wardell-armstrong.com

ENERGY AND CLIMATE CHANGE
ENVIRONMENT AND SUSTAINABILITY
INFRASTRUCTURE AND UTILITIES
LAND AND PROPERTY
MINING AND MINERAL PROCESSING
MINERAL ESTATES
WASTE RESOURCE MANAGEMENT

TARMAC LTD

OLD QUARRINGTON AND COLD KNUCKLE QUARRY

HYDROGEOLOGICAL RISK ASSESSMENT REVIEW

SEPTEMBER 2021

wardell armstrong

Wardell Armstrong
Baldhu House, Wheal Jane Earth Science Park, Baldhu, Truro, Cornwall, TR3 6EH, United Kingdom
Telephone: +44 (0)1872 560738 www.wardell-armstrong.com

DATE ISSUED:	**SEPTEMBER 2021**
JOB NUMBER:	**NT14345**
REPORT NUMBER:	**0011**
VERSION:	**V1.0**
STATUS:	**FINAL**

TARMAC LTD

OLD QUARRINGTON AND COLDKNUCKLE QUARRY

HYDROGEOLOGICAL RISK ASSESSMENT REVIEW

SEPTEMBER 2021

PREPARED BY:		
Joe Skuse	Hydrogeologist	
REVIEWED BY:		
Lauren Ballarini	Service Lead – Hydrology and Hydrogeology	L Ballarini
APPROVED BY:		
Lauren Ballarini	Service Lead – Hydrology and Hydrogeology	L Ballarini

CONTENTS

TABLES

APPENDICES

DRAWINGS	TITLE	SCALE
Q003-00197-1	Site Location	1 : 50,000
NT14345-012	Permit Boundary	1 : 4,100
Q003-00197-48	Proposed Permit Extension Area and Cross Section	As Shown
NT14345-015	Location of 2021 Borehole Series	1 : 4,100
NT14345-016	Requisite Surveillance Monitoring Array	1:4,100

1 INTRODUCTION

1.1.1 Wardell Armstrong LLP (WA) have been commissioned by Tarmac Trading Ltd (Tarmac) to produce a Hydrogeological Risk Assessment Review (HRAR) for Old Quarrington and Cold Knuckle Quarry (the Site) to support a variation to the existing environmental permit. The Site is a quarry complex in Durham County, approximately 1.2km east of Bowburn and 6km south east of the City of Durham (Grid reference: NZ 32904 38071) – see Drawing Q003-00197-1.

1.1.2 The 85ha site is located on the western edge of a ridge of Magnesian Limestone (Raisby Formation Dolostone) that runs north/south through County Durham. Limestone and Permian Sand (Yellow Sands Formation) are extracted from Old Quarrington and replaced with inert landfill and some remaining Raisby Formation Dolostone to achieve the approved restoration profile. Cold Knuckle, immediately to the south, is currently used for sand extraction only, however, is undergoing planning to extract Magnesian Limestone. The Site has undergone various permitting and planning permission over the years.

1.1.3 Historical inert waste has been deposited within the Site's north western corner. Inert waste has also been deposited under permit reference: EPR/BB3007CA (previously TP3730BA), at Old Quarrington between 2005 and 2017. The permit was varied in 2018 under variation number EPR/BB3007CA/V005 to increase annual tonnage. This increased tonnage is deposited within central areas of the existing void at Old Quarrington. The extant permit area is shown within Drawing NT14345-012 (green line). Historical waste depositions are shown on Drawing Q003-00197-48.

1.2 Report Context

1.2.1 Tarmac are seeking to vary environmental permit EPR/BB3007CA to include Cold Knuckle Quarry to the south, increasing the proposed inert waste area by 10 – 15% and the lifetime of the works on-site. Annual tonnage is also proposed to be increased over the next 15 years with an annual 200,000 t.p.a of landfill input (inert waste and limestone). The proposed extension area is shown on Drawing NT14345-012 (dashed green line). The permit variation application will require a Hydrogeological Risk Assessment Review (HRAR) to support the application.

1.2.2 The permit variation is proposed to the south of the existing extant permit area along the southern boundary of Old Quarrington and into Cold Knuckle Quarry, removing a

limestone escarpment which separates the two areas and replacing it with inert waste.

1.2.3 Quarrying on-site has been/is being undertaken in five phases (Phases 1 – 5) that have been progressively worked (quarried) for Limestone (planning permission will allow the extraction of Raisby Formation Dolostone not currently authorised within Cold Knuckle Quarry area) and Permian Yellow Sands Formation and replaced within inert waste. Phases 1 and 5 are located centrally within Old Quarrington, inside the current extant permit area, therefore the permit variation only corresponds to phases 2 – 4 which extend outside the southern portion of Old Quarrington and into Cold Knuckle Quarry. The phasing plan is shown on Drawing Q003-00197-48.

1.2.4 The report references the Site, the proposed extension area, Old Quarrington and the study area. These terms are defined below:

- The Site – Includes the existing works at Old Quarrington and the extension area into Cold Knuckle Quarry;
- The proposed extension area – Cold Knuckle Quarry area, to the south of the Old Quarrington, see Drawing NT14345-012 (dashed green line); and
- Old Quarrington – Quarry and landfill site located within the green line (Environmental Permit boundary) on Drawing NT4345-012.
- Study Area – the study area comprises all land within 1km of the Site boundary.

1.3 Purpose and Basis of the HRAR

1.3.1 This report reviews updated information provided by Tarmac and the Environment Agency (EA) and the proposed extension of the landfill area to include Cold Knuckle Quarry and uses this information to review the current Hydrogeological Conceptual Site Model (HCSM) for the Site.

1.3.2 This report also details the findings of said hydrogeological risk assessment and additionally reviews the requisite surveillance undertaken at the Site in light of the proposed permit variation.

1.3.3 This report is based on the following reports and documents relating to the Site:

- Environment Agency (2006). Variation notice with introductory note – Old Quarrington Quarry Landfill (TP3730BA);

- Environment Agency (2018). Notice of variation with introductory note – Old Quarrington Quarry Landfill (EPR/BB3007CA/V005);
- Crestwood Environmental (2004). Conceptual Model, Environmental Setting and Installation Design Report – Old Quarrington Quarry Landfill;
- Tarmac (2004 – July 2021) - On-site monitoring data;
- Hafren Water (2011). Old Quarrington Landfill – Hydrogeological Risk Assessment Review;
- Tarmac – Borehole Logs;
- WA (2021) Pre-Application Report;
- Tarmac (2021) CQA Installation Report for 2021 Groundwater Monitoring Piezometers at Tarmac's Q003 - Old Quarrington Quarry; and
- SLR and WA Construction Quality Assurance (CQA) plans and validation reports for the artificially established geological barrier (a recent CQA verification statement is included as Appendix 1).

1.3.4 The Pre-Application Report detailed the current understanding of the Site and described the proposed approach to the permit variation. The report reviewed groundwater, spring and surface water data to December 2019 and presented a HCSM for the Site. The Pre-Application Report was provided to the Environment Agency in March 2021 and an enhanced pre-application telecon between the WA, the EA and Tarmac was held on 21 July 2021. For completeness, this report includes the description of the site design and site setting which were presented in the Pre-Application Report. Additional site investigation data (Q003 boreholes series, drilled in 2021) and monitoring data to July 2021 are included in this report.

2 SITE DESIGN AND CONSTRUCTION

2.1 Previous Landfilling

2.1.1 There are two historical areas of inert waste landfilling on-site; restored landfill located to the north west of Site and the 2005 – 2017 inert waste landfill located on the western side of Old Quarrington Quarry. Drawing Q003-00197-48 shows the location of each landfill area. These areas have not been lined.

2.2 Current Landfilling

2.2.1 The proposed extension and backfill area has been broken up into three phases (Phase 2, 3 and 4 mentioned above), located to the south of Old Quarrington and into Cold Knuckle Quarry. These phases correspond with quarrying excavation which is also currently underway on-site. Phase 1 and 5 are located entirely within the extant permit area and are therefore not considered within the permit variation.

2.2.2 Following permit variation in 2018 (variation number EPR/BB3007CA/V005), inert waste and overburden material is being deposited within Phase 1 located within Old Quarrington. The northern area of Phase 2, located inside the current permit area, is also undergoing backfilling. The area of Phase 2 located outside of the permit boundary, to the south (inside Cold Knuckle Quarry) has not received any waste. This is shown on Drawing Q003-00197-48.

2.2.3 The 2018 landfill phases are lined with 1m of low permeability geological barrier (crushed dolostone), which has previously been proven to achieve $1x10^{-7}$ m/s permeability (Appendix 1). This is artificially established geological barrier (basal and sidewall liner) also proposed for the new landfill phasing plan (Phase 1 – 5).

2.3 Proposed Landfilling

2.3.1 Proposed landfilling works are comprised of the remaining phases not currently being filled (Phases 2 – 5). The proposed phases are located to the south of Old Quarrington and into Cold Knuckle Quarry area. Phases 2, 3 and 4 are located partially inside the existing permit boundary and partially within the proposed extension area. Quarrying is complete in Phases 1 - 3, Phase 4 is nearing completion and Phase 5 is yet to be worked. No waste has been input to Phases 3, 4 or 5 or outside of the extant permit boundary. Drawing Q003-00197-48 shows the location of each phase. Each phase is also summarised in Table 1.

Table 1: Summary of Proposed Phasing			
Phase	**Liner and Cap**	**Waste Type**	**Summary**
1	Lined with 1m of crushed dolostone. Uncapped.	Inert waste (clays and subsoils)	Not included within permit variation (not located within extension area). Quarried. Currently receiving waste along its northern boundary. Phase 1 is located inside the current extant permit boundary. Filled with inert waste and overburden.
2	Lined with 1m of crushed dolostone. Uncapped.	Overburden and inert waste	Quarried. Areas inside the existing permit boundary have been lined and filled with inert waste and overburden. Areas within the Cold Knuckle quarry area have been backfilled with overburden Marl Slate Formation and Yellow Sand Formation Waste (not waste as per the Mining Waste Directive). The quarry currently does not have permission to extract Raisby Formation Dolostone for economic uses within Cold Knuckle Quarry. This will be revisited/reworked following approval.
3	Proposed - Lined with 1m of crushed dolostone. Uncapped.	Overburden and inert waste	Quarried. No waste input.
4	Proposed - Lined with 1m of crushed dolostone. Uncapped.	Overburden and inert waste	Quarrying is ongoing within this phase. Working is currently ongoing within the northern part of Phase 4. No waste input.
5	Proposed - Lined with 1m of crushed dolostone. Uncapped.	Overburden and inert waste	Not included within permit variation (not located within extension area). Quarrying imminent. No waste input.

3 SITE SETTING

3.1 Surface Water

3.1.1 There is only one mapped water feature within the Site, which is a small pond outside of the quarry void in the north west of Old Quarrington. The south of the study area is within the Croxdale Beck surface water catchment. There are a number of ponds, springs and issues located c.300m to the south of the Site within the Study Area within Crowtrees Local Nature Reserve. These issues and springs feed Bowburn Beck which flows in a south westerly direction to Coxhoe Beck, outside of the Study Area. The Coxhoe Beck flows in a general south east to north west direction before becoming the Tursdale Beck. The Tursdale Beck becomes the Croxdale Beck in the vicinity of Croxdale. The Croxdale Beck has a confluence with the River Wear at National Grid Reference (NGR) NZ 27213 38536.

3.1.2 The north of the study area is within Old Durham Beck surface water catchment. Runoff from the north of the study area drains into the Chapman Beck, c.400m north east of the Site. Chapman Beck flows in a general south east to north direction from a large pond in Cassop Vale, c.875m east/north east. The Chapman Beck joins the Whitwell Beck outside of the Study Area, which joins the Sherburnhouse Beck to become the Old Durham Beck in the vicinity of Old Durham and has its confluence with the River Wear at NGR NZ 28575 42052.

3.1.3 The majority of the study area lies within the Northumbria River Basin District, the Wear Management Catchment, the Wear Lower and Estuary Operational Catchment and the EA's Croxdale Beck from Source to Wear Water Framework Directive (WFD) surface body (catchment) (ID: GB103024077410)[1]. This waterbody was in 2019 classified with an overall WFD status of moderate. The northeastern corner of the Site and study area is located within the Old Durham Beck from Chapman Beck to Wear surface water body (catchment) (ID: GB103024077470). This waterbody was classified with an overall WFD status of poor in 2019 as a result of poor biological quality elements, in particular; Macrophytes and Phytobenthos Combined, not associated to site works.

[1] Environment Agency (2019). Catchment Data Explorer [online] – Surface Waterbodies. Accessed: 28/12/2020. Available at: https://environment.data.gov.uk/catchment-planning/

Surface Water Abstractions

3.1.4 There are no licensed surface water abstractions within 2km of the Site.

Surface Water Quality Monitoring Points

3.1.5 Three monitoring points are located within the complex of drains springs and issues to the south of the Site. Drawing NT14345-016 indicates the location of each monitoring point. SW1 and SW3 are surface water monitoring locations whilst SW2 monitors a spring located between the two surface water monitoring points. Results from SW2 are therefore discussed with groundwater results in Section 3.6. SW1 and SW3 are sampled on a quarterly basis for a range of determinands, as well as the parameters identified within the existing permit including (Permitted parameters are provided within Section 5): pH, Visible Oil, Electrical Conductivity, Chloride, Ammonium as N, Total Suspended Solids, Nitrate, Nitrite, Sulphate, Potassium, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Organic Carbon. The following parameters are monitored on an annual basis: Sodium, Calcium, Magnesium and Alkalinity. SW2 is sampled for a larger suite of parameters, see Section 4 for further information.

Surface Water Quality

3.1.6 The majority of the Site lies within the Northumbria River Basin District, the Wear Management Catchment, the Wear Lower and Estuary Operational Catchment and the Croxdale Beck from Source to Wear surface waterbody (catchment) (ID: GB103024077410)[1]. The waterbody has an overall 'Moderate' status, with an ecological status of 'Moderate' and a chemical status of 'Good'[1]. The ecological status has been classified as 'Moderate' by the EA due to biological quality elements and phosphate[1].

3.1.7 The northeastern corner of the Site is located within the Old Durham Beck from Chapman Beck to Wear surface water body (catchment) (ID: GB103024077470). The waterbody has an overall 'Poor' status, with an ecological status of 'Poor' and a chemical status of 'Good'[1]. The ecological status has been classified as 'Poor' by the EA due to biological quality elements and phosphate[1].

3.1.8 Surface water quality samples have been collected along Bowburn Beck, c.300m south of the Site since 1997. Samples are collected at monitoring points SW1 and SW3, up and down gradient of SW2 a spring which expresses down hydraulic gradient of the Site.

3.1.9 No trigger levels were set for SW1 or SW3 within the Permit, therefore results from surface water quality monitoring between September 2010 and December 2019 have been compared with Environmental Quality Standards (EQS)[2]. Results from surface water quality sampling are provided in Appendix 2 and shown graphically in Appendix 3.

