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QUEENSFERRY CONTAINMENT RISK ASSESSMENT

October 2024

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QUEENSFERRY CONTAINMENT RISK ASSESSMENT

October 2024

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Contents

Tables

Figures

Executive summary

To support the Industrial Emissions Directive permit submission for the Queensferry Sludge Treatment Centre (STC) Mott MacDonald has been appointed by Welsh Water to carry out a risk assessment of the impact to the environment in the event of a loss of primary containment within the STC. The study is based on CIRIA C376 Containment Systems for the Preventions of Pollution (London, 2014) and includes review of the existing containment and procedures in line with Best Available Techniques (BAT) principles.

The assessment uses a source-receptor-pathway approach to idenitfy the required classification of containment. The main sources of sludge storage on the site are identified and the required CIRIA containment Modelling was undertaken to assess the extent of sludge from a catastrophic failure event and the impact of flooding and fire on the site.

This report discusses the site's condition, potential sources, modelling of surface water flows and sludge pathways to identify the spill containment requirement, and assessed options for secondary containment in case of catastrophic failure of the assets/tanks in Queensferry STC.

In this study, the high-level enhanced secondary containment options are proposed based on the spill modelling and assessment. The high-level proposed option extends beyond the STC to capture all identified sources and would require additional concrete walls and the use of speed humps across trafficable areas. The volume for containment was compared between the CIRIA 110% and 25% rule and the 25% rule applies. The options to achieve this containment considered reuse of existing secondary containment in impermeable ground and kerbs/speed humps, along with further bund walls and ramps. The hydraulic modelling demonstrates that the proposed mitigation option meets the CIRIA C736 volume requirements and are effective at retaining sludge on the site. These were discussed with site operations to ensure the measures are feasible to operate and maintain the STC. The proposed option will be taken forward by DCWW for detailed design and implementation.

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1 Introduction

1.1 Background

Dwr Cymru Welsh Water (DCWW) is required to provide containment of sludge spills at their Sludge Treatment Centres (STC), to comply with the Industrial Emissions Directive. Natural Resources Wales (NRW) provides permits to demonstrate compliance with the Directive. Sewage Sludge[1] is the residue produced by wastewater treatment processes. It is a residual semi solid slurry, produced as a by-product when industrial or municipal wastewater is treated. Since it is a by - product of treated wastewater, it must be managed and disposed of properly. The sludge contains both organic and inorganic materials, as well as a large concentration of plant nutrients and pathogens. Treating the sludge reduces its weight and volume, at the same time reducing its disposal costs and potential health risks on land, plants, humans, and animals. Hence, the Sludge Treatment Centre (STC) is important for the safe disposal of sludge. Queensferry Wastewater Treatment Works (WwTW) contains one STC, with associated infrastructure, where sludge is treated through anaerobic digestion (AD).

Mott MacDonald has been appointed by DCWW to carry out a risk containment assessment of Queensferry STC. The purpose of this report is to assess the risks present at the Queensferry STC, the existing capacity available to contain accidental spills, and identify potential high-level enhanced secondary containment mitigation that could be implemented. This study is based on *CIRIA C376, Containment Systems for the Preventions of Pollution (London, 2014)*[2], which provides guidance on identifying the hazards, assessing the risks, and mitigating the potential consequences of a failure of the primary sludge storage facility, as well as the design of new containment systems. A summary of the approach to spill containment is described in Section 1.2.

1.2 Levels of Containment

Primary containment or storage is provided by the actual tank or vessel. It is the most important means of preventing major incidents involving the loss of sludge. It comprises the equipment used to store or transfer sludge such as storage tanks, intermediate bulk containers (IBCs), drums, pipework, valves, pumps and associated management and control systems. It also includes equipment that prevents the loss of primary containment under abnormal conditions, such as high-level alarms linked to shut-down systems.

[1] Sludge: Types, Uses, Objectives and Methods of Removing Sludge - Conserve Energy Future (conserve-energy-future.com)

[2] https://statics.teams.cdn.office.net/evergreen-assets/safelinks/1/atp-safelinks.html

Secondary containment is provided by a bund immediately surrounding the primary vessel or tank or as remote containment. It minimises the consequences of a failure of the primary storage. It comprises equipment that is external to and structurally independent of the primary storage, for example, localised concrete or earth bunds around storage tanks, or the walls of a warehouse storing drums. Secondary containment may also provide storage capacity for firefighting and cooling water.

Enhanced secondary containment minimises the consequences of a failure in the primary and secondary containment systems by providing an additional level of protection preventing the uncontrolled spread of the sludge. These include purpose-built structures such as diversion tanks and lagoons but can also use other measures such as containment kerbing to roadways and parking areas and impervious liners and/or flexible booms. Enhanced secondary containment will be used when there is an event that causes the escape of liquids from the secondary containment through failure or overflow (e.g., bund joint failure, or firewater overflowing from a bund or escaping from a building/warehouse during a prolonged fire).

1.3 Overview of Site and Activities

Queensferry STC is situated within Queensferry WwTW, which is located within the Queensferry Industrial Estate adjacent to the River Dee in Deeside. The address for the site is Queensferry WwTW, Factory Road, Pentre, Flintshire, CH5 2QL (NGR SJ 323 681). A satellite overview of the location is presented in Figure 1.1.

The STC operation is a non-hazardous waste activity which comprises of imports, physio-chemical and anaerobic digestion (AD) treatment, and the storage of waste, all for recovery purposes. The STC solely handles waste derived from the wastewater treatment process, either indigenously produced on-site or imported from other Welsh Water owned assets. The Site undertakes AD of sewage sludge from the on-site WwTW only. All dewatered sludge cake is transported to the Five Fords Advanced Anaerobic Digestion (AAD) Site, located off Cefn Road to the South East of Wrexham.

Figure 1.1: Satellite View of Queensferry WwTW and STC

This document discusses the site's condition, potential pollution sources, modelling of surface water flows and sludge pathways to determine the spill containment requirement, and the effectiveness of the proposed containment assessment in the event of catastrophic failure of assets or tanks within the STC.

With careful design and planning a system can be provided that is capable of providing the necessary degree of environmental protection. The overriding concern is the robustness and reliability of the system, which depends on a number of factors:

- Its complexity – the more there is to go wrong, the greater the risk. Passive systems relying solely on gravity are more reliable than pumped.
- Whether manual intervention is relied on to make the system work or whether the system can be automated to include fail-safes and interlocks.
- The ease of maintenance and monitoring of the system's integrity, and repair of any defects.

During and after an incident any rainfall runoff from the remote secondary storage areas, from the spillage catchment areas and from the transfer systems must also be prevented from reaching any outfall(s) to surface water, or wider environment, by closure of control valve(s).

1.3.1 Existing Secondary Containment

Information on the containment existing at the site was provided and included in the spill model – Refer Figure 1.2. It includes kerbs of 0.1m, speed hump of 0.1m and walls of varying heights ranging from 0.5m up to 1.35m. This containment generally covers around the STC and the higher walls (1.35m) are observed near the Digested sludge holding tank in the west of the containment boundary. Walls of 1m height is observed in the north of the containment boundary to avoid any spills outside the site.

Figure 1.2: Existing Secondary Containment

2 Site Assessment

2.1 Site Operation and Process

The flow diagram of the process at the STC is shown in Figure 2.1 where the assets involved in the sludge treatment process and sludge flow direction are marked.

The site receives flow from 6 pumping stations, both industrial effluent and domestic waste. The inlet pumping station transfers crude sewage to two Primary Settlement Tanks (PSTs). Biologically treated effluent passes to eight humus tanks for secondary settlement; two radial tanks receive flow from the hi-rate filters and six Dortmund style tanks receive flow from the traditional filters. Before flow reaches the final effluent outfall to the River Dee, it passes through an ultraviolet disinfection system to denature any remaining bacteria and virus. Indigenous primary sludge is transferred to two 206 m^3 covered concrete sludge holding tanks before being pumped to a drum thickener, which thickens the sludge to approximately 6% dry solids with the aid of a polymer. The sludge is then stored in the digester feed tank, which is further transferred to concrete digester tanks to undergo anaerobic digestion. The digested sludge is then transferred and held in secondary digesters for a set period. The treated sludge is then pumped to a centrifuge feed tank and de-watered via a single centrifuge. The de-watered sludge is then transferred and stored in cake pads ready for further treatment. The biogas generated during digestion is stored in a gas holder and used for electricity generation, which supplies the digestion plant and for recovering heat, to maintain digester temperature. Any excess biogas is flared off via the on-site waste bio-gas burner.

