BRITISH SUGAR, YORK

Updated Hydrogeological Risk Assessment

10024487-AUK-XX-XX-RP-GE-0020-01-Updated Hydrogeological Risk Assessment

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Updated Hydrogeological Risk Assessment

British Sugar, York

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1 Introduction

Arcadis (UK) Limited (Arcadis) was commissioned by British Sugar to update the Hydrogeological Risk Assessment (HRA) of the Former British Sugar Factory, Millfield Lane, York, YO26 6AY (the Site).

The Site is a demolished sugar refinery, which imported and washed sugar beet, which was then refined into granulated sugar. The Site started activity in the 1920's and ceased activity in 2008, with the northern portion of the Site subject to an Environmental Permit (EP). It is understood that British Sugar intends to divest the Site for the development of residential dwellings and that this HRA has been undertaken as part of a larger scheme of works.

Two Detailed Quantitative Risk Assessments (DQRA) have previously been completed for the Site with the most recent, completed by URS in 2015 incorporating a HRA, included within the Remediation and Reclamation Strategy for the Site. The Remediation and Reclamation Strategy was submitted in support of a planning application for the construction of a development platform, engineering works and remediation and reclamation of the Site (Application reference 14/02798/FULM) and following comment from the Environment Agency's (EA) contaminated land team, planning permission was approved by the City of York Council.

While planning permission has been approved subject to conditions, an update to the HRA has been commissioned to support the EP surrender liaison with the EA and to additionally fulfil the EP requirement to update the HRA for the Site every 6 years.

A plan showing the Site location is presented as Figure 1, while the current Site layout and exploratory hole location plan is presented as Figure 2, including the EP boundary.

The work was conducted in line with the scope of works outlined within the Memo 'British Sugar York – DQRA' (dated 29 August 2019, Arcadis ref: 10024487 CV7) and with reference to English legislation and regulatory guidance pertinent at the time of reporting.

1.1 Background Information

Item	Comment
Site status	Demolished sugar factory
Intended end use	Residential
OS National Grid Coordinates	457483, 4453135 (approximate)
Elevation	14 to 29 metres Above Ordnance Datum (m AOD)

The updated HRA has been undertaken following on from the findings of the previous phases of works. As such, this report should be read in conjunction with the previous environmental reports as the information presented provides the basis for the conceptual understanding of the Site. A large number of reports have been produced for the Site; the reports most pertinent to this updated HRA are detailed in Section 2.

1.2 Aims & Objectives

The overall aim of the works is to update the existing HRA to support liaison with the EA regarding permit surrender. The specific objective of the updated HRA was to:

- Incorporate additional Site data collected since the previous HRA; and
- Derive risk-based Site-specific assessment criteria (SSAC) for contaminants of concern (CoC) in groundwater for comparison with concentrations of contaminants measured in groundwater.

The update is also in line with the EP (EPR/QP3593NF) requirement to update the HRA for the Site every 6 years.

1.3 Scope of Work

The scope of work was developed with reference to the Department of the Environment Food and Rural Affairs (DEFRA) and the EA's Land Contamination: Risk Management, June 2019 (LC:RM).

1.4 Reliance

This report is only valid when read in its entirety. Any information or advice included in this report should not be relied on unless considered in the context of the whole report. Reference should be made to the notes on study limitations at the end of this report.

There are neither third party rights nor benefits conferred under this report. Use of this report is strictly limited to British Sugar and its direct and indirect subsidiaries, which are the sole parties to whom Arcadis intends to confer any rights. Any reliance on the contents of this report by any other party is the sole responsibility of that party.

1.5 Limitations

The following scenarios are not considered in the derivation of SSAC:

- Risks to Construction Workers – any redevelopment and construction work should be conducted in full recognition of HS(G)66.
- Nuisance health effects – the Statutory Nuisance Act considers olfactory impacts from odours and allows comparison of enclosed space air concentrations with odour threshold concentrations.
- Risk to human health from concentrations of CoC in soil and groundwater. A Remediation and Reclamation Strategy (URS, 2015) for the Site which considered potential risks to human health from concentrations CoC in the subsurface was submitted and approved by the City of York Council as part of Planning Application 14/02798/FULM.

Arcadis' liability, pursuant to the terms of the appointment of Arcadis by British Sugar, is strictly limited to the work undertaken and the matters contained and specifically referred to in this report.

A copy of Arcadis' study limitations are included in Appendix A.

2 Summary of Pertinent Information

2.1 Overview of Previous Reports

A number of previous environmental investigations have been undertaken at the Site dating back to the early 2000's. On-going Site activities include monthly gas and groundwater monitoring, undertaken by Golder Associates (UK) Ltd. These are reported on a quarterly basis with an additional annual report presenting the results of gas and groundwater monitoring produced as required under the EP.

At the time of writing, the most recent annual report available was:

- Golder 2019a. British Sugar York Environmental Permit – Annual Monitoring Report 2018 (Golder report ref. 1777526.605/A.0), dated March 2019.

The most recent quarterly monitoring report available was:

- Golder 2019b. British Sugar York: Quarter 2 2019 Gas and Groundwater Permit Monitoring Factual Report (Golder report ref. 18109944.602/A.0), dated August 2019.

Data presented in Golder 2019a and Golder 2019b form a key part of this HRA, representing current conditions. Environmental analysis of groundwater conducted in 2009 and 2010 has also been reviewed in this HRA to provide information about the wider Site (outside of the EP area) and to assess variation in concentrations of CoC over time, where relevant. In addition, a number of reports were reviewed which were considered pertinent with regards to developing the conceptualisation of the Site and providing background information to inform the updated HRA. These include (but are by no means limited to) the following:

- Enviros 2008. Phase 1 Land Quality Assessment Desk Study – York Sugar Factory (Enviros report ref. AS0690001) dated February 2008.
- Golder 2010. Factual Vendor Due Diligence Report (report ref. 09514540114.500/A.0) dated April 2010.
- Scott Wilson 2010. British Sugar, York – Phase III Geo-environmental Remediation Options Appraisal dated December 2010.*
- Golder 2011. British Sugar York Definitive Closure Management Plan – Annual Monitoring Report 2010 (Golder report ref. 0951450125.501/A.0), dated February 2011.
- URS 2015. British Sugar Site, York – Remediation and Reclamation Strategy – Final (URS report ref: 47068825), dated February 2015.*
- Arcadis 2019a. British Sugar, York - Ground Investigation Factual Report. (report ref. 10024487-AUK-XX-XX-RP-GE-0015-01) dated August 2019.

*These reports included the previous HRA

2.2 Summary of Previous HRA

A summary of the reports containing the previous HRA is presented below for context. It is noted that the URS 2015 report was submitted to the local authority in support of a planning application for the construction of a development platform, engineering works and remediation and reclamation of the Site (Application reference 14/02798/FULM). Planning permission has been granted and the previous URS DQRA reviewed and accepted by the EAs contaminated land department, although an update to the HRA has been undertaken as part of the permit requirement to update the HRA every 6 years, and additionally to provide confidence that impacts in groundwater do not represent a significant risk to the identified water resource receptors.

2.2.1 Scott Wilson, 2010

Scott Wilson undertook a Phase III Remediation Options Appraisal to determine the most appropriate remediation technique for the Site, which incorporated a controlled waters DQRA to aid development of remedial target values (RTVs). The focus of this review is on the controlled waters risk assessment, given that it contains pertinent information for the updated HRA.

Following a screening exercise (undertaken as part of Scott Wilson 2010. British Sugar, York, Phase II Geotechnical and Geo-environmental Assessment report dated October 2010), concentrations of ammoniacal nitrogen, manganese and nickel in soil leachate and groundwater were considered to require further assessment, as concentrations were exceeding their respective compliance criteria (Environmental Quality

Standard or Surface Water (Fishlife) Directions 2010). A detailed assessment was then undertaken using the Remedial Targets Worksheets, 3.1 (RTW 3.1). The scenarios considered as part of the assessment were:

- Leaching of soil impacts into groundwater within the Secondary A Aquifer (superficial deposits)
- Leaching of soil impacts into groundwater within the Principal Aquifer (Sherwood Sandstone)
- Lateral migration of impacted groundwater to the River Ouse.

Following assessment, the compliance criteria for ammoniacal nitrogen, manganese and nickel remained unchanged for both leachate and groundwater and the concentrations of these compounds were considered to represent a risk to the three controlled water receptors identified (Secondary A Aquifer, Principal Aquifer and River Ouse). The absence of attenuation of impacts was in part attributed to the half lives adopted (1×10^{100} years, which for ammoniacal nitrogen was considered to represent anaerobic conditions – i.e. no degradation).

The River Ouse was considered to be a 'critical' receptor with groundwater resting in the Secondary A Aquifer considered to be more significant as a pathway to the River Ouse than a receptor. Given that the Site was not situated within a Source Protection Zone (SPZ), it was considered that remediation of the Sherwood Sandstone Principal Aquifer was not cost effective, if impacts were identified to extend into this formation.

2.2.2 URS, 2015

The Remediation and Reclamation Strategy developed by URS (formerly Scott Wilson) in 2015 set out the proposals for the remediation and reclamation works required to provide a development platform for a comprehensive predominantly residential development at the Site. As part of the works, the HRA for the Site was updated by URS and further consideration given to the source of the CoC.

URS considered that whilst the presence of ammoniacal nitrogen in groundwater was likely to be a result of leaching from the Made Ground, the presence of nickel and manganese in groundwater resting in shallow natural superficial deposits was likely to be the result of natural mineralisation. As such, the focus of further assessment was on ammoniacal nitrogen only, and following review, increased degradation rates were considered likely to be present due to the aerobic conditions identified beneath the Site.

The updated HRA considered the following scenario:

- Leaching of soil impacts into groundwater and subsequent lateral migration towards the River Ouse.

The shallow aquifer was not considered as a receptor on the basis that there were no potable groundwater abstractions within 1km of the Site and no SPZs within 5km of the Site. The Ings Cliffs (Carr) Drain was not considered to be a receptor since it was contained in a culvert and not considered to be in hydraulic continuity with shallow groundwater.

Following an EA comment on the report regarding the potential for interaction between groundwater in the Secondary A Aquifer within shallow superficial deposits and groundwater in the Principal Aquifer of the Sherwood Sandstone, AECOM (formerly URS) completed a review of ten Site specific borehole records spread evenly across the Site which proved the base of the superficial deposits. In all of the boreholes a clayey stratum was proven at the base of the superficial deposits which had a minimum thickness of 1.3m which increased up to 10.9m. Additionally, groundwater strikes were reviewed. Within the superficial granular deposits groundwater was encountered as seepages, however, when boreholes were progressed through the clay stratum, groundwater was struck again at, or just above, the base of the drift deposits and found to be under pressure (it rose several meters following the groundwater strike). Based on this, AECOM concluded that at a Site scale, the presence of clay deposits effectively confined the Sherwood Sandstone Aquifer with minimal mixing between groundwater in the Secondary A Aquifer and in the Principal Aquifer.

The HRA was updated using RTW 3.2 and Site-specific RTVs for soil leachate were calculated, although no significant risk was identified in relation to the River Ouse. SSAC for comparison with concentrations of CoC in groundwater were not calculated as part of this assessment as the RTVs based on soil pore water were considered to provide a source reduction approach rather than direct intervention in groundwater.

2.3 Summary of Works Following URS, 2015

As stated in section 2.1, monthly gas and groundwater monitoring has been undertaken following the URS, 2015 report, since October 2015, prior to which less frequent monitoring was undertaken. The most recent visit available for review at the time of reporting was June 2019, with further details of the findings presented in section 4.2.

In addition to the gas and groundwater monitoring, an additional intrusive investigation was undertaken by Arcadis in June and July 2019. The aim of the investigation was to address identified data gaps and collect additional Site data to facilitate detailed remediation and reclamation design in order to support future Site redevelopment.

The scope of works included the advance of trial pits, boreholes, Cone Penetrometer Testing (CPT), soil, leachate and groundwater analysis, gas monitoring, topographic surveying and bathymetric/hydrographic surveying of the lagoons was undertaken. The report provides a factual account of the investigation.

The ground conditions encountered during the ground investigation can be placed into two stratums: anthropogenic and superficial deposits. The anthropogenic deposits were sub-divided into seven subgroups comprising: topsoil, sub-soil, cohesive Made Ground, granular Made Ground, organic rich soil, lagoon sediment and limex. Lagoon sediments comprising silty clay or clayey silt were typically encountered at the greatest depths in the Made Ground. The superficial deposits encountered were sub-divided into granular natural deposits comprising sand or sandy gravel with occasional clay-rich layers and were typically encountered between 5 and 15 m bgl, and cohesive natural deposits comprising sandy/gravelly clay typically encountered between 9.6 and 20 m bgl. Sandstone bedrock was not encountered during the investigation. During the investigation, groundwater was encountered in the superficial deposits only, ranging from 0.77 m bgl to 13.32 m bgl.

Soil leachate samples were collected from across the Site with the highest concentrations of ammoniacal nitrogen measured in leachate analysed from soil samples collected from the northern part of the Site, within the vicinity of the lagoons.

2.4 Summary of Environmental Site Setting

The Site occupies an area of 38 hectares to the north west of York City Centre. Between the 1920's and 2008 the Site was used for the preparation and refinement of sugar beet into granulated sugar. As part of this process, the northern, western and southern areas of the Site were used for waste water treatment which included settlement ponds and lagoons which were reportedly present from the 1950's / 1970s. In the central part of the Site bulk oil and thick juice was stored, with processing in the central and southern areas and disused railway lines to the east (Enviros 2008). The Site has now been demolished although a variable topography caused by built up Made Ground at the Site remains. In the present day, residential properties border the Site to the south with commercial units and properties to the north-west and north. A railway line runs along the eastern boundary of the Site with agricultural land and a water treatment plant beyond.

Review of the British Geological Society (BGS) 'GeoIndex' indicates that the Site is mostly underlain by superficial deposits of the Poppleton Glaciofluvial Member which comprise sands and gravels. In the southernmost tip of the Site, the Alne Glaciolacustrine Formation, which consists of laminated clay with silt and some subordinate fine-grained sand beds, is shown to underly the Site. Below the superficial deposits, the bedrock comprises sandstone of the Sherwood Sandstone Group. Previous ground investigation at the Site (Enviros 2008) have encountered large and variable thickness of Made Ground overlying the superficial deposits. The Made Ground is described as gravelly sand or sandy gravel, grading to clayey sand and gravels with brick, concrete, ash, clinker and cobbles of sandstone and limestone and the greatest thicknesses were noted in the north and north-western portions of the Site.

During previous intrusive investigations (Enviros 2008, URS 2015 and Arcadis 2019), groundwater has generally been encountered within the superficial deposits, with an additional groundwater strike encountered where intrusive holes were progressed into the bedrock (URS 2015). The depth to groundwater across the Site varies to the differing topography, although groundwater is indicated to flow towards the River Ouse in a northeasterly direction.

Review of the Department for Environment, Food and Rural Affairs (DEFRA) 'MAGIC' map indicates that the superficial deposits are classified as a Secondary A Aquifer with the underlying Sherwood Sandstone classified as a Principal Aquifer. The Site is not located within 5km of a SPZ however it is noted that five licensed groundwater abstractions have previously been present on Site, with the license held by British Sugar Plc to abstract water from the Sherwood Sandstone for cooling and general use (Enviros 2008).

Surface water features on the Site have included settlement and aeration ponds and the Ings Cliff Drain which is noted to have been culverted beneath the Site since the mid-1900s (Enviros 2008). The River Ouse, flowing north to south past the Site is located 200m from the Site boundary at its closest point and in 2016 (the most recent data available) was ranked as “good” for chemical status, “moderate” for ecological status, and “moderate” for overall status by the EA (https://environment.data.gov.uk/catchment-planning/WaterBody/GB104027069593).

Review of DEFRA’s ‘MAGIC’ map indicates that Clifton Ings and Rawcliffe Meadows, which is classified as a Site of Special Scientific Interest (SSSI), is approximately 200m to the north east of the Site. It is noted that this is on the northern side of the River Ouse and therefore on the other side of the river to the Site.

3 Water Quality Standard Screening

It was considered prudent to undertake a screening exercise prior to undertaking detailed fate and transport modelling, to ensure the HRA focuses on the CoC requiring further assessment.

3.1 Selection of Assessment Criteria

The focus of this report is on the risk to identified water resources, as such water quality standards protective of water resources have been used to screen concentrations of CoC measured in groundwater. In addition, Minimum Reporting Values (MRV), as defined by the EA, have been included in the comparison, where available. Where these are not available, the "*Concentrations in groundwater below which the danger of deterioration in the quality of the receiving groundwater is avoided*" as defined by the UK Technical Advisory Group on the Water Framework Directive (UK TAG) have been included, although it is noted that these values have not yet been adopted by the EA.

Based on the designation of the underlying superficial deposits as a Secondary A Aquifer, concentrations of CoC in groundwater have been compared directly to Drinking Water Standards (DWS) where available. It is noted that the Principal Aquifer (Sherwood Sandstone) is not considered to be in hydraulic continuity with groundwater in the shallow Secondary A Aquifer (discussed in Section 2.2.4) beneath the Site and as such, has not been considered as a potential receptor.

The primary surface water resource receptor associated with the Site is the River Ouse which is located between 200m and 550m away from the Site's eastern boundary. Based on groundwater elevations measured on the Site, the River Ouse is considered to be hydraulically down gradient and as such, concentrations of CoC in groundwater have also been compared to Environmental Quality Standards (EQS) where available.

There is an additional water course, the Ings Cliff (Carr) Drain which flows from west to east near to the southern boundary of the Site. However, it is reportedly culverted (and has been since 1900's) throughout the length of its crossing of the Site (Enviros 2008 and URS 2015) and as such, is not considered to be in hydraulic continuity with groundwater beneath the Site.

Where DWS and/or EQS are not available for a specific compound, a review of available water quality standards has been undertaken and the most appropriate selected. Details of the water quality standards selected are included in the notes of Appendix B.

3.2 Methodology

The maximum measured concentrations of CoC in groundwater measured during groundwater monitoring undertaken by Golders in June 2019, were compared to the relevant water quality standards (DWS and EQS where available) and MRV and UKTAG values, in Appendix B. Only concentrations measured in wells on the hydraulically down-gradient Site boundary were included for comparison, on the basis that impacted soils (the primary source) are situated immediately adjacent to the EP boundary, with the boundary monitoring wells located adjacent to the permit boundary and in the lateral migration flow path.

