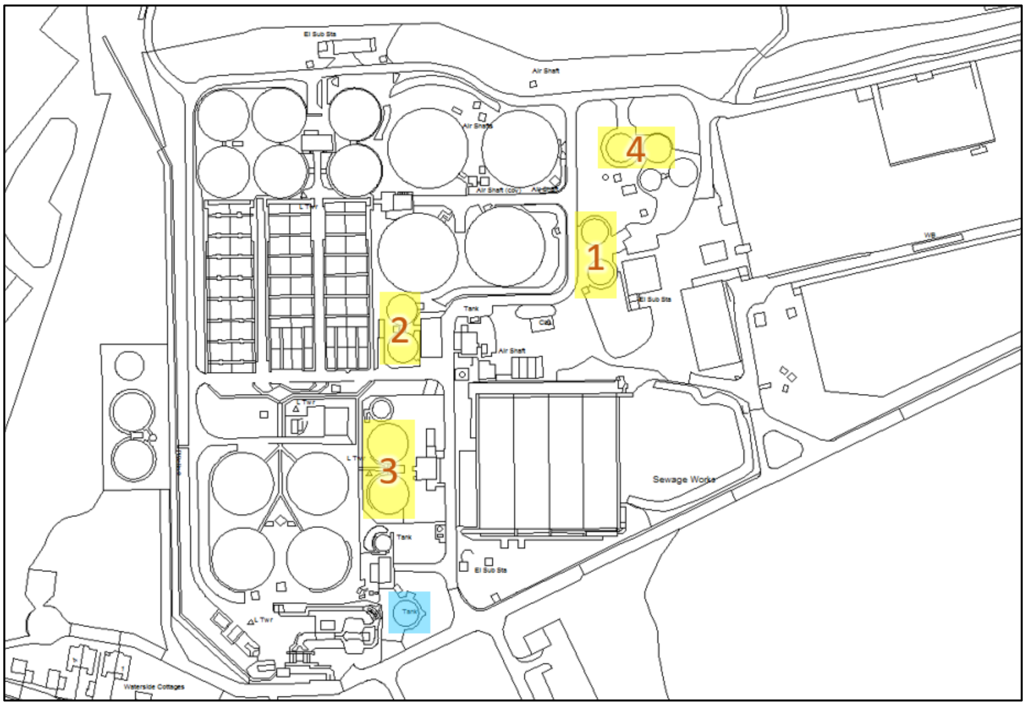


Figure 18. Aldwarke single tank (blue) and multi-tank installation areas (yellow).

Table 2. Volume of material used in spill modelling scenarios

Scenario	Capacity calculation	Modelled containment volume (m^3)	Modelling reference
CIRIA C736 rule	Single tank and multi-tank installations	7,369 (see Appendix Figure 3)	Figure 19

3.5 PondSIM modelling of unmitigated pathways

This section presents the modelling outputs showing unmitigated spills and resulting pathways from the identified sources, via surface pathways as calculated by PondSIM to the identified receptors.

This modelling assessment considered the effect of a simultaneous loss of containment from all the single and multi-sludge tank areas at the STF. Therefore, the model presented in Figure 19 represents the CIRIA C736 scenario, recognising limitations discussed in 3.4.1 Spill modelling. The location and direction of the modelled spills and adjacent treatment assets are discussed in section 3.7 Spill pathways.

It is important to note that owing to the limitations described in 3.4.1.1, and the specific topography of the Aldwarke site, it is not felt that PondSIM outputs at Aldwarke are fully representative of the likely impact of a tank collapse. The detail of this is discussed in following sections, but common themes are:

- PondSIM models fluids as having very low viscosity. In the hilly areas of a site such as Aldwarke, this leads to fluids travelling significant distances. In practice, pooling is likely to occur i.e., large spread in a small area, rather than long 'streams' covering significant distances.
- The aerial survey used to support the modelling is imperfect. At Aldwarke there are several small surface features which would be likely to retain sludge, that were not captured in the aerial survey. See photos in the following section for additional detail.
- PondSIM cannot model capture of liquid within site drainage system. In practice, the modelled flows travel over some areas of ground that has contained drainage which will capture a proportion of spilt material.

Note: the 'as is' model (Figure 19) shows the ASPs situated at the west of the site becoming inundated. This is unrepresentative of the site, as a sufficient tank lip height exists. Therefore, subsequent model runs to show bund effectiveness will be modified to increase barrier height to improve site representation and volume dispersion.

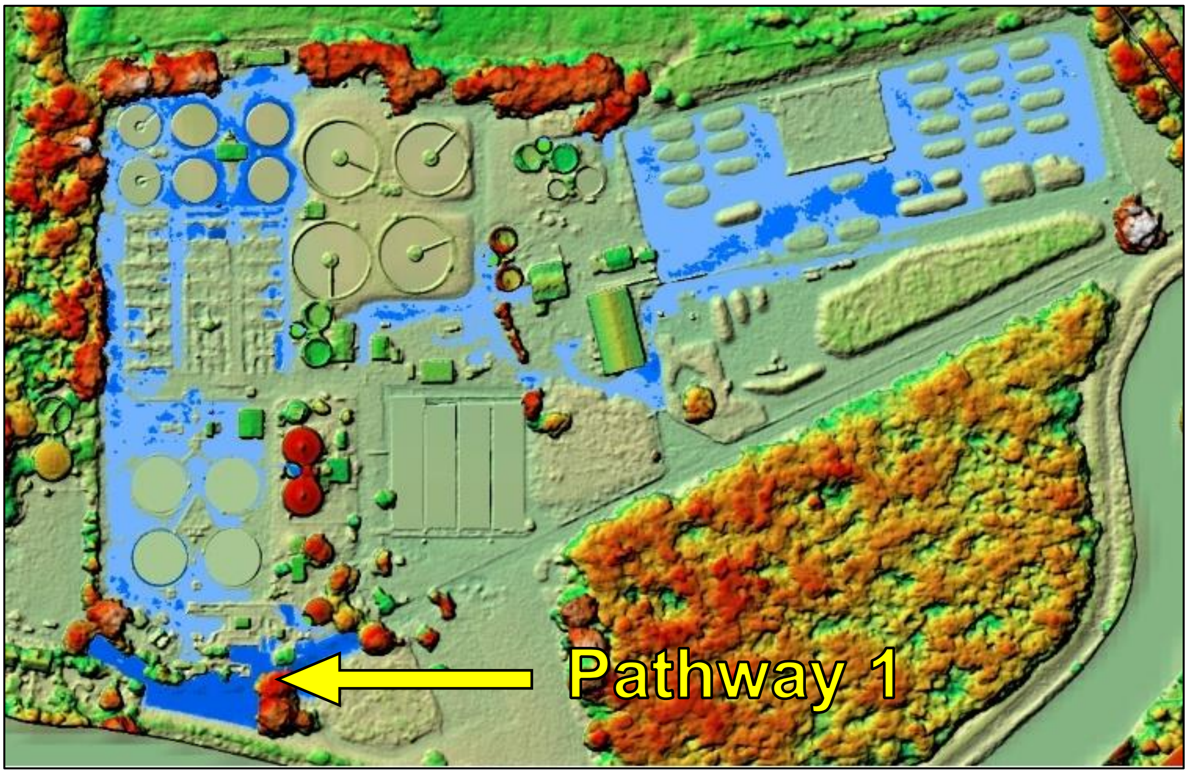


Figure 19. Model showing unmitigated result of spills and resulting pathways from existing tanks at Aldwarke STF using the CIRIA C736 rule.

3.6 Spill pathways

3.6.1 Surface drainage

A surface water drainage survey was completed at Aldwarke WwTW in September 2022. The survey mapped the location of gullies and manholes and identifying them as contained or non-contained drainage routes, as illustrated in Figure 20. Surface water drainage routes, shown in red, are routed to the inlet of the WwTW i.e., contained and routes shown in blue are routed to the outlet i.e., un-contained.