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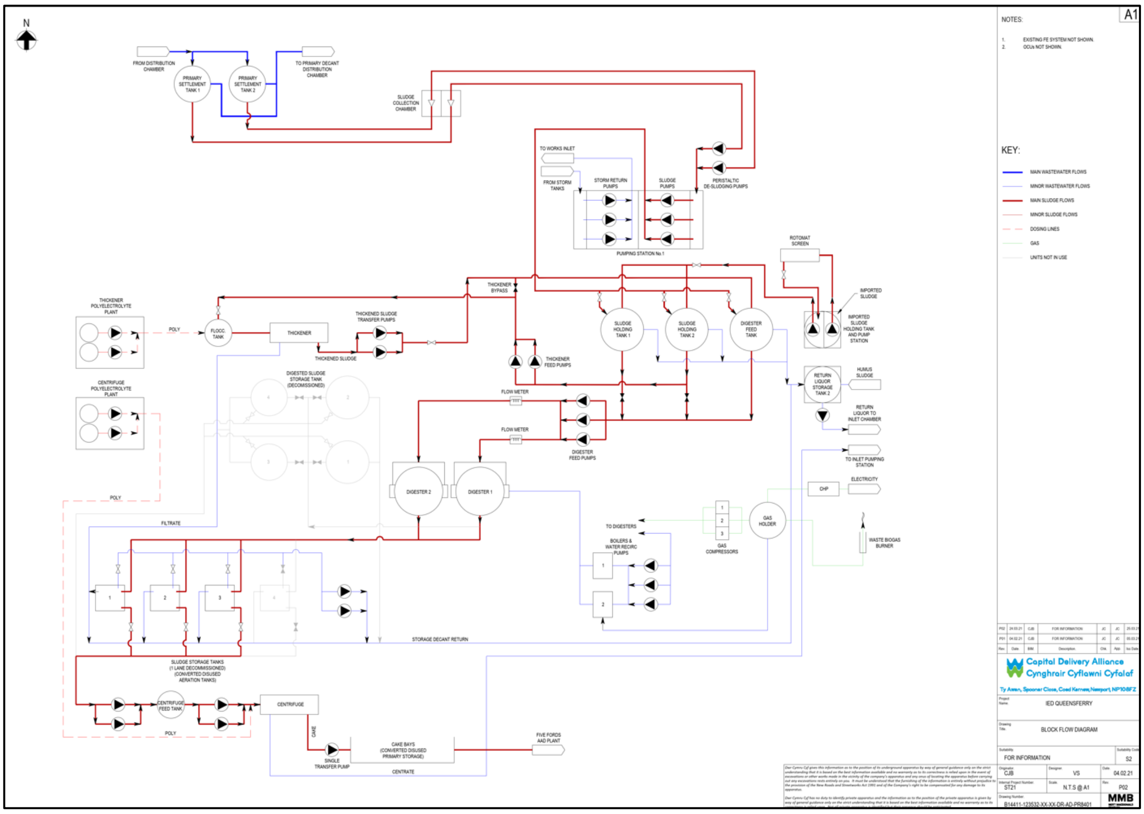
Figure 2.1: Process Flow Diagram for STC



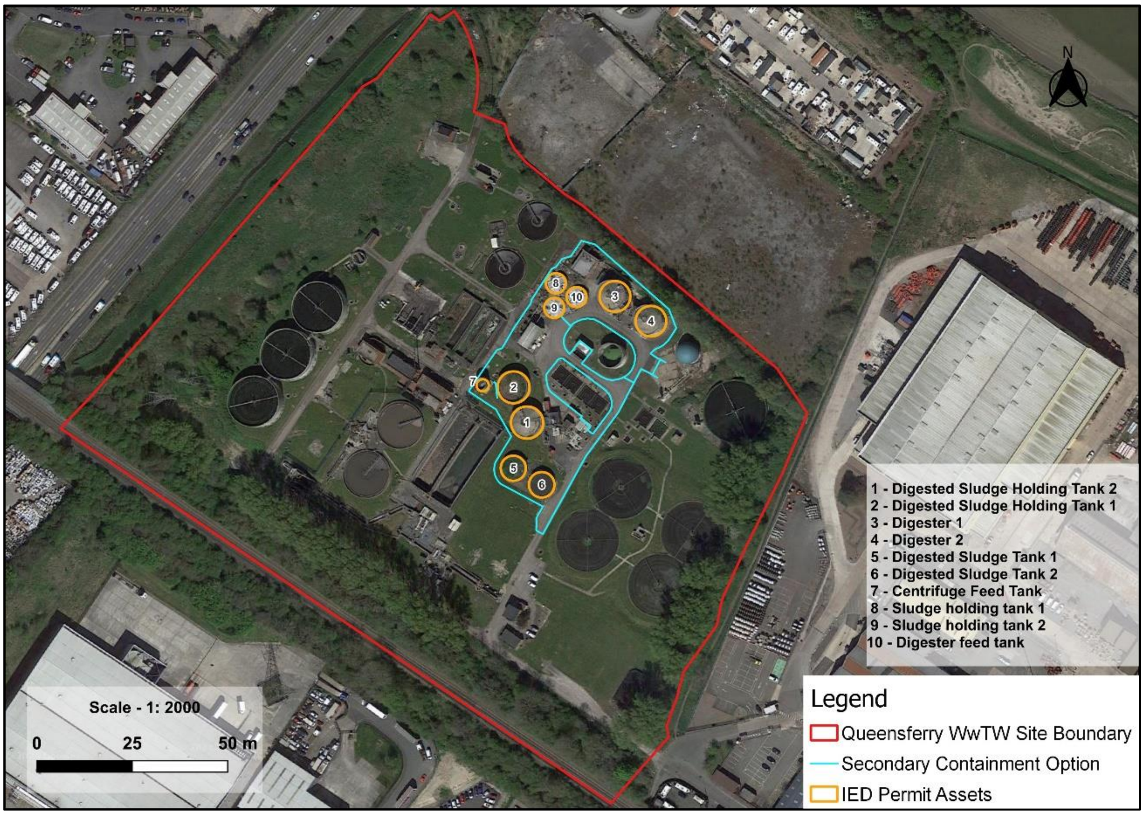
The IED permit includes the assets which are tabulated in Table 2-1 and the location of these assets is marked in Figure 2.2.

Table 2-1: List of IED permit assets

Sr. No.	Asset Name	Description	Volume/ Capacity	Considered as "Source"	Justification to consider as source
1	Sludge Holding Tank	2 Nos	75 m^3	No	Raw Sludge
2	Digester Feed Tank	1 No	75 m^3	No	Raw Sludge
3	Digester	2 Nos	1420 m^3	Yes	Digested Sludge
4	Imported Screened Sludge Tank	1 Nos	0 m^3	No	Raw Sludge
5	Digested Sludge Holding Tank 1	1 Nos	1334 m^3	Yes	Digested Sludge
6	Digested Sludge Holding Tank 2	1 Nos	1442 m^3	Yes	Digested Sludge
7	Digested Sludge Holding Tanks	2 Nos	468 m^3	Yes	Digested Sludge
8	Centrifuge feed tank	1 Nos	159 m^3	Yes	Digested Sludge
9	Cake Bays	3 Nos	70 m^3 each	No	Raw Cake
10	Sludge Holding Tanks	3 Nos	100 m^3 each	No	Digested Sludge

Source: IED Permit Application (Queensferry Main Supporting Document PDF) - B14411-123532-ZZ-XX-NN-ZA-DI1035, May 2021

Figure 2.2: IED Permit Assets



Loss of containment consist of loss of gaseous materials, failure of the liquid containment systems and material storages. In order to minimise the potential for accidental releases, various measures have been adopted at the site. All staff have been provided with responsibility for the handling or transfer of gaseous/liquid materials receive appropriate training for their role. All staff on site receive training in site emergency procedures and the actions to take in the event of discovering a gas leak /liquid spillage and the use of spill containment measures as part of their mandatory site induction training. Regular monitoring of storage vessels, pipework and gas levels/fluid levels shall be undertaken to ensure no fugitive emissions are being released and to ensure the structural integrity of the system remains uncompromised. All sludge treatment activities are undertaken in enclosed buildings or tanks.

2.2 Site Condition

The Site Condition Report (SCR)[3] provides detailed information about land use, geology, hydrogeology, and flooding which can be found in sections below.

[3] B14411-123532-ZZ-XX-RP-ZA-SE1038 IED Queensferry Site Condition Report

2.2.1 Hydrology and flooding

The site is approximately 220m south-west of the River Dee, and approximately 5km from the Dee estuary. There are several land drains/streams in the area surrounding the site, most notably a drain that enters the Dee which runs adjacent to the north-western boundary of the site. There are 19 discharge consents within 250m of the site (although none are within the proposed permitted installation boundary). Various flood risks are referred are provided in the following sub sections.

