Sandall Secondary Containment Assessment

June 2024

YorkshireWater

Stantec

Sign-Off Sheet

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1 Introduction

As part of the Industrial Emissions Directive (IED) permit application for Sandall Sludge Treatment Facility (STF), Yorkshire Water (YW) has undertaken an assessment of the significance and 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 C736[1].

Sandall 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 5: Site Condition Report.

1.1 Site details

Sandall Wastewater Treatment Works (WwTW) is located within the Long Sandall area of Doncaster, approximately 3.5 km north-east of Doncaster town centre, Yorkshire. The River Don is located to the north and the STF installation is bordered primarily by open land and commercial properties to the east and south, and scrubland including allotments to the west. Sandall STF treats indigenous sludge from the co-located WwTW and liquid sludge imported from other YW WwTW.

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

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

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

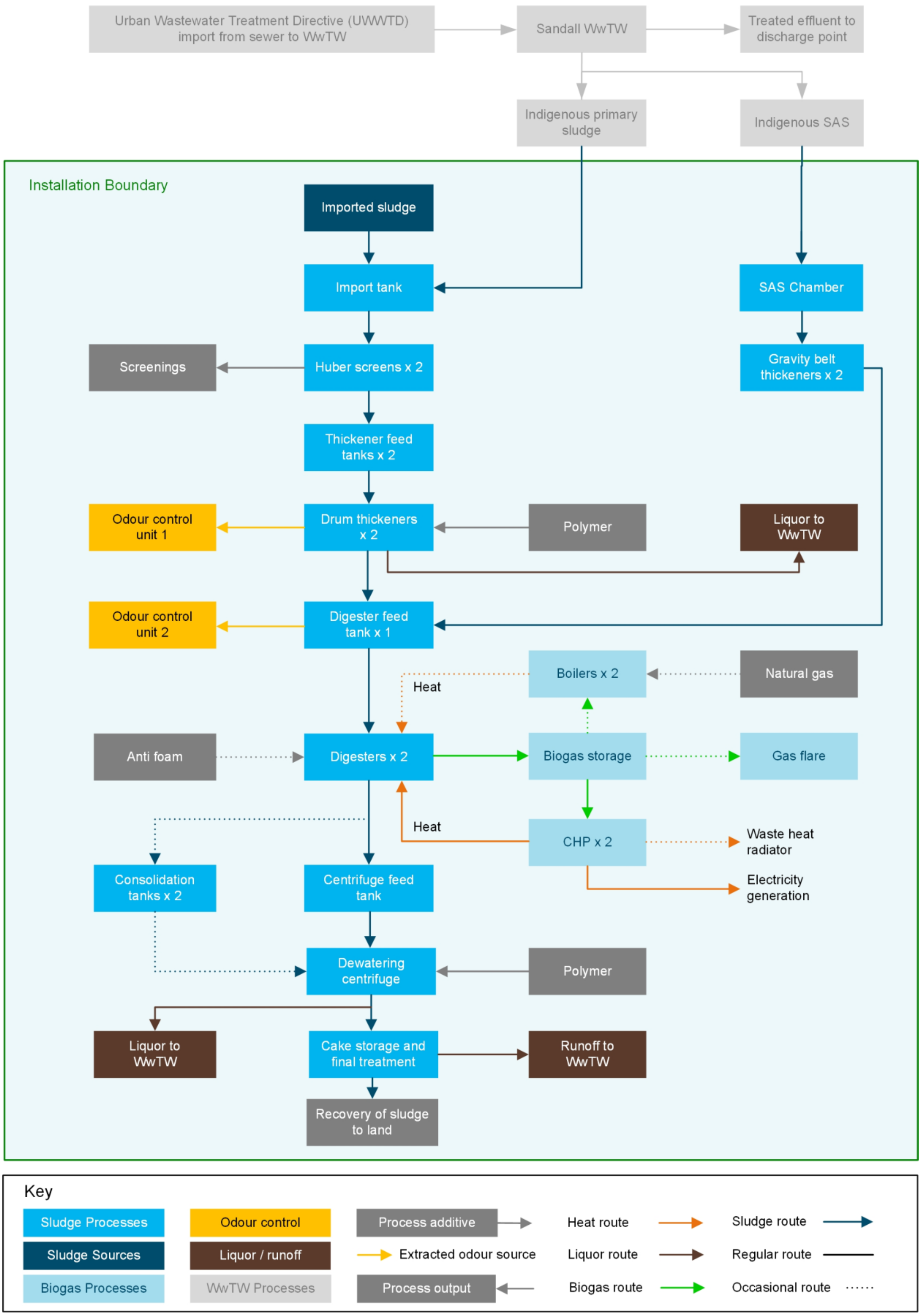


Figure 2. Sandall STF process flow diagram.

1.2 Overview

YW commissioned Stantec to assess existing provisions and potential 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 IED BAT compliance using CIRIA C736 standards. To fully understand the requirement for secondary containment and to provide environmental protection at Sandall, two different 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 Sandall. 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 Sandall 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.

Having regard to 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 Sandall.

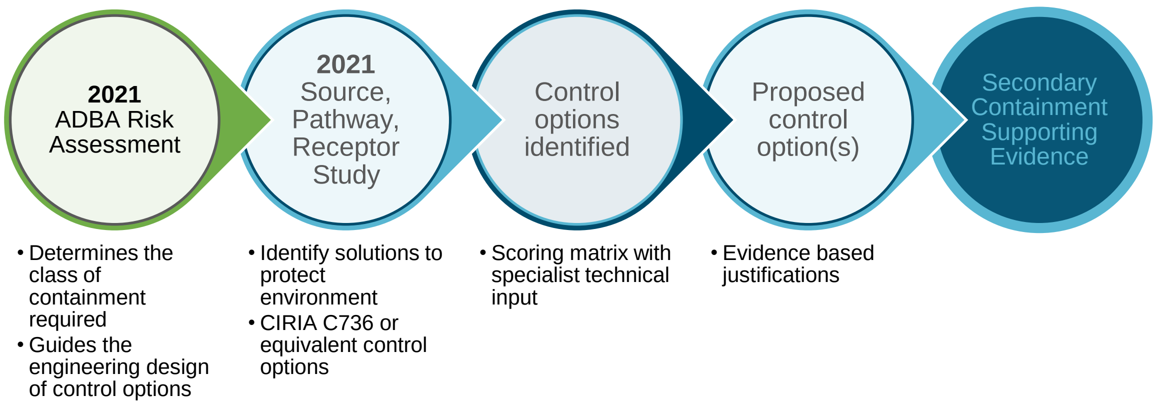


Figure 3. Flow chart showing the approach taken to provide secondary containment supporting evidence.

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 Sandall

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.

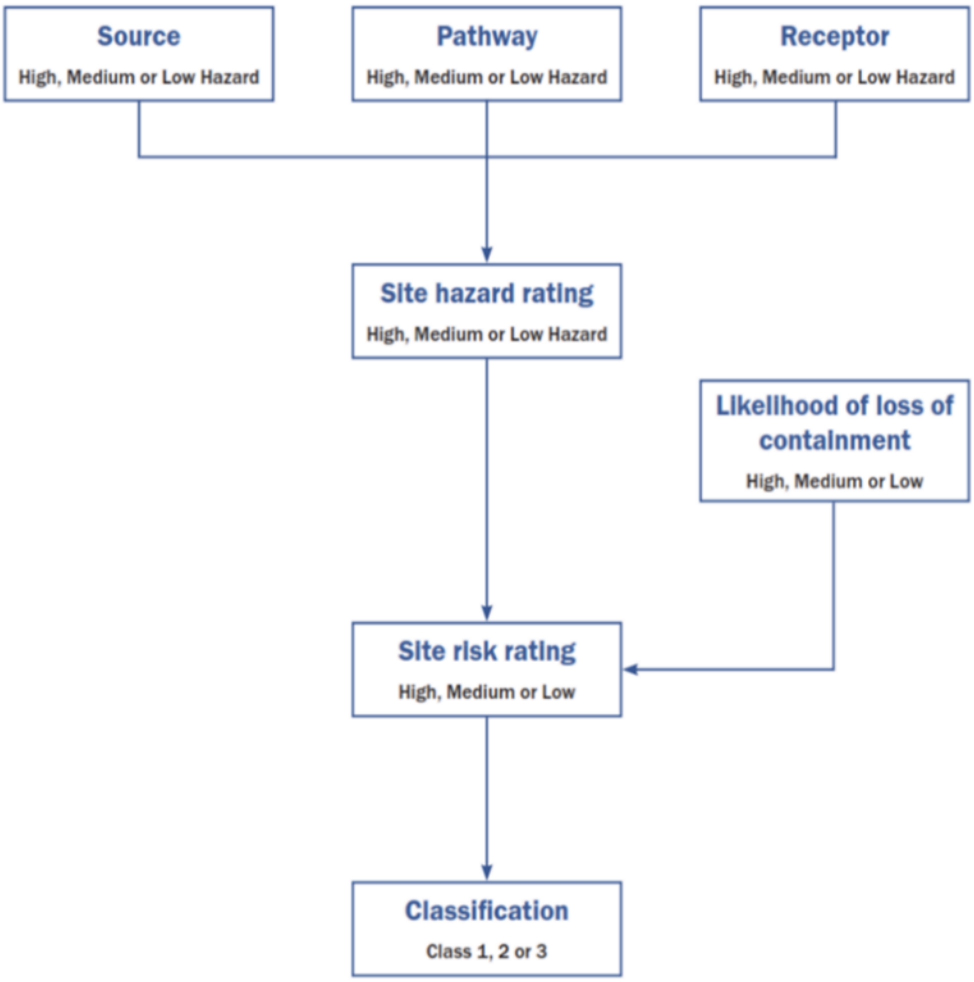


Figure 4. ADBA risk assessment classification flowchart.

The ADBA Risk Assessment Tool scored the source element as 'High risk', pathway elements as 'High risk' and the receptor element as 'High risk' at Sandall owing to the significant volumes of sewage sludge stored on site and site drainage pathways to the sensitive receptor, the River Don. In summary, this assessment approach indicates that Sandall 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 C736), 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 **Sandall 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 'Sandall STF ADBA Secondary Containment Risk Assessment' contains detailed justification for this scoring and is included in Appendix 1.

The conclusion that 'Class 2' type secondary containment is indicated for the Sandall site was taken forward to inform the next stage of the risk assessment, spill modelling and if necessary, the site-specific options appraisal carried out by Stantec in 2021 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 Sandall 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 Sandall STF

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

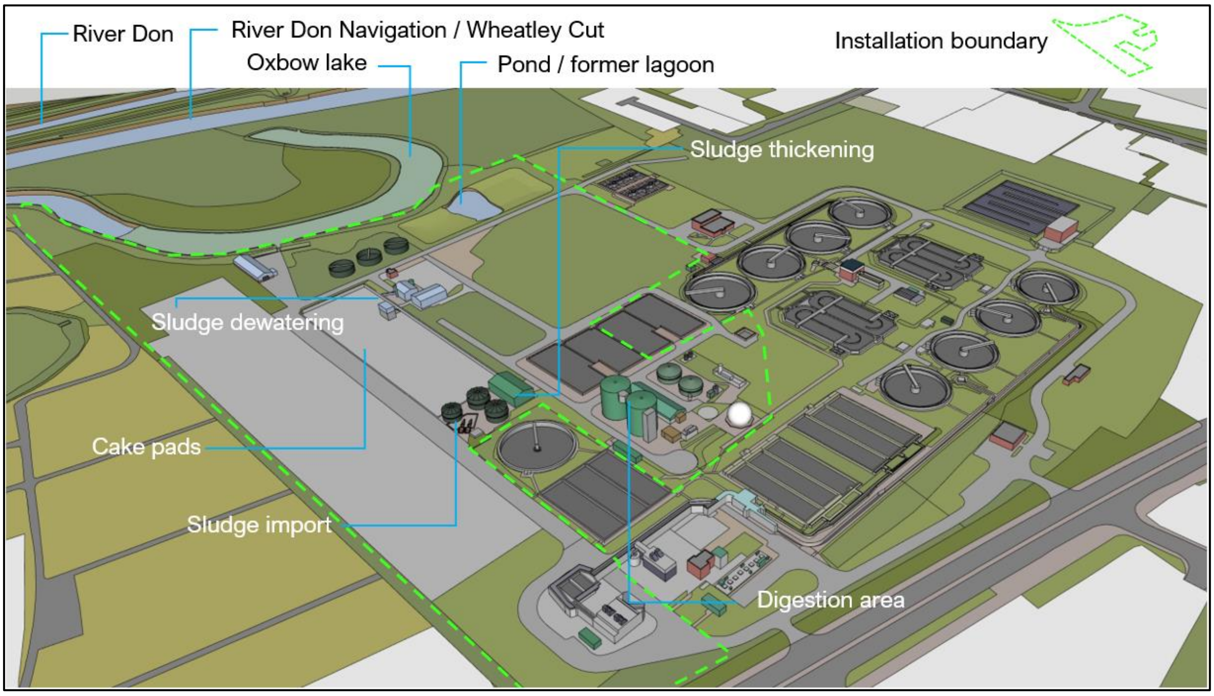


Figure 6. Sandall sources of risk and site areas.

3.2.1 Bulk storage vessels

The bulk storage vessel locations are shown and labelled in Figure 7, Figure 8 and Figure 9. 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.

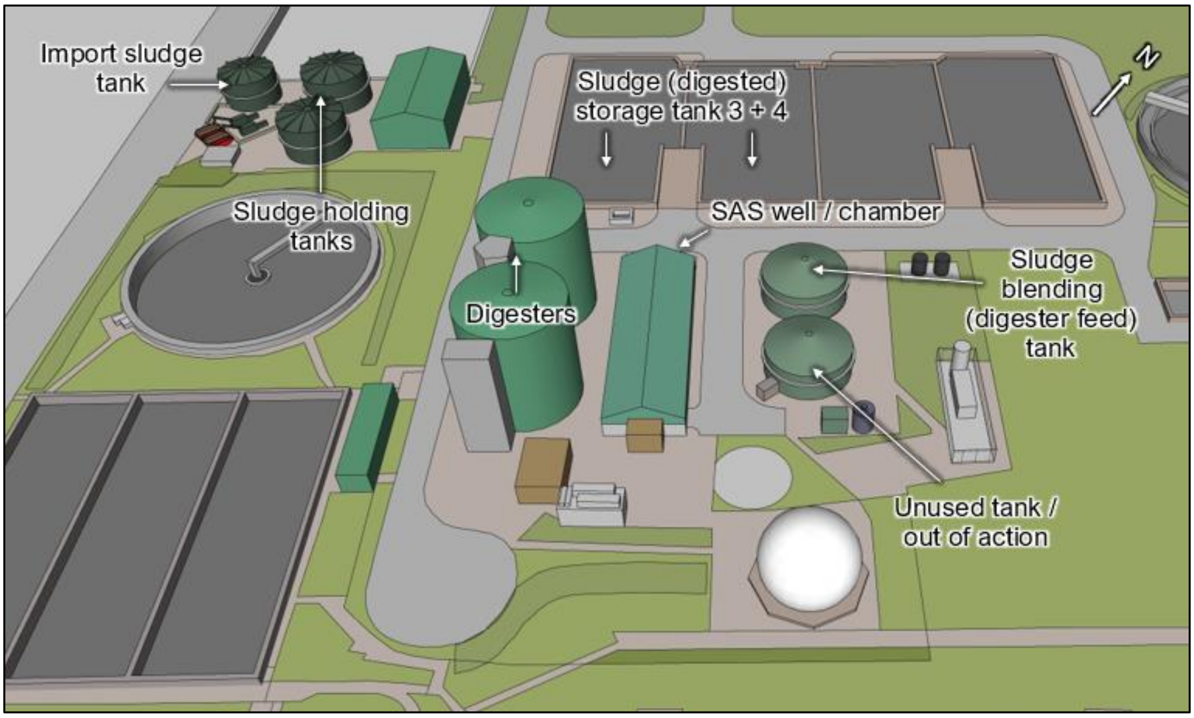


Figure 7. Sludge vessels located in the central section of the site (view 1).

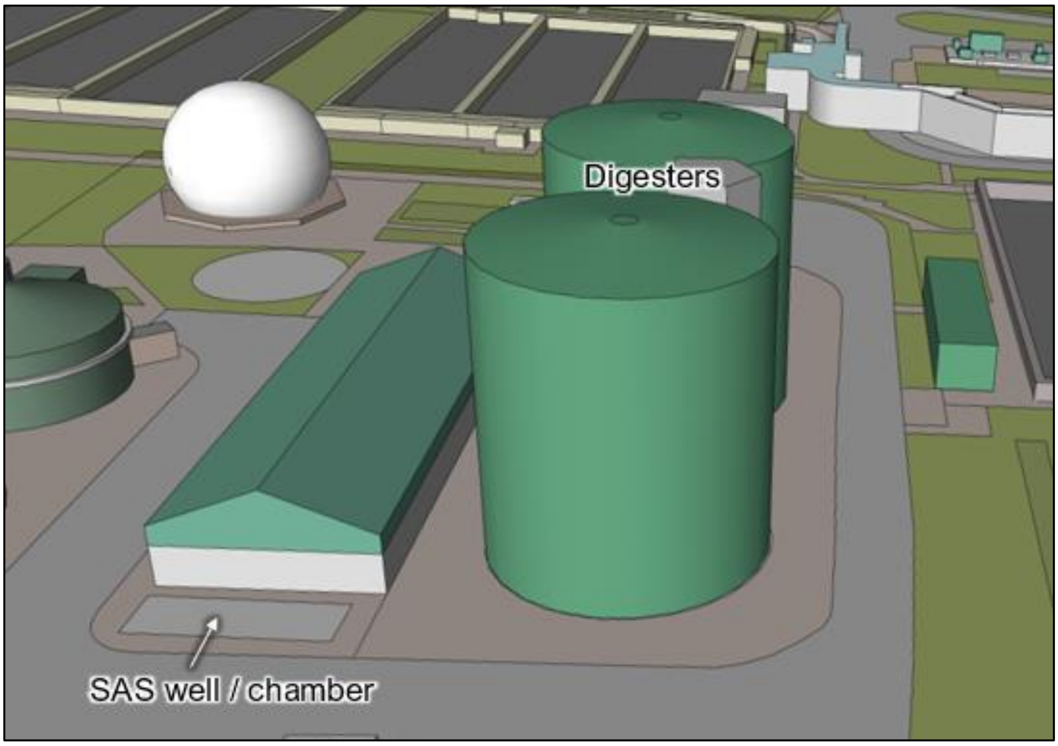


Figure 8. Sludge vessels located in the central section of the site (view 2).

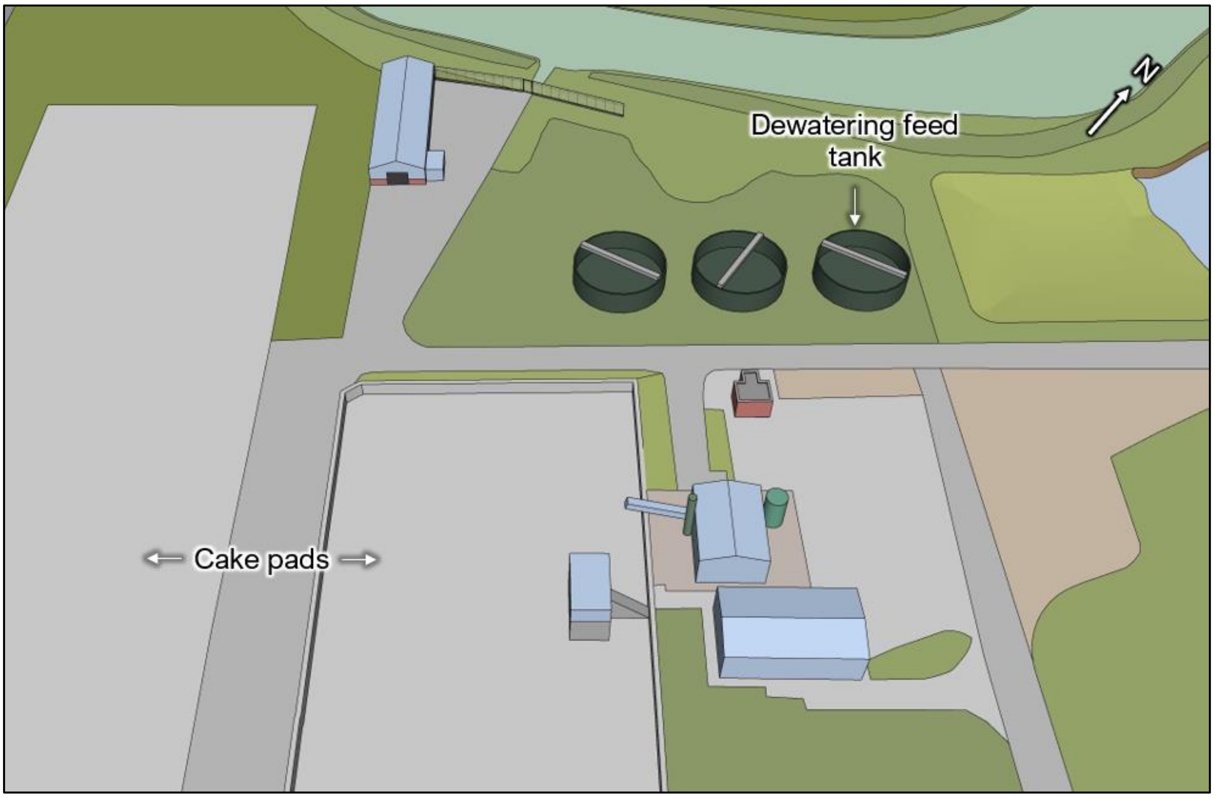


Figure 9. Sludge vessels located in the western section of the site.