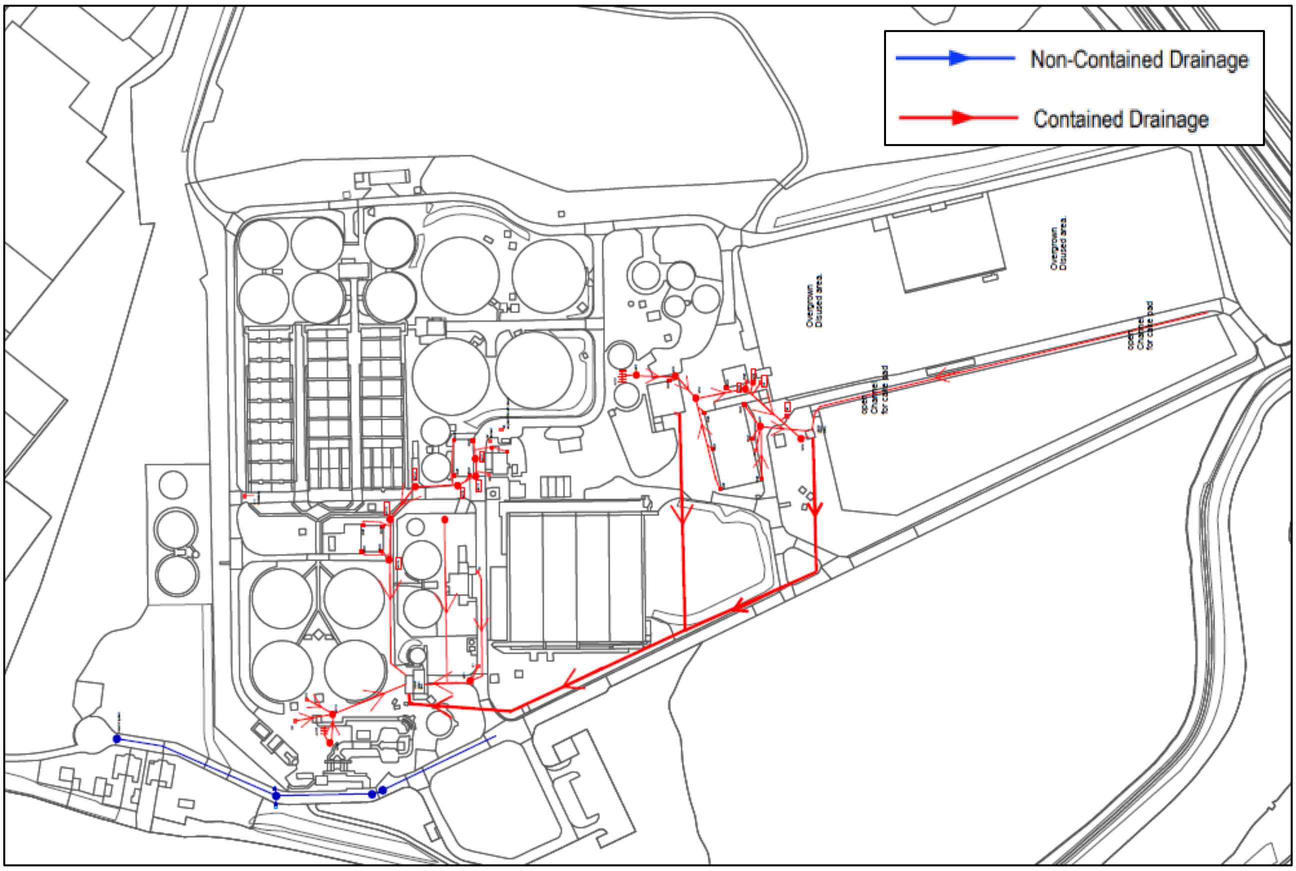


Figure 20. Aldwarke WwTW surface drainage route survey.

3.6.2 Unmitigated pathways

The unmitigated modelled spills show the potential of spill, predominantly from the digester and return liquor tanks to surround the primary settlement tanks (PSTs), including the access road that leads toward the domestic properties, as illustrated in Figure 21. Contained surface drainage is present throughout the site, mainly on access roads, which returns to the WwTW for treatment. However, surface drainage present on the access road south of the site is uncontained, and therefore presents a direct route to River Don (Pathway 1).

Medium confidence is given to these spills due to the limitations of the PondSIM in modelling surface drainage features that are contained, including the spread and exaggerated distances of a spill from digester contents.

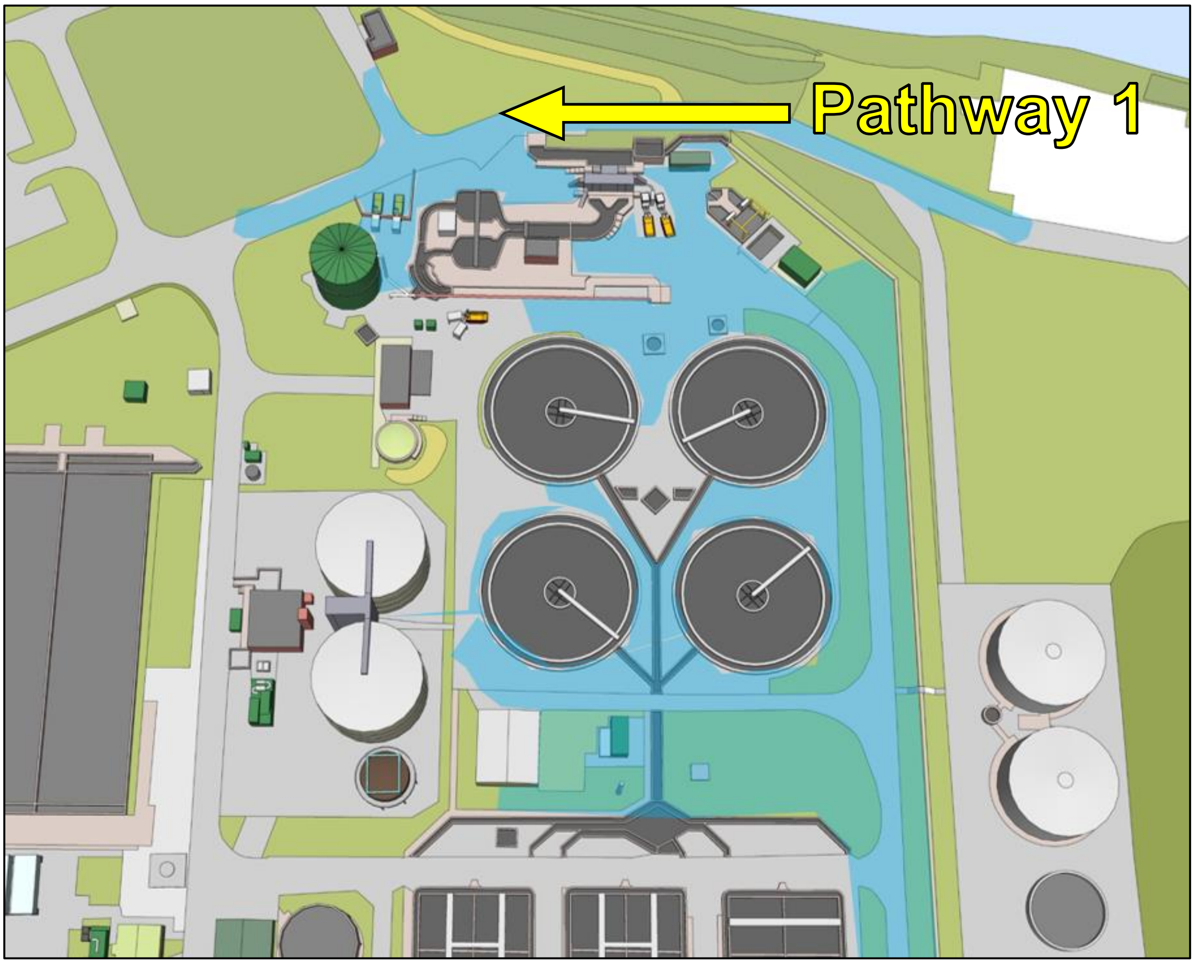


Figure 21. Spill pathway around and within the digester area.

Figure 22 shows the potential for an unmitigated flow of sludge merging and spilling toward the northern section of the site via a hardstanding access road, pooling around the ASPs and FSTs on top of soft landscaping, predominantly from the digester feed tanks. Additionally, potential spills from the thickener feed tanks spill across hardstanding access roads and soft landscaping central to the site.

Medium confidence is given to these spills due to the limitations of the PondSIM in modelling vegetation and rough surfaces, including the spread and exaggerated distances of a spill from digester feed tanks contents.

Figure 23 shows the potential for an unmitigated flow of sludge merging and spilling from the thickener and centrifuge feed tanks toward the western section to inundate the disused northern cake pad.

Medium confidence is given to these spills due to the limitations of the PondSIM in modelling surface drainage features that are contained in this area, including the spread and exaggerated distances of a sludge spill particularly from the contents of a centrifuge feed tank.

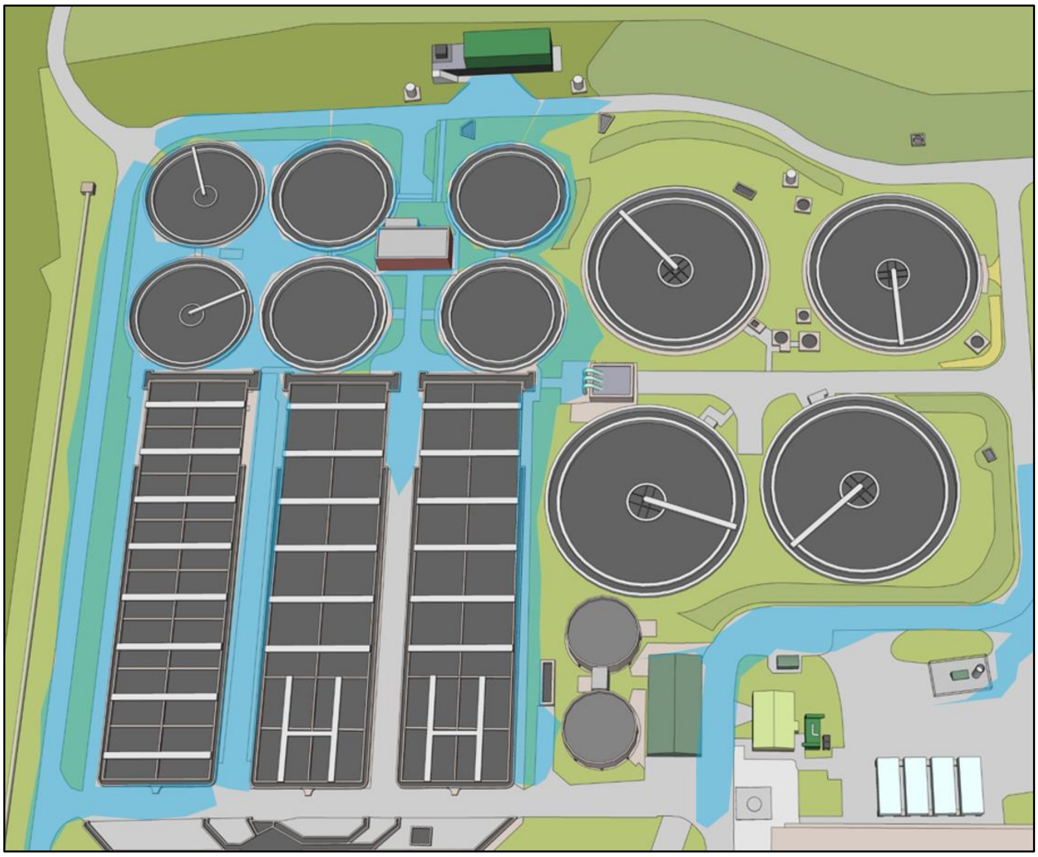


Figure 22. Spill pathway around the FST area.