2.2.1.1 Risk of flooding from rivers

Queensferry STC site including the proposed permit boundary, is at high risk (3.3% chance of flooding each year) of flooding from rivers and local watercourses (Refer Appendix A).

2.2.1.2 Risk of flooding from surface water and small watercourses

Queensferry STC site is at very low risk (0.1% chance each year) of flooding from surface water (Refer Appendix A).

2.2.1.3 Risk of flooding from the sea

Queensferry STC site is at **Error! Reference source not found.** very low risk (0.1% chance e ach year) of flooding from sea.

In summary, the flood risk, due to various sources are discussed in the above sections. It shows that except flooding from rivers, other sources of flooding have very low risk - Refer Appendix Afor the flood risk report.

2.2.1.4 Risk of flooding from Groundwater

The superficial deposits[4] (Tidal Flat Deposits) beneath the site are classed by the Environment Agency as a Secondary Undifferentiated aquifer. The bedrock geology, (PLCM, PMCM and Etruria Formation) are all classed as Secondary A aquifers and likely in continuity with each other.

The groundwater is assumed to be relatively shallow and tidally may be fluctuating due to the proximity of the mouth of the River Dee into Liverpool Bay (the Irish Sea) approximately 5km to the north-west.

The site, including the proposed permitted installation, is not located within 250m of a Source Protection zone (SPZ).

There are no known discharges to groundwater (historical/current) within 250m of the site, including the proposed permitted installation.

[4] B14411-123532-ZZ-XX-NN-ZA-DI1035 Queensferry Permit Application Main Supporting Document

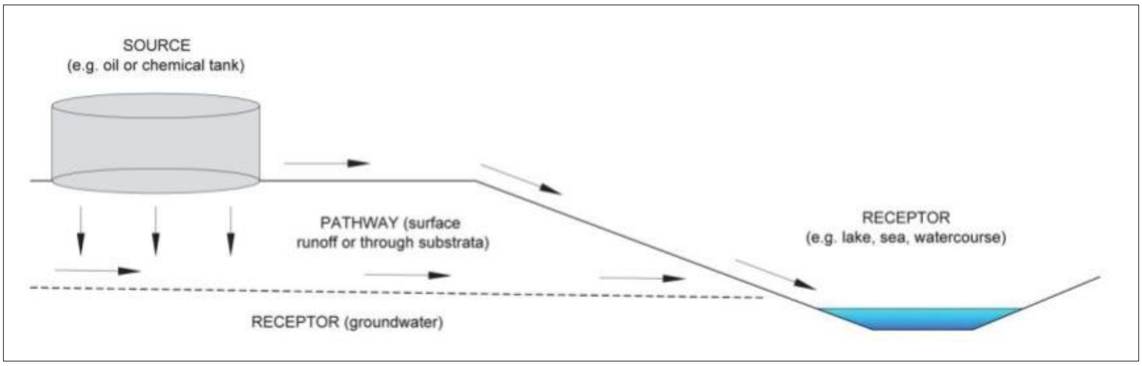
3 Source – Pathway – Receptor Analysis

3.1 Introduction

CIRIA C736 and ADBA Industry Guidance state how the hazard rating of the site risk and classification are to be calculated. This is detailed below and in “B16564-123532-ZZ-XX-AS-ZA-CI0035 - Queensferry ABDA Assessment“.

Source – Pathway – Receptor analysis is important for determining the Site Hazard Rating which helps to identify the level of containment requirement. Figure 3.1 shows the schematic diagram of the Source, Pathway and Receptor.

Figure 3.1: Schematic diagram of Source – Pathway - Receptor



The following sections discuss how the potential sources are identified, and how the sludge would travel/ spread along the pathways and reach the receptors.

3.2 Source

3.2.1 Tanks

To model the event of a credible and catastrophic tank failure which would result in loss of containment of sludge at Afan, the assets on site must be evaluated to identify the most significant failure events.

A list of tanks considered to be potential sources are tabulated in Table 3-1 and in the attached ADBA Tool (Refer Appendix **Error! Reference source not found.**). The location of these tanks c an be referred from Figure 2.2.

Table 3-1: List of potential sources within STC

Sr. No.	Asset Name	Description	Volume/Capacity
1	Digested Sludge Holding Tank 1	1 Nos	1334 m^3
2	Digested Sludge Holding Tank 2	1 Nos	1442 m^3
3	Digester 1	1 Nos	1420 m^3
4	Digester 2	1 Nos	1420 m^3
5	Digested Sludge Tank 1 (GFS)	1 Nos	468 m^3
6	Digested Sludge Tank 2 (GFS)	1 Nos	468 m^3
7	Centrifuge Feed Tank	1 Nos	159 m^3
8	Sludge Holding Tanks	2 Nos	75 m^3
9	Digester Feed Tank	1 Nos	75 m^3

Source: IED Permit Application (Queensferry Main Supporting Document PDF) - B14411-123532-ZZ-XX-NN-ZA-DI1035, May 2021

The total volume of all sources containing sludge is 7,446m^3, with the two 1,420m^3 digesters along with digested sludge holding tanks of volume 1,334m^3 and 1,442m^3 making up the majority. The location of these tanks can be referred from Figure 2.2. These tanks are filled with digested sludge, and they contain Nitrogen, Phosphorous, Ammonia, BOD, TSS, COD, and the process can create algae blooms, methane and death of organisms. All tanks are reinforced concrete tanks, apart from the Digested Sludge Holding tanks and Centrifuge feed, which are all steel tanks. Their flammability and corrosivity is low.

As per CIRIA C736, the volume contained must be the larger of 110% of the capacity of the largest tank or 25% of the total storage capacity within the bunded area. The 110% and 25% rules were compared, and it was found that the 110% volume of one 1,442m3 digested sludge holding tank (1,586m3) is lesser than the volume of 25% of all tanks within the IED permit (1,862m3).

Therefore, for this containment assessment, the source to be contained is 1,862m3 of sludge.

3.2.2 Containment of all raw materials stored on site

As shown in Table 3-1, the volumes of each kind of raw material storage are significantly smaller than the volume of the digesters and digested sludge holding tanks. The total volume of all sources is 7,446m3, and 25% of this volume is higher than the 110% of the largest tank within the site (Digested sludge holding tank). However, due to the location of the higher volume tanks, any storage that contains and sized using the CIRIA 110% rule and 25% rule will be capable of containing a spill from any sources within the site. For this assessment, the location of each source (i.e. each raw material storage) is considered as a part of the containment options.

3.2.3 Firefighting Water

As per CIRIA C736 the volume of firefighting demand for chemical plants is around 4000m^3. The volume of water required would be less for an STC site compared to chemical plants. It is considered that the firefighting water demand would be less than 4000m^3 and less than the highest volume identified from the sources listed. The likelihood of a fire from the biogas holders resulting in the digestors failing and spilling during a 1 in 10 year rainfall event is highly unlikely, less than 1 in a million, hence, the firefighting water is not considered further as a potential source in this study.

Table 3-2: Firefighting water demand

Table 4.4 Forecast of firefighting water needed to tackle major chemical plant fires (courtesy ICI)

Plant hazard rating[1]	Firefighting water demand
High severity	Total demand 1620–3240 m^3/hr for four hours
Medium severity	Total demand 1080–1620 m^3/hr for four hours
Low severity	Total demand 540–1080 m^3/hr for four hours

Notes[1]

High severity includes plants with:

- over 500 tonnes of flammable liquid above its flashpoint
- over 50 tones LPG above its boiling point and over 50 bars
- over 100 tonnes combustible solid with ready flame propagation
- other factors what increase severity

Medium severity covers plants that fall between high and low severity ratings.

Low severity includes plants with:

- less than 5 tonnes flammable liquids above or below flashpoint
- less than 100 kg flammable gas under 1 bar or a flash liquid
- less than 5 tonnes readily combustible solid
- other factors that decrease severity

Source: CIRIA C736

3.2.4 Cake Bay

The cake bay at the site is located within the STC boundary. The treated sludge is pumped to a centrifuge feed tank and then de-watered via a single centrifuge with the aid of polymer to increase the percentage dry solids to between 20 and 25%. The de-watered sludge is then transferred and stored on open concrete cake pads ready for export to Five Fords for further treatment. The existing containment boundary excludes the cake bay as they run along the road from north to south west of the site and in particular along the east side of humus tank and the digested sludge tanks.

3.3 Pathway

Pathways are how a hazardous substance would reach a receptor. As per CIRIA C736, the area of search for potential receptors is governed by the potential pathways and these might include:

1. Simple overland flow following the local topography.
2. Existing pipes, sewers, drains or other underground features that could lead to a receptor such as a watercourse.

3. Permeable sub-soils and strata underlying a site that could provide a pathway to groundwater or a watercourse.

Multiple combinations of pathways may exist and should be considered. In considering the hazard rating of potential pathways the following should be considered[5].

