Old Whittington 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 Old Whittington Treatment Facility (STF), Yorkshire Water (YW) has undertaken an assessment of the significance and potential environmental risks associated with a loss of containment of sludge containing process vessels. YW has also reviewed existing provisions and potential improvement options against Best Available Techniques (BAT) principles, in alignment with CIRIA C736[1].

Old Whittington 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, digestion, 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 Section V: Site Condition Report.

1.1 Site details

Old Whittington Wastewater Treatment Works (WwTW) is located approximately 3.3 km to the north of Chesterfield and processes 37,530 m^3 of wastewater per day from 119,365 population equivalent. The site is bounded by the River Rother / Whitting with Chesterfield Canal running alongside the river.

An aerial view of Old Whittington STF along with its permitted boundary is shown Figure 1. The key activities at Old Whittington 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 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)

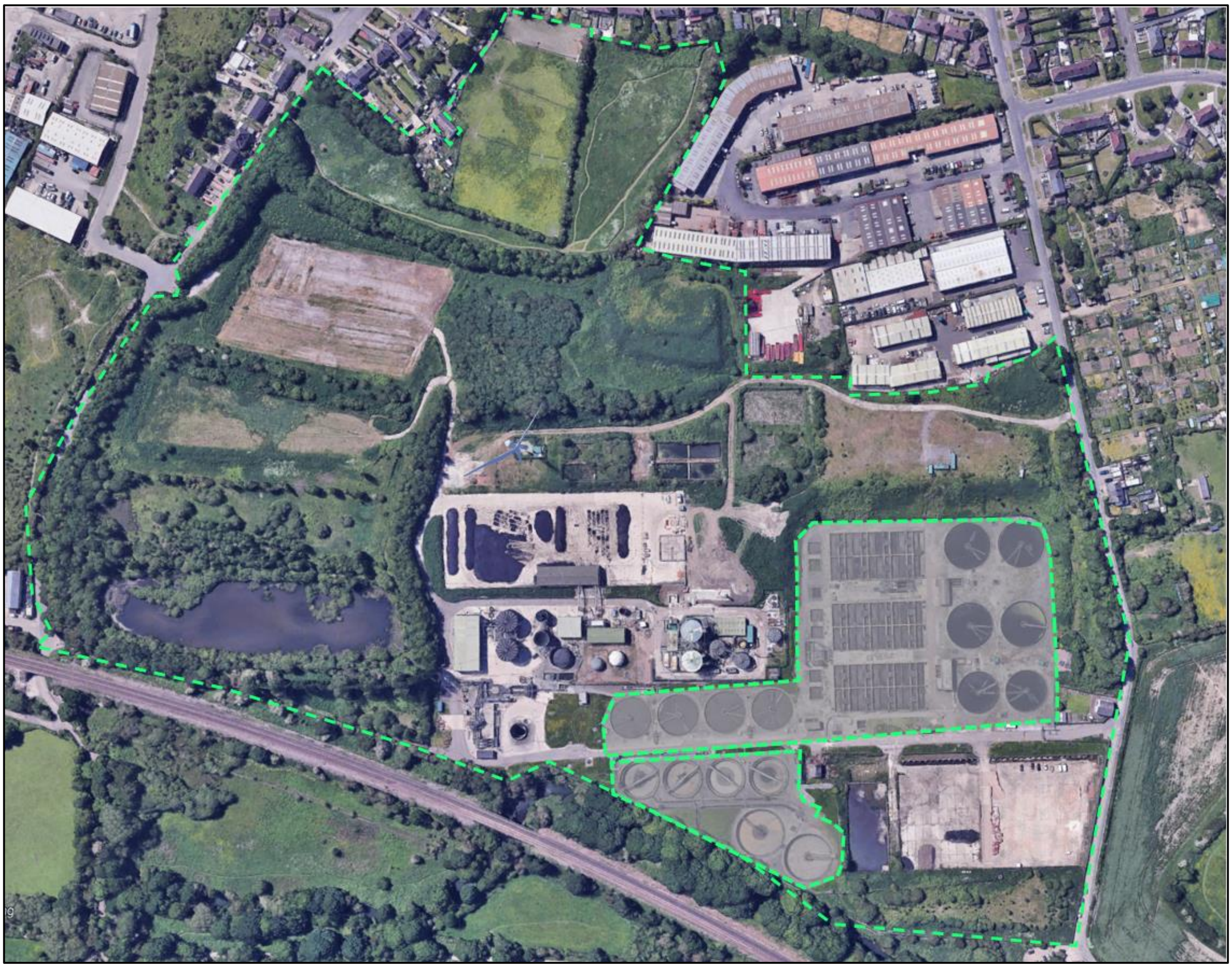


Figure 1. Old Whittington STF aerial view. Permit boundary in green. © Google, 2021

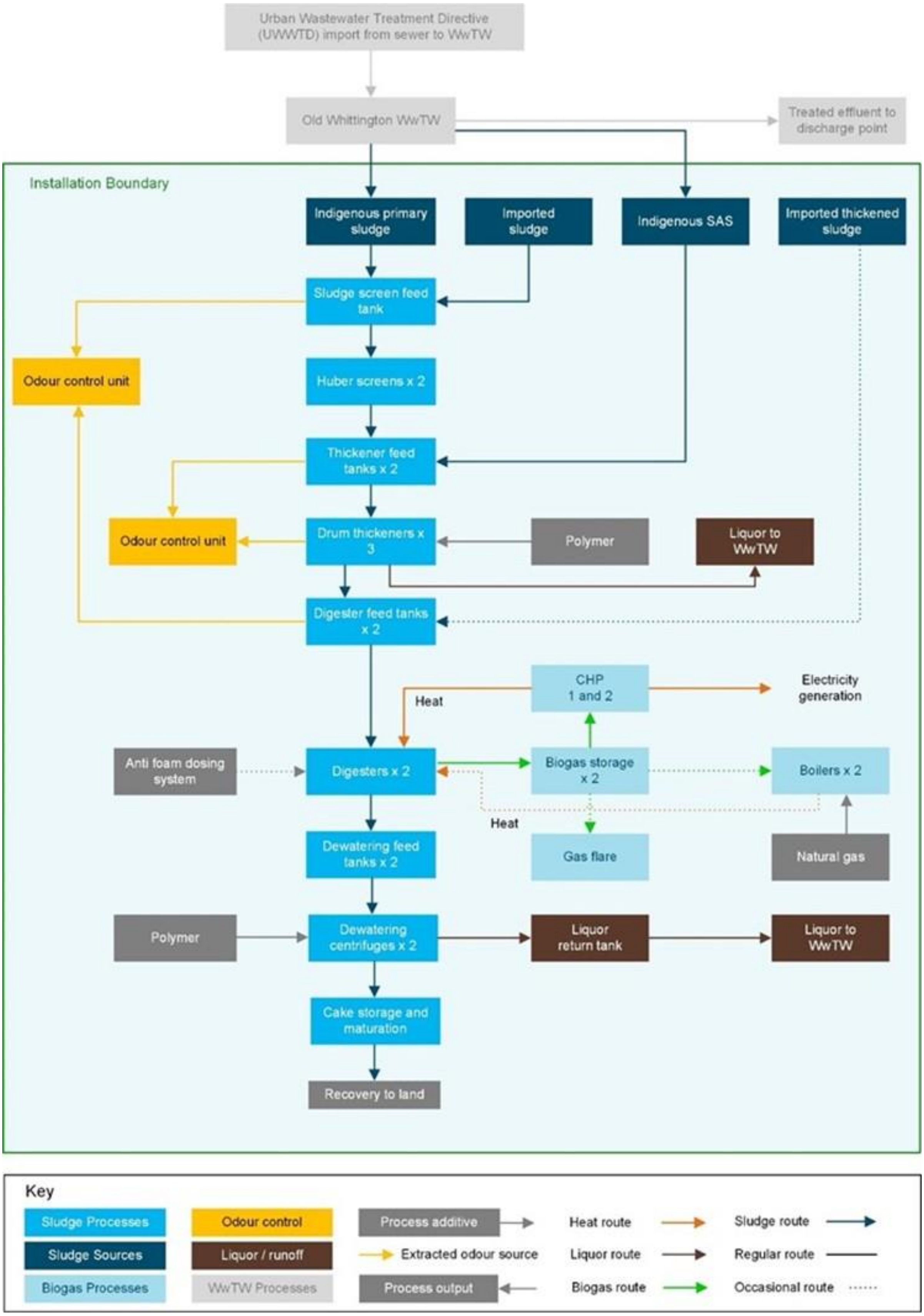


Figure 2. Process flow diagram Old Whittington STF.

1.2 Overview

YW commissioned Stantec to assess existing provisions and, where necessary, improvement options for secondary containment at the site. Stantec have provided risk-based supporting evidence to accompany the permit application, which demonstrates the most appropriate solution(s) for IED BAT compliance using CIRIA C736 standards. To fully understand the requirement for secondary containment and to provide environmental protection at Old Whittington, 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 Old Whittington. 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 Old Whittington 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 detailed evidence base for assessment of secondary containment options at Old Whittington.

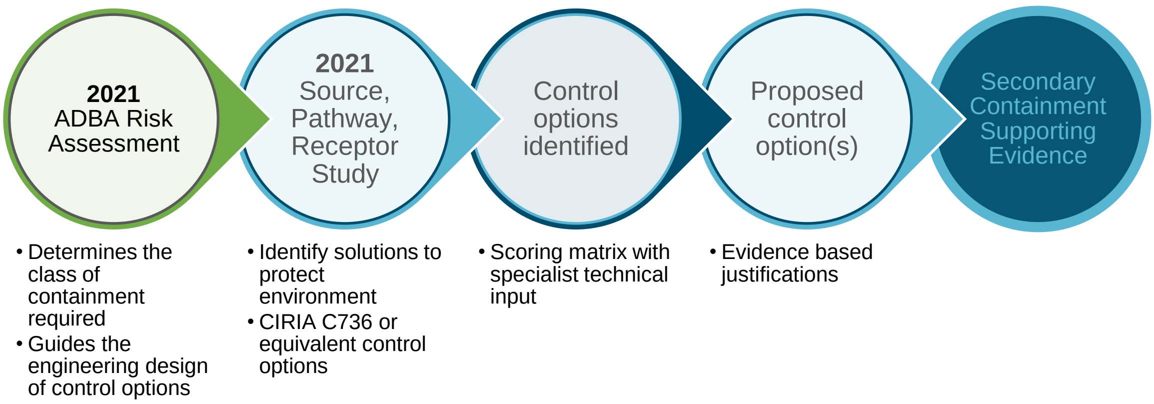


Figure 3. Flow chart showing the approach taken to provide secondary containment supporting evidence.

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. The assessment is presented in Appendix 1 and the findings are summarised in this chapter.

2.1 Class of required secondary containment for Old Whittington

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

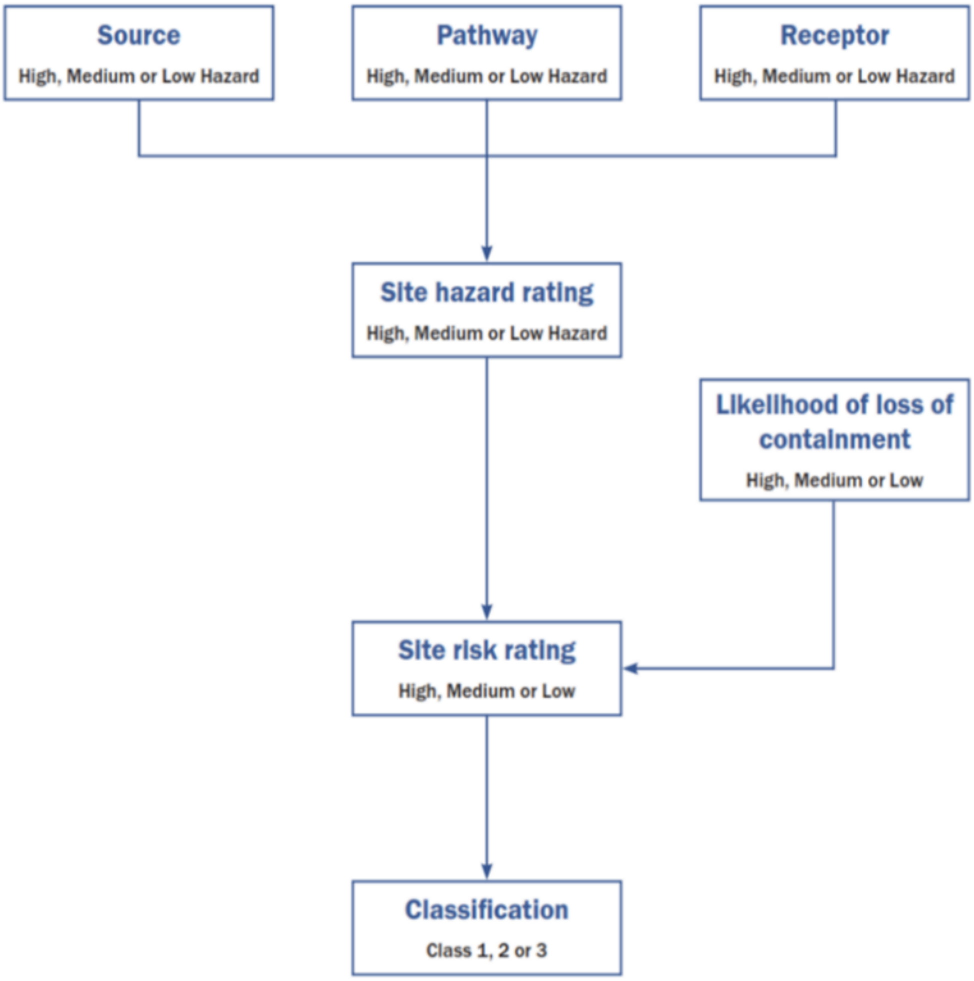


Figure 4. ADBA risk assessment classification flowchart.

The ADBA Risk Assessment Tool scored the source element as 'High risk', pathway elements as 'Medium risk' and the receptor element as 'High risk' at Old Whittington owing to the significant volumes of sewage sludge stored onsite and site drainage pathways to the sensitive receptor, the River Rother/ Whitting. In summary, this assessment approach indicates that Old Whittington 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 **Old Whittington 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 'Old Whittington STF ADBA Secondary Containment Risk Assessment' outlines the information and data utilised in greater detail, as well as the assumptions applied to undertake a secondary containment risk assessment. The requirement for 'Class 2' type secondary containment within Old Whittington STF has been used to inform the next stage of the risk assessment, spill modelling and 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 of environmental risks associated with a loss of containment from sludge vessels within the Old Whittington STF, and to review existing provisions and potential improvement options 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. Potential improvement options considered as part of this assessment include controls as set out in CIRIA C736 as well as alternative control options which are considered to provide an equivalent level of environmental protection to CIRIA C736.

3.2 Sources at Old Whittington STF

The sources of risk which have been identified at Old Whittington as shown in Figure 6. These STF operational assets mainly occupy the central, southern, and southwestern areas of the site and comprise sludge import, thickening, digestion, dewatering and cake storage area. The easterly cake pad is not part of the STF.

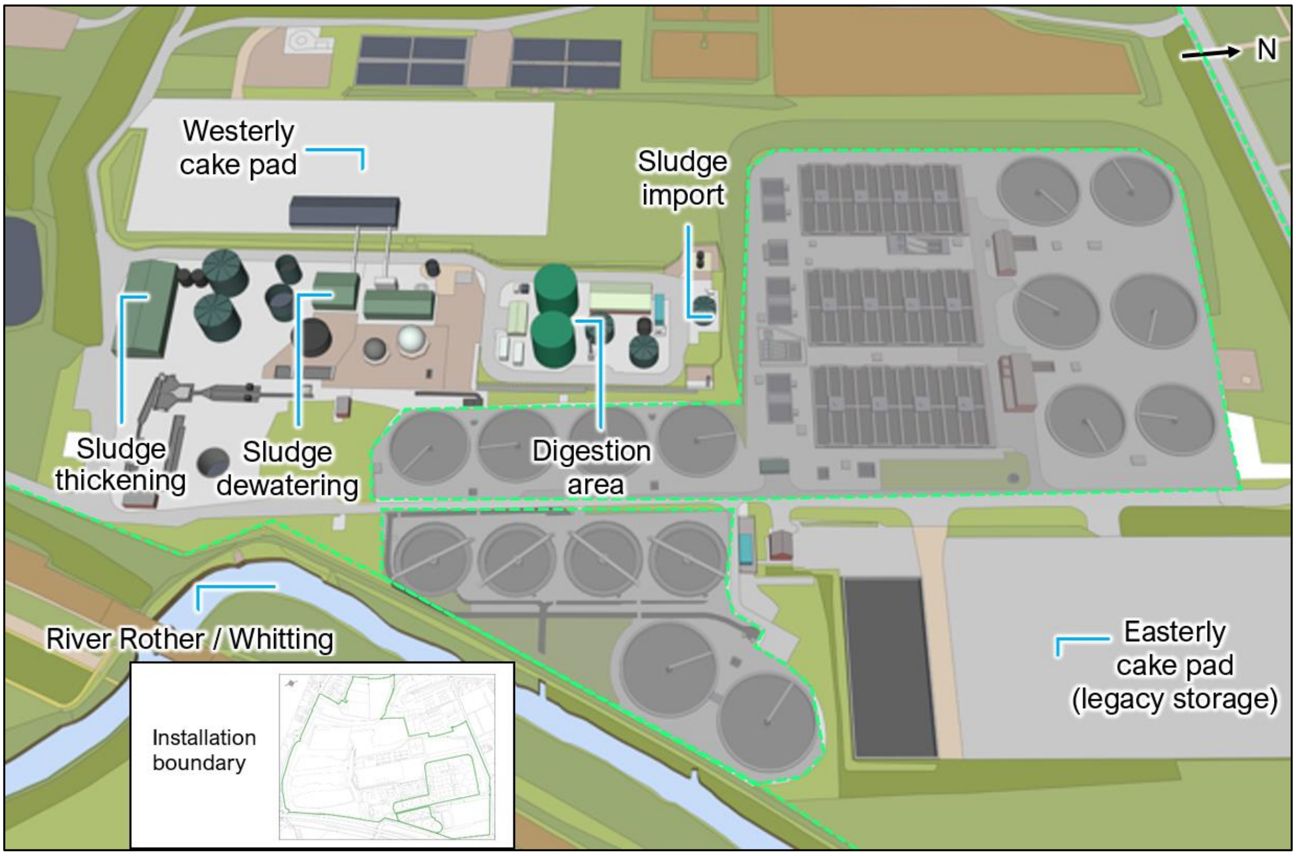


Figure 6. Old Whittington sources of risk and site areas.

3.2.1 Bulk storage vessels

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

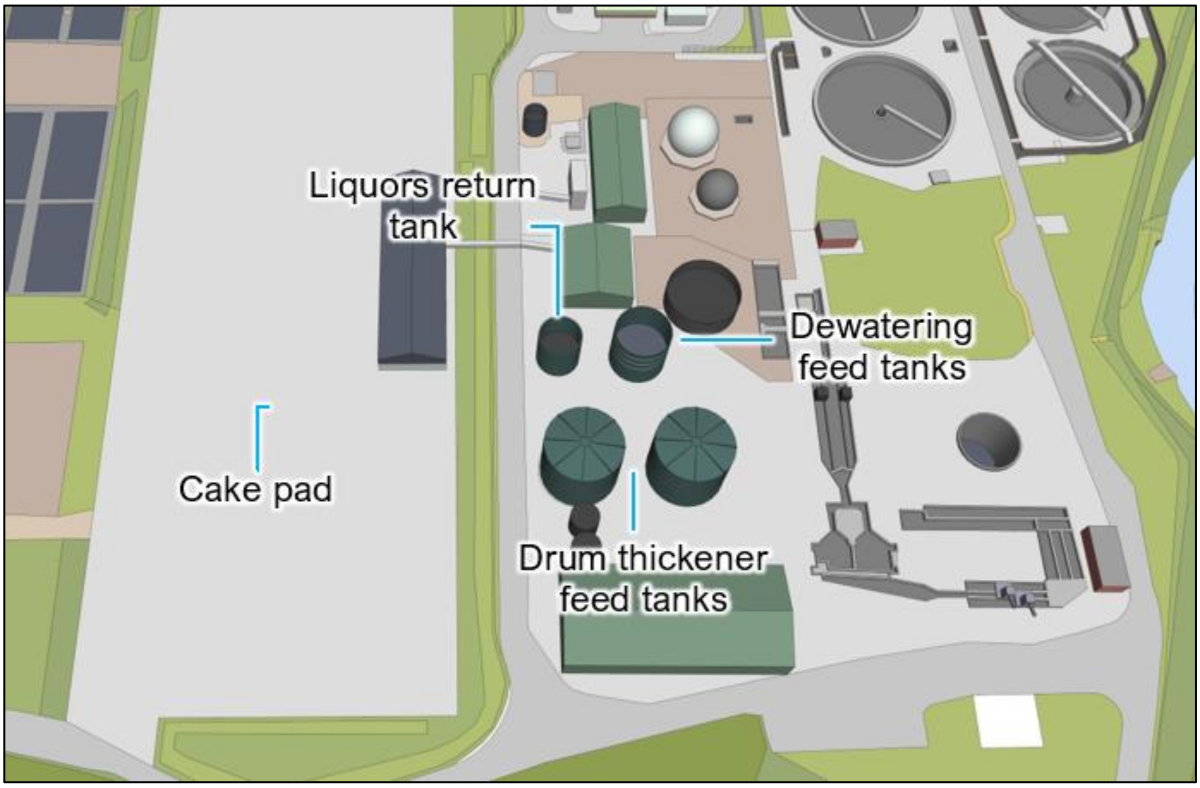


Figure 7. Sludge vessels located in the southern and southwestern sections of the site.