Where exceedances were considered to be marginal, localised, or not associated with a site source, further assessment in the form of modelling was not considered warranted, as detailed in Appendix B.

3.3 Comparison of Analytical Results to Criteria

Measured concentrations of ammoniacal nitrogen in groundwater were identified in excess of the water quality standards protective of both aquifer and surface water and were considered to require further consideration. None of the remaining measured concentrations of CoC were considered to require further assessment. As such, the focus of the following sections is on the risk to water resources from measured concentrations of ammoniacal nitrogen in groundwater, only.

4 Review of the Conceptual Site Model

The conceptual Site model has been reviewed in the context of the additional data collected since 2014, following the URS 2015 report, and has been updated where applicable.

4.1 Receptors

The River Ouse, located between 200m and 550m from the eastern Site boundary, was considered as the primary potential water resource receptor in the most recent HRA (URS, 2015) and has been retained. Groundwater within the Secondary A Aquifer, associated with the superficial deposits, has also been included as a receptor in this assessment. However, it is noted that there are no potable groundwater abstractions within 1km of the Site, there are no SPZ located within 5km of the site and groundwater ultimately discharges into the River Ouse. As such, the primary receptor is considered the River Ouse.

The Ings Drain and the Principal Aquifer (Sherwood Sandstone) are not considered to be in hydraulic continuity with groundwater in the shallow Secondary A Aquifer (discussed in Section 2.2) and as such, are not considered to be significant receptors. Further, that the SSSI located on the adjacent side of the River Ouse has not been considered a significant receptor in relation to the Site as it is anticipated that groundwater will discharge into the River Ouse.

4.2 Sources

The sources of ammoniacal nitrogen considered within the existing HRA (URS, 2015) remain principally unchanged since the Site is no longer in use. The primary source is considered to be associated with a substantial and variable thicknesses of Made Ground across the Site, particularly in the vicinity of settlement ponds and soil treatment areas in the north of the Site, with ammoniacal nitrogen present as a result of decomposition of organic matter containing nitrogen. The ammoniacal nitrogen measured in groundwater is considered to represent a secondary source and is considered to be present largely as a result of leaching of ammoniacal nitrogen from soil into groundwater, although it is noted that ammoniacal nitrogen is also naturally occurring in the environment.

It is noted that ammoniacal nitrogen can be present as either ammonia or ammonium, depending on pH. However, ammoniacal nitrogen has been adopted for the purposes of modelling and is considered representative of the substances ammonia and ammonium, which is in line with the approach adopted by URS (URS, 2015).

4.2.1.1 Contaminant Distribution

During the most recent EP groundwater monitoring visit conducted by Golder in June 2019, ammoniacal nitrogen was identified at concentrations greater than the MDL in all of the groundwater samples collected. The distribution of ammoniacal nitrogen in groundwater in the most recent groundwater monitoring visit is presented on Figure 3. The most recent groundwater sampling of monitoring wells located outside of the environmental permit area was undertaken in 2009 and has also been presented on Figure 3 to provide wider Site coverage.

The highest concentration of ammoniacal nitrogen measured in June 2019 was 231 mg/l which was measured in groundwater sampled from BH04A in the central, northern part of the Site, adjacent to the lagoons and within the EP boundary. Measured concentrations of ammoniacal nitrogen in groundwater sampled from GA-GW18, GA-GW19 and GA-GW24, also in the central and northern parts of the Site were also above 100 mg/l. Concentrations were generally lower in hydraulically up-gradient wells along the western boundary of the Site with concentrations hydraulically down-gradient, along the north-eastern boundary, ranging from 3.38 to 38.8mg/l (monitoring wells GA-GW02, GA-GW03 and GA-GW04).

The highest measured concentrations of ammoniacal nitrogen in groundwater sampled from monitoring wells outside the EP area, to the south of the Site, in April 2009 were an order of magnitude lower than the highest measured inside the EP area (Golder, 2010). Concentrations of ammoniacal nitrogen in GA-GW09 were the highest in that area at 69 mg/l and correlate with the location of the elevated concentrations of ammoniacal nitrogen in leachate in the south of the Site.

4.2.1.2 Consideration of Background Concentrations

Review of EA, 2007, indicates background concentrations of ammonium ranging from <0.003 to 12mg/l, with a mean of 0.14mg/l. It is noted that concentrations of ammoniacal nitrogen measured hydraulically up-gradient of the EP area were typically within the range presented by the BGS for ammonium, with concentrations ranging from 0.01 to 0.04mg/l in June 2019, with the exception of GA-GW21, where ammoniacal nitrogen was measured at 73.7mg/l. Additionally, measured concentrations of ammoniacal nitrogen in several of the hydraulically down-gradient wells were considered to lie within the range representative of background concentrations.

4.2.1.3 Review of Trends

A review of the trend in ammoniacal nitrogen concentration has been undertaken for locations designated as “up-gradient”, “on-Site” and “down-gradient”, as defined within the EP. Concentrations in ammoniacal nitrogen over time from 2010 / 2011 to June 2019 are presented on Figures 4, 5 and 6, for up-gradient, on-Site and down-gradient wells. Also presented for each dataset are averaging trend lines to enable easier assessment of potential patterns within the data. It is noted that that the Site ceased activity in 2008, and as such, the monitoring period considered is post closure.

Up-gradient

Up-gradient wells as defined by the EP comprise BH02, GA-GW01, GA-GW13, GA-GW20, GA-GW21 and GA-GW22.

Review of the Figure 4 indicates that typically, concentrations have remained relatively stable over this time period, as would be expected given that they are hydraulically up-gradient of the primary sources. Minor variations in concentrations have been observed, primarily in GA-GW01 and GA-GW22, although these typically fall within the range of background ammonium concentrations, as presented by the EA (EA, 2007).

The exception is measured concentrations of ammoniacal nitrogen in GA-GW21, where elevated readings of ammoniacal nitrogen in the tens of mg/l have consistently been identified, and outside of what would be considered typical background levels, as discussed in Section 4.2.2. However, concentrations of ammoniacal nitrogen in GA-GW21 appear to show a general decrease over the monitoring period.

On-Site

On-Site wells as defined by the EP comprise BH04A, BH5, GA-GW02, GA-GW14, GA-GW17 – GA-GW19 and GA-GW23 – GA-GW25.

Review of Figure 5 indicates that typically, concentrations show relatively little fluctuation with the averaging trend lines indicating a slight decreasing trend in the majority of locations. The exception was GA-GW24, GA-GW02 and GA-GW17. Within GA-GW24 and GA-GW02, a slight increase is indicated by the averaging trend line, while within GA-GW17, where although an overall decreasing trend is indicated, concentrations of ammoniacal nitrogen appear to have fluctuated.

Down-Gradient

Down-gradient wells as defined by the EP comprise BH09, GA-GW03 – GA-GW06, GA-GW15 and GA-GW16.

Review of Figure 6 indicates that typically, concentrations fluctuate relatively little, with concentrations relatively stable or decreasing. The exception of GA-GW04, where an increasing trend is indicated by the averaging trendline. The exception was GA-GW16, in which concentrations of ammoniacal nitrogen have fluctuated over time (albeit a decreasing trend is still observed) and GA-GW04, which is located centrally within the northern EP boundary and which shows an overall increasing trend over the monitoring period. It is noted that while GA-GW04 is considered hydraulically down-gradient within the EP, it is also located within the EP boundary approximately 20m from one of the on-Site ponds and adjacent to an area where relatively high concentrations of ammoniacal nitrogen have been identified in the unsaturated zone. While it is possible that the increase in concentrations is as a result of lateral migration of ammoniacal nitrogen in the dissolved phase, it is also plausible that the concentrations observed are potentially associated with leaching of soil impacts.

4.2.2 Modelled Source

Review of the groundwater data indicated two potential sources are present as detailed overleaf:

- Source 1: located in the northern part of the Site and including a large proportion of the EP area; and,
- Source 2: located in the southern-most part of the Site, and outside of the EP area.

The sources have been primarily based on:

- The distribution of concentrations of ammoniacal nitrogen measured in groundwater collected as part of a monthly programme of EP groundwater monitoring in the groundwater monitoring visit in June 2019 (Golder 2019a); and,
- The distribution of concentrations of ammoniacal nitrogen measured in groundwater collected as part of Site wide groundwater monitoring in April 2010 (Golder 2010).

It is noted that the most recent HRA (URS 2015) did not model impacts in groundwater directly. However, for the purpose of assessing impacts in soil and leachate, split the Site into seven averaging areas (AA1a, AA1b, AA2, AA3a, AA3b, AA4a and AA4b). The averaging areas were defined primarily based primarily on the previous uses of the areas by Scott Wilson 2010, and while useful in identifying where contaminant mass may be stored in the unsaturated zone, have not been used for the purpose of assessing the risk from impacts in groundwater.

The modelled source widths for Source 1 and 2 are presented on Figure 3, and are considered representative of the identified source beneath the Site. It is noted that a source length is not required for the purpose of modelling lateral migration of impacts in groundwater.

4.2.3 Chemical Characterisation

The chemical properties for ammoniacal nitrogen are presented in Appendix C.

4.3 Pathways

4.3.1 Modelled Pathways

In order to assess the level of risk presented to the identified receptors, the pathways defined as potentially active within the pollutant linkages need to be considered further. Site-specific information is used where possible to assign parameter values for the physical characterisation of the geological and hydrogeological setting of the Site.

Based on the results of the previous environmental investigations completed at the Site, the source zone / aquifer has been conceptualised as a granular lithology, in line with the previous HRA, as presented on Figure 7.

A sensitivity analysis has been carried out in line with the methodology outlined in the Remedial Targets Methodology (RTM) Guidance (EA,2006), to assist with selection of parameter values required for the key fate and transport pathways. The RTW was adopted for sensitivity testing. The results of the sensitivity testing, which was completed for ammoniacal nitrogen is presented in Appendix D.

A full listing of the physical parameter adopted within the assessment is presented in Appendix E.

4.3.2 Environmental Fate and Transport Pathways

The following fate and transport pathways have been considered in the updated HRA:

- Lateral migration of potentially impacted groundwater towards identified water resource receptors.

4.4 Summary

The modelled environmental pathways and a Site-specific cross-section are presented on Figure 7.

5 Updated HRA

5.1 Assessment Approach

The non-statutory regulatory technical guidance consulted in undertaking the updated HRA, the methodology used and available modelling tools are presented in Appendix F.

5.2 Selection of the Assessment Tools

The updated HRA has been undertaken using Site-specific information, where available, to derive risk-based assessment criteria, which can be used to assess whether the concentrations of CoC in groundwater beneath the Site present potentially unacceptable risks to the identified water resource receptors.

The following modelling tool was selected for the updated assessment:

Receptor	Media	Selected modelling tool
Water resources	Groundwater	Remedial Targets Worksheet (RTW) version 3.2

5.3 Water Resources

5.3.1 Methodology

The water resources risk assessment has been undertaken using RTW to back-calculate evaluation criteria, or water resource SSAC, as outlined in Appendix F.

5.3.2 Model Run Parameters

Following sensitivity testing, and where appropriate, the parameters adopted in the updated HRA have been retained from the most recent HRA, and for completeness are summarised below.

Where parameters have been updated, these are discussed in more detail in the following sections.

Parameter	Value	Comment
Time frame	Ogata-Banks solution	In line with Remedial Targets Methodology (RTM)
Dispersivity	Longitudinal and transverse dispersivities have been calculated within the RTW model as 10% and 1% of the compliance point distance respectively. Vertical transmissivity has been limited so as not to exceed the saturated aquifer thickness.	In line with RTM methodology.
Compliance Criteria	CoC Specific	Appendix B

5.3.2.1 Degradation

Ammoniacal nitrogen degrades only under aerobic conditions, with negligible degradation occurring under anaerobic conditions (Buss et al, 2004). The distribution of ammoniacal nitrogen in groundwater, as discussed in section 4.2.1 suggests degradation is potentially occurring, on the basis that lower concentrations of ammoniacal nitrogen are observed on the hydraulically down-gradient Site boundary. However, to support this, a review of geochemical data has been undertaken to understand whether degradation is an active process. It is noted that ammoniacal nitrogen can be oxidised by certain bacteria to nitrite, with nitrite also oxidised to nitrate. The degradation processes beneath the Site are likely complex, due to the presence of a carbon source creating localised changes in redox conditions (due to the historical use of the Site for storage of organic waste).

Concentrations of nitrate and nitrite in groundwater during monitoring in June 2019 have been assessed and the distribution of these has been presented on Figures 8 and 9, respectively. In addition, the distribution of dissolved oxygen and oxygen reduction potential (ORP) is presented on Figures 10 and 11, to understand whether conditions are likely aerobic or anaerobic. The distribution of ammoniacal nitrogen during monitoring in June 2019 is presented on Figure 3.

Review of the figures indicates that ORP is typically higher (more oxidising) in the up-gradient monitoring wells and down-gradient monitoring wells, with the lowest ORP values (most reducing) typically observed in the central portion of the EP area, and generally coinciding with the highest ammoniacal nitrogen concentrations. Higher ORP in the up-gradient and down-gradient locations suggests more oxidising conditions are present in these areas, while potentially reducing conditions may be present in locations where the most elevated concentrations of ammoniacal nitrogen are identified. Review of the dissolved oxygen figure is not as conclusive, but does show relatively elevated oxygen levels, typically falling within the 0.5 to 5ppm range. The highest dissolved oxygen is typically measured on the hydraulically down gradient boundary wells.

Review of the nitrate distribution (Figure 8) indicates a fairly distinctive pattern, with nitrate concentrations elevated in the up-gradient locations and hydraulically down-gradient location and typically depleted within the areas where ammoniacal nitrogen has been identified. Elevated nitrate suggests the potential for relatively oxidising conditions. Nitrite shows a similar pattern (Figure 9), albeit nitrite is depleted both beneath the EP area and hydraulically down gradient locations.

Review of the data as a whole suggests that oxidising conditions are present hydraulically up gradient and down gradient, with reducing conditions beneath the most impacted areas. The relationship of nitrate and nitrite is complex, and while it might be anticipated that higher concentrations of nitrate may be present within the source area based on the degradation of ammoniacal nitrogen, it is possible that its depletion is due to other oxidising processes. In particular, nitrate is converted to nitrite by microbes when organic matter is present, with a large organic source present on Site due to the historical use of the Site for storage of organic waste. As such, while aerobic degradation of ammoniacal nitrogen immediately within the source area may be limited (based on the reducing conditions observed), degradation is considered to be active process via aerobic degradation during lateral migration within the plume (based on the oxidising conditions observed down gradient).

On the basis of the above, it is considered that degradation is an active process, and dual phase degradation has been selected within the model based on model validation. It is noted that this is in line with the existing HRA (URS, 2015).

The findings of the model validation, undertaken to further support that dual phase degradation is occurring at the Site, is presented in Section 5.3.3.

5.3.2.2 Compliance Point Distance

The River Ouse is considered the primary surface water receptor associated with the Site. Two compliance points have been used to assess the risk to the River, reflecting the distance from Source 1 and Source 2:

- Source 1 compliance point: 400m
- Source 2 compliance point: 250m

For the assessment of the risk to the Secondary A Aquifer, a compliance point of 250m from the source has been selected. Ammoniacal nitrogen is considered to be a non-hazardous substance, based on a review of the *Joint Agencies Groundwater Determinations Advisory Group*'s *Confirmed Hazardous Substances List* (published in 2018 and accessible https://www.wfduk.org/resources/groundwater-hazardous-substances-standards). Review of the EA guidance indicates the a compliance point of up to 250m can be adopted for non-hazardous substances in groundwater with local resource potential (rather than strategic resource potential), while for hazardous substances a compliance point of 50m is typically (https://www.gov.uk/guidance/land-contamination-groundwater-compliance-points-quantitative-risk-assessments). A compliance point of 250m is considered appropriate in the context of the environmental Site setting, given that there are no potable groundwater abstractions within 1km of the Site, there are no SPZ located within 5km of the Site. The sensitivity of the compliance point distance over a range of 50m to 400m, has been assessed in Appendix D for context, with a visual representation of the compliance point respective to each source presented on Figure 3.

5.3.3 Model Validation

Validation of the model predictions versus the measured concentrations of ammoniacal nitrogen in groundwater at the Site was undertaken to provide calibration of the model and also as a line of evidence to further support the occurrence of dual phase degradation at the Site.

Measured concentrations of ammoniacal nitrogen in groundwater sampled from GA-GW24, GA-GW19 and GA-GW18 in April 2010 (Golder 2011) were averaged and used to represent source concentrations in the model validation. GA-GW24, GA-GW19 and GA-GW18 were selected as they have historically had the highest concentrations of ammoniacal nitrogen on the Site and form a cluster of wells hydraulically up-gradient of a number of down-gradient boundary monitoring wells. The four hydraulically down-gradient wells considered in the model validation were GA-GW16, GA-GW05, GA-GW25 and BH09, which typically contained only a limited thickness of Made Ground (and therefore potential source material). Groundwater monitoring data collected in June 2019 was used to represent current down-gradient conditions.

The Site was developed in the 1920s, although the EP area, which is where the highest concentrations of ammoniacal nitrogen are identified in groundwater was only developed towards the early 1970s (Golder, 2010). Two of the ponds in the northern most portion of the Site are indicated to have been constructed around the 1950s based on historical maps, although anecdotal evidence and Site records suggest that these were potentially constructed in the early 1970s (Golder, 2010). Given this, model calibration was undertaken a based on a 50 year timeframe, to represent the length of time the source has potentially been present.

The model calibration output is summarised in the table below.

Measured source area concentration (i.e. start concentration)	Approximate distance to down-gradient monitoring well	Predicted concentration at down-gradient monitoring well (single phase)	Predicted concentration at down-gradient monitoring well (dual phase)	Measured concentration at down-gradient monitoring well in June 2019
174 mg/l (2010)	GA-GW25: 40m	113 mg/l	42.1 mg/l	0.03 mg/l
	GA-GW16: 65m	87.2 mg/l	20 mg/l	31 mg/l
	GA-GW05: 160m	26.5 mg/l	1.88 mg/l	0.05 mg/l
	BH09: 175m	21.3mg/l	1.34 mg/l	0.01 mg/l

The results of the model calibration indicate that predicted concentrations 40m, 160m and 175m down-gradient of the adopted source wells exceed measured concentrations by several orders of magnitude when modelled for dual phase degradation. However, the predicted concentration 65m down-gradient of the adopted source wells was below the measured concentrations when modelled using dual phase degradation. While concentrations of ammoniacal nitrogen in GA-GW16 are an order of magnitude lower than those within GA-GW24, GA-GW19 and GA-GW18 and potentially representative of the plume, it is also plausible that impacts in soil in this area may also be contributing to the elevated concentrations of ammoniacal nitrogen observed in groundwater, given the observed ammoniacal distribution in soil, and that Made Ground in this location was deeper than in the remaining validation wells (thickness of 1.7m). Predicted concentrations of ammoniacal nitrogen based on dissolved phase degradation only were typically an order of magnitude higher than those for dual phase degradation.