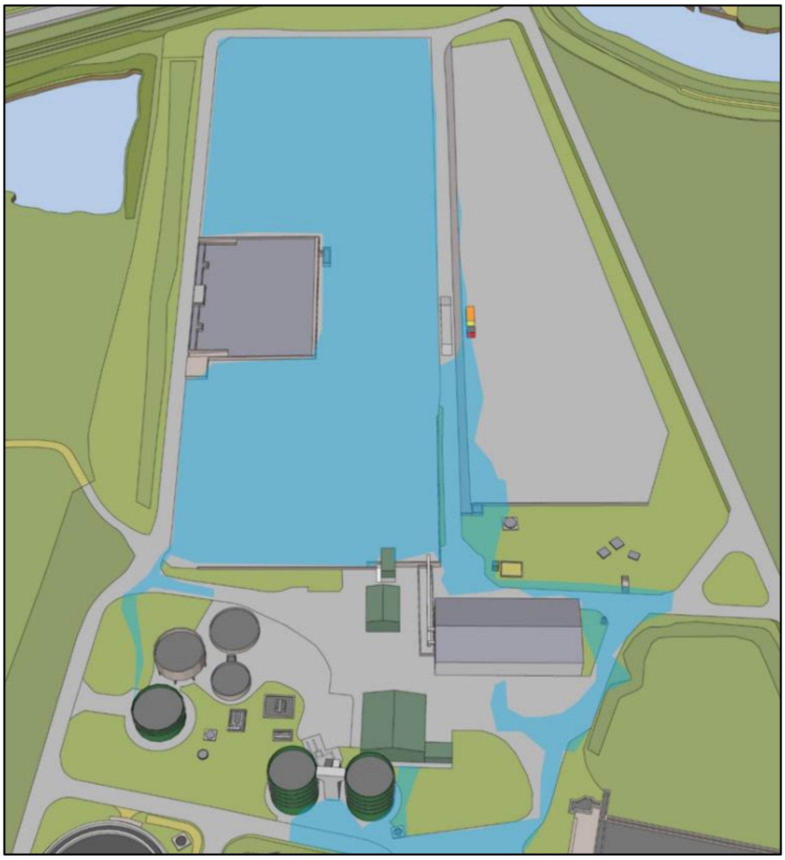


Figure 23. Spill pathway within and around the cake pads.

3.6.3 Spill pathway summary

Table 3 lists the resulting pathways associated with tank failure at Aldwarke determined using the PondSIM model. Full model results are presented in Section 3.4.

Table 3. Surface pathways from the key assets at Aldwarke.

Common area / Tanks	Surface pathways	Comments
Multi-tank installation area 1. (2 no. thickener feed tanks)	Overall medium confidence. Overland run-off to: • West of the site towards the ASPs • East of the site towards the disused northern cake pad	Spill volume captured on existing site access roads and cake pad hardstanding areas. Local surface water drainage in between the thickener feed tanks and in the centre of the cake pads is contained and is returned to the WwTW for treatment prior to discharge.
Multi-tank installation area 2. (2 no. digester feed tanks)	Overall medium confidence. Overland run-off to: • West of the site towards the ASPs and FSTs.	Spill flows across the site and is captured on hardstanding and road surfaces, including soft landscaping before reaching perimeter fencing to the west and the northern section of the site.
Multi-tank installation area 3. (2 no. digesters) + single tank area (return liquors balance tank)	Pathway 1 - overall medium confidence. Overland run-off to: • West of the site towards the storm tanks. • South of the site along access road and landbank.	Spill flows over both permeable and hardstanding surface and before reaching perimeter fencing to the west, including the landbank to the south of site. Local surface water drainage located south of the storm tanks and is returned to the WwTW for treatment prior to discharge. Surface water drainage on the southern access road is uncontained and therefore a route to river exists.
Multi-tank installation area 4. (2 no. centrifuge feed tanks)	Overall medium confidence. Overland run-off to: • Northeast of the site within the disused cake pad.	Spill flows over both permeable and impermeable surfaces before reaching the disused cake pad. The disused cake pad is not within the permit boundary and will not form a part of the bunding solution. Local surface water drainage in the centre of the cake pads is contained and is returned to the WwTW for treatment prior to discharge. Although not captured in PondSIM modelling, a tank rupture could lead to a significant spill to the grassed area south of the centrifuge feed tanks.

3.7 Receptors

To complete the source pathway receptor model, a review of sensitive receptors was conducted in conjunction with the accompanying ADBA Assessment and Site Condition Report detailing site setting, geology and groundwater. These were identified based on professional judgement, modelling results and potential flow paths which may take any cardinal direction in lower lying areas. Figure 24 shows the receptors identified which could theoretically be impacted by a loss of containment from sludge vessels at Aldwarke.

Table 4 lists the type of pathway potentially leading to each receptor e.g., indirect, such as via FSTs, permeable surfaces or direct to the environment, e.g., a flow path into the River Don.

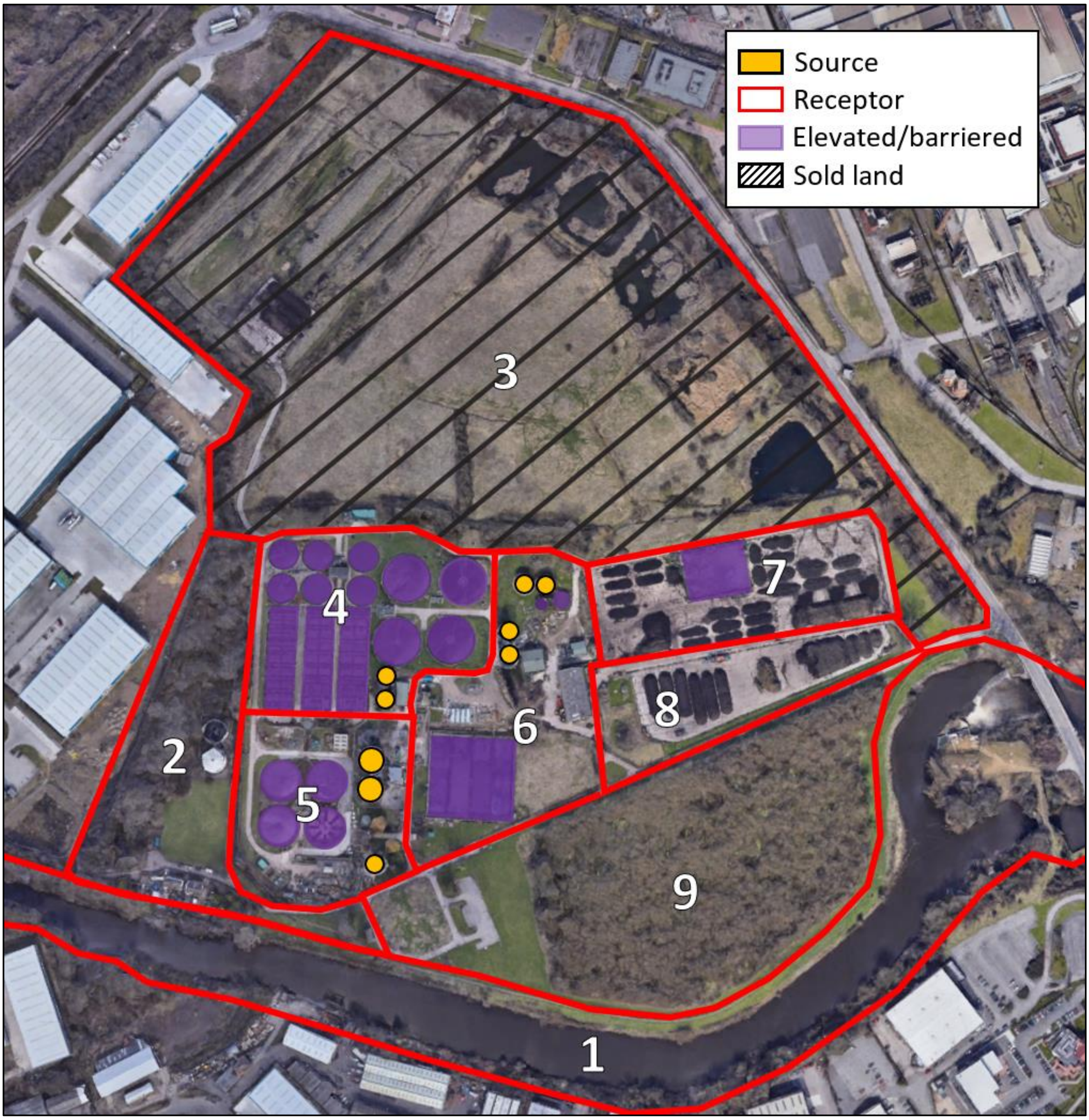


Figure 24. Map of numbered receptors at Aldwarke. © Google, 2021.