3.2.1.1 Sludge reception, treatment, and handling

Sandall STF treats the following sewage sludges:

- Indigenous primary liquid sludges and thickened surplus activated sludge (SAS) arising from sewage treatment processes operating within the wider Sandall 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 Sandall STF for additional treatment.

Imported liquid sludge is delivered to site by tanker. The tanker unloads at the dedicated sludge import area and sludge is pumped (using vehicle mounted pumps) into the import tank (Figure 10, 213 m^3 gross capacity covered steel tank). 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.

Indigenous primary sludge from the wider Sandall WwTW is also pumped into the import tank. The sludge is then screened using two Huber ROTAMAT enclosed rotating screens. Screenings drop into a skip and are disposed of off-site

Figure 10. Imported sludge buffer tank.

Drum Thickeners

After screening, liquid sludge is pumped via a sub-surface concrete sump, in above ground and below ground pipework to the thickener feed tanks (Figure 11, 2 no. 390 m^3 steel tanks). The liquid sludge is mixed (using air injection compressors) and operate in fill / draw mode. The tanks are covered and the headspace air is routed to a vent on the top of each tank.

Figure 11. Imported sludge holding tanks (2 no.).

Sludge from the thickener feed tanks is transferred to the drum thickener building, via above and below ground pipework, serving two drum thickeners each with a maximum feed flow rate of 21 m^3/hour, which operate on a duty/standby basis.

Within the thickener building powdered polymer stored within 750kg bags is dropped into a hopper and then mixed with potable water in a *c.* 3,000 litre polymer 'ageing' tank prior to transfer to an adjacent *c.* 3,000 litre polymer stock tank where the polymer solution is held prior to use. The polymer solution is injected into the sludge stream within the flocculation tank (one flocculation tank per drum thickener) with final treated effluent added as a 'carrier' before being transferred to thickener drums. The polymer encourages separation of water from the sludge as the sludge is rotated in the drum to remove excess liquid. The thickener liquors are returned to the WwTW for full treatment. The thickened sludge is passed forward to the digester feed tank.

The drum thickeners are equipped with automatic spray bars which provide continual self-cleaning. 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.

Best available techniques for sludge reception, treatment and handling includes trace heating, reducing fracture on freezing and largely automated PLC. PLC includes level sensors to reduce risk of tank overtopping, resulting in contamination and potential odour generation. Tanks also have an emergency overspill facility connected to site drainage (that is discharged back to the WwTW inlet) as a last line of defence to prevent overtopping.

Gravity Belt Thickeners

Indigenous SAS from Sandall WwTW is piped to the STF via a separate process stream to indigenous primary sludge. SAS is transferred from the activated sludge process (ASP) to an uncovered below ground SAS chamber (Figure 12, subsurface concrete tank with approximate capacity of 35 m^3) located adjacent to the gravity belt thickener (GBT) building.

From the SAS chamber the liquid sludge is pumped to the GBT building. Within the GBT building, potable (towns) water is used to make up powdered polymer (stored in 25kg bags within the building) into a solution. The polymer solution is held within the polymer blend tank (steel, bunded tank with an approximate capacity of 5 m^3), is then transferred to the polymer transfer tank (steel, bunded tank with an approximate capacity of 5 m^3), and then dosed into the GBTs. Final effluent is added as a "carrier" downstream of the polymer dosing pumps, depending on the exact concentration of polymer required by the operators. The polymer solution is mixed with sludge within the GBT hopper. From here the sludge enters the GBT and migrates down the moving, porous belt where excess liquid is able to drain away, leaving the thickened sludge on the belt. The thickened sludge is passed forward to join imported and primary indigenous sludge at the digester feed tank.

The GBTs are cleaned according to a timed schedule using final treated effluent via automatic spray bars. Additional cleaning using a pressure washing (and potable water) is undertaken according to need (approximately weekly).

Figure 12. SAS chamber containing un-thickened SAS.

3.2.1.2 Sludge digestion

The thickened sludge is transferred to the covered digester feed tank (Figure 13, 412 m^3 steel tank), where it is joined by the thickened SAS. Sludge within the digester feed tank is mixed via an air mixing system. Air is extracted from the digester feed tank and dispersed via OCU 2 (currently bypassed) and 5m vent stack located to the east of the digester feed tank.

Sludge is pumped from the digester feed tank to the anaerobic digesters (Figure 14, 2 no. 1,730 m^3 steel tanks). The anaerobic digesters operate as a continuous process with sludge being added and treated sludge extracted. The two digesters have a typical feed rate of around 100-120 m^3/day combined; the combined maximum feed rate is 259.5m^3/day (at 6% dry solids) giving a 12-day retention time as required by Hazard Analysis and Critical Control Points (HACCP) controls. The digesters are mixed by gas mixing systems, which utilise biogas from the headspace of each digester; the gas is compressed and then reintroduced using an array of mixing nozzles on the floor of the digester.

Figure 13. Sludge blending (digester feed) tank.

A hot water circuit provides heating to ensure optimum conditions for digester microbial activity. Potable water is heated to around 70°C by the CHPs and/or boiler. This hot water then heats the digester using tube-in-tube, counter-current heat exchangers. Sludge from the digesters is continually recirculated around the heat exchangers using 2 no. (duty/standby) recirculation pumps per digester. A 3-way modulating valve on the water side moderates 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, treated final effluent is sprayed into the digester head space through nozzles in the digester roof. If this is not effective in breaking up the foam, a chemical anti-foam is mixed with treated final effluent and dosed into the headspace of the digester via the same spray nozzles. Antifoam may also be dosed directly into the sludge recirculation line, both options are available depending on requirements. This system includes operator-adjustable dosing setpoints and failsafe systems; if the foam level continues to increase mixing systems are inhibited and if this continues the digester feed will be inhibited. Antifoam is stored in 20 litre plastic containers located within an adjacent building prior to transfer to the integrally bunded antifoam dosing tank (approximate capacity of 0.25m^3).

Sludge extracted from the digesters is transferred via below ground pipeline to the centrifuge feed tanks.

Figure 14. Digesters (2 no.).

Best available techniques for sludge digestion include largely automated PLC, monitoring for optimum digester health and foam levels to avoid potential loss of containment, including an anti-foaming system. Additionally, 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 pumped via below ground pipes to a centrifuge feed tank, (Figure 15, 320 m^3 uncovered steel tank) located approximately 180 m to the northwest of the anaerobic digesters. There is currently no mixing of the digestate within this tank.

In addition, there are two large tanks, located adjacent to the digester feed tank, which are retained on site for contingency storage of digested sludge. These are known as consolidation tanks 3 and 4 and are concrete lined uncovered rectangular tanks with an approximate capacity of 800 m^3 each (Figure 16). These tanks are retained for temporary storage of digested sludge in the event of maintenance or failure of the downstream dewatering centrifuge.

From the centrifuge feed tank, digested sludge is transferred to the dewatering centrifuge. Within the adjacent polymer room, powdered polymer stored in 750kg bags is dropped into a hopper and then mixed with potable water in a *c.* 3,000 litre polymer ‘ageing’ tank prior to transfer to an adjacent *c.* 3,000 litre polymer stock tank where the polymer solution is held prior to use. The digested sludge is then mixed with the polymer solution and passed to the dewatering centrifuge where the sludge coagulates, and supernatant liquor is removed by centrifugal forces. The liquor drops from the centrifuges into a sump and is pumped back to the WwTW for treatment.

Figure 15. Dewatering feed tank (on the right).

Figure 16. Emergency sludge storage tanks 3 & 4.

The final digested and dewatered sludge cake is dropped directly from the centrifuge onto the cake pad (Figure 17). The area under the centrifuge and adjacent sludge cake pads are an engineered impermeable surface, with water runoff collected in drains and pumped back to the WwTW for full treatment.

Figure 17. Sludge cake conveyor and pad.

Sludge cake is moved by mechanical loaders into piles on the cake pad area (Figure 18). There is no lime addition at Sandall; instead, cake is placed in piles according to age and left for further pathogen reduction according to the Critical Limit in the HACCP plan. The maximum storage capacity of the cake pads is approximately 8,000m^3; although significantly less than this is stored under normal operating conditions. Greater volumes may be stored on site in emergency/abnormal conditions such as following processing problems at other YW sites or in extreme weather conditions when landspreading operations are temporarily paused. Once treatment is complete, sludge cake is removed from site and landspread in accordance with legislative requirements. Samples of digested, fully treated cake are taken every 3 months and analysed for metals and pathogens to ensure HACCP standards are being met.

Figure 18. Sludge cake storage pad.

The best available techniques for digested sludge treatment, handling and disposal comprises of an engineered cake pad with leachate and washwater collection for treatment at the WwTW, and an inspection and testing programme for pipes and valves, which include 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. Sandall STF tanks, capacities, age, and construction materials.

Tank	Size m^3 (each tank)	Age (years)	Construction material
1 no. imported sludge buffer tank	213	1	Steel
2 no. imported sludge holding tanks	390	13	Steel
1 no. SAS chamber	35[a]	88	Concrete
2 no. liquid polyelectrolyte tank (ageing and stock – drum thickening)	3	13	Steel
2 no. liquid polyelectrolyte tank (blend and transfer – GBT thickening)	5	13	Steel
1 no. sludge blending (digester feed) tank	412	13	Steel
2 no. digesters	1,728	9	Steel
2 no. digested sludge storage tanks 3 + 4	800	32	Concrete
2 no. polymer tanks (ageing and stock - dewatering)	3	14	Steel
1 no. dewatering feed tank	320	20	Steel
1 no. diesel tank	1.3	N/A	Steel

[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 Sandall, 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 Sandall 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 surfacing

Most of the active process areas within the installation are covered by buildings and hardstanding, with some peripheral areas of soft landscaping (grass and gravel cover). Surfacing was generally observed to be in good condition across the site with no significant evidence of cracks or erosion. Site surfacing for Sandall is illustrated in Figure 19.

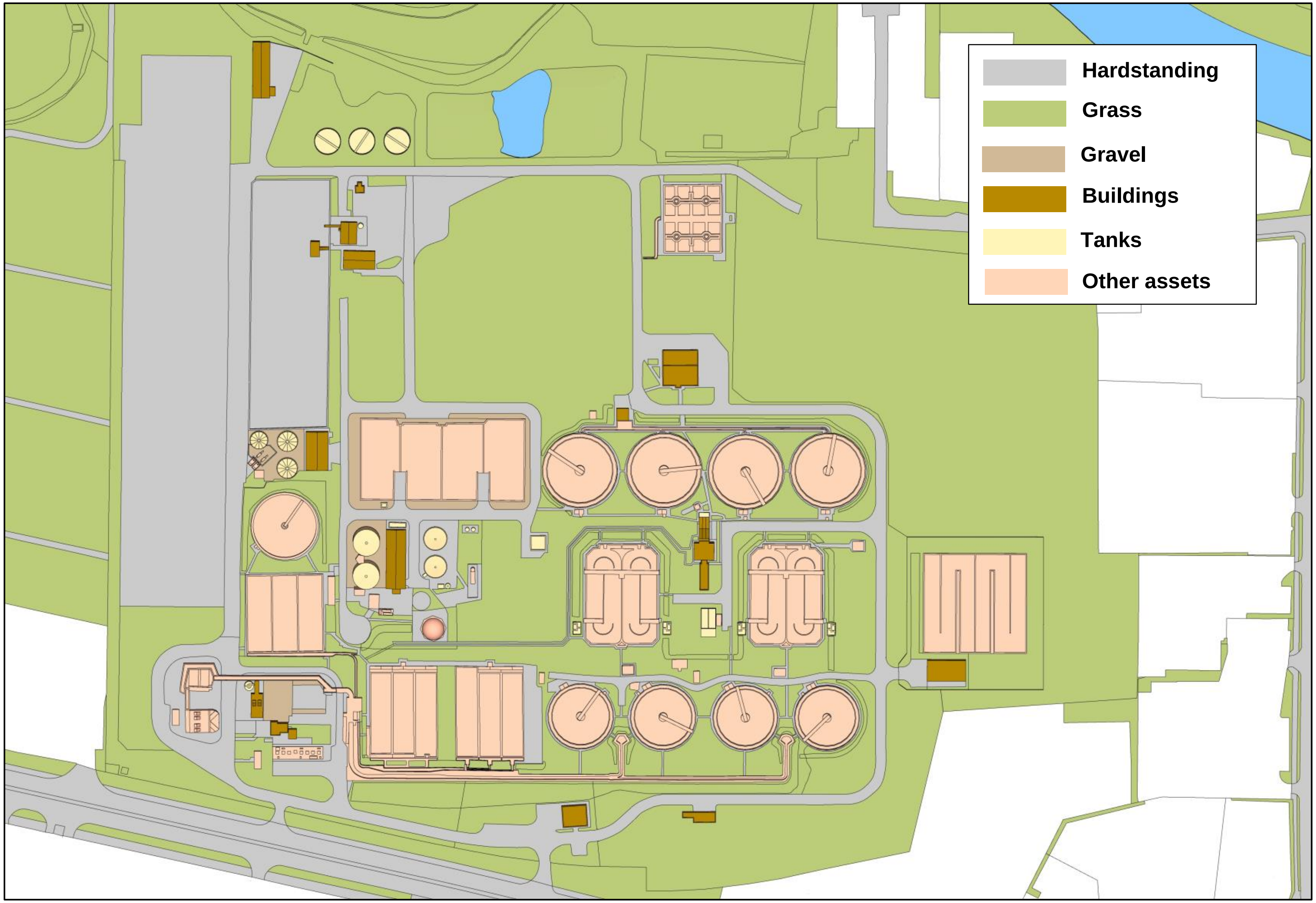


Figure 19. Sandall existing site surfaces.

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 Sandall 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 Sandall 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 CIRIA C736 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 Sandall. 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 should be 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 should be treated as if they were a single tank.

The Sandall sludge storage tanks and treatment processes are installed as either multi-tank or single tank installations, as shown in Figure 20, 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 CIRIA C736 rule spill modelling scenario and associated containment volumes is listed in Table 2, whilst full calculations can be viewed in Table 6.

The SAS chamber is an entirely subsurface installation, whilst the digested sludge storage tanks 3 and 4 are located partially below ground, therefore any volumes below ground can be considered contained. Consequently, only above ground volumes were used in the calculation of modelling volumes.

Figure 20. Sandall single tank and multi-tank installation areas.

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	4,233 (see Table 6)	Figure 21

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 21 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 3.6 Spill pathways.

It is important to note that owing to the limitations described in 3.4.1.1, and the specific topography of the Sandall site, it is not felt that PondSIM outputs at Sandall are 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 Sandall, 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 Sandall 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 21 shows a rectangular tank is situated at the north of the site becoming inundated. This is unrepresentative of the site, as a sufficient tank lip height exists. Therefore, subsequent model runs will be modified to increase barrier height to improve site representation and effectively display spill volume dispersion within the site.

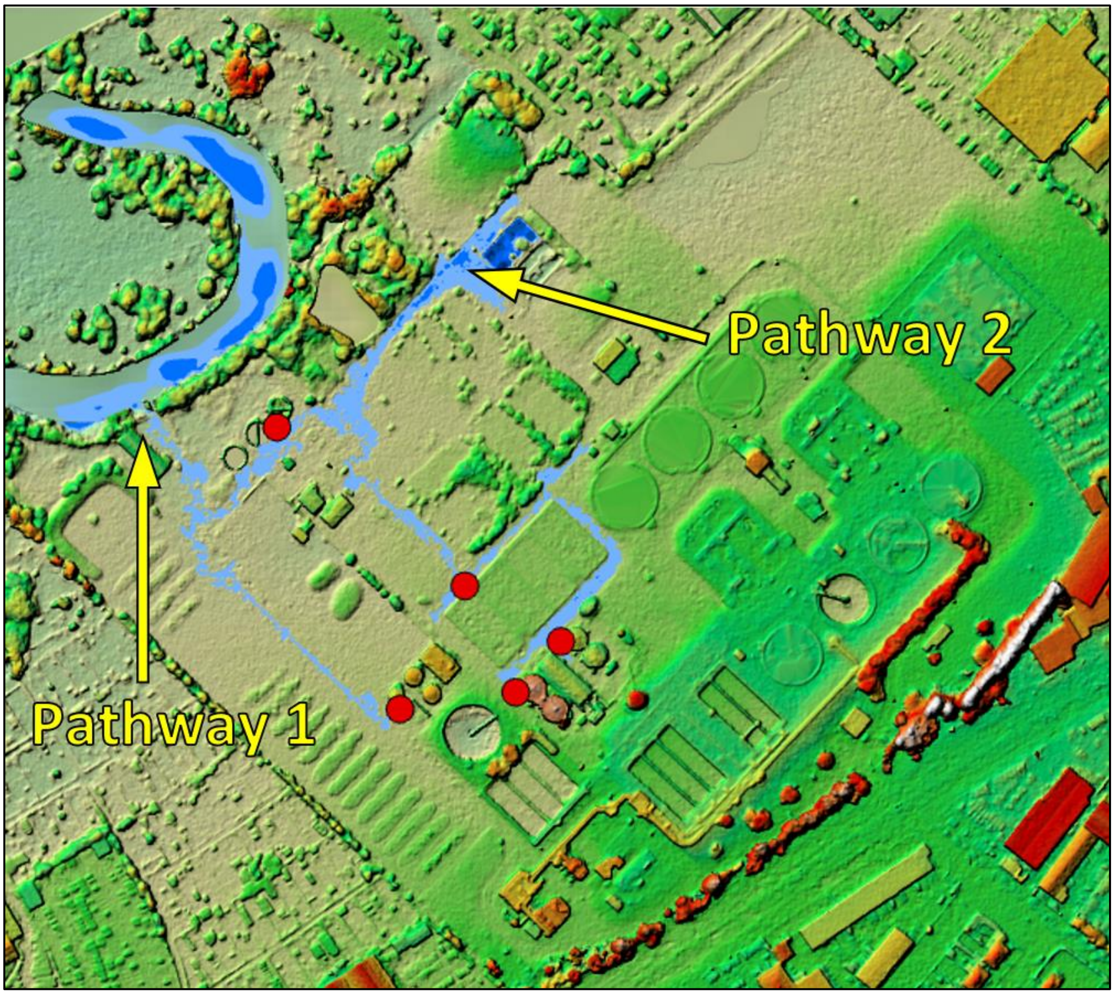


Figure 21. Model showing unmitigated result of spills and resulting pathways from existing tanks at Sandall STF using the CIRIA C736 rule.

3.6 Spill pathways

3.6.1 Surface drainage

A surface water drainage survey was completed at Sandall WwTW in February 2020. The survey mapped the location of gullies and manholes, separating them into contained and non-contained drainage routes, as illustrated in Figure 22. 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.

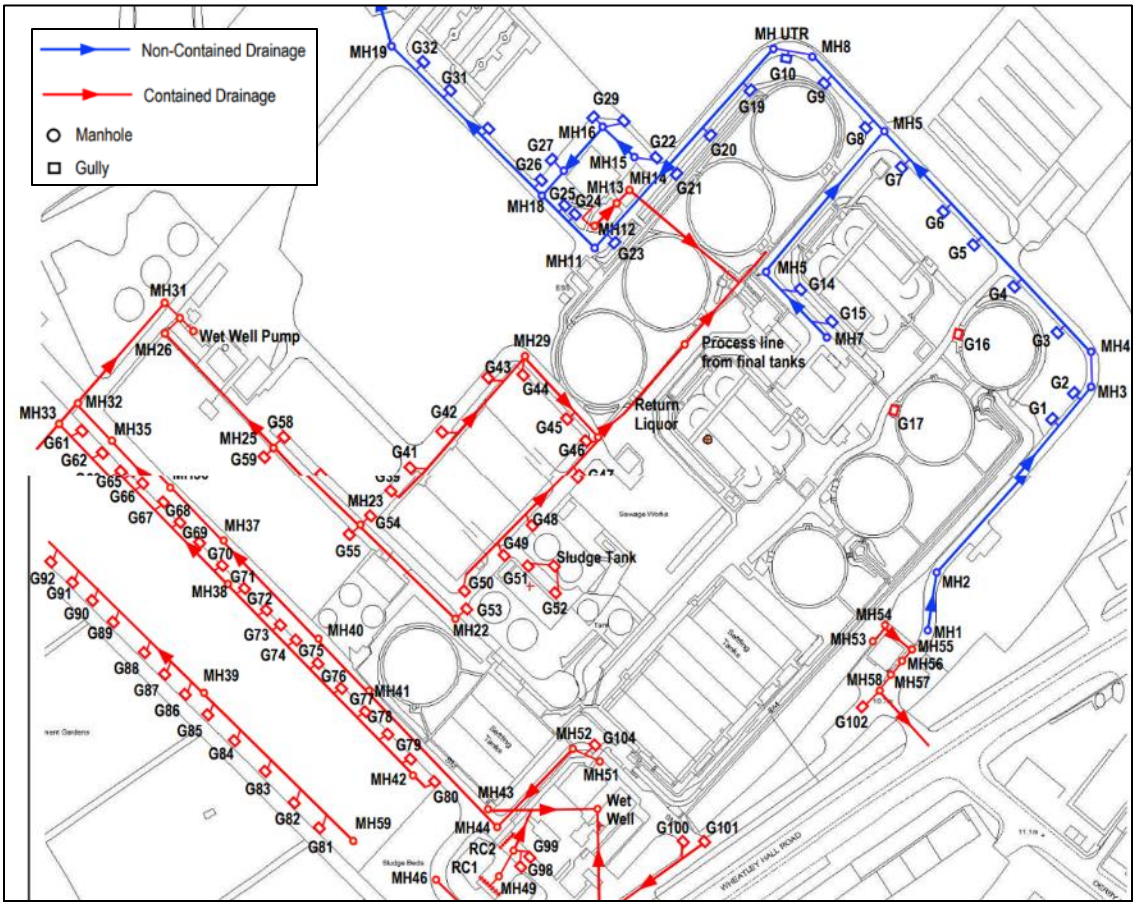


Figure 22. Sandall WwTW surface drainage route survey.