The results of the model calibration indicate that degradation rates are likely to be more rapid than those predicted via single phase degradation and potentially via dual phase degradation. It is noted that this could also be associated with other mechanisms that are not readily modelled, such as precipitation and cation exchange. As such, use of a dual phase degradation model is considered appropriate when assessing the potential risk to the identified water resource receptors from concentrations of CoC measured in groundwater underlying the Site, while acknowledging that there is likely to be conservatism within the modelling based on the validation undertaken.

Consideration of Steady State Conditions

To provide confidence that increases within the boundary wells are unlikely to occur, the model validation set up above, incorporating dual phase degradation, has been reviewed in the context of steady state conditions (i.e. a time frame of 9e99 days). Changing the timeframe from 50 years (length of time the source has potentially been present) to 9e99days indicates that steady state conditions are present at 40m (GA-GW25) and 65m (GA-GW16), with only a negligible increase (approximately 0.1mg/l) in predicted concentrations at 165m (GA-GA05) and 175m (BH09).

As such, the model suggests steady state conditions are likely to be present on the Site boundary. This is supported by the Site data, where review of approximately the last ten years of monitoring data indicates stable or decreasing trends in the locations adopted for validation purposes (see section 4.2.3).

5.3.4 Development of Water Resources SSAC

The updated SSAC defined for the protection of the identified water resource receptors have been derived and are presented in Table 1.

RTW output sheets for ammoniacal nitrogen for Source 1 and 2 are presented in Appendix G.

5.3.5 Water Resources Risk Estimation and Evaluation

The concentrations of ammoniacal nitrogen measured in groundwater sampled in the groundwater monitoring visit conducted by Golder in June 2019 (Golder 2019b) have been compared to the updated water resource SSAC derived for Source 1 in Table 2. Concentrations of ammoniacal nitrogen measured in groundwater sampled in the most recent groundwater monitoring undertaken outside of the EP area, in April 2009 (Golder 2010) have been compared to the updated water resource SSAC derived for Source 2 in Table 3. Only those locations which were considered to be within their respective source areas have been included within the comparison.

Measured concentrations of ammoniacal nitrogen in groundwater have not been identified in excess of the updated SSAC derived for the protection of the Secondary A Aquifer and the River Ouse.

5.3.6 Consideration of Soil RTVs

Review of the RTV calculated for ammoniacal nitrogen in soil pore water (URS 2015) has been undertaken in the context of the Arcadis groundwater model, to confirm that the RTV will support the SSACs derived for the protection of groundwater. The RTV were derived by URS using RTW, in line with the Arcadis assessment of groundwater, and included Level 1 soil (predicted pore water concentration resulting from a soil source), Level 2 soil (dilution of pore water concentrations within the underlying aquifer) and Level 3 soil (lateral migration within the underlying aquifer). It is noted that Level 3 soil is equivalent to Level 3 groundwater within RTW (i.e. both sheets derive an attenuation factor associated with lateral migration in the dissolved phase).

The RTV derived in URS 2015 were calculated for each averaging area and ranged from 2 mg/l to 46 mg/l.

To review the RTV in the context of the Arcadis groundwater model; the attenuation factor calculated in the most conservative groundwater model (Source 1 with an aquifer compliance point of 250m) has been multiplied by the compliance criteria (0.5 mg/l) and by the dilution factor calculated in the RTW Level 2 soil model (URS 2015) for each averaging area. The range in acceptable pore water concentrations calculated in the context of the revised groundwater model is: 269 mg/l to 545 mg/l.

Given that the acceptable pore water concentration calculated in the context of the groundwater model are one to two orders of magnitude higher than the existing RTVs derived in URS 2015, the existing RTVs are considered to be supportive of achieving the SSAC for the protection of groundwater.

6 Summary and Conclusions

Using additional Site-specific data collected since 2014 and with reference to previous HRAs (Scott Wilson 2010 and URS 2015) this report presents an update of the HRA for the British Sugar, York Site.

The Site is a demolished sugar refinery, which imported and washed sugar beet, which was then refined into granulated sugar. The Site started activity in the 1920's and ceased activity in 2008, with the northern portion of the Site subject to an EP. It is understood that British Sugar intends to divest the Site for the development of residential dwellings and that this HRA has been undertaken as part of a larger scheme of works. While planning permission has been granted and the previous URS DQRA reviewed and accepted by the EAs contaminated land department, an update to the HRA was undertaken as part of the permit requirement to update the HRA every 6 years, and additionally to provide confidence that impacts in groundwater do not represent a significant risk to the identified water resource receptors.

There has been extensive investigation of the Site which includes monthly groundwater monitoring conducted by Golder Associates Ltd. Analysis of groundwater sampled at the Site has identified concentrations of nickel and ammoniacal nitrogen on the hydraulically down-gradient Site boundary which are in excess of their respective water quality standards (DWS and EQS). Additional information relating to the bioavailability of nickel is pending and as such this report is focussed on ammoniacal nitrogen only. The report will be re-issued following receipt of the information relating to nickel.

The primary source of ammoniacal nitrogen is considered to be large thicknesses of Made Ground on the Site which contain a high proportion of organic material. Ammoniacal nitrogen in groundwater represents a secondary source, primarily as a result of leaching of impacts from soil. For the purpose of assessing risk, two groundwater source areas were defined based on a review of the ammoniacal nitrogen distribution in groundwater; one in the north of the Site encompassing the majority of the EP, with a secondary source in the southern most part of the Site.

A review of potential water resource receptors identified groundwater in the Secondary A Aquifer associated with the superficial deposits underlying the Site as a potential water resource receptor. Additionally, the River Ouse, which is located 200m east of the Site at its closest point, was also identified as a potential surface water receptor. The Ings Drain and the Principal Aquifer (Sherwood Sandstone) were not considered to be in hydraulic continuity with groundwater in the shallow Secondary A Aquifer and as such, were not considered to be significant receptors.

Site-specific data has been used where possible to conceptualise the aquifer underlying the Site through which the bulk of the transport and attenuation of ammoniacal nitrogen is anticipated to occur. RTW 3.2 was adopted for the purpose of deriving SSAC protective of the identified water resource receptors. Soil was not assessed as RTVs based on pore water concentrations were derived previously by URS (URS, 2015), which were considered protective of the River Ouse.

The following conclusions were drawn based on model validation and evaluation of the findings:

- Measured concentrations of ammoniacal nitrogen in groundwater were not identified in excess of the updated SSAC derived for the protection of the Secondary A Aquifer or the River Ouse. As such, measured concentrations of ammoniacal nitrogen were not considered to represent a significant risk to water resources.
- Groundwater conditions at the Site boundary were considered to be near steady state, with typically stable or reducing concentrations observed in the majority of locations.
- The RTVs derived for the Site in URS 2015 are considered to be supportive of achieving the SSAC for the protection of water resources.

7 References

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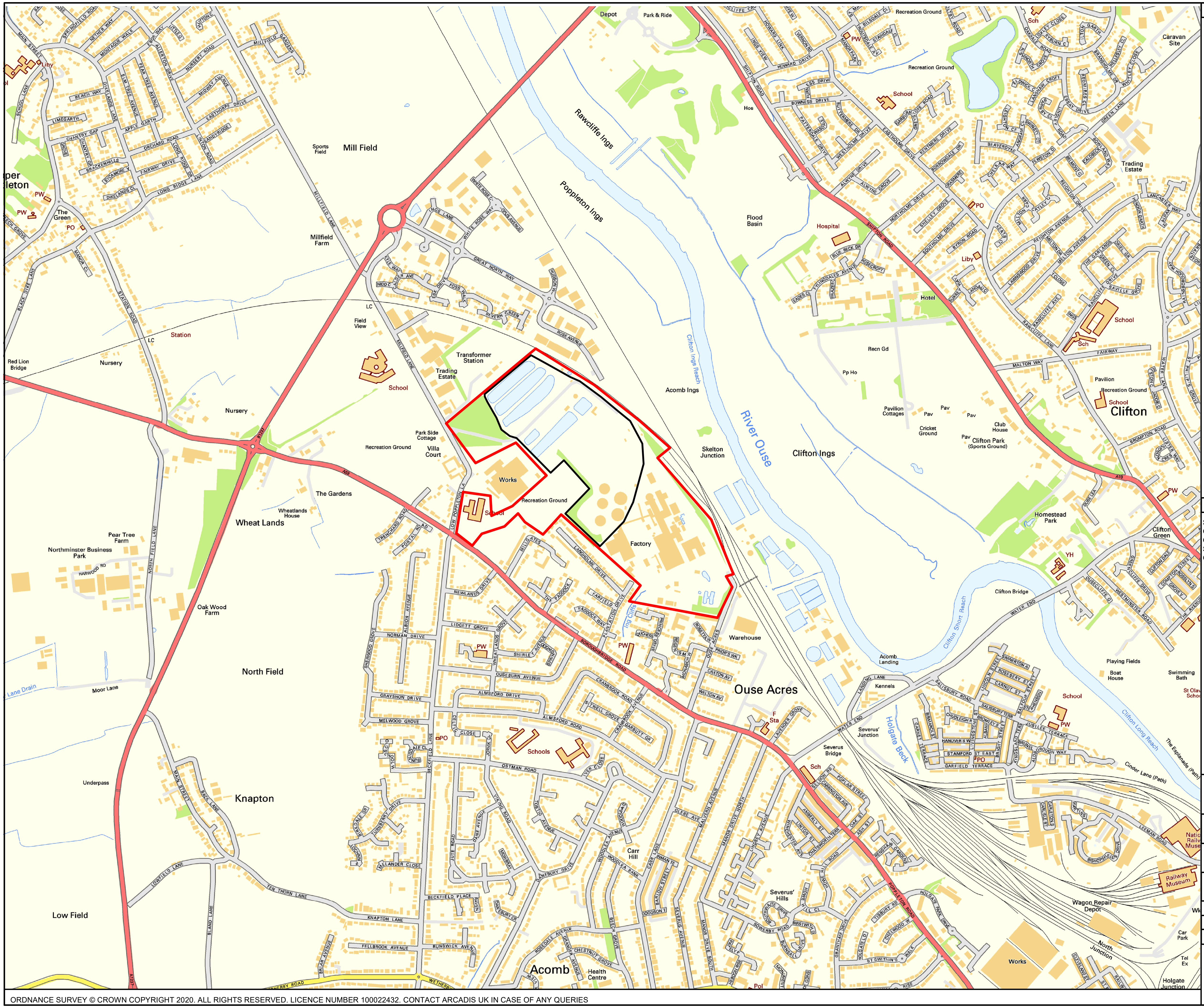
FIGURES



LEGEND

🟥 SITE BOUNDARY

☐ ENVIRONMENTAL PERMIT AREA

NOTES

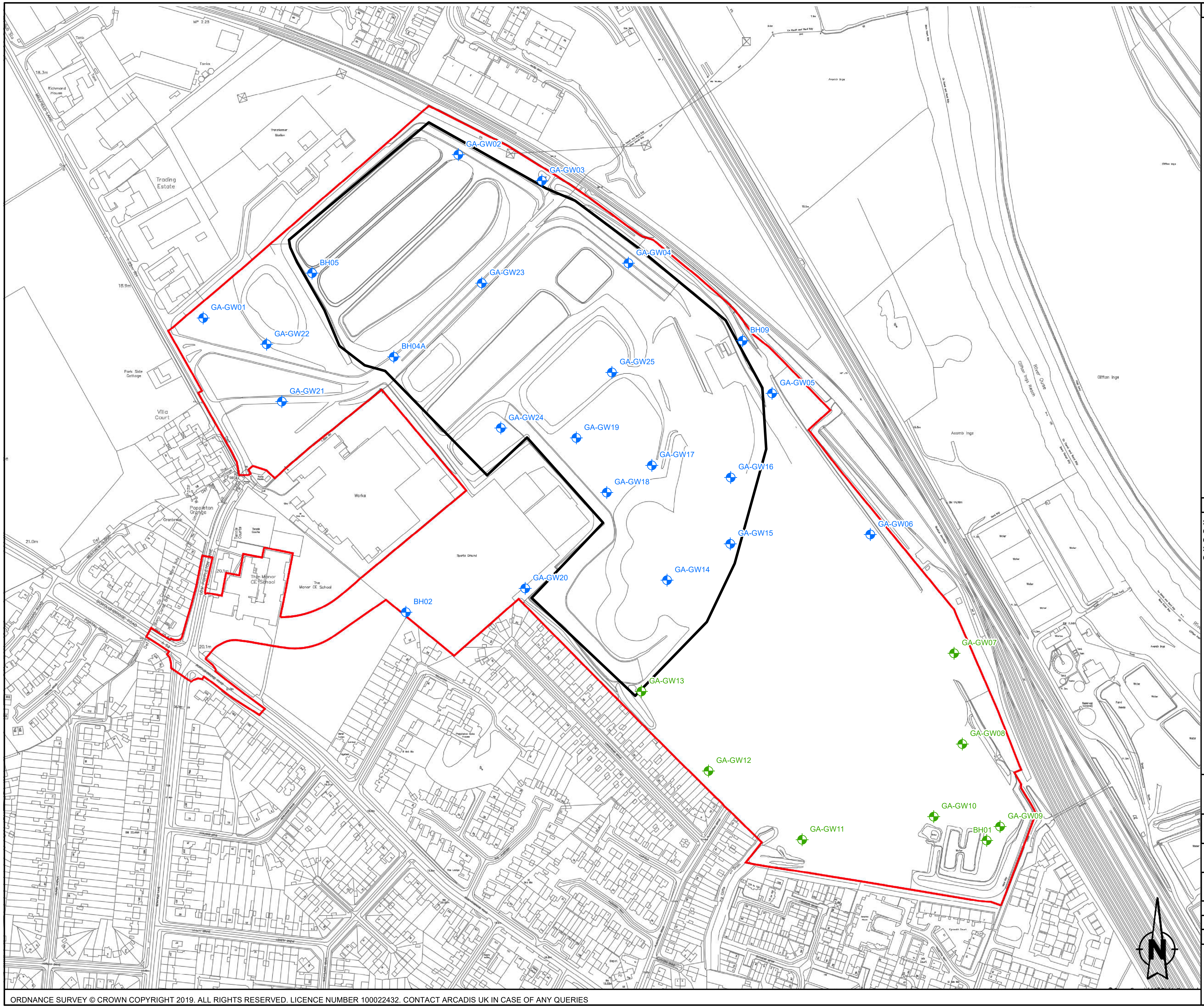
SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE.

0 45 90 180 270 360 450
Metres

N

TITLE:	**SITE LOCATION PLAN**
SITE :	**BRITISH SUGAR YORK**
CLIENT :	**BRITISH SUGAR**
PROJECT :	**10024487** **FIGURE 1**
DATE : 29/01/20	DRAWN BY : AP
DRG No. :	10024487-AUK-XX-XX-DR-ZZ-0022-P1 GIS
SCALE : 1 : 12,000	PRINT : A3

ARCADIS Design & Consultancy for natural and built assets



LEGEND

▭ ENVIRONMENTAL PERMIT AREA

⊕ ENVIRONMENTAL PERMIT MONITORING WELLS

⊕ WIDER SITE MONITORING WELLS

NOTES

SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE.

0 15 30 60 90 120 150 Metres

N

TITLE:
SITE LAYOUT AND EXPLORATORY HOLE LOCATION PLAN

SITE :
BRITISH SUGAR YORK

CLIENT :
BRITISH SUGAR

PROJECT : **10024487** **FIGURE 2**

DATE : 13/11/19 DRAWN BY : AP

DRG No. : 10024487-AUK-XX-XX-DR-ZZ-0023-P1 GIS

SCALE : **1 : 4,000** PRINT : **A3**

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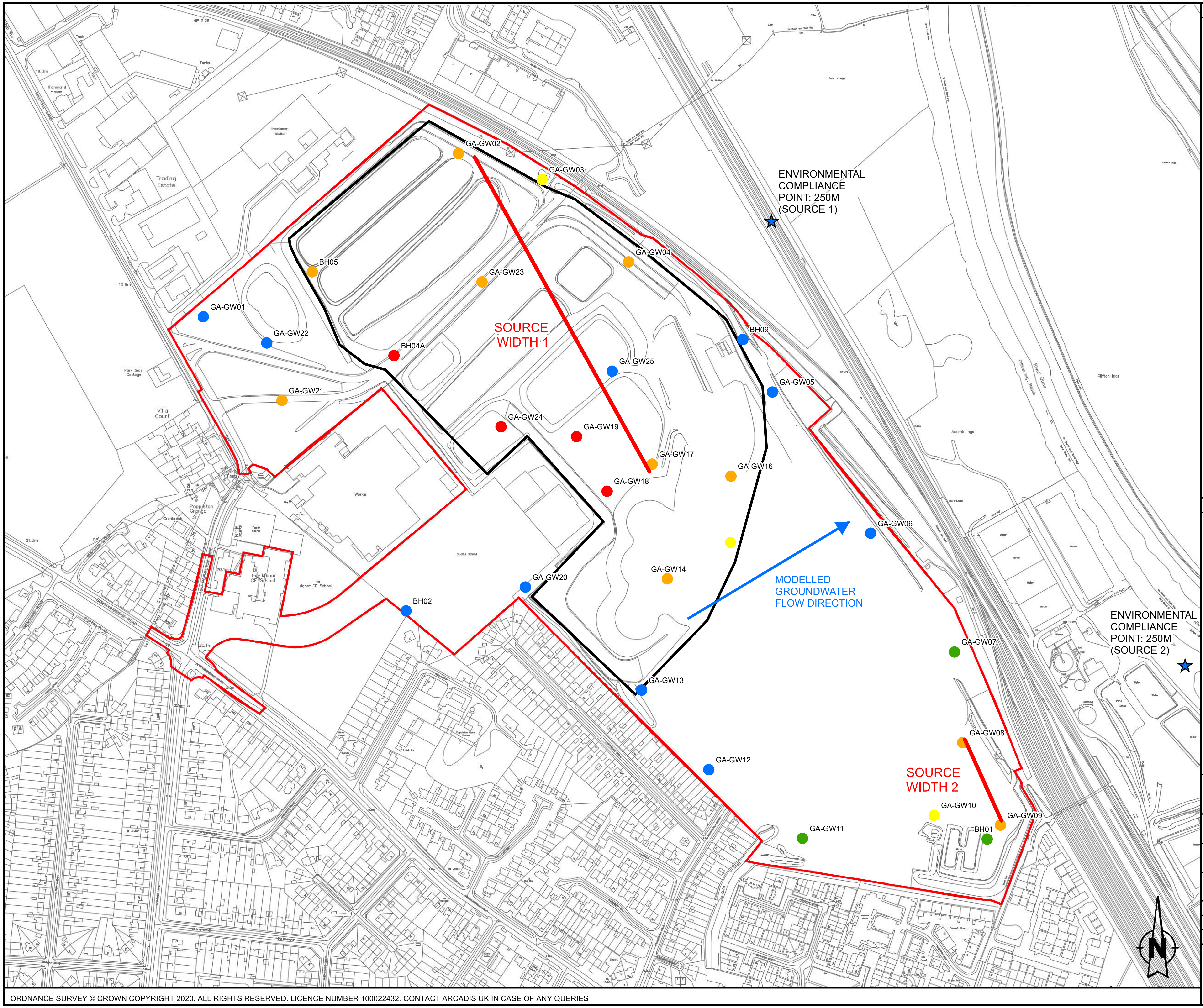

LEGEND

🟥 SITE BOUNDARY
⬛ ENVIRONMENTAL PERMIT AREA
🔵 MDL- 0.1mg/l
🟢 0.1 - 1.0 mg/l
🟡 1.0 - 10 mg/l
🟠 10.0 - 100 mg/l
🔴 > 100 mg/l
★ ENVIRONMENTAL CPMPLIANCE POINT
— MODELLED SOURCE WIDTH

NOTES

SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE.