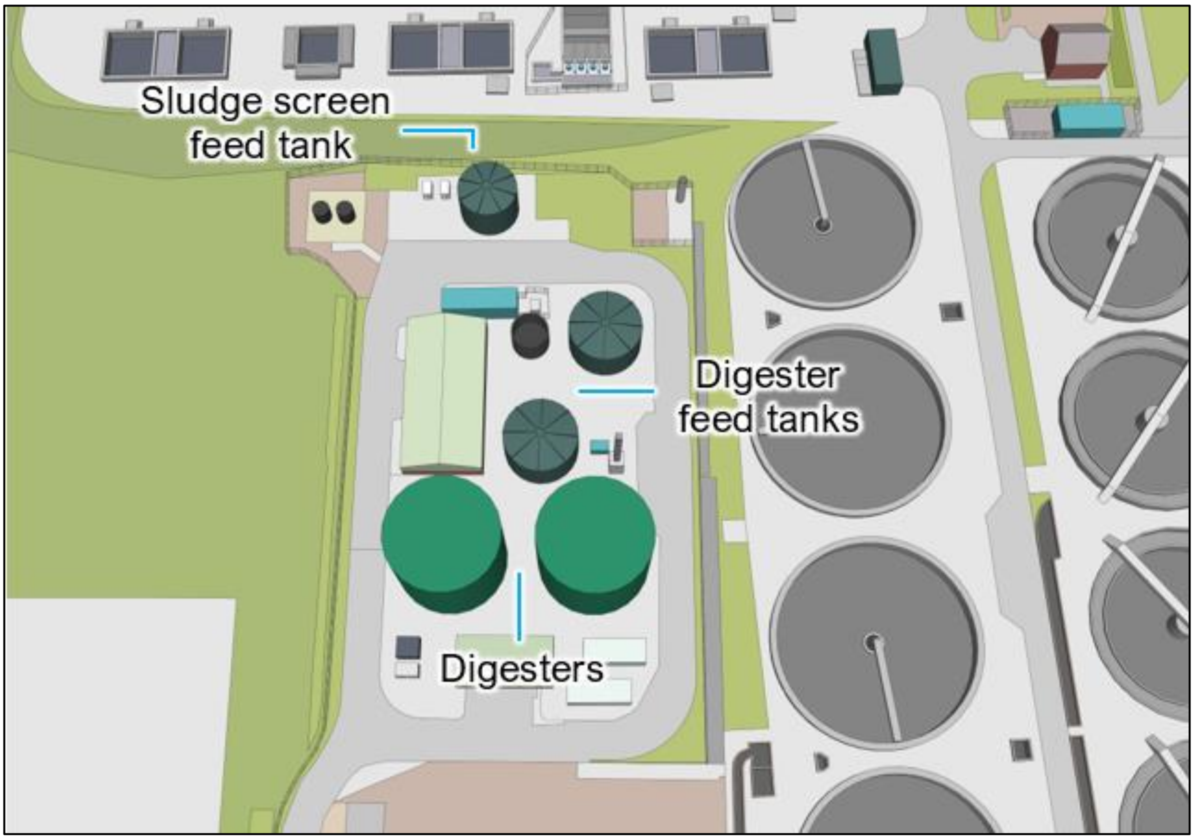


Figure 8. Sludge vessels located in the central section of the site.

3.2.1.1 Sludge reception, treatment, and handling

Old Whittington STF treats the following sewage sludges:

- Indigenous primary sludges and surplus activated sludge (SAS) arising from sewage treatment processes operating within the wider Old Whittington WwTW piped directly to the STF.
- Liquid sludges generated by other YW WwTW (with lower capacity or capability for treating sludges on-site) that are imported to Old Whittington 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 sludge screen feed tank (Figure 9, 183m^3 steel tank with concrete collar). 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 'WaSP' loggers, valves on the discharge pipework will only open when a driver presents appropriate authentication to the system. The WaSP loggers record 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 is also pumped into the sludge screen feed tank. Both sludge sources are screened using two Huber ROTAMAT enclosed rotating screens. Screenings drop into a skip and are disposed of off-site.

Figure 9. Sludge screen feed tank

The screened imported sludge and indigenous primary sludge is discharged to a sub-surface pumping station and pumped to 2 no. drum thickener feed tanks (Figure 10, 1,600m^3 steel tanks). The SAS is piped directly to the drum thickener feed tanks.

If the screens are unavailable or the pumping station fails, the sludge screen feed tank can be isolated. There is also the facility for indigenous primary sludge to bypass the sludge screen feed tank and be routed directly to the screened sludge pumping station to avoid backing up the primary settlement tanks at the WwTW.

Figure 10. Drum thickener feed tanks (2 no.).

Liquid sludge from the drum thickener feed tanks is transferred to the drum thickeners in the adjacent drum building using three feed pumps, located outside of the building. A liquid polymer is used to encourage separation of water from the liquid sludge. Liquid polymer is delivered in 1m^3 IBCs or bulk delivered and stored in a bulk storage tank (c.6m^3) within the building. It is then diluted with potable water and stored in an adjacent, smaller poly make-up tank (2m^3), before being introduced to the sludge via in-line injection with final treated effluent used as a carrier.

The polymer storage tanks, and associated pumps are surrounded by a large below ground sump to provide secondary containment in the event of spills and leaks. Drainage of the sump is controlled by a normally closed manually actuated valve, which returns bundwater to the WwTW for treatment. The sump is fitted with a high-level probe, alarmed to the PLC.

After injection of the polymer, the sludge passes through a shear valve on the front of each drum thickener, to ensure contact time for flocculation. There are 3 no. drum thickeners which usually operate on the basis of two duty and one standby. The polymer encourages separation of water from the sludge as the thickened sludge is rotated in the drum to remove excess liquid. Filtered final effluent water introduced via spray bars is used to wash down the drums, with potable water used for the manual jet wash. The thickener liquors from the drums are returned directly to the WwTW for full treatment.

The thickened sludge is then transferred to the 2-no. covered digester feed tanks (Figure 11, 463m^3 steel tanks) via discharge transfer pumps. There is also the facility for tankers to deliver imported thickened sludge (above 4% solids) directly to the digester feed tanks, with the sludge being macerated prior to being piped directly to the digesters. This facility is only used occasionally as it is not the preferred import route.

The best available techniques for sludge reception, treatment, and handling include trace heating to reduce the risk of loss containment from pipe fracture, isolation valves, largely PLC operated and level sensors to reduce risk of overtopping.

Figure 11. Digester feed tanks (2 no.).

3.2.1.1 Sludge digestion

Thickened sludges are pumped from the digester feed tanks to the anaerobic digesters (Figure 12 no. 2,300m^3 epoxy coated mild steel tanks). The anaerobic digesters operate as a continuous process with sludge being added at the bottom and treated sludge displaced out of the top of the digester via the outlet pipe. There are two feed pumps which operate alternatively; the pumps are controlled by SCADA (they run for approximately 19 minutes/hour).

The digesters each have a typical feed rate of around 238m^3/day at 5.5% dry solids (13.1 tDS/day); the maximum feed rate is 345m^3/day at 6% dry solids (20.7 tDS/day) giving a 12-day retention time as required by Hazard Analysis and Critical Control Points (HACCP) controls. The sludge in each digester is mechanically mixed using two duty/standby mixer pumps with automatic timer control.

Figure 12. Digesters (2 no.).

A hot water circuit provides heating to ensure optimum conditions for digester microbial activity. Treated potable water is heated to around 70°C by the CHP and/or boilers and is used in a heat exchange system. Each digester has two recirculating pumps (one duty/one standby).

A 3-way modulating valve (temperature controlled) on the water side moderates the amount of hot water that passes into the heat exchangers, depending on the heat demands of the digesters.

The sludge in the recirculation circuit passes through a tube-in-tube heat exchanger to maintain the digester temperature. This system is located adjacent to the digester compound. The feed sludge is added to the digesters through a digester sludge feed selector valve on the recirculation circuit, downstream of the heat exchanger.

Grit build-up within digesters is a normal feature of operation, the digesters are cleaned out (including accumulated grit) 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 the chemical anti-foam will be dosed directly into the digester feed pipework. This system includes operator-adjustable dosing setpoints and failsafe systems; if the foam level continues to increase, the mixing systems are inhibited; and if this continues the digester feed would then also be inhibited.

The best available techniques for sludge digestion include PLC operations with key stages being automated, monitoring to ensure digestion process is healthy and stable including foam level monitoring and an anti-foam system proposed for 2022, and high-level probes and pressure sensors to avoid potential loss of containment.

3.2.1.2 Digested sludge treatment, handling and disposal

Digested sludge from the anaerobic digesters is gravity fed to 2 no. uncovered dewatering feed tanks (Figure 13, one 623m^3 steel; one 835m^3 steel) prior to onward processing. The digestate is mechanically mixed to prevent settlement and anoxic conditions.

Figure 13. Dewatering feed tanks (2 no.).

From the dewatering feed tanks, the digestate is piped to a centrifuge building containing one centrifuge, and a separate adjacent second centrifuge in its own enclosure. These operate on a duty/standby basis. A polymer solution is added to the digestate in order to aid dewatering. The powdered polymer is mixed with potable water to achieve a 0.5% solution; the solution remains in the polymer mixing tank for 45 minutes to cure. Once cured, the solution drops into a tank below to feed the centrifuge; both tanks have a volume of approximately 2.6m^3. Carrier water (treated final effluent) is added to the cured polymer solution to reduce the strength to 0.1% and it is introduced directly into the centrifuge. After injection of the polymer solution, the sludge is passed to the centrifuges where the sludge coagulates and supernatant liquor is removed by centrifugal forces. The liquor drops from the centrifuges into a sump and is pumped to an uncovered liquor return tank (Figure 14, 494m^3, steel), prior to discharge to the WwTW for full treatment.

Figure 14. Liquor return tank.

The final digested and dewatered sludge cake is transferred via centreless screw conveyers from the centrifuges through the side of the cake barn and onto the cake pad, as shown in Figure 15 and Figure 16. The area under the conveyer and adjacent sludge cake pads are an engineered impermeable surface, with water runoff collected in drains running along the eastern edge of the pad. These liquids are pumped back to the WwTW for full treatment.

Figure 15. Digested sludge conveyer system.

Figure 16. Sludge cake barn.

Sludge cake is moved by mechanical loaders into storage rows on the cake pad area, as shown in Figure 17. There is no lime addition at Old Whittington; instead, cake is stored in piles according to age and is left to mature for a minimum of four weeks in accordance with HACCP requirements. The maximum storage capacity of the cake pad is approximately 15,000 tonnes; although significantly less than this is stored under normal operating conditions (approximately 5,500 tonnes). 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 maturation is complete, sludge cake is removed from site and landspread in accordance with legislative requirements. Samples of digested, matured cake are taken every 3 months and analysed for metals and pathogens to ensure HACCP standards are being met.

The best available techniques for digested sludge treatment, handling and disposal sludge include largely PLC automation and level sensors to reduce risk of overtopping, inspection and testing programme via visual examination and non-destructive testing for above and below ground vessels, pipes and valves. The cake pad is engineered for leachate and washwater to be collected and routed for treatment at the WwTW.

Figure 17. Sludge cake storage pad.

3.2.2 Tank volumes

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

Table 1. Old Whittington STF tanks, capacities, age, and construction materials.

Tank	Size m^3 (each tank)	Year constructed	Construction material
1 no. sludge screen feed tank	183	2011	Steel
2 no. drum thickener feed tanks	1,600	2013	Steel
2 no. thickener polymer tanks (dilution)	8 2	2014 2013	GRP
2 no. digester feed tanks	463	2011	GRP lined steel tank
2 no. digesters	2,300	2013	Steel
2 no. dewatering feed tanks	623 835	2012	Steel
2 no. centrifuge polymer storage tanks (mix and make-up)	2.6 2.6	2008	GRP
1 no. liquors return tank	494	2012	Steel
1 no. red diesel tank	1	Unknown	Steel

3.2.3 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 Old Whittington, 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 Old Whittington 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 Old Whittington is illustrated in Figure 18.

Figure 18. Old Whittington 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 Old Whittington 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 Old Whittington 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 Old Whittington. Notwithstanding these limitations, the use of PondSIM is considered appropriate for the purpose intended in this study and allows for the rapid screening and assessment of asset risks to support prioritisation of risk mitigation.

To counter these limitations, several worst-case assumptions were selected relating to the potential failure events, including spill volumes.

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 Old Whittington sludge storage tanks and treatment processes are installed in common areas of the site as either multi-tank or single tank installations, as shown in Figure 19, 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 legislation and YW's asset standards. The spill modelling scenarios for either the CIRIA C736 rule, or 'worst-case' and associated containment volumes are listed in Table 2, whilst full calculations can be viewed in Table 6.

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 installation	4,491 (see Table 6)	Figure 20

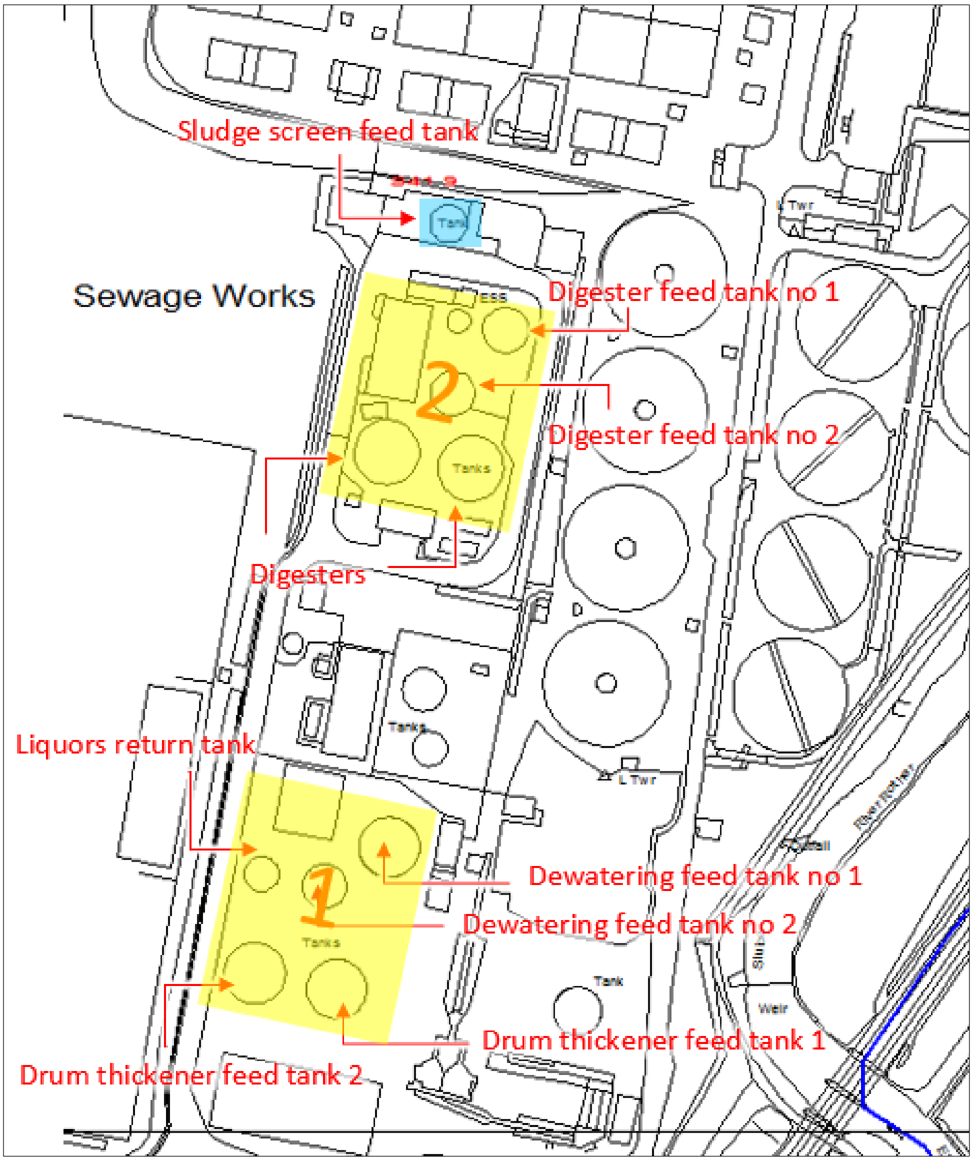


Figure 19. Old Whittington single tank and multi-tank installation areas.

3.5 PondSIM modelling of unmitigated pathways

This section presents the modelling outputs showing unmitigated flow routes from the identified source, 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 20 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.

Figure 20. Model showing unmitigated result of spills from existing tanks at Old Whittington using the CIRIA C736 rule.

3.6 Spill pathways

The unmitigated modelled spills show the potential pooling of sludge on hardstanding surfaces around the WwTW inlet works, operator/thickening building, and in between the thickener feed and dewatering feed tanks emanating from multi-tank installation area 1 as illustrated in Figure 21. Where these tanks are open topped e.g PSTs, no risk of sludge entering them has been identified. Contained surface water drainage is present adjacent to the inlet screen, this returns to the WwTW for treatment. The spill travels along the inlet screen towards the primary settlement tanks (PSTs) crossing a grassy section of permeable surface.

Figure 22 shows sludge spills from the single sludge screen feed tank and multi-tank installation area 2. Results show the sludge is contained on hardstanding surfaces within the access roads surrounding the northern and eastern sections of the digester compound. Surface water drainage is present along the kerbs of the northern, eastern, and southern access roads, this again returns to the WwTW for treatment.

Figure 23 illustrates the potential of pooling in the areas between the western PSTs due to spills directed from multi-tank installation area 1 and 2, as shown in Figure 21 and Figure 22. The ground between the primary tanks is hardstanding and surface water drainage in this area is present along the westerly kerb situated on the access road adjacent to the tanks. Surface water drainage in this area is contained and returns to the WwTW for treatment.

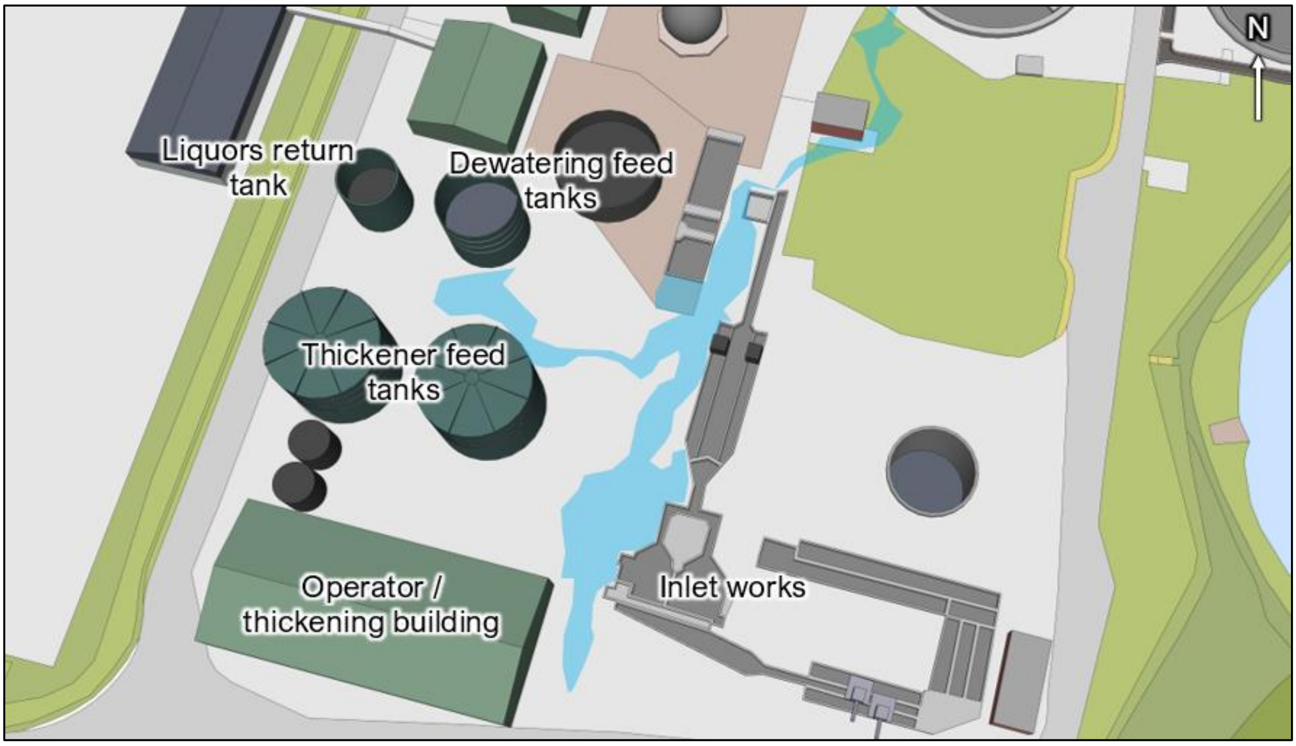


Figure 21. Pooling potential around WwTW inlet works and operator/ thickening building.