1. The distance between the source and the various potential receptors.
2. Site layout (including topography), and the position and effectiveness of drains and other internal and external pathways.
3. Geographical, geological, and hydrogeological features that could either impede or facilitate the escape of inventory from the site. In addition, building foundations may impede or alter sub-surface drainage paths.
4. Climatic conditions and expected variability.
5. The direct effects of fire and the introduction of firefighting water, or foam.
6. The presence of treatment plants (on or off-site).
7. Modification of the inventory during passage through the pathway such as the cooling of a liquid.
8. Inventory that is not particularly mobile in ambient conditions may be soluble in water.
9. The scale of potential incidents (larger incidents and firewater generally have greater potential for mobilisation in the environment than smaller spills).

As per the ADBA tool, the guidance gives the following pathways are given the following hazard rating.

Table 3-3: Pathway – Environmental Hazard Rating

Pathway - the route from primary containment to receptor (extent of loss of containment)	Hazard - Transport potential
Tanks are surrounded by, grass, permeable hardstanding stone and impermeable concrete Permeable soil that act as a pathway	M
Permeable area saturation will lead to transporting sludge downstream and towards the River Dee	M
Tidally fluctuating groundwater	M
Existing underground services – ductwork, troughs, pipework	L
Impermeable concrete surfacing on site/ Saturated permeable ground may cause sludge to get transported along the road reaching gullies and into the site drainage system. Soakaways which are connected to this system may allow sludge to infiltrate into the soil.	M
Soakaway blockage - Overflow to the drainage system (liquor return)	M

[5] Legislation and Guidance :: GPT Environmental Management Services

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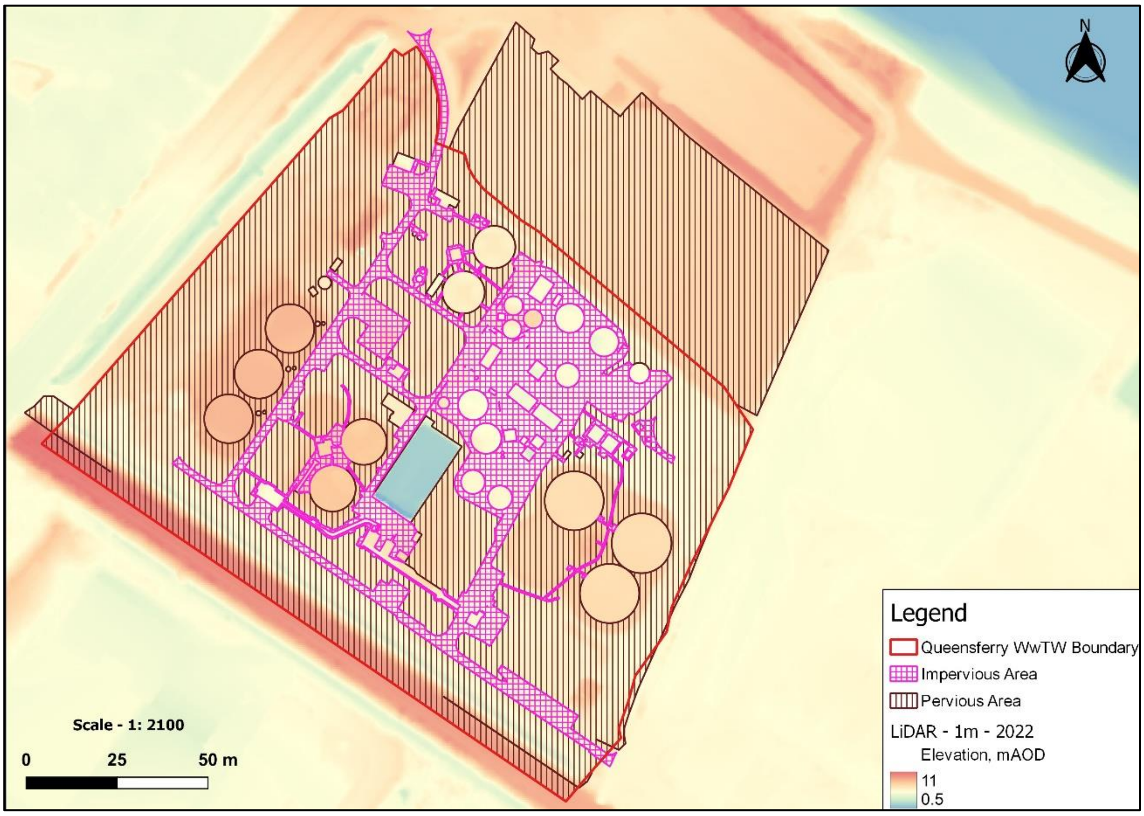
3.3.1 Overland Flow Pathway

Overland flow paths within the site are as per the existing topography. From the LiDAR data, it is observed that the elevation at the site varies from 0.5mAOD to 9.5mAOD. The majority of the site is covered by impervious layers (Refer to Figure 3.2). These will serve as a major pathway for sludge to reach on-site receptors.

Figure 3.2: Pathways at Queensferry WwTW



3.3.2 Groundwater/ subsurface Flow Pathway

There are some grass and bushes (pervious area) within the site which could potentially serve as a pathway for sludge to enter the groundwater (see Figure 3.2)

3.3.3 Pathway Risk Rating

Using the ADBA tool as guidance, the site has been given a pathway risk rating with no containment of **medium**. This is due to the presence of the Secondary A aquifer in Queensferry, and the run-off time for the site inventory to reach the sea or surrounding grass areas, which would occur in hours.

3.4 Receptor

As per the ADBA tool, the guidance for environmental hazard rating for receptors are as follows and have been used to assess the receptor risk from spills as shown in Table 3-4.

Table 3-4: Receptors – Environmental Hazard Rating

Receptor	Hazard - Damage potential
Watercourse and bodies	
Groundwater – contaminated through percolation or through fluctuating tidal groundwater level Site within a Secondary A aquifer. Over a very long period, can contaminate river through groundwater base flow underground	M
Sludge storage within 50m of a watercourse that discharges into River Dee - designated as a Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC).	H
Local environment including grassy area - through overland flow from uncontrolled spill. <5m away	M
WWTW - internal drainage system returns effluent to the head of the works prior to discharge into the River Dee	M
Habitation	
Third party land (Bromborough Plastics Ltd) 100m from digesters	M
Other	
River Dee SSSI within 250m of the site	H

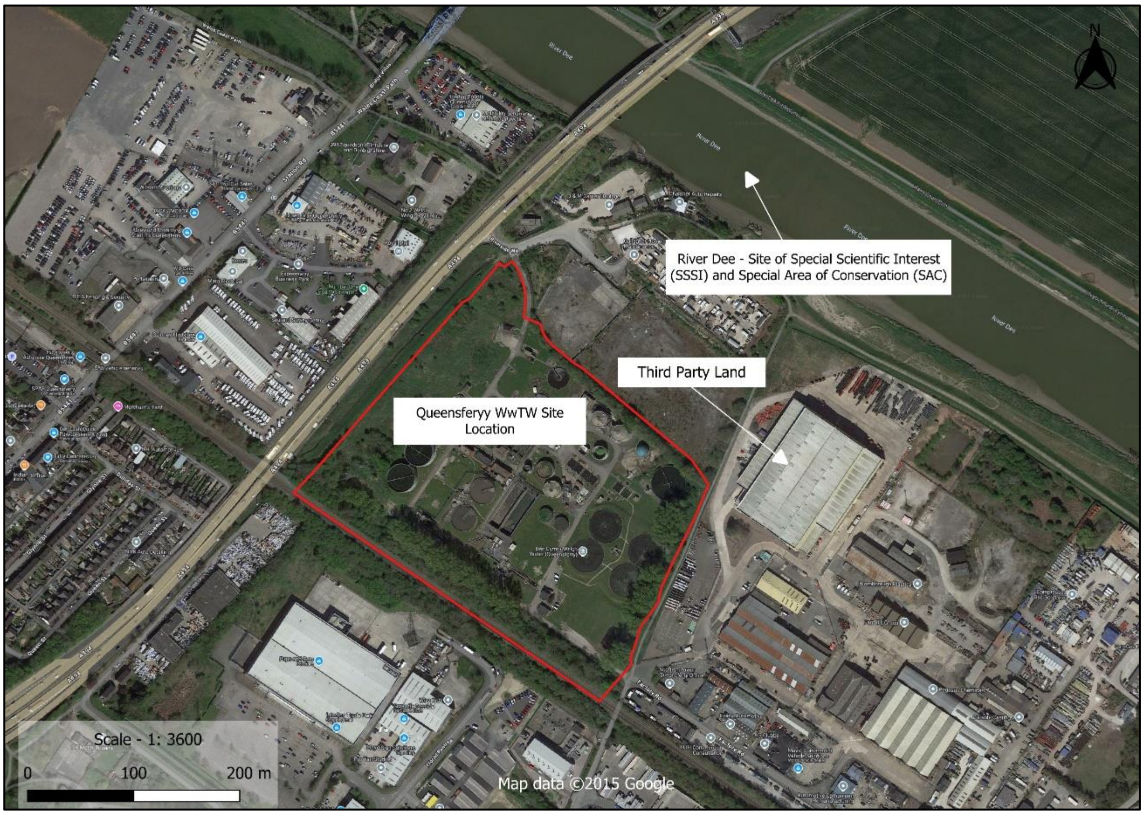
3.4.1 Off-site receptors

Queensferry STC is located adjacent to River Dee. The site falls within 250m of a Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC).