3.6.2 Pathway 1 – direct route to the oxbow lake

The unmitigated modelled spills show the potential of spill contained mainly on impermeable hardstanding surfaces, including a direct route to a sensitive receptor, the oxbow lake, illustrated in Figure 23. The pathway is the result of spills merging from multi-tank installation 1, 2 and 3, and then finding a route to the oxbow lake through a gap in between a low-lying wall at the west of the site, as shown in Figure 24. Contained surface drainage is present throughout the site, mainly on access roads, which returns to the WwTW for treatment.

A medium confidence is given to the modelled route of sludge shown in Pathway 1 due to the limitations of PondSIM in modelling the spread of sludge spills, and a tendency to exaggerate the distance sludge would flow in the event of a spill. Whilst the modelling at this site is likely to exaggerate the extent of a real-life sludge spill, this spill pathway shows a potential pathway to the sensitive receptor and therefore mitigations will be placed to enhance environmental protection.

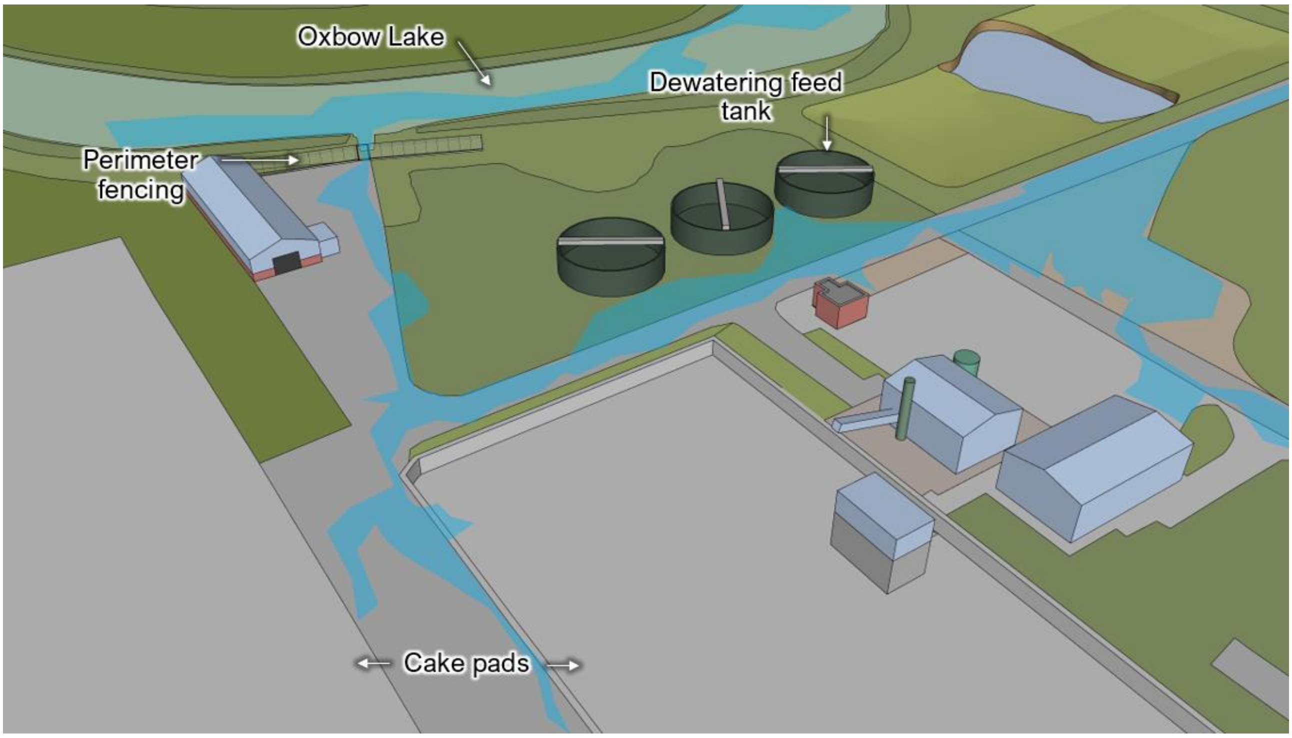


Figure 23. Potential spill pathway to Oxbow Lake.

Figure 24. Spill entrance to oxbow lake under perimeter fencing.

3.6.3 Pathway 2 – indirect route to the River Don

Figure 25, shows the potential for an unmitigated flow of sludge merging and spilling toward the northern section of the site pooling on access road hardstanding surfaces. Surface drainage along the access road located in the north is un-contained and therefore presents an indirect route to the River Don via the un-contained drainage outlet.

Medium confidence is given to Pathway 2 due to the limitations of the PondSIM in modelling surface drainage features that are contained, particularly within the central and southwest sections of the site, including the spread and exaggerated distances of a sludge spill. Mitigations will be placed to enhance environmental protection as this pathway shows a route to a sensitive receptor.

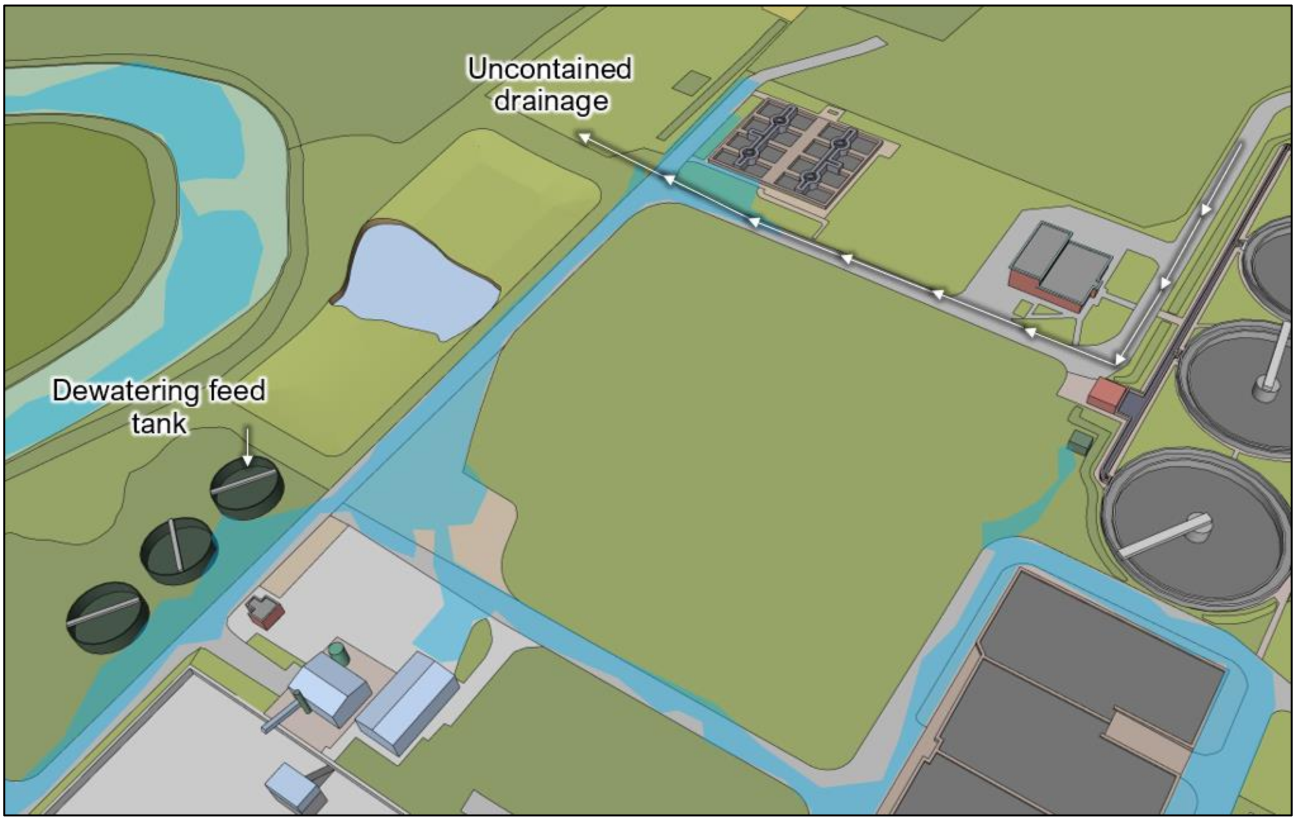


Figure 25. Potential spill pathway to River Don via un-contained surface drainage north of the site.

3.6.4 Spill pathway summary

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

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

Common area / Tanks	Surface pathways	Comments
Multi-tank installation area 1. (Sludge import tank, 2 no. imported sludge holding tanks)	Pathway 1 – overall medium confidence. Overland run-off over mostly sealed surfaces to: • West of the site towards the oxbow lake.	Spill volume captured on existing site access roads and cake pad hardstanding areas before reaching perimeter fencing and route to a sensitive receptor. Local surface water drainage in this area is contained and is returned to the WwTW for treatment prior to discharge.
Multi-tank installation area 2. (2 no. digesters, 1 no. SAS well) + Multi-tank installation area 3. (2 no. sludge storage tanks) + Single tank installation (sludge blending tank)	Pathway 1 – overall medium confidence. Pathway 2 – overall medium confidence. Overland run-off over mostly sealed surfaces to: • West of the site towards the oxbow lake. • North of the site towards the un-contained surface drainage	Spill flows across the site and is captured on hardstanding and road surfaces before reaching perimeter fencing to the west and the northern section of the site. Local surface water drainage located north of the site is un-contained. Elsewhere, this is contained and is returned to the WwTW for treatment prior to discharge.
Single tank installation area. (1 no. dewatering feed tank)	Pathway 1 – overall medium confidence. Pathway 2 – overall medium confidence. Overland run-off over un-sealed and sealed surfaces to: • West of the site towards the oxbow lake. • North of the site towards the un-contained surface drainage.	Spill flows over both permeable and hardstanding surface and before reaching perimeter fencing to the west and the northern section of the site. Local surface water drainage located north of the site is un-contained. Elsewhere, this is contained and is returned to the WwTW for treatment prior to discharge

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 26 shows the receptors identified which could theoretically be impacted by a loss of containment from sludge vessels at Sandall.

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.

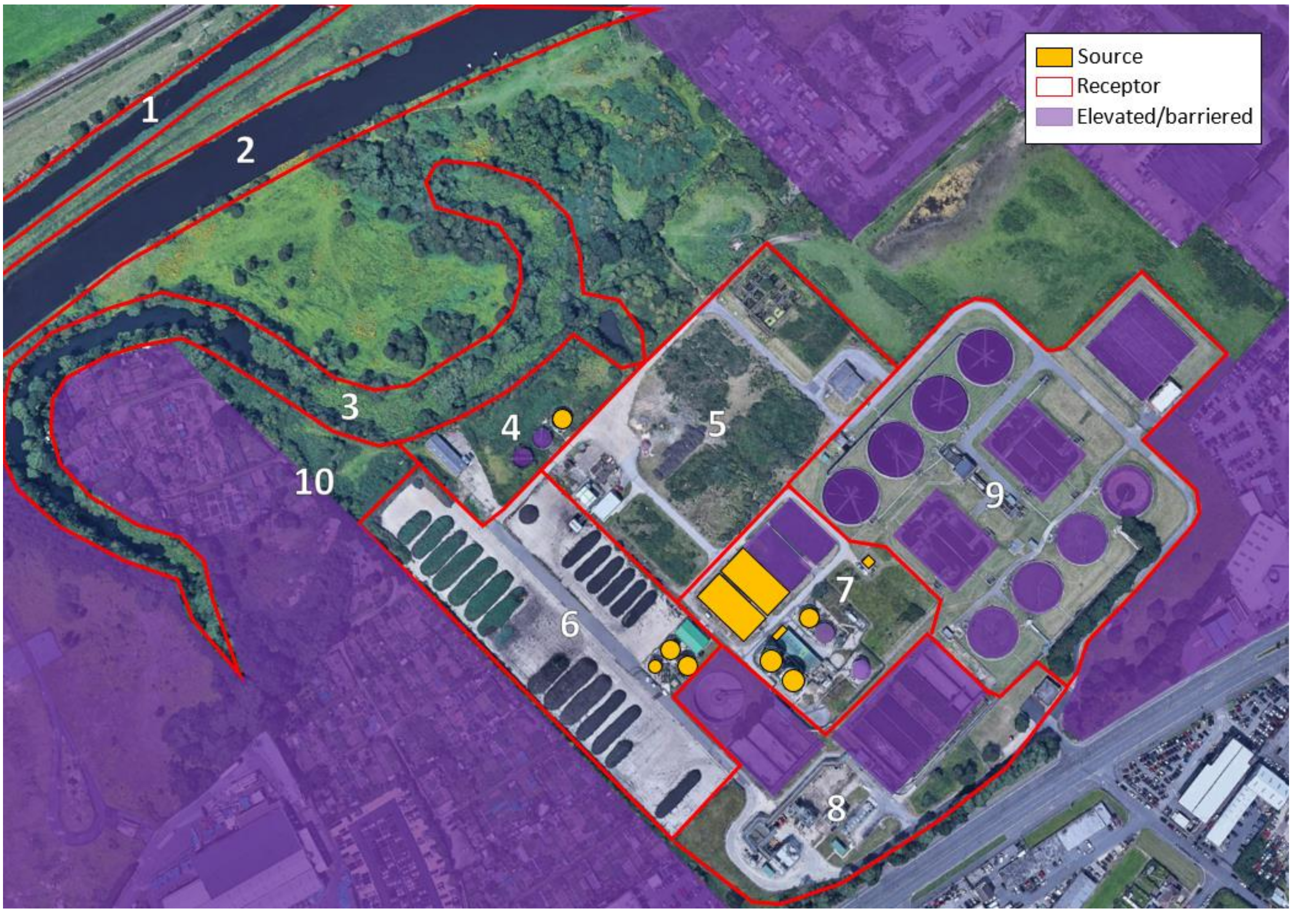


Figure 26. Map of numbered receptors at Sandall. © Google, 2021.

Table 4. Receptor number and description.

Receptor no.	Receptor
1	River Don (including adjacent habitats).
2	River Don Navigation / Wheatley Cut and River Don (including adjacent habitats).
3	Oxbow lake and pond / former lagoon (including adjacent habitats).
4	Ground / groundwater - areas surrounding the dewatering feed tanks.
5	Ground / groundwater - areas central to the site.
6	Ground / groundwater - areas including and surrounding the cake pads, including sludge import and holding tanks
7	Ground /groundwater – area surrounding digestion plant, including blending and digested sludge holding tanks.
8	Ground / groundwater - areas including and surrounding site inlet works.
9	Ground / groundwater - areas including and surrounding PSTs and FSTs.
10	Ground / groundwater – areas of sold land, local wildlife sites and allotments

3.8 Source-pathway-receptor summary

A summary of the receptors at risk following the modelling of spill pathways from identified sources at Sandall STF is listed in Table 5. According to the modelling, receptors 8 (site inlet) and 9 (PSTs and FSTs) 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. (Sludge import tank, 2 no. imported sludge holding tanks)	Pathway 1 – overall medium confidence. Overland run-off over mostly sealed surfaces to: • West of the site towards the oxbow lake.	• Receptor 6 - Ground / groundwater - areas including and surrounding the cake pads, including sludge import and holding tanks [high confidence]. • Receptor 10 - Ground / groundwater – areas of sold land, local wildlife sites and allotments [medium confidence]. • Receptor 4 – Ground / groundwater - areas surrounding the dewatering feed tanks [medium confidence]. • Receptor 2 - River Don Navigation / Wheatley Cut and River Don [medium confidence]. • Receptor 5 - Ground / groundwater - areas central to the site [low confidence].
Multi-tank installation area 2. (2 no. digesters, 1 no. SAS well) + Multi-tank installation area 3. (2 no. sludge storage tanks) + Single tank installation (sludge blending tank)	Pathway 1 – overall medium confidence. Pathway 2 – overall medium confidence. Overland run-off over mostly sealed surfaces to: • West of the site towards the oxbow lake. • North of the site towards the un-contained surface drainage	• Receptor 7 - Ground /groundwater – area surrounding digestion plant, including blending and digested sludge holding tanks [high confidence]. • Receptor 5 - Ground / groundwater - areas central to the site [medium confidence]. • Receptor 3 - Oxbow lake and pond / former lagoon (including adjacent habitats) [low confidence]. • Receptor 2 - River Don Navigation / Wheatley Cut and River Don [low confidence]. • Receptor 4 – Ground / groundwater - areas surrounding the dewatering feed tanks [low confidence]. • Receptor 10 - Ground / groundwater – areas of sold land, local wildlife sites and allotments [low confidence].
Single installation area. (1 no. dewatering feed tank)	Pathway 1 – overall medium confidence. Pathway 2 – overall medium confidence. Overland run-off over un-sealed and sealed surfaces to: • West of the site towards the oxbow lake. • North of the site towards the un-contained surface drainage.	• Receptor 4 - Ground / groundwater - areas surrounding the dewatering feed tanks [high confidence]. • Receptor 5 - Ground / groundwater - areas central to the site [high confidence]. • Receptor 3 - Oxbow lake and pond / former lagoon (including adjacent habitats) [medium confidence]. • Receptor 10 - Ground / groundwater – areas of sold land, local wildlife sites and allotments [low confidence]. • Receptor 2 - River Don Navigation / Wheatley Cut and River Don [low confidence].

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 27, with further specification and dimensions given in Appendix Table 1. This solution achieves CIRIA C736 compliance, including approaches for improving the sustainability of construction in the following ways:

- **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 reference in Figure 19 and as shown in Figure 27 within areas of red lines) will be made impermeable where construction allows, and considers poured concrete and matting, including bentonite clay matting to reduce embodied carbon.
- **Ramps & flood gates:** will be used as required to provide access into bunds. Ramps are the preferred solution, as they provide access without affecting the integrity of the bund. Floodgates may be installed where the need for access is very infrequent, and installation of a ramp is not practical. Where floodgates are required an appropriate management system will be implemented to ensure an appropriate level of environmental protection is maintained when they are in use.
- **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.

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.

The total containment volume required within the bund was calculated as per Table 6. Following the CIRIA requirement to contain the larger volume of 110% of the largest tank or 25% of all tanks, a site wide bunding solution is necessary to contain volumes of 858 m^3, 453 m^3,1,901 m^3, 669 m^3 and 352 m^3 containment within the site boundary. Additional volumes will be allowed for freeboard to handle surge (Appendix Table 1).