SW1

3.1.10 Surface water results from SW1 indicate exceedances of Ammoniacal Nitrogen in October 2010 (0.31 mg/l), June 2011 (0.66 mg/l) and September 2017 (1.2mg/l) when compared to an EQS of 0.3 mg/l. Copper (0.009 mg/l and 0.009 mg/l), Lead (0.036 mg/l and 0.006 mg/l) and Zinc (0.087 mg/l an 0.018 mg/l) were also reported to exceed EQS's (Copper: 0.001 mg/l, Lead: 0.0012 mg/l and Zinc: 0.001 mg/l) in samples collected in September 2011 and September 2012.

3.1.11 In February 2011, sulphate concentrations were recorded at 734 mg/l, above the EQS of 400 mg/l. Selenium also exceeded EQS in October 2013 with a concentration of 0.012 mg/l in comparison to an EQS of 0.001 mg/l.

SW3

3.1.12 One sample collected in September 2011 at SW3 recorded exceedances of Copper of 0.002 mg/l in comparison to an EQS of 0.001 mg/l, Lead of 0.014 mg/l in comparison to an EQS of 0.0012 mg/l and Zinc of 0.007 mg/l in comparison to an EQS of 0.001 mg/l. Only one other exceedance of EQS was recorded in SW3 of Selenium with a recorded concentration of 0.022 mg/l in October 2013 compared to an EQS of 0.001 mg/l.

3.1.13 Occasionally heavy metal concentration (Copper, Lead, Zinc and Selenium) within Bowburn Beck, both up and down gradient of the groundwater spring (SW2) exceed EQS. The concentrations reported up and down gradient are very similar.

[2] The Water Framework Directive (Standards and Classification) Directions (England and Wales) (2015). Available at: http://www.legislation.gov.uk/uksi/2015/1623/pdfs/uksiod_20151623_en_auto.pdf. Last accessed: 16/12/2020.

Trends

3.1.14 During pre-application discussions with the EA, the EA requested further information regarding "apparent rising trends in electrical conductivity, TOC [Total Organic Carbon], chloride, sulphate, and potassium in some or all of the surface water monitoring points SW1-SW3 down-gradient of the site". Results for surface water monitoring points SW1 and SW3 are shown graphically in Appendix 3 and for SW2 (Spring within Coal Measures Strata) are shown graphically in Appendix 6. The trends are described below with reference to the groundwater quality data which is discussed in Section 3.6.

3.1.15 Electrical conductivity in SW1 to SW3 showed an increasing trend between 2010 and 2016, however since 2017 electrical conductivity has generally stabilised. A similar pattern is seen in electrical conductivity in up gradient groundwater quality in the Coal Measures (borehole P-03).

3.1.16 TOC concentrations at SW1 to SW3 have generally been similar to up gradient groundwater quality in the Coal Measures (borehole P-03), although concentrations in the 2021 boreholes QUA_Q003-2021(P)-05 to QUA_Q003-2021(P)-07 are lower in P-03.

3.1.17 Chloride concentrations in SW1 to SW3 showed an increasing trend between 2010 and 2017, however since 2018 chloride concentrations have generally stabilised. The concentrations are generally similar to up gradient groundwater quality in the Coal Measures (borehole P-03) with the exception of three samples in December 2010, March 2011 and June 2012 with concentrations of 250-293 mg/l.

3.1.18 Sulphate concentrations in SW1 to SW3 are generally steady at around 250 mg/l. Groundwater concentrations in boreholes QUA_Q003-2021(P)-05 and QUA_Q003-2021(P)-6 are similar to SW1 to SW3, although concentrations in boreholes P-03 and QUA_Q003-2021(P)-07 are lower (less than 100 mg/l).

3.1.19 Potassium concentrations in SW1 to SW3 showed a steady trend between 2010 and 2013, and between 2014 and 2020 increased slightly. Groundwater concentrations in up gradient boreholes P-03 were variable but generally slightly higher than the SW1 to SW3 concentrations. Boreholes QUA_Q003-2021(P)-05 and QUA_Q003-2021(P)-06 are similar to SW1 to SW3, whilst concentrations in borehole QUA_Q003-2021(P)-05 are slightly lower (less than 2 mg/l).

3.1.20 Chloride, sulphate and potassium are all associated with the Coal Measures in the Durham coalfield[3] and in general up and down gradient groundwater concentrations of chloride and potassium are similar to concentrations in SW1 to SW3 and no apparent sustained increasing trends are seen.

3.2 Geology

3.2.1 The geology of the Site is defined in full within a report by Millfields Geotechnical Services Ltd (2000) "Geological Report on the 1999 Exploration Drilling at Old Quarrington Quarry"[4]. A summary of the on-site geology is presented in the following sections to inform the review of the HCSM and provide information.

Superficial Geology

3.2.2 Glacial Till (diamicton) partially underlies the Site and was been recorded within nine of the 1999 exploratory boreholes to a maximum depth of 1.9m. The north west of the quarry area is absent of any quaternary cover. Boulder clay is defined as firm, grey brown boulder clay. Where quarrying operations have been undertaken glacial deposits have been striped. The surrounding area is covered by thicker Glacial Till (diamicton) as recorded within BGS Borehole Log ID: 778721[5] to a depth of c.7m located 50m east of the Site.

Bedrock Geology

3.2.3 The bedrock geology underlying the Site is dominated by the Raisby Formation Dolostone[5] (Previously Lower Magnesian Limestone) deposited during the Permian period. The Raisby Formation Dolostone is comprised of two broad rock types: dolomite and dolomitic limestone. The dolomitic limestone is comprised of a pale grey to brownish, often banded, strong limestone. The dolomite is defined as a yellowish (varying from yellowish grey to yellowish brown). The dolomite is also much weaker than the dolomitic limestone[4]. The Raisby Formation Dolostone is at its thickest in the east of the Site, recorded in borehole Q3\99-8 located to the east of Phase 5 on the

[3] Bearcock, J. and Smedley, P.L. 2009. Baseline groundwater chemistry: the Magnesian Limestone of County Durham and north Yorkshire. British Geological Survey Open Report, OR/09/030. 63 pp. Available at http://nora.nerc.ac.uk/id/eprint/8147/1/OR09030.pdf

[4] Millfields Geotechnical Services Ltd (2000). Geological Report on the 1999 Exploration Drilling at old Quarrington Quarry

[5] British Geological Survey (2020). Geoindex – Borehole Scans. Last Accessed: 11/11/2020. Available at: [http://mapapps2.bgs.ac.uk/geoindex/home.html]

Site's eastern boundary, at a thickness of 30.6m. The deposit is more characteristically 15m – 20m elsewhere on-site.

3.2.4 There is a gradational contact between the Raisby Formation Dolostone and the top of the Marl Slate Formation. The Marl Slate Formation was noted to comprise a series of pale yellowish brown, strong thinly laminated dolomitic shales[4]. The thickness of the Marl Slate Formation on average varies between 1.5m to 2m up to over 3m in the north west and north east of the quarried area.

3.2.5 Permian Basal Sand belonging to the Yellow Sands Formations[4], directly underlies the Marl Slate Formation and is defined as a yellowish brown and greyish brown, relatively loose and unconsolidated sand. In some areas a moderately weak to moderately strong, coarse grained sandstone was encountered; however, this was observed to be sparse. The Yellow Sands Formations was recorded at its thickest within the southeastern corner of the Site at a thickness of 18.9m. Thickness is then seen to reduce northwards to a more characteristic thickness of 11m – 13m. Along the southern boundary of the Site, a more characteristic thickness of 3m – 4m was encountered.

3.2.6 The Yellow Sands Formations lower boundary forms a sharp, unconformable contact with the Carboniferous Pennine Middle Coal Measures (Coal Measures). The Coal Measures are comprised of cyclic sandstones, siltstones, mudstones and coal seams. Coal measures flank the Site to the west.

3.3 Geological Features

3.3.1 Coal Measures strata is heavily faulted to the west of the Site with east-west trending faults and subordinate north-south trending faults. There are no noted faults identified by BGS Geoindex linear features mapping on-site within the Permian limestones, marls and sands.

3.3.2 Geological strata dip in an eastern direction towards the coast.

3.4 Hydrogeology

3.4.1 Glacial Till deposits are classified by the EA as a Secondary (Undifferentiated) Aquifer, defined "as an aquifer where it has not been possible to attribute either category A or B to a rock type"[6].

[6] Environment Agency (2020). What are the Aquifer Designations? Last Accessed: 11/11/2020. Available at [http://apps.environment-agency.gov.uk/wiyby/117020.aspx]

3.4.2 The Raisby Formation Dolostone is classified by the EA as a Principal Aquifer, defined as "an aquifer with high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale"[6]. The Yellow Sands Formation are also classified as a Principal Aquifer.

3.4.3 The Marl Slate Formation are classified as Unproductive strata, defined as "rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow"[5].

3.4.4 The Pennine Middle Coal Measures Formation are classified as a Secondary A Aquifer, defined as "permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers"[6].

3.4.5 The existing quarry is dry worked and thus the workings and inert landfilling are both situated above the water table.

3.4.6 The Site is located within a Source Protection Zone III (SPZ3) and located with a Nitrate Vulnerability Zone (NVZ)[7]. The Site is located within category B (on the coalfield area) of The Coal Authorities 'NE Mining and Groundwater Constraints' map[8] and within the Coal Authority's North East Mining & Groundwater Constraints Bowburn block[9]. Coal Authority consider that mine water levels in the Bowburn mine water block are recovered[10].

3.4.7 The study area is entirely within the EA's Wear Magnesian Limestone WFD groundwater catchment. This waterbody was classified in 2016 with an overall WFD status of poor[11].

[7] DEFRA (2020). Magic Maps – Source Protections Zones and Nitrate Vulnerability Zones. Last Accessed: 11/11/2020. Available at: [https://magic.defra.gov.uk/MagicMap.aspx]
[8] 'NE Mining & Groundwater Constraints' Layer on The Coal Authority Interactive Map (online). Last Accessed: 11/11/2020. Available at: http://mapapps2.bgs.ac.uk/coalauthority/home.html
[9] The Coal Authority (2020) Interactive Map [online]. Last Accessed: 11.11.2020. Available at: http://mapapps2.bgs.ac.uk/coalauthority/home.html
[10] The Coal Authority (2018) Guidance North East England mine water block factsheets [online]. Last Accessed: 11.11.2020. Available at: https://www.gov.uk/government/publications/mine-water-block-factsheets/north-east-england-mine-water-block-factsheets#bowburn-mine-water-block-factsheet
[11] Environment Agency (2020.) Catchment Data Explorer: Wear Magnesian Limestone Overview [online]. Accessed 11/11/2020. Available at: https://environment.data.gov.uk/catchment-planning/WaterBody/GB40301G703900

3.5 Groundwater Elevations and Flows

3.5.1 Where low permeability Glacial Till is present, infiltration to the underlying aquifer will be limited and precipitation will run-off. Where till is absent, infiltration can occur unimpeded.

3.5.2 As the Site is located at a topographic high, along a Magnesian Limestone ridgeline, dipping to the east, the origin of any water within the Raisby Formation Dolostone will be directly from rainfall recharge. The Raisby Formation Dolostone is reported as dry on-site. This is reported through working conditions experienced within the working area since 1997 and through monitoring borehole P-05 which is screened at the base of the Limestone Formation. P-05 has been reported as dry on-site since September 2010, except on one occasion when water was reported at the base of the borehole in July 2019. This was at the base of the borehole and could have been a result of recharging rainfall following a high rainfall event or through water seepage down the borehole void. Groundwater elevations within P-05 are shown in Appendix 4. Any groundwater within the Raisby Formation Dolostone will be confined to the formation's secondary permeability (fractures, fissures and joints) and will likely flow down regional dip, towards the east. Groundwater within this formation is likely to be hydraulically isolated from formations below as a result of the underlying low permeability Marl Slate Formation.

3.5.3 The Site lies within an SPZ3, associated to abstraction wells within the Raisby Formation Dolostone. As the Site is located at the edge of the formations outcrop, there is no connectivity to groundwater abstracted within the abstraction boreholes to the west.

3.5.4 The Marl Slate Formation is likely to have a very low permeability and therefore will likely act as an aquitard.

3.5.5 The Yellow Sands Formation are primarily reported as dry on-site. This is confirmed by borehole P-06 screened at the base of the Yellow Sands Formation and into the Coal Measures. Between April 2017 and December 2020 groundwater was only recorded a small number of times within P-06 at the base of the borehole. This was likely a result of high groundwater elevations within Coal Measures strata rather than groundwater within the Yellow Sands Formation. Since September 2010, P-06 has primarily been reported as dry.

3.5.6 Similar to the Raisby Formation Dolostone, the Yellow Sands Formation outcrop along the ridgeline and will likely be primarily fed by recharging rainwaters. As the Site is located at the top of the ridgeline, the Site's surface water drainage system will likely pick up surface waters that would have previously recharged the Yellow Sands Formation. The underlying Coal Measures are water bearing and are likely to be in continuity with the Yellow Sands Formation. Therefore, water seepage at the base of the Yellow Sands Formation may occur occasionally when water levels in the Coal Measures are high. This was reported in the 2004 Conceptual Setting report[14] and more recently within borehole P-06 in January 2020 when water was recorded at the base of the Yellow Sands Formation. Any groundwater within the Yellow Sands Formation is likely to flow down regional dip, towards the east.

3.5.7 Groundwater elevations recorded within monitoring boreholes on-site are presented in Appendix 4.

3.5.8 The Coal Measures are water bearing. Regional groundwater flow within Coal Measures strata is south easterly, following the regional bedrock dip. In close proximity to the Site, localised radial groundwater flow is evident towards the east and south as well as down regional gradient to the south east. This is because the Site's location on top of a hill (recharge mound) with topography falling to the south and east. A sandstone horizon was encountered at the top of the Coal Measures during the March 2021 site investigation and two boreholes (0003-2021(P)-08 and Q0003-2021(P)-09) were screened across this sandstone horizon (see Section 4).

3.5.9 A hydraulic gradient of 0.02 has been calculated based on groundwater elevation dipping results within the 2021 monitoring boreholes.

3.6 Groundwater Quality

3.6.1 Groundwater monitoring has been undertaken at Old Quarrington and within the surrounding area since 1997. Groundwater samples have been collected from borehole P-03, QUA_Q003-2021(P)-05, QUA_Q003-2021(P)-06, QUA_Q003-2021(P)-07 and SW2 (Spring within Coal Measures Strata). P-03 is an up-gradient borehole, located to the west of the Site installed within Coal Measures Strata. QUA_Q003-2021(P)-05, QUA_Q003-2021(P)-06, QUA_Q003-2021(P)-07 are boreholes drilled in March 2021 and installed in the Coal Measures Strata with monitoring commencing on 30/03/2021. SW2 is a spring located down gradient, to 300m south of the Site located within Coal Measures Strata.

3.6.2 Results have been reviewed from September 2010 to July 2021. Groundwater results have been compared with the trigger levels stated within the permit and where absent, to UK Drinking water Standards[12] (UKDWS) and where appropriate Minimum Reporting Values (MRV)[13]. Groundwater results are provided within Appendix 5 and shown graphically in Appendix 6. Groundwater quality results solely relate to Coal Measures groundwater. No other aquifer horizons were able to be sampled.

3.6.3 The suites analysed are provided within Section 4.3 (SW2) and 4.5 (P-03, QUA_Q003-2021(P)-05, QUA_Q003-2021(P)-06, QUA_Q003-2021(P)-07).