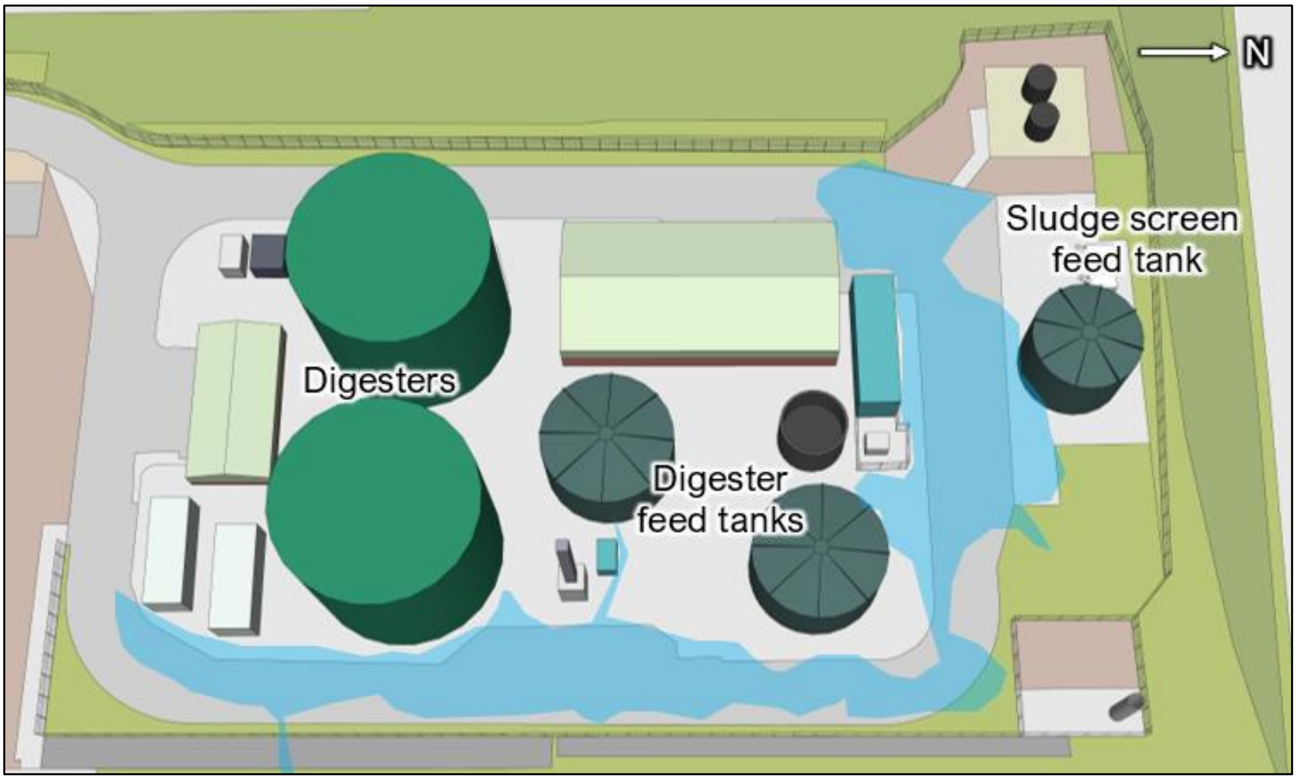


Figure 22. Pooling potential within the digester compound and sludge screen feed tank.

The spill continues further north of the site beyond the PSTs along the access roads and finally pools within the easterly cake pad, as shown in Figure 24Figure 24. Potential pooling within the easterly cake storage pads.. Sludge spills in this area are again contained, predominantly within the hardstanding area of the eastern cake pad, currently used for storage of legacy material. Surface water drainage is present within the easterly cake pad (legacy storage) adjacent to the access road; this also returns to the WwTW for treatment. Therefore, a spill in this area will not create a route to river or affect operation.

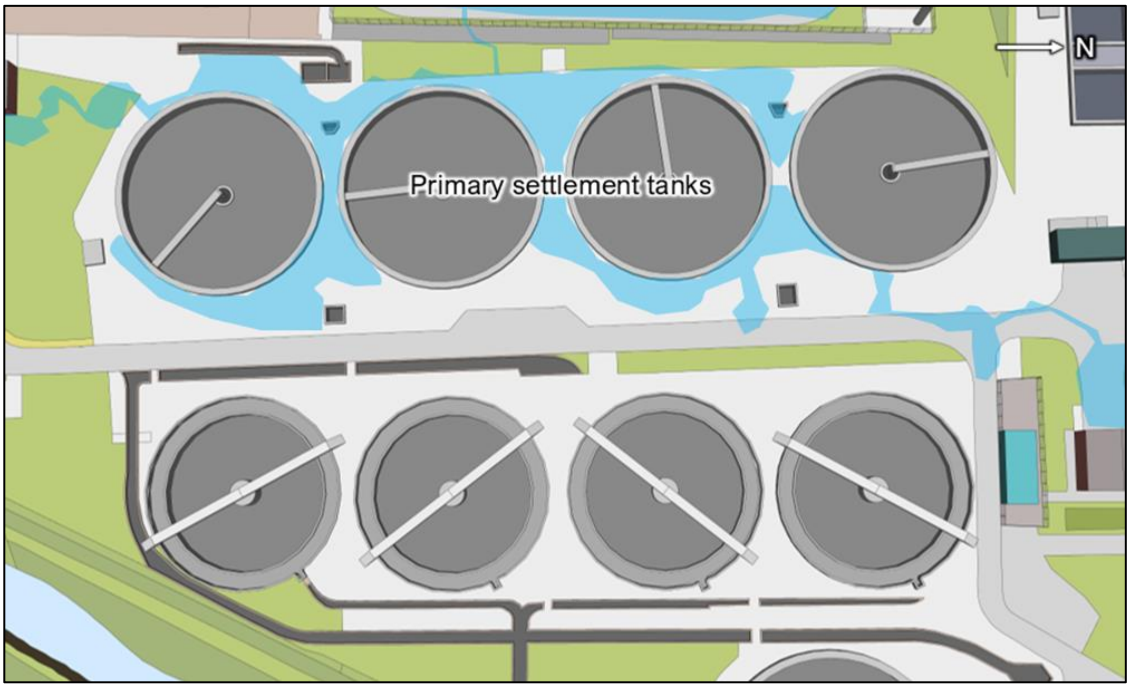


Figure 23. Potential pooling around the western PSTs.

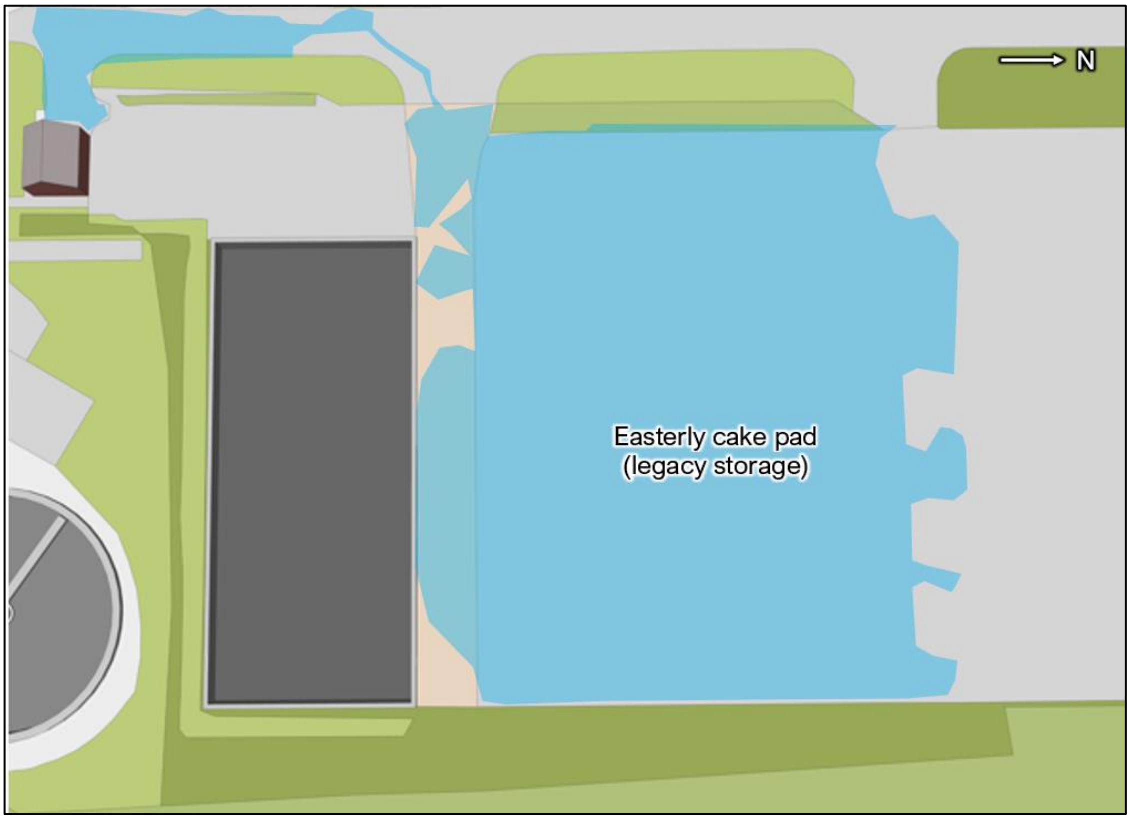


Figure 24. Potential pooling within the easterly cake storage pads.

3.6.1 Surface drainage

Old Whittington WwTW underwent a surface drainage survey in April 2020. The survey mapped the location of gullies and manholes, separating the surface water drainage, liquor transfer and combined drainage routes, as illustrated in Figure 25. The survey shows that all surface water drainage features, are routed back to the WwTW for treatment i.e., contained. None of the surface drainage directly discharges to sensitive receptors.

These contained routes present a spill pathway that cannot be directly modelled by PondSIM. Therefore, the modelled spills do not represent the additional mitigation provided by the surface drainage.

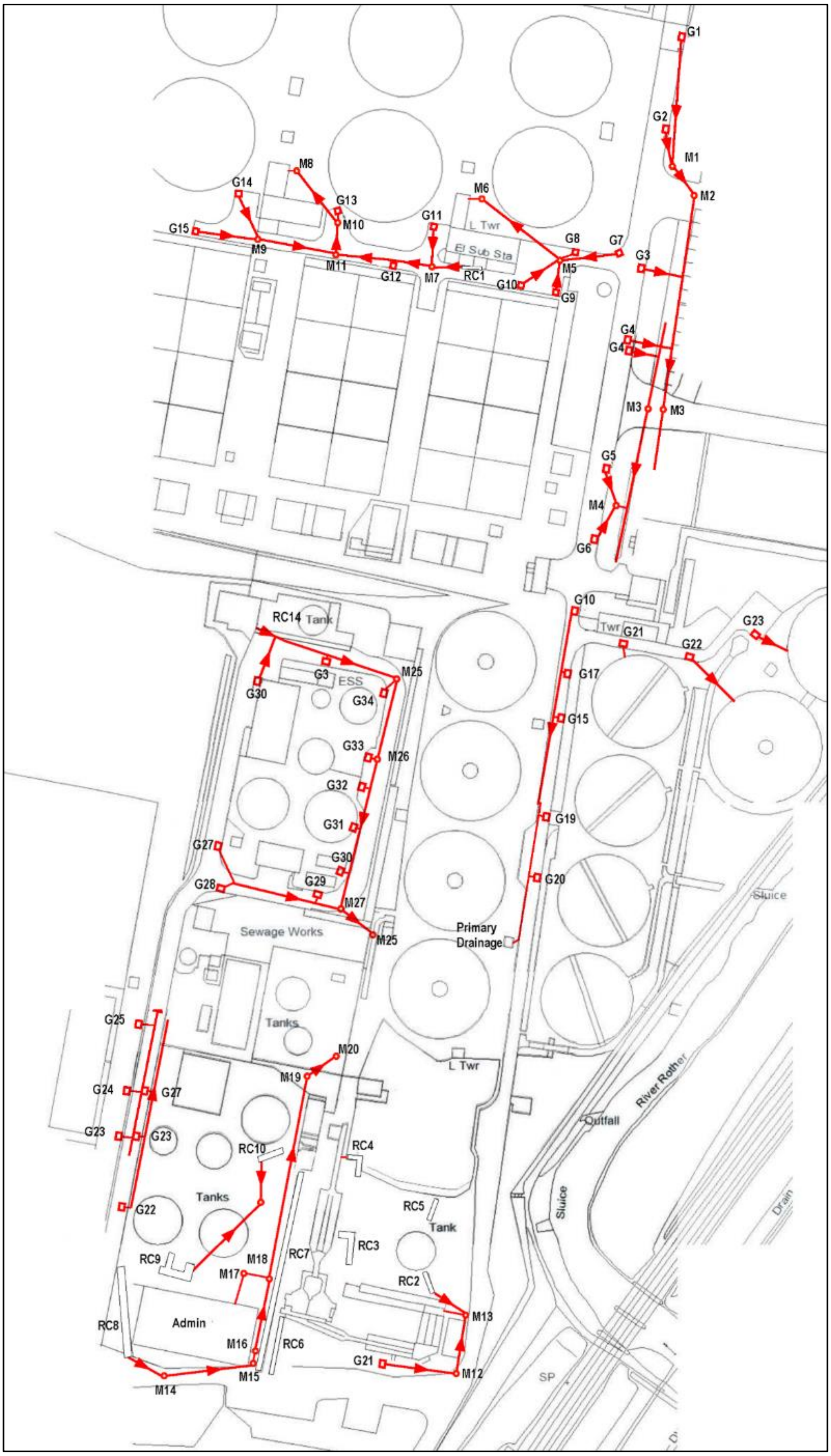


Figure 25. Old Whittington WwTW site drainage plan.

3.6.2 Spill pathway summary

The table below lists the resulting pathways associated with tank failure at Old Whittington determined using the PondSIM model. Full model results are presented in Section 3.4.

Table 3. Surface pathways from the key sludge holding assets at Old Whittington.

Common Area / Tank	Surface Pathways	Comments
Multi-tank installation area 1. (2 no. drum thickener feed tanks, 2 no. dewatering feed tanks)	Overland run-off over mostly sealed surfaces to: • South of the site around the operator/ thickening building and head of the inlet works. • Centre of the site surrounding the PSTs. • North of the site pooling within the easterly cake pad.	Principal spill volume captured on existing site hardstanding areas and access roads, with a small amount captured on grassy permeable surface. Surface water drainage in this area is contained and returned to the main WwTW for treatment prior to discharge.
Multi-tank installation area 2. (2 no. digester feed tanks, 2 no. digesters)	Overland run-off over sealed surfaces to: • Centre of the site surrounding the digester compound. • Centre of the site surrounding the PSTs. • North of the site pooling within the easterly cake pad.	Spill flows across and is captured on hardstanding and road surfaces. Surface water drainage in these areas are contained and returned to the main WwTW for treatment prior to discharge.
Sludge screen feed tank	Overland run-off over sealed surfaces to: • Centre of the site surrounding the digester compound. • Centre of the site surrounding the PSTs. • North of the site pooling within the easterly cake pad.	Spill flows across and is captured on hardstanding and road surfaces within the vicinity of multi-tank installation area 2. Surface water drainage in these areas are contained and 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 Reports detailing site setting, geology and groundwater. These were identified based on 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 Old Whittington.

Table 4 lists the type of pathway potentially leading to each receptor e.g., indirect, such as via the Final Settlement Tanks (FSTs), permeable surfaces or direct to the environment, e.g., a flow path into the River Rother/ Whitting.

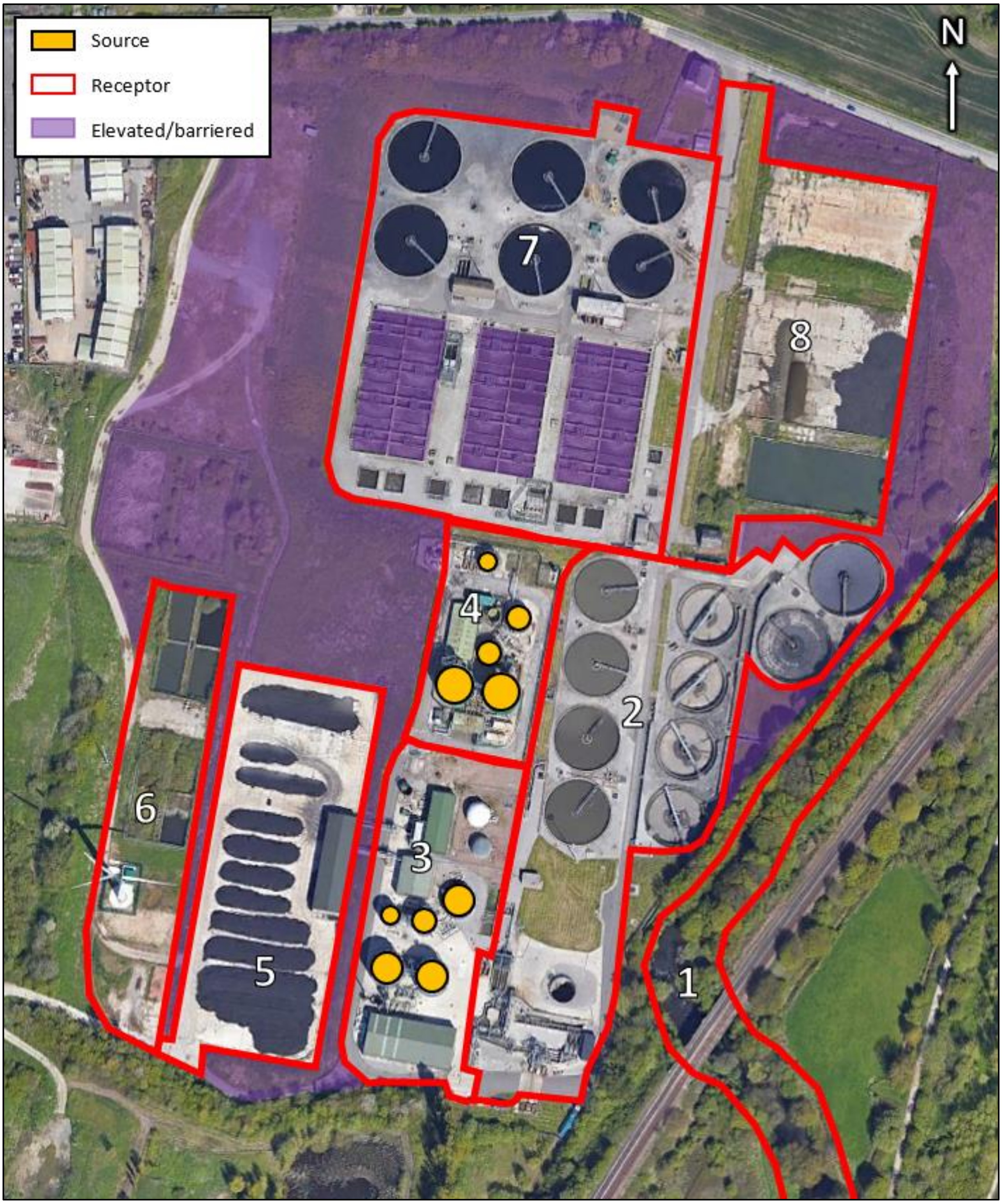


Figure 26. Map of numbered receptors at Old Whittington. *© Google, 2021*

Table 4. Receptors

Receptor no.	Receptor
1	River Rother / Whitting (including adjacent habitats).
2	Ground / groundwater – areas around inlet works, PSTs and storm tanks.
3	Ground / groundwater – area around thickener, dewatering feed and liquor return tanks.
4	Ground / groundwater – areas within the digester site, digester feed tanks and sludge screen feed tank.
5	Ground / groundwater – areas within the sludge cake pad and barn.
6	Ground / groundwater – areas around the wind turbine asset and lagoons.
7	Ground /groundwater – area including and surrounding the ASP's and FSTs.
8	Ground /groundwater – area within and surrounding the legacy cake pad and lagoon.

3.8 Source-pathway-receptor summary

A summary of the receptors at risk following the modelling of spill pathways from identified sources at Old Whittington STF is listed in Table 5. According to the modelling, receptors 1 (River Rother /Whitting), 5 (sludge cake pad and barn), 6 (wind turbine asset and lagoons), 7 (ASP's and FSTs) are unlikely to be at risk.

Table 5. Source-pathway-receptor summary

Common Area / Tank	Surface Pathways	Receptors at risk
Multi-tank installation area 1: 2 no. drum thickener feed tanks, 2 no. dewatering feed tanks, 1 no. liquors return tank.	Overland run-off over mostly sealed surfaces to: • South of the site around the operator/ thickening building and WwTW inlet works. • Centre of the site surrounding the PSTs . • North of the site pooling within the easterly cake pad.	• Receptor 3 - Ground / groundwater - area around thickener, dewatering feed, and liquor return tanks. • Receptor 2 - Ground / groundwater – areas around inlet works, PSTs and storm tanks. • Receptor 8 - Ground /groundwater – area within and surrounding the legacy cake pad and lagoon.
Multi-tank installation area 2: 2 no. digester feed tanks, 2 no. digesters.	Overland run-off over sealed surfaces to: • Centre of the site surrounding the digester compound. • Centre of the site surrounding the PSTs.	• Receptor 4 - Ground / groundwater - areas within the digester site, digester feed tanks and sludge screen feed tank. • Receptor 2 - Ground / groundwater – areas around inlet works, PSTs and storm tanks.

Common Area / Tank	Surface Pathways	Receptors at risk
	• North of the site pooling within the easterly cake pad.	• Receptor 8 - Ground /groundwater – area within and surrounding the legacy cake pad and lagoon.
Sludge screen feed tank	Overland run-off over sealed surfaces to: • Centre of the site surrounding the digester compound. • Centre of the site surrounding the PSTs. • North of the site pooling within the easterly cake pad.	• Receptor 4 - Ground / groundwater - areas within the digester site, digester feed tanks and sludge screen feed tank. • Receptor 2 - Ground / groundwater – areas around inlet works, PSTs and storm tanks. • Receptor 8 - Ground /groundwater – area within and surrounding the legacy cake pad and lagoon.