CONCENTRATIONS OF AMMONIACAL NITROGEN MEASURED IN GROUNDWATER SAMPLED IN JUNE 2019 (GOLDERS 2019B), WITH THE EXCEPTION OF BH01, GA-GW07 - GA-GW13, WHICH WERE SAMPLED IN APRIL 2009 (GOLDER, 2010)

0 15 30 60 90 120 150 Metres
N

TITLE:
DISTRIBUTION OF AMMONIACAL NITROGEN IN GROUNDWATER (mg/l), SOURCE WIDTH AND COMPLIANCE POINT

SITE :
BRITISH SUGAR YORK

CLIENT :
BRITISH SUGAR

PROJECT : **10024487** | **FIGURE 3**
DATE : 30/01/20 | DRAWN BY : AP
DRG No. : 10024487-AUK-XX-XX-DR-ZZ-0024-P1 GIS
SCALE : **1 : 4,000** | PRINT : **A3**

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Figure 4a - Ammoniacal Nitrogen Over Time: Up-gradient Wells

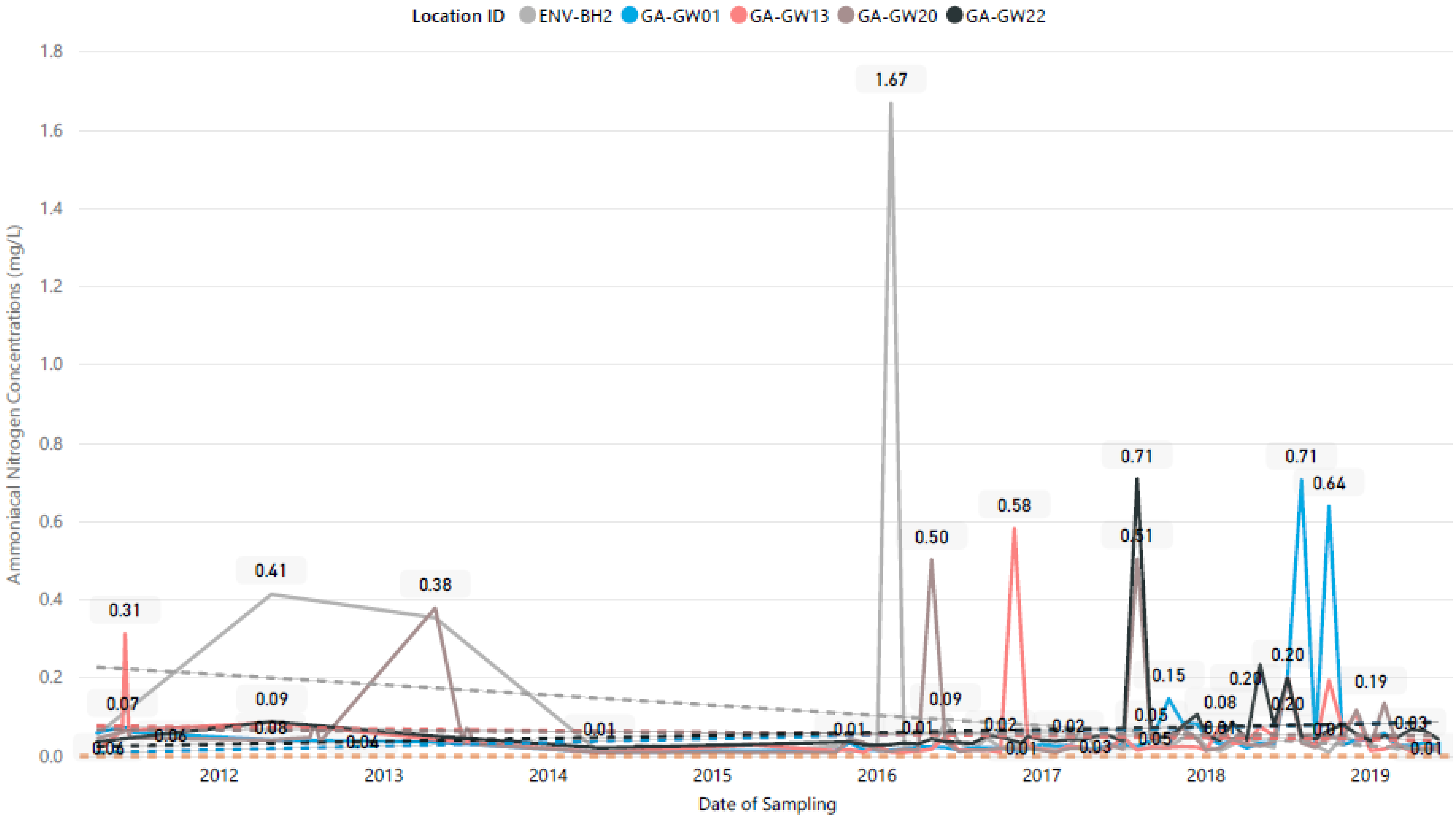

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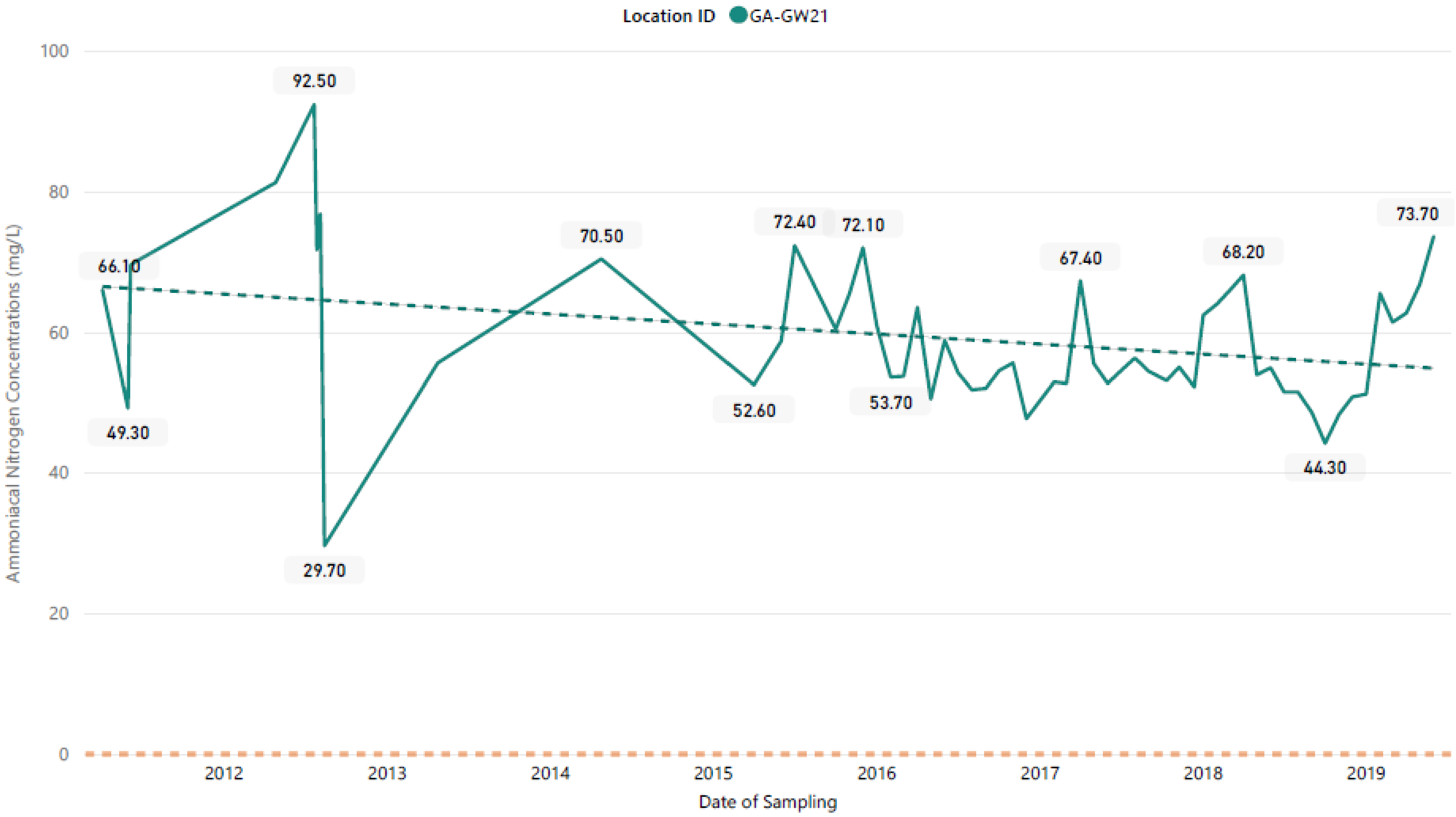
Figure 4b - Ammoniacal Nitrogen Over Time: Up-gradient Wells



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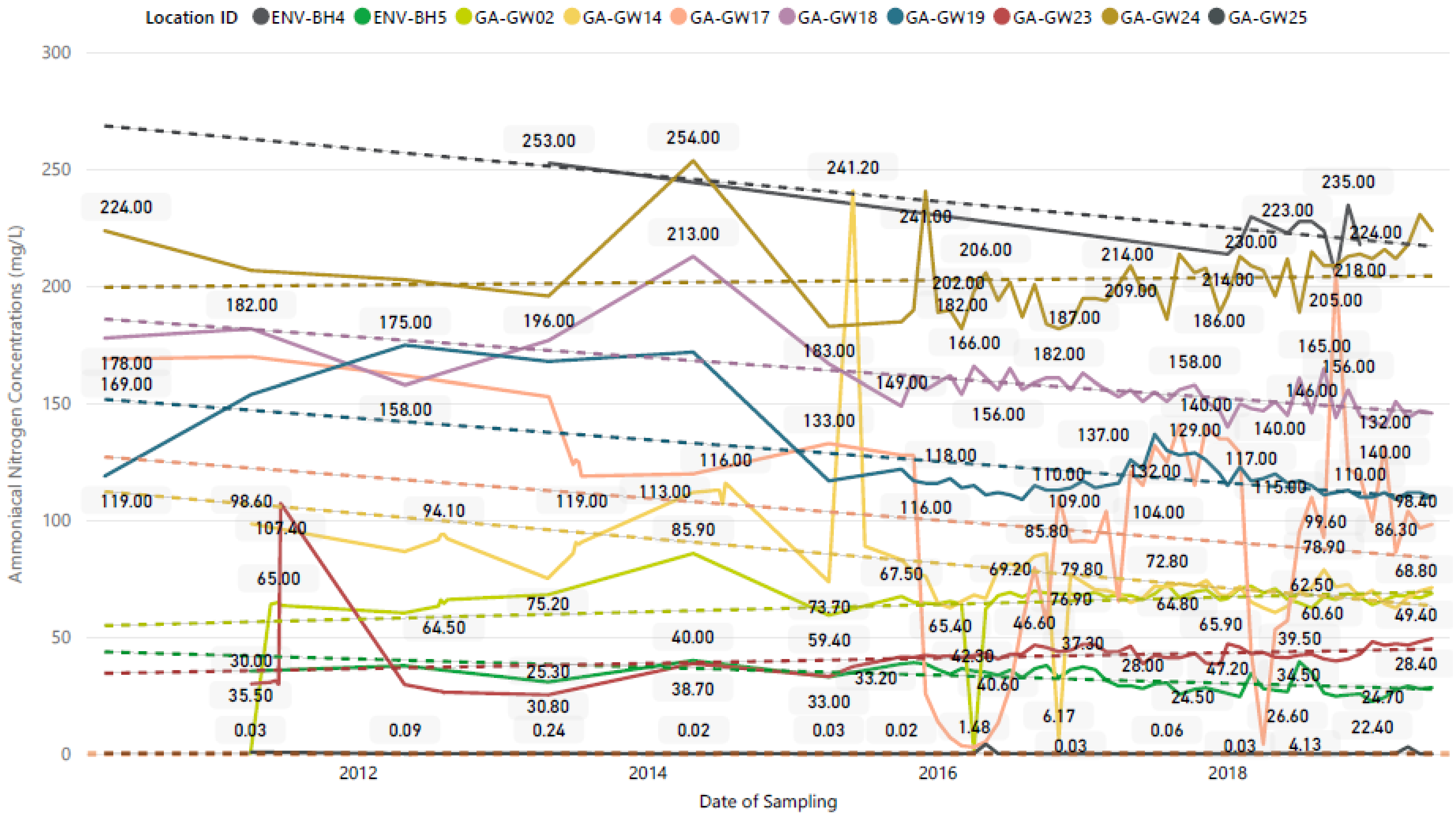
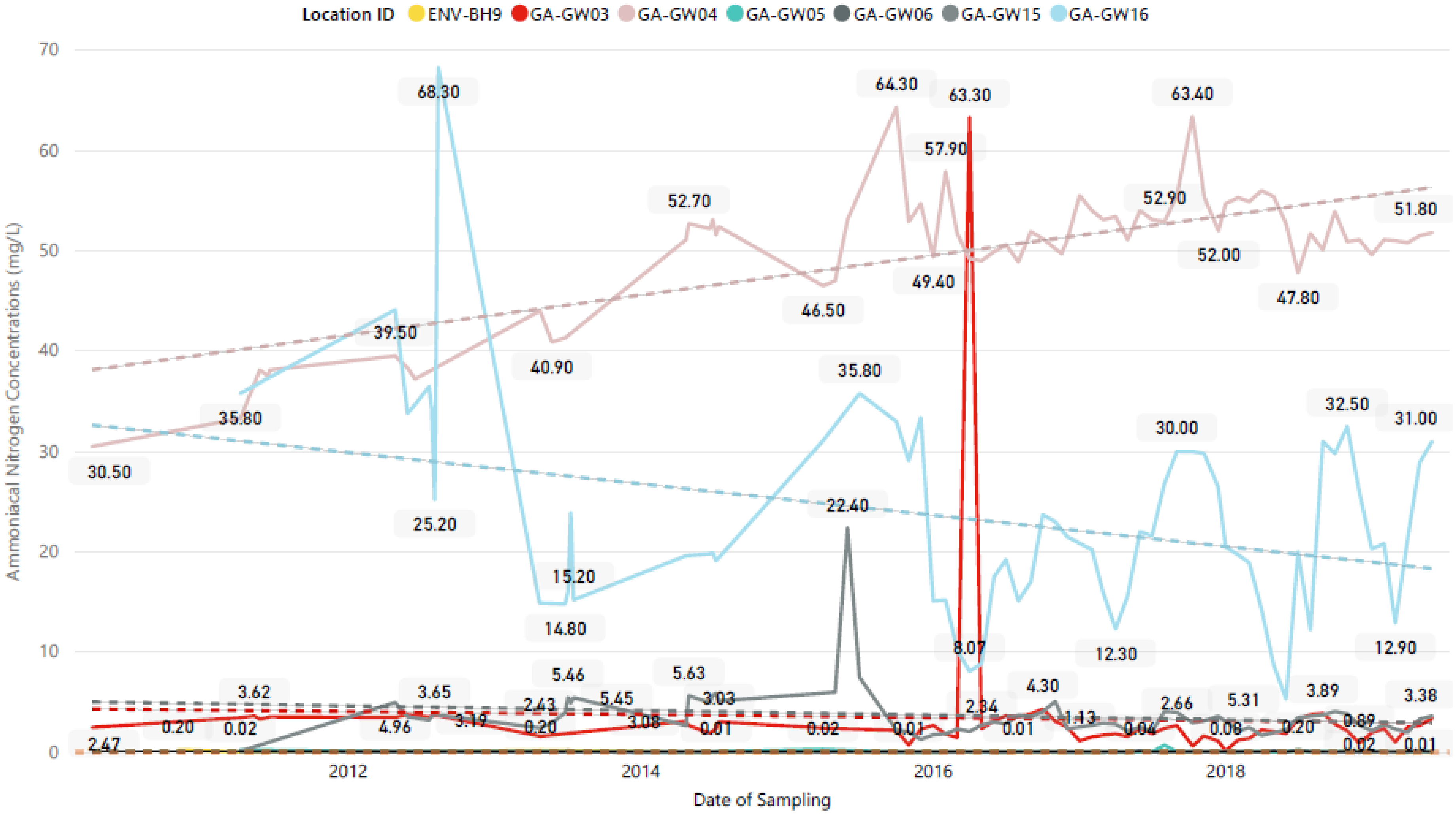
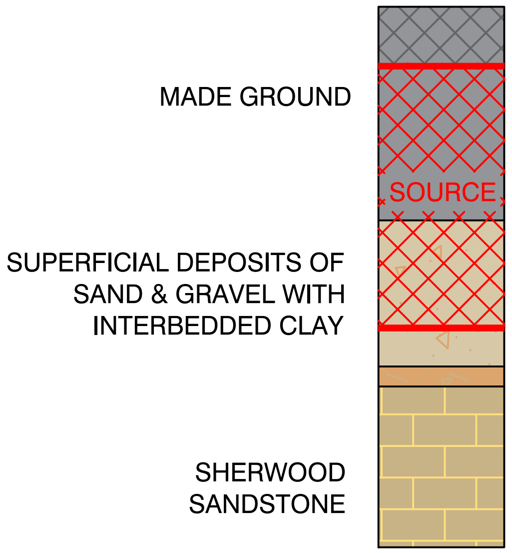