Table 4. Receptor number and description.

Receptor no.	Receptor
1	River Don (including adjacent habitats).
2	Ground / groundwater – area surrounding west of the site, including domestic properties.
3	Ground / groundwater – scrubland area north of the site.
4	Ground / groundwater - areas surrounding the digester feed tanks, including FSTs.
5	Ground / groundwater - areas surrounding the digesters and return liquors balance tank, including PSTs.
6	Ground / groundwater - areas surrounding the thickener and centrifuge feed tanks.
7	Ground /groundwater – area including and surrounding the northern cake pad and lagoon.
8	Ground / groundwater – area including and surrounding the southern cake pad.
9	Ground / groundwater - areas including and surrounding woodland.

3.8 Source-pathway-receptor summary

A summary of the receptors at risk following the modelling of spill pathways from identified sources at Aldwarke STF is listed in Table 5. According to the modelling, receptors 3 (scrubland area) and 9 (woodland) are unlikely to be at risk.

Table 5. Source-pathway-receptor summary

Common area / Tanks	Surface pathways	Receptors at risk
Multi-tank installation area 1. (2 no. thickener feed tanks)	Overall medium confidence. Overland run-off to: • West of the site towards the ASPs • East of the site towards the cake pads	• Receptor 6 - Ground / groundwater - areas surrounding the thickener and centrifuge feed tanks [high confidence]. • Receptor 8 - Ground / groundwater – area including and surrounding the southern cake pad [medium confidence]. • Receptor 7 - Ground /groundwater – area including and surrounding the northern cake pad and lagoon [medium confidence]. • Receptor 4 - Ground / groundwater - areas surrounding the digester feed tanks, including FSTs [low confidence].
Multi-tank installation area 2. (2 no. digester feed tanks)	Overall medium confidence. Overland run-off to: • West of the site towards the ASPs and FSTs.	• Receptor 4 - Ground / groundwater - areas surrounding the digester feed tanks, including FSTs [high confidence]. • Receptor 5 - Ground / groundwater - areas surrounding the digesters and return liquors balance tank, including PST tanks [medium confidence]. • Receptor 2- Ground / groundwater – area surrounding west of the site, including domestic properties [low confidence].
Multi-tank installation area 3. (2 no. digesters) +	Pathway 1 - overall medium confidence.	• Receptor 5 - Ground / groundwater - areas surrounding the digesters and return liquors balance tank, including PST tanks [high confidence].

Common area / Tanks	Surface pathways	Receptors at risk
single tank area (return liquors balance tank)	Overland run-off to: • West of the site towards the storm tanks. • South of the site along access road and landbank.	• Receptor 1 - River Don (including adjacent habitats) – direct route via uncontained surface drainage. • Receptor 2- Ground / groundwater – area surrounding west of the site, including domestic properties [medium confidence]. • Receptor 2- Ground / groundwater - areas surrounding the digester feed tanks, including FSTs [low confidence].
Multi-tank installation area 4. (2 no. centrifuge feed tanks)	Overall medium confidence. Overland run-off to: • Northeast of the site within the northern cake pad.	• Receptor 6 - Ground / groundwater - areas surrounding the thickener and centrifuge feed tanks [high confidence]. • Receptor 7 - Ground /groundwater – area including and surrounding the northern cake pad and lagoon [high confidence]. • Receptor 8 - Ground / groundwater – area including and surrounding the southern cake pad [medium confidence]. • Receptor 7 - Ground /groundwater – area including and surrounding the northern cake pad and lagoon [medium confidence]. • Receptor 1 – Sludge entering the open chamber (south of the centrifuge feed tanks) that is linked to the final effluent (FE) line would quickly flow to the River Don.

3.9 Mitigation solutions

An iterative process was completed to develop bunding options that provide environmental protection in accordance with CIRIA C736, including different methods for achieving impermeable surfaces within the bunded area. Determination of the preferred solution considered financial viability, sustainability to reduce impacts from embodied carbon and availability of materials to allow timely implementation given the timeframes of meeting compliance.

The solution identified is illustrated in Figure 25, with further specification and dimensions given in Appendix Table 1. This solution achieves CIRIA C736 compliance and includes consideration of the following:

- **Bund height:** calculated using the CIRIA C736 25/110 percent rule, divided by the area encompassing the bunded area not including the footprint of tanks, buildings, and other obstructions. Rainwater handling was also considered.
- **Surge allowance:** CIRIA C736 table 6.3 specifies the freeboard required to protect against surge. Recognising these recommendations, an allowance of 0.25m for walling and 0.75m for earth works has been added to the bund heights to protect against surge.
- **Drainage**: all surface drainage infrastructure will be assessed during the design phase to confirm sufficient capacity is available to deal with rainwater falling into the bund.
- **Walling**: in-situ or pre-cast products are considered to allow for installation where space is limited and considers pre-existing walling as part of the installation.
- **Earth works:** non-engineered and engineered constructed earth bund materials are considered where space is available, this includes existing earth embankments. Where earth bunds are a preferred option, bentonite clay matting, concrete matting, or poured concrete will be used to produce an impermeable outer surface.

- **Permeable areas:** all permeable areas of land within the bund (as referenced in Figure 17 and as shown in Figure 25 within areas of red) will be made impermeable where construction allows, and considers poured concrete and matting, including bentonite clay matting to reduce embodied carbon.
- **Hardstanding areas:** existing areas of hardstanding that will form part of the containment solution (in-situ concrete, access roads) will be assessed to ensure that they provide a level of containment consistent with the requirements of CIRIA C736.
- **Asset access requirements:** the digester feed pumps are situated very closely to the digester feed tanks and proposed containment bund, therefore access to the pumps will be severely impacted. YW have committed to relocate the digester feed pumps to improve operational access and to reduce the complexity of constructing the bund.
- **Open grating:** a final effluent wet well is present on a grassy section in between the centrifuge and thickener feed tanks (Figure 26), which is connected to the site outfall. YW commit to building mitigation on or around the open well for spill containment, including protection against both surge and jetting, for example a sealed lid.

YW have committed to install a containment solution that complies with CIRIA C736. The current preferred design is shown below but may be subject to minor modifications and amendments during detailed design phase.

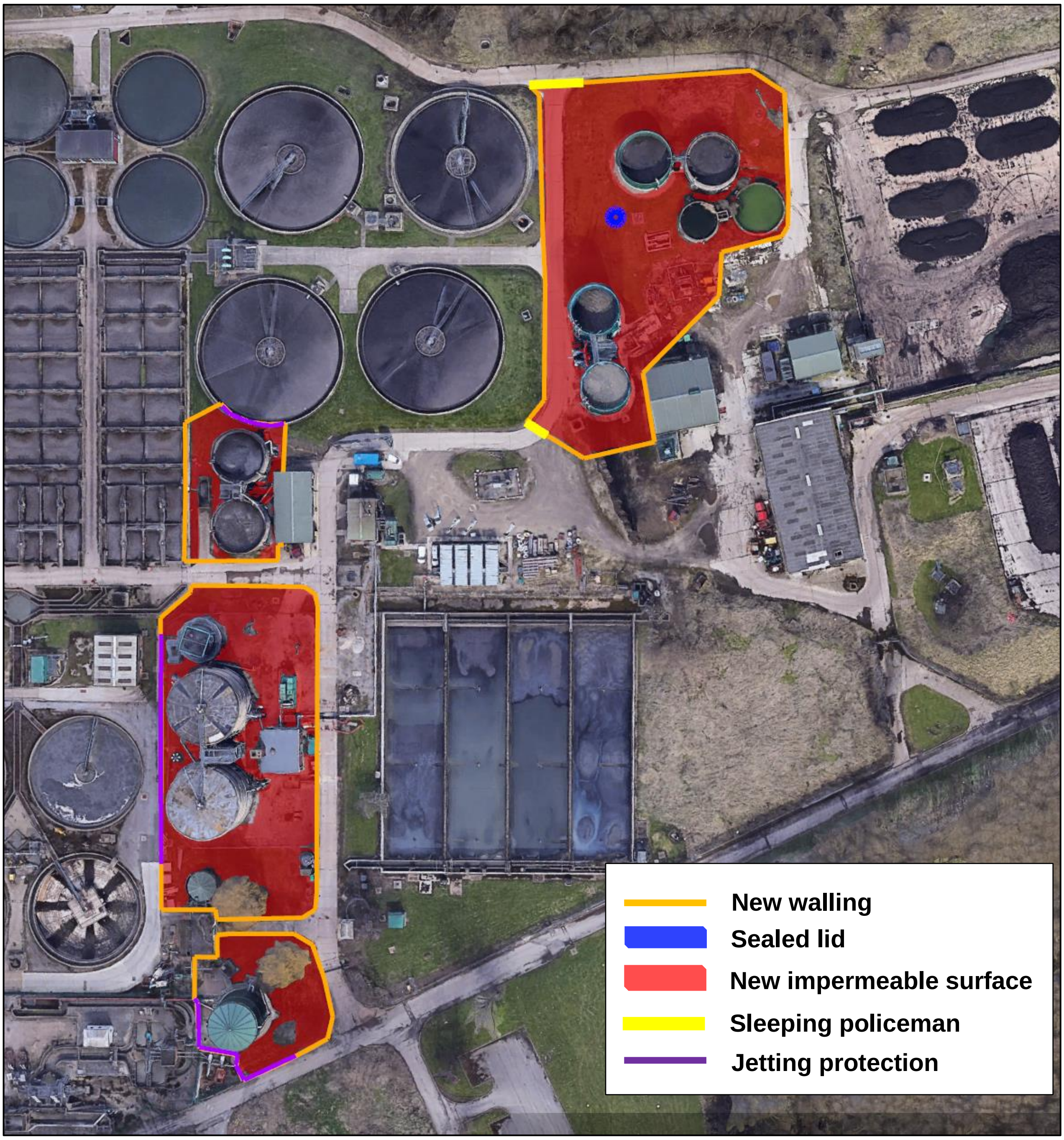


Figure 25. Full bunding solution for Aldwarke.