3.4.1.1 Designated sites

There are some designated sites in the vicinity of Queensferry STC, and these are shown in Figure 3.3. There is a third-party land (Bromborough Plastics Ltd) situated at 100m from the digesters. River Dee is a Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC) which is within 250m of the site. Therefore, the risk is deemed **high**.

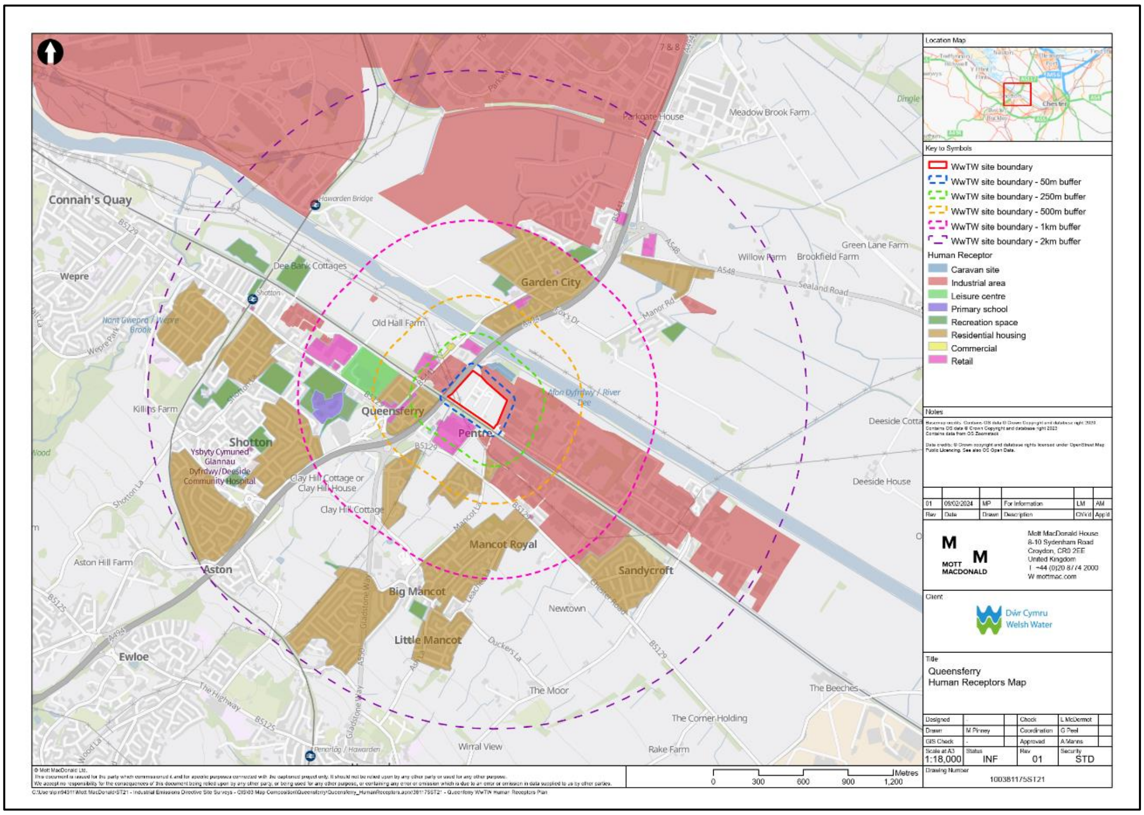
Figure 3.3: Receptors – Designated habitats



3.4.2 Sensitive Human Receptors

The closest sensitive human receptors are industrial area, residential buildings and retail within 250m of the site (Refer Figure 3.4).

Figure 3.4: Human receptors



3.4.3 Receptor risk rating

Using the ADBA tool as guidance, the site has been given a receptor risk rating of **high.** This is due to the presence of SSSI and SAC within 250m of the site.

3.5 Overall Site Classification

Based on the use of the ADBA risk assessment, considering the source, pathway and receptor risk, Queensferry site hazard rating is deemed to be **high,** and the likelihood of a spillage is classed as **medium**. Based on these risks, an overall site risk rating was determined to be **high**, meaning that Class 3 containment is required – Refer Table 3.5.

Table 3.5: Overall Site Risk Rating

Source Risk	Pathway Risk	Receptor Risk	Site Hazard Rating	Likelihood	Overall Site Risk Rating
Medium	**Medium**	**High**	**High**	**Medium**	**High (Class 3)**

4 Assessment of Failure Risk

4.1 Introduction

This section discusses the modelling of the site carried out to identify the potential impact due to the failure of possible sources identified in Section 3. Hydraulic modelling (spill modelling) has been carried out to understand the extent of a primary containment failure of sludge stored at Queensferry STC. As described in Section 1.3.1, secondary containment has already been installed across the STC and the same is verified through modelling. The following scenarios were used in the failure assessment of the STC.

a) Post-failure without containment options – Breaching of the critical source is applied without existing secondary containment options.
b) Post-failure with existing secondary containment options – Breaching of the critical source is applied with existing secondary containment options.
c) Post-failure with enhanced secondary containment options - Breaching of the critical source is applied with enhanced secondary containment options by increasing the height of the existing walls and including additional walls at various locations (wherever necessary) to completely contain the sludge within the containment boundary.

Detailed explanation on the Secondary containment option and its enhancement is provided in Section 5.1.

4.2 Factors influencing sludge movement

When there is a sudden failure, the sludge from the critical sources would follow the local topography of the site as shown in Figure 4.1. The movement of sludge is influenced by various factors as below.

a) Topography
b) Surface Roughness
c) Initial storage/ water levels

4.2.1 Topography

The ground elevations on the site generally varies between 0.5mAOD to 10mAOD. The Digested Sludge Holding Tanks and the Digested Sludge Tanks are in the centre of the site (at a height of 1m and 5m respectively) along with the Centrifuge Feed Tank which is raised by 4m from the ground. Both the digesters are installed in the north-east of the site. The Sludge Holding tanks and the digester feed tank are located near to the digesters. Figure 4.1 shows the location of all these sources with the topography of the site.

Figure 4.1: Topography with Potential Sources

4.2.2 Surface Roughness

Different surface types are represented within the model as shown in Figure 4.2 **Error! Reference source not found.** to replicate the on-site condition in the model. The roughness values are assigned based on the land use listed in Table 4-1**Error! Reference source not found.**.

Figure 4.2: Different Surface types within WwTW

Table 4-1: Manning's n value adopted in the model

Materials ID	Manning's n	Description
1	0.300	Buildings
2	0.016	Roads – Concrete/ Asphalt
3	0.013	Hard standing area around the assets – concrete finish
4	0.030	Sand/ Gravels
5	0.035	Pasture/ Short Grass
6	0.110	Woodland – Trees with heavy growth of sprouts

Source: Open Channel Hydraulics, Ven Te Chow

4.2.3 Initial Storage

In this study, the breach of the tanks is applied with no initial storage/ initial water levels at the site. Sludge movement and storage depends on the available storage capacity on the site. As described in CIRIA C736, the containment should allow for accumulated rainfall within the bunded area 24 hours prior to a failure event. As Queensferry is a manned site, it is not practical to assume rainfall would remain within the containment for an extended period of time. Also, as per the previous scope of work, all the drainage within the containment were tied back to a site return pumping station which would pump the drain. Hence rainfall data is not taken into account for the modelling work.

4.3 Post Failure Assessment

4.3.1 Breach Inputs

CIRIA C736 states that when considering a loss of containment of sludge, the volume of substance should be based on the loss from a credible scenario, this need not necessarily involve the entire site inventory. The focus of this assessment is on the complete failure of any primary containment within the IED permit area.