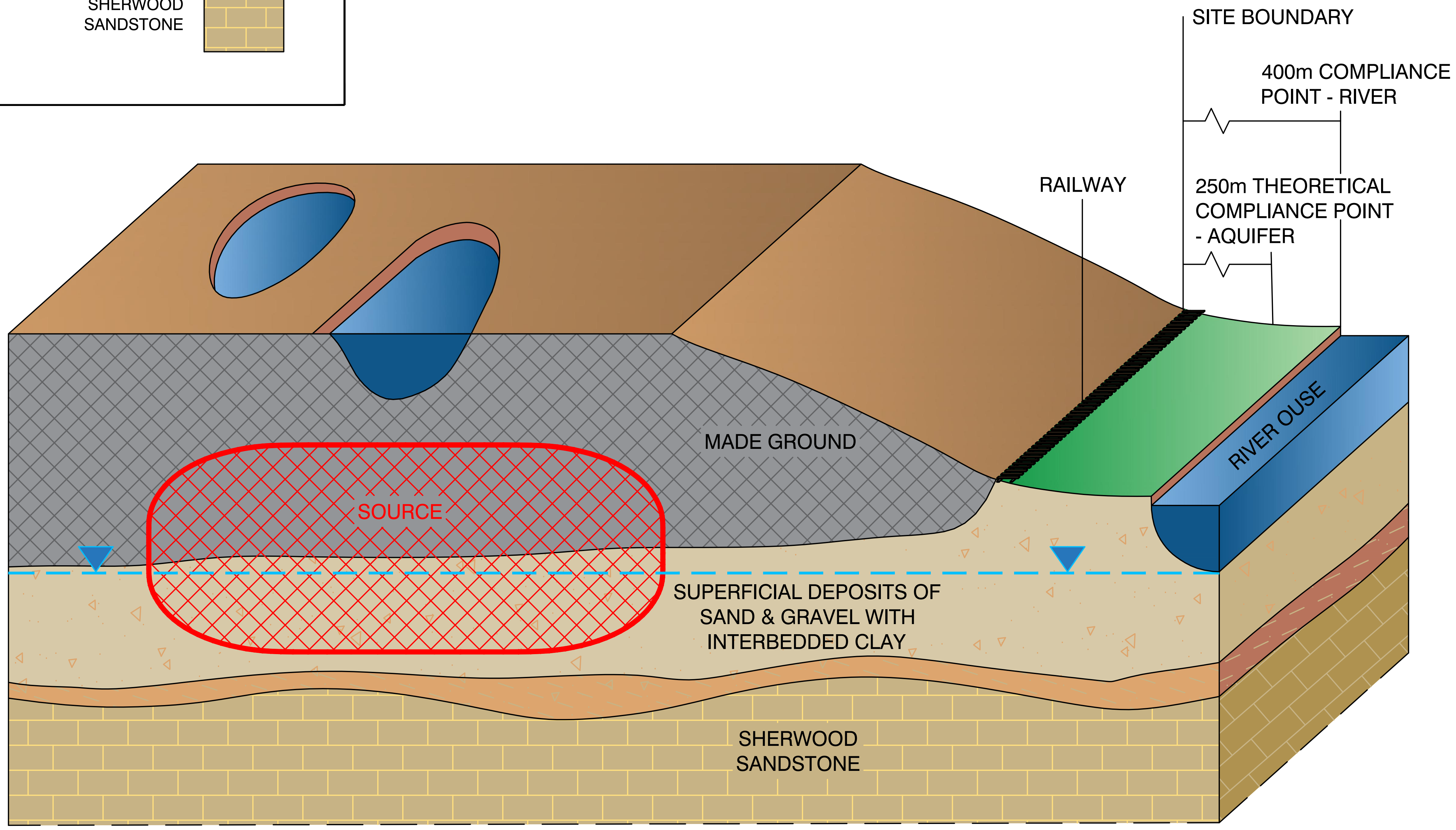
Figure 5 - Ammoniacal Nitrogen Over Time: On-Site Wells

Figure 6 - Ammoniacal Nitrogen Over Time: Down-Gradient Wells





Conceptual Zone	Physical Characteristics	Justification
Saturated Zone	Sand & Gravel	Representative of the deposits ecountered beneath the site through which off-site migration of groundwater in anticapted to take place.



KEY

- - - GROUNDWATER LEVEL

REV	DATE	COMMENT	CAD

TITLE: CONCEPTUAL SITE MODEL

SITE: BRITISH SUGAR YORK

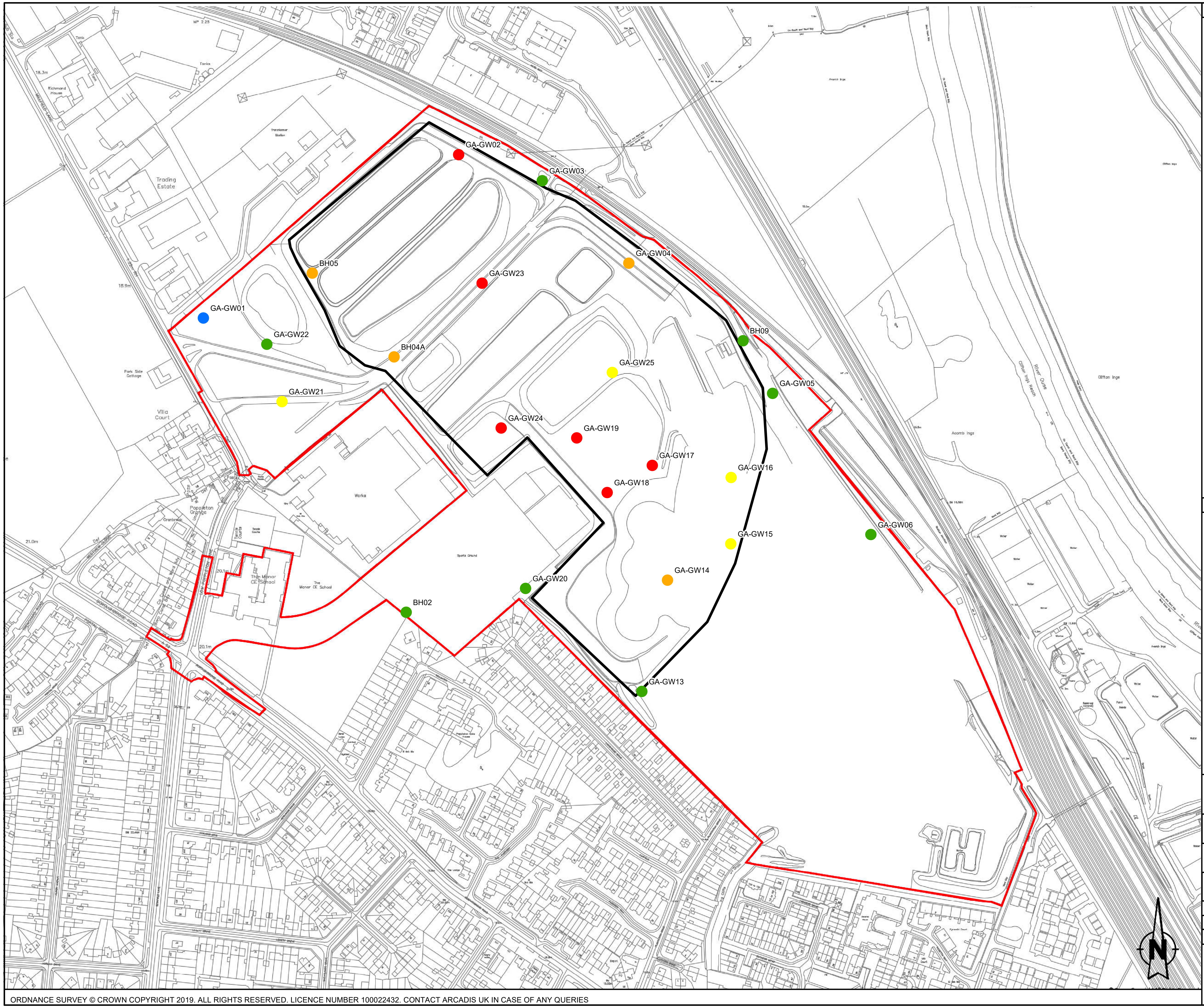
CLIENT: BRITISH SUGAR

PROJECT: 10024487 FIGURE 7

DATE: 12/11/19 DRAWN: JC REV: -

DRG.No.: 10024487-AUK-XX-XX-DR-ZZ-0021 PRINT: A3

NOTE: ALL ENTITIES SHOWN ON THIS DRAWING ARE TO BE REGARDED AS APPROXIMATE AND ARE INDICATIVE ONLY. NO MEASUREMENTS TAKEN FROM THIS DRAWING SHOULD BE USED FOR THE LOCATION OF INTRUSIVE INVESTIGATION WORKS ON SITE. SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE. - CONTACT ARCADIS UK IN CASE OF ANY QUERY



LEGEND

🟥 SITE BOUNDARY
⬛ ENVIRONMENTAL PERMIT AREA
🔴 < MDL
🟠 MDL- 1 mg/l
🟡 1 - 10 mg/l
🟢 10 - 50 mg/l
🔵 > 50 mg/l

NOTES

SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE.

CONCENTRATIONS OF NITRATE MEASURED IN GROUNDWATER SAMPLED IN JUNE 2019 (GOLDERS 2019B)

0 15 30 60 90 120 150 Metres

N

TITLE: **DISTRIBUTION OF NITRATE IN GROUNDWATER (mg/l)**

SITE : **BRITISH SUGAR YORK**

CLIENT : **BRITISH SUGAR**

PROJECT : **10024487** **FIGURE 8**

DATE : 15/11/19 DRAWN BY : AP

DRG No. : 10024487-AUK-XX-XX-DR-ZZ-0025-P1 GIS

SCALE : **1 : 4,000** PRINT : **A3**

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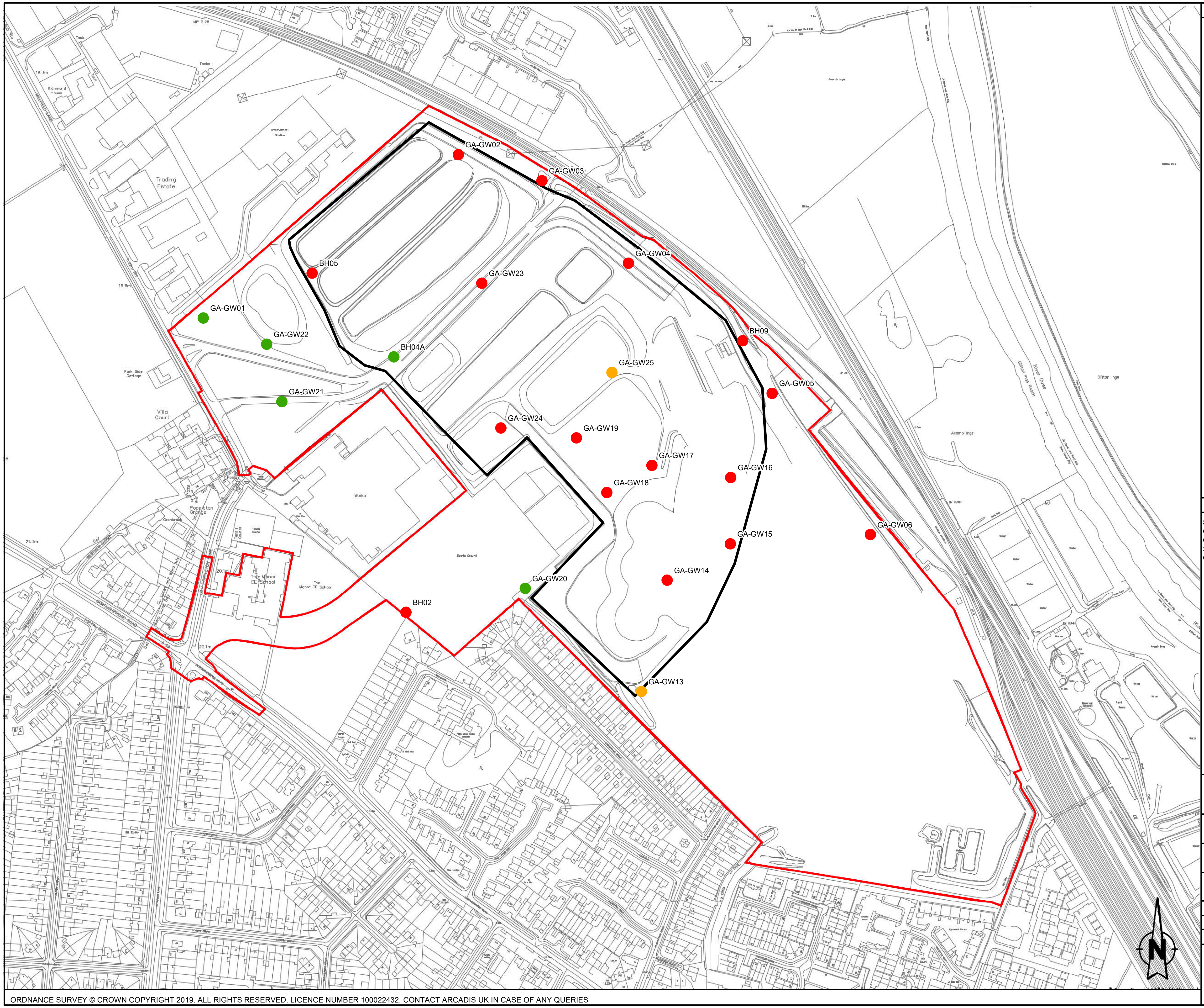

LEGEND

□ SITE BOUNDARY

□ ENVIRONMENTAL PERMIT AREA

● < MDL

● MDL - 0.1 mg/l

● 0.1 - 1 mg/l

● > 1 mg/l

NOTES

SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE.

CONCENTRATIONS OF NITRITE MEASURED IN GROUNDWATER SAMPLED IN JUNE 2019 (GOLDERS 2019B)

0 15 30 60 90 120 150 Metres

N

TITLE: **DISTRIBUTION OF NITRITE IN GROUNDWATER (mg/l)**

SITE : **BRITISH SUGAR YORK**

CLIENT : **BRITISH SUGAR**

PROJECT : **10024487** **FIGURE 9**

DATE : 15/11/19 DRAWN BY : AP

DRG No. : 10024487-AUK-XX-XX-DR-ZZ-0026-P1 GIS

SCALE : 1 : 4,000 PRINT : A3

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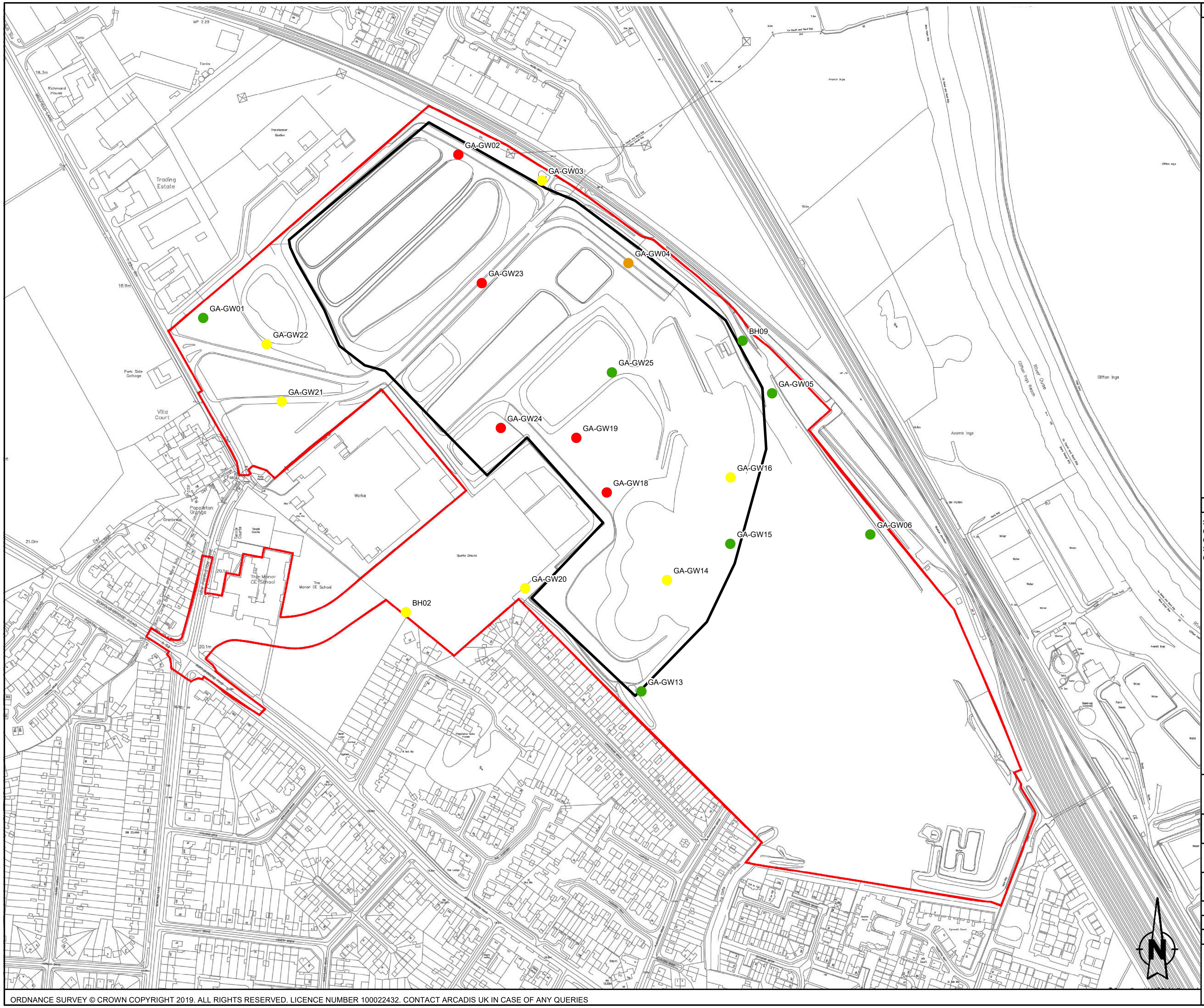

LEGEND

🟥 SITE BOUNDARY

⬛ ENVIRONMENTAL PERMIT AREA

🔵 0 to -50 mV

🟢 -50 to -100 mV

🟡 -100 to - 150 mV

🟠 -150 to - 200 mV

🔴 < -200 mV

NOTES

SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE.