Figure 26. Outlet open well near steel centrifuge feed tank.

3.9.1 Surge

The catastrophic collapse of a tank would lead to a rapid release of sludge. As is normal for liquids, the sludge will tend to flow over obstacles. CIRIA C736 provides guidance on the height of bund wall that is required to ensure surge flow does not pass containment walls. This guidance is particularly relevant where the bund wall is close to, or downhill from, the vessels for which it is providing containment. As flow travels across flat ground, it will lose speed and the risk from surge will rapidly decrease. This is particularly true with a relatively viscous liquid such as sewage sludge.

The digesters at Aldwarke initially pose containment risk for a potential surge spill to impact the primary settlements tanks (PSTs) directly adjacent to them, including the rectangular storm tanks on the opposite side, as illustrated in Figure 27 and Figure 28. However, the proposed solution for containment, as discussed above, includes the CIRIA C736 surge protection height requirement and will mitigate a surge of sludge from reaching the WwTW assets.

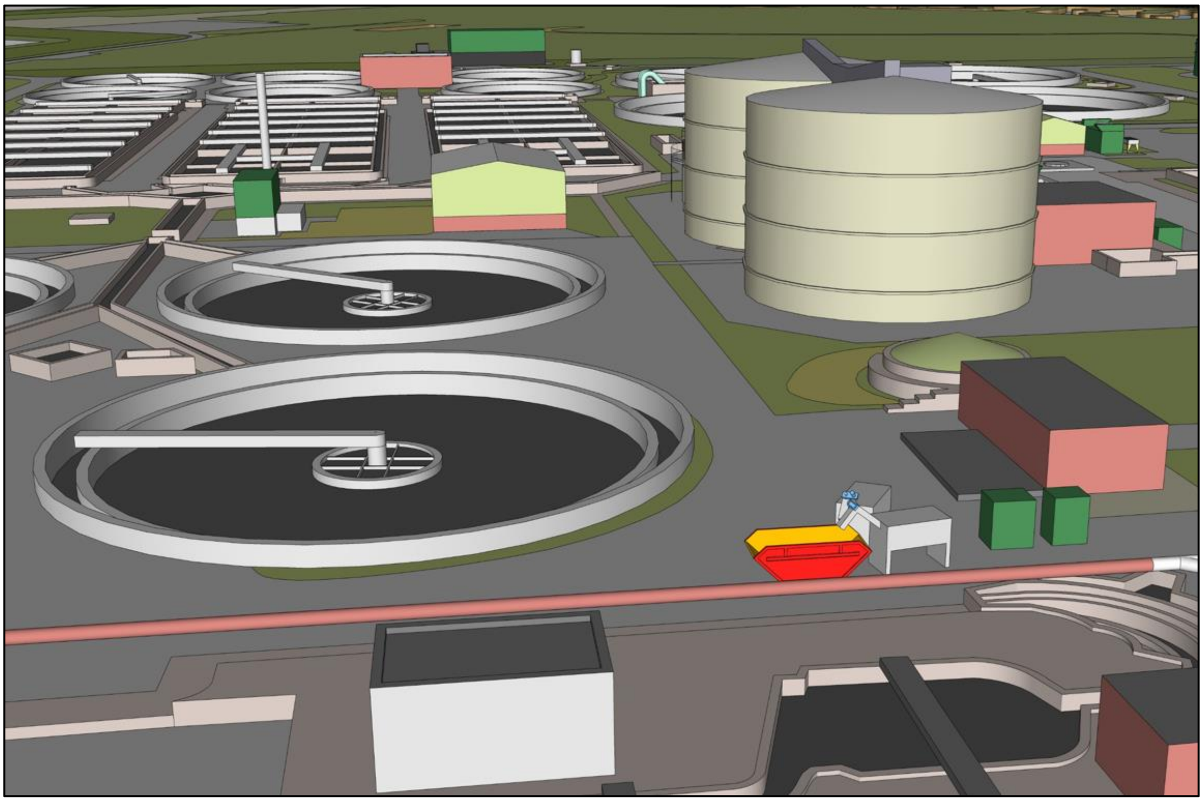


Figure 27. Surge concern from digesters to PSTs.

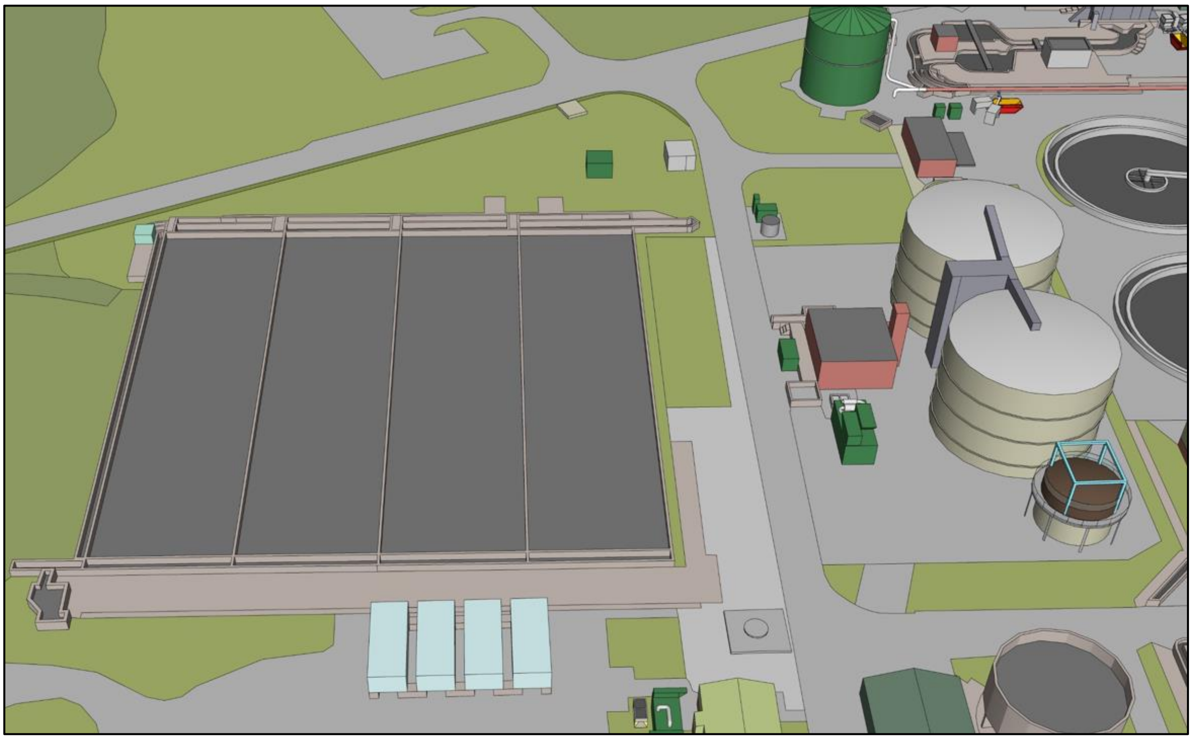


Figure 28. Surge concern from digesters to storm tanks.

3.9.2 Jetting

YW recognises that surfaces which could receive a sludge spill because of tank failure will require an impermeable surface. This means tank leaks, including jetting, will be contained at Aldwarke. There is a risk at the outer edges of these compounds, where jetting could cause sludge to pass out of the bunded area, including the permit boundary or at close vicinity of indirect routes to sensitive receptors.

Within this context, the tanks that are of particular risk are shown within Figure 29, the blue circles show segments where jetting is a concern. Purple lines show where mitigation is required where it overlaps the bund wall and FST tanks. Figure 30 shows requirement of jetting protection due to the vicinity of the FST (indirect route to River Don) with respect to the northernmost digester feed tank.

In addition, the jetting profile of the right centrifuge feed tank located in the northern section of the site overlaps two open tanks directly adjacent to it. These two tanks are out of service and are redundant. They are currently isolated and are appropriately incorporated into the final bund design in this area to ensure full containment of any spills is achieved.