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 solutions 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 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.
- **Permeable areas:** all permeable areas of land (as represented in Figure 18 and shown within Figure 27 as red areas) 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.
- **Slopes and gradients:** existing site formations, such as sloping access roads or graduated levels on existing asset flooring will be utilised as part of the bunding solution. However, this will be dependent on the spill depth, including surge freeboard allowance, is less than the total alleviation of the slope or gradient feature and is comprised of an impermeable surface.

YW have committed to install these containment solutions that complies with CIRIA C736, as discussed in the next section. The current preferred designs are 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 201 m^3, 1,760 m^3 and 2,530 m^3 containment within the site boundary. Additional volumes will be allowed for freeboard to handle surge (Appendix Table 1).

Table 6. Old Whittington 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
Sludge screen feed tank	Single tank area	-	183	183	201
			Largest 110% size		201
			Total volume	183	
			25% of total volume	46	
Drum thickener feed tanks	Multi-tank area 1	No	1,600	3,200	1,760
Dewatering feed tank no 1		No	623	623	685
Dewatering feed tank no 2			835	835	919
Liquors return tank		-	494	494	543
			Largest 110% size		1,760
			Total volume	5,152	
			25% of total volume	1,288	
Digester feed tanks	Multi-tank area 2	No	436	872	480
Digesters		No	2,300	4,600	2,530
			Largest 110% size		2,530
			Total volume	5,472	
			25% of total volume	1,368	

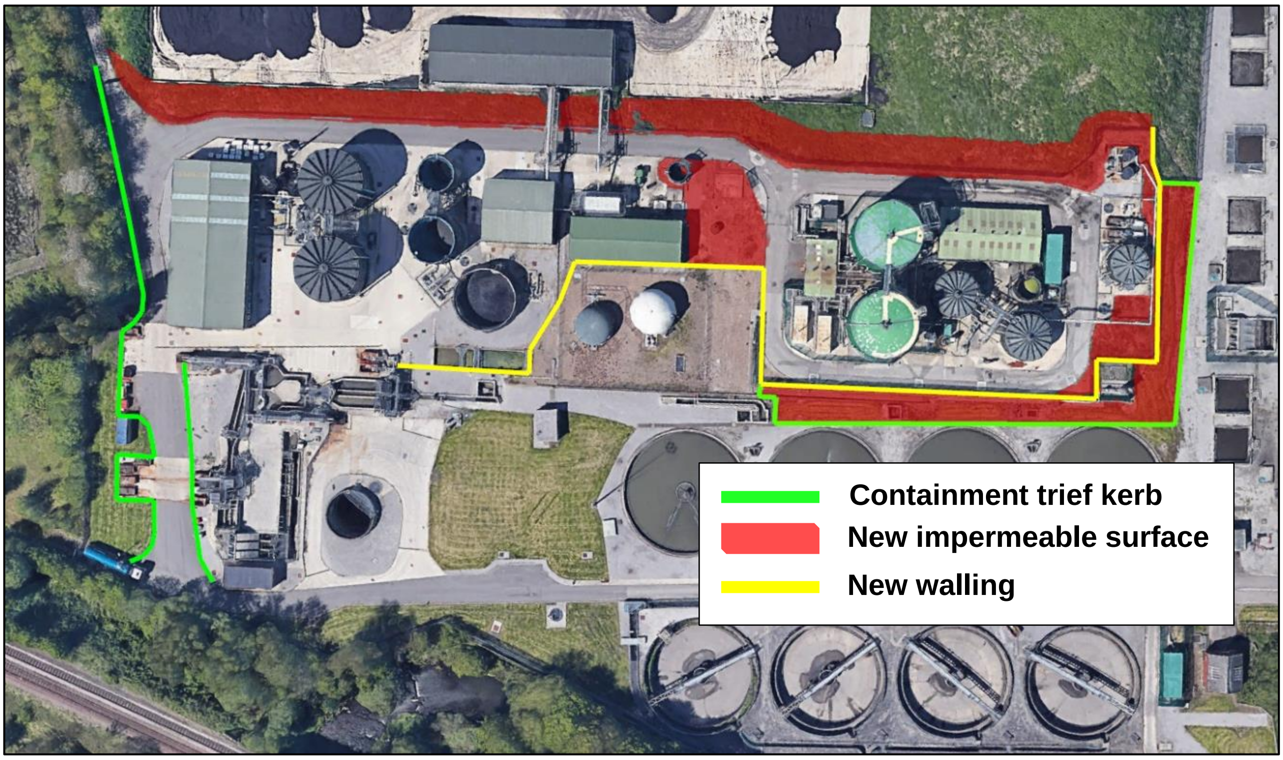


Figure 27. Bunding solution for Old Whittington.

3.9.1 Surge

The catastrophic collapse of a tank would lead to a rapid release of sludge which will then flow across the surrounding area. This is particularly true on steep gradients, which will encourage flow to travel further. As flow travels across flat ground, it will lose speed and the risk from surge will rapidly decrease.

Sludge released in this way will tend to flow over obstacles, but physics limits the height of barrier which it can pass. It is possible, but complex to calculate the extent of flow over obstacles using specialist software, but it would be prohibitively expensive to do this for every site where containment is being considered. The options considered within this document have been developed with surge protection as a key functional requirement and in the absence of detailed modelling, CIRIA C736 provides guidance on the additional height of bund wall (Figure 28), above settled spill level, that is required to ensure surge flow does not pass containment walls.

Table 4.7 Surge allowance (in the absence of detailed analysis)

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 28. Surge protection requirements. Taken from CIRIA C736 pg. 54.

Old Whittington is a large site, with significant distances between assets. Although the gradient of the site means sludge has the potential to travel a significant distance, the velocity of the flow is expected to decrease rapidly because of ground conditions. This study did not identify any areas where surge flow has the potential to lead to pollution of a watercourse. It is particularly important to note that the FSTs, which present the only potential direct route to a watercourse, are situated north of the site with a large distance from sludge sources and have walls of sufficient height that there is no realistic scenario in which a surge of sludge could enter them.

3.9.2 Jetting

YW recognises that surfaces which could receive a sludge spill because of tank failure will require an impermeable surface. This means tank leaks, including jetting, within the southern and northern tank areas will be contained. There is a risk at the outer edges of these compounds, where jetting could cause sludge to pass out of the walled bunded area. Within this context, the tanks that are of particular risk are shown within Figure 29 and Figure 31 , the blue circles show segments where jetting is a concern and mitigation is likely to be required where it overlaps the new bund walling.

The northern tanks show sludge import and rightmost digester tank jetting potential overlapping the new bund wall (yellow lines). The land adjacent to the new bund wall is sloped towards the WwTW, therefore, to contain the grassy sections will be made impermeable and will include containment trief kerbing around its perimeter for containment. Furthermore, there are two open underground chambers in the associated jetting area (as shown in Figure 30), these do not pose a risk to a sensitive receptor as these feed the primary settlement tanks, i.e. contained within the WwTW.

The leftmost digester, drum thickener feed tank no.2 and liquor return feed tank jetting potential overlaps new impermeable sections of land. No containment trief kerb or walling is required at the perimeter here due to the land bank being at sufficient height and downward slope, approx. 1m height at the tallest section.

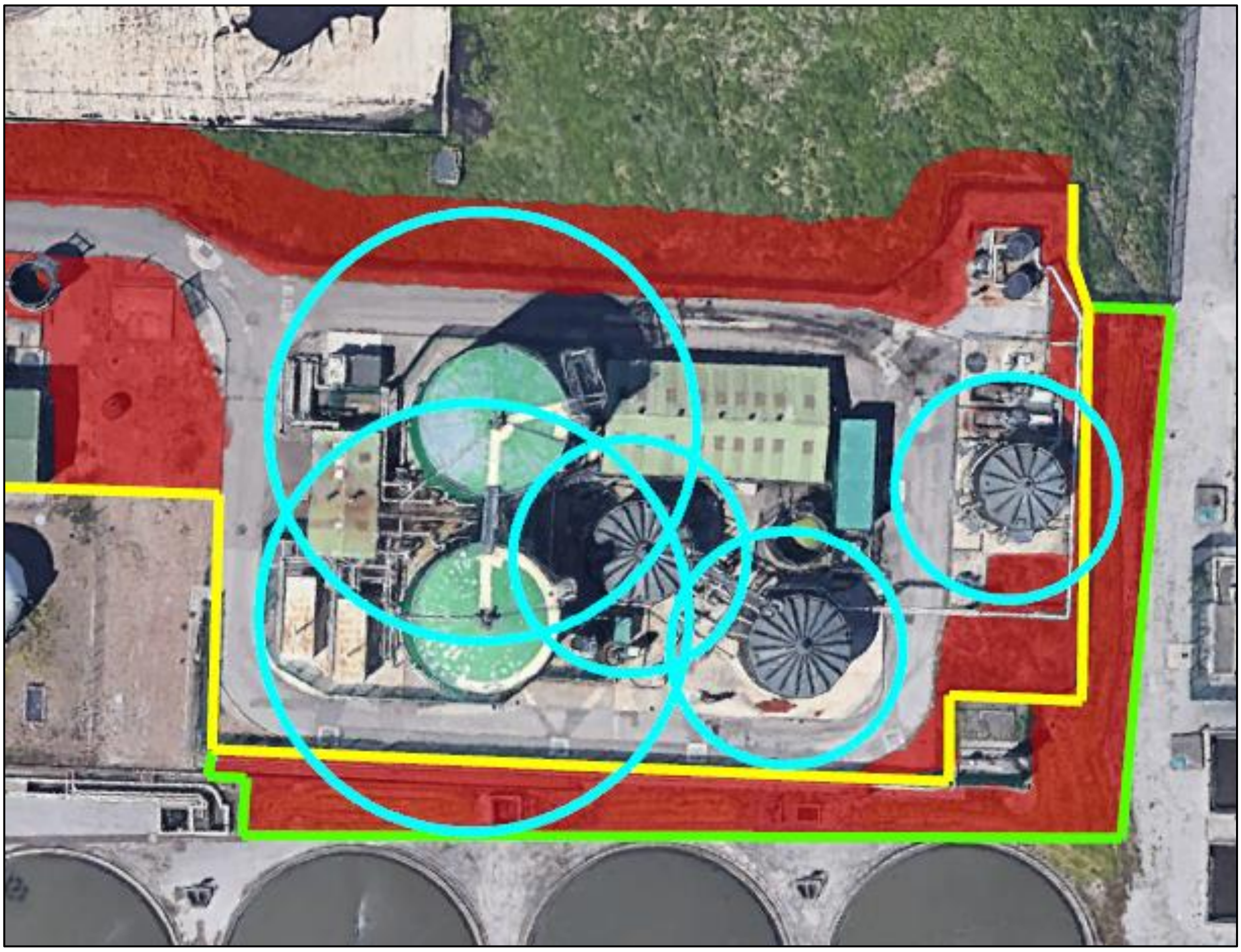


Figure 29. Northern tanks jetting potential.

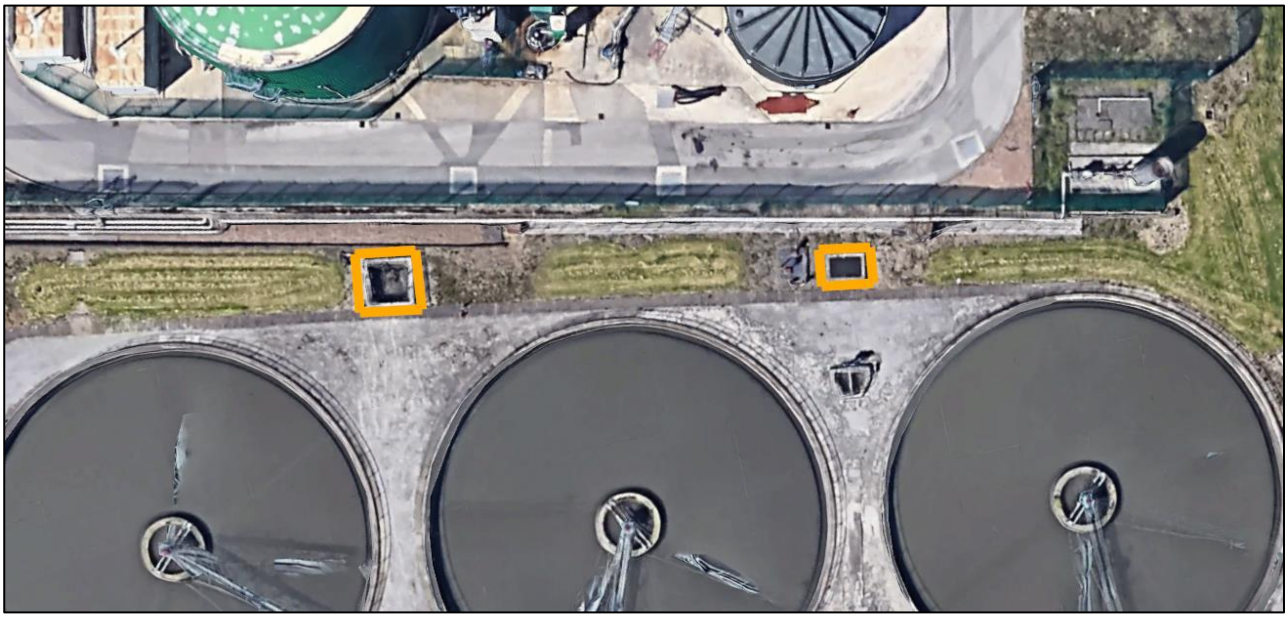


Figure 30. Primary distribution chambers, highlighted in orange.

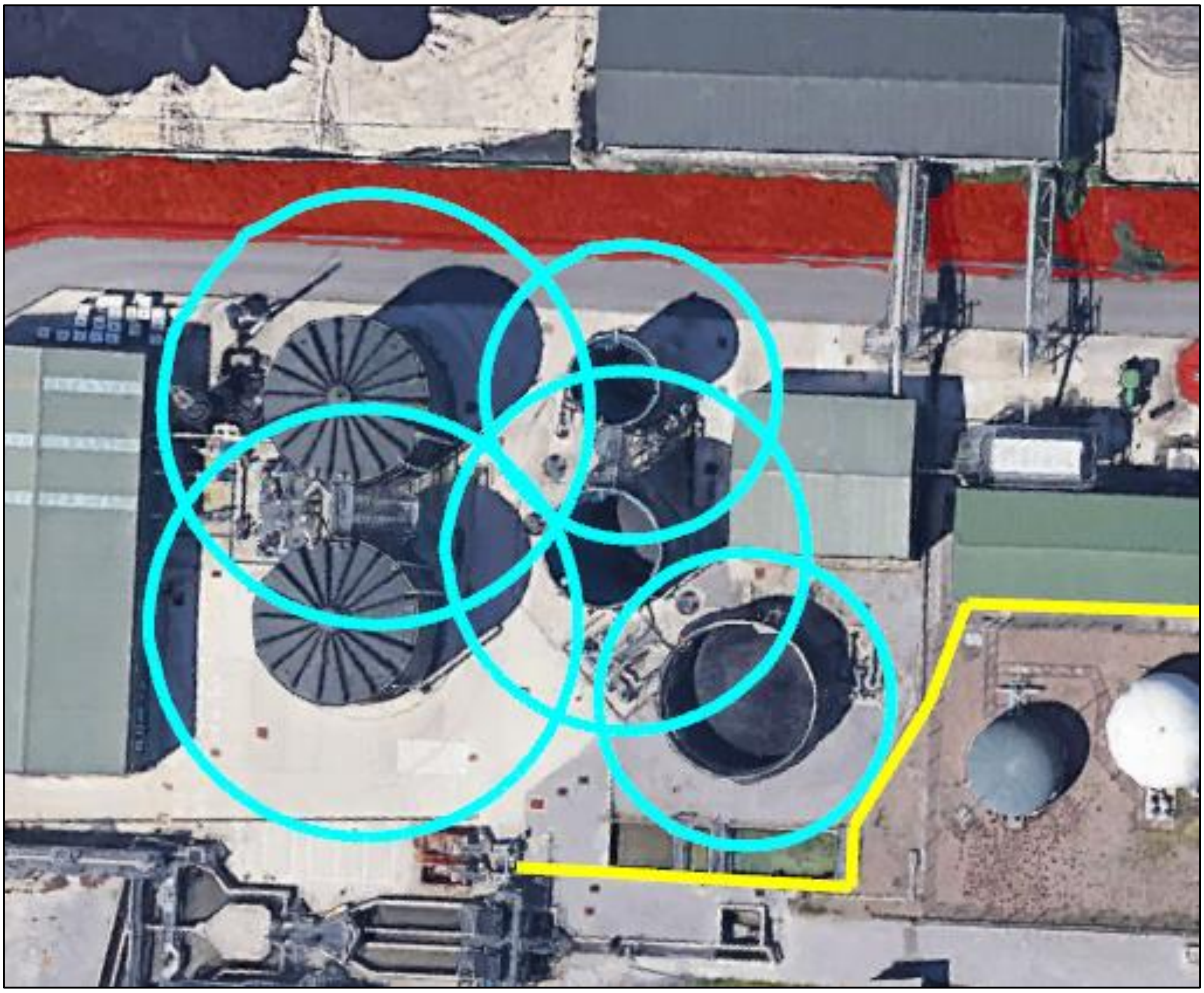


Figure 31. Southern tanks jetting potential.

3.10 CIRIA C736 compliance and construction

The secondary containment solution at Old Whittington 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 by the appointed construction company, who will use the bunding design described in this document as a starting point for development of detailed design. 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 Old Whittington 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 Old Whittington 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 Old Whittington 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 Old Whittington have been developed to contain sludge tanks in a bunded area within the site. The design was tested using Tuflow modelling and the design proposal and post mitigation spill modelling can be seen (appendix 6).

The secondary containment design will involve a containment wall with freeboard in areas that will act as a physical barrier, preventing any sludge from escaping the designated areas.

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 may not be achieved. In these instances, an alternative measure will be implemented to achieve an equivalent standard to provide the same level of environmental protection.

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.

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 of the design.

8 Appendices

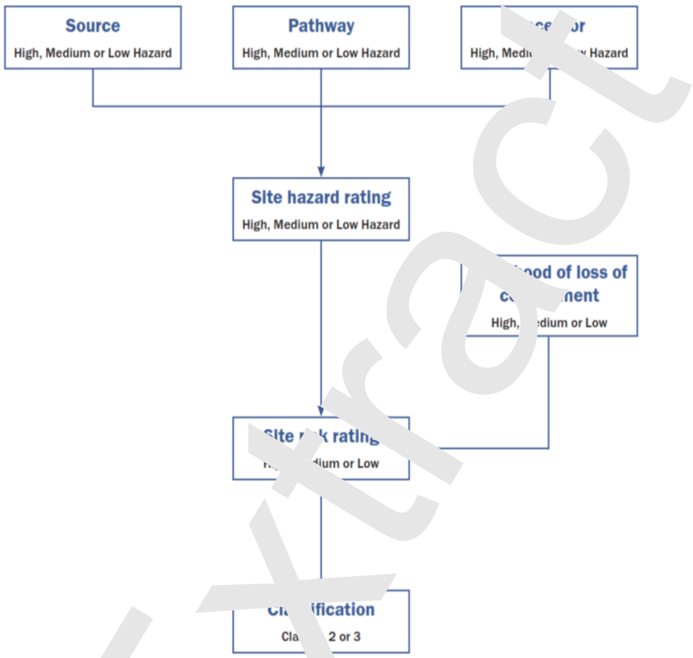
Appendix 1 - ADBA assessment tool

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

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

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

Appendix Figure 1. ADBA spreadsheet screenshot

Appendix 2 – CIRIA C736 compliant solution

Appendix Table 1. Old Whittington bunding solution design specification and dimensions.

Category	Criteria	Unit	Value
Design specification	CIRIA C736 spill volume [25/110%]	m^3	2,715
	Bund perimeter length	m	773
	Total containment surface area	m^2	8,557
	Maximum final spill depth	m	0.32
Bunding requirements	Concrete bund/ sleeping policemen height	m	0.57
	Total concrete wall length	m	326
Existing bunding	Existing concrete walling length	m	0
Build required	Required concrete walling/ sleeping policemen length	m	278
	New containment trief kerbing	m	357
	Impermeable surfacing area	m^2	3,665
	No. ramps		0

Appendix 3 – Structural integrity note for concrete tanks

Technical Note

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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.

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1

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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:

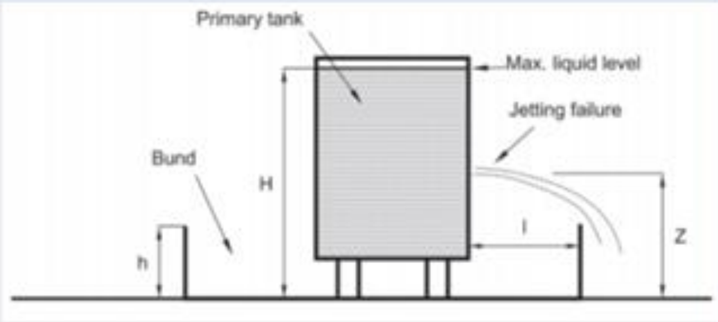
$$l^2 = [4(z-h)(H-z)]^{0.5}$$

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 post mitigation modelling

ARUP

Technical Note

Project title	Yorkshire Water IED
Job number	293261
File reference	IED_OWH-ARP-TRT-ZZ-TN-Z-0001
cc	
Prepared by	Iain Dillon
Date	01 December 2023
Subject	Old Whittington Flow Modelling - Supporting Note

Admiral House Rose Wharf 78 East Street Leeds LS9 8EE United Kingdom
t +44 113 242 8498 d +44 113 301 6040
arup.com

1. Introduction

A detailed assessment using Tuflow© modelling software has been undertaken to simulate potential spill scenarios at the Old Whittington 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 at Old Whittington. 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 screen feed tank
2	Drum thickener feed tank 1
3	Drum thickener feed tank 2
4	Digestor feed tank 1
5	Digestor feed tank 2
6	Anaerobic digester 1
7	Anaerobic digestor 2
8	Dewatering feed tank 1
9	Dewatering feed tank 2
10	Liquor return tank

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,

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Job number	293261
Date	27 November 2023

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.