ORP MEASURED IN GROUNDWATER SAMPLED IN JUNE 2019 (GOLDERS 2019B)

0 15 30 60 90 120 150 Metres

N

TITLE: **DISTRIBUTION OF OXIDATION REDUCTION POTENTIAL IN GROUNDWATER (mg/l)**

SITE : **BRITISH SUGAR YORK**

CLIENT : **BRITISH SUGAR**

PROJECT : **10024487** **FIGURE 10**

DATE : 15/11/19 DRAWN BY : AP

DRG No. : 10024487-AUK-XX-XX-DR-ZZ-0027-P1 GIS

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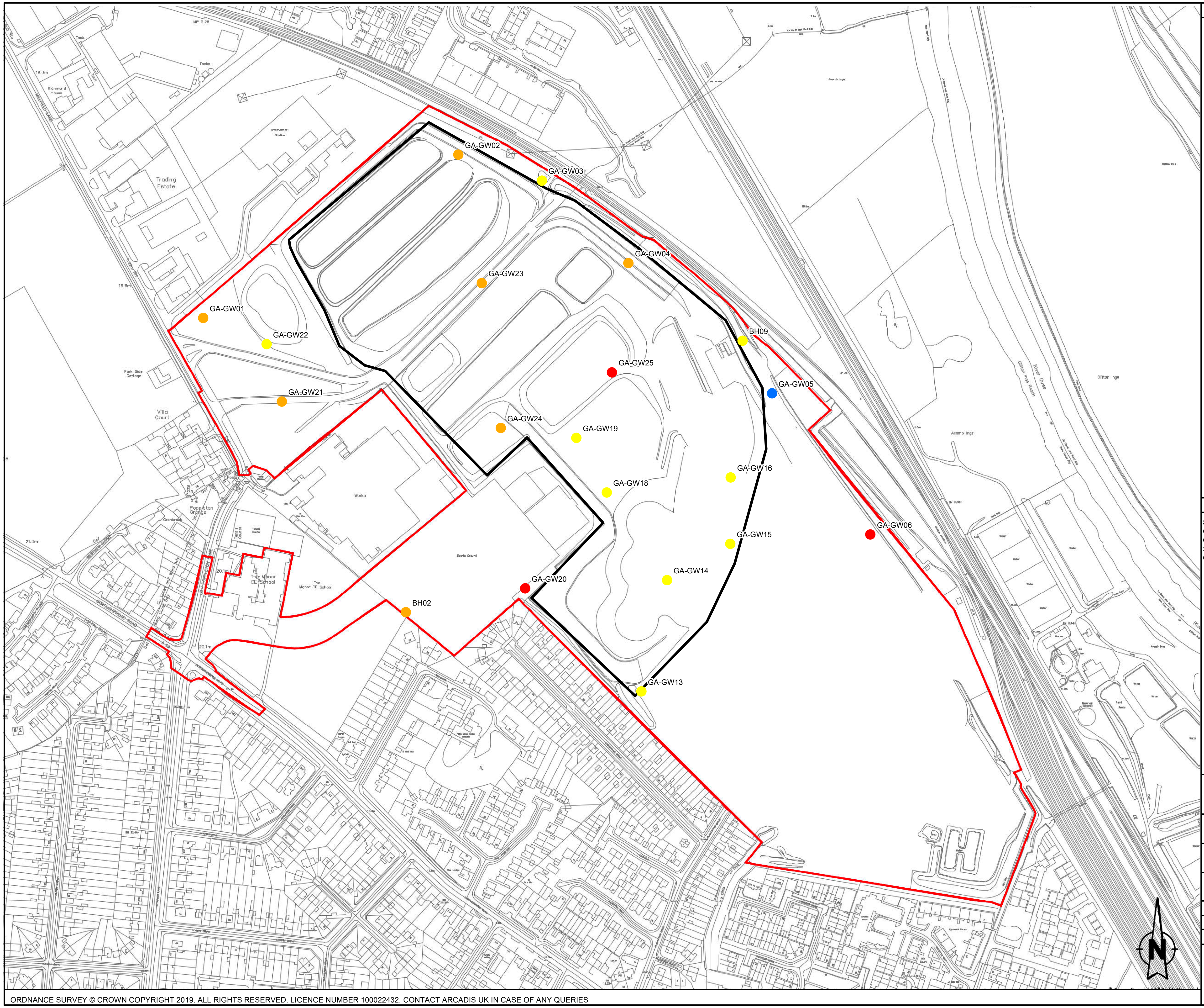


LEGEND

▭ SITE BOUNDARY

▭ ENVIRONMENTAL PERMIT AREA

🔴 < 0.5 ppm

🟠 0.5 - 1 ppm

🟡 1 - 5 ppm

🟢 5 - 10 ppm

🔵 > 10 ppm

NOTES

SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE.

DISSOLVED OXYGEN MEASURED IN GROUNDWATER SAMPLED IN JUNE 2019 (GOLDERS 2019B)

0 15 30 60 90 120 150 Metres

N

TITLE:
DISTRIBUTION OF DISSOLVED OXYGEN IN GROUNDWATER

SITE :
BRITISH SUGAR YORK

CLIENT :
BRITISH SUGAR

PROJECT :	**10024487**	**FIGURE 11**	
DATE :	15/11/19	DRAWN BY :	AP
DRG No. :	10024487-AUK-XX-XX-DR-ZZ-0028-P1 GIS		
SCALE :	**1 : 4,000**	PRINT :	**A3**

ARCADIS Design & Consultancy for natural and built assets

TABLES

Table 1: Updated Site Specific Assessment Criteria (SSAC) for Groundwater (mg/l)

Contaminant of Concern	Updated Water Resources SSAC (mg/l)			
	Source 1 - Aquifer	Source 1 - Surface Water	Source 2 - Aquifer	Source 2 - Surface Water
	250m Compliance Point	400m Compliance Point	250m Compliance Point	250m Compliance Point
Ammoniacal Nitrogen	256	3520	308	370

Notes:

SSAC	Site Specific Assessment Criteria

Table 2: Comparison of Measured Concentrations of Ammoniacal Nitrogen in Groundwater (mg/l) with Updated SSAC for Source 1

Monitoring Well Location*	Updated Water Resources SSAC (mg/l)		GA-GW21	BH04A	BH05	GA-GW02	GA-GW14	GA-GW17	GA-GW18	GA-GW19	GA-GW23	GA-GW24	GA-GW25	GA-GW04
Sample Identity	Source 1 - Aquifer	Source 1 - Surface Water												
Sample Date	250m Compliance Point	400m Compliance Point	11.06.2019	15.05.2019	11.06.2019	11.06.2019	12.6.2019	11.06.2019	11.06.2019	11.06.2019	13.6.2019	11.06.2019	12.06.2019	12.6.2019
Ammoniacal Nitrogen	256	3520	73.7	231	28.4	68.8	71.3	98.4	146	110	49.4	224	0.0278	51.8

Notes:

SSAC	Site Specific Assessment Criteria
*	Only monitoring wells considered to be located within the source area have been included in the comparison. These have been selected independently to the designation of locations within the permit (e.g. GA-GW21 i considered to be up-gradient according to the permit but review of the data suggests it is located within the source)

Table 3: Comparison of Measured Concentrations of CoC in Groundwater (mg/l) with Updated SSAC for Source Area 2

Sample Identity	Updated Water Resources SSAC (mg/l)		GA-GW08	GA-GW09	GA-GW10
	Source 2 -Aquifer	Source 2 - Surface Water			
Sample Date	250m Compliance Point	250m Compliance Point	08.04.09	08.04.09	07.04.09
Ammoniacal Nitrogen	308	370	48	69	10

Notes:

SSAC	Site Specific Assessment Criteria

APPENDICES

APPENDIX A

Arcadis' Study Limitations

IMPORTANT. This section should be read before reliance is placed on any of the information, opinions, advice, recommendations or conclusions contained in this report.

1 This report has been prepared by Arcadis (UK) Limited (‘Arcadis’), with all reasonable skill, care and diligence within the terms of the Appointment and with the resources and manpower agreed with British Sugar (the ‘Client’). Arcadis does not accept responsibility for any matters outside the agreed scope.

2 This report has been prepared for the sole benefit of the Client unless agreed otherwise in writing. otherwise in writing. The contents of this report may not be used or relied upon by any person other than this party without the express written consent and authorisation of Arcadis.

3 Unless stated otherwise, no consultations with authorities or funders or other interested third parties have been carried out. Arcadis is unable to give categorical assurance that the findings will be accepted by these third parties as such bodies may have unpublished, more stringent objectives. Further work may be required by these parties.

4 All work carried out in preparing this report has used, and is based on, Arcadis’ professional knowledge and understanding of current relevant legislation. Changes in legislation or regulatory guidance may cause the opinion or advice contained in this report to become inappropriate or incorrect. In giving opinions and advice, pending changes in legislation, of which Arcadis is aware, have been considered. Following delivery of the report, Arcadis has no obligation to advise the Client or any other party of such changes or their repercussions.

5 This report is only valid when used in its entirety. Any information or advice included in the report should not be relied upon until considered in the context of the whole report.

6 Whilst this report and the opinions made are correct to the best of Arcadis’ belief, Arcadis cannot guarantee the accuracy or completeness of any information provided by third parties. provided by third parties. Arcadis has taken reasonable steps to ensure that the information sources used for this assessment provided accurate information, and has therefore assumed this to be the case.

7 This report has been prepared based on the information reasonably available during the project programme. All information relevant to the scope may not have been received.

8 This report refers, within the limitations stated, to the condition of the Site at the time of the inspection. No warranty is given as to the possibility of changes in the condition of the Site since the time of the investigation.

9 The content of this report represents the professional opinion of experienced environmental consultants. Arcadis does not provide specialist legal or other professional advice. The advice of other professionals may be required.

10 Where intrusive investigation techniques have been employed they have been designed to provide a reasonable level of assurance on the conditions. Given the discrete nature of sampling, no investigation technique is capable of identifying all conditions present in all areas. In some cases the investigation is further limited by Site operations, underground obstructions and above ground structures. Unless otherwise stated, areas beyond the boundary of the Site have not been investigated.

11 If below ground intrusive investigations have been conducted as part of the scope, safe location of exploratory holes has been carried out with reference to the Arcadis ground disturbances procedure. No guarantee can be given that all services have been identified. Additional services, structures or other below ground obstructions, not indicated on the drawing, may be present on Site.

12 Unless otherwise stated the report provides no comment on the nature of building materials, operational integrity of the facility or on any regulatory compliance issues.

13 Unless otherwise stated, an inspection of the Site has not been undertaken and there may be conditions present at the Site which have not been identified within the scope of this assessment.

14 Unless otherwise stated, samples from the Site (soil, groundwater, building fabric or other samples) have not been obtained.

15 Arcadis has relied upon the accuracy of documents, oral information and other material and information provided by the Client and others, and Arcadis assumes no liability for the accuracy of such data, although in the event of apparent conflicts in information, Arcadis would highlight this and seek to resolve.

16 Unless otherwise stated, the scope of works has not included an environmental compliance review, health and safety compliance review, hazardous building materials assessment, interviews or contacting Local Authority, requests for information to the petroleum officer, sampling or analyses of soil, ground water, surface water, air or hazardous building materials or a chain of title review.

17 Unless otherwise stated, this assessment has considered the ongoing use of the Site and has not been prepared for the purposes of redevelopment which may act as a trigger for Site investigation and remediation works not needed for ongoing use.

APPENDIX B

Comparison of Measured Concentrations of CoC measured in Groundwater with DWS, EQS, MRV and UKTAG values

British Sugar, York

Appendix B: Comparison of Measured Concentrations of CoC measured in Groundwater with DWS, EQS, MRV and UKTAG values

Compound	Units	Water Resources DWS	Water Resources EQS	MRV / UKTAG value	Maximum Measured Concentration[1]	Further Consideration required in relation to aquifer water resources?	Further Consideration required in relation to surface water resources?	Further Consideration required in relation to MRV / UKTAG value?
		Aquifer	Surface Water					
Aliphatic TPH								
>C_{12}-C_{16}	ug/l	-	-	-	<10	No	No	No
>C_{16}-C_{35}	ug/l	-	-	-		No	No	No
Aromatic TPH								
>EC_{12}-EC_{16}	ug/l	-	-	-	<10	No	No	No
>EC_{16}-EC_{21}	ug/l	-	-	-	70	No*	No*	No
>EC_{21}-EC_{35}	ug/l	-	-	-	<10	No	No	No
VOC								
Phenol	ug/l	5800[5]	7.7	-	18.8	No**	No**	No
Cresols	ug/l	1500[5]	100[6]	-	84.8	No	No	No
Metals and Inorganics								
Arsenic	ug/l	10	50	5[8]	***33***	No***	No	No***
Cadmium	ug/l	5	0.09[2]	0.1[7]	***0.176***	No	No****	No****
Nickel	ug/l	20	4	-	327	Yes	Yes	Yes
Ammoniacal Nitrogen	mg/l	0.5[3]	0.6[4]	-	68.8	Yes	Yes	Yes
Nitrate	mg/l	50	-	-	39.5	No	No	No
Nitrite	mg/l	0.50	-	-	<0.05	No	No	No
Sulphate	mg/l	250	400	-	75.3	No	No	No
PAH								
Naphthalene	ug/l	2.00	2.00	-	0.0218	No	No	No
Acenaphthylene	ug/l	-	-	-	<0.005	No	No	No
Acenaphthene	ug/l	-	-	-	0.0112	No*****	No*****	No
Fluorene	ug/l	-	-	-	0.0125	No*****	No*****	No
Phenanthrene	ug/l	-	-	-	<0.005	No	No	No
Anthracene	ug/l	-	-	0.05[8]	<0.005	No	No	No
Fluoranthene	ug/l	-	-	-	<0.005	No	No	No
Pyrene	ug/l	-	-	-	0.0053	No*****	No*****	No
Benzo(a)anthracene	ug/l	-	-	-	<0.005	No	No	No
Chrysene	ug/l	-	-	-	<0.005	No	No	No
Benzo(b)fluoranthene	ug/l	0.025	-	0.05[8]	<0.005	No	No	No
Benzo(k)fluoranthene	ug/l	0.025	-	0.05[8]	<0.005	No	No	No
Benzo(a)pyrene	ug/l	0.01	0.00017	0.005[8]	<0.002	No	No	No
Indeno(123cd)pyrene	ug/l	0.025	-	-	<0.005	No	No	No
Dibenzo(ah)anthracene	ug/l	-	-	-	<0.005	No	No	No
Benzo(ghi)perylene	ug/l	0.025	-	0.05[8]	<0.005	No	No	No

Notes:

Concentrations of contaminants of concern in groundwater sampled from the boundary wells: BH09, GAGW02, GAGW03, GAGW04, GAGW05 and GAGW06 in June 2019 have been compared to drinking water standards where available to assess the risk to the Secondary A Aquifer. Environmental Quality Standards have been used to assess the risk to the River Ouse where available, unless otherwise stated. Concentrations have additionally been compared to the MRV and UKTAG values, where available. Where these were unavailable, comments in relation to the assessment of water resources are considered applicable.