SW2

3.6.4 Between September 2010 and May 2021 there was one exceedance of the ammoniacal nitrogen trigger level (0.39 mg/l) at the down gradient spring monitoring point (SW2) on 30/03/2021 (0.51 mg/l). There were no other exceedances of trigger levels at SW2.

3.6.5 Sulphate was reported to regularly exceed the UKDWS of 250 mg/l at SW2. Magnesium was also reported to regularly exceed the UKDWS of 50 mg/l at SW2. Lead was reported to exceed UKDWS in SW2 in September 2011 with a concentration of 0.039 mg/l when compared to UKDS of 0.01 mg/l. Selenium was also reported to exceed UKDWS in SW2 in September 2019 with a concentration of 0.023 mg/l when compared to UKDS of 0.01 mg/l and exceeded the UKDWS throughout the March to May 2021 monitoring rounds (0.022-0.029 mg/l).

3.6.6 The MRV for Cadmium (0.0001 mg/l) was exceeded twice within SW2 between September 2010 and December 2019 on 23/09/2011 at 0.003 mg/l and on 28/09/2012 at 0.0006 mg/l.

P-03

3.6.7 Chloride trigger levels were exceeded twice in P-03 between December 2010 and June 2021. Chloride exceedances were reported at 293 mg/l on 16/12/2010 and 279 mg/l on 15/06/2012, when compared to a trigger level of 250 mg/l. No other exceedances of trigger levels were reported between December 2010 and June 2021.

[12] The Water Supply (Water Quality) Regulations (2016). Available at: http://www.legislation.gov.uk/uksi/2016/614/pdfs/uksi_20160614_en.pdf. Last accessed: 16/12/2020.
[13] Environment Agency (2017). Hazardous Substances to groundwater: Minimum Reporting Values. Available at: https://www.gov.uk/government/publications/values-for-groundwater-risk-assessments/hazardous-substances-to-groundwater-minimum-reporting-values. Last Accessed: 26/01/2021.

3.6.8 Where trigger levels are absent, groundwater quality results have been compared to UKDWS and where appropriate MRV. Results have been provided between December 2010 and June 2021. Calcium exceeded UKDWS on one occasion during the monitoring period in P-03. Calcium concentration was reported at 278 mg/l on 28/09/2012. Magnesium was reported to exceed UKDWS in six of the 18 samples tested for magnesium. The highest of which was reported at 119 mg/l on 28/09/2012 when compared to a UKDWS of 50 mg/l. Iron was reported to exceed UKDWS in four of the 17 samples tested for Iron. The highest of which was reported at 8 mg/l on 14/12/2016 when compared to a UKDWS of 0.2 mg/l.

3.6.9 The MRV for Cadmium (0.0001 mg/l) was exceeded twice within P-03 between September 2010 and June 2021 on 28/09/2012 at 0.0006 mg/l and on 22/03/2013 at 0.0002 mg/l.

3.6.10 Manganese was reported to exceed UKDWS in four of the 10 samples tested for Manganese. The highest of which was reported at 19 mg/l on 14/12/2016 when compared to a UKDWS of 0.05 mg/l. Lead was reported to exceed UKDWS in two of the 19 samples tested for lead. The highest of which was reported at 0.037 mg/l on 28/09/2012 when compared to a UKDWS of 0.01 mg/l. Antimony was reported to exceed UKDWS once of the five samples tested for Antimony. A concentration of 0.02 mg/l was reported on 22/03/2013 when compared to a UKDWS of 0.005 mg/l.

QUA_Q003-2021(P)-05

3.6.11 Magnesium was reported to exceed the UKDWS on all nine monitoring rounds during the monitoring period. The highest of which was reported at 81 mg/l on 27/07/2021 compared to a UKDWS of 50 mg/l. Sulphate was reported to regularly exceed the UKDWS of 250 mg/l at QUA_Q003-2021(P)-05 with a maximum concentration of 287 mg/l recorded on 04/06/2021. Manganese was reported to exceed the UKDWS on all nine monitoring rounds. The highest of which was reported at 0.282 mg/l on 04/05/2021 when compared to a UKDWS of 0.05 mg/l.

QUA_Q003-2021(P)-06

3.6.12 Magnesium was reported to exceed the UKDWS (50 mg/l) in all eight samples. The highest concentration of magnesium was 68 mg/l on 27/07/2021. Manganese was reported to exceed the UKDWS (0.05 mg/l) in all eight samples. The highest concentration of manganese was 0.119 mg/l on 21/04/2021.

QUA_Q003-2021(P)-07

3.6.13 Selenium was reported to exceed the UKDWS (0.01 mg/l) in one of the seven samples tested for Selenium on 30/03/2021 (0.011 mg/l).

4 MONITORING INFRASTRUCTURE

4.1 Introduction

4.1.1 Groundwater and surface water monitoring has taken place on-site since 1997 in accordance with permit EPR/BB3007CA. Additional monitoring has also been undertaken in order to characterise the hydrological and hydrogeological condition of the Site and surrounding area. This chapter describes the monitoring system employed/previously employed on-site and within the surrounding area. Section 5 describes the surface water and groundwater monitoring system required, in order to comply with permit EPR/BB3007CA, including assessment of any exceedances.

4.2 Surface Water Monitoring

4.2.1 The Site is dry, there are no surface water discharges off-site. Surface water is monitored at two locations (SW1 and SW3) along Bowburn Beck c.300m south of the Site.

4.2.2 Since 2011, surface water quality samples have been taken quarterly for the following parameters: Alkalinity, Biological Oxygen Demand, Ammoniacal Nitrogen, Chloride, pH, Electrical Conductivity, Total Organic Carbon, Suspended Solids, Potassium, Sulphate, Nitrite and Nitrate. Surface water samples have been taken annually for Sodium, Calcium, Magnesium, Total Organic Nitrogen and Chemical Oxygen Demand. Less frequently, heavy metals (minor ions) have been collected including; Iron, Manganese, Cadmium, Chromium, Copper, Nickel, lead, Zinc, Antimony, Selenium, Molybdenum. Visible oil is also monitored on every occasion. Prior to 2011 samples were collected monthly.

4.2.3 The location of SW1 and SW3 are shown on Drawing NT14345-016.

4.3 Spring Monitoring

4.3.1 Surface water monitoring points SW1 and SW3 are located up and down gradient respectively of SW2, a spring located within Coal Measures strata down hydraulic gradient of the Site.

4.3.2 Since 2011, SW2 has been sampled quarterly for the following parameters: pH, Conductivity, Chloride, Ammoniacal Nitrogen, Nitrate, Sulphate, Chemical Oxygen Demand, Biological Oxygen Demand, Total Organic Carbon and Suspended Solids, and at least annually for Potassium, Calcium, Magnesium, Sodium, Nitrite, Antimony, Total

Oxidised Nitrogen, Alkalinity, Iron, Manganese, Cadmium, Chromium, Copper, Nickel, lead, Zinc, Antimony, Selenium, Molybdenum.

4.3.3 The location of SW2 is shown on Drawing No NT14345-01.

4.4 Borehole Monitoring

4.4.1 There are three series of boreholes employed on-site to monitor groundwater elevations and quality:

- The P-0 borehole series comprised of six monitoring boreholes installed along the eastern and western flanks of the existing void. Of these six boreholes, two have been lost or destroyed (P-02 and P-04) and one blocked (P-01). The remaining boreholes are; P-03, P-05 and P-06. Details for each of these boreholes, including; ground elevation, location, depth, screened interval, geological logs and average groundwater elevation (where available), is provided within Appendix 7 and explained below; and
- The QUA borehole series comprised of 12 monitoring boreholes, primarily installed along the western flank of the existing void. Of these 12 boreholes, five have been buried, destroyed, are lost or have no access. The remaining boreholes are QUA_0001 – QUA_007. Appendix 7 details all the available information for this series of wells, including borehole location, ground elevation and average groundwater elevation. Limited information is held for the QUA borehole series. No borehole logs, screening intervals, screened geology are available therefore, it is not certain what geological unit each of the QUA boreholes in Appendix 7 are monitoring. Furthermore, no groundwater quality monitoring is undertaken within any of the QUA boreholes, they are used for elevation monitoring only.
- The Q003 boreholes series, drilled in 2021, comprised of five boreholes installed along the southern and eastern flanks of the Site. Q003-2021(P)-07 is a replacement borehole for P-01. Further details are provided below.

4.4.2 The third series of boreholes, the Q003 boreholes series, was drilled in 2021, comprising five boreholes installed along the southern and eastern flanks of the Site mainly in the proposed extension area. Q003-2021(P)-07 is a replacement borehole for P-01. Further details are provided in Appendix 7. Three boreholes were installed in the Coal Measures mudstone (Q003-2021(P)-05 to Q003-2021(P)-07) and two were

installed within a sandstone bed encountered at the top of the Coal Measures in the southern part of the Site (Q003-2021(P)-08 and Q003-2021(P)-09).

4.4.3 The location of the monitoring points that are included in the current monitoring network are shown on Drawing No NT14345-016.

4.5 Borehole Status

4.5.1 Borehole P-01, located to the east of the existing quarry void is still active, however was replaced by P-05 and P-06 within the permit as an improvement condition. The three boreholes form a triplicate, with screens installed across different geological horizons.

4.5.2 As reported within Appendix 7, P-01 was drilled to a depth of 122.2m above ordnance datum (AOD) (63m below ground level (m BGL)) into the underlying Coal Measures. The borehole was screened within the Yellow Sands Formation between 129 and 126m AOD (56 – 59m BGL). It is noted that no low permeability seal between the Yellow Sands Formation and Coal Measures Strata was added within the borehole. Nor was a low permeability seal added between the Yellow Sands Formation and the Raisby Formation Dolostone. When dipped between July 2013 and January 2020, the base of the borehole was reported at c.150 – 151m AOD (33 – 34m BGL), some 20m higher within the Raisby Formation Dolostone. The borehole is primarily reported as dry, groundwater is occasionally reported within the borehole, however only slightly above the reported base at c. 153m AOD. It is therefore suggested that the borehole is blocked. Any groundwater recorded within the borehole could be a result of infiltration from overlying strata or high groundwater conditions within the Coal Measures. The borehole is no longer representative, therefore data from this borehole will not be considered further in this report due to uncertainties surrounding it.

4.5.3 Borehole P-03, located to the north west of the quarry void is also active. P-03 encounters the Marl Slate Formation and Yellow Sands Formations close to the surface before both formations dip and thicken eastwards. The borehole was drilled to 149.3m AOD (6.7m BGL) and was entirely screened within the Coal Measures, between 152.2 – 149.3m AOD. Groundwater is often recorded within this borehole, on average at 150.4 m AOD (1.2m above the base of the borehole). Only a small number of monitoring rounds reported the borehole as dry. Groundwater is unconfined within the Coal Measures at P-03.

4.5.4 Borehole P-05, located to the east of the existing quarry void is reported as active. P-05 was drilled as a triplicate alongside P-06 to replace P-01 (not installed correctly) in accordance with an improvement condition set out in 2006. P-05 is the most northerly of the three boreholes within the triplicate. P-05 was drilled to a depth of 147m AOD (38m BGL) and installed within the Marl Slate Formation and Raisby Formation Dolostone. Between April 2017 and January 2020, groundwater was recorded on one occasion within P-05 at a depth of 148m AOD, 1m above the base of the borehole, corresponding with high groundwater conditions within the Coal Measures (P-03). On every other monitoring round the borehole was reported as dry.

4.5.5 Borehole P-06, located to the east of the existing quarry void is active, and is the most southerly of the boreholes within the triplicate. P-06 was drilled to a basal depth of 128.8m AOD (56.2m BGL) and screened across the Yellow Sands Formation and Coal Measures. In November 2020, P-06 was dipped to a basal depth of 131.5m AOD (53.5m BGL). Between April 2017 and January 2020, groundwater has been recorded a small number of times within P-06, on average at an elevation of 132m AOD. 0.5m above the base of the borehole. The borehole is primarily dry. Groundwater recorded within P-06 could be associated with potential seepage from the underlying Coal Measures during periods of high groundwater elevation.

4.5.6 Boreholes P0-2 and P0-4 were destroyed. No groundwater was recorded in either.

4.5.7 In summary, the Raisby Formation Dolostone and Marl Slate Formation are primarily reported as dry on-site. This is confirmed by borehole P-05 and through conditions experienced throughout the operational life of the Site. Groundwater was only recorded once in P-05, between March 2017 and January 2020. Groundwater was recorded at the base of the borehole and could have been a result of infiltrating water through the limestone sequence and perching on the low permeability Marl Slate Formation. Water could also have entered the borehole through its cap and flown down the borehole void.

4.5.8 The Yellow Sands Formation is also thought to be dry. This is confirmed by borehole P-06 and through conditions experienced throughout the operational life of the Site. Groundwater was recorded a small number of times within P-06 at the base of the borehole, however this was likely as a result of high groundwater elevations within Coal Measures strata rather than groundwater within the Yellow Sands Formation.

4.5.9 As a result of the dry conditions experienced in P-01, P-05 and P-06, no groundwater quality monitoring has been able to be undertaken within these wells.

4.5.10 P-03 and SW2, both located in the Coal Measures, are therefore the only remaining historic groundwater monitoring points where groundwater quality samples can/have been taken. The frequency and suite sampled in SW2 is provided in Section 4.3. Groundwater in P-03 is monitored quarterly for the following parameters Ammoniacal Nitrogen, Chloride, pH, Ammonium as N, Electrical Conductivity, Chemical Oxygen Demand, Total Organic Carbon, Total Oxidised Nitrogen. The following parameters are monitored biannually, Calcium, Magnesium, Sodium, Potassium, Sulphate, Iron, Manganese, Cadmium, Chromium, Copper, Nickel, Lead, Zinc, Antimony, Selenium and Molybdenum.

4.5.11 Five new monitoring wells (Q003-2021(P)-05 – Q003-2021(P)-09) have been installed on-site in March 2021 and monitoring of these boreholes commenced in March 2021.

5 REQUIRED MONITORING UNDER PERMIT EPR/BB3007CA

5.1 Surface Water Monitoring

5.1.1 Surface water quality monitoring is required under environmental permit: EPR/BB3007CA along Bowburn Beck at surface water monitoring points: SW1 and SW3, upstream and downstream of SW2 (spring) respectively. The following suite is required to be monitored on a quarterly basis: pH, Electrical Conductivity, Chloride, Ammoniacal Nitrogen, Suspended Solids, Nitrate, Nitrite, Sulphate, Potassium, Biological Oxygen Demand, Chemical Oxygen Demand, Total Organic Carbon and Visible Oil. Calcium, Magnesium, Sodium and Alkalinity are required to be monitored annually.

5.2 Surface Water Quality Results

5.2.1 Surface water monitoring results from SW1 and SW3 recorded between September 2010 and June 2021 are provided in Appendix 2. Graphical results are provided within Appendix 3.

5.2.2 No trigger levels were set for SW1 or SW3 within the Permit, therefore surface water quality results have been compared with EQS[4].

SW1

5.2.3 Surface water results from SW1 indicate exceedances of Ammoniacal Nitrogen in October 2010 (0.31 mg/l), June 2011 (0.66 mg/l) and September 2017 (1.2mg/l) when compared to an EQS of 0.3 mg/l.