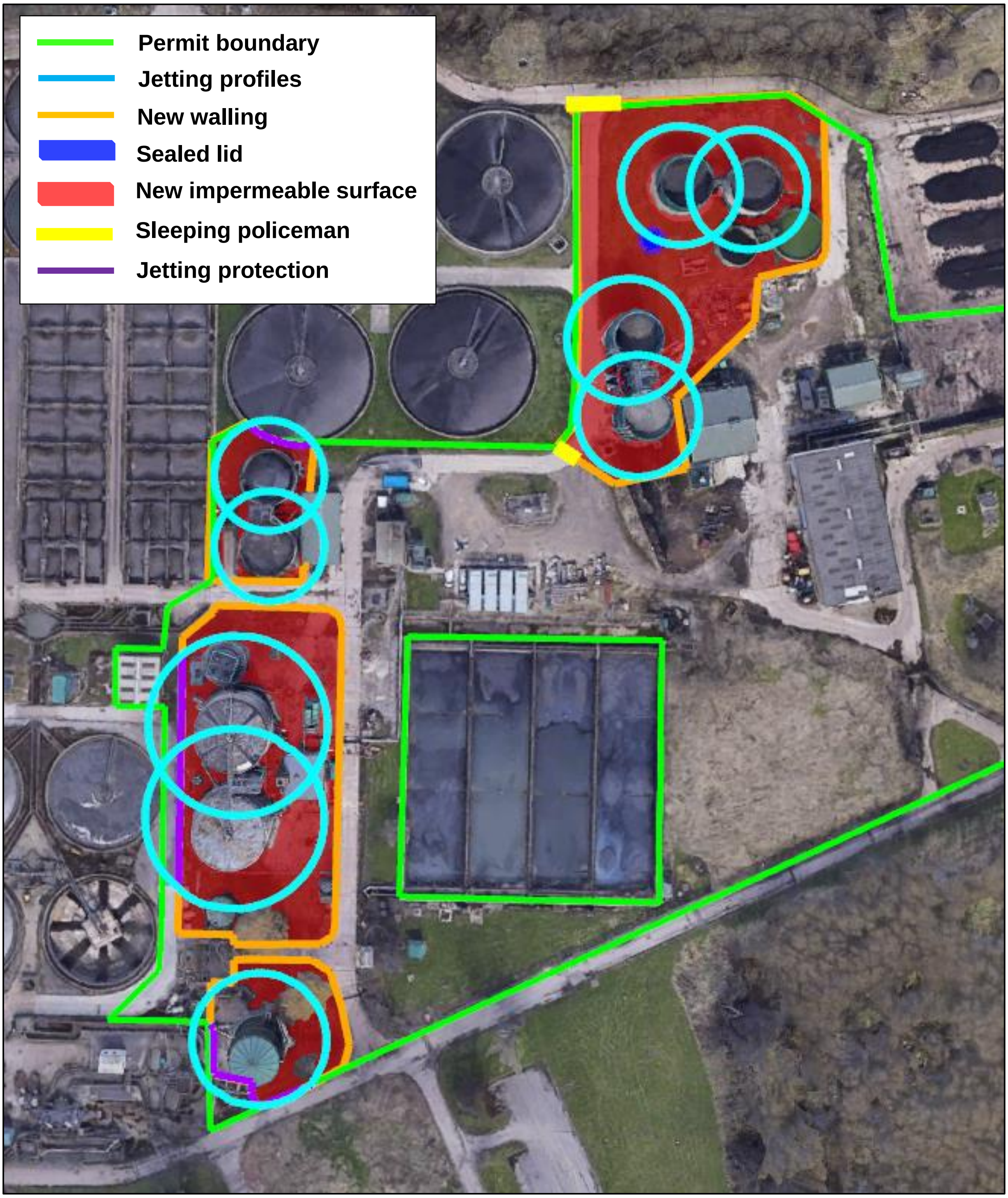


Figure 29. Jetting profiles for Aldwarke.

Figure 30. Northernmost digester feed situated close to an FST.

The risk of environmental harm as a result of jetting from these tanks has been assessed as low for the following reasons:

- YW design, construction and monitoring controls ensure tanks are constructed to a high standard and would identify any critical weaknesses at an early stage, and well before catastrophic failure occurred.
- The concrete tank construction means that formation of a hole large enough to allow jetting, but small enough to avoid total tank collapse is hard to envisage. If failure were to occur, it is much more likely to initially show as cracking, giving time to respond before significant sludge escaped.
    - A technical note has been provided in Appendix 3 that validates the failure mechanism of a tank constructed from concrete.
- The sludge in the concrete digesters is relatively viscous and this is likely to reduce the extent of jetting as viscous materials will travel relatively slowly through an orifice.
- The most likely cause, albeit still very unlikely, of a tank wall puncture that would allow jetting is a direct impact. If this were to happen, it would almost certainly be at ground level. The containment walls which YW have already committed to build would contain this kind of release.

YW understand that while risk is low, the design of the containment walls shown in Figure 25 must consider protection against jetting. The recently issued EA guidance on spills to permeable surfaces means YW is reconsidering its approach to jetting, but this work is in progress and no final designs are available for jetting protection as these will not be standard retrofit solutions, furthermore the space available between the tanks and bund walls is limited, therefore creating an additional challenge to its implementation.

Jetting mitigation solutions, with respect to the CIRIA C736 jetting calculation (Appendix 5), including space and access constraints are likely to look like the following:

- Freestanding baffled walls comprised of rolled steel joists and suitable panelling materials.
- Installation of jetting deflection panels/mesh attached to, or very close to, tank wall.
- Jetting deflection screen on top of bund wall in locations necessary to prevent liquid passing over the wall.

YW understand the CIRIA736 requirements linked to jetting and will confirm that the preferred jetting solution is acceptable to the EA prior to construction. The jetting solution will be identified when a civil contractor has been appointed and detailed design stage of the bund commences.

3.10 CIRIA C736 compliance, effectiveness, and construction.

The secondary containment solution at Aldwarke will be implemented by contractors chosen via YW's procurement process. This process is designed to ensure contractors have the knowledge and experience to build a secondary containment solution that complies with CIRIA C736.

The effectiveness of the containment and jetting solution will be confirmed using a 3D model and spill modelling software. YW will confirm that the final bunding solution is acceptable to the EA prior to commencement of the build.

4 Preventative maintenance and inspection regime

4.1 Above ground tanks

All tanks are tested and inspected as part of initial construction quality assurance checks; an example of a tank check is shown in Appendix 6.

The tanks at Aldwarke are regularly inspected by a qualified engineer. As part of these inspections, the reinspection period of each tank will be determined by the inspection engineer (anywhere from 6-months to 3 years depending on the condition of the tank). Any defects identified during inspections will be actioned and remedial works carried out as soon as possible.

Visual checks on tanks also form part of daily/weekly operational checks. These ensure that any damage or major degradation of tanks is identified as a risk and is reported before a hazard can develop.

4.2 Below ground level tanks/chambers

YW understand the environmental risk associated with underground structures and are committed to identifying and rectifying any leaks from them at the earliest possible opportunity. To support this aim, YW commit to the following:

- Daily visual inspection (Mon-Fri on certain sites) of subsurface tanks, wells, and surrounding ground by site operational team. These checks will identify major structural issues visible above liquid/ground level and any changes in ground conditions.
- Monthly visual inspection of subsurface tanks, wells, and surrounding ground by a technically competent manager.
- Apply additional monitoring.
    - Three monitoring techniques have been identified as appropriate for subsurface tanks/chambers. For each subsurface, liquid containing structure, the single most appropriate monitoring technique will be confirmed and implemented.
        - Borehole monitoring – sampling of up- and down-hydraulic gradient boreholes located around a tank perimeter will allow leaks from the tank to be detected and investigated as required. Following an initial period of monitoring to establish a baseline, trigger levels will be set and agreed with the EA.
        - Drop testing - the chamber/tank will be filled to normal maximum operating level, covered to prevent loss by evaporation, and left for 24 hours. For each tank an acceptable drop in level will be specified, if this is passed during the test, a repair will be completed
        - Empty and inspect – tanks will be emptied, cleaned and a visual inspection completed.
- Risk assessments in line with CIRIA C736 will be completed to confirm inspection frequencies on all subsurface tanks.
- Repair timescales.
    - Where a leak is detected using any of the above techniques, YW will isolate the source of the leak e.g., empty or bypass the tank as soon as practicable, with a target time of less than 14 days. The tank will not be returned to service until a repair has been completed

The use of inlet/outlet flowmeters to detect leaks has been considered, but the large volumes of flow passing through pipes combined with accuracy limitations of the instrument mean that leaks are likely to have already had an environmental impact, visible at ground level, by the time they are large enough to be detected. On this basis YW do not consider flow comparison to be a useful tool for leak detection.

4.3 Underground pipes

To mitigate the risk of failure of underground pipework, e.g., cracks and splits, surveys are completed using in-pipe crack detection technology every 2 years if mechanical joints are present, and 5 years if they are not. For future pipe installations, underground pipework will be avoided. Where this is not possible, pipes will be installed with secondary containment and leak detection.

In the event of an incident/ accident a team will be deployed immediately to isolate the damaged pipe and a spill management procedure will be followed. Thereafter, repairs to the damaged pipework will be arranged. Additionally, the incident will be logged, and hazard assessed to reduce or eliminate the risk of occurrence.