Table 6. Sandall containment volumes

Tank	Area	Hydraulically linked to another tank?	Above ground volume m^3 (per tank)	Total volume m^3 (group)	110% size m^3
Imported sludge buffer tank	Multi-tank area 1	-	165	165	182
Imported sludge holding tanks		Yes	390	780	858
			Largest 110% size		858
			Total volume	165	
			25% of total volume	41	
Sludge blending tank	Single tank area	-	412	412	453
			Largest 110% size		453
			Total volume	412	
			25% of total volume	103	
Digesters	Multi-tank area 2	No	1,728	3,456	1,901
SAS well / chamber[a]		-	0	0	0
			Largest 110% size		1,901
			Total volume	3,456	
			25% of total volume	864	
Sludge storage tanks[a]	Multi-tank area 3	No	608	1,216	669
			Largest 110% size		669
			Total volume	1,216	
			25% of total volume	304	
Dewatering feed tank	Single tank area	-	320	320	352
			Largest 110% size		352
			Total volume	320	
			25% of total volume	80	

[a] subsurface tank installation

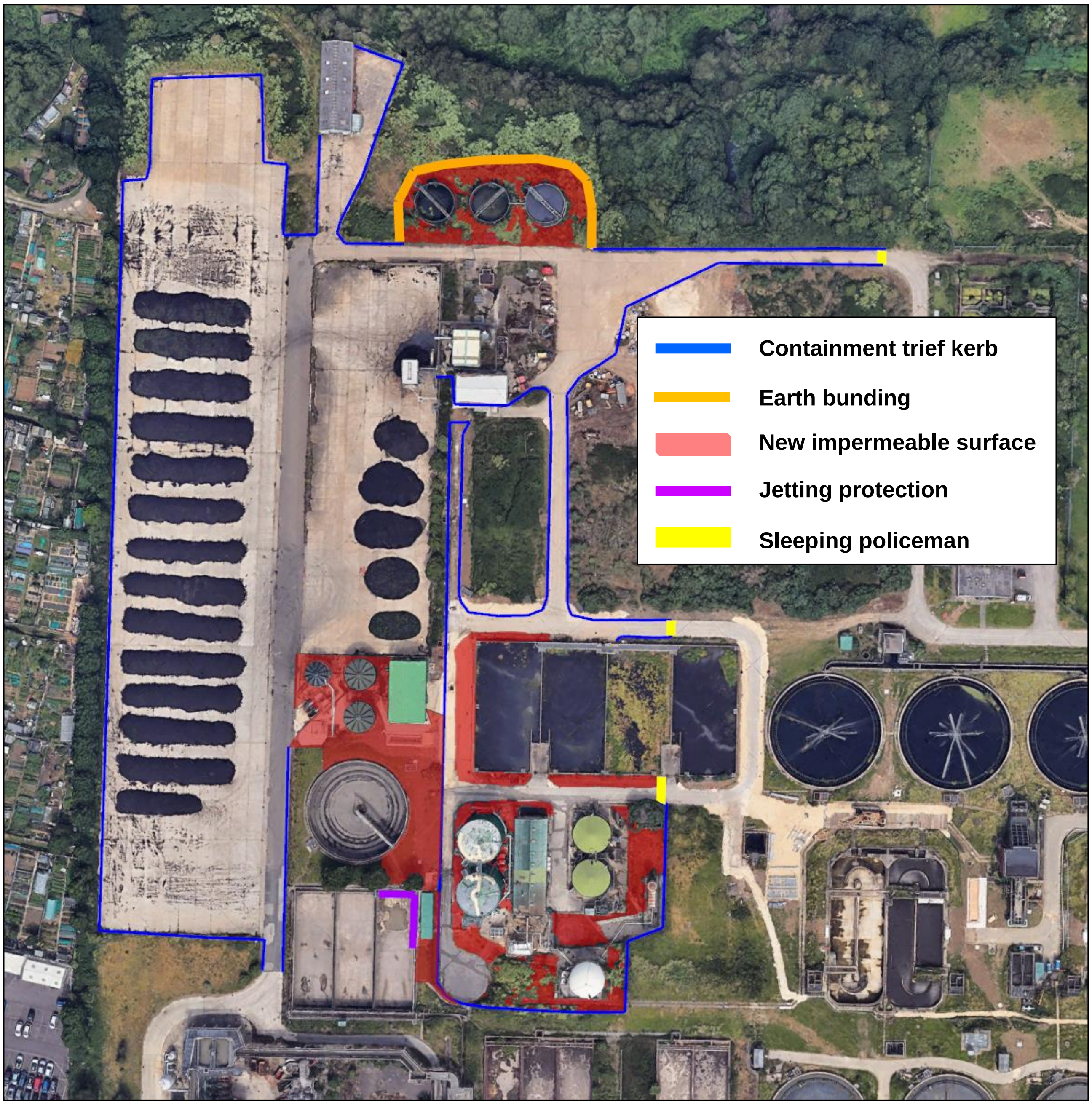


Figure 27. Bunding solution for Sandall.

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 Sandall initially pose containment risk for a potential surge spill to the adjacent circular and rectangular storm tanks, as illustrated in Figure 28. However, both the rectangular and blind storm tanks are elevated and have walled barriers with sufficient height to provide protection against a spill wave, thereby preventing sludge from flowing into the tanks.

Evidence of ground elevation and wall height of the storm tanks is shown in Figure 29. Moreover, a large kiosk building, including fencing is present in-between the digester and rectangular storm tanks, providing additional barriers to the rectangular storm tank. Furthermore, the circular blind tank does not have a weir overflow. Weirs are located at the foot of the rectangular tanks, however the risk of sludge entering them is minimal due to the elevation, wall height and obstructions on site.

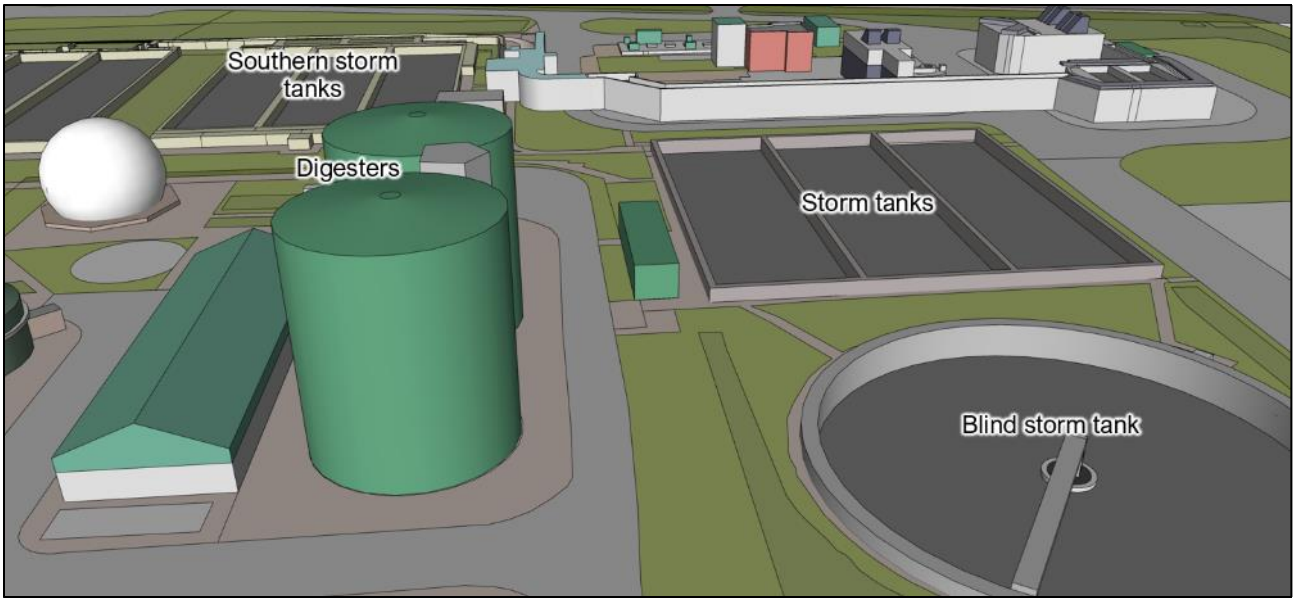


Figure 28. Digesters near storm tanks.

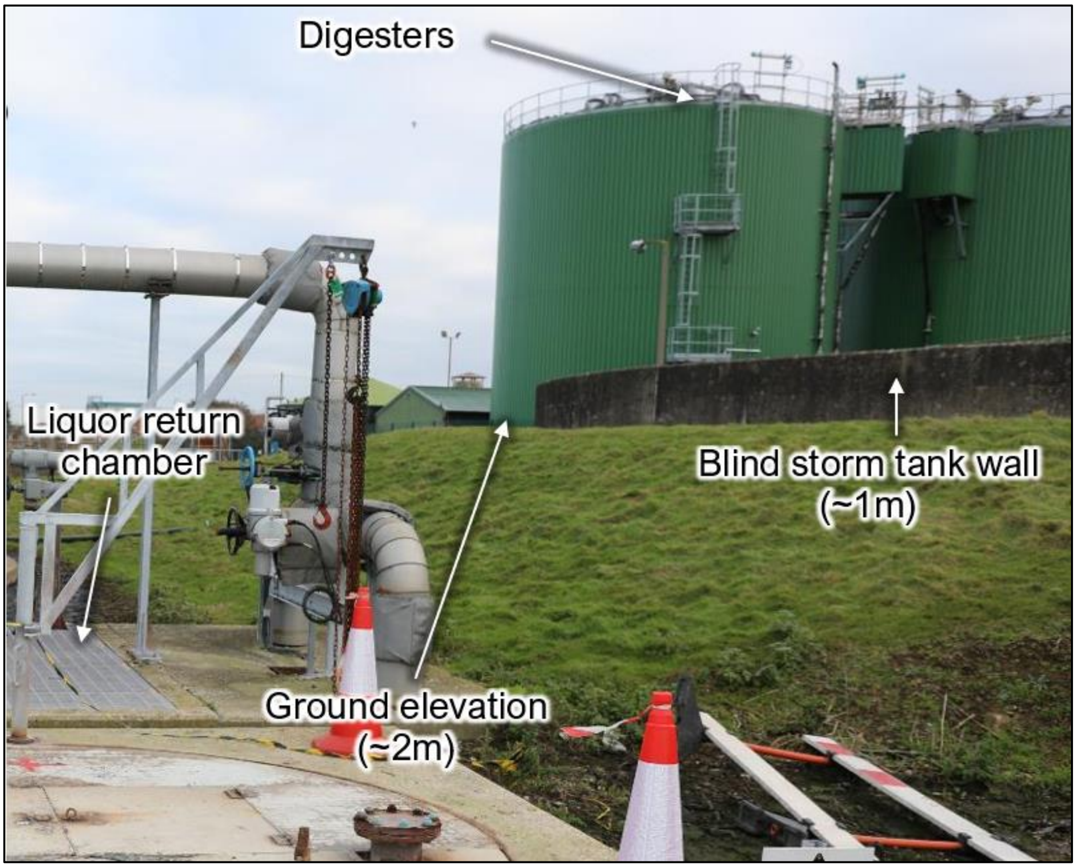


Figure 29. Storm tank walls and ground elevation.

3.9.2 Jetting

Yorkshire Water understand that while risk is low, consideration of jetting remains a requirement of CIRIA C736.

The blue circles in Figure 30 show areas which could be affected by jetting. These have been calculated according to CIRIA C736 guidelines, Appendix 4. The two digesters are tall and sit relatively close to the circular and rectangular storm tanks of the WwTW. The storm tanks flow directly to a watercourse when the valves are open, and if sludge were to enter them during a storm event, it is very likely that pollution would result. Jetting protection compliant to CIRIA C736 will be considered during the design process, especially where the jetting zone overlaps the rectangular storm tank (as shown by the purple line in Figure 30).

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 it 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 the CIRIA C736 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.

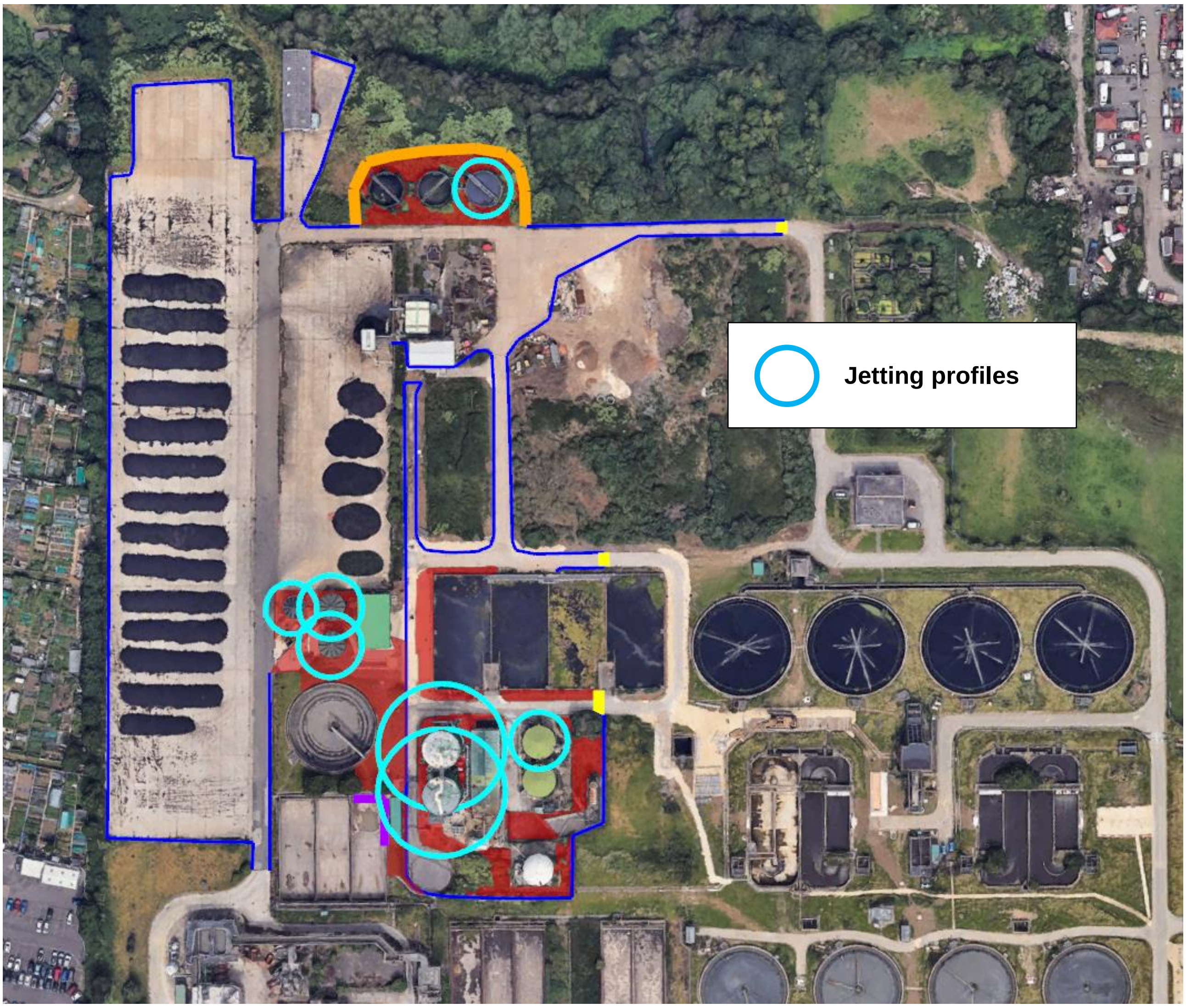


Figure 30. Jetting profiles from the tanks at Sandall.

3.10 CIRIA C736 compliance, effectiveness, and construction.

The secondary containment solution at Knostrop 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 5.

The tanks at Sandall 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

- Yorkshire Water understand the environmental risk associated with underground structures and are committed to identifying and rectifying any leaks from them. 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 external visual inspection of subsurface tanks, wells, and surrounding ground by a technically competent manager.
- Risk assessed additional monitoring.
- Three monitoring techniques have been identified as potentially appropriate for subsurface tanks/chambers identified as high risk.
    - 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.
    - 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.
- 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. 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 5 years if mechanical joints are present, and 10 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.

4.4 Impermeable surfaces

Appropriate containment of potential spills in large part relies on capturing them on impermeable surfaces that protect underlying ground. At Sandall these surfaces are typically made of concrete and YW are committed to keeping these in good condition to ensure that any potentially polluting liquids cannot pass the impermeable layer. The most likely path for liquids is through cracks and other damaged areas.

Responsibility for monitoring the condition of impermeable surfaces sits with two roles within YW.

- Site operators will carry out daily visual inspection of impermeable surfaces as part of their normal duties.
- The Technically Competent Manager (TCM) with responsibility for the site will carry out a monthly inspection of impermeable surfaces.

Where damage is identified a high priority job will be raised for repairs to be completed through the YW reactive maintenance system. In cases of severe damage, temporary protection will be installed around the damaged area to ensure that effective liquid capture is maintained.

5 Implementation and timescales

5.1 Construction

A plan outlining the implementation of containment solutions identified is shown in Table 7. 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 7. Secondary containment implementation stages and schedule.

Stage	Estimated date complete
Completed detailed final design	1st March 2024
Commence construction	Autumn 2024
Complete construction	March 2025

6 Conclusions and recommendations

This study has considered the risks associated with CIRIA C736 defined loss of containment scenarios at Sandall STF installation. This assessment was completed using a source-pathway-receptor model. A computational modelling study has been undertaken, which adopted conservative assumptions to understand a worst-case scenario for the spread of spills. A computational modelling study has been undertaken, which adopted conservative assumptions to understand a worst-case scenario for the spread of spills. This enabled the potential effects of a substantial, unmitigated loss of containment to be considered; this has shown that further mitigation is required to protect sensitive receptors (the metric of compliance being an equivalence to a traditional 25 / 110 per cent capacity secondary containment bund in line with CIRIA C736 via the ADBA study).

The need for additional secondary containment infrastructure has been confirmed and YW commit to installing this. YW also understand the following factors and existing mitigation measures should be maintained to ensure an appropriate level of environmental protection:

Current controls

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

Existing infrastructure

- Site drains are able to return liquid to the inlet works for treatment, providing containment and flow mitigation.
- The sludge cake storage and loading pad has been engineered to drain liquid contents which returns to the inlet works of the WwTW, acting as remote containment.
- In most areas the site surfacing and drainage would capture spills, leaks and catastrophic pipe failures, transferring the liquid to the WwTW for safe treatment. This will minimise the potential effects of loss of containment.

Reducing 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, 5 of these sites have Environmental Permits. Within 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 to reduce pollution and impacts to biodiversity.

7 ARUP Design Overview

The Stantec containment outline, as described in Section 3, was passed to Arup for detailed design.

The design of the secondary containment has been developed to standards as set out in the “establishing best available techniques (BAT) conclusions for waste treatment, under Directive 2010/75/EU of the European Parliament and of the Council” document; specifically, BAT 19c and 19d. The design proposals for the site have been developed to be compliant with the recommendations and best practice set out in CIRIA C736. The secondary containment proposals at Sandall have been developed to contain sludge tanks in bunded areas within the site. An overview of the design proposal is shown and is supported by the Tuflow modelling that was carried out (IED_WHM-ARP-TRT-ZZ-TN-Z-0001 (appendix 6)).

The secondary containment design will involve a perimeter of the installation area that will act as a physical barrier, preventing any sludge from escaping the designated areas. The defence shall include containment walls of varying height depending on the requirement for spill containment.

The design also includes resurfacing the bunded areas to ensure the ground impermeability within the containment area. This will effectively prevent any seepage or penetration of sludge into the surrounding soil. The design includes, where appropriate, alterations to the existing drainage and utility infrastructure. These modifications are necessary to redirect any potential spillage or leakage of inventory to the designated containment systems.

As the secondary containment design is being retrofitted, there are elements of the CIRIA 736 guidance which cannot be achieved. In these instances, an alternative measure will be implemented to achieve an equivalent standard to provide the same level of environmental protection.

7.1 Surface Water Drainage

The site benefits from an existing drainage system which will be used as part of the design. The design will be used to manage surface water accumulating within the containment area.

Ciria C736 dictates that a new site would have a fully bunded and blind drainage system. This is difficult to retrofit on an existing site. YW is proposing an alternative level of protection would be to install new drainage (where necessary) to accommodate the increase in surface water that will be created by the additional impermeable surface area. A gate valve (or similar) would be provided to enable the bund to be isolated in the event of a spill. It would remain open as standard.

Furthermore, Ciria C736 states the bund should be sized to accommodate a 10% AEP 24 hour storm event preceding a spill incident and an 10% AEP 8 day event following an incident. This would require a significant storage vessel for rainwater. As described previously, the bund would be maintained in an empty state up until the point of a spill event. Therefore, YW is proposing to retain the AEP 8-day volume post spill but remove the 10% AEP 24hour storm event volume.

7.2 Impermeability

Ciria c736 states the replacement of permeable areas with impermeable surfaces and directs the use of reinforced concrete pavements for class 1-3. Ciria c736 requires a clay liner under concrete. This existing site was not designed with a clay liner situated underneath the existing concreted areas.

YW is proposing that existing concrete and paved areas within the installation bund will not be lifted to replace with a clay liner. To lift the existing surfaces would result in many tonnes of waste material. It’s proposed we would retain existing flexible pavements (concrete and tarmac) and undertake repairs to ensure surface integrity where needed. Permeable liners would be installed on the current landscaped area with drainage at the base. It’s proposed a clay liner would not be required under this liner.

Please refer to appendix 6 for further details.

8 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:

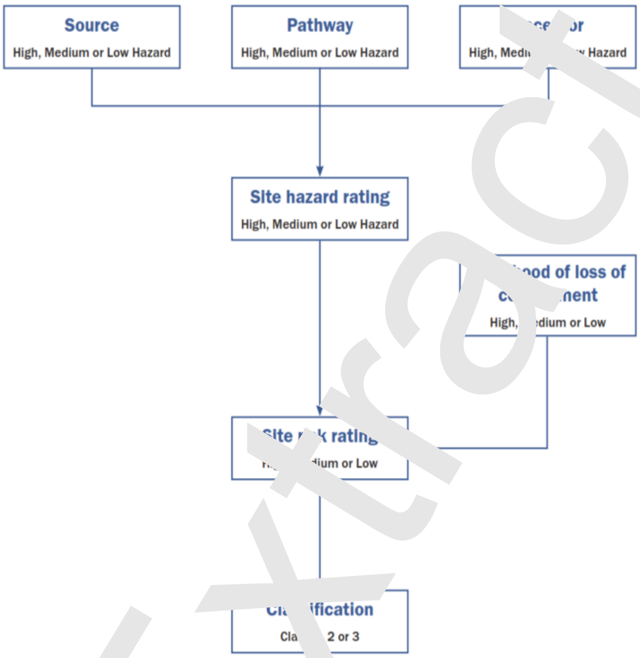
1) Identify the hazard posed to the environment by the inventory of materials held on the site and the location of the site
   a. Categorise the source
   b. Identify the pathways
   c. Identify the receptor

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 … of CIRIA C736, determining an overall hazard rating for the site is largely subjective, and assessing the combined 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 screensho

Appendix 2 – Bunding solution

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

Category	Criteria	Unit	Value
Design specification	CIRIA C736 spill volume [25/110%]	m^3	4,233
	Bund perimeter length	m	Approx. 2055
	Total containment surface area	m^2	Approx. 29,787
	Maximum Final Spill depth	m	0.06
Bunding requirements	Concrete bund height	m	NA
	Total concrete wall length	m	NA
	Earth bund height	m	1
	Total earth bund length	m	99
Existing bunding	Existing concrete walling length	m	NA
	Existing earth works length	m	NA
Build required	Required concrete walling length	m	NA
	Required earth works length	m	99
	Impermeable surfacing area	m^2	5,266
	Trief kerb length	m	2,742
	Sleeping policeman	m	17.7
	Jetting protection	m	25

Appendix 3 – Structural integrity note for concrete tanks

Technical Note

aquaconsultants
water · environment · energy

Project: Yorkshire Water – IED

Title – Leakage of water through concrete sections.