5.2.4 In February 2011, sulphate concentrations were recorded at 734 mg/l, above the EQS of 400 mg/l.

5.2.5 Further heavy metal exceedances of EQS were recorded within SW1, however these were parameters were not listed on the permit. For details of these see Section 3.1.

SW3

5.2.6 No parameters listed on the permit were exceeded between September 2011 and June 2021. A few heavy metal exceedances of EQS were recorded within SW3, however these parameters were not listed on the permit. For details of these see Section 3.1.

5.3 Spring Monitoring

5.3.1 According to permit EPR/BB3007CA, the following parameters are required to be sampled on a quarterly basis: pH, Conductivity, Chloride, Ammoniacal Nitrogen, Nitrate, Sulphate, Chemical Oxygen Demand, Total Suspended Solids, Nitrate, Nitrite, Potassium, Total Organic Carbon and Biological Oxygen Demand. Whilst the following parameters are required to be monitored annually: Sodium, Calcium, Magnesium, Lead, Copper, Zinc, Chromium, Cyanide, Cadmium, Mercury, Nickel and Phenol.

5.3.2 Trigger levels set out in environmental permit: EPR/BB3007CA (previously TP3730BA) are shown in Table 2.

Table 2: Trigger Levels for Spring Water

Parameter	Compliance Limit	Units
Suspended Solids	60	mg/l
Ammonia	0.5	mg/l
pH	>6 to <9	pH units
Visible Oil	None	Visible Trace

5.4 Spring Water Quality Results

5.4.1 SW2 monitoring results recorded between September 2010 and May 2021 are provided in Appendix 5. Graphical results are provided within Appendix 6.

5.4.2 No exceedances of any trigger levels were recorded between September 2010 and December 2020.

5.4.3 Where trigger levels are absent, spring water quality results have been compared to UKDWS and where appropriate MRV. Sulphate was reported to regularly exceed the UKDWS of 250 mg/l. Sulphate was reported at similar levels within Bowburn Beck at surface water monitoring points SW1 and SW3.

5.4.4 Magnesium was also reported to regularly exceed the UKDWS of 50 mg/l. Lead was reported to exceed UKDWS in September 2011 with a concentration of 0.039 mg/l when compared to UKDS of 0.01 mg/l.

5.4.5 The MRV for Cadmium (0.0001 mg/l) was exceeded twice within SW2 between September 2010 and May 2021 on 23/09/2011 at 0.003 mg/l and on 28/09/2012 at 0.0006 mg/l.

5.4.6 Any exceedances of parameter not stated within the permit are described in Section 3.6.

5.5 Borehole Monitoring

5.5.1 Under environmental permit: EPR/BB3007CA (previously TP3730BA), groundwater in boreholes P-02 to P-06 are to be sampled quarterly for the following parameters: Ammoniacal Nitrogen, Chloride, pH, Ammonium as N, Electrical Conductivity, Chemical Oxygen Demand, Total Organic Carbon, Total Oxidised Nitrogen and biannually for; Calcium, Magnesium, Sodium, Potassium, Sulphate, Iron, Manganese, Cadmium, Chromium, Copper, Nickel, Lead, Zinc, Antimony, Selenium and Molybdenum. A List I and List II screen should be done annually.

5.5.2 Control measures set out in environmental permit: EPR/BB3007CA state Ammoniacal Nitrogen should not exceed 0.3 mg/l and chloride should not exceed 56 mg/l within boreholes P-02, P-03, P-05 and P-06. If exceeded actions stated within the Groundwater Action Plan shall be instigated. Trigger levels for ammoniacal nitrogen of 0.39 mg/l and Chloride of 250 mg/l should not be exceeded within boreholes P-02, P-03, P-05 and P-06.

5.5.3 Due to the absence of groundwater within P-05 and P-06 (both largely dry), no sampling has been undertaken within either borehole. In addition, P-02 and P-04 are both lost/destroyed; therefore, no groundwater sampling has been undertaken.

5.5.4 Groundwater sampling has therefore only taken place in P-03, upgradient of the Site. The spring at SW2 is taken as the Site's down gradient monitoring point. Water quality results for SW2 are described in Section 5.4.

5.6 Groundwater Quality Results

5.6.1 Groundwater quality results from P-03 are provided in Appendix 5 and graphically in Appendix 6.

5.6.2 Chloride trigger levels were exceeded on two occasions in P-03 between December 2010 and December 2019. Chloride exceedance were reported at 293 mg/l on 16/12/2010 and 279 mg/l on 15/06/2012, when compared to a trigger level of 250

mg/l. No other exceedances of trigger levels were reported between December 2010 and 2019.

5.6.3 Where trigger levels are absent, groundwater quality results have been compared to UKDWS and MRV. Results have been provided between December 2010 and December 2019. Calcium exceeded UKDWS on one occasion during the monitoring period in P-03. Calcium concentration was reported at 278 mg/l on 28/09/2012. Magnesium was reported to exceed UKDWS on six of the 11 monitoring rounds during the monitoring period. The highest of which was reported at 119 mg/l on 28/09/2012 when compared to a UKDWS of 50 mg/l. Iron was reported to exceed UKDWS in four of the 10 samples tested for Iron. The highest of which was reported at 8 mg/l on 14/12/2016 when compared to a UKDWS of 0.2 mg/l.

5.6.4 Manganese was reported to exceed UKDWS in four of the 10 samples tested for manganese. The highest of which was reported at 19 mg/l on 14/12/2016 when compared to a UKDWS of 0.05 mg/l. Lead was reported to exceed UKDWS in two of the 10 samples tested for lead. The highest of which was reported at 0.037 mg/l on 28/09/2012 when compared to a UKDWS of 0.01 mg/l. Antimony was reported to exceed UKDS once of the five samples tested for antimony. A concentration of 0.02 mg/l was reported on 22/03/2013 when compared to a UKDWS of 0.005 mg/l.

5.6.5 The MRV for Cadmium (0.0001 mg/l) was exceeded twice within P-03 between September 2010 and December 2019 on 28/09/2012 at 0.0006 mg/l and on 22/03/2013 at 0.0002 mg/l.

5.7 Permit Compliance

5.7.1 The Site operative monitors as far as possible within the requirements of their permit in terms of wells, compounds and frequencies.

5.7.2 No exceedances of any trigger levels were recorded within down gradient monitoring point, SW2. Trigger levels were exceeded twice within P-03 with respect to Chloride in 2010 and 2012 but have not been exceeded since. No other trigger levels were exceeded in P-03.

5.7.3 As stated within Section 5.6, a list of major and minor ions are reported to exceed UKDWS in P-03, these include: Calcium, Magnesium, Iron, Manganese, Lead and Antimony. These metal exceedances have not been reported within SW2, down-gradient of the Site, baring Magnesium which is reported to frequently exceed UKDWS in SW2 and P-03.

5.7.4 Sulphate concentrations within SW2 are elevated with respect to concentrations recorded within P-03 and UKDWS, however are consistent with sulphate concentrations recorded within Bowburn Beck up and down gradient of SW2.

5.7.5 Monitoring undertaken on-site, detailed above, complies with the monitoring required to be undertaken in line with Permit EPR/BB3007CA. Monitoring results comply with the permit and identify that the Site is having no adverse effect on the surrounding area.

6 REVIEW OF HYDROGEOLOGICAL CONCEPTUAL SITE MODEL

6.1 Source

6.1.1 Inert waste landfilling within quarry void. Inert waste is deposited across the Site in four locations as summarised in Section 2 above. Inert waste proposed to be filled into the proposed permit area are consistent with what is listed in the original permit. Details of waste types are listed below:

- Waste glass base fibrous material;
- Glass packaging;
- Glass;
- Concrete;
- Soil and stones;
- Bricks;
- Tiles and ceramics; and
- Mixtures of concrete, bricks, tiles and ceramics.

6.1.2 Some limestone overburden is also proposed to be backfilled within the quarry void as is the current case on-site.

6.2 Pathway

6.2.1 Pathways for groundwater contamination are summarised below:

- Vertical migration of recharging waters through the unsaturated Lower Raisby Formation Dolostone and Yellow Sands Formation;
- Groundwater flow down regional dip, through secondary permeability within the Raisby Formation Dolostone, above the impermeable Marl Slate Formation;
- Lateral migration of groundwater within Yellow Sands Formation;
- Flow of groundwater within the Coal Measures Formation predominantly to the south / south east.

6.3 Receptor

6.3.1 Water receptors potentially at risk are provided below:

- Water within Secondary A Aquifer – Coal Measures;
- Water within Principal Aquifers; Yellow Sands Formation and Raisby Formation Dolostone (perched above Marl Slate Formation);
- Surface watercourse (Bowburn Beck) to the south of Site; and
- Springs to the south of Site.

6.4 Summary of Updated Hydrogeological Conceptual Site Model

6.4.1 Conceptual understanding of the Site is provided within the bullet points below.

- Old Quarrington and Cold Knuckle Quarry target the Raisby Formation Dolostone and Yellow Sands Formation. Where sand and limestone is removed from the quarry, the Site is proposed to be backfilled with inert waste overlying a low permeability dolostone geological barrier. This low permeability dolostone geological barrier will also be applied to the lateral sides of the landfill void, to mitigate lateral pathways from the inert waste into the adjacent Yellow Sands Formation and Raisby Formation Dolostone. The artificially established geological barrier (basal and sidewall liner) will have a permeability of $1x10^{-7}$ m/s or less.
- As a result of the dry conditions reported on-site throughout the duration of works at Old Quarrington (since 1997), and as reported within on-site monitoring borehole P-05 installed at the base of the Raisby Formation Dolostone, the limestone formation is dry within the Site and surrounding area.
- The Raisby Formation Dolostone dips and thickens from west to east across the Site and is defined as a Principal aquifer by the EA. The Site is entirely located within a SPZ3 (total catchment), associated to the Raisby Formation Dolostone and Yellow Sands Formation.
- Infiltration of rainwater into the limestone may occur within the surrounding area, where superficial till is absent. Rainwater will likely infiltrate through the limestones secondary permeability, to its boundary with the Marl Slate Formation. The Marl Slate Formation is likely to have very low permeability and therefore will act as an aquitard, limiting further vertical migration. This recharged groundwater is then likely to flow down regional dip, to the east away from Site. The area immediately to the east of the Site is however known

to be highly fractured from the surface down through the Raisby Formation Dolostone, Yellow Sands Formation and Marl Slate Formation and into Coal Measures strata. Fractures are associated to historical coal mining within the area. Therefore, localised vertical migration of recharging waters into the Coal Measures strata may occur where fractures are present. Elsewhere the Marl Slate Formation acts as an aquitard.

- As the Site sits at the top of the limestone ridge, above an impermeable layer (Marl Slate Formation), groundwater can only enter the limestone via direct rainfall recharge; the limestone at the site has no catchment area.
- Any surface water/precipitation on to the limestone within the Site area is allowed to infiltrate directly into the underlying formation. There is no surface water management system employed on-site.
- The Marl Slate Formation separates the Raisby Formation Dolostone and the Yellow Sands Formation;
- The Yellow Sands Formation are also thought to be largely dry throughout their depth. This is reported within monitoring borehole P-06, installed at the interface between the Coal Measures and Yellow Sands Formation. Groundwater has only been reported within this borehole on a small number of occasions between April 2017 and January 2020 and this was likely a result of high groundwater conditions within Coal Measures strata. Furthermore, dry conditions within the Yellow Sands Formation have been reported on-site since working Old Quarrington in 1997.
- It is likely that the Yellow Sands Formation and Coal Measures strata are in hydraulic continuity with each other, giving rise to damp conditions/seepages occasionally at the base of the Yellow Sands Formation.
- Any groundwater within the Raisby Formation Dolostone and Yellow Sands Formation within the surrounding area will likely flow down regional dip, towards the east/south east. Radial flow especially to the south is also likely to occur as a result of the topography within the area, falling in a southerly direction. Formation of groundwater in these formations to the east is likely to experience a significant degree of underdrainage due to the heavily fractured nature of the Coal Measures in this area.

- Coal Measures strata are water bearing. This is shown in P0-3 and QUA_Q003-2021(P)-05 to QUA_Q003-2021(P)-08 where groundwater is recorded throughout the monitoring period, although borehole QUA_Q003-2021(P)-09, installed in the upper sandstone unit in the Coal Measures is sometimes dry;
- Regional groundwater flow within Coal Measures strata is thought to be towards the south east. However local groundwater flows are thought to follow a flow path towards the east and south, as a result of steep sided topography, towards the spring line and watercourse located to the south of the Site.
- Groundwater quality up-gradient (P-03) of Site reports exceedances of trigger levels and UKDWS for a number of major and minor ions. These exceedances are less common at the down-gradient monitoring point (SW2) indicating the Site is having not impact on groundwater underlying the Site.

6.4.2 The above CSM agrees with the CSM presented within the 2004 Conceptual Site Model Report[14] in that the Raisby Formation Dolostone and Yellow Sands Formation are largely dry on-site. The Yellow Sands Formation in some areas is reported to have a damp base, and this is potentially a result of hydraulic continuity with the underlying Coal Measures. However, this CSM expands on a likely component of radial groundwater flows within the Coal Measures strata as a result of the Site's location, on top of a steep hill/escarpment. This location potentially gives rise to localised groundwater flow, towards the south and east.

[14] Crestwood Environmental (2004). Conceptual Model, Environmental Setting and Installation Design Report – Old Quarrington Quarry Landfill

7 HYDROGEOLOGICAL RISK ASSESSMENT

7.1 Nature of the Hydrogeological Risk Assessment

7.1.1 The EA guidance proposes a tiered approach to risk assessment such that the degree of effort and complexity reflects the potential risk posed by a particular Site or situation. This process commences with a risk screening exercise, which is the process used to determine whether a landfill development represents, or potentially represents, a risk to groundwater or surface water resources.

7.1.2 Due to the sensitive nature of the Site, located on a Principal Aquifer a Generic Quantitative Risk Assessment (GQRA) was proposed. The level of risk assessment was presented to, and agreed with, the EA as part of the pre-application process.

7.2 Risk Screening

Compliance with Groundwater Directive

7.2.1 Based upon the waste types to be accepted (inert waste) at the Site it is considered that the quantity and concentration of listed substances "are likely to be very small and likely to be similarly stringent to Drinking Water Standards"[15] hence the Site falls outside the scope of the Groundwater Directive.

Collection of Leachate

7.2.2 As the waste accepted at the Site is inert, in accordance with EA guidance, it is considered that there is no requirement to collect and manage leachate. Therefore, there is no requirement for an artificial sealing liner, however an artificially established geological barrier (basal and sidewall liner) is provided.

Geological Barrier

7.2.3 The artificially established geological barrier (basal and sidewall liner) is required to provide sufficient attenuation between the landfill source and any potential groundwater receptor in order to ensure compliance with the Groundwater Directive. The proposed geological barrier at the Site comprises approximately 1m crushed Raisby Formation Dolostone compacted in place over the Coal Measures strata. The geological barrier is also required along the flanks of the Site. The geological barrier will have a permeability of $1x10^{-7}$ m/s or less.

[15] Quote from paragraph 12 of the statutory "Guidance on the Groundwater Regulations, 1998", DETR 2001. Last Accessed: 12/12/2020.