5 Implementation and timescales

5.1 Monitoring

- At present YW do not have any boreholes installed for leak detection. YW commit to completing site surveys to confirm where these are an appropriate monitoring technique by 31st November 2023.
- After completion of surveys, YW commit to providing the EA with an updated list of all subsurface tanks, with detail of monitoring technique, frequency and how results will be recorded by 31st November 2023.
- YW commit to supplying a detailed procedure for the appropriate site-specific method for monitoring sub surface tanks by 31st November 2023.

5.2 Construction

A plan outlining the implementation of containment solutions identified is shown in Table 6. The timescales and estimated dates are indicative, and subject to timely external contract appointment, including acceptance of the procedures and ideal weather conditions for construction. Furthermore, bottlenecks, such as resource availability due to ongoing number of installations has not been factored in. These will be revisited once contractors are appointed, and capacities understood.

Table 6. Secondary containment implementation stages and schedule.

Stage	Estimated date complete
Procurement, tender and award of contractor for detailed bunding design	October 31st 2022
Completed design	1st January 2024
Commence construction	30th April 2024
Complete construction	Within current AMP

6 Conclusions and recommendations

This study has used a source-pathway-receptor model to consider risks associated with credible worst-case loss of containment scenarios in each of the main working areas of the Aldwarke STF installation. A computation modelling study has been undertaken, which has adopted conservative assumptions to address known limitations of this type of modelling tool. This enabled the potential effects of a substantial, unmitigated loss of containment to be considered; a need enhanced mitigation was identified to achieve an equivalent level of environmental protection for the identified sensitive receptors (the metric of compliance being an equivalence to a traditional 25 / 110 per cent capacity secondary containment bund in line with CIRIA 736 via the ADBA study).

YW have considered the following factors and will ensure current and new mitigation measures are maintained to ensure adequate environmental protection:

- **Operability**
  - The construction of a standard, complete concrete bund around all tanks within the STF would introduce significant operational issues around vehicle access to those assets and a health and safety risk in the event of a catastrophic failure associated with potentially trapped personnel.

- **Buildability**
  - Adding secondary containment to an existing, operational, site presents significant challenges. Whilst a solution may ‘on paper’ present itself as a viable and effective candidate option, reality and practicality dictates that it must be deliverable, or it would not fall under the ‘available’ definition of BAT.

- **Likelihood**
  - Whilst the potential for catastrophic tank failure can never be wholly mitigated when sites are operated with large tank inventories, the likelihood of substantial failure is very low, as evidenced by YW’s own track record of operating sludge storage/treatment vessels across its asset base.
  - In support of likelihood of failure YW has reviewed actual failure data. YW has over 40 years of experience in operating AD plants and STF’s. YW has 14 AD sites. In this time YW has not experienced the catastrophic collapse of a storage vessel.
  - YW has found from experience that ‘failures’ of concrete tanks are generally associated with ancillaries such as joints, waterstops, seals, etc, rather than any inherent defect with the actual civil structure. YW has experienced one incident of note, and this was at Hull STF digester number 5. This example is a case in point; the release of sludge that occurred was caused by the failure of a ‘link seal’ mechanical coupling that should have provided a watertight seal around the outside of a mixer pipe intrusion. In comparison with a catastrophic collapse scenario, this resulted in relatively controlled spill of small volume.

- **Environmental impact**
  - Receptors in the area must be protected from the effects of major sludge spills.
  - The carbon impact of creating entirely impermeable containment areas is significant and counter to YW’s aim of achieving net zero carbon emissions by 2030, it also potentially alters the catchment flow characteristics of what is a very large site in immediate proximity to a major river, with a demonstrable history of flooding in recent years.

Considering the conservative assumptions of the modelling (such as the viscosity of sludge compared to water) and the scoring approach which considers multiple decision factors including the significant carbon impact of the CIRIA 736 standard options, YW concludes that the identified combination of potential solutions will deliver an optimal balance between:

- **Use of existing infrastructure**
  - Site drains in the north and eastern sections are able to return liquid to the inlet works for treatment, providing containment and flow mitigation.
  - The cake pad has been engineered to drain liquid contents, which returns to the inlet works of the WwTW, acting as remote containment.
  - For most spills, leaks and catastrophic pipe failures the site surfacing and drainage would transfer liquid to the WwTW, which would contain and minimise potential effects of loss of containment.

- **Continuation of the measures already in place** to minimise the likelihood of catastrophic failure of sludge vessels, through the use of stringent technical standards and regular visual inspections.

- **Controlling the risk to sensitive receptors** from sludge spills resulting from a worst-case scenario of catastrophic tank failure.

- **Reducing the carbon footprint** associated with the construction and operation of the solution; and

- Ensuring that the solution has **no negative health and safety implications** for staff on the site.

The study undertaken, although considered comprehensive and robust, does represent an initial feasibility / conceptual stage design exercise and extensive further work will be required to validate a solution for a potential build. Once it is confirmed that the preferred options put forward in this report are acceptable in principle to the EA, YW commits to commence a technical feasibility and detailed design study, with associated timetable for implementation of the resulting final mitigation measures. This will allow remaining uncertainties regard engineering integrity, modelled flow extents, design safety, cost engineering and constructability to be resolved.

7 Appendices

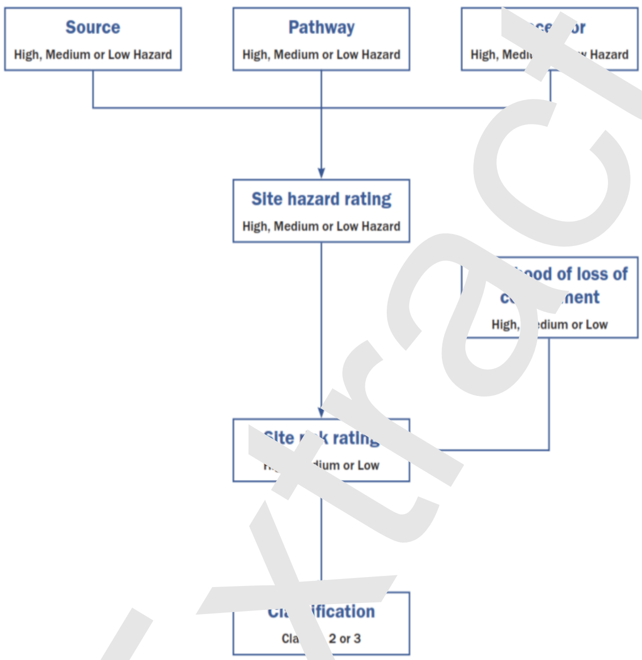
Appendix 1 – ADBA assessment tool

Screenshot from spreadsheet containing full assessment. Full document included as part of permit submission.

Although this tool works as a standalone tool, we recommend you read this first: ADBA CIRIA736 Bund Classification Assessment

There are 5 steps to follow:

1) Identify the hazard posed to the environment by the inventory of materials held on the site and the location of the site
   a. Categorise the source
   b. Identify the pathways
   c. Identify the receptor
2) The Site Hazard Rating is derived by this tool from the combination of the hazards assessed above
3) Calculate the likelihood of a loss of primary containment event occurring
4) The combination of the Site Hazard Rating and the likelihood of a loss of containment occuring gives the site risk rating and required secondary containment classification
5) From the class of containment needed, identify suitable designs from the 'Standard Containment Designs' sheet



Additional Guidance

As detailed in section [illegible] of CIRIA C736, determining an overall hazard rating for the site is largely subjective, and assessing the [illegible] effects is a judgement based on knowledge, experience and the degree of confidence in the information available.

Section 2.4 of CIRIA C736 states: *"where there is uncertainty about the correct categorisation of any of the individual source, pathway or receptor hazard ratings, it may be appropriate to move the overall site hazard category to the next higher rating".*

The worksheets in this spreadsheet are protected to prevent inadvertant damage to the tool. To remove the protection, the password is CIRIA736

Appendix Figure 1. ADBA spreadsheet screenshot.