DWS	Drinking Water Standard - adopted from The Water Supply (Water Quality) Regulations 2018, unless otherwise stated
EQS	Environmental Quality Standard - adopted from the Water Framework Directive, 2015, unless otherwise stated
MDL	Method Detection Limit
MRV	Minimum reporting value
UKTAG	UK Technical Advisory Group on the Water Framework Directive
[1]	Maximum concentration of compound measured in groundwater boundary wells sampled in June 2019 (Golders BS York Monitoring Q2 2019 Report)
[2]	Amended based on the water hardness for the Site which was determined using Yorkshire Water's 'Check you water hardness' 2018 annual average for calcium. (96.8mg/l)
[3]	UK DWS for ammonium, as reported in The Water Supply (Water Quality) Regulations 2018
[4]	Compliance criteria from the Water Framework Directive protective of a 'good' status for a 'Type 3' River (altitude of less the 80m and 50 to over 100 mg/l of $CaCO_3$).
[5]	Adopted from the US EPA Region 9 Screening Levels for Tapwater, April 2019
[6]	Proposed Environmental Quality Standard
[7]	MRV as defined by the Environment Agency (https://www.gov.uk/government/publications/values-for-groundwater-risk-assessments/hazardous-substances-to-groundwater-minimum-reporting-values)
[8]	UK TAG *"Concentrations in groundwater below which the danger of deterioration in the quality of the receiving groundwater is avoided".*
-	No water quality standard / value identified
🟦	Maximum measured concentration in excess of the water quality standard
🟦	Maximum measured concentration in excess of the water quality standard and MRV / UKTAG value
🟨	Further consideration given in the main text of the report
🟩	Further consideration given in Appendix I and H
*	DWS and EQS values are not available for individual fractions of Total Petroleum Hydrocarbons and only heavy end hydrocarbons fractions have been tested for. Concentrations of TPH aromatic fraction EC16 to EC21 have been measured above the method detection limit (MDL) in groundwater sampled from boundary wells however concentrations are in the same order of magnitude as the MDL. Review of the last three sets of data (collected in April, May and June 2019) indicates that concentrations of TPH aromatic fraction EC16 to EC21 have fluctuated between less than MDL and 78ug/l (BH09 in May 2019) over the three months. Given that the concentrations measured are in the same order of magnitude as the MDL and that concentrations measured above the MDL have not consistently measured in groundwater, the risk to controlled waters is not considered to be significant, and aromatic EC16 - EC21 has not been considered further.
**	Groundwater sampled from GA-GW03 only, was in excess of the DWS and EQS for phenol. On review of the trends in phenol concentrations in groundwater at GA-GW03, concentrations have been less than the water quality standards every month for the last three years. On this basis, measured concentrations of phenol are not considered to represent a significant risk to water resources and phenol has not been
***	Arsenic has been measured at concentrations above the water quality standards protective of the aquifer and UKTAG value in two of the six groundwater samples tested from the site boundary. Measured concentrations of arsenic in the remaining four groundwater samples were two orders of magnitude below the DWS and one order of magnitude below the UKTAG value. Given that the concentrations are generally marginally in excess of the compliance criteria and are relatively isolated, the risk to identified water resource receptors is not considered to be signficiant and has not been considered further.
****	Concentrations of cadmium have been measured above the compliance criteria for surface water in two of the six groundwater samples tested from the site boundary and above the MRV in one of six samples. The concentrations in excess are within an order of magntiude of the compliance critera / MRV and are considered to be marginal. Given this, and that the concentrations in excess are relatively isolated (2 and 1 samples of 6 samples along the boundary, respectively), the risk to the River Ouse is not considered to be signficiant with further consideration of cadmium not considered warranted.
*****	DWS and EQS data is not available for all the PAH. However, typically PAH were not detected above the laboratory MDL, or where detected were below the EQS or DWS, where

APPENDIX C

Chemical Input Parameter Values

Appendix C: Chemical Input Parameter Values

Contaminant	Soil Water Partition Coefficient (Kd) (l/kg)	Half Life
Symbol	Kd	$t_{1/2}$
Units	l/kg	days
Ammoniacal Nitrogen	0.4[1]	2190[2]

Notes

Sources:

[1] A review of literature sources providing values for the soil water partition coefficient for ammoniacal nitrogen was undertaken. Buss et al (2004) give a triangular distribution in Kd of 0-0.4-0.9 for a 'clean' sand and gravel for ammonium, with a range of 0.4 to 0.9 for a clayey sand and gravel. The Kd value used in URS 2015 was sourced from ConSim which presents a range in Kd for a sand of 0.5 and 2 (siting the original reference of Golder Associates 25/5/95 and Entenmann W, Foundation Engineering and Environmental Technology). Given that the value adopted by URS represents the upper end of the range presented by Buss et al (which is based on a review of multiple literature sources) a Kd of 0.4 has been selected to represent the mode.

[2] Buss et al (2004) present a half life of 1 to 6 years for ammonium in sands and gravel under aerobic conditons, while degradation is not indicated to occur under anaerobic conditions. Further discussion on degradation is presented in Section 5.3.2.1 of the main report. Aerobic conditions are anticipated to be present, and as such, a half life of 6 years (2190 days) has been adopted.

APPENDIX D

Sensitivity Testing

Appendix D
Sensitivity Testing

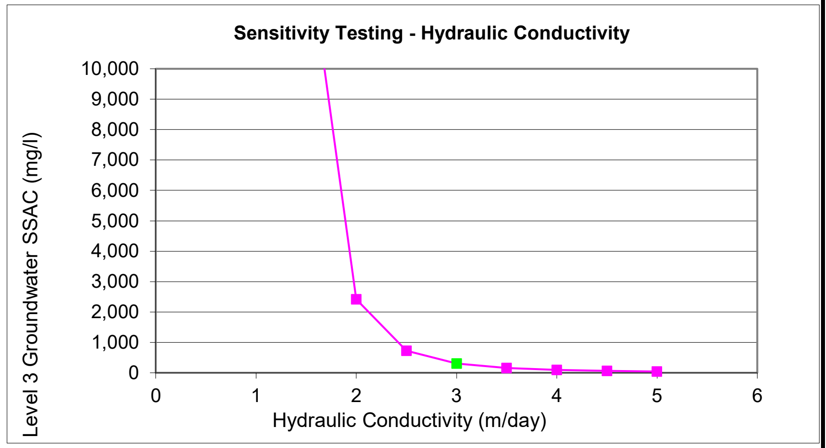
To account for the inherent uncertainty present when simplifying the environment for modelling purposes, a range of values was specified for each parameter adopted within the assessment. The RTW model is set up using a value from each of the ranges for the water resource; this value is not necessarily the final chosen value.

Each parameter is modified, one at a time, whilst maintaining the remaining parameters at the starting values to identify which parameters have the greatest effect on the site model.

The process is repeated to ensure the site model is appropriate for the site conditions. The RTW model was setup with the chemical parameters for ammoniacal nitrogen. The range in input values and sensitivity of each parameter are presented on the following sheets.

Parameter	Range	Data Source
Hydraulic Conductivity (m/day)	0.5 to 5	Site specific data available from 11 slug tests (Golders, 2009 Definite Closure Report) indicates a minimum hydraulic conductivity of 0.11m/day (measured in GA-GW19) and a maximum of 190m/day (measured in GA-GW11). The geometric mean hydraulic conductivity reported for the slug tests was 1.0m/day. Given the large range of hydraulic conductivities calculated for the Site, emphasis has been put on the geometric mean when selecting the range for sensitivity testing. Further, that hydraulic gradient and hydraulic conductivity are intrinsically linked, with the highest hydraulic conductivity calculated by third parties considered unsustainable based on the hydraulic gradient calculated for the Site. As such, a range in hydraulic conductivity of 0.5 to 5m/day was selected for sensitivity testing. The results of the sensitivity testing indicate that the parameter is sensitive albeit the sensitivity reduces once the hydraulic conductivity is increased beyond 2.5m/day. As such, 3m/day was selected, which is in line with the value adopted by URS based on the literature value of 3.08m/day (sandy loam, CLEA).

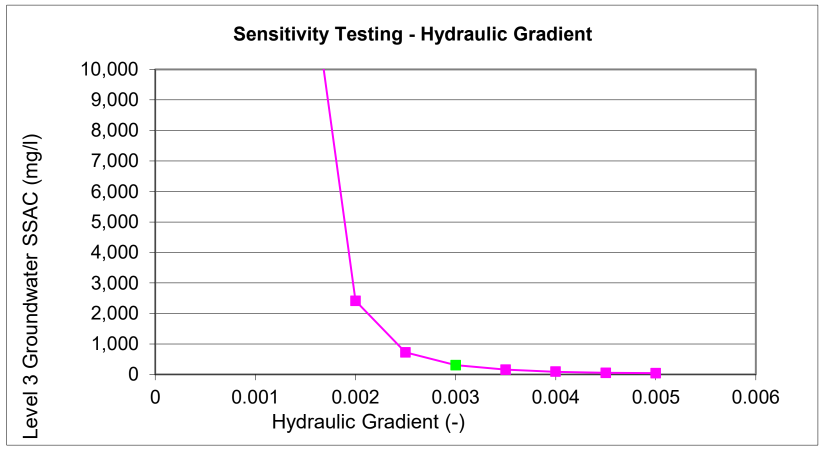
Hydraulic Conductivity (m/day) Groundwater	Level 3 Groundwater SSAC (mg/l)
0.5	3.4E+08
1	3.0E+05
1.5	14,395
2	2,418
2.5	731
3	307
3.5	158
4	93
4.5	61
5	43



Selected value highlighted green	3

Parameter	Range	Data Source
Hydraulic Gradient (-)	0.001-0.005	Hydraulic gradients were calculated using groundwater elevations measured in April 2018 in monitoring wells across the Site which screen the superficial deposits and with reference to the 'Drift Groundwater Contour Plan April 2018' presented in Golder's Annual Report 2018. The hydraulic gradients calculated were typically within the range calculated by URS 2015, which was calculated using Scott Wilson's 2010 Phase II Report, and as such a range of 0.001 to 0.005 was adopted for sensitivity testing. The results of the sensitivity testing indicate that hydraulic gradient is a sensitive parameter. A hydraulic gradient of 0.003 has been selected with consideration to the decrease in the sensitivity of the parameter when it increases above 0.0025 and to pair with the hydraulic conductivity value of 3m/day.

Hydraulic Gradient (-) Groundwater	Level 3 Groundwater SSAC (mg/l)
0.001	3.0E+05
0.0015	14,395
0.002	2,418
0.0025	731
0.003	307
0.0035	158
0.004	93
0.0045	61
0.005	43



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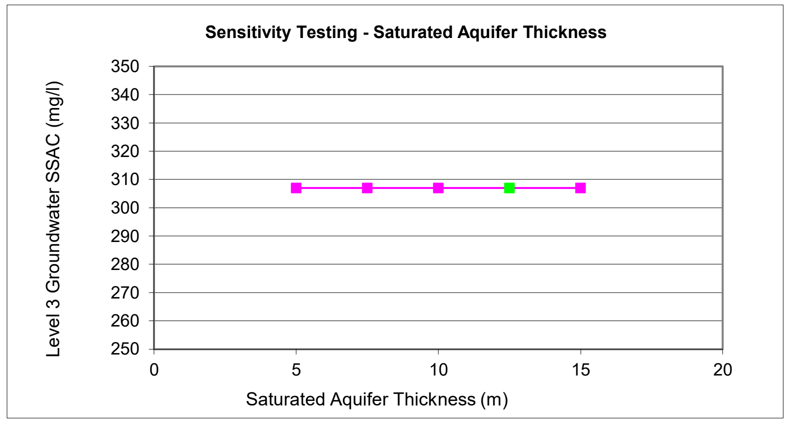
Parameter	Range	Data Source
Saturated Aquifer Thickness (m)	5 - 15	The assessment considers that the main component of flow beneath the site will occur through the superficial deposits comprising predominantly granular material. URS 2015 defined a saturated aquifer thickness of 12.5m by assuming an average groundwater level of 11.53m AOD and calculating a saturated aquifer thickness using the maximum proven base of superficial deposits (-1.01m AOD). Since then, additional data has been collected by Arcadis (2019) with four additional boreholes progressed at the Site. The average saturated aquifer thickness (with the base defined by a stiff clay) was calculated as 3.3m. A range of 5 to 15m has been defined with consideration of the Arcadis 2019 value but based predominantly on the URS 2015 value given that this was calculated using a significantly larger data set. The results of the sensitivity testing indicate that the saturated aquifer thickness is not a sensitive parameter and as such the URS 2015 value has been retained.

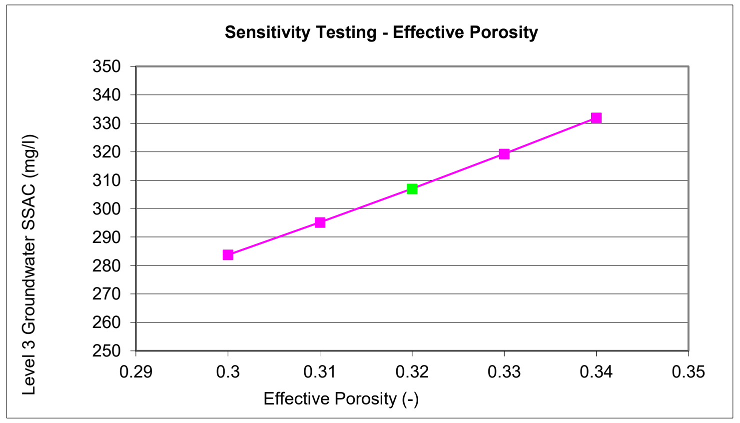
Saturated Aquifer Thickness (m) Groundwater	Level 3 Groundwater SSAC (mg/l)
5	307
7.5	307
10	307
12.5	307
15	307



Selected value highlighted green	12.5

Parameter	Range	Data Source
Effective Porosity (-)	0.3-0.34	McWorter and Sunada (1977) report a range of 0.16 to 0.46 for effective porosity for a medium sand with an arithmetic mean of 0.32. The same literature source gives a range of 0.17 to 0.44 and an arithmetic mean of 0.24 for a medium gravel, while SESOIL (2004) report an effective porosity of 0.3 for a sand. Following review of literature sources, a range of 0.3 to 0.34 was selected for sensitivity testing. The results of the sensitivity testing indicate that effective porosity is a relatively insensitive parameter. A mid value has been selected in line with the value selected by URS 2015.

Effective Porosity (-) Groundwater	Level 3 Groundwater SSAC (mg/l)
0.3	284
0.31	295
0.32	307
0.33	319
0.34	332

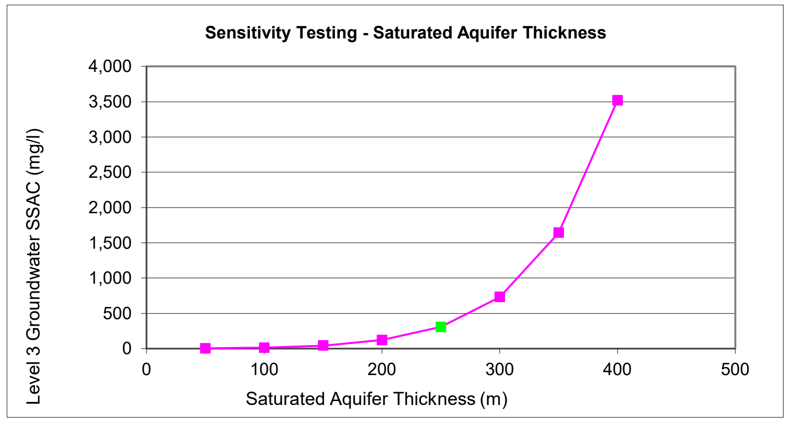


Selected value highlighted green	0.32

Appendix D
Sensitivity Testing

Parameter	Range	Data Source
Compliance Point Distance (m)	50 - 400	Both the Secondary A Aquifer underlying the Site and the River Ouse are considered to be potential controlled water receptors of concern. The compliance point of 50m used for hazardous substances, has been used to define the lower end of the range, with the distance from the site boundary in the northern part of the Site to the River Ouse (400m), used to define the upper end of the range. The compliance point used for non-hazardous substances (250m) falls comfortably within this range and as such 50-400m was considered appropriate for sensitivity testing.

Compliance Point (m)	Level 3 Groundwater SSAC (mg/l)
50	3
100	13
150	43
200	120
250	307
300	731
350	1643
400	3520



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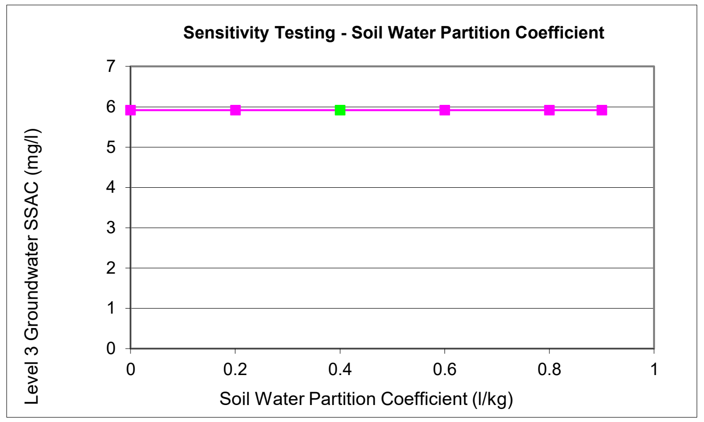
Parameter	Range	Data Source
Ammoniacal Nitrogen Soil Water Partition Coefficient - Kd (l/kg)	0 - 0.9	A review of literature sources providing values for the soil water partition coefficient for ammoniacal nitrogen was undertaken. Buss et al (2004) give a triangular distribution in Kd of 0-0.4-0.9 for a 'clean' sand and gravel for ammonium, with a range of 0.4 to 0.9 for a clayey sand and gravel. Given that lateral migration is considered to occur preferentially within the more granular lithology, a range in Kd of 0 to 0.9 has been incorporated for sensitivty testing. While Kd appears to be an insensitive value, it is considered sensitive in relation to travel time. A mid value was selected following sensitivty testing.

Soil Water Partition Coefficient (l/kg)	Level 3 Groundwater SSAC (mg/l)
0	6
0.2	6
0.4	6
0.6	6
0.8	6
0.9	6



Selected value highlig	250

APPENDIX E

Physical Input Parameter Values

British Sugar, York		
Appendix E: Physical Input Parameter Values		
Parameter	Value adopted	Comment
Aquifer Parameters (Source 1 and 2)		
Width of source (m)	400m (Source 1) 100m (Source 2)	The width of the source areas has been calculated based on site data.
Effective porosity (cm^3/cm^3)	0.32	Reviewed and selected following sensitivity testing presented in Appendix D.
Hydraulic conductivity (m/day)	3.00	Reviewed and selected following sensitivity testing presented in Appendix D.
Hydraulic gradient (m/m)	0.003	Reviewed and selected following sensitivity testing presented in Appendix D.
Saturated Aquifer Thickness (m)	12.5	Reviewed and selected following sensitivity testing presented in Appendix D.
Soil bulk density (g/cm^3)	2.08 (Source 1) 2.09 (Source 2)	In URS 2015, site specific data was used to define the soil bulk density. As an additional check, a review of literature sources was undertaken by Arcadis. ConSim (2000) reported values of 1.37 g/cm^3 to 1.81 g/cm^3 for a gravelly sand with Tomlinson (1995) reporting 1.7 g/cm^3 to 2.1 g/cm^3 for medium to coarse sands and 1.6 g/cm^3 to 2.00 g/cm^3 for a gravel. In some cases the site specific values for bulk density are higher than those suggested by literature sources however given that there is likely to be a clay component to the natural soils, the site specific values are considered appropriate. As no additional site data for bulk density has been collected, it is considered appropriate to retain the values used by URS in the 2015 Hydrogeological Risk Assessment. For Source 1 the bulk density for AA1a and AA1b of 2.08 g/cm^3 has been selected as these averaging areas form the bulk of the source area. For Source 2, 2.09g/cm^3 has been selected as averaging area AA4a forms the bulk of the second source area.
Plume thickness (m)	12.50	Adopted from URS, 2015

* Mixing depth is typically caluclated in Level 2 soil within the Remedial Targets Worksheet, which is subsequently adopted as the plume thickness. The mixing zone depth calculated within the URS 2015 report for average areas AA1a and AA1b and additionally AA4a were limited by the saturated aquifer thickness of 12.5m, with Source 1 encompassing the majority of AA1a and AA1b, and Source 2 typically consistent with AA4a. As such, the mixing zone depth of 12.5 defined within URS 2015 has been adopted as the plume thickness within the groundwater model.