Landfill Location

7.2.1 The Site is located on the western extremity of the Raisby Formation Dolostone sub-crop which together with the Yellow Sands Formation forms a Principal Aquifer of regional importance. There is no down-gradient receptor from these formations at the Site as the Site sits on the formations western extents and the geology is reported as dry in both formations. The Site is located within Zone III (Total Catchment) of several public water supply boreholes. Although the Site setting is deemed sensitive, due to the nature of the waste stream the location complies with the EA position statement on landfill location[16]. As outlined within Section 6, the Source-Pathway-Receptor is associated to the underlying Coal Measures Strata, which is not related to the SPZ, therefore reducing the Site's sensitivity.

7.3 Priority Contaminants to be Modelled

7.3.1 Given the inert nature of the material and the strict pre-acceptance and acceptance procedures that will be in place for the Site, it is unlikely that any leachate will contain any significant contamination.

7.3.2 Arsenic and lead (hazardous substances) may be present in paints/glazes used on ceramic products or tiles. Arsenic and lead have been selected as an indicator of pollution from these types of materials. Nickel has also been modelled as a potential contaminant found in inert waste material.

7.3.3 The source term for the inert waste is based on proposed waste types and Waste Acceptance Criteria (WAC) values for inert waste, provided within Appendix 8. WAC data have been compared to the UKDWS and a "risk factor" has been calculated by dividing the WAC data by the UKDWS. Each parameter has been ranked based on the calculated risk factor, see Appendix 8. Lead and arsenic have the highest risk factor (both 5) which confirms that lead and arsenic are the key contaminants of concern and these contaminants have been modelled. Arsenic and lead are both hazardous substances. Nickel, a non-hazardous pollutant, has the second highest risk factor of 2 (i.e. the WAC leachate concentration (0.04mg/l) is higher than the UKDWS (0.02mg/l)). Lead has been reported to exceed UKDWS on a number of occasions during the monitoring period at the upgradient monitoring point, however, the UKDWS has only been exceeded once at the down gradient monitoring point. Nickel has not been

[16] Landfill Directive Regulatory Guidance Note 3 (v4, December 2002). Groundwater Protection: Locational aspects of landfills in planning consultation responses and permitting decisions.

reported to exceed the UKDWS at the upgradient monitoring point, however concentrations are close to exceedance on a number of occasions. Nickel is reported at lower concentrations within the down-gradient monitoring point. Arsenic has not been monitored.

7.3.4 Mercury, cadmium and ammonia were used as priority contaminants of concern in the 2004 HRA[17] - P20 assessment for rogue loads. Mercury has a risk factor of 1 (i.e. the WAC leachate concentration (0.001mg/l) is the same as UKDWS (0.001 mg/l)) and cadmium has a risk factor of 0.8 (i.e. the WAC leachate concentration (0.004mg/l) is lower than the UKDWS (0.005mg/l)). Ammonia does not have a WAC value. Mercury and cadmium are deemed to be pose a lower risk than lead, arsenic and nickel (higher risk factors). Mercury and cadmium are also expected to behave in a similar way to the modelled parameters, therefore they are not deemed necessary to be modelled.

7.3.5 Interim compliance limits have been proposed for the selected modelling parameters; lead, arsenic and nickel, and for consistency with the 2004 HRA, mercury, cadmium and ammonium. Interim compliance points are provided in Section 7.10. Monitoring of groundwater quality will include additional hazardous substances and non-hazardous pollutants, as detailed in Sections 4, 5 and 9.

7.4 LandSim Model

7.4.1 As discussed in Section 7.3 above, priority contaminants to be modelled are lead, arsenic and nickel. A simple LandSim model was developed for the Site to support the permit application. The model parameterisation based on site specific information (where available) and conservative assumptions is summarised in Appendix 9. The thickness of the unsaturated zone is set at a uniform distribution between 0m and 4m, as indicated by groundwater elevations recorded on Site. The LandSim model inputs are also provided within Appendix 9. LandSim results are included as Appendix 10 and electronic model files are included in Appendix 11. The model incorporates the existing landfill on-site and the proposed extension area. As per the conceptual site model, groundwater flow is thought to be radial, to the east and south. The model has been run with the conservative assumption that groundwater flow is to the east (larger source term). The duration of landfill filling has been based on the start of waste deposition on-site in 2005. It is assumed that waste will cease to be deposited

[17] Hafren Water (2004). Old Quarrington landfill Hydrogeological Risk Assessment. Report Reference OQ/HRA. Version 1.1.

in 2031, hence 26 years till the end of filling, as is the case for the management control duration. The barrier type has been selected as clay, as is the Landsim default and the hydraulic conductivity has been set at $1x10^{-7}$ m/s to reflect the conductivity of the 1m crushed dolostone barrier. Hydraulic gradient (0.02) has been calculated based on dip data from March 2021, within the 2021 borehole series.

Water Balance

7.4.2 The leachate head will depend on the inflows, outflows and changes in storage. Inflows comprise infiltration into the landfill. Outflows comprise leakage through the engineered barrier system, off-site disposal of leachate and surface breakout. When run in "specified head" mode a leachate head is specified for the operational phase and during this period LandSim assumes any excess leachate is removed from the landfill to maintain the specified head, although in practice there is no requirement for leachate management for inert landfill sites. Leachate leakage will depend on the leachate head, the properties of the liner system and the properties of the underlying unsaturated zone. After management control ends (post closure) the leachate head will depend on infiltration and leakage. For a landfill the head at which leachate breakout will occur is the height of the lowest edge of the void.

7.4.3 Appendix 10 illustrates the leachate head, leakage from the engineered barrier system, flow to a leachate treatment plant and surface breakout. During the operational phase leachate heads are set at a nominal leachate head of 0.1m as inert waste is unlikely to generate significant volumes of leachate. The results show that outflow to a leachate treatment plant would be zero (i.e. no leachate management would be required at the Site). The leachate heads, and leakage from the engineered barrier system, decrease at the end of the operational phase.

Modelled Concentrations

7.4.4 For arsenic and lead, in accordance with EA guidance[18], the compliance point has been set at the base of the unsaturated zone. For nickel (non-hazardous pollutant), the compliance point has been assessed at the off-site monitoring point, 50m down gradient of Site.

[18] Environment Agency (2021). Landfill developments: groundwater risk assessment for leachate. Last accessed 19/04/2021. Available: https://www.gov.uk/guidance/landfill-developments-groundwater-risk-assessment-for-leachate#compliance-points

7.4.5 The model results are assessed against Environmental Assessment Limits (EALs). For hazardous substances, the EALs are typically based on the Minimum Reporting Values (MRV). If there is no published MRV, as is the case for lead and arsenic, the EAL is based on the laboratory method limit of detection (LOD). For non-hazardous pollutants, the EALs are typically based on the UKDWS. The EALs are summarised in Table 3.

7.4.6 LandSim modelling suggests that at the base of the unsaturated zone, no concentrations of arsenic or lead are likely to breakthrough. LandSim modelling also suggests that at the compliance point, no concentrations of nickel are likely to breakthrough. Modelling results calculated by LandSim, summarised in Table 3, therefore suggest that concentrations of both arsenic and lead at the base of the unsaturated zone and nickel at the compliance point are lower than the EALs. The Site is therefore not deemed to pose a risk to the water environment.

Table 3. Modelled Concentrations of Hazardous Substances at Base of the Unsaturated Zone and Non-hazardous Pollutants at the off-site Compliance Point

	95th Percentile Concentration (mg/l)	Model Year of Occurrence of Peak Concentration	EAL (mg/l)
Lead	0	-	0.001*
Arsenic	0	-	0.001*
Nickel	0	-	0.02**
Notes * Based on laboratory method LOD as no published MRV ** UKDWS			

7.5 Assessment Scenarios

Lifecycle Phases

7.5.1 Given the inert nature of the material, the absence of any biodegradable materials and the strict pre-acceptance and acceptance procedures that will be in place for the Site, the physical characteristics of the deposited material are envisaged to remain constant. Any significant change in quality of any leachate generated over the life of the Site is unlikely.

7.5.2 The basal and side slope lining systems will be an artificially established geological barrier. Due to the inert nature of the waste it is not necessary to provide an artificial

sealing layer above this mineral layer. In the absence of an artificial sealing layer the integrity of the containment system is unlikely to change with time.

7.5.3 The hydrogeological risk assessment presented is therefore considered appropriate for all stages of the landfill's lifecycle from operation to closure.

7.6 Accidents and Their Consequences

7.6.1 The possibility of rogue loads of non-inert material being deposited at the Site is considered in the selection of priority contaminants (Section 7.3). Non-inert material may lead to the generation of leachate containing potentially polluting substances. However, in the unlikely event of this occurring it is considered that the concentrations of pollutants within a leachate would be low due to the relatively low volume of any non-inert material within the landfill.

7.7 Review of Technical Precautions

7.7.1 Due to the inert nature of the material there is no requirement to prevent the formation of leachate. No formal capping is required; however, the site will be restored with topsoil and magnesian limestone and will be reinstated as magnesian grassland.

7.7.2 The primary measure to prevent the deposition of rogue loads of non-inert material at the Site is the strict adherence to material acceptance criteria.

7.8 Emissions to Groundwater

Hazardous Substances

7.8.1 For hazardous substances, the compliance point would be the point at which the substance would enter groundwater below the Site (base of unsaturated zone).

Non-Hazardous Pollutants

7.8.2 For non-hazardous pollutants, the compliance point would be groundwater immediately downgradient of the Site boundary – in this case 50m down-gradient of modelled groundwater flow (to the east).

7.9 Surface Water Management

7.9.1 The Site is designed to allow surface water to either infiltrate at source into the highly permeable bedrock or flow overland into the quarry void, where it will then infiltrate into the bedrock. There is no surface water discharge from the Site.

7.10 Hydrogeological Completion Criteria

7.10.1 Interim groundwater compliance limits are proposed for lead, arsenic, nickel, mercury, cadmium and ammonium within Table 4 based on MRV and the maximum recorded concentrations during the baseline groundwater monitoring programme. The interim compliance limits relate to boreholes P-03, and Q0003-2021(P)-05 to Q0003-2021(P)-07 only as Q0003-2021(P)-08 and Q0003-2021(P)-09 were dry or contained insufficient water to obtain a sample. Interim groundwater compliance points will be updated once baseline monitoring is completed (following collection of 12 samples from boreholes Q0003-2021(P)-05 to Q0003-2021(P)-07).

Table 4. Proposed Interim Groundwater Compliance Limits (mg/l)						
Substance	**Hazardous Substance / Non-Hazardous Pollutant**	**UKDWS (mg/l)**	**MRV for Hazardous Substances**	**Maximum Upgradient Background Groundwater Quality (mg/l) for Non-Hazardous Pollutants**	**Proposed Interim Compliance Limit (mg/l)**	**Basis**
Lead	Hazardous Substance	0.01	0.01*	-	0.01	MRV
Arsenic	Hazardous Substance	0.01	0.01*	-	0.01	MRV
Nickel	Non-Hazardous Pollutant	0.02	-	0.019	0.021	Maximum upgradient baseline groundwater concentration plus 10%
Mercury	Hazardous Substance	0.001	0.01	-	0.01	MRV
Cadmium	Non-Hazardous Pollutant	0.005	-	$6x10^{-4}$	$6.6x10^{-4}$	Maximum upgradient baseline groundwater concentration plus 10%
Ammonium	Non-Hazardous Pollutant	0.5	-	0.41	0.39	As stated within existing Permit – Table S4.2.
Notes: MRV = Minimum Reporting Value for hazardous substance. Where an MRV is not defined by the EA the laboratory method limit of detection has been used (indicated by *).						

8 REQUISITE SURVEILLANCE

8.1.1 Under the Groundwater Regulations 1998, there is a requirement for 'requisite surveillance' in the form of leachate, groundwater and surface water monitoring.

8.1.2 Requisite surveillance is summarised in Table 5 below.

8.1.3 The monitoring suite within the permit is suggested to be modified to conform with EA requirements. All metals tested within groundwater samples should be as dissolved, not total concentrations, with spring and surface water sampled for dissolved and total.

Table 5. Updated Monitoring Requirements for Permit.

Emission Point Reference	Parameter	Monitoring Frequency	Monitoring Standard	Other Specification
Surface Waters				
SW1 and SW2	Electrical Conductivity, Chloride, Ammoniacal Nitrogen, pH; Total Alkalinity, Magnesium, Potassium, Sulphate, Calcium, Sodium, Chromium (VI), Antimony, Copper, Iron, Lead, Nickel, Zinc, Manganese, Selenium, Cyanide, Suspended Solid, Total Organic Carbon, Chemical Oxygen Demand; Arsenic, Mercury, Benzene, Toluene, Ethyl Benzene, Xylene, Benzo(a)pyrene, Total Poly Chlorinated Biphenyls (PCB), Total Polycyclic Aromatic Hydrocarbons (PAH).	Quarterly: Annually Annually for first six years of operation then every two years	EQS[2]	n/a

Table 5. Updated Monitoring Requirements for Permit.				
Emission Point Reference	**Parameter**	**Monitoring Frequency**	**Monitoring Standard**	**Other Specification**
Groundwaters				
Upgradient				
P-03	Water level, Electrical Conductivity, Chloride, Ammoniacal Nitrogen, pH; Total Alkalinity, Magnesium, Potassium, Sulphate, Calcium, Sodium, Chromium (VI and Total), Antimony, Copper, Iron, Lead, Nickel, Zinc, Manganese, Selenium, Cyanide Total; Monitoring point base, Hazardous substances, Arsenic, Mercury, Benzene, Toluene, Ethyl Benzene, Xylene, Benzo(a)pyrene, Total Poly Chlorinated Biphenyls (PCB), Total Polycyclic Aromatic Hydrocarbons (PAH).	Quarterly Annually Annually for first six years of operation		
Downgradient				
Q0003-2021(P)-05, Q0003-2021(P)-06 andQ0003-2021(P)-07 and SW2.	Water level, Electrical Conductivity, Chloride, Ammoniacal Nitrogen, pH; Monitoring point base, Total Alkalinity, Magnesium, Potassium, Sulphate, Calcium, Sodium, Chromium (VI), Antimony, Copper, Iron, Lead, Nickel, Zinc, Manganese, Selenium, Cyanide, Total Organic Carbon, Chemical Oxygen Demand;	Quarterly Annually		

Table 5. Updated Monitoring Requirements for Permit.				
Emission Point Reference	**Parameter**	**Monitoring Frequency**	**Monitoring Standard**	**Other Specification**
	Arsenic, Mercury, Benzene, Toluene, Ethyl Benzene, Xylene, Benzo(a)pyrene, Total Poly Chlorinated Biphenyls (PCB), Total Polycyclic Aromatic Hydrocarbons (PAH).	Annually for first six years of operation then every two years		
Q0003-2021(P)-08 and Q0003-2021(P)-09	Water level Monitoring point base	Quarterly Annually		
Note: This table should supersede the monitoring requirements currently stated within Tables S4.5 and S4.6 within the original permit schedule. This table relates to operational phase monitoring requirements, after-care phase monitoring requirements will be defined as part of the formal closure procedures.				