The list of potential sources tabulated in Table 3-1 are considered in the failure assessment. Failure of all the potential sources were assessed separately and interaction was noted in the spread of sludge from the failure of these sources. The critical sources include two digested sludge holding tanks, two digested sludge tanks, two digesters and a centrifuge feed tank, which have the largest volumes and pose the highest risk of spillage. However, as per CIRIA C736, 25% rule is also considered where 10 tank failures are considered at the same time (Refer Section 4.3.2)

Breach modelling is done based on Environment Agency, EA's breach guidelines, the reservoir's breach equation – Refer below. This equation is used with a few assumptions to arrive at the inflow hydrograph. The equation is based on Froehlich (1995) theory.

Reservoir Breach equation, $Q_p = FOS \cdot \left[0.607 \left(V_w^{0.295} H_w^{1.24}\right)\right]$

Where,

Q_p is the peak discharge in m^3/s

V_w is the reservoir volume (m^3) at the time of dam breach (Volume of the tank is assumed in this study)

H_w is the height of water (m) in the reservoir at the time of failure above the final bottom elevation of the breach (Height of the tank is assumed in this study)

FOS is Factor of Safety (assumed as 1 in this study)

End time of the hydrograph is calculated from the below equation and the time to peak is assumed to the 1/3rd of the end time (t_e).

$$t_e = \frac{2V_w}{Q_p}$$

Inflow hydrograph is developed with the calculated peak discharge, end time of the hydrograph and the time to peak to represent the sudden failure of the source.

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4.3.2 Breach – Failure of critical sources

The spread of sludge varies depending on the source of the breach. Sludge spreads all over the site area from the location of critical sources. The combined sludge extent from the failure of all the sources together without any secondary containment option is shown in Figure 4.3**Error! Reference source not found.**. The sludge spreads within the site area through different access roads.

Figure 4.3: Combined Extent of Sludge from the post-failure of all sources – without Existing Secondary Containment

As per CIRIA C736, containment capacity should be estimated based on following two criteria.

(a) 110% of the capacity of the largest tank within bund (in m3)
(b) 25% of the total capacity of all the tanks within the bund (in m3)

Since the volume considering 25% criteria is higher than the volume of 110% of largest tank within the site (Refer Table 4-2), this volume is considered as an additional scenario to review the containment capacity in this study.

Table 4-2: Containment system capacity comparison – '110%' and '25%' rules

110% of the capacity of the largest tank within bund (in m³)	25% of the total capacity of all the tanks within the bund (in m³)
1586.2	1862

4.3.3 Recovery

The time to recovery and return site back to operation has been set at 3-4 days following direction by DCWW. The site is manned from 8am-4pm, however there is a 24hr control centre monitoring and on-call cover outside this time, therefore the response to an event will be immediate. If the worst-case scenario has occurred, a response team will have been stepped up in accordance with DCWW's emergency management procedures (see B16383-123532-XX-XX-PR-OA-HD0106 - QUY Accident Management Plan October 2024 for details) to determine measures to respond and recover quickly from the event, which could include stopping the treatment works or tankering off waste.

4.4 Spill Volume Summary

The component that contributes to the required capacity of secondary containment is the source spill volume requiring containment. Section 4 of CIRIA C736 forms the basis of this assessment. Section 4.2 (CIRIA C736) reviews current industry practice relating to source spill volume, section 4.2.8 (CIRIA C736) then summarises current industry practice relating to source spill volume in a tabular form.

Within section 4.2.1 (CIRIA C736), there is detailed reference to the use of 110% of the largest tank or 25% of the total tank inventory volume, whichever is greater, and the rationale for this. CIRIA C736 recognises that this approach is not quantitative or based on a risk assessment and are arbitrary methods.

4.5 Total Spill Volumes

Error! Reference source not found. Table 4-3 below summarises the spill volumes used for this study:

Table 4-3: Total Spill Volumes

Tanks within containment area	No. of tanks	Effective volume per tank (m³)	Total effective volume (m³)
Sludge Holding Tank	2 Nos	75	150
Digester Feed Tank	1 No	75	75
Digester	2 Nos	1420	2840
Imported Screened Sludge Tank	1 Nos	0	0
Digested Sludge Holding Tank 1	1 Nos	1334	1334

Tanks within containment area	No. of tanks	Effective volume per tank (m^3)	Total effective volume (m^3)
Digested Sludge Holding Tank 2	1 Nos	1442	1442
Digested Sludge Holding Tanks	2 Nos	468	936
Centrifuge feed tank	1 Nos	159	159
Cake Bays	3 Nos	70	210
Sludge Holding Tanks	3 Nos	100	300
Total	**17**	-	**7446**
110% of largest tank (m^3)			1586.2
25% of all tanks			1862
Design Spill Volume (m^3) = 25% of all tanks			**1862**

5 Proposed Mitigation

This section provides a detailed assessment of the mitigation measures which are being proposed and the potential impact of these improvements.

5.1 Enhanced Secondary Containment Options

The base case option is to confirm whether the existing secondary containment is sufficient to contain the required volume as per CIRIA736. This is tested by updating the walls/ kerbs as per Figure 1.2 and the containment wall is observed to be overtopping. Figure 5.1 shows that the existing secondary containment is not sufficient in retaining the sludge within the containment boundary.

Figure 5.1: Combined Extent of Sludge from the post-failure of all sources - With Existing Secondary Containment Option

As the existing containment option is insufficient to contain the sludge completely, this is enhanced further by raising the walls wherever necessary – Refer Figure 5.2. Containment bunds are raised, and additional walls and ramps are proposed to ensure the protection of the tanks within the WwTW site. The enhanced secondary containment options are intended to contain the

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sludge within the site by raising the existing containment bunds and including additional walls at various locations whilst having a minimum impact on the operation of the site.

Figure 5.2: Enhanced Secondary Containment Options

5.2 Suitability of proposed mitigation

The proposed mitigation incorporates the existing secondary containment and fully contains any spills from all the identified sources – Refer Figure 5.3. Enhanced secondary containment option includes increasing the wall height at few locations of the existing containment and new walls slightly extending in the east and south. (Refer Figure 5.2). There is also a requirement for a 0.4m high wall in the road at the south side of the site, which was agreed with DCWW operations to be changed to a ramp and increased ground profile to ensure containment and vehicular access.

Figure 5.3: Combined Extent of Sludge from the post-failure of all sources - With Enhanced Secondary Containment Option

Figure 5.4: Enlarged extent – Combined Extent of sludge from the post-failure – With Enhanced Secondary Containment Option