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

The 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.

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 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.
- Where the maximum spill depths are greater than the final spill depths, a surge freeboard has been added to the minimum defence heights. Surge freeboard has been based on the Ciria C736 guidance, see (below).

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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 a risk of surge effects has been identified but freeboard has been excluded, due to site constraints, these areas have been assessed in Section 5 of this note.

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

5. Areas excluding a surge freeboard

This section highlights the areas where surge freeboard has been excluded and provides justification for the approach taken.

5.1 Southern Boundary

The southern boundary of the site (Figure 2) does not include a freeboard allowance as Tuflow modelling did not identify a risk of the effects of surge in this location.

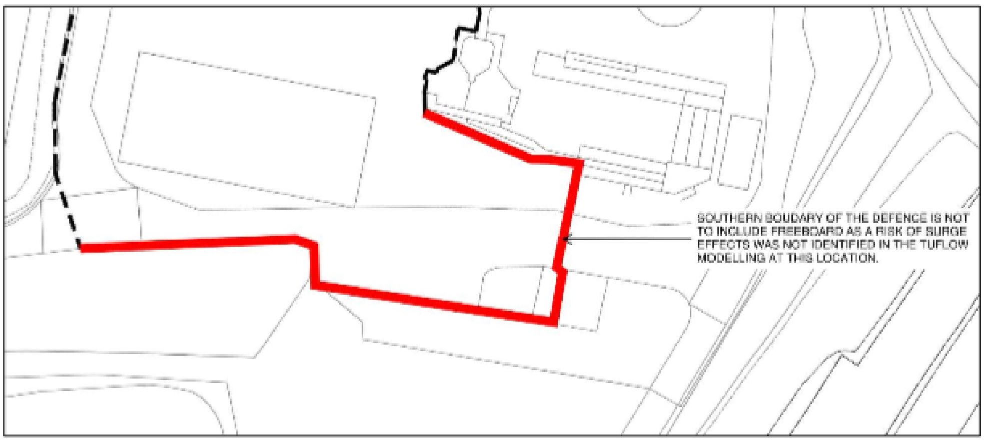

Figure 2 Southern Defence boundary (freeboard excluded along red alignment)

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5.2 Inlet works

A small section of the existing inlet works wall will not be raised due to site constraints. This means that for an 8m section the wall height will remain at 64.78mAOD (30mm above final spill depths), and defence heights do not include a freeboard allowance for surge.

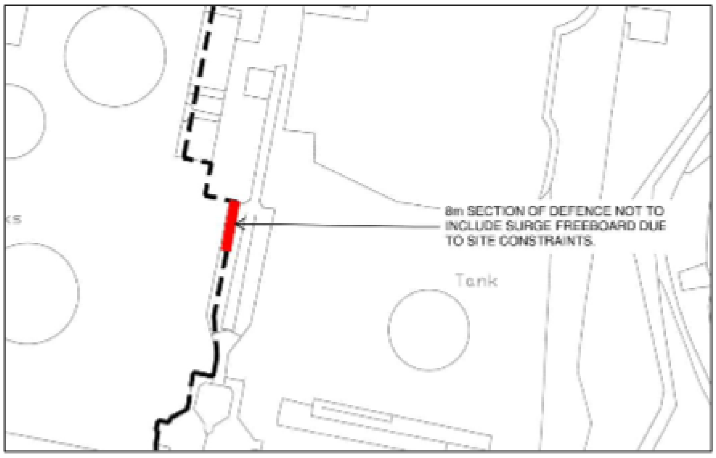

Figure 3 Inlet Works (freeboard excluded along red alignment)

This 8m section of wall is where the inlet works screens, grit conveyors and inspection bridges are located (Figure 4). The presence of this infrastructure prevents the existing wall of the inlet works to be raised for this section.

Although the existing wall height at the inlet works is sufficient for the final spill depths, for all tank spill scenarios, there will be a residual risk of containment entering the inlet works. This risk would only apply if a tank failure was immediate and significant enough to result in a wave effect to this area. Any containment that breaches this section of wall due to surge effects would enter the head of the sewage works and would undergo the full treatment processes of the works, prior to leaving the site. Any spill would not interface with any sensitive receptors at this location and therefore this residual risk is deemed acceptable for YW Ops teams in this instance.

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Date 27 November 2023

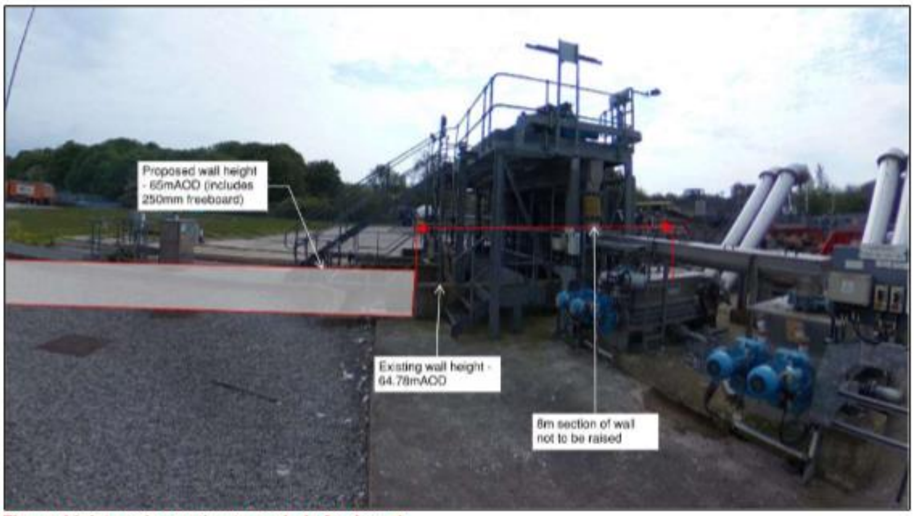

Figure 4 Inlet works section to exclude freeboard

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Appendix A – Tuflow Modelling Results

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Job number	293261
Date	27 November 2023

Maximum Spill Depths

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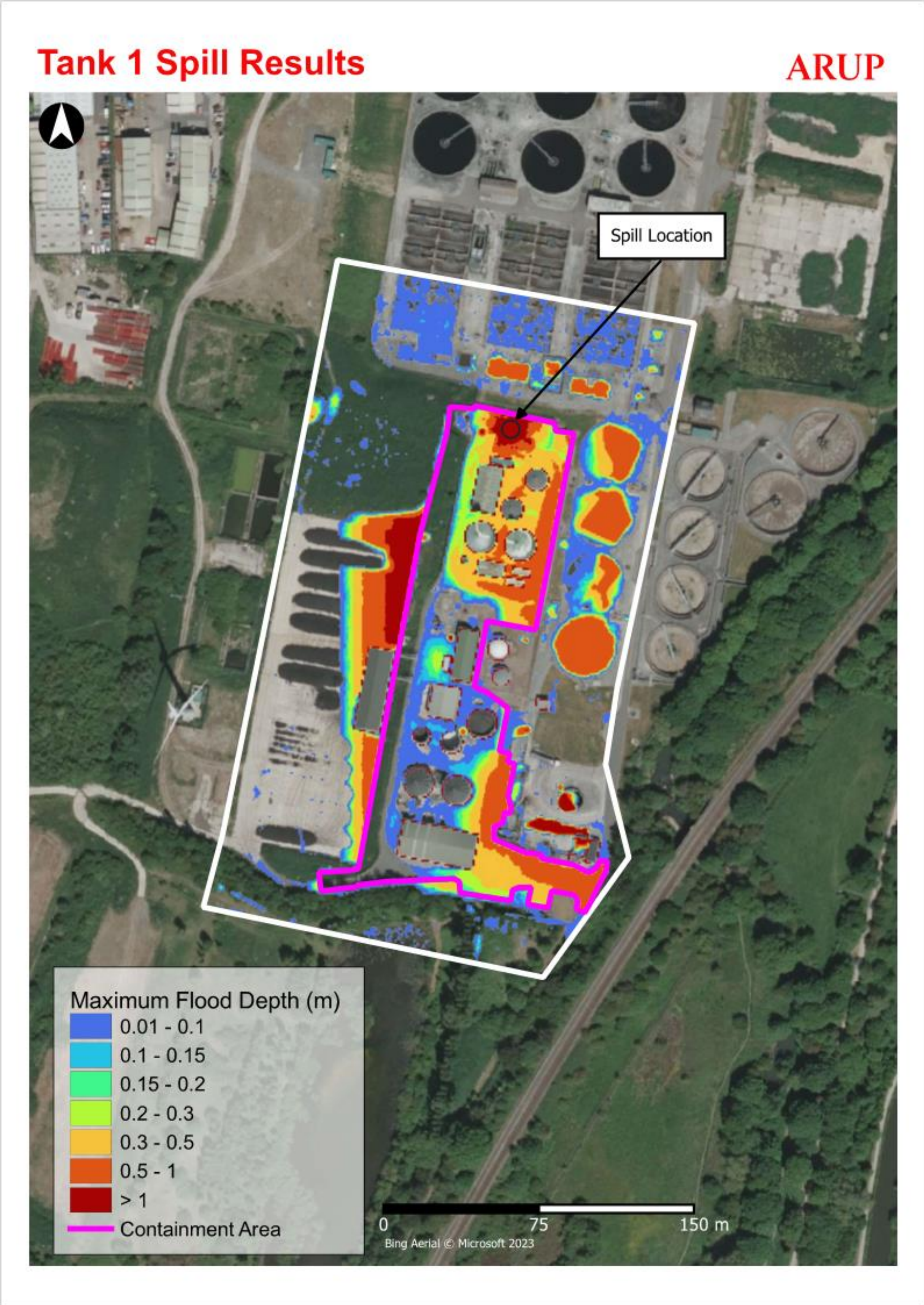
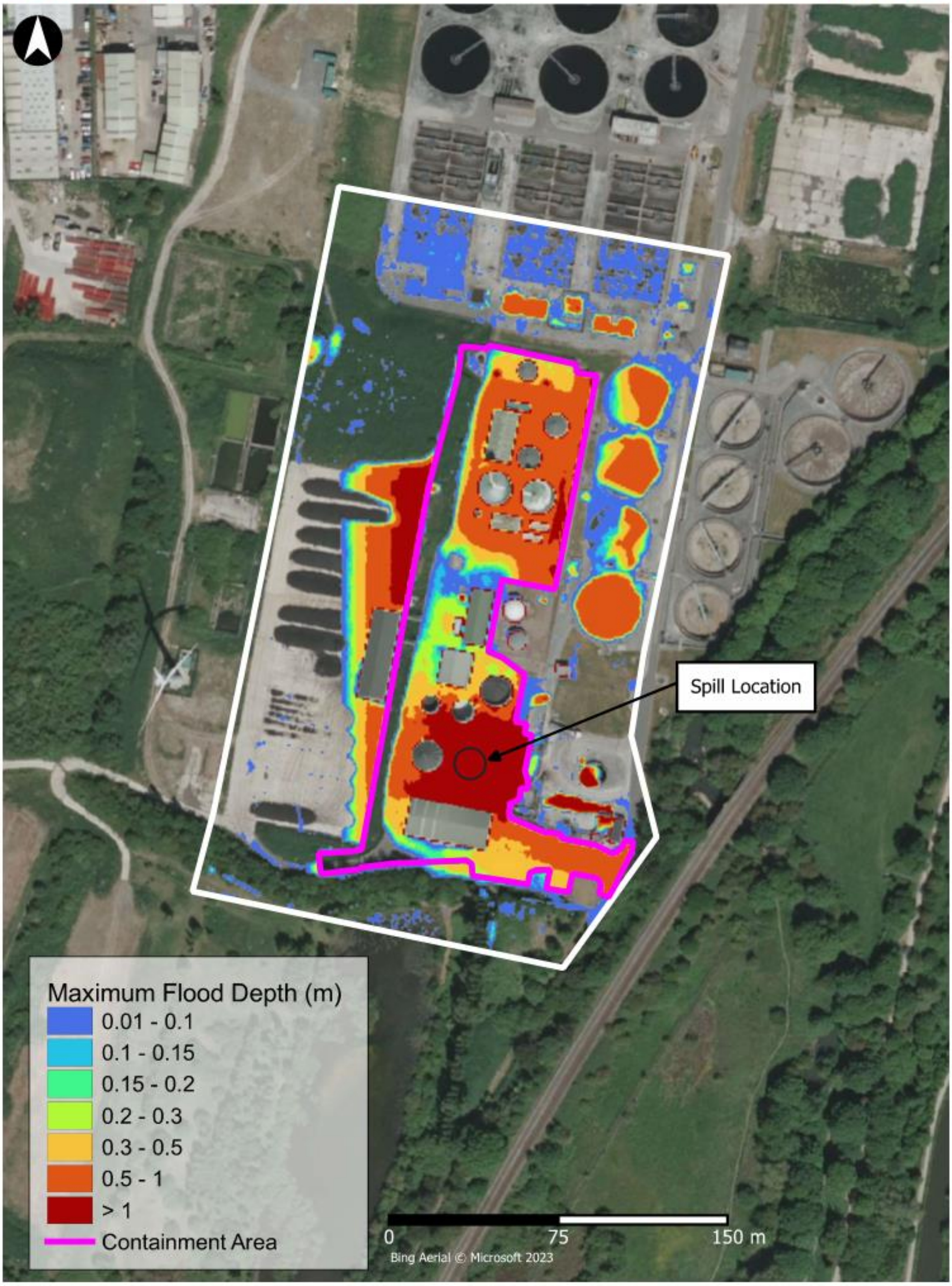
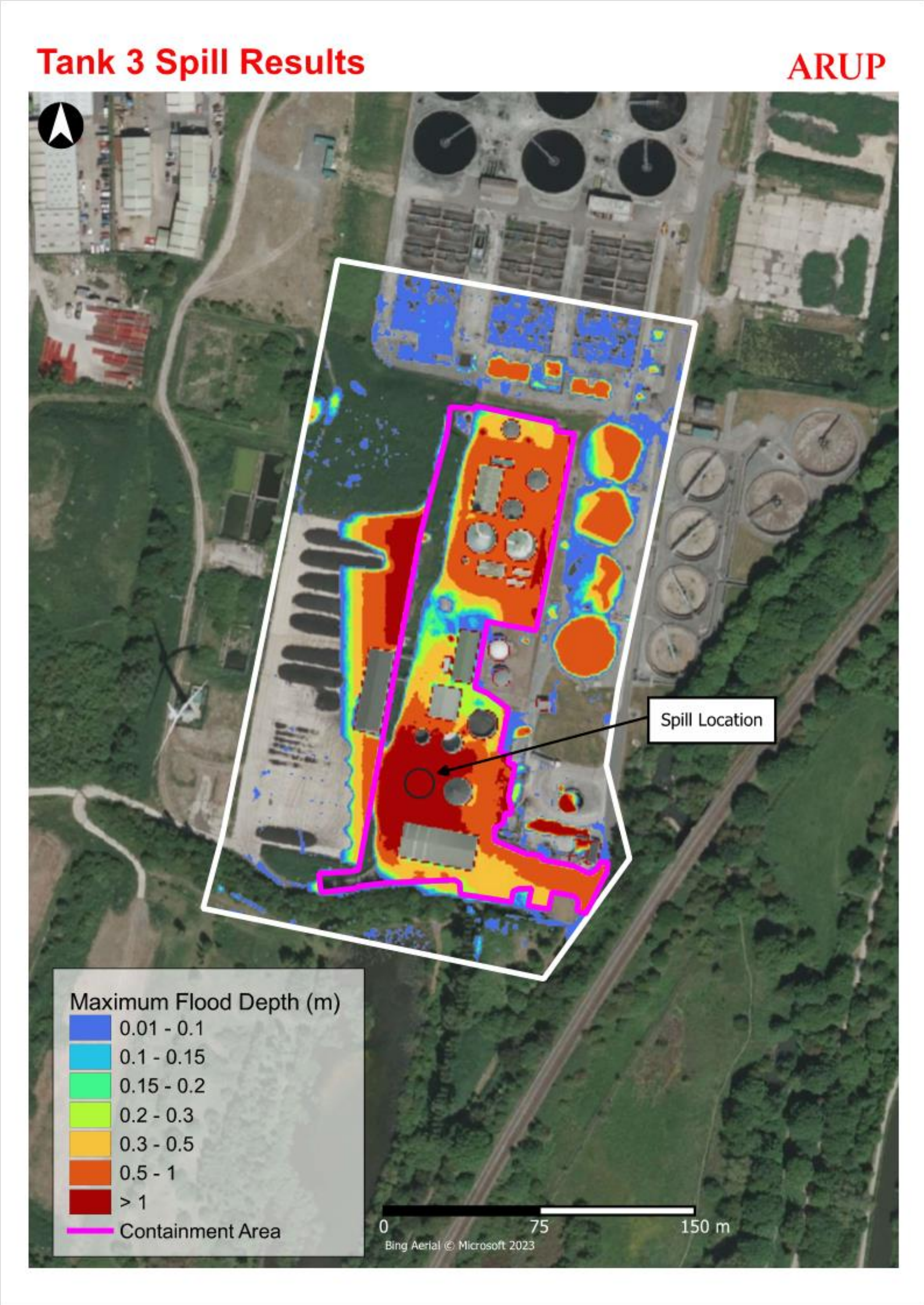
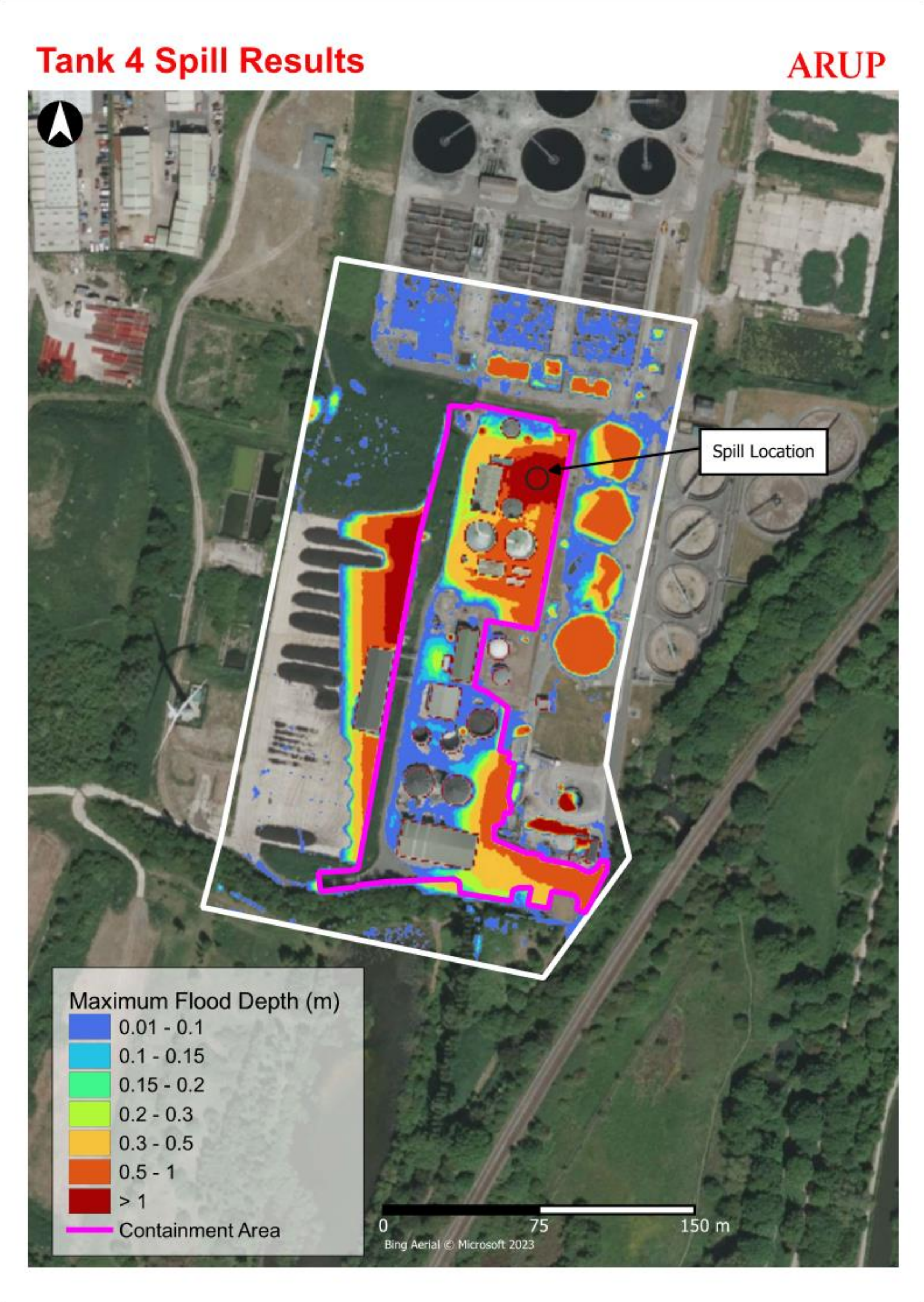