Author – Imran Nawaz MEng CEng MICE

Date 08/06/2022

1. Introduction

This Technical Note discusses the possibility of concrete tank walls developing an aperture through which fluids could be ejected at speeds resembling a jet. In fluid terms a jet develops when laminar flow is achieved at significant velocity at 90 degrees from the plane of the aperture.

2. Concrete section construction

Concrete is formed from angular aggregate suspended in a matrix of cement paste and sand. Upon pouring and vibrating fresh concrete the aggregates settle at the bottom of the mixture while being fully surrounded and immersed in the cement and sand paste. During this process the excess water and cement paste rises to the top and careful mix design and match management is needed to ensure this paste is not too much or too little; in both cases the result would be poor surface finish and weaker concrete.

The final product is well compacted angular aggregate with a good degree of interlock bound by the hardened cement paste.

3. Concrete in service.

Concrete in service is subject to many effects that cause expansion and contraction. These include drying shrinkage as the water which is not chemically bound by hydration evaporates; autogenous shrinkage as the product of the chemical reaction takes up a smaller volume than the constituents; thermal strain; and differential settlement. In addition to these, the structural stresses in the concrete cause tension and bending, both of which cause a tension force in the concrete. All the effects described here contribute to cracks developing on the face and within the interior of the concrete. In all reinforced concrete section including those that are structurally sound, the concrete will crack and redistribute the tension force to the steel reinforcement by a combination of chemical bonding (between steel and cement paste) and aggregate interlock with the ribbed bars. Cracks are generally designed to be 0.3mm, although acceptable crack width will be less than 0.2m for water retaining concrete, which will allow water retention while keeping water egress through the cracks to a small an acceptable level.

4. Concrete deterioration.

Concrete hardens and strengthens over time as the hydration reaction continues along an asymptotic curve. However, processes such as chlorine attach, carbonation and freeze-thaw can cause weakening and deterioration of the concrete. In addition to this, acidity, ground conditions and the nature of the retained material within a tank can accelerate deterioration.

Technical Note

In extreme cases the effects of this can be:

- Severe weakening of the concrete leading to crushing failure.
- Severe delamination of surface layers over a great length exposing the steel reinforcement, causing it to corrode so the section fails in tension.
- Severe steel and/or concrete deterioration at junctions i.e., slab/wall/beam/column interfaces leading to shear failure and adjacent sections becoming detached.

Although exceedingly rare, the cases above describe total failure conditions. In these cases, leakage of fluids is not so much of a problem as structural collapse. Less extreme cases allowing water or fluid egress a tank are described below.

- Significant damage or corrosion to reinforcement leading to excessive crack width and significant leakage. In this situation the crack can be significant and even penetrate the full section of concrete wall. The water flowing through follows a tortuous path around the aggregate before it leaks out of the surface.
- Significant spalling and loss of material from a zone on the inside and outside of the concrete wall. In this situation the remaining thickness can retain the water. If this location also coincides with a crack, water will flow through a tortuous path as described above.

This type of damage allows water leakage, water jetting would not occur as long as a small intact section of concrete is present to impede laminar flow.

Considering the possibility of an aperture opening in the wall, this could in theory occur if spalling, and loss of cement and aggregate became so severe that it penetrated the section. Although it is not rare for severe material loss to occur, for conditions to be this aggressive they would affect a large area or the majority of the structure, causing significant loss of section leading to structural failure in stages preceding development of a full thickness aperture.

5. Conclusions

When the concrete is in service or subject to significant concrete deterioration, spalling and loss of section, the condition of laminar flow through an aperture will not develop.

Under severe concrete deterioration, any conditions approaching aperture formation will lead to structural failure before an aperture can form therefore the likelihood of this happening are considered to be negligible.

- End -

Appendix 4 – 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:

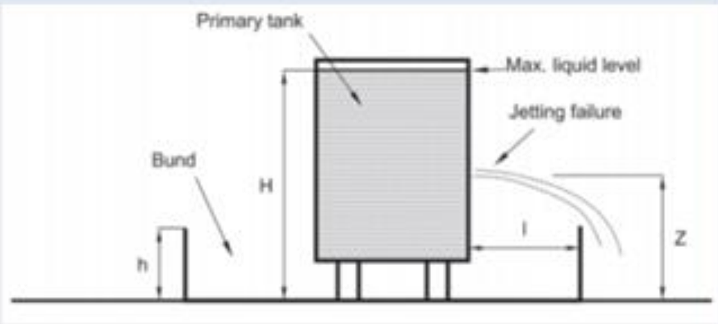
$$l^2 = [4(z-h)(H-z)]^{0.5}$$

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 2. CIRIA C736 jetting calculation to determine jetting solution.

Appendix 5 – Tank inspection report

A full copy of the example document below is included as an attachment with the RFI response.

Form No: YW-INSP-FRM-1, Issue 1, 2018 08 09

Yorkshire Water Limited
INSPECTION GROUP

YorkshireWater

EQUIPMENT INSPECTION REPORT
Knostrop Top Site New Sulphuric Acid Tank Inspection

Report Number:	KNO2-INSP-003	Written Scheme No.	N/A
Equipment Number:	N/A	Category:	Visual
Service:	Sulphuric Acid Tank	Equipment Used:	Camera
P&ID Number:	N/A	Site Operator:	N/A
Associated IAN's:		Site Manager:	N/A

Inspection to be as defined in the INSPECTION MANUAL

Type of Inspection:	Scheduled Interval (months):	Date of Last Inspection (mth-YYYY):	Next Inspection Date (mth-YYYY):	Maximum Interval (months):
Thorough External Inspection:	5	Nov-2018	March-2019	60
Thorough Internal Inspection:	N/A	N/A	N/A	N/A
On-Stream Thickness Survey:	N/A	N/A	N/A	N/A

An Opportunistic site visit to the Knostrop Top Site was undertaken on the 26/11/2018 on available equipment where access allowed. The purpose of the visit was to review the condition of the new Sulphuric Acid Tank after repairs to the Tee's was carried out by the manufacturer. The Plant was built in 2018, Due to be commissioned 2019.

The site is situated within the Knostrop Site Complex.

Appendix Figure 3. Example equipment inspection report.

Appendix 6 – Arup Tuflow Design Modelling

ARUP

Technical Note

Project title	Yorkshire Water IED
Job number	293261
File reference	IED_SAN-ARP-TRT-ZZ-TN-Z-0001
cc	
Prepared by	Andy Pittam
Date	26 February 2024
Subject	Sandall Flow Modelling - Technical Note

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t +44 113 242 8498 d +44 20 7755 9421
arup.com

1. Introduction

A detailed assessment using Tuflow© modelling software has been undertaken to simulate potential spill scenarios at the Sandall site. These model results have then been assessed to determine appropriate defence elevations for the proposed bunds, resurfacing and extents of the containment design.

This technical note outlines the modelling process that has been undertaken, any key assumptions, the model results and how these have been used to inform the secondary containment design. Outputs from the Tuflow modelling are included in Appendix A.

2. Modelling Process

A TUFLOW model was produced to simulate breaches in each of the tanks. Breaches were applied in turn, at the following tanks:

Spill Model Reference Number	Primary Containment Tanks
1	Sludge Import Tank
2	Thickener Feed Tank 1
3	Thickener Feed Tank 2
4	Digester Feed Tank
5	Anaerobic Digester 1
6	Anaerobic Digester 2
8	Centrifuge Feed Tank 1
9	Sludge Storage Tank 3
10	Sludge Storage Tank 4

This was achieved by calculating a maximum water level within each tank based on known above-ground capacities and dimensions of the tanks. This level was applied spatially at the location of the tank as an Initial Water Level (IWL) within the software. When the model simulation commences, this level spills onto an applied LiDAR level obtained from DEFRA, following the flow path that the contents of the tank would take should a breach occur.

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Additionally, known rainfall depths for a 1 in 10-year return period (10% AEP) was applied simultaneously to each spill scenario, to give an indication of the combined depths of rainfall and the contents of each breached tank. Rainfall is based on the sum of a 1 in 10-year 24-hour and 8-day storm event, as per the Ciria C736 guidance.

The outputs of this modelling exercise will be used to inform the design of suitable works to contain the flow, be it bunds, walls, kerbs or similar, to be determined on a case-by-case basis.

3. Modelling Assumptions

A limitation of the below method is that the modelling assumes the contents of the tanks have the same physical properties of water, and will propagate across the site in the same manner as water would. This results in a worse-case scenario for the initial surge maximum depths that if the spills were to be modelled using effluent. However, the impact on the settled results is negligible, as consistent rainfall would mix with the effluent, resulting in similar material properties to water.

Additionally, in using IWL's to simulate the breach, it assumes all sides of the tanks instantaneously burst. Therefore, maximum spill depths around the tanks immediately after breach are excessively conservative.

4. Results

Two sets of results have been produced as part of the Tuflow modelling and included within Appendix A:

1. **The maximum spill depths** – these plans show the maximum spill depths recorded within the modelled area, across the full duration of the simulated storm and spill, for each tank. This data shows the dynamic impacts of an instantaneous spill.
2. **The final spill depths** – these plans show the spill depths of at the end of the spill event, i.e. on the completion of the simulated storm and once the spill inventory has dissipated and settled within the contained area to the final depths.

Typically, the final spill depths equate to the maximum spill depths across the site. Where there are instances that the maximum spill depths are greater than the final spill depth, this highlights a risk of surge effects from the spill influencing the containment depths.

In designing the containment defences, both sets of results have been used with the following approach:

- Minimum defence heights across the site have been set based on the final spill depths. The varying levels across the site results in a range of different required elevations.
- Where the final spill depth is greater than 0m above existing ground level and the maximum spill depths are greater than the final spill depths, a surge freeboard has been added to the minimum defence heights.
- Where the final spill depth is 0m and the maximum spill depth is greater than 0m above existing ground level heights, a surge freeboard has been added to the existing ground level.

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Surge freeboard has been based on the Ciria C736 guidance, see Figure 1.

Type of structure (see Part 3)	Allowance
In situ reinforced concrete and blockwork bunds	250 mm
Secondary containment tanks	250 mm
Earthwork bunds	750 mm

Figure 1 Surge Allowance Extract from CIRIA 736

- Where the maximum spill depths are equal to the final spill depths, freeboard has not been included. This is because the Tuflow modelling has not identified a risk of surge impacts at these locations.

A summary plan of the minimum defence height requirements, based on the above methodology, is included in Appendix B.

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Job number 293261

Date 26 February 2024

DOCUMENT CHECKING

	Prepared by	Checked by	Approved by
Name	Andy Pittam	Niall Bourke	Niall Bourke
Signature		Niall Bourke	Niall Bourke