9 PERMIT VARIATION

9.1 Improvement Condition

9.1.1 An expediated monitoring programme within the new monitoring wells (as mentioned in Section 4) is currently underway. Between March and July 2021 nine samples have been obtained from borehole QUA_Q003-2021(P)-05, eight from borehole QUA_Q003-2021(P)-06 and seven from borehole QUA_Q003-2021(P)-07. The results are generally comparable to the existing data for borehole P-03 and interim compliance limits have been derived (Section 7.10). The interim compliance limits will be reviewed following collection of 12 samples from each borehole and it is envisaged that this requirement will be included as an improvement condition in the permit variation.

10 CONCLUSIONS

10.1 A Conceptual Hydrogeological Site Model was developed in Section 6, following a review of the baseline conditions for the Site. Groundwater was identified as the key pathway for the potential migration of pollutants. The Site is considered dry. Damp seeps at the base of the Yellow Sands Formation occur occasionally. This likely occurs as a result of high groundwater levels within the underlying, water bearing, Coal Measures Formation that are in hydraulic continuity with the Yellow Sands Formation. The key pathway for pollutant migration suggested to be through basal and side wall liner leakage into the underlying bedrock (Coal Measures) aquifer.

10.1.1 A Generic Quantitative Risk Assessment was conducted to model priority contaminants for the proposed inert landfill. A LandSim Model, incorporating site-specific data and conservative assumptions was produced to emulate the conditions present at Old Quarrington.

10.1.2 Hazardous substances; arsenic and lead and non-hazardous pollutant, nickel were modelled as a result of their high, risk factors determined in Section 7. Results from LandSim modelling indicate that there will be no breakthrough of arsenic, lead or nickel at their respective compliance points, which for hazardous substances is the base of the unsaturated zone and for non-hazardous pollutants is the off-site compliance point, 50m down gradient of the Site.

10.1.3 It is therefore suggested that inert waste infilling within Old Quarrington will have no adverse impact on the water environment.

10.1.4 Interim compliance limits for a number of parameters potentially encountered with the waste have also been provided. The interim compliance limits will be reviewed following collection of 12 samples from each borehole and it is envisaged that this requirement will be included as an improvement condition in the permit variation.During the operational phase, groundwater monitoring is proposed within all current groundwater monitoring boreholes on a six-monthly basis.

APPENDICES

APPENDIX 1

Construction Quality Assurance (CQA) Validation Report for Geological Barrier

Wardell Armstrong LLP
City Quadrant, 11 Waterloo Square, Newcastle upon Tyne, NE1 4DP, United Kingdom
Telephone: +44 (0)191 232 0943 www.wardell-armstrong.com

Our ref: NT12720/016 *Date*: 25 February 2021
Your ref:

Quarrington Quarry Landfill Lining Works, North Slope Batter Phase 1
CQA Verification Statement

A Wardell Armstrong engineer visited the above site on two recent occasions, the 18th December 2020 and 15th February 2021 to oversee testing on the upper Phase 1 area, as outlined in red on the attached drawing (Q003 LINER 2020-02-11_A3). The most recent lining has been carried out on the upper north batter slope of the site, a total area of approximately 5,600m^2, the areas shaded green on the drawing are where in excess of 1.0m liner thickness has been proved by survey. Visual observation of the attenuation layer was undertaken to indicate that the material was satisfactorily compacted, site photographs from the two visits are attached below.

18th December 2020

The east half of the slope has been lined with crushed dolomite, in line with previous phase areas of the site.

In accordance with previous onsite testing and as detailed and agreed in the CQA Plan, the lining material was tested using a Nuclear Density Gauge (NDG) correlated by Sand Replacement Testing (SRT). A total of 5 NDG tests were conducted by Ian Farmer Associates, backed up with 1 SRT. The approximate testing locations are shown annotated 1 to 5 on the drawing. The frequency of testing equates approximately to 1 test per 500m^2, comfortably exceeding the CQA requirement of 1 test per 2500m^2.

The attached testing report shows that test locations 1, 2 and 3 recorded dry density values of 1.83 Mg/m^3, 1.91 Mg/m3 and 1.87 Mg/m3 respectively, all exceeding the 90% relative compaction acceptance criteria (equivalent to a maximum permeability of 1 x 10^{-7}m/s, determined through the CQA plan process). Moisture contents fell within the acceptable range of 9.6% to 14.5%, the optimum moisture content being 13%. The result of the SRT test, taken at location 2, recorded a dry density value of 1.94 Mg/m^3 (95.6% relative compaction) with a moisture content of 13.9%, therefore correlating with the result of the NDG.

The test report shows that for test locations 4 and 5, the dry density values were lower at 1.57 Mg/m3 and 1.69 Mg/m3, equivalent to 77% and 83% relative compaction.

Test locations 1 – 3 were located on the eastern part of the area, with locations 4 and 5 further to the west. It transpired, on completion of testing, that the western area was incomplete and that this part of the site is to be formed from clay rather than dolomite. The two test results from the west area can therefore be disregarded. The three acceptable test results represent an amended test frequency within this area of approximately 1 test per 900m^2.

15th February 2021

The west half of the slope has been lined with clay to 1.0 metre in thickness. The attached Drawing Q003 LINER 2020-02-11_A3 shows the area of attenuation layer lining highlighted in red. The works represent a westward extension of the Phase 1 Area, north side slope. The area lined extends to 2,800m^2. Three clay cores were taken as part of the inspection, the approximate locations of which are shown on the drawing. At a frequency of 1 test per 900m^2, this exceeds the requirement (1 per 2,500m2) set out in the CQA Plan.

The results of testing (certificates attached) show the 3 permeability values at between 1.36 x 10-9m/s and 4.99 x 10-10m/s easily exceeding the required minimum value of 1.0 x 10-7m/s set out in the CQA Plan.

Validation

Wardell Armstrong is satisfied that the recent area of attenuation layer lining represented by the red highlighted area on the attached drawing, achieves the criteria laid out by the Construction Quality Assurance Plan.

for Wardell Armstrong LLP

Mike Gill
Associate Director
mgill@wardell-armstrong.com

Encl: Drawing, Test Certificates

18th December 2020

Compaction on east part of Phase 1 north batter slope. Note clay dividing bund separating eat and west areas to upper right of photograph

Nuclear Density Testing on north batter slope

Testing on incomplete western area (eastern area to rear, beyond clay bund)

15th February 2021

Extraction of clay cores using core cutter on west clay lined area of Phase 1 north batter

Clay core retrieval

Clay core retrieval and packaging

IAN FARMER ASSOCIATES

Unit 4, Faraday Close, Pattinson North Industrial Estate, Washington, NE38 8QJ. Tel: 0191 482 8500 Fax: 0191 482 8520
ceg@ianfarmer.co.uk www.ianfarmer.co.uk

TEST CERTIFICATE

IN-SITU DENSITY - NUCLEAR DENSITY TESTING

BS 1377: Part 9:1990: Clause 2.5

Job Number:	2250860C	Report Number:	2250860C/1-5/NDG
Client:	Wardell Armstrong	Sample Number:	2250860C/1-5
Address:	11 Waterloo Square Newcastle Upon Tyne NE1 4DP	Date Tested:	18/12/2020
		Date Received:	18/12/2020
		Tested By:	D Sugden
		Tested At:	Site
		Groundwater Level:	Unknown
		Weather Conditions:	Cloudy 11°C

Site: Quarrington Quarry

Requested By: Mike Gill
Test Location: Site
Test Depth: 150mm

Test / Sample Ref	Bulk Density Mg / m³	Moisture %	Dry Density Mg / m³	Compaction %	Sample Description
1	2.086	14.1	1.828	90.1	Quarried Stone
2	2.182	14.5	1.906	93.9	Quarried Stone
3	2.045	9.6	1.866	91.9	Quarried Stone
4	1.854	18.3	1.567	77.2	Quarried Stone
5	1.917	13.7	1.686	83.1	Quarried Stone

Comments: Percentage compaction devised using an average target density of 2.03Mg/m³ as specified by client.

Interpretation of compaction percentage is outside of the scope of UKAS accreditation

Authorised By:  Date: 04/01/2021

J. Curry
Senior Project Supervisor

IAN FARMER ASSOCIATES

Unit 4, Faraday Close, Pattinson North Industrial Estate, Washington, NE38 8QJ. Tel: 0191 482 8500 Fax: 0191 482 8520
ceg@ianfarmer.co.uk www.ianfarmer.co.uk

TEST CERTIFICATE

IN-SITU DENSITY - SAND REPLACEMENT BY LARGE POURING CYLINDER

BS 1377: Part 9:1990: Clause 2.2

Job Number:	2250860C	Report Number:	2250860C/1/SRT
Client:	Wardell Armstrong	Sample Number:	2250860C/1
Address:	11 Waterloo Square	Date Tested:	18/12/2020
	Newcastle Upon Tyne	Date Received:	18/12/2020
	NE1 4DP	Sampled By:	D Sugden
		Sampled At:	Site
		Groundwater Level:	Unknown
		Weather Conditions:	Cloudy 11°C

Site: Quarrington Quarry

Requested By: Mike Gill
Test Location: Site
Test Depth: 150mm

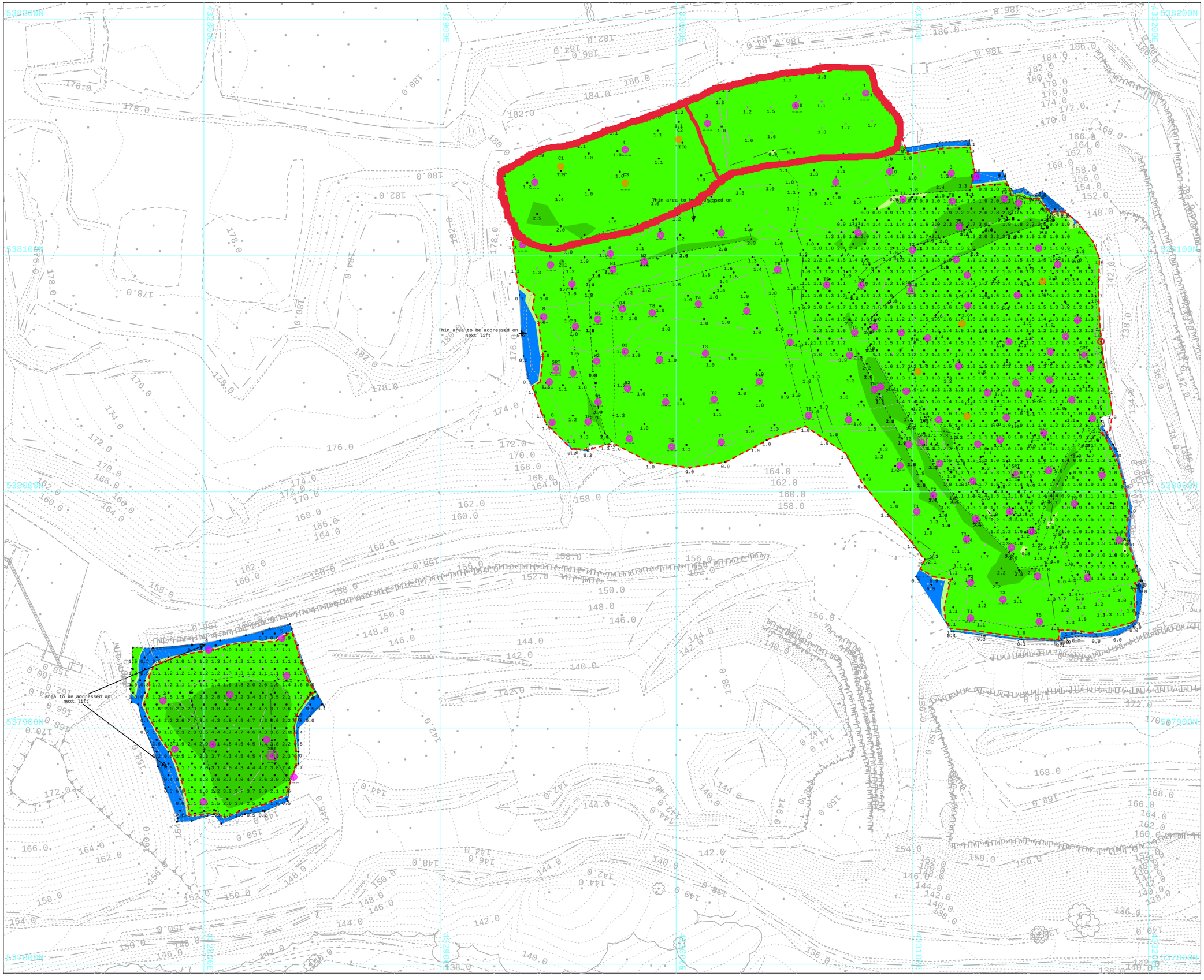
Test / Sample Ref	Bulk Density Mg / m3	Moisture %	Dry Density Mg / m3	Compaction %	Sample Description
SRT 1	2.21	13.9	1.940	95.6	Stone

Comments: Percentage compaction devised using an average target desity of 2.03Mg/m³ as specified by client.

Interpretation of compaction percentage is outside of the scope of UKAS accreditation

Authorised By: Date:

J. Curry
Senior Project Supervisor



KEY

- In-situ core test
- NDG test
- Current certified

N

TARMAC
A CRH COMPANY

Tarmac Limited.
Geology and Land Survey,
Fellbank, Birtley,
Chester-le-Street County Durham. DH3 2ST
Tel +44(0)748 3325184
e-mail: marc.little@tarmac.com

Q003 OLD QUARRINGTON

LINER THICKNESS TO-DATE
24th FEBRUARY 2021

LSS Models Used To Create Plot

Drawn By	Date
MC	FEBRUARY 2021
Scale	Drawing No.
1 : 1500	Q003 LINER 2021-02-11_A3

ALLIED EXPLORATION & GEOTECHNICS LIMITED

Head Office: Unit 25 Stella Gill Industrial Estate, Pelton Fell, Chester-le-Street, Co. Durham, DH2 2RG - Tel: 0191 3874700 Fax: 0191 3874710
Regional Office: Unit 20 Business Development Centre, Eanam Wharf, Blackburn, BB1 5BL – Tel: 01722 735 300 Fax: 01722 735 999

LABORATORY REPORT CERTIFICATE

UKAS TESTING
1367

Contract Title: Quarrington Quarry

AEG Reference: SLS1224

Client Address: Wardell Armstrong LLP
City Quadrant
11 Waterloo Square
Newcastle upon Tyne
NE1 4DP

We certify that Laboratory testing was carried out on samples from the above contract in accordance with techniques outlined in BS 1377: 1990, BS EN ISO 17892:2014 or other appropriate standards as quoted. The samples were received on 15th February 2021 and the following results, given on the attached enclosures, were obtained.

The tests carried out are indicated in the attached table showing the enclosure number and the total number of pages.

For and on behalf of Allied Exploration & Geotechnics Limited

- ☐ Nick Vater (Managing Director)
- ☐ Kevin Warriner (HSE & Quality Director)
- ☑ Michelle Selkirk (Laboratory Manager)

Signed _____ Date: 24 February 2021

Tests marked not UKAS accredited in this certificate are not included in the UKAS accreditation schedule for our laboratory. Any opinions and interpretations expressed herein are outside the scope of the laboratory's UKAS accreditation.

Please note the material was derived from samples taken outside the control of the laboratory.