Tank 1 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

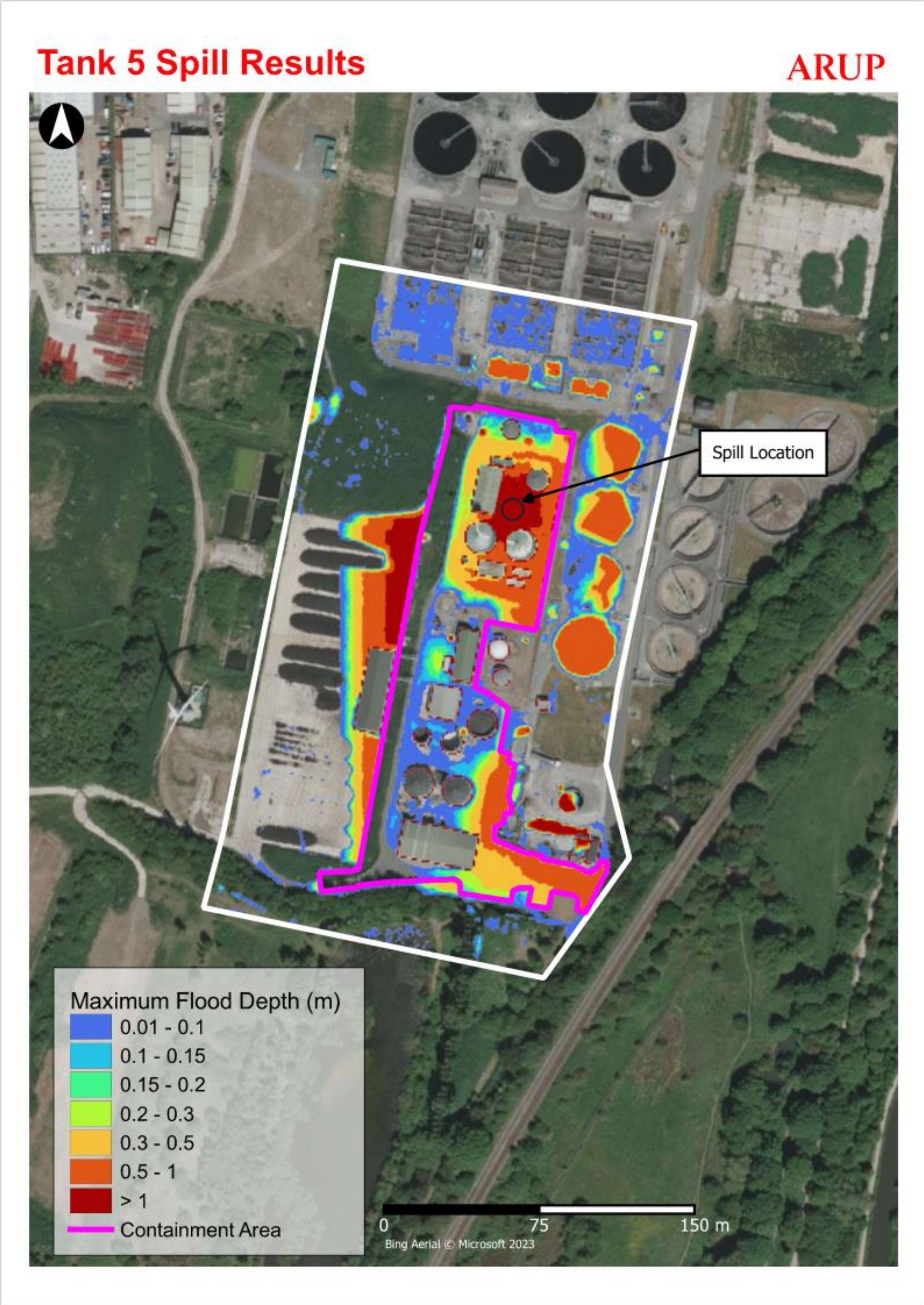
Tank 2 Spill Results

ARUP




Tank 3 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 4 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 5 Spill Results
ARUP
Spill Location
Maximum Flood Depth (m)
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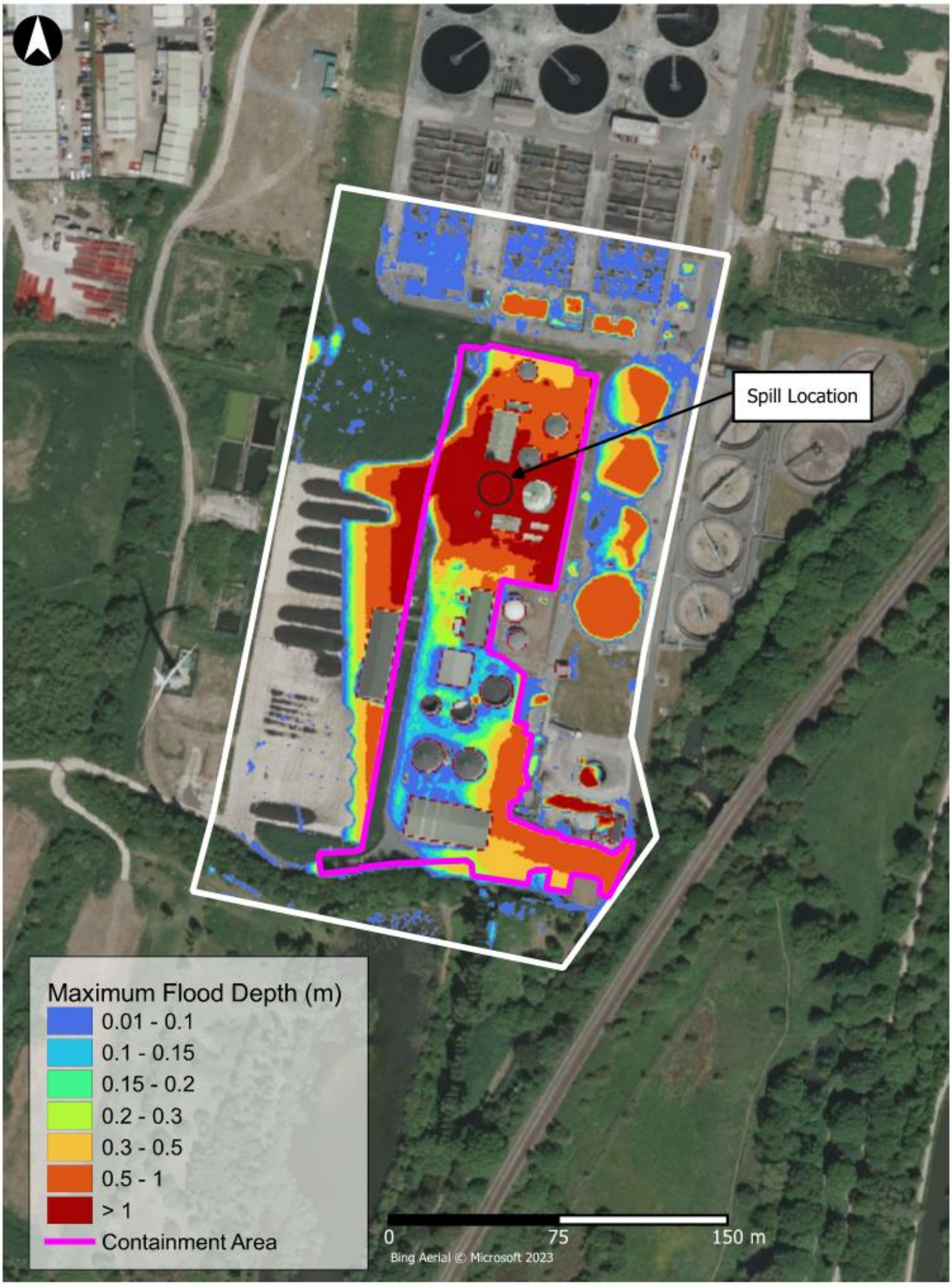
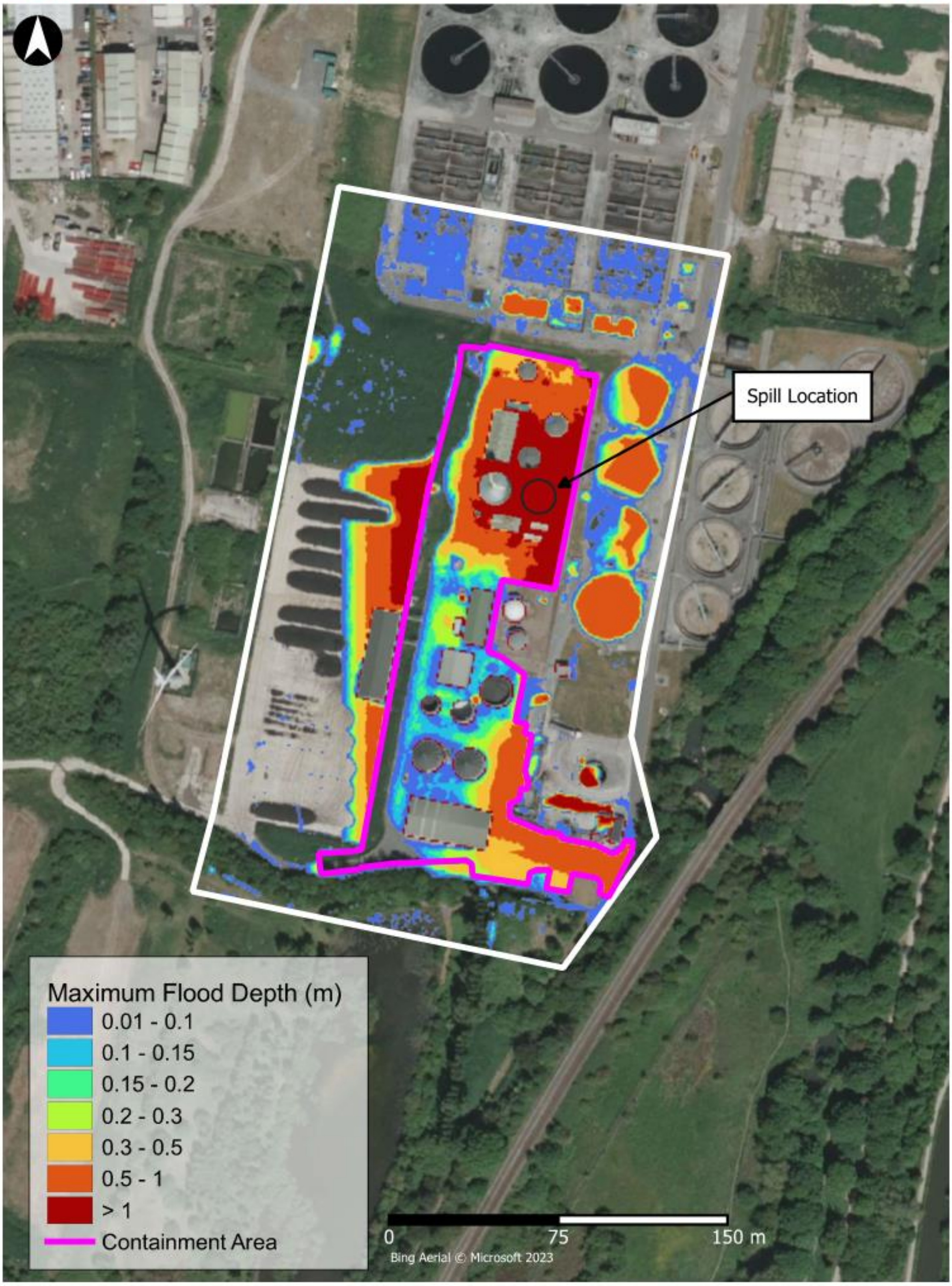
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

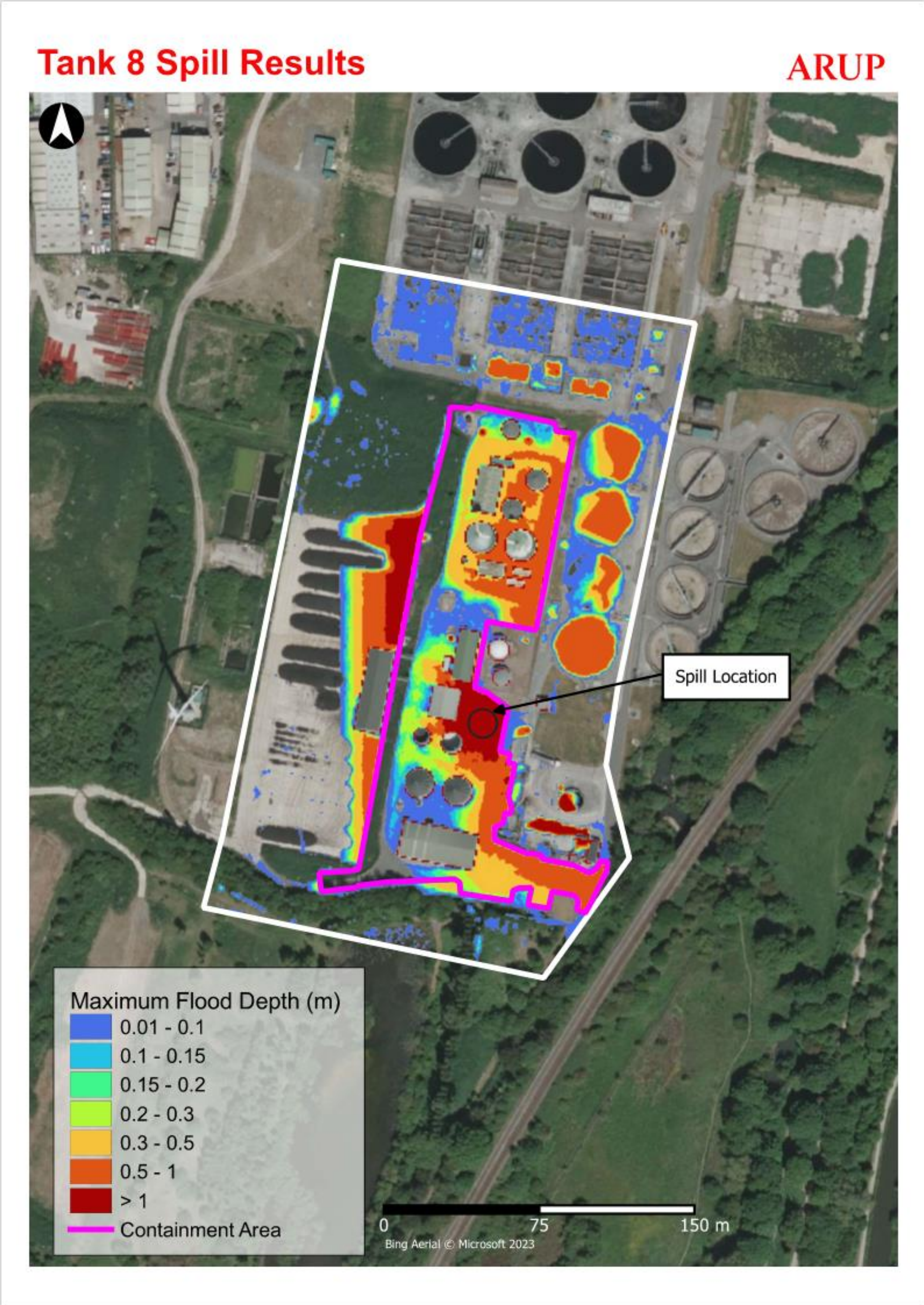
Tank 6 Spill Results



Tank 7 Spill Results

ARUP




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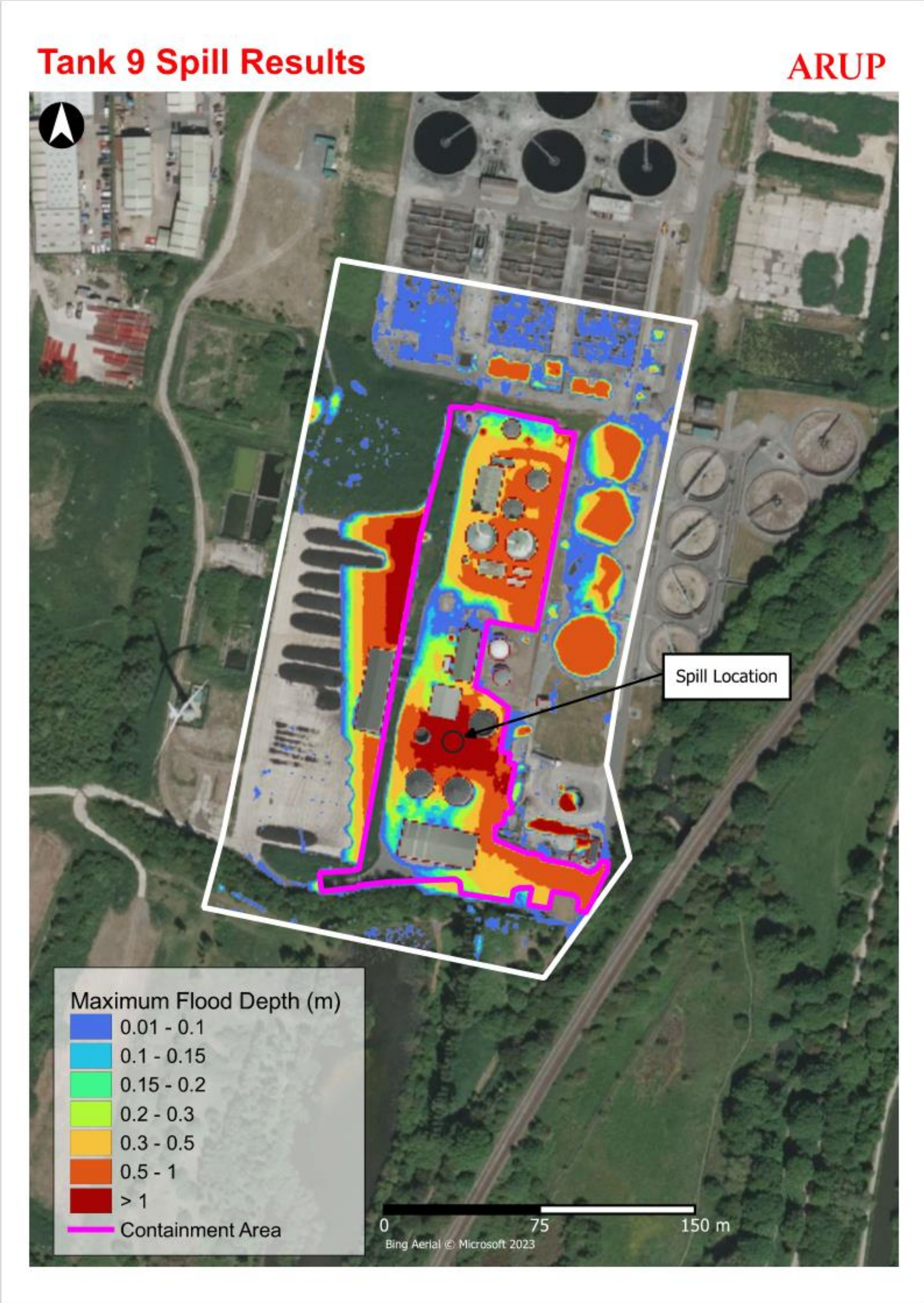
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


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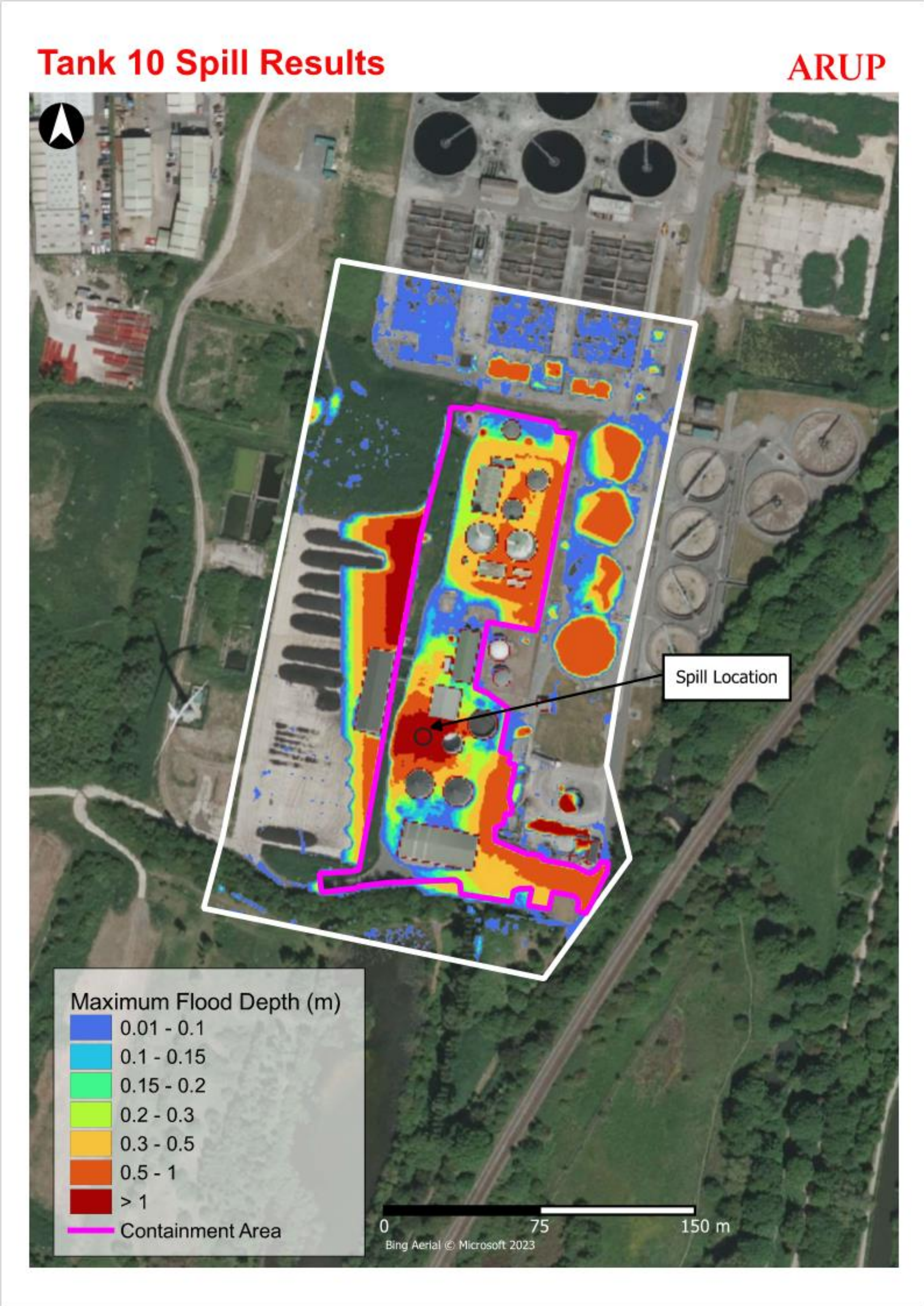
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 10 Spill Results
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Spill Location
Maximum Flood Depth (m)
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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