ARUP

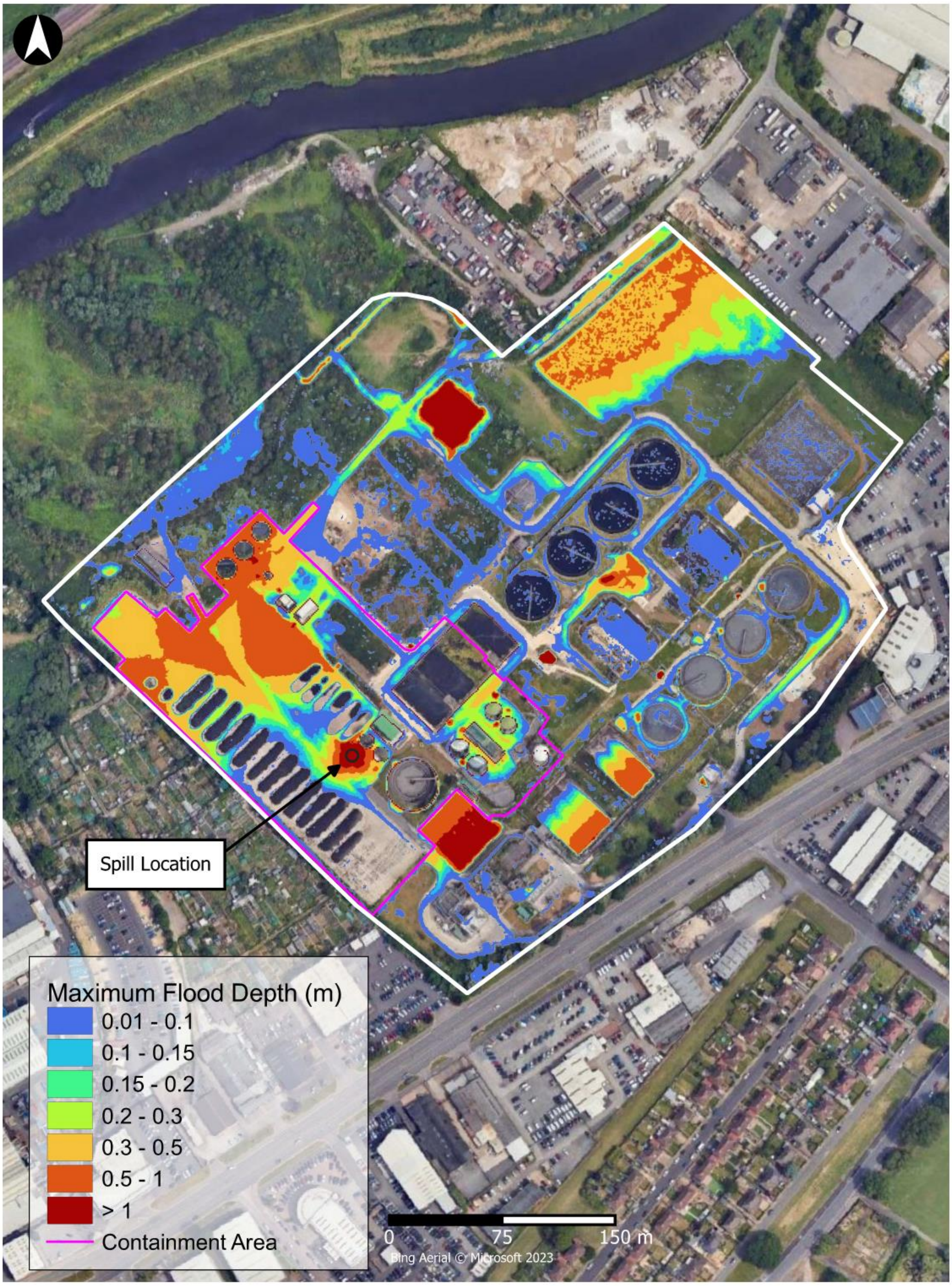
Job number 293261

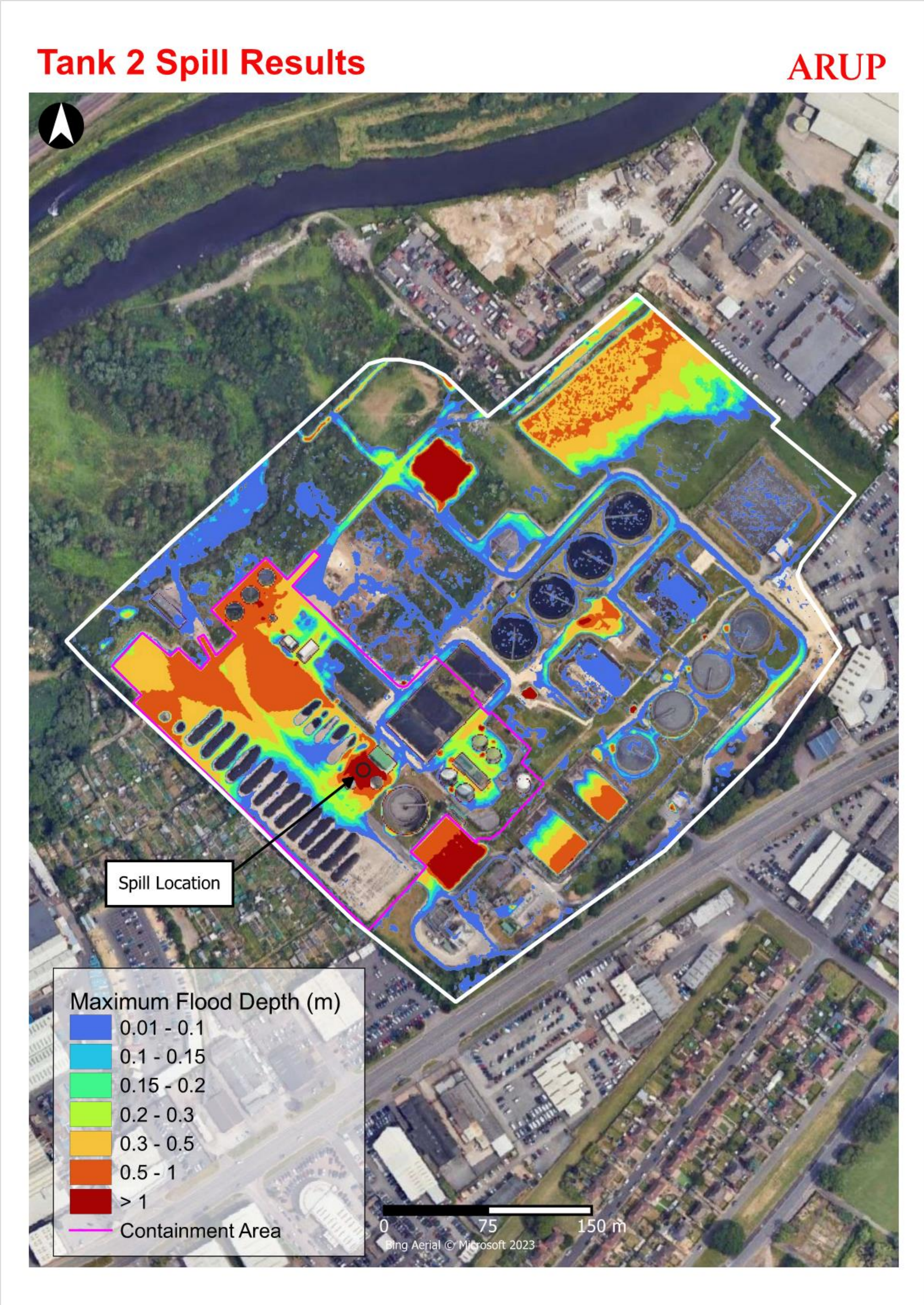
Date 26 February 2024

Appendix A – Tuflow Modelling Results

Tank 1 Spill Results

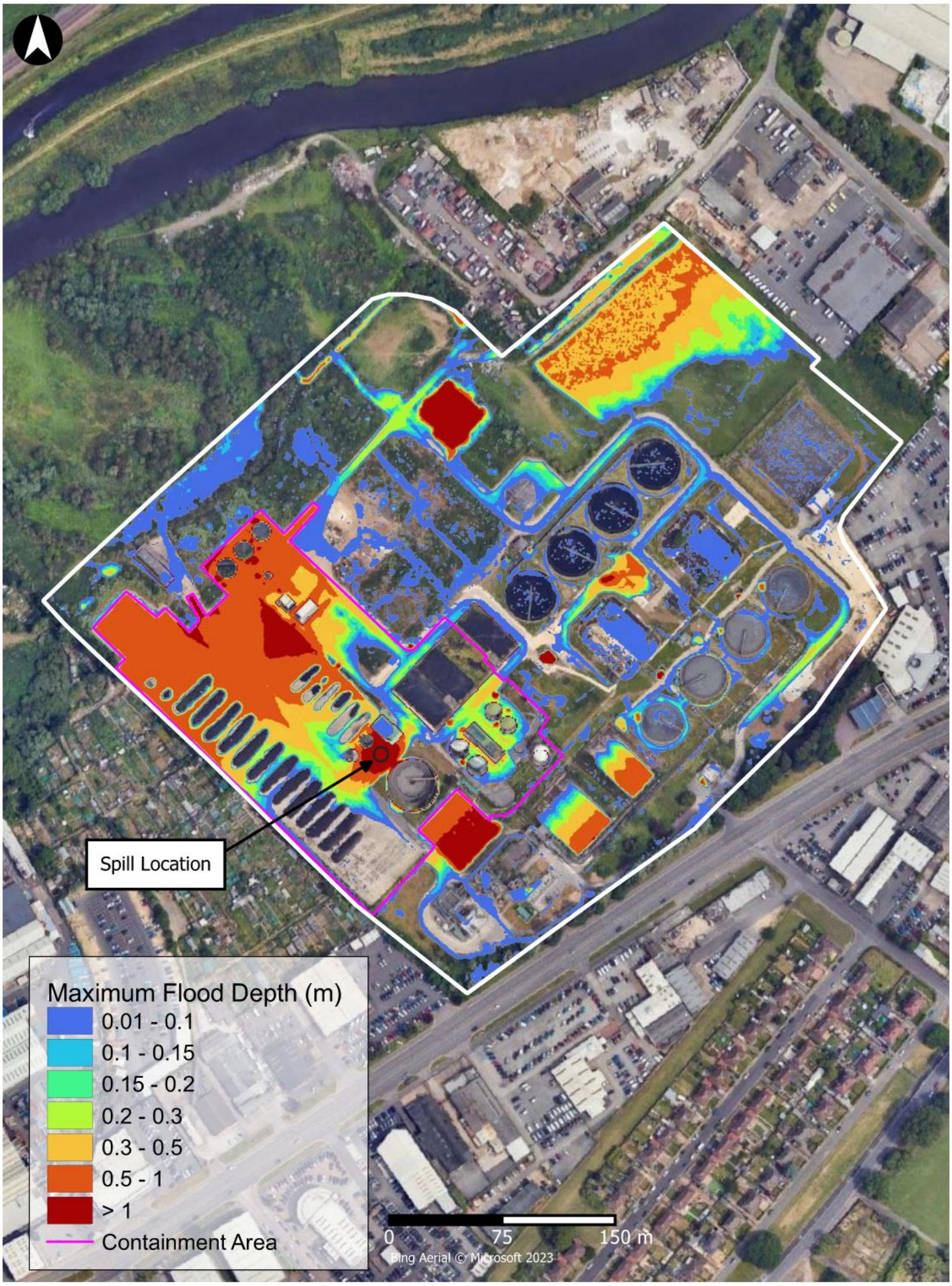
ARUP



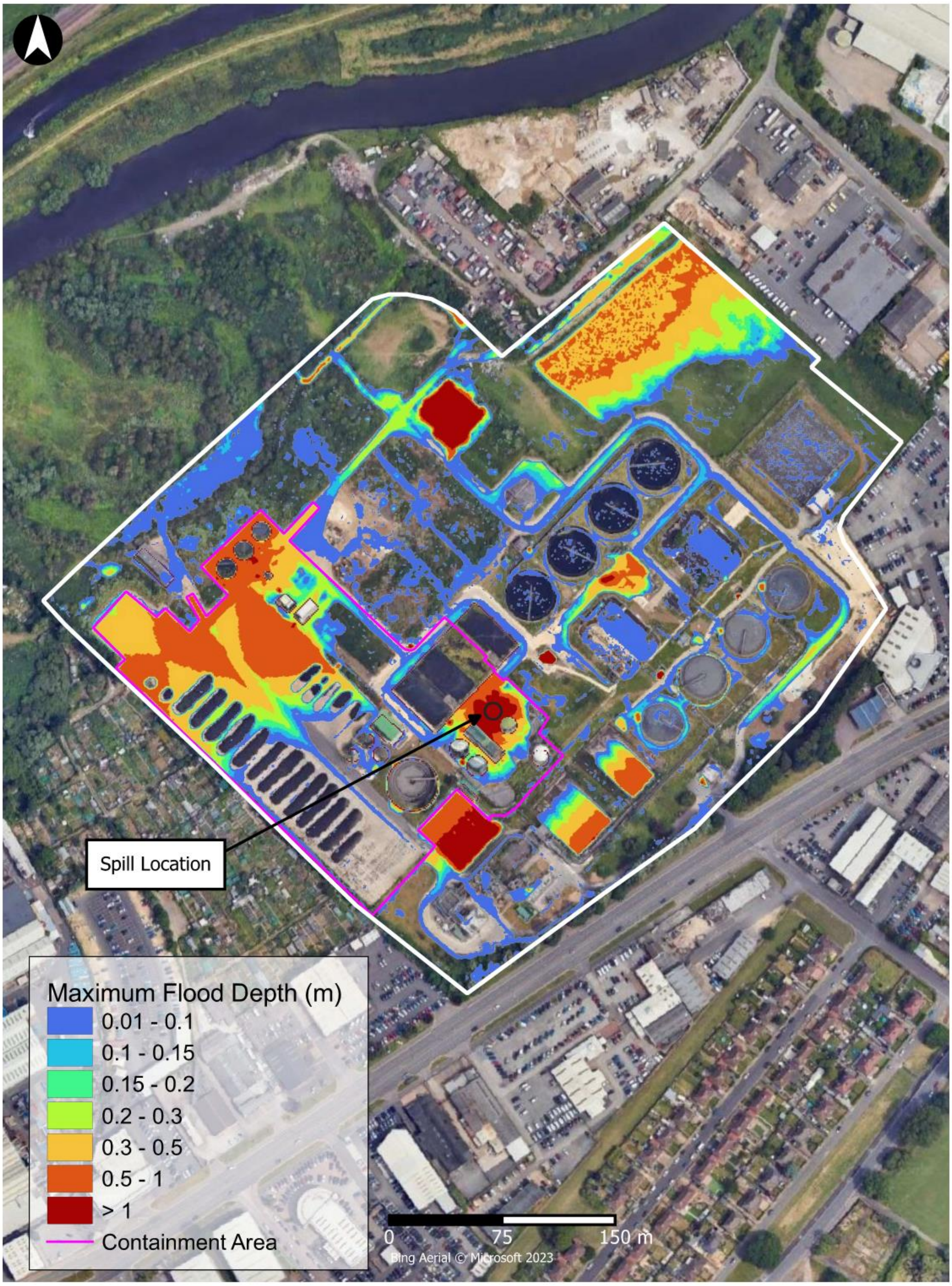

Tank 2 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

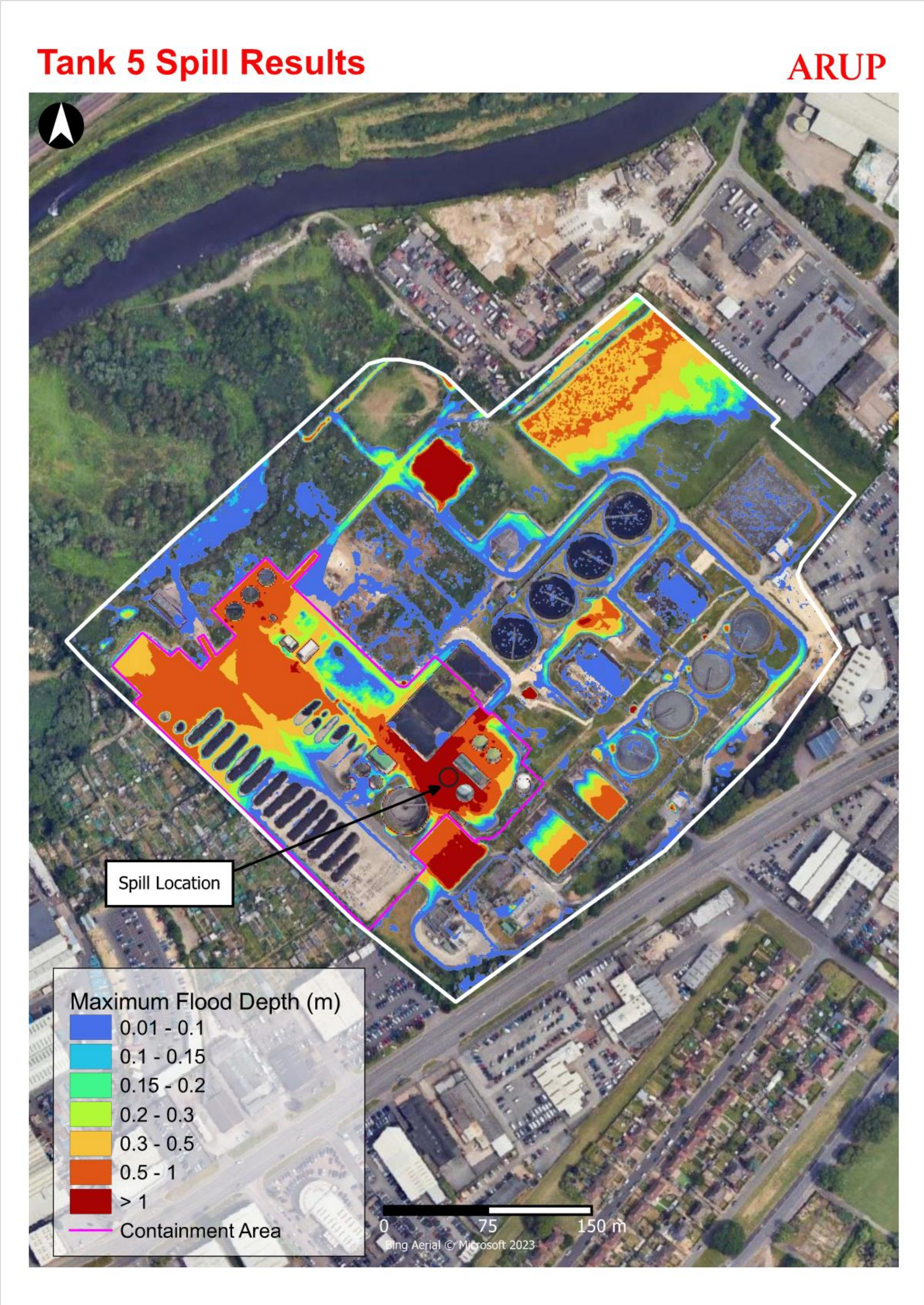
Tank 3 Spill Results

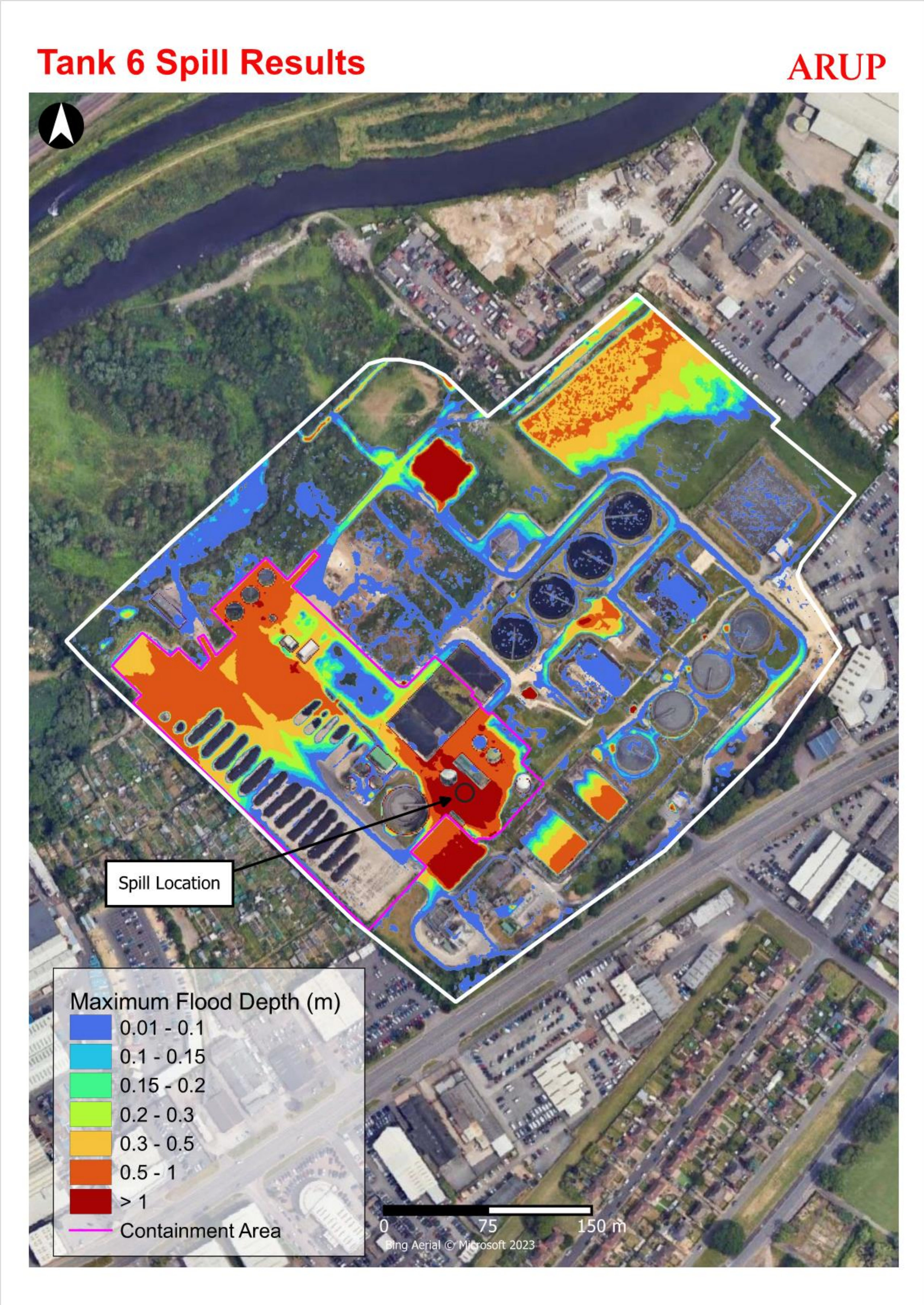
ARUP



Tank 4 Spill Results

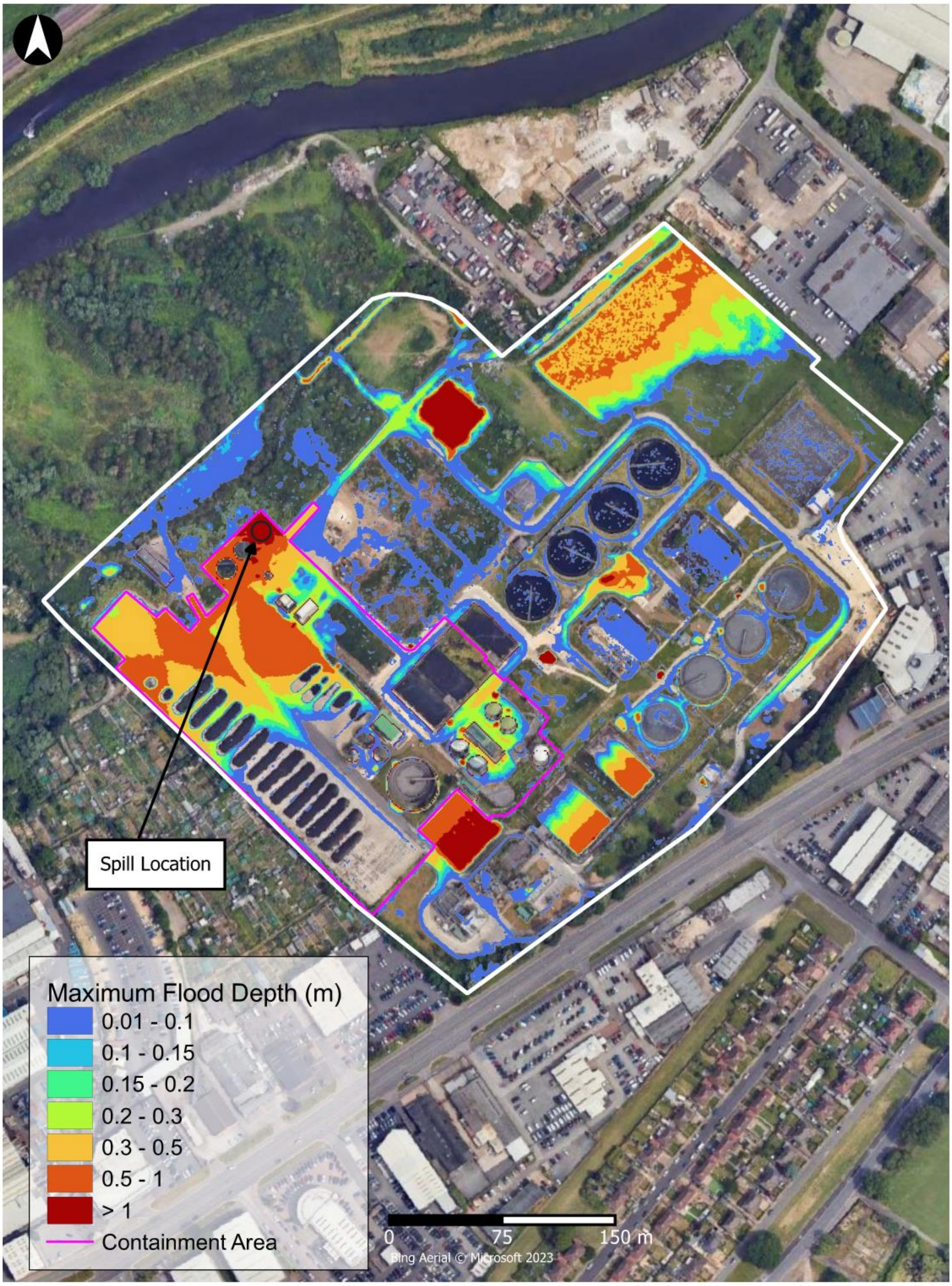


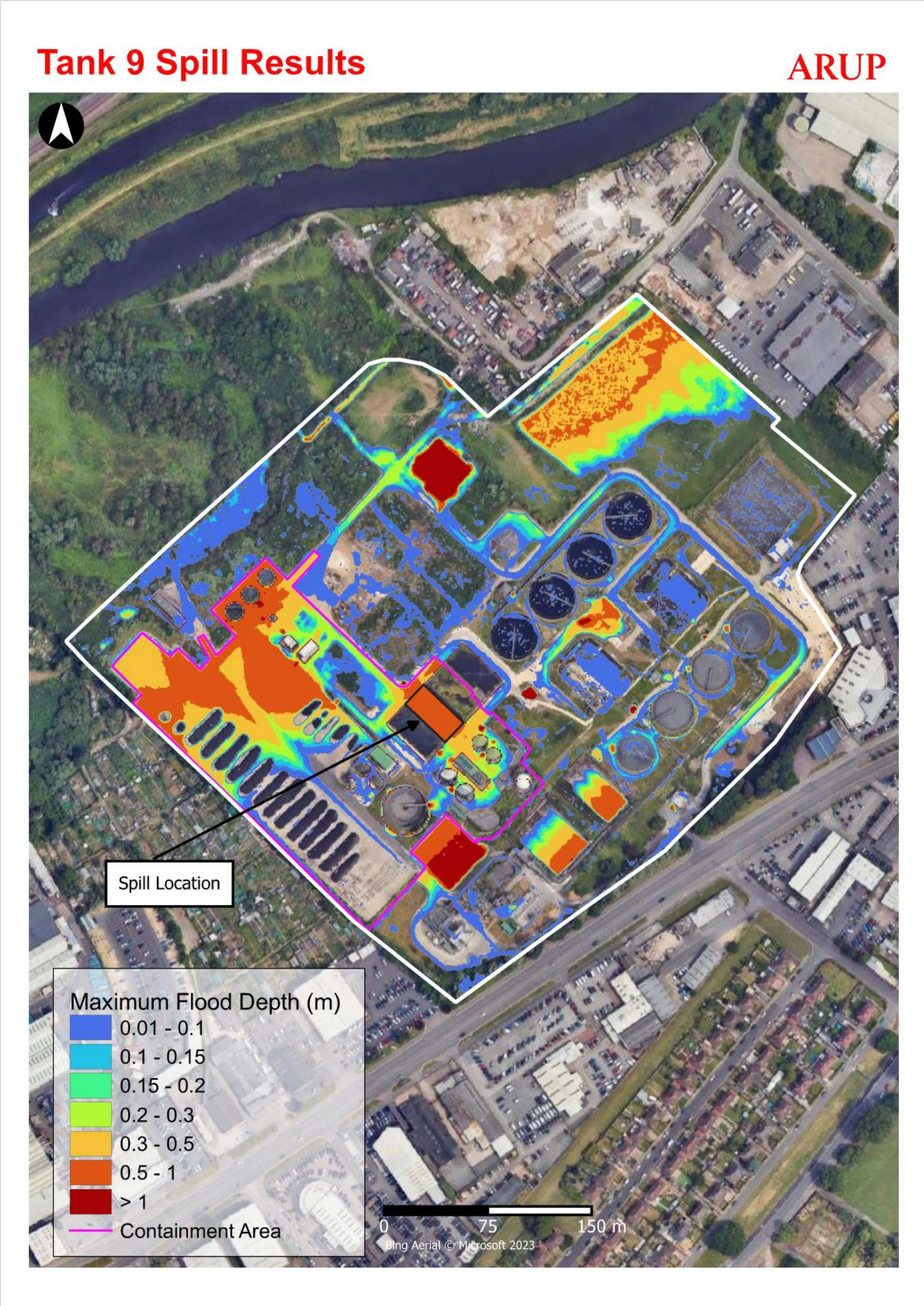

Tank 5 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

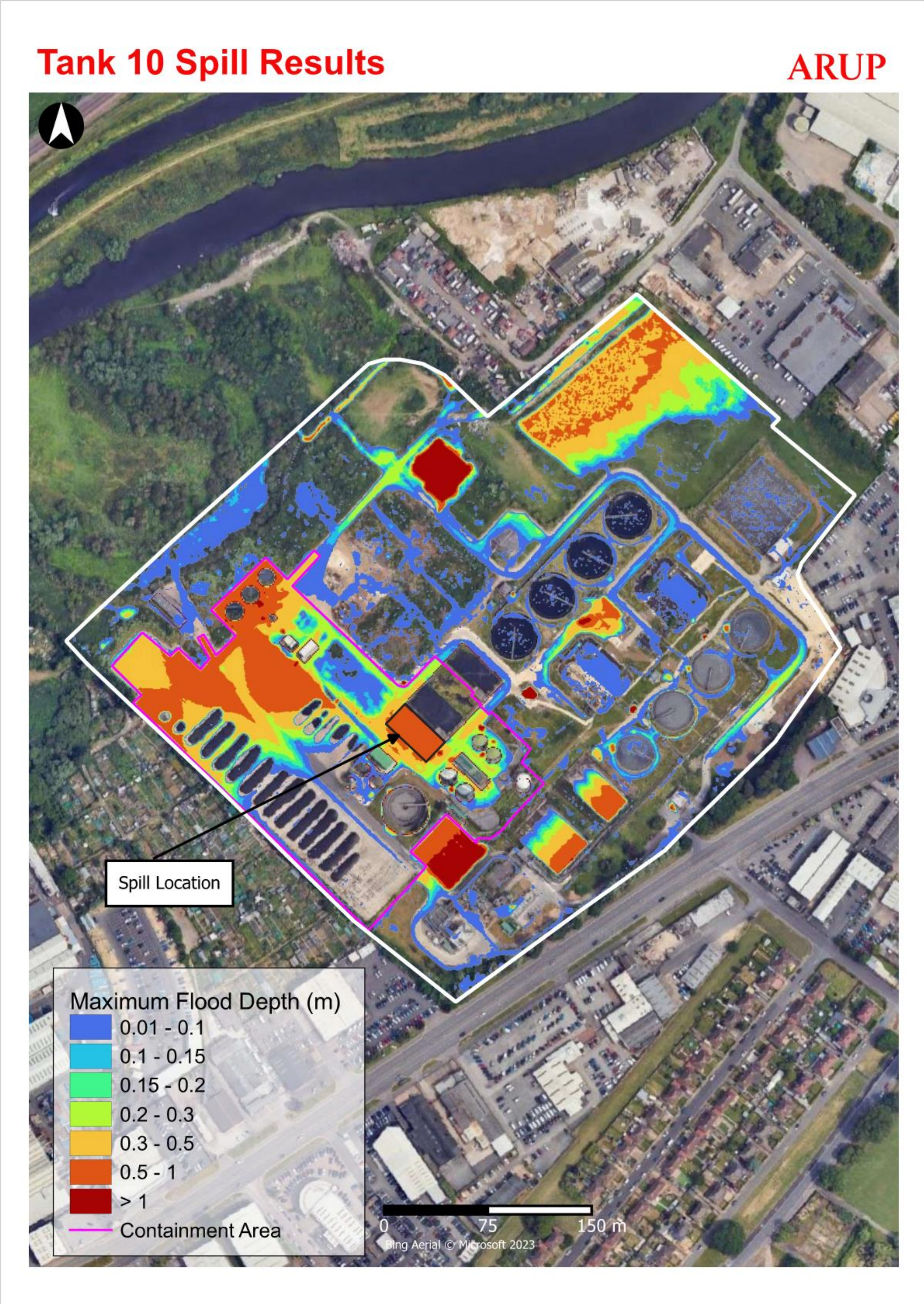

Tank 6 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