LABORATORY REPORT CERTIFICATE

ENCLOSURES

Enclosure Number	Description	UKAS Accredited	Reference	No. of Pages
0	Laboratory Report Certificate	N/A		3
1	Sample Description Sheets	N/A		1
2	Determination of Density by Core Cutter Method	Yes	BS 1377 Part 9 1990	1
3	Determination of Permeability (Falling Head)	Yes	*In-house* Method	3

LABORATORY REPORT CERTIFICATE

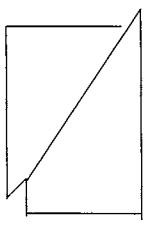
ABBREVIATIONS

All the abbreviations used on the laboratory certificates are given below:

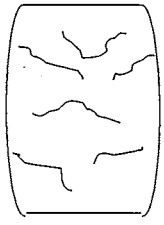
Br	Brittle	**PSD**	Particle Size Distribution by sieve analysis
C	Compound	**SB**	Shear Box
CBR	California Bearing Ratio	**SED**	Sedimentation Analysis
CDT	Consolidated Drained Triaxial	**SO4**	Sulphate (total, water extract, groundwater)
CL	Chloride content (water or soil)	**CP2**	Dry Density/Moisture Content 2.5kg rammer
US	Unsuitable sample for test	**CP4**	As above using 4.5kg rammer
UUT	Undrained Unconsolidated Triaxial	**CPV**	As above using vibrating hammer
HSV	Vane Test	**CUT**	Consolidated Undrained Triaxial
IS	Insufficient sample for test	**R**	Remoulded
LOI	Loss On Ignition	**U**	Undisturbed
M	Multi-stage testing	**MC**	Moisture Content
MCV	Moisture Content Value	**PL**	Point Load
NAT	Natural preparation method	**NMC**	Natural (or as received) moisture content
P	Plastic	**PFH**	Permeability Falling Head Method
OED	Oedometer	**PTXL**	Permeability in Triaxial Cell
OMC	Optimum Moisture Content	**ORG**	Organic content
B	Large disturbed (bulk) sample	**PD**	Particle Density (SG)
J	Small disturbed (jar) sample	**PI**	Liquid limit, plastic limit and plasticity index

Typical Mode of Failure for Triaxial Testing

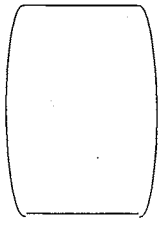
Brittle



Compound



Plastic



ALLIED EXPLORATION & GEOTECHNICS LIMITED

Head Office: Unit 25 Stella Gill Industrial Estate, Pelton Fell, Chester-le-Street, Co. Durham, DH2 2RG - Tel: 0191 387 4700 Fax: 0191 387 4710
Regional Office: Unit 20, Business Development Centre, Eanam Wharf, Blackburn, BB1 5BL - Tel: 01772 735 300 Fax: 01772 735 999

LABORATORY SAMPLE DESCRIPTION SHEET

Exploratory Hole No.	Sample Depth (m)	ID	Description	Laboratory Tests/Remarks
CC1	0.00	C	MADE GROUND (Brown slightly sandy gravelly clay).	Density PFH
CC2	0.00	C	MADE GROUND (Brown slightly sandy gravelly clay).	Density PFH
CC3	0.00	C	MADE GROUND (Brown slightly sandy gravelly clay).	Density PFH

Contract Title :- Quarrington Quarry	Client :- Wardell Armstrong

Signed :-	Name :-		Page 1 of 1
Date of issue :- 24/02/2021	Certificate No :- SD/SLS1224/1	AEG Contract No. :- SLS1224	

UKAS TESTING 1367

ALLIED EXPLORATION & GEOTECHNICS LIMITED

Head Office: Unit 25 Stella Gill Industrial Estate, Pelton Fell, Chester-le-Street, Co. Durham, DH2 2RG - Tel: 0191 387 4700 Fax: 0191 387 4710
Regional Office: Unit 20, Business Development Centre, Eanam Wharf, Blackburn, BB1 5BL - Tel: 01772 735 300 Fax: 01772 735 999

IN-SITU DENSITY TEST CORE CUTTER METHOD

BS 1377 : Part 9 : Clause 2.4 : 1990

Exploratory Hole No.:-	Sample Type & No.:-	Sample Depth (m):-	Specific Depth (m):-	Bulk Density (Mg/m^3):-	Dry Density (Mg/m^3):-	Moisture Content (%):-	Date Tested	Test Method
CC1	C	0.00	0.00	2.08	1.72	21	15/02/2021	Undisturbed
CC2	C	0.00	0.00	2.13	1.79	19	15/02/2021	Undisturbed
CC3	C	0.00	0.00	2.08	1.76	18	15/02/2021	Undisturbed

For description of sample please refer to the Laboratory Sample Description Sheet

Contract Title :-	Client :-
Quarrington Quarry	Wardell Armstrong

Signed :-	Name :-		Page 1 of 1
Date of issue :- 24/02/2021	Certificate No :- DENS/SLS1224/1	AEG Contract No. :- **SLS1224**	

UKAS TESTING 1367

ALLIED EXPLORATION & GEOTECHNICS LIMITED

Unit 25 Stella Gill Industrial Estate, Pelton Fell
Chester-le-Street, Co. Durham DH2 2RG
a UKAS TESTING Laboratory No. 1367

UKAS TESTING
1367

PERMEABILITY TEST (FALLING HEAD METHOD)

In-House method AEG 21 based on Head,K H: Manual of Soil Laboratory Testing, Vol 2, Section 10.7.2

SITE: **Quarrington Quarry**

CLIENT: **Wardell Armstrong** **JOB No. : SLS1224**

Sample: CC1 **Depth:** 0.00m **Specific Depth:** N/A

For sample description please refer to sample description sheet.

SPECIMEN DETAILS		INITIAL	FINAL
Length	mm	48.80	48.80
Diameter	mm	75.3	75.3
Moisture Content	%	21	20
Wet Density	Mg/m^3	2.08	2.08
Dry Density	Mg/m^3	1.72	1.73

METHOD OF PREPARATION Undisturbed

SATURATION STAGE

Duration	Day (s)	5

PERMEABILITY STAGE

Duration	Day (s)	1
Permeability (K)	m/sec	1.365E-09
Average Temperature	C	19.0

DATE TESTED: 17/02/2021 **DATE OF ISSUE:** 23/02/2021

APPROVED BY: MSelk **NAME:** Michelle Selkirk

ALLIED EXPLORATION & GEOTECHNICS LIMITED

Unit 25 Stella Gill Industrial Estate, Pelton Fell
Chester-le-Street, Co. Durham DH2 2RG
a UKAS TESTING Laboratory No. 1367

UKAS TESTING
1367

PERMEABILITY TEST (FALLING HEAD METHOD)

In-House method AEG 21 based on Head,K H: Manual of Soil Laboratory Testing, Vol 2, Section 10.7.2

SITE: **Quarrington Quarry**

CLIENT: **Wardell Armstrong** **JOB No. : SLS1224**

Sample: CC2 **Depth:** 0.00m **Specific Depth:** N/A

For sample description please refer to sample description sheet.

SPECIMEN DETAILS		INITIAL	FINAL
Length	mm	48.70	48.70
Diameter	mm	75.1	75.1
Moisture Content	%	19	18
Wet Density	Mg/m^3	2.13	2.13
Dry Density	Mg/m^3	1.79	1.80

METHOD OF PREPARATION Undisturbed

SATURATION STAGE

Duration	Day (s)	5

PERMEABILITY STAGE

Duration	Day (s)	1
Permeability (K)	m/sec	7.903E-10
Average Temperature	C	19.0

DATE TESTED: 17/02/2021 **DATE OF ISSUE:** 23/02/2021

APPROVED BY: **NAME:** Michelle Selkirk

ALLIED EXPLORATION & GEOTECHNICS LIMITED

Unit 25 Stella Gill Industrial Estate, Pelton Fell
Chester-le-Street, Co. Durham DH2 2RG
a UKAS TESTING Laboratory No. 1367

UKAS TESTING
1367

PERMEABILITY TEST (FALLING HEAD METHOD)

In-House method AEG 21 based on Head,K H: Manual of Soil Laboratory Testing, Vol 2, Section 10.7.2

SITE: **Quarrington Quarry**

CLIENT: **Wardell Armstrong** **JOB No. : SLS1224**

Sample: CC3 **Depth:** 0.00m **Specific Depth:** N/A

For sample description please refer to sample description sheet.

SPECIMEN DETAILS		INITIAL	FINAL
Length	mm	48.70	48.70
Diameter	mm	75.2	75.2
Moisture Content	%	18	19
Wet Density	Mg/m^3	2.08	2.06
Dry Density	Mg/m^3	1.76	1.73

METHOD OF PREPARATION Undisturbed

SATURATION STAGE

Duration	Day (s)	5

PERMEABILITY STAGE

Duration	Day (s)	1
Permeability (K)	m/sec	4.997E-10
Average Temperature	C	19.0

DATE TESTED: 17/02/2021 **DATE OF ISSUE:** 23/02/2021

APPROVED BY: **NAME:** Michelle Selkirk

APPENDIX 2

Surface Water Quality Results

SW1	Units	Guideline Values for Environmental Screening Criteria	Date																																										
Determindand		EQS	24/09/2010	22/10/2010	25/11/2010	16/12/2010	14/01/2011	24/02/2011	10/03/2011	03/06/2011	23/09/2011	09/12/2011	09/03/2012	15/06/2012	28/09/2012	14/12/2012	22/03/2013	14/06/2013	25/10/2013	14/03/2014	20/06/2014	19/09/2014	12/12/2014	20/03/2015	18/06/2015	17/09/2015	09/12/2015	10/03/2016	16/06/2016	15/09/2016	14/12/2016	15/03/2017	29/06/2017	20/09/2017	14/12/2017	19/03/2018	28/06/2018	27/09/2018	12/12/2018	26/03/2019	25/06/2019	30/09/2019	11/12/2019	30/03/2021	30/06/2021
Ammoniacal Nitrogen	mg/l	0.3	0.19	0.31	0.19	0.19	0.19	0.19	0.19	0.66	0.28	0.19	0.27	0.27	0.27	0.04	0.02	0.03	0.2	0.15	0.3	0.02	0.06	<0.01	<0.27	<0.41	<0.41	<0.41	<0.06	0.19	<0.05	0.08	0.07	1.2	0.07	<0.05	0.12	0.12	0.14	0.06	0.11	0.2	0.05	0.03	0.04
Chloride	mg/l	250	63.5	67.3	57.2	51	55.8	23	70	65.2	65	68.7	70.4	46.4	45.6	48	46	51	71	79	103	51	85	93	110	121	81.9	52.3	152	120	63	80	94	100	77	79	100	100	89	98	100	105	64	94	105
pH	pH Units	-	7.8	8	8.2	7.8	8.2	7.6	8.5	8.3	7.8	7.8	8	7.7	7.9	8.2	8.2	7.6	7.7	7.8	7.91	8.01	8.2	7.7	8.5	8.5	8.5	8.4	8.4	8.3	8.5	8.1	8	7.7	7.9	8.1	8.2	8.3	8.2	8.3	8.2	7.9	7.9	7.9	7.7
Electrical Conductivity	µS/cm	-	1000	1050	942	723	992	1310	1090	1000	1080	1140	1140	905	884	1050	966	1030	1090	1160	1250	967	1320	1330	1120	1400	1040	926	1440	1354	1226	1200	1200	1200	1300	1200	1300	1200	1200	1400	1200	1200	1250	1280	
Chemical Oxygen Demand	mg/l	-	11	22	17	13	20	11	21	320	134	25	11	11	13	7	10	5	8	6	11	<5	9	11	16	18		<11.0		<20.0	<20.0	30	<20.0	<20.0	<20.0	<20.0	43	30	26	<20.0	<20.0	12	7	14	15
Total Organic Carbon	mg/l	-	2.11	1.56	3.06	2.32	3.07	3.9	1.88	1.89	2.34	1.91	1.89	4.6	2.5										3.7	3.5	2.7	1.6	3.9	12	8	8	16	11	6	11	24	13	8	5	11	4.6	3.2	3.2	6.4
Total Oxidised Nitrogen	mg/l	-																	2.8																										
Suspended Solids	mg/l		5	7	7	3	5	14	23	10	236	11.5	3	5	4	5	5	15		30	69	13	<5	<5	2	3	2	6	5	<10.0	<10.0	230	<10.0	<10.0		<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	40	8	9	<5
Visible Oil	-																																												
Calcium	mg/l	-	149	140	150	124	153	326	170	145	136	138	173	121	121	122	120	118		155	150	145	155	165	134	146	130	122	135		140			120								127			
Magnesium	mg/l	-	62	61	59	46	51	86	57	58	51	58	54.2	53.1	47.3	54	54	49	57	71	72	58	63	70	63.6	68.2	56.8	53.5	67.4					59							64	61			
Sodium	mg/l	-	36.1	36.4	35.1	28.6	30.2	12.7	41.3	40.8	30.6	35.8	41.4	26.7	25.1	28	27	26	40	46	50	33	41	49	46.8	53.2	36	30.6	59.6		33			61								57			
Potassium	mg/l	-	3.74	3.75	3.65	2.84	3.51	7.32	4.13	3.8	3.81	3.58	3.14	3.26	2.78	3	3	3	3	5	6	4	4	5	4.01	4.81	3.71	3.77	5.19	4.7	4.9	5.5	4.8	6	5.4	4.3	4.6	6	6.2	5.3	4.3	6	7	5	4
Sulphate	mg/l	400	272	269	250	203	274	734	297	291	293	297	310	208	219	206	196	200	208	209	209	240	245	265	289	278	230	240	242	260	250	250	220	240	300	260	310	260	270	300	220		372	366	295
Iron	mg/l	1																																											
Manganese	mg/l	0.002																																											
Cadmium	ug/l	0.25									0.0033				0.0006				<0.0001																										
Chromium	mg/l	0.0034									0.0007				0.002				0.001																										
Copper	mg/l	0.001									0.009				0.009				0.002																										
Nickel	mg/l	0.004																	0.002																										
Lead	mg/l	0.0012									0.036				0.006				<0.001																										
Zinc	mg/l	0.001									0.087				0.018																														
Antimony	mg/l	-																	<0.001																										
Selenium	mg/l	0.001																	0.012																										
Molybdenum	mg/l	-													0.003				<0.001																										

Key
*EQS - Environmental Quality Standard.
**Red highlighted text boxes indicate exceedances of EQS.