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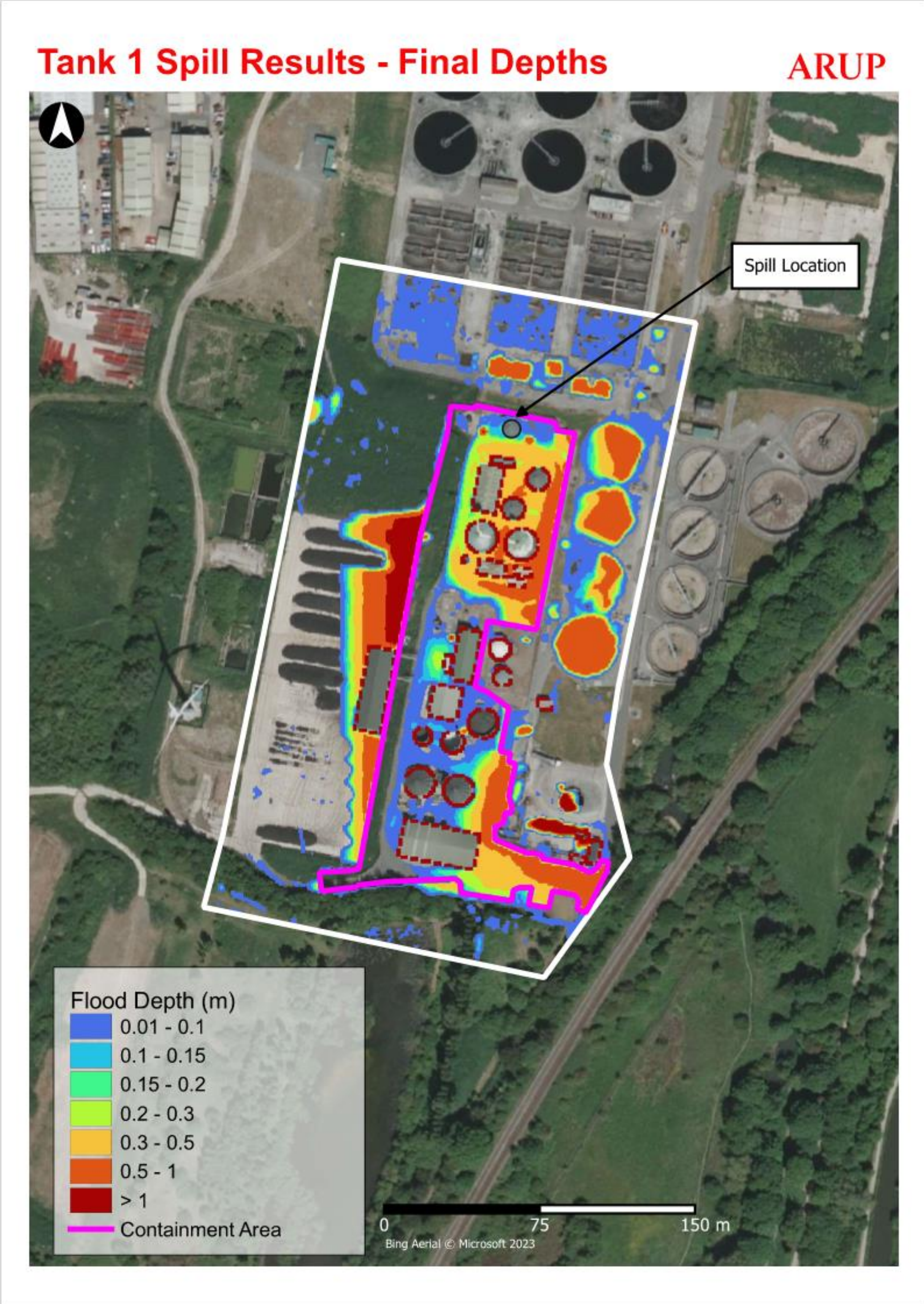
Final Spill Depths


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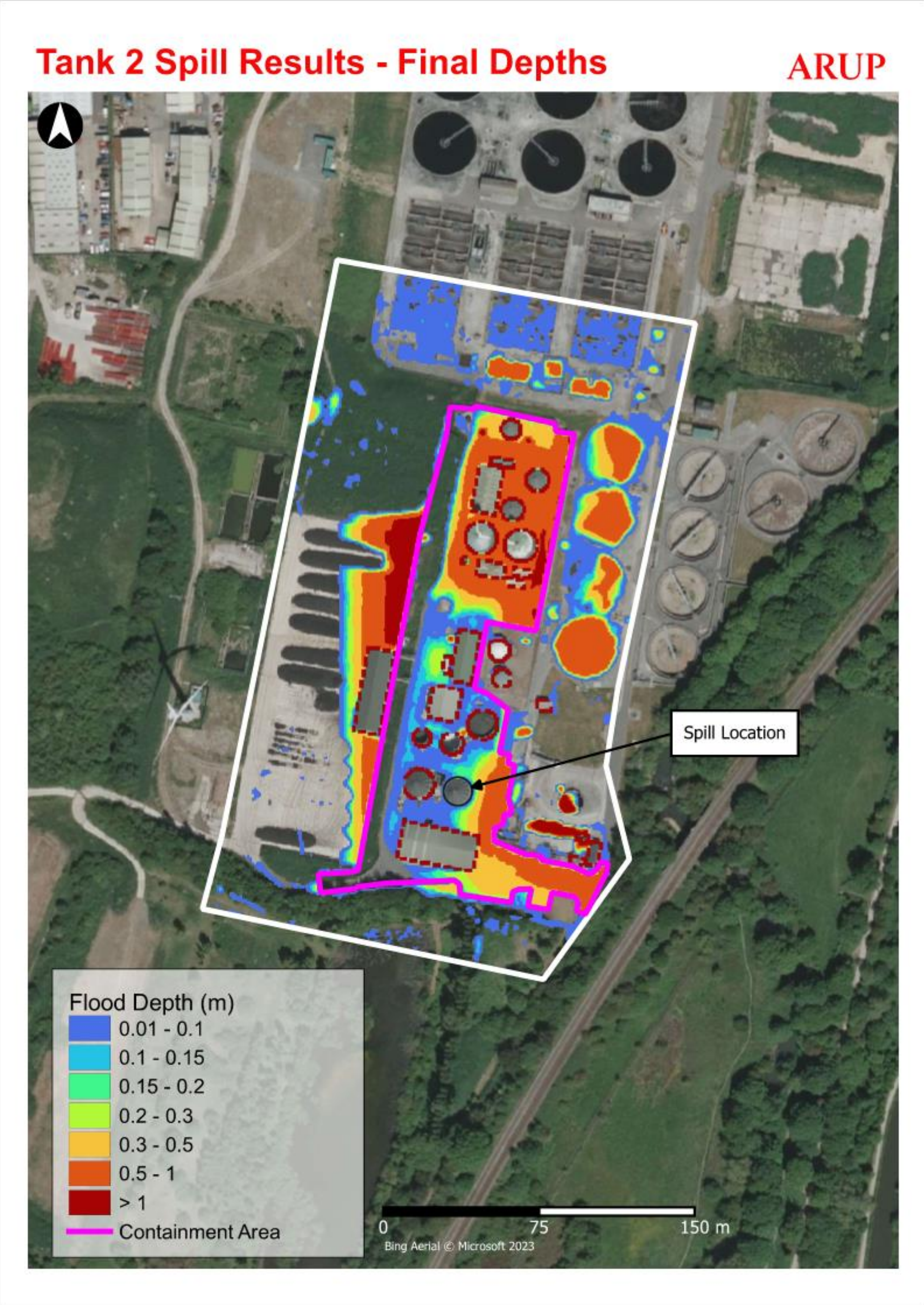
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


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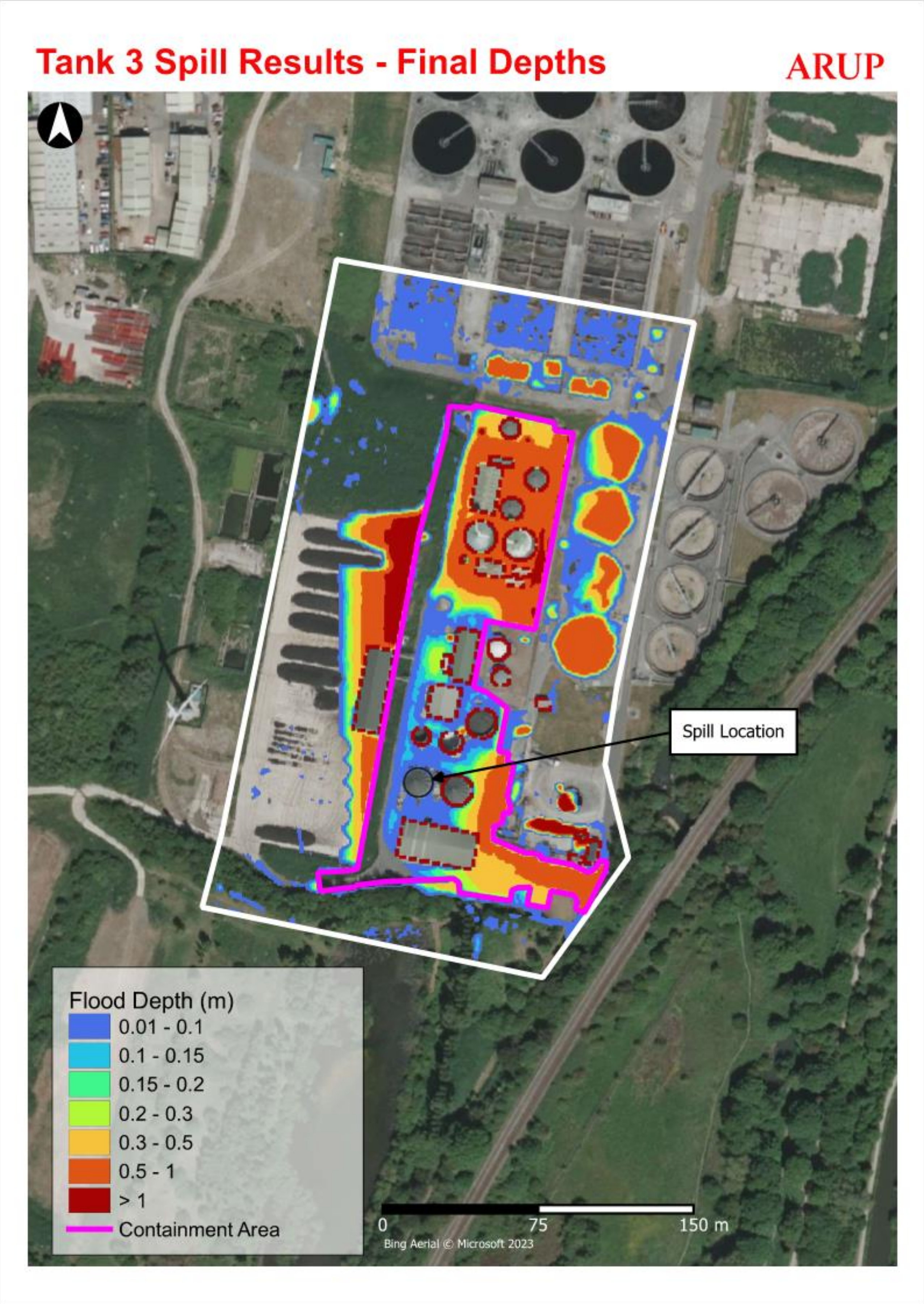
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


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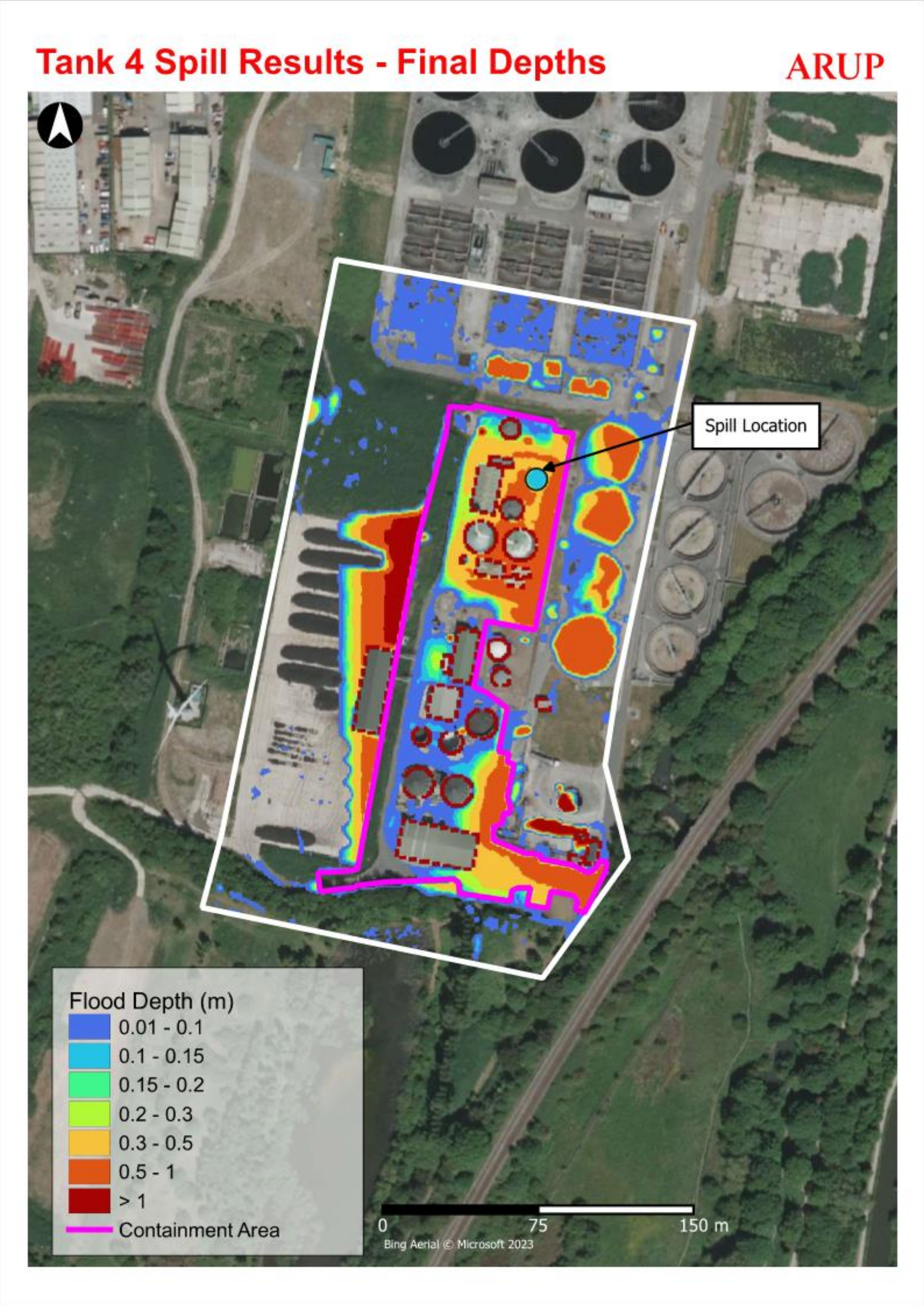
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 4 Spill Results - Final Depths
ARUP
Spill Location
Flood Depth (m)
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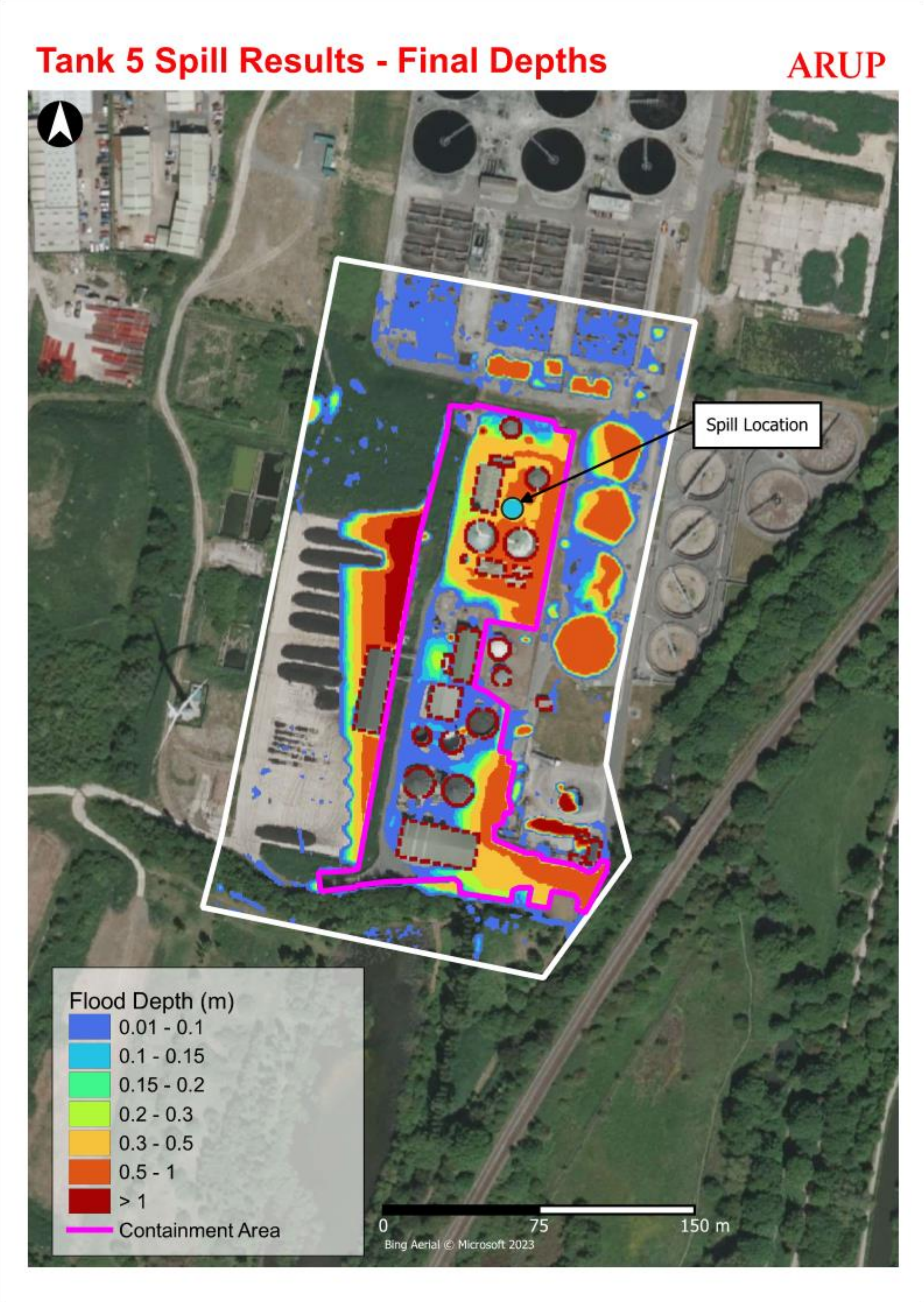
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