Tank 8 Spill Results

ARUP




Tank 9 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 10 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
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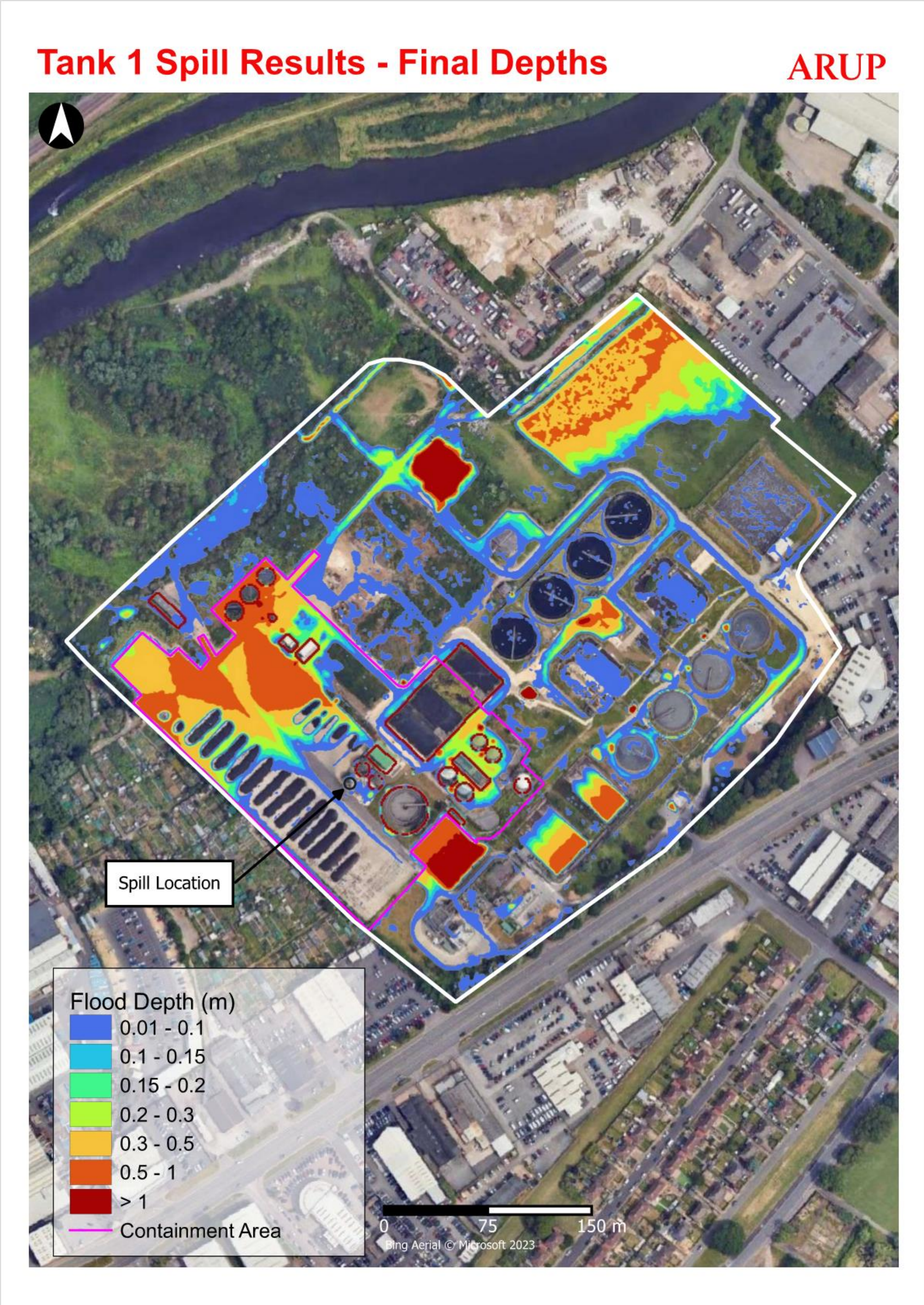
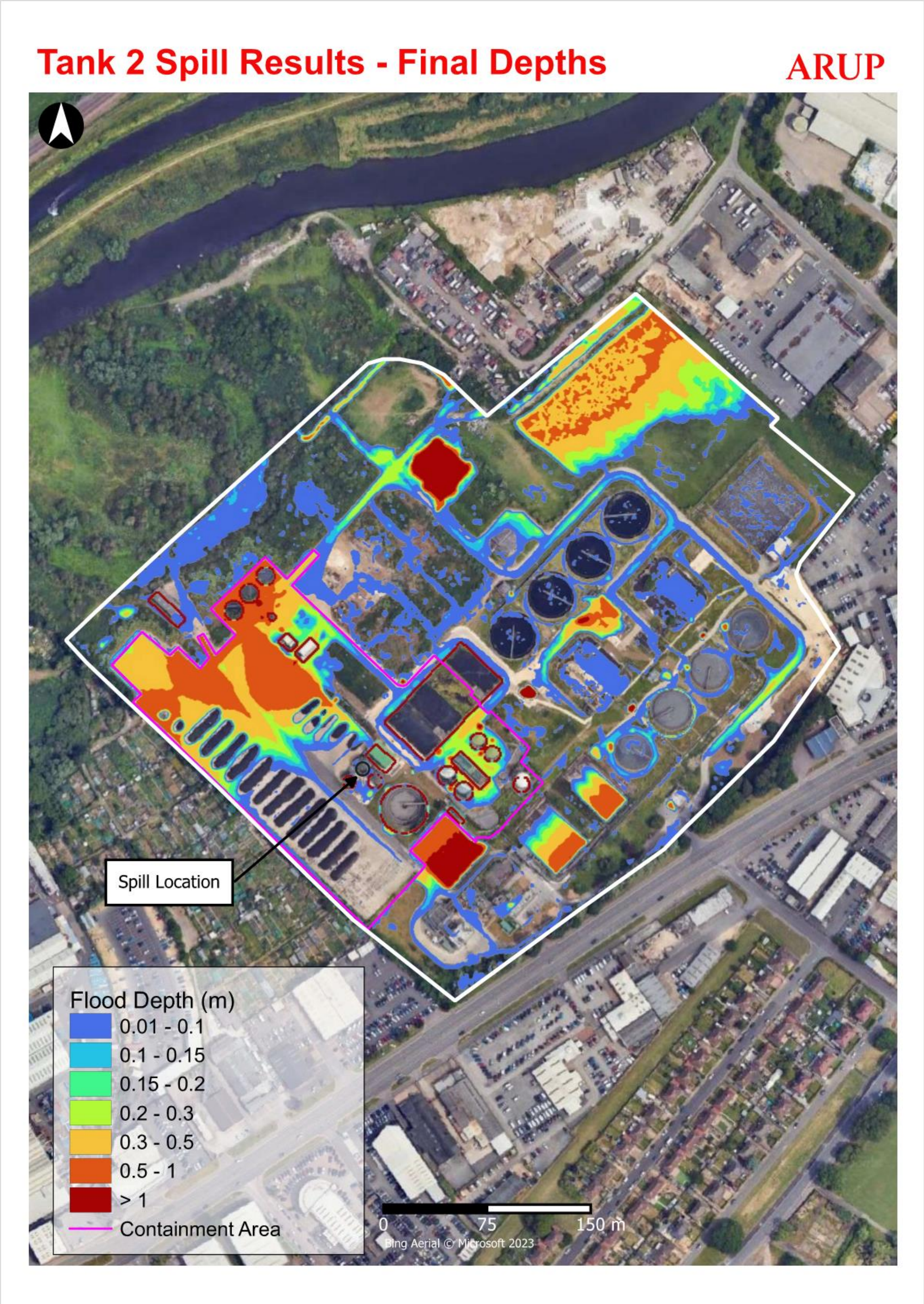
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 1 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 2 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
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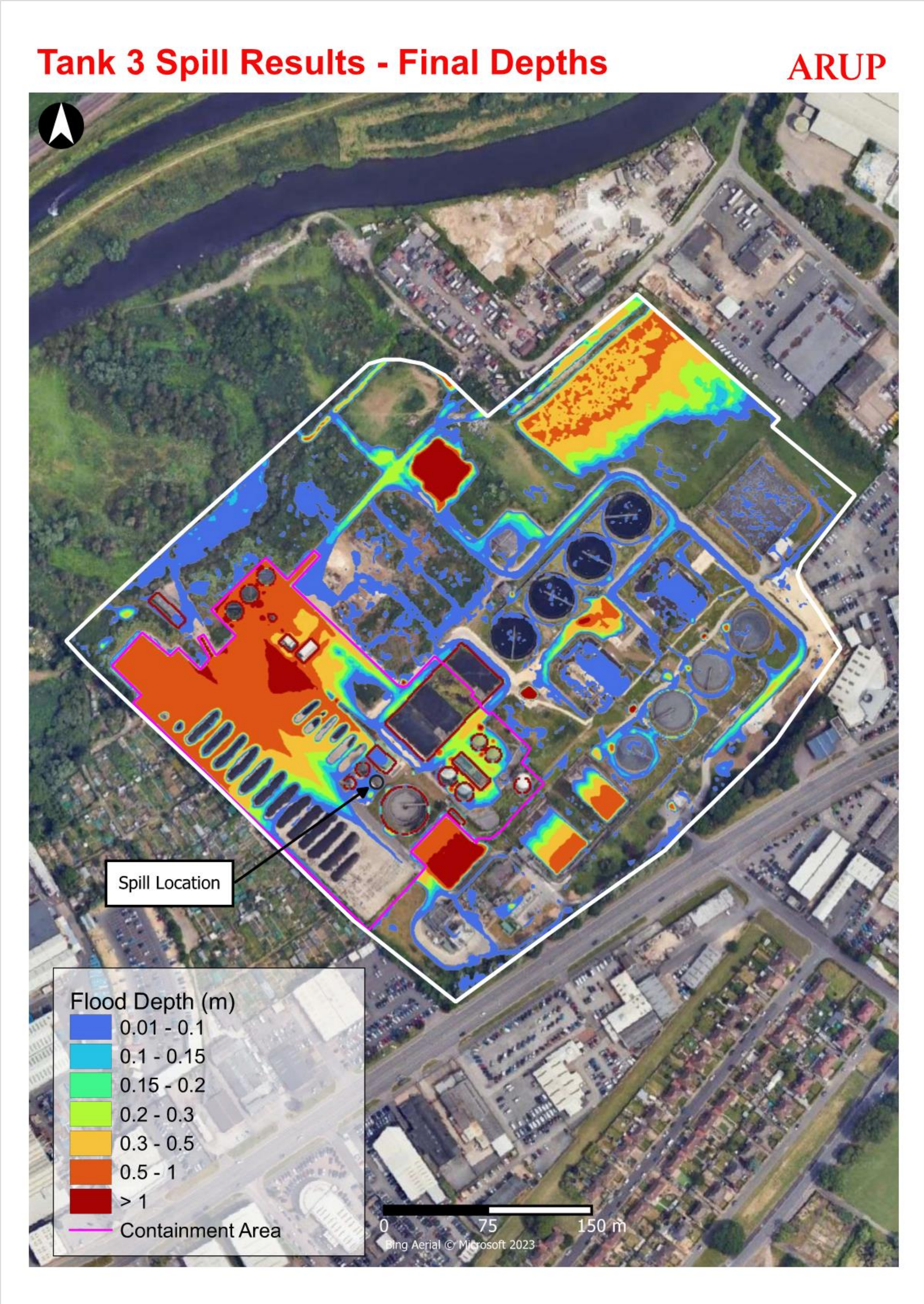
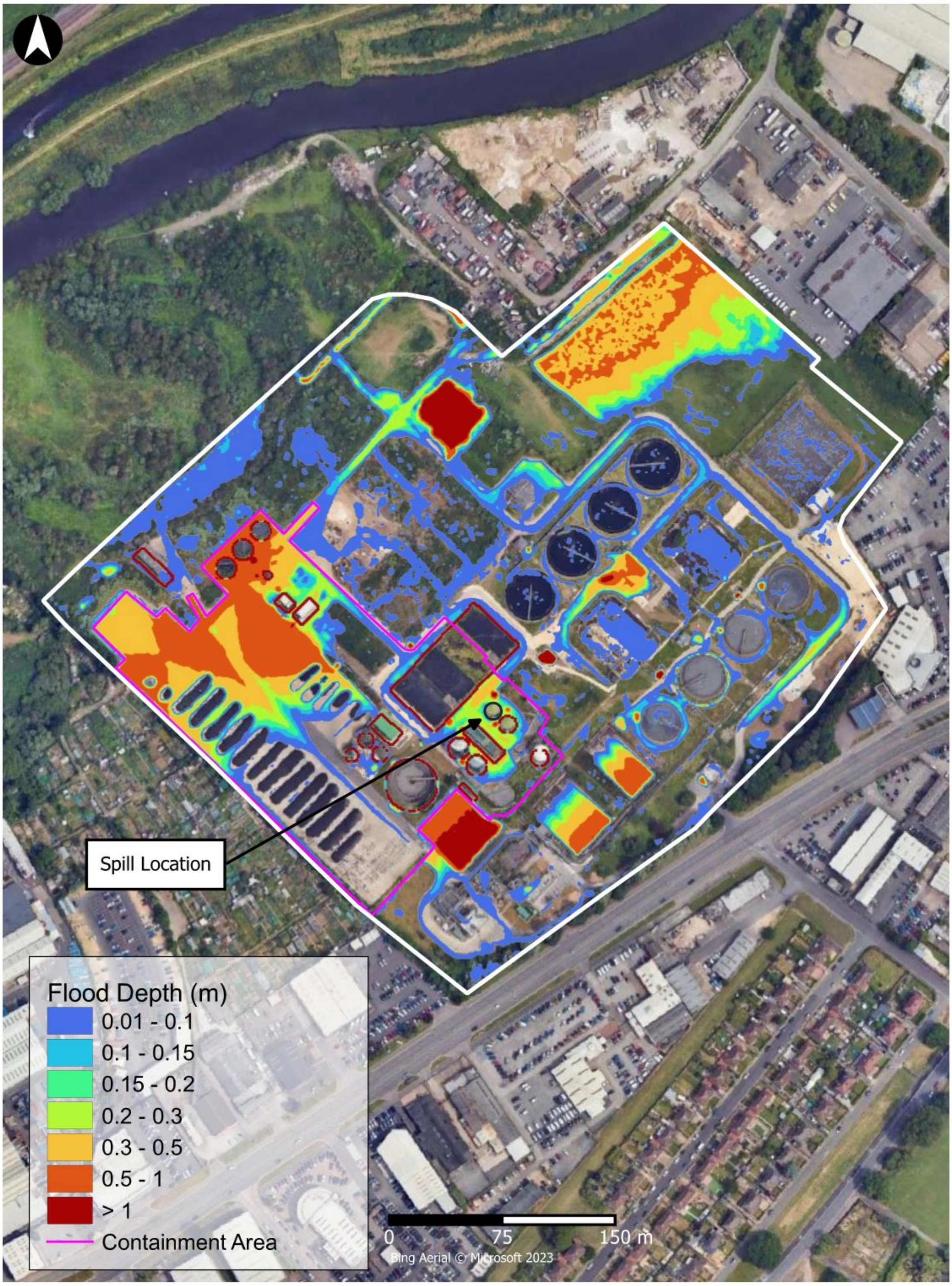
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 3 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