SW3	Units	Guideline Values for Environmental Screening Criteria	Date												
Determindand		EQS	24/09/2010	22/10/2010	25/11/2010	16/12/2010	14/01/2011	24/02/2011	10/03/2011	03/06/2011	23/09/2011	09/12/2011	09/03/2012	15/06/2012	28/09/2012
Ammoniacal Nitrogen	mg/l	0.3	0.19	0.19	0.24	0.19	0.19	0.19	0.19	0.19	0.21	0.2	0.27	0.27	
Chloride	mg/l	250	68	73.8	56	45.8	47.7	54.7	60.8	72.5	65.7	67.5	62	48	
pH	pH Units	-	8	8.4	8	7.4	8.3	7.8	8.3	8.4	8.3	8.3	8.3	8.3	
Electrical Conductivity	µS/cm	-	898	984	950	380	898	974	1010	937	923	987	893	845	
Chemical Oxygen Demand	mg/l	-	12	16	20	20	13	11	11	30	27	25	15	13	16
Total Organic Carbon	mg/l	-	3.74	2.97	1.99	1.82	2.46	2.54	2.63	4.48	2.54	3.5	3.33	4.1	4.5
Total Oxidised Nitrogen	mg/l	-													
Suspended Solids	mg/l	-	3	10	6	3	4	4.5	6.5	19	7	4.5	7	1	5
Visible Oil	-														
Calcium	mg/l	-	115	121	149	139	150	160	156	114	87.2	110	107	113	
Magnesium	mg/l	-	63	64	59	49	54	57	60	65	51	59	51.7	55.9	
Sodium	mg/l	-	41.1	40	32.2	27.2	28.3	30.3	34.1	45.5	31.9	36.5	33.1	28.7	
Potassium	mg/l	-	3.81	3.78	3.76	3.64	3.01	3.06	3.11	3.39	2.5	2.91	1.69	3.82	
Sulphate	mg/l	400		256	258	232	225	293	300	269	234	246	214	201	202
Iron	mg/l	1													
Manganese	mg/l	0.002													
Cadmium	ug/l	0.25									0.0012				
Chromium	mg/l	0.0034									0.0007				
Copper	mg/l	0.001									0.002				
Nickel	mg/l	0.004													
Lead	mg/l	0.0012									0.014				
Zinc	mg/l	0.001									0.007				
Antimony	mg/l	-													
Selenium	mg/l	0.001													
Molybdenum	mg/l	-									0.005				

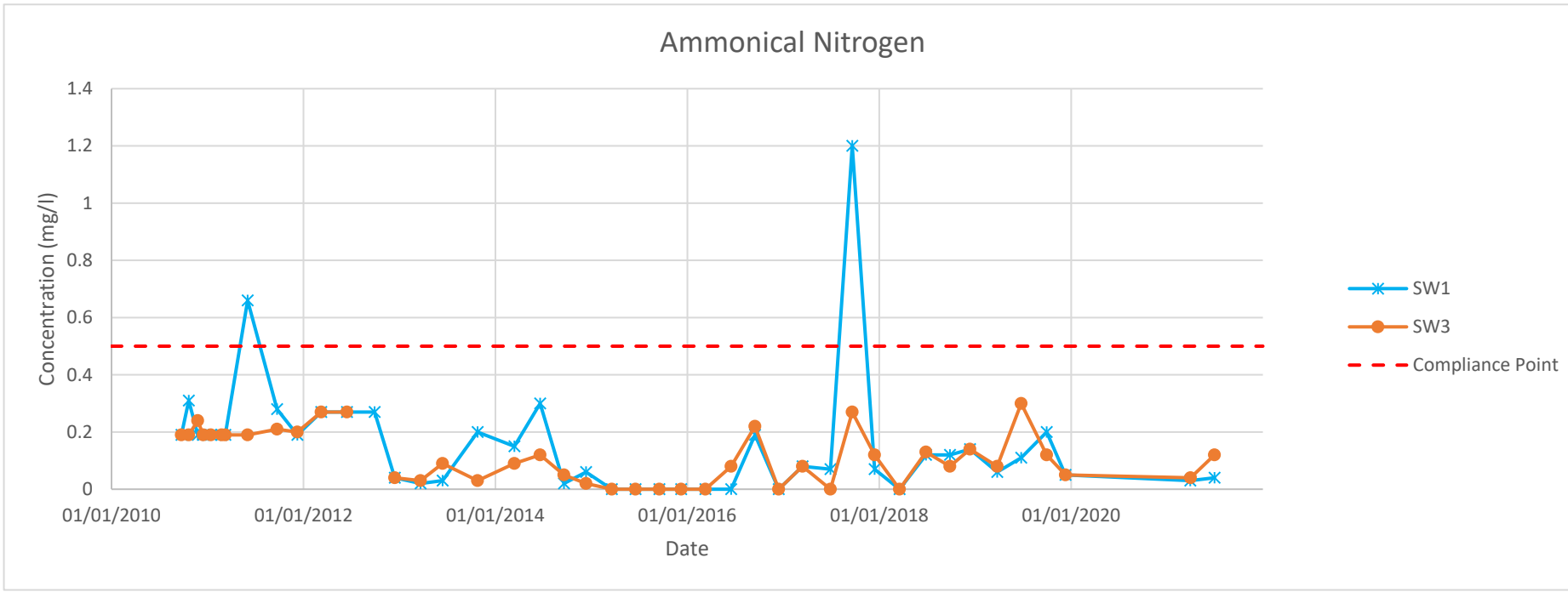
SW3	Units	Guideline Values for Environmental Screening Criteria	Date													
Determindand		EQS	14/12/2012	22/03/2013	14/06/2013	25/10/2013	14/03/2014	20/06/2014	19/09/2014	12/12/2014	20/03/2015	18/06/2015	17/09/2015	09/12/2015	10/03/2016	16/06/2016
Ammoniacal Nitrogen	mg/l	0.3	0.04	0.03	0.09	0.03	0.09	0.12	0.05	0.02	<0.01	<0.27	<0.41	<0.41	<0.41	0.08
Chloride	mg/l	250		44	52	49	57	57	71	66	70	88.2	84.4	69.6	66.3	82.7
pH	pH Units	-	8.1	8.3	7.9	7.7	8	8.32	8.16	8.3	7.6	8.7	8.4	8.4	8.43	8.43
Electrical Conductivity	µS/cm	-	1060	953	1040	932	1070	962	961	1250	1200	1040	999	1000	919	964
Chemical Oxygen Demand	mg/l	-	5	15	5	8	6	<5	5	10	14	31	23		16	
Total Organic Carbon	mg/l	-										6.8	4.5	3.1	2.6	5.4
Total Oxidised Nitrogen	mg/l	-				7.4										
Suspended Solids	mg/l	-	9	5	5		15	16	<5	5	14	5	10	2	4	6
Visible Oil	-															
Calcium	mg/l	-	127	123	117		147	129	140	140	155	109	124	129	121	117
Magnesium	mg/l	-	54	54	55	36	66	62	63	58	67	63.1	59.7	56.2	52.9	62.1
Sodium	mg/l	-	26	26	29	20	36	34	41	34	38	39.4	40.9	32.2	33.4	37
Potassium	mg/l	-	3	4	3	1	5	4	5	4	4	3.27	4.59	3.95	3.77	4.51
Sulphate	mg/l	400		209	215	214	253	234	255	235	250	286	248	245	250	269
Iron	mg/l	1				0.11										
Manganese	mg/l	0.002														
Cadmium	ug/l	0.25				<0.0001										
Chromium	mg/l	0.0034				0.001										
Copper	mg/l	0.001				<0.001										
Nickel	mg/l	0.004				0.001										
Lead	mg/l	0.0012				<0.001										
Zinc	mg/l	0.001														
Antimony	mg/l	-				<0.001										
Selenium	mg/l	0.001				0.022										
Molybdenum	mg/l	-				0.001										

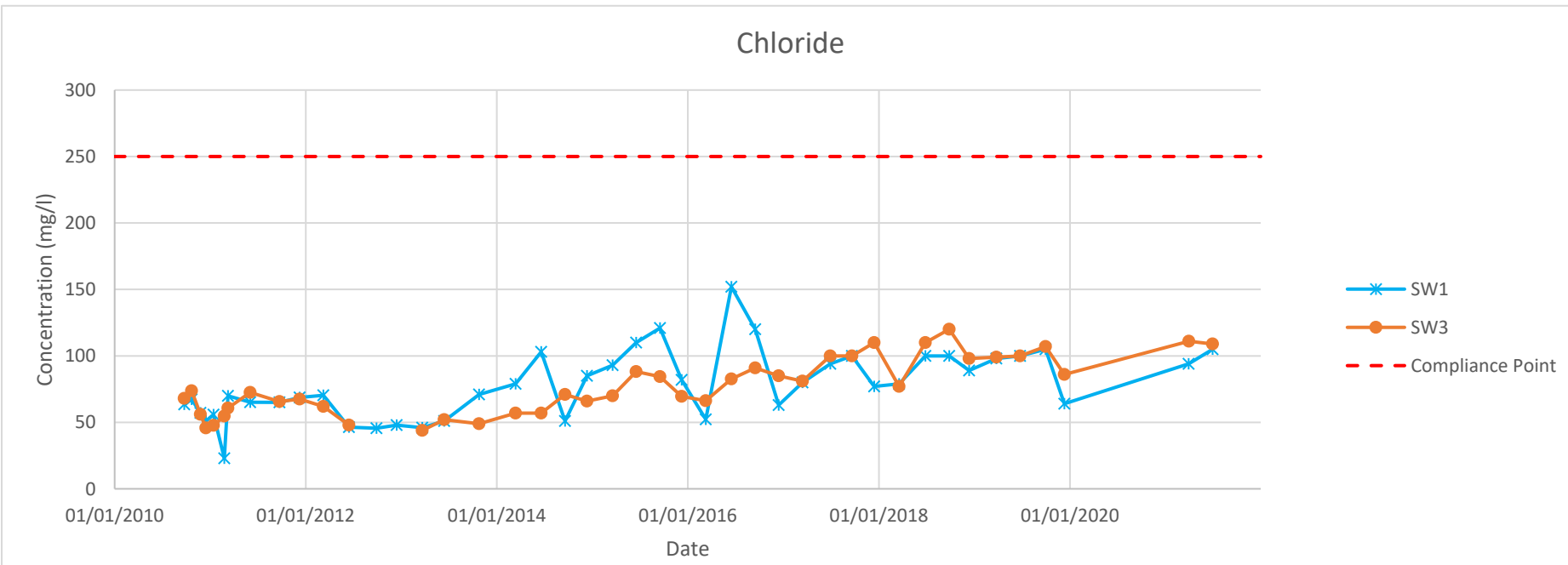
SW3	Units	Guideline Values for Environmental Screening Criteria	Date															
Determindand		EQS	15/09/2016	14/12/2016	15/03/2017	29/06/2017	20/09/2017	14/12/2017	19/03/2018	28/06/2018	27/09/2018	12/12/2018	26/03/2019	25/06/2019	30/09/2019	11/12/2019	31/03/2021	30/06/2021
Ammoniacal Nitrogen	mg/l	0.3	0.22	<0.05	0.08	<0.05	0.27	0.12	<0.05	0.13	0.08	0.14	0.08	0.3	0.12	0.05	0.04	0.12
Chloride	mg/l	250	91	85	81	100	100	110	77	110	120	98	99	100	107	86	111	109
pH	pH Units	-	8.4	8.8	8.2	8.1	7.8	8.1	8.1	8.3	8.3	8.4	8.2	8.2	7.9	7.9	8	7.7
Electrical Conductivity	µS/cm	-	1105	1261	1100	1200	1200	1400	1100	1300	1200	1300	1300	1200	1140	1180	1170	
Chemical Oxygen Demand	mg/l	-	<20.0	<20.0	37	<20.0	25	<20.0	<20.0	30	25	<20.0	22	20	12	6	13	10
Total Organic Carbon	mg/l	-	14	9	10	17	10	8	7	16	13	7	18	11	4.5	2.8	2.5	5.1
Total Oxidised Nitrogen	mg/l	-																
Suspended Solids	mg/l	-	<10.0	21	<10.0	<10.0	<10.0		<10.0	<10.0	<10.0	<10.0	16	<10.0	76	6	10	5
Visible Oil	-																	
Calcium	mg/l	-		140			120								116			
Magnesium	mg/l	-					61								64	57		
Sodium	mg/l	-		44			62								56			
Potassium	mg/l	-	4.9	5.6	4.4	5.1	7	7.7	3.7	4.3	5.4	5	4.8	4.2	6	5		4
Sulphate	mg/l	400	230	230	230	240	240	280	220	250	250	250	260	210		239		224
Iron	mg/l	1																
Manganese	mg/l	0.002																
Cadmium	ug/l	0.25																
Chromium	mg/l	0.0034																
Copper	mg/l	0.001																
Nickel	mg/l	0.004																
Lead	mg/l	0.0012																
Zinc	mg/l	0.001																
Antimony	mg/l	-																
Selenium	mg/l	0.001																
Molybdenum	mg/l	-																

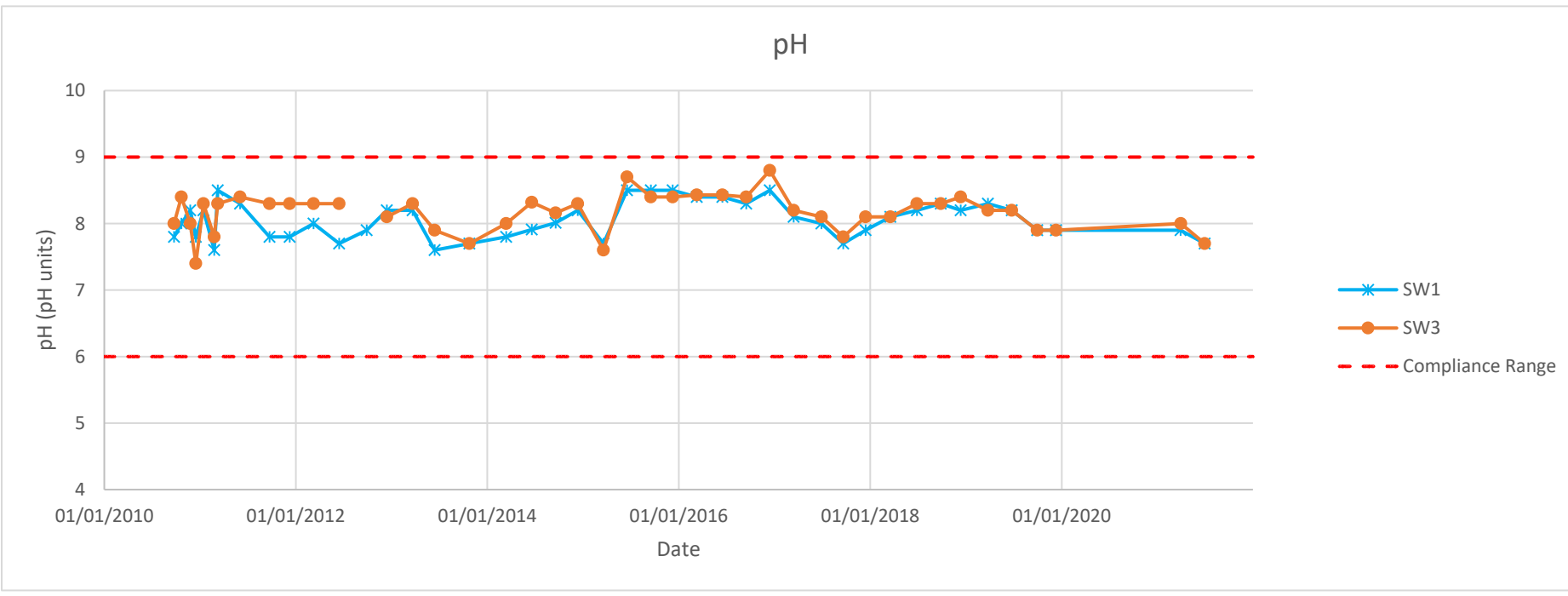
Key
*EQS - Environmental Quality Standard.
**Red highlighted text boxes indicate exceedances of EQS.

APPENDIX 3