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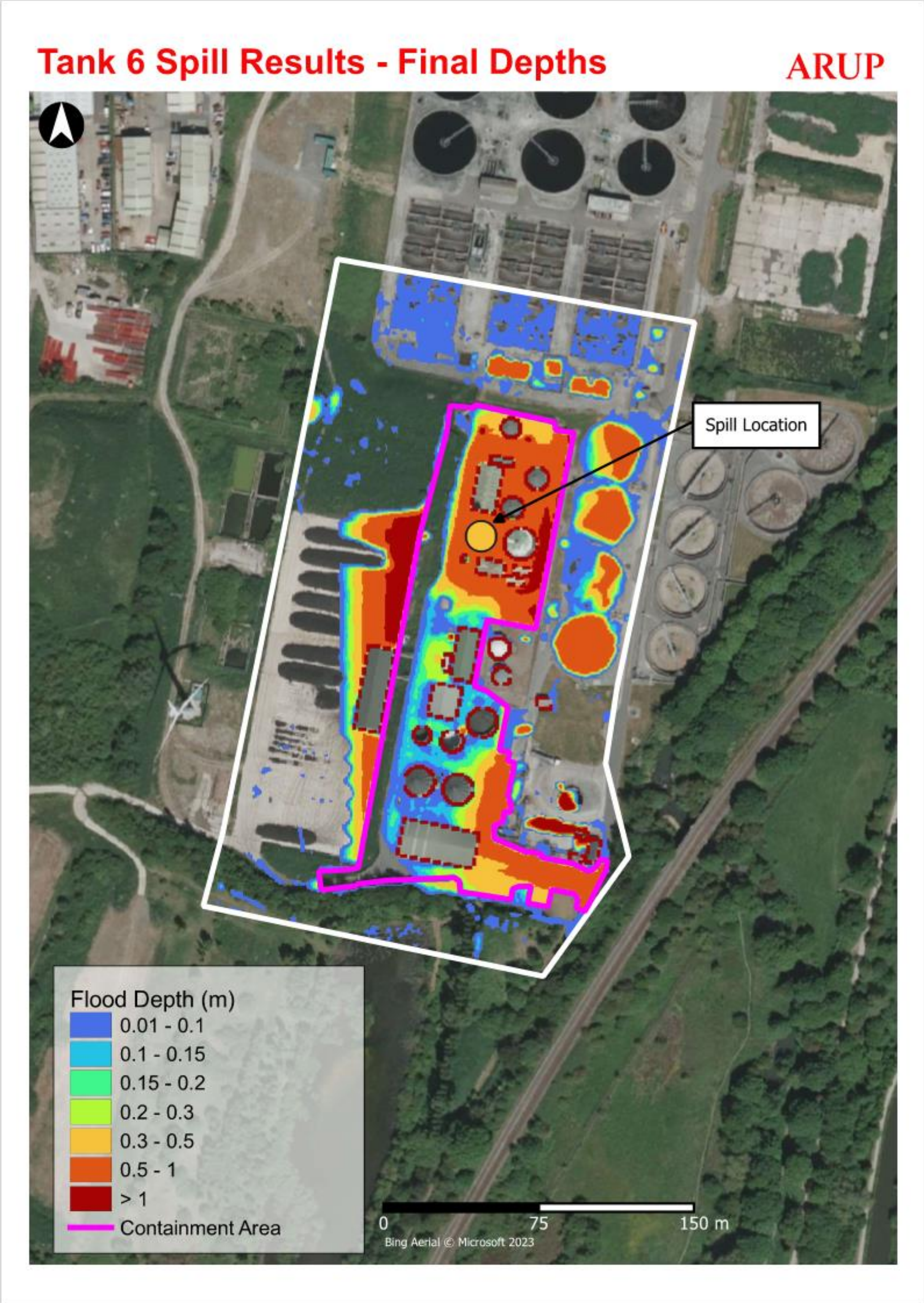
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


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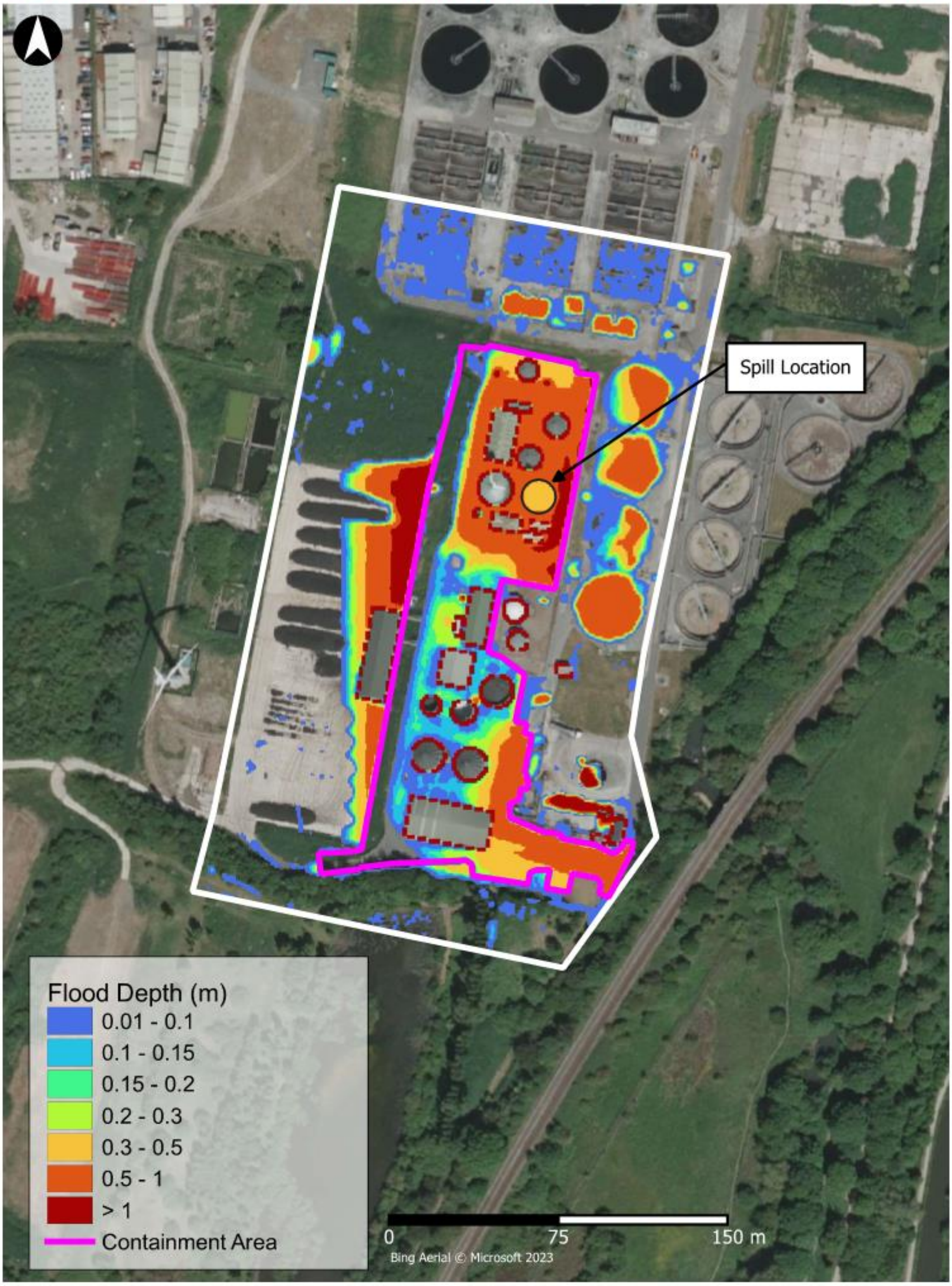
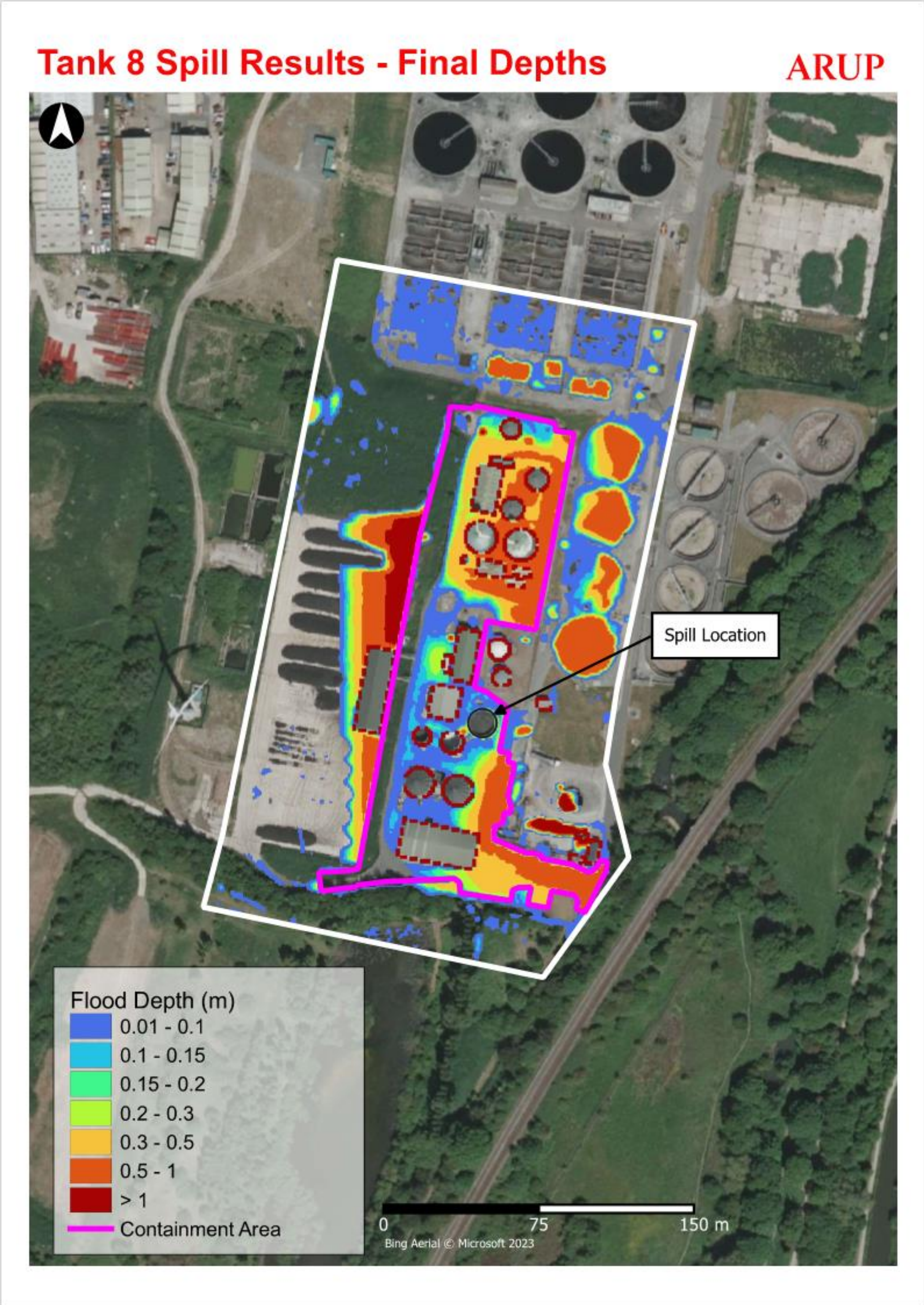
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023

Tank 7 Spill Results - Final Depths




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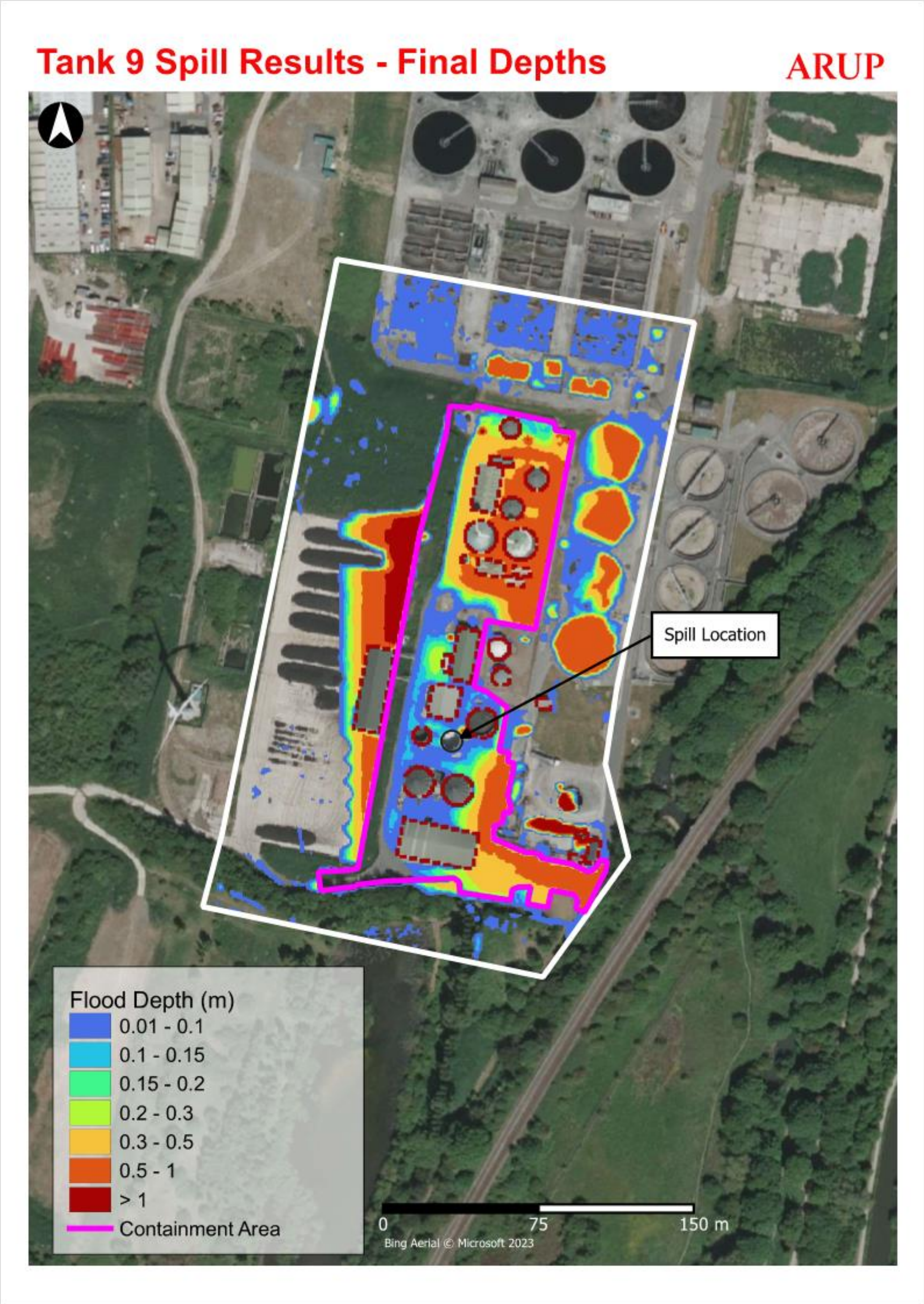
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


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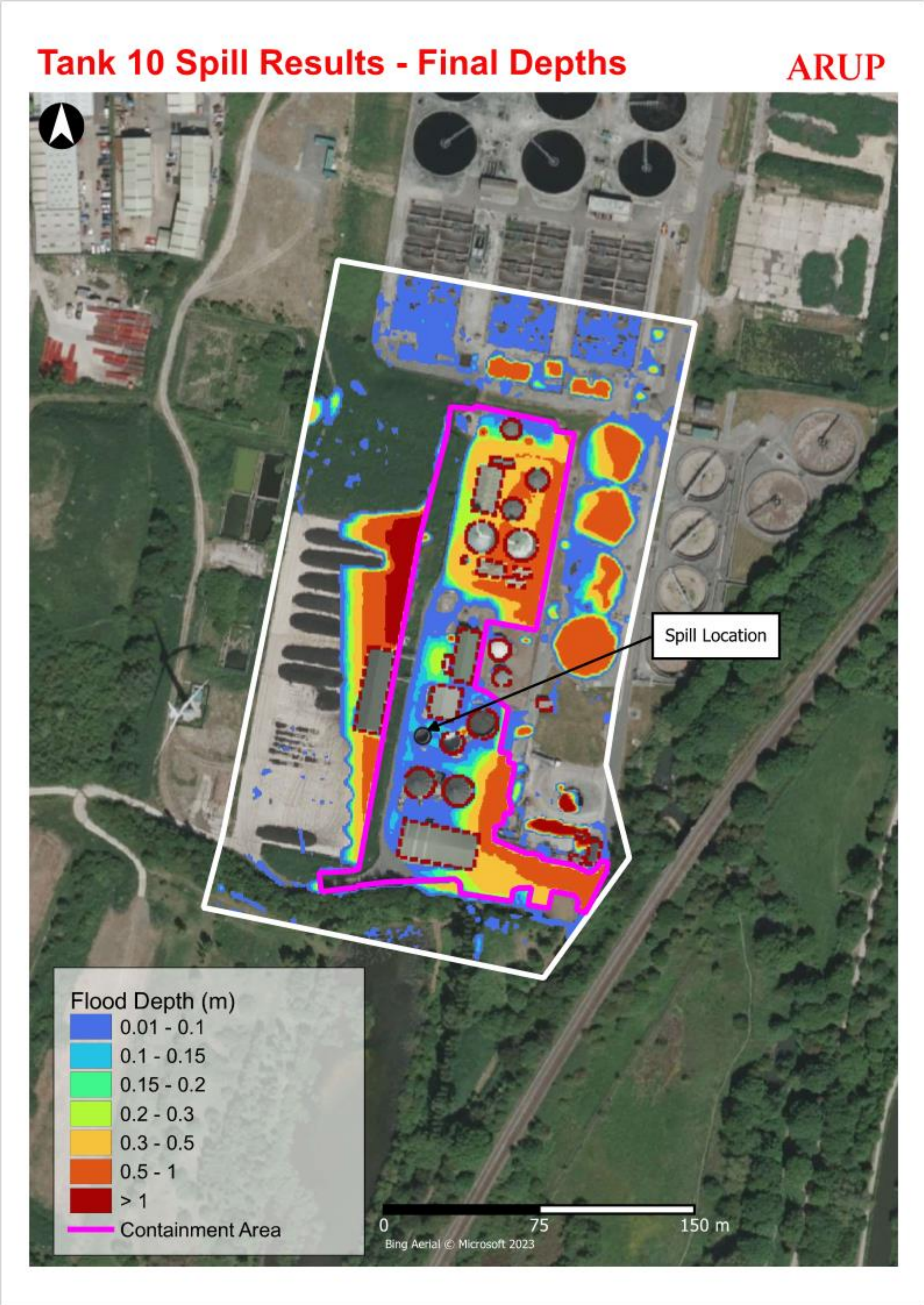
Spill Location
Flood Depth (m)
0.01 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1
> 1
Containment Area
0
75
150 m
Bing Aerial © Microsoft 2023


Tank 10 Spill Results - Final Depths
ARUP
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

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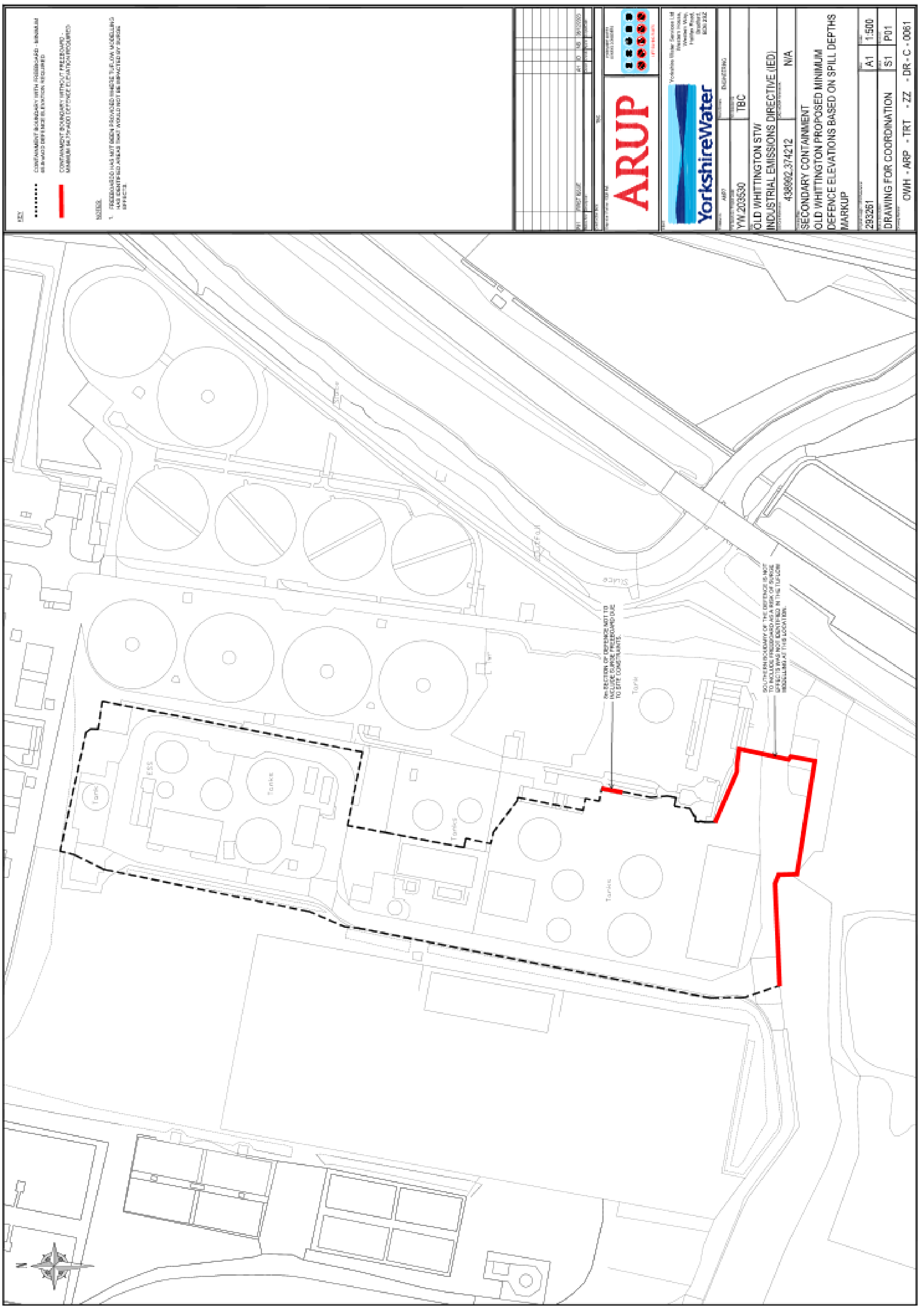
Job number	293261
Date	27 November 2023

Appendix B – Defence Design Markup based on Tuflow Modelling


ARUP
YorkshireWater
YW 203630
TBC
OLD WHITTINGTON STW
INDUSTRIAL EMISSIONS DIRECTIVE (IED)
438692,374212
N/A
SECONDARY CONTAINMENT
OLD WHITTINGTON PROPOSED MINIMUM
DEFENCE ELEVATIONS BASED ON SPILL DEPTHS
MARKUP
293261
A1 1:500
DRAWING FOR COORDINATION
S1 P01
OWH - ARP - TRT - ZZ - DR - C - 0061
Tanks