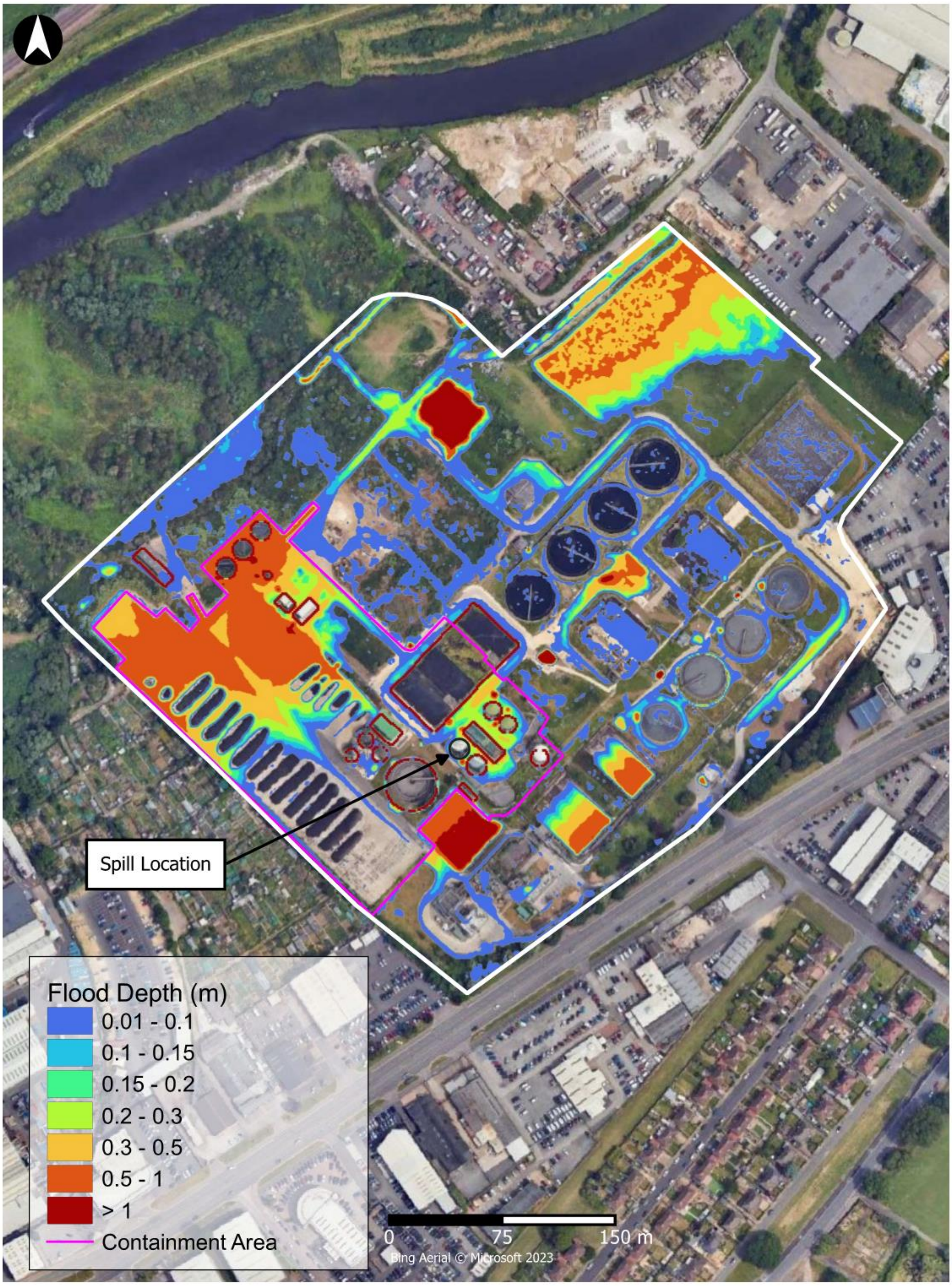
Tank 4 Spill Results - Final Depths

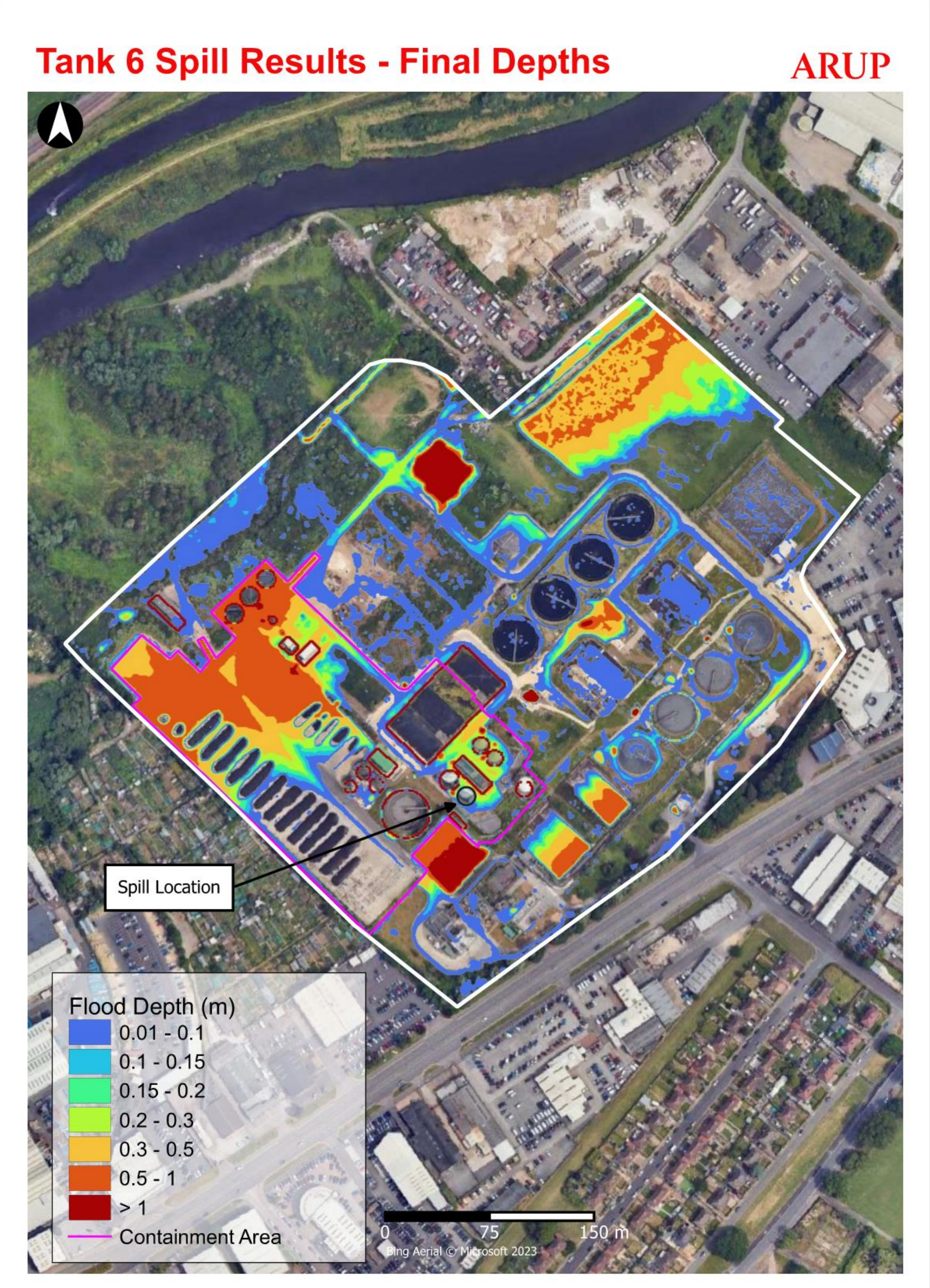
ARUP

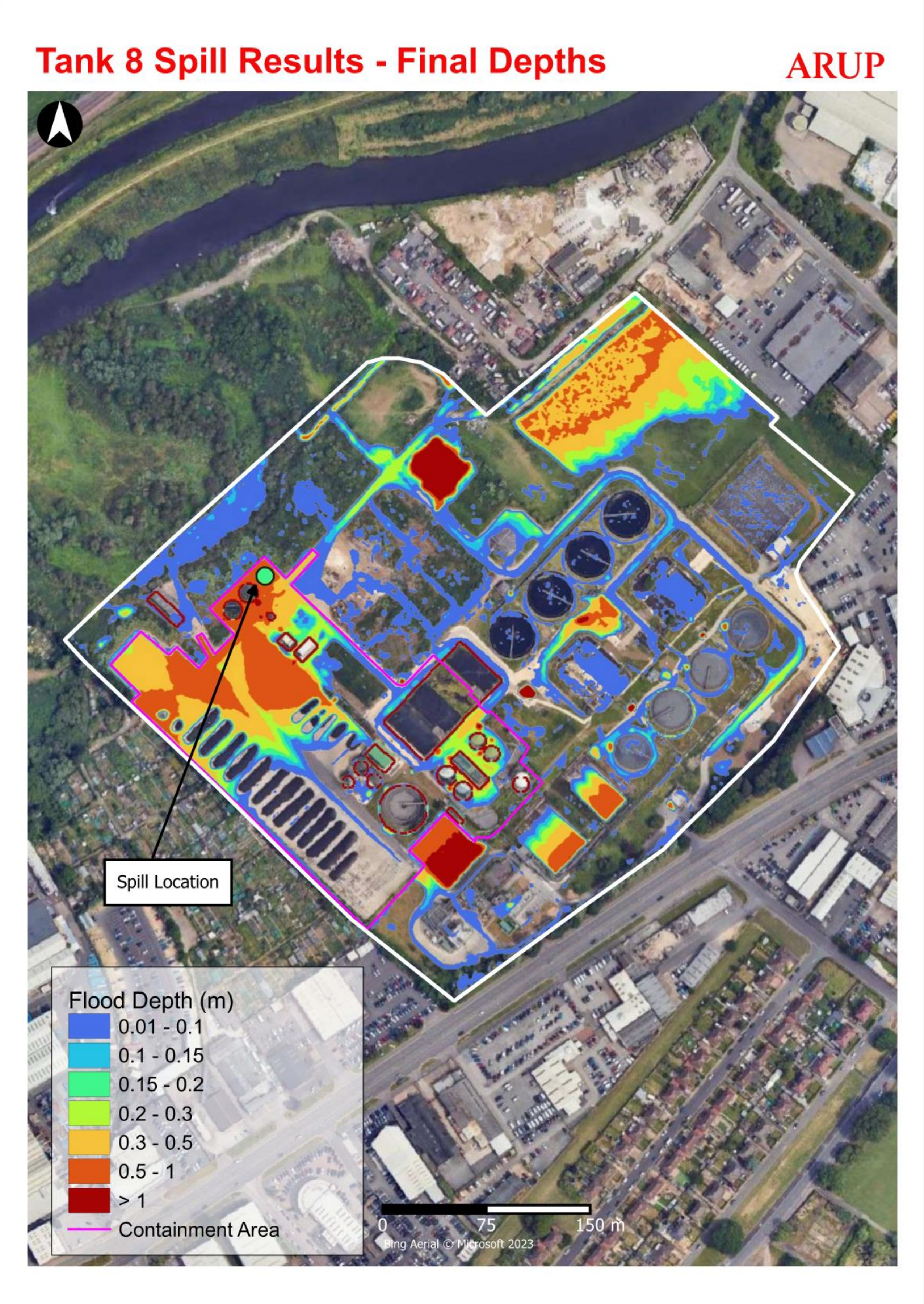


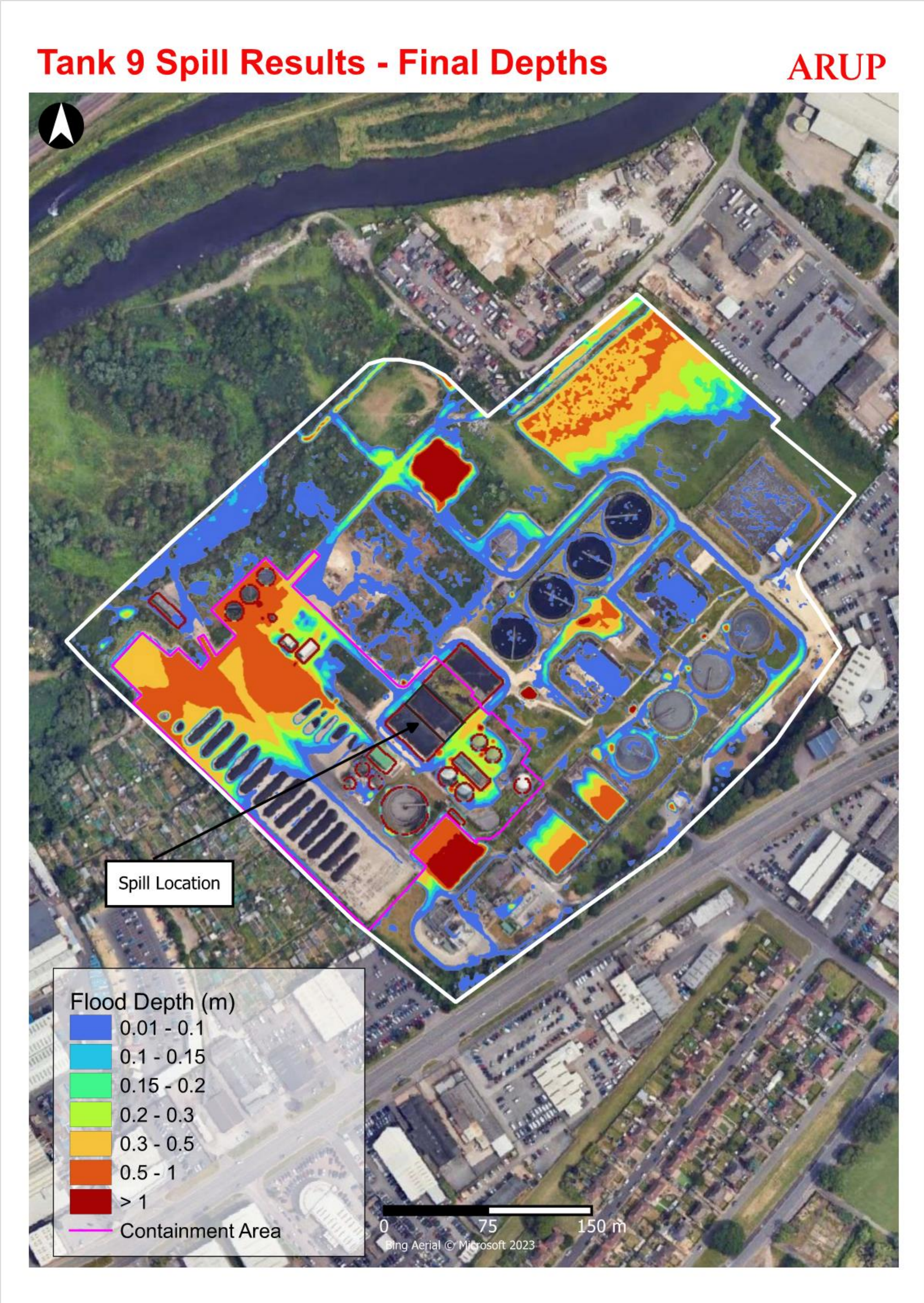
Tank 5 Spill Results - Final Depths

ARUP



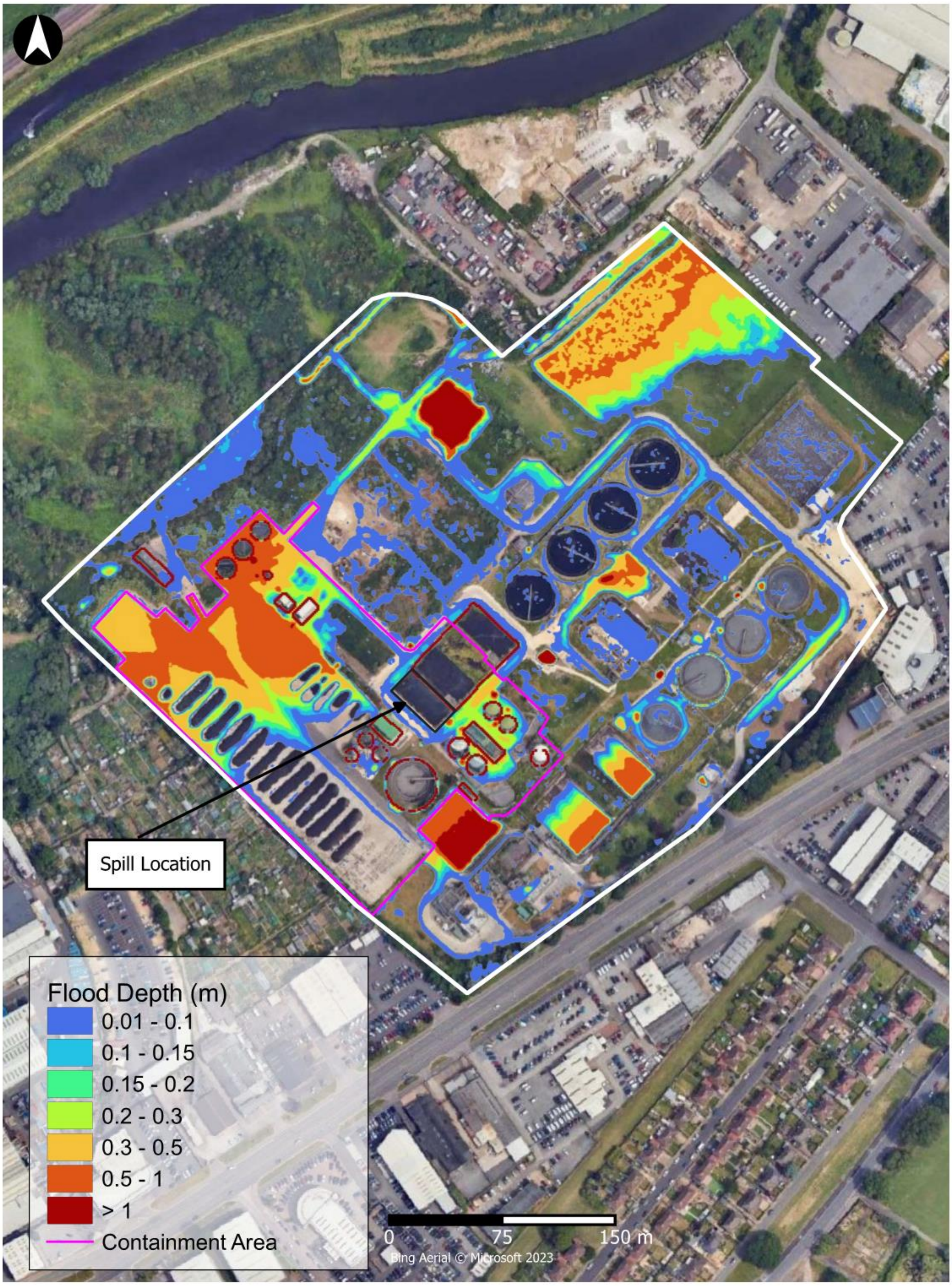

Tank 6 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 8 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 9 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

Tank 10 Spill Results - Final Depths

ARUP



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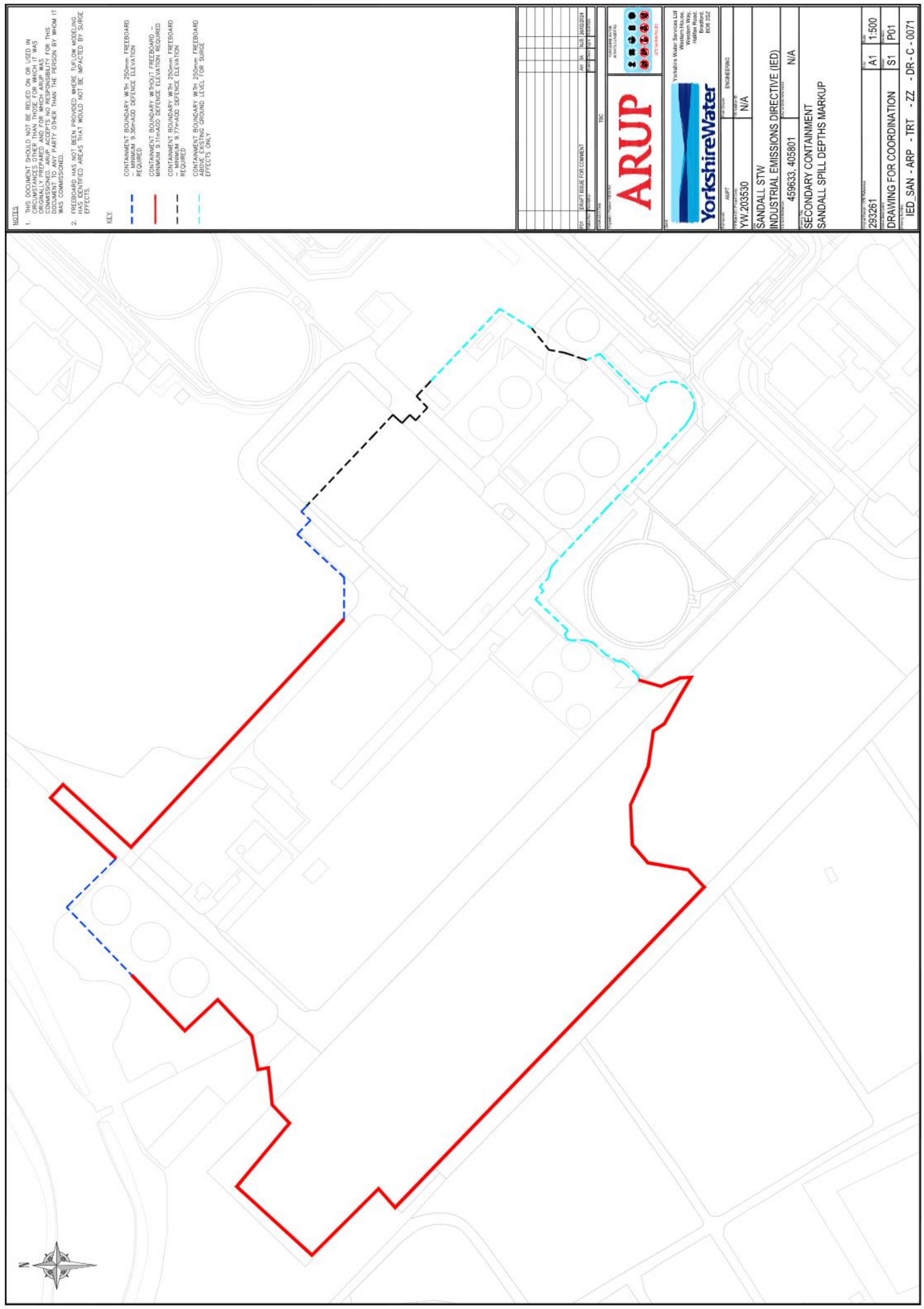
Job number	293261
Date	26 February 2024

Appendix B – Defence Design Markup based on Tuflow Modelling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2. FREEBOARD HAS NOT BEEN PROVIDED WHERE TUFLOW MODELLING HAS IDENTIFIED AREAS THAT WOULD NOT BE IMPACTED BY SURGE EFFECTS.
KEY
CONTAINMENT BOUNDARY WITH 250mm FREEBOARD – MINIMUM 9.36mAOD DEFENCE ELEVATION REQUIRED
CONTAINMENT BOUNDARY WITHOUT FREEBOARD – MINIMUM 9.11mAOD DEFENCE ELEVATION REQUIRED
CONTAINMENT BOUNDARY WITH 250mm FREEBOARD – MINIMUM 9.77mAOD DEFENCE ELEVATION REQUIRED
CONTAINMENT BOUNDARY WITH 250mm FREEBOARD ABOVE EXISTING GROUND LEVEL FOR SURGE EFFECTS ONLY
ARUP
YorkshireWater
YW 203530
N/A
SANDALL STW
INDUSTRIAL EMISSIONS DIRECTIVE (IED)
459633, 405801
N/A
SECONDARY CONTAINMENT
SANDALL SPILL DEPTHS MARKUP
293261
A1
1:500
DRAWING FOR COORDINATION
S1
P01
IED_SAN - ARP - TRT - ZZ - DR - C - 0071