APPENDIX F

Risk Assessment Methodology

Appendix F
Risk Assessment Methodology

Non-statutory Regulatory Technical Guidance

The following documents, which have been consulted in undertaking this Detailed Quantitative Risk Assessment (DQRA), present guiding principles in assessing potentially contaminated land:

General	• Model Procedures for the Management of Land Contamination, DEFRA & EA (R&D Publication CLR 11). • Land contamination: risk management, DEFRA & EA, June 2019.
Water Resources	• Remedial Targets Methodology (RTM): Hydrogeological Risk Assessment for Land Contamination (EA, 2006).

Calculating Evaluation Criteria

Water Resources

In order to estimate the risk to water resource receptors, fate and transport algorithms are used to predict a concentration at a defined receptor point, which is then compared to an appropriate water quality standard. A predicted concentration in excess of the water quality standard suggests the need to undertake a further level of investigation or action. Water resources SSAC are defined using a water quality standard at the point of compliance, then back-calculating to determine the contaminant level which is acceptable beneath the Site in soils and/or groundwater.

The SSAC can be compared to the measured concentrations of the CoC to evaluate whether unacceptable risks are present, and with which pollutant linkage or linkages the unacceptable risks are associated.

Modelling Tools

Modelling tools are developed to enable the calculations associated with fate and transport, exposure modelling and risk evaluation to be undertaken by risk assessors in a time-efficient manner, and producing defensible and consistent outputs.

Water Resources

There are two commonly used modelling tools that have been developed to implement the guidance presented within the EA's Remedial Targets Methodology. These are:

RTW v.3.2	The Remedial Target Worksheet (RTW) version 3.2 is an excel-based model tool produced by the EA to implement the guidance presented in the hydrogeological risk assessment methodology. RTW assesses the potential risk to a defined receptor point using a tiered analysis process (Level 1 soils – partitioning, Level 2 soils – dilution, Level 3 soils and groundwater – attenuation). RTW is a deterministic model.
ConSim v.2.5	Contamination Impact on Groundwater: Simulation by Monte Carlo Method, version 2.5 (ConSim), was developed by Golder Associates in association with the EA. ConSim is a probabilistic modelling tool, which implements the hydrogeological risk assessment guidance in a similar manner to RTW. However, ConSim allows a more detailed assessment of vertical migration pathways in the unsaturated zone, and, as such, is a useful tool for sites where groundwater is present at a considerable depth.

APPENDIX G

RTW Results

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

Input Parameters (using pull down menu)	Variable	Value	Unit	Source
Contaminant		Ammoniacal Nitrogen		from Level 1
Target Concentration	C_T	6.00E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to pollutants in all phases (e.g. field derived value**

	Variable	Value	Unit	Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	1.00E+00	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	2.19E+03	days	
Calculated decay rate	λ	3.17E-04	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+02	m	
Plume thickness at source	Sy	1.25E+01	m	
Saturated aquifer thickness	da	1.25E+01	m	
Bulk density of aquifer materials	ρ	2.09E+00	g/cm^3	
Effective porosity of aquifer	n	3.20E-01	fraction	
Hydraulic gradient	i	3.00E-03	fraction	
Hydraulic conductivity of aquifer	K	3.00E+00	m/d	
Distance to compliance point	x	2.50E+02	m	
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	9.00E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	4.00E-01	l/kg	*see options*
Longitudinal dispersivity	ax	2.50E+01	m	*see options*
Transverse dispersivity	az	2.50E+00	m	*see options*
Vertical dispersivity	ay	2.00E-99	m	*see options*

Select Method for deriving Partition Co-efficient (using pull down menu)

User specified value for partition coefficient

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd	4.00E-01	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc		fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	4.00E-01	l/kg

Define dispersivity (click brown cell and use pull down list)

User defined values for dispersivity

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	2.50E+01	2.50E+01	6.86E+00	m
Transverse dispersivity	**az**	2.50E+00	2.50E+00	6.86E-01	m
Vertical dispersivity	**ay**	2.00E-99	2.50E-01	6.86E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

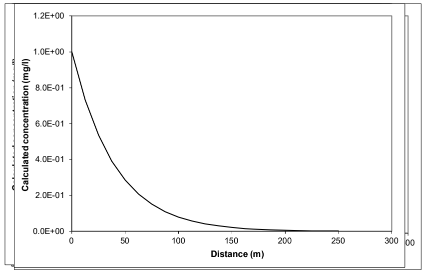
Calculated Parameters

Calculated Parameters	Variable		
Groundwater flow velocity	v	2.81E-02	m/d
Retardation factor	Rf	3.61E+00	fraction
Decay rate used	λ	3.17E-04	d^{-1}
Rate of contaminant flow due to retardation	u	7.79E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.62E-03	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**6.17E+02**	

Remedial Targets

Remedial Target		**3.70E+02**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**250**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.62E-03**	**mg/l**	Ogata Banks
after		**9.0E+99**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared
with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	British Sugar
Completed by:	Rachel Barratt
Date:	########
Version:	1

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	1.0E+00
12.5	7.31E-01
25.0	5.35E-01
37.5	3.91E-01
50.0	2.86E-01
62.5	2.08E-01
75.0	1.52E-01
87.5	1.10E-01
100.0	7.99E-02
112.5	5.79E-02
125.0	4.19E-02
137.5	3.03E-02
150.0	2.19E-02
162.5	1.58E-02
175.0	1.14E-02
187.5	8.25E-03
200.0	5.95E-03
212.5	4.30E-03
225.0	3.11E-03
237.5	2.24E-03
250.0	1.62E-03

APPENDIX H

Consideration of Nickel

Appendix H
Consideration of Nickel

Measured concentrations of nickel in groundwater were in excess of DWS and EQS following the water standard quality screening presented as Appendix B. Concentrations of nickel in groundwater are further considered here.

Site Specific Assessment of Nickel

Additional groundwater data was collected by Golders Associates in October, November and December 2019 for use in the calculation of a site-specific Predicted No Effect Concentration (PNEC) value protective of surface waters for nickel in groundwater. Of the 23 groundwater samples collected, concentrations of nickel above MDL were measured in all of them. The maximum concentration of nickel was measured in groundwater sampled from GAGW04 at 289 µg/l in October with concentrations over 100 µg/l also measured in GAGW21, BH05 and GAGW23 during the three-month monitoring period. The lowest concentration of nickel was measured in GAGW13 at 0.50 µg/l in October 2019.

The PNEC values have been calculated using the mean concentration of nickel measured at each monitoring location over the three-month monitoring period and using the Water Framework Directive UK Technical Advisory Group's Metal Bioavailability Assessment Tool (M-BAT). Concentrations of nickel in 12 of the 23 groundwater samples were measured in excess of their respective PNEC value with two of the groundwater samples in excess, BH09 and GAGW04, taken from down hydraulic gradient wells (as defined by the Environmental Permit). The input parameters and the calculated site-specific PNEC values are presented in Appendix I. An average PNEC of 15µg/l was derived for the Site.

Given that concentrations of nickel in groundwater were measured an order of magnitude above the site specific PNEC in two of the seven downgradient monitoring locations, with the highest concentration also noted on the hydraulically down gradient boundary, further assessment is warranted. As an initial step, a review of the distribution and potential sources has been undertaken.

Review of Distribution / Potential Sources

Within the existing HRA (URS 2015), the only potential source of nickel identified in relation to the Site was considered to be diffuse metals within soil within Made Ground. Nickel is however also noted to be naturally occurring in the environment. To further assess the potential for nickel in soil to be acting as a source of the identified measured concentrations in groundwater, a review of soil, leachate and groundwater nickel concentrations and distribution has been undertaken, along with local / regional background concentrations, where available.

Review of the measured concentrations of nickel in soil, based on those reported in Scott Wilson (which included a review of third party data, Scott Wilson, 2010), URS, 2015 and Arcadis data indicated that the maximum measured concentration of nickel was less than 45mg/kg, with the mean concentration of nickel measured in soil sampled on Site reported by URS as 20 mg/kg (with 94 samples considered). Review of nickel concentrations in topsoil based on the National Soil Inventory (NSI) survey (mapapps2.bgs.ac.uk/ukso/home.html) suggest that concentrations of nickel in topsoil in the local area are around 14 mg/kg to 19 mg/kg, which is generally in line with the concentrations identified in soil beneath the Site. This suggests that concentrations of nickel in soil on Site are generally representative of background nickel concentrations within the local area.

Further to the above, measured concentrations of nickel in leachate as reported within URS, 2015, which included a review of third party findings, indicated concentrations were measured below 26µg/l (23 leachate samples), with the exception of a single outlier (15,000µg/l). AECOM (formerly URS) commented that 15,000µg/l was not representative of the sample population, with a resulting mean concentration of 9.5µg/l (URS, 2015). The maximum measured concentration of nickel in leachate (with the exception of the single outlier) were noted to be an order of magnitude lower than those observed in groundwater, suggesting that while site soils may be contributing to dissolved phase nickel in groundwater, they are not the sole source. Further, that the outlier of 15,000µg/l in soil leachate did not correspond with locations in which elevated concentrations of nickel were identified in groundwater. It is noted that the measured concentrations of nickel in soil leachate beneath the Site were typically in line with the findings of an off-Site greenfield investigation[1] located 4km to the south of the Site, where nickel was identified at a maximum concentration of 21.8 ug/l in groundwater.

While the above suggests that nickel in groundwater is unlikely to be originating from the overlying soils, localised concentrations of nickel in the hundreds of µg/l have been identified in locations where waste has been identified, and additionally on the hydraulically down gradient boundary in locations immediately adjacent to waste. Review of the distribution indicates that lower concentrations of nickel have typically been identified on the hydraulically up-gradient boundary, albeit concentrations have been observed in the tens of µg/l (GAGW22). In addition, hundreds of µg/l of dissolved nickel were identified in GAGW21 (considered up gradient from a permit perspective, but was also noted to have elevated concentrations of ammoniacal nitrogen). However, in hydraulically down gradient locations (e.g. BH09, GAGW05 and GAGW06) located more distant from the main organic waste mass, concentrations of nickel have been comparable to selected up gradient locations, with concentrations of nickel typically in the ones of µg/l..

The presence of nickel in Site soils at what is considered to be representative of background concentrations, and the presence of elevated concentrations of nickel in groundwater in selected up hydraulic gradient boreholes, suggests concentrations may be originating from off Site. However, it is considered more likely that groundwater conditions beneath the EP area have affected the partitioning of nickel between aquifer sediments and the dissolved phase in localised areas. Reference has been made to the EPA Monitored Natural Attenuation of Inorganic Contaminants in Ground Water (Volume 2, EPA/600/R-07/140 October 2007).

The mobility of nickel within groundwater is controlled by partitioning reactions to aquifer sediments including direct adsorption to clay minerals, adsorption and/or coprecipitation with metal oxides, complexation with natural organic particles, ion exchange with charged surfaces, and direct precipitation as an hydroxide, carbonate or sulfide (Snodgrass, 1980). While a detailed assessment of aquifer hydrogeochemistry has not been undertaken there are considered two plausible mechanisms which affect nickel mobility that support the distribution of measured nickel concentrations across the Site. These are a shift to more reducing conditions and increased dissolved organic matter within groundwater directly beneath, and resulting from the presence of, deposited waste within the EP boundary.

Nickel may be co-precipitated during the formation of iron hydroxides, however, reductive dissolution of such precipitates may occur as groundwater conditions change to be more reducing (Zachara et al , 2001) which may lead to increase nickel concentrations being measured in groundwater.

The groundwater data collected during the October, November and December 2019 indicates that while groundwater pH measured within up gradient, EP area and down gradient locations doesn't not significantly change (see Appendix I), ORP is typically higher (more oxidising) in the up-gradient monitoring wells and down-gradient monitoring wells, with the lowest ORP values (most reducing) typically observed in the central portion of the EP area.

Nickel may also form dissolved complexes with organic ligands such as natural/synthetic carboxylic acids and dissolved humic compounds (Bryce and Clark, 1996; Baeyens et al., 2003; Strathman and Myneni, 2004) which may limit sorption of nickel to mineral surfaces in aquifer sediments. The high organic content of the deposited waste within the EP boundary, and unsurfaced nature of EP area allowing for infiltration, is considered highly likely to have resulted in elevated dissolved organic matter concentrations within the groundwater which may increase measured nickel concentrations.

It is noted that such partition processes reflect reversible equilibria and that once conditions become more oxidising and elevated dissolved organic matter attenuates down gradient of the EP area nickel is may form less soluble / mobile forms, as evidenced by the concentrations observed in BH09, GAGW05 and GAGW06 (located hydraulically down gradient.

Additional Lines of Evidence

As an additional line of evidence that soil concentrations are not significantly contributing to those concentrations observed in groundwater, RTW 3.2 has been used to predict concentrations of nickel which

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[1] Peter Brett 2008. Lane at Moor Lane, York, Combined Phase 1 and Phase 2 Ground Condition Assessment, ref 29426/3503, dated October 2018 – identified following review of the York Planning Portal

would be present in porewater and groundwater at the Site using the concentrations of nickel measured in soil samples. The RTW model set up used in URS 2015 for Averaging Area AA1a (located within the EP area) has been retained with a Kd value of 500 l/kg adopted for nickel (Updated technical background to the CLEA model, Science Report SC050021, dated January 2009). The maximum concentration of nickel measured in soil (reported as below 45mg/kg within URS, 2015) has been used as the input concentration in the model and the predicted results compared with the maximum concentration of nickel measured in leachate and the maximum concentration of nickel measured in groundwater sampled in October, November and December 2019 (289 µg/l). The results of the prediction are presented in the table below:

Concentration of nickel in soil (mg/kg)	Predicted concentrations of nickel in soil leachate (µg/l)	Maximum measured concentration of nickel in leachate (µg/l)*	Predicted concentrations of nickel in groundwater (µg/l)	Maximum measured concentrations of nickel in groundwater (November 2019) (µg/l)
45	90	26	81.8	289

* Excludes outlier of 15,000µg/l

The predicted concentration of nickel in soil leachate is marginally higher than that measured, whilst the concentration of nickel measured in the groundwater are an order of magnitude higher than the predicted concentrations. The disparity between concentrations predicted and those measured in groundwater indicates that the soil is unlikely to be the primary source of concentrations of nickel measured in groundwater.

Summary and Conclusions

Based on the above, it is considered that elevated nickel concentrations in groundwater beneath the Site are associated with naturally occurring nickel. The presence of localised "highs" is considered to be associated with changes in conditions immediately beneath the organic waste mass (such as increased dissolved organic carbon and change from oxidising to reducing conditions), which may affect the partitioning and mobilisation naturally present nickel. The presence of nickel in selected locations on the hydraulic down gradient boundary at what would be considered background concentrations, suggests that the mobilisation of nickel is likely to be localised to beneath the organic waste mass. On this basis, nickel has not been included for further assessment.

It is noted that the above conclusion is broadly in line with AECOM, who following review of site investigation results and a detailed assessment of nickel in the surrounding area, suggested that the concentrations of nickel in soil were low and that the concentrations of nickel measured in groundwater beneath the Site were likely to have originated from natural soil minerals. URS ultimately concluded that nickel concentrations were representative of background concentrations and did not include nickel as a potential contaminant requiring modelling or further consideration (reported in URS, 2015 - contained within their response to the EA).

It is also noted that the proposed remediation strategy will involve aerobic bioremediation to reduce levels of organic matter within deposited waste and thus reduce the source of dissolved organic matter and associated reducing conditions within the underlying aquifer. Furthermore, the vast majority of site soils will be lime stabilised and compacted which will reduce infiltration rates through the recovered waste.

APPENDIX I

Derivation of Site-specific PNEC Value for Nickel

British Sugar, York

Appendix I: Derivation of site-specific PNEC value for nickel

Area	Monitoring Well	M-BAT Input Parameters				M-BAT Results
		Concentration of Nickel[1]	pH[1]	DOC[2]	Calcium[1]	Site Specific PNEC
		µg/l	pH units	mg/l	mg/l	µg/l
Up Hydraulic Gradient	BH02	0.985	7.64	4.40	89.1	13.57
	GAGW01	6.1	7.55	4.40	134	14.48
	GAGW13	0.613	7.77	4.40	94.1	12.33
	GAGW20	1.9	7.41	4.40	139	15.96
	GAGW21	103	7.46	4.40	153	15.45
	GAGW22	49.8	7.16	4.40	251	18.46
Down Hydraulic Gradient	BH09	0.931	7.57	4.40	103	14.31
	GAGW03	6.1	7.16	4.40	210	18.46
	GAGW04	261	7.39	4.40	117.1	16.13
	GAGW05	1.4	7.47	4.40	128	15.35
	GAGW06	10.4	7.69	4.40	91.0	13.07
	GAGW15	9.3	7.49	4.40	115	15.08
	GAGW16	29.5	7.39	4.40	168	16.09
On-Site	BH04A	21.1	7.28	4.40	259	17.29
	BH05	242	7.20	4.40	274	18.08
	GAGW02	73.4	7.45	4.40	212	15.55
	GAGW14	11.0	7.88	4.40	74.6	12.15
	GAGW17	21.6	7.54	4.40	89.9	14.61
	GAGW18	29.8	7.40	4.40	62.3	16.06
	GAGW19	37.4	7.65	4.40	57.2	13.21
	GAGW23	165	8.19	4.40	168	8.00
	GAGW24	18.7	7.49	4.40	32.1	11.25
	GAGW25	17.4	7.15	4.40	232	18.60
Average PNEC		-	-	-	-	14.94

Notes:

M-BAT	Metal Bioavailability Assessment Tool by Water Framework Directive - united Kingdom Technical Advisory Group
PNEC	Predicted No Effect Concentration
DOC	Dissolved Organic Carbon
[1]	Value is an average of the pH, dissolved calcium and dissolved nickel measured in groundwater samples collected by Golders Associates in October, November and December 2019
[2]	Value of DOC measured in water body GB104027069590 River Swale/Ouse from Wiske to Naburn and presented in the Water Framework Directive - United Kigdom Technical Advisory Groups: 'The Importance of Dissolved Organic Carbon in the Assessment of Environmental Quality Standard Compliance for Copper and Zinc, report ref SC080021/7a' dated May 2012.
🟨	Measured concentration of nickel exceeds the PNEC

Up-gradient, on-site and down-gradient monitoring locations classified in line with the Environmental Permit

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