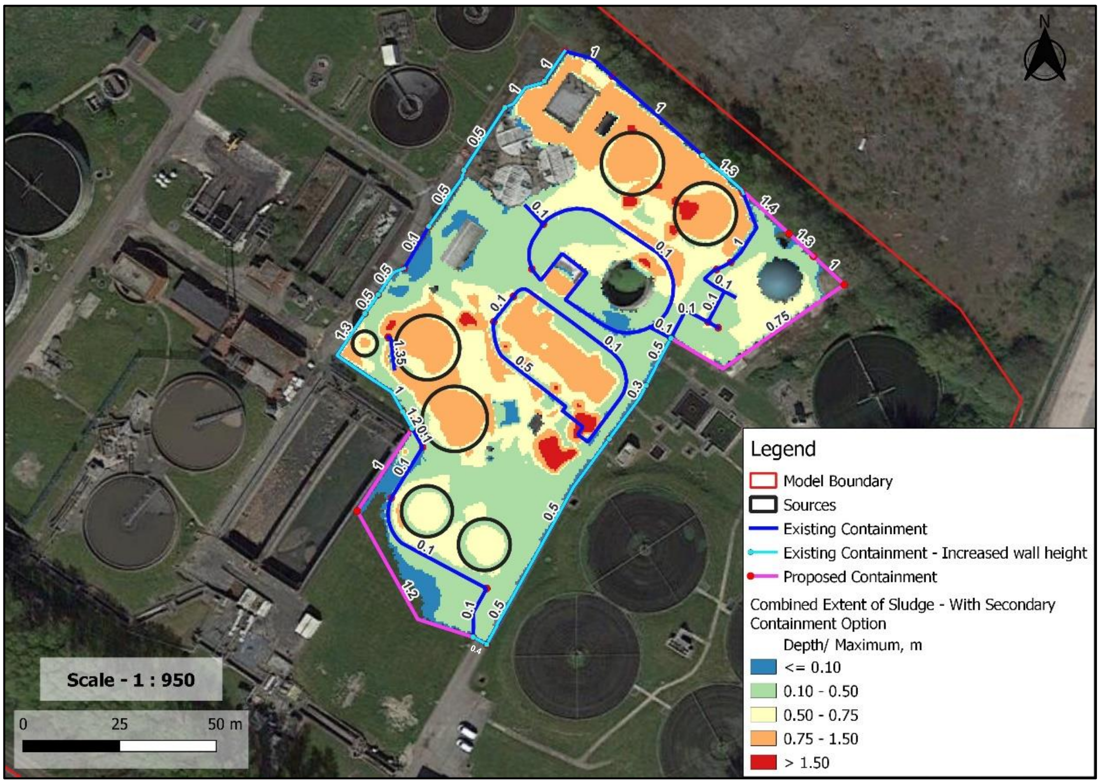
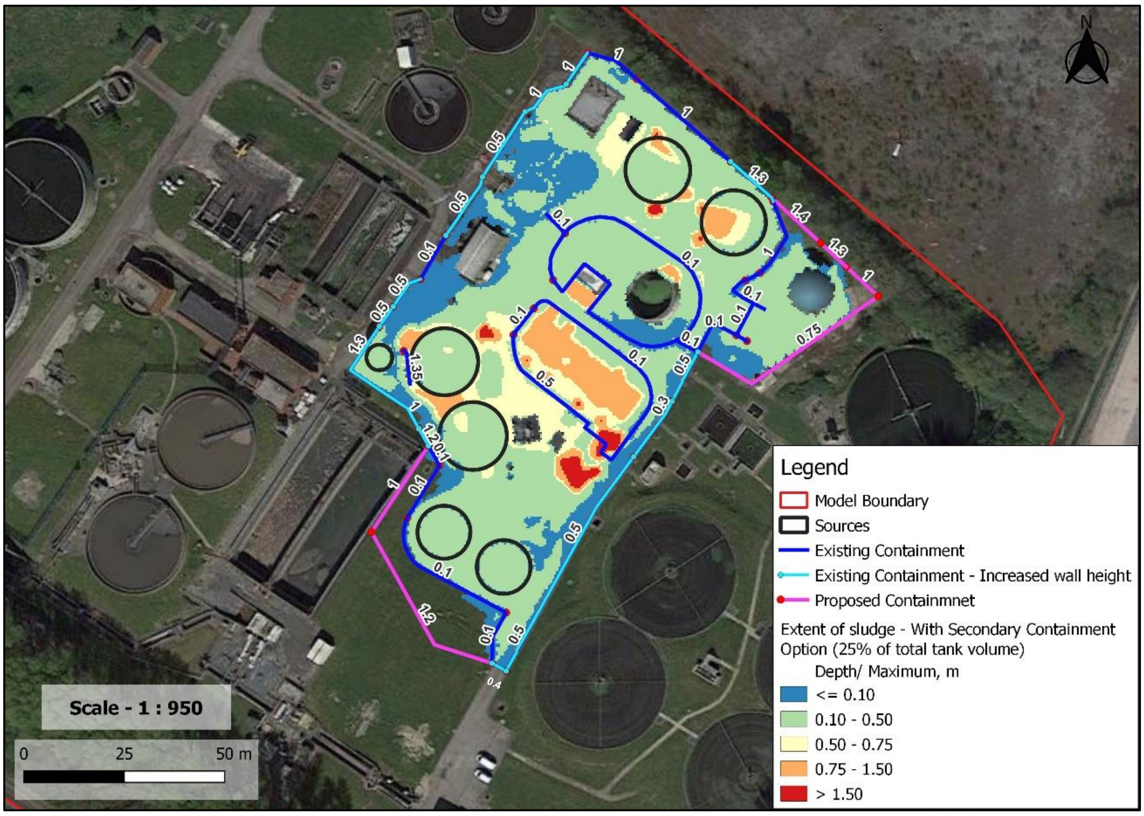


Figure 5.5: Extent of Sludge from the post-failure of all sources (25% of total volume) - With Enhanced Secondary Containment Option

Figure 5.6: Enlarged extent – Extent of Sludge from post-failure (25% of total volume) – With Enhanced Secondary Containment Option



5.3 Summary

It is evident that the high-level proposed option for enhanced secondary containment helps in retaining the sludge completely within the containment boundary. Proposed containment option includes a wall with varying heights (maximum height of 1.4m + freeboard) around the containment boundary along with a few speed humps and ramps for containment and access. The proposed location of the ramp (0.4m high) is in the southside of the containment along the road to ensure that there is no containment loss while providing access within the containment region.

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6 Conclusion

Based on the use of the ADBA risk assessment, considering the source, pathway and receptor risk, Queensferry site hazard rating is deemed to be **high** and the likelihood of a spillage was classed as **medium**. Based on these risks, an overall site risk rating was determined to be **High**, meaning that Class 2 containment is required.

Source Risk	Pathway Risk	Receptor Risk	Site Hazard Rating	Likelihood	Overall Site Risk Rating
Medium	**Medium**	**High**	**High**	**Medium**	**High (Class 3)**

For this assessment, as per CIRIA C736, the volume contained must be the larger of 110% of the capacity of the largest tank or 25% of the total storage capacity within the bunded area. The assessment shows that 25% of the total capacity (1,862m3) is the minimum volume to be contained.

The current containment on the Queensferry site does not protect the wider environment and a mitigation option is required. Various options were explored and the proposed option is a combination of walls and flood gates on the STC boundary contains sludge within the site boundary and to prevent it from leaving site, entering into the critical assets or affecting other sensitive receptors. The hydraulic modelling shows that the proposed mitigation option has a containment volume of 5215m^3, greater than the minimum volume and is successful in retaining sludge on the site from a complete failure of one primary digestor including in the event of a 1 in 10 year return period rainfall event falling 24 hours before. Using the drainage pump station on site as well as tankers, any spill could be cleared up within 3 to 4 days.

This study only provides a high-level proposed option, though it has comprehensively assessed risks and feasbility has been agreed with DCWW operations. Once it is confirmed with NRW, DCWW will resolve the remaining uncertainties in the proposed option by progressing with detailed design and identifying the additional measures required to meet Class 3 containment. This will then be implemented to protect the STC and comply with the future IED permit, within a timeline agreed between DCWW and NRW.

7 Assumptions

- The sludge spillage is modelled as a typical water flow in terms of viscosity.
- The extent of the model is adopted based on the property boundary of WwTW and along the ridges.
- Buildings, tanks, and other assets within WRC which are elevated above the ground are raised in the model (post-failure scenario) based on information received from the client and a high roughness value is assigned. However, at a few locations (where information from the client) is missing, the height of the buildings/ assets is assumed based on the aerial imagery.
- The terrain is defined using the latest 2022 LiDAR data of 1m resolution
- Land use, buildings and roads were digitized and included in the model based on Google Satellite Aerial Imagery.
- The breach/failure analysis was undertaken by applying the polygon inflow in the model. The location of the polygon inflow is the same as that of the storage facility.
- Breach modelling is done based on Environment Agency, EA's breach guidelines, the reservoir's breach equation (given below). This is used with some assumptions to arrive at the inflow hydrograph – Refer Section 4.3.1
  The equation is based on Froehlich (1995) theory.
  - Froehlich (1995) Reservoir Breach equation -

$$Q_p = FOS \cdot [0.607 \, (V_w^{0.295} \, H_w^{1.24})]$$

$$t_e = \frac{2V_w}{Q_p}$$

- The breach was represented by a triangular hydrograph with the volume of the asset discharged over a duration (calculated as per the above formula for t_e) representing the sudden failure of the source. Time to peak is assumed as $1/3^{rd}$ of the end time (t_e).
- In the breach analysis, the tanks are raised by 0.5m only in their respective failure scenario to avoid the instabilities and represent the real-time situation at the time of failure.
- Volume of the tanks are referred from the Anaerobic Digestion Bioresources Association (ADBA) sheet - “B16564-123532-ZZ-XX-AS-ZA-CI0035 - Queensferry ABDA Assessment“
- As the cake bay and sludge holding tanks (three lanes) are located outside of the containment bund boundary, they have not been considered as a source in the model.
- Existing containment bunds are included in the model based on the received information (B14411-123532-XX-XX-DR-CA-CI9000.dwg).

A. Flood Risk Report at Queensferry WwTW

https://check-your-flood-risk.naturalresources.wales 25/09/2024 05:09

Flood risk report for the area within 10 metres of:

1, BRIDGE COTTAGES, CHESTER ROAD, SANDYCROFT, DEESIDE, CH5 2QL

High risk	**Flooding from rivers** Risk greater than 3.3% chance each year
Very low risk	**Flooding from the sea** Risk less than 0.1% chance each year
Very low risk	**Flooding from surface water and small watercourses** Risk less than 0.1% chance each year

The risk levels are: High, Medium, Low and Very low.

This area:

- Does not benefit from flood defences
- Has recorded flooding in the past

This risk level takes into account the effect of any flood defences that may be in this area. Flood defences reduce, but do not completely stop the chance of flooding as they can be overtopped or fail.

Please note

We cannot give the flood risk for individual buildings because this depends on building features and other local factors like drainage conditions.