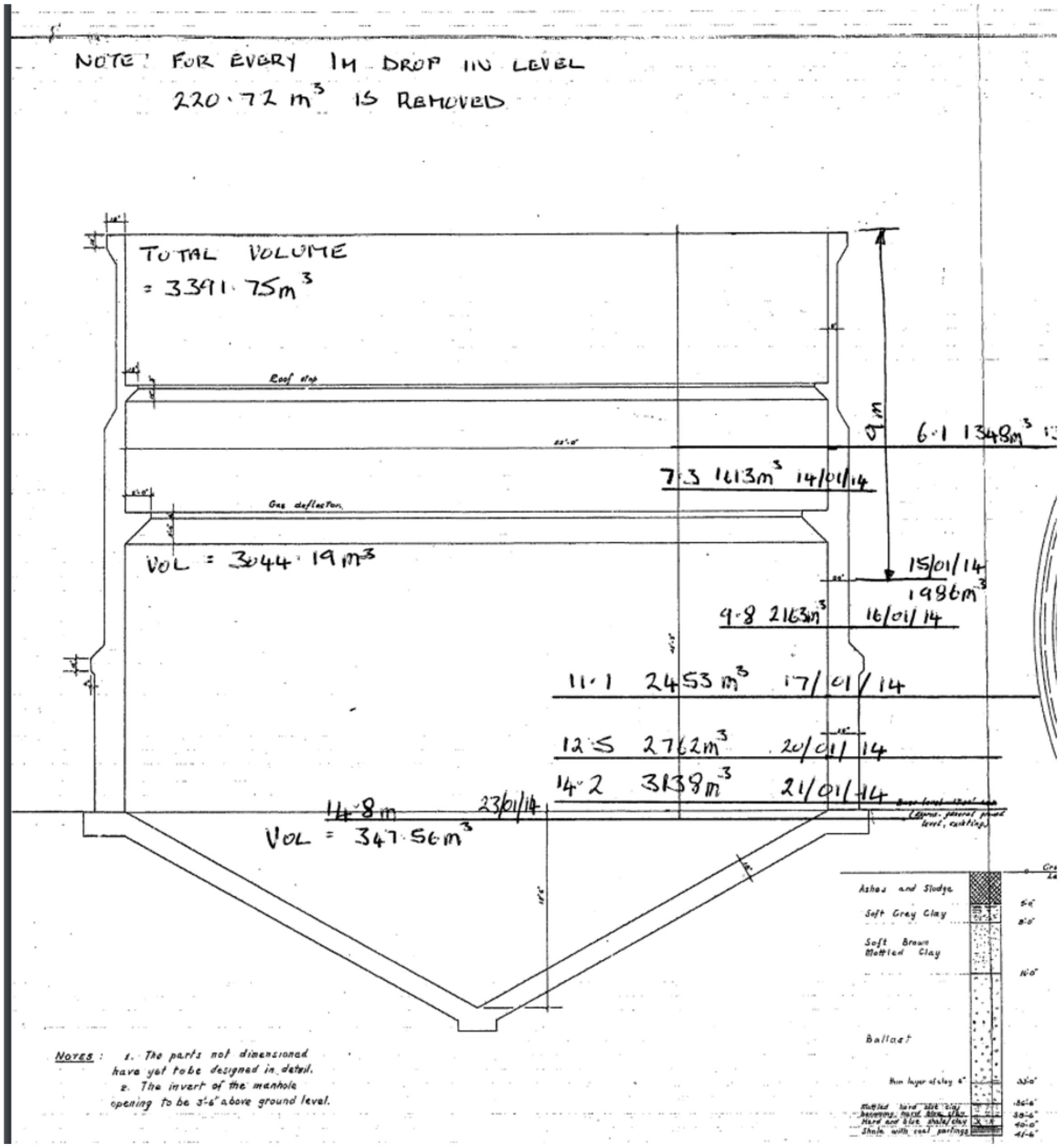
Appendix 2 – Bunding solution

Appendix Table 1. Aldwarke bunding solution design specification and dimensions.

Category	Criteria	Unit	Value
Thickener and centrifuge feed tank bund			
Design specification	CIRIA C736 spill volume [25/110%]	m^3	1,642
	Bund perimeter length	m	293
	Total containment surface area	m^2	3,598
	Maximum Final Spill depth	m	0.46
Bunding requirements	Concrete bund height	m	0.71
	Total concrete wall length	m	293
Existing bunding	Existing concrete walling length	m	0
Build required	Required concrete walling length	m	293
	Impermeable surfacing area	m^2	3,411
	Sleeping policeman total length	m	19.75
	Surge + Jetting protection		On / around the outfall wet well
Digester feed tanks bund			
Design specification	CIRIA C736 spill volume [25/110%]	m^3	550
	Bund perimeter length	m	120
	Total containment surface area	m^2	705
	Maximum Final Spill depth	m	0.78
Bunding requirements	Concrete bund height	m	1.03
	Total concrete wall length	m	120
Existing bunding	Existing concrete walling length	m	50
Build required	Required concrete walling length	m	70
	Impermeable surfacing area	m^2	364
	Jetting protection		On the FST circumference section overlapping the jetting profile

Category	Criteria	Unit	Value
Digester tanks bund			
Design specification	CIRIA C736 spill volume [25/110%]	m^3	3,102
	Bund perimeter length	m	234
	Total containment surface area	m^2	2,668
	Maximum Final Spill depth	m	1.16
Bunding requirements	Concrete bund height	m	1.41
	Total concrete wall length	m	234
Existing bunding	Existing concrete walling length	m	0
Build required	Required concrete walling length	m	234
	Impermeable surfacing area	m^2	2,241
	Jetting protection		Section where jetting profile overlaps permit boundary
Return liquor balance tank bund			
Design specification	CIRIA C736 spill volume [25/110%]	m^3	1,305
	Bund perimeter length	m	123
	Total containment surface area	m^2	931
	Maximum Final Spill depth	m	1.40
Bunding requirements	Concrete bund height	m	1.65
	Total concrete wall length	m	123
Existing bunding	Existing concrete walling length	m	0
Build required	Required concrete walling length	m	123
	Impermeable surfacing area	m^2	931
	Jetting protection		Section where jetting profile overlaps permit boundary

Appendix 3 – Digester dimensions



Appendix Figure 2. Construction diagram of digesters at Aldwarke

Appendix 4 – PondSIM modelling volumes

				Worst-case	CIRIA rule (selected volume in green)		
					Single tank installation	Multi-tank installation (largest selected)	
	Aldwarke sludge tanks	Hydraulically linked configuration	Above ground capacity (m^3)	110% volume	110% volume	25% volume	110% volume of largest tank
Multi-tank area 1	Thickener feed tank no.1 Thickener feed tank no.2	No	1,493 1,493	1,642 1,642		747	1,642
Multi-tank area 2	Digester feed tank no.1 Digester feed tank no.2	No	500 500	550 550		250	550
Multi-tank area 3	Digester no.1[a] Digester no.2[a]	No	2,820 2,820	3,102 3,102		1,410	3,102
Multi-tank area 4	Centrifuge feed tank no.1 Centrifuge feed tank no.2	No	700 700	700 700		350	770
Single tank area	Return liquors balance tank	-	1,186	1,305	1,305		
			Total volume modelled:	13,293	7,369		

[a] tank built into the ground

Appendix Figure 3. Calculation of worst-case and CIRIA rule volumes for PondSIM modelling

Appendix 5 – CIRIA C736 jetting calculation

For a small diameter sharp edged discharge orifice, it can be demonstrated that:

$$l^2 = 4\,C_v^2\,(z-h)\,(H-z)$$

where C_v = coefficient of velocity

In practice, $C_v \cong 0.99$. Assuming $C_v = 1$ leads to the conservative solution:

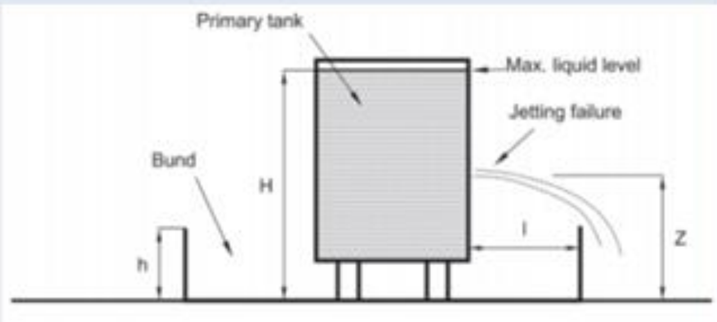
$$l^2 = [4(z-h)(H-z)]^{0.5}$$

For a given value of h, it may be shown the l is a maximum when:

$$z = 0.5H + 0.5h$$

which leads to the solution:

$$l_{max} = H-h$$



Appendix Figure 4. CIRIA C736 jetting calculation to determine jetting solution.

Appendix 6 – Tank inspection report

Form No: YW-INSP-FRM-1, Rev 4a, 2020 11 04

YorkshireWater

EQUIPMENT INSPECTION REPORT

Aldwarke STW/STF. Centrifuge feed tank No: 2.

Report Number:	**ALDWK-INSP-023**	**Inspection Procedure**	**YW-InsProc-20**
Equipment Number:	**PLI N/A.**	**Category:**	**External visual**
Service:	**Sludge storage.**	**Equipment Used:**	**Camera**
P&ID Number:		**Site Operator:**	**Dale Bingham.**
Associated IAN's	**ALDWK-IAN-002**	**Site Manager:**	**Adam Broughton**
Associated MAL's	**ALDWK-MAL-007**	**PoWRA Completed**	**Yes**

Inspection to be as defined in the INSPECTION MANUAL

Type of Inspection:	Date of Inspection (Mth-YYYY):	Scheduled Interval (months):	Next Inspection Date (Mth-YYYY):	Maximum Interval (months):
Thorough External Inspection:	**MAY-2021**	**36**	**MAY-2024**	**60**
Thorough Internal Inspection:	**N/A**	**N/A**	**N/A**	**120**
On-Stream Thickness Survey:	**N/A**	**N/A**	**N/A**	**N/A**

Site address. Aldwarke Lane. Rotherham. S65 1SU.
Inspection date: 15/05/21.
Previous reports. Initial inspection.

Equipment list.

- **Centrifuge feed tank No: 2.**

Inspection details. Centrifuge feed tank No: 2.
Manufacturer: Permastore. **Installed:** N/A **Capacity:** N/A. **Material:** Shell. GFS. Glass fused steel.

External. This inspection was requested by Ed Sutherland (Project Manager) regarding the expected remaining life of storage tanks on the Aldwarke site. This inspection opinion is based on the external condition of the tank's shell and does not consider any future degradation issues such as internal corrosion.

Appendix Figure 5. Example equipment inspection report.