B. Spill Containment Equipment

Equipment	Reactive	Proactive	Ease of Remote Activation	Retrofittable	Manual Handling	Solar Powered	Testable	Sustainability & Recycling. L=LOW	Suitable for Firewater Containment	Comments
Spill Kit	Yes	No	N/A	Yes	Yes	N/A	No	L	No	Mainly used for maintenance and small volume spills, should be used by trained staff. Generates contaminated waste which requires disposal.
Fixed Bund	Yes	Yes	N/A	Yes	N/A	N/A	Yes	H	Yes	Refer to CIRIA736. Expensive and generally requires capital investment. Essential for high risk storage. Normally only protects the primary vessel.
Portable Bund	Yes	No	N/A	Yes	Yes	N/A	Yes	H	No	Designed for storage of IBC's mainly used in production areas.
Chemical Store	Yes	Yes	N/A	Yes	N/A	N/A	Yes	H	Yes	Primarily used for Chemical and IBC storage. Normally fitted with bunded base.
Drain Cover	Yes	No	N/A	Yes	Yes	N/A	Yes	L	Yes	Drain covers are part of the spill kit and require correct fitting. Clay mats are single use only. When used for spills it is important to use correct PPE. Can expose operator to the spillage. No containment capacity so tertiary area must be good to prevent ground contamination.
DrainBlok	Yes	Yes	N/A	Yes	Yes	N/A	Yes	L	No	DrainBlok can be used multiple times to seal off drainage. These are used by the fire service when the site has no control of drainage run off. Requires trained operators.
Fixed Bladder System	Yes	Yes	Yes	Yes	No	Yes	Yes	H	No	Uses a fixed bladder (stopper). Originally developed in 1998 as a single use emergency containment valve. Air leaks and rodent damage can make them unreliable. Any air leaks will result in containment loss. Easy to retrofit to most drains. Large stoppers are slow to inflate. Not suitable for long term fire water containment due to air leakage.
Penstock Valves / Sluice Gates	Yes	Yes	Yes	Yes	Yes/No	No	Yes	L	Yes/No	Penstocks require correct installation and are most suited to the water and process industry. Have been used as the preferred containment valve by the Environmental Regulators. The word Penstock is generic and fails to consider the leak rate of valves. Any site using a valve for containment should consider the need for the valve to stop all flow. Expensive and difficult to retrofit to drains.
ToggleBlok	Yes	Yes	Yes	Yes	Yes/No	Yes	Yes	H	Yes	Specifically designed as a drop seal valve for spill and fire water containment. Developed to use low power radio and solar power.

Source: Making Water Pollution Prevention Pay (Prepared by David Cole from Sandfield Penstock Solutions, 2018)

C. Site Risk Assessment from ABDA Tool

Refer B16564-123532-ZZ-XX-AS-ZA-CI0035 - Queensferry ADBA Assessment for full details of the ABDA tool

C.1 Hazard Posed

C.1.1 Source

1.1 Source

For the purposes of the ADBA Assessment, assets containing sludge have been listed only

Name	Number	Physical properties	Maximum quantity (above ground)	units	Storage	Flammability	Corrosive	Ecotoxicity (based on LD and quantity)	Hazard rating
Sludge Holding Tank (Screened Sludge Storage Tanks) (partially below ground)	2	Raw Sludge	75	m3	Concrete	Low	Low	Organic heavy - Nitrogen, Phosphorous, Ammonia, BOD, TSS, COD - Environmental hazard (algae blooms and death of organisms)	M
Digester Feed Tank (Thickened Sludge Tank) (partially below ground)	1	Raw Sludge	75	m3	Concrete	Low	Low	Organic heavy - Nitrogen, Phosphorous, Ammonia, BOD, TSS, COD - Environmental hazard (algae blooms and death of organisms)	M
Digester (partially below ground)	2	Digested Sludge	1420	m3	Concrete	Methane produced is flammable Digestate isn't flammable	Low	Organic heavy - Nitrogen, Phosphorous, Ammonia, BOD, TSS, COD - Environmental hazard (algae blooms and death of organisms)	M
Imported Screened Sludge Tank (underground)	1	Raw Sludge	0	m3	Concrete	Low	Low	Organic heavy - Nitrogen, Phosphorous, Ammonia, BOD, TSS, COD - Environmental hazard (algae blooms and death of organisms)	M
Digested Sludge Holding Tank 1 (partially below ground)	1	Digested Sludge	1334	m3	Concrete	Methane produced is flammable Digestate isn't flammable	Low	Organic heavy - Nitrogen, Phosphorous, Ammonia, BOD, TSS, COD - Environmental hazard (algae blooms and death of organisms)	M
Digested Sludge Holding Tank 2 (partially below ground)	1	Digested Sludge	1442	m3	Concrete	Methane produced is flammable Digestate isn't flammable	Low	Organic heavy - Nitrogen, Phosphorous, Ammonia, BOD, TSS, COD - Environmental hazard (algae blooms and death of organisms)	M
Digested Sludge Holding Tanks	2	Digested Sludge	468	m3	GFS	Methane produced is flammable Digestate isn't flammable	Low	Organic heavy - Nitrogen, Phosphorous, Ammonia, BOD, TSS, COD - Environmental hazard (algae blooms and death of organisms)	M
Centrifuge feed tank	1	Digested Sludge	159	m3	GFS	Methane produced is flammable Digestate isn't flammable	Low	Organic heavy - Nitrogen, Phosphorous, Ammonia, BOD, TSS, COD - Environmental hazard (algae blooms and death of organisms)	M
Cake Bays	3	Raw Cake	70	m3	Existing impermeable hardstanding	Low	Low	Organic heavy - Nitrogen, Phosphorous, Ammonia, BOD, TSS, COD - Environmental hazard (algae blooms and death of organisms) Pathogens - Human hazard (E.coli etc.)	L
Sludge Holding Tanks (3 Lanes) (partially below ground)	3	Digested Sludge	100	m3	Concrete	Methane produced is flammable Digestate isn't flammable	Low	Organic heavy - Nitrogen, Phosphorous, Ammonia, BOD, TSS, COD - Environmental hazard (algae blooms and death of organisms)	M
							Overall	M	
		Total Volume	7,446	m3					
		25% Volume	1,862	m3	25% volume to be taken forward.				
		110% Largest Tank (Digested Sludge Holding Tank 2)	1,586	m3					

C.1.2 Pathway

Pathway - the route from primary containment to receptor (extent of loss of containment)	Time of concentration/ duration of source outside containment	Hazard - Transport potential	Receptor	Hazard - Damage potential
Tanks are surrounded by, grass, permeable hardstanding stone and impermeable concrete. Based on available ground information, soil is permeable and will act as a pathway	Direct contamination but over an extended period of time	M	Watercourse and bodies	
If permeable area gets saturated (high groundwater or due to the area flooding as the treatment works is in Flood Zone 3) or becomes blocked with sludge, areas will act as impermeable and transport sludge downstream and towards the River Dee.	Direct contamination but over an extended period of time	M	Groundwater - contaminated through percolation through soil or through fluctuating tidal groundwater level Site is not located within 250m of a Source Protection Zone (SPZ), however the entire site and locality area (surface water) and within a	M
Tidally fluctuating groundwater	Direct contamination but over an extended period of time	M	Sludge storage within 50m of a watcourse that discharges into the River Dee, which is designated as a Site of Special Scientific Interest (SSSI) and	H
Existing underground services - ductwork, troughs, pipework.	Direct contamination but over an extended period of time	L	Local environment including grassy area - through overland flow from uncontrolled	M
There is impermeable concrete surfacing on site If inventory is lost or cascaded onto the road (saturated permeable ground), sludge will be transported downstream along the road surface into the road gullies and into the site drainage system which is connected to soakaways next to abandoned gas holder. These soakaways infiltrate into the soil.	Minutes - hours	M	WWTW - internal drainage system returns effluent to the head of the works prior to discharge into the River Dee	M
If the soakaways get blocked, each soakaway has an overflow to the drainage system (liquor return).	Minutes - hours	M	Habitation	
	Overall	M	Third party land (Bromborough Plastics Ltd) 100m from	M
			Other	
			River Dee SSSI within 250m of the site	H
			Overall	H

Possible Combination			Site Hazard
L	L	L	Low
M	M	L	Low
H	L	L	Low
M	M	M	Medium
H	M	L	Medium
H	H	L	Medium
H	M	M	High
H	H	M	High
H	H	H	High

Combination of Hazards	MMH
Overall risk rating for zone (Ciria	High

C.1.3 Hazard Rating and Containment

1.4	Overall zone hazard rating	
	Overall zone hazard rating (Ciria 736)	High
1.5	Containment required	
	Containment required	Class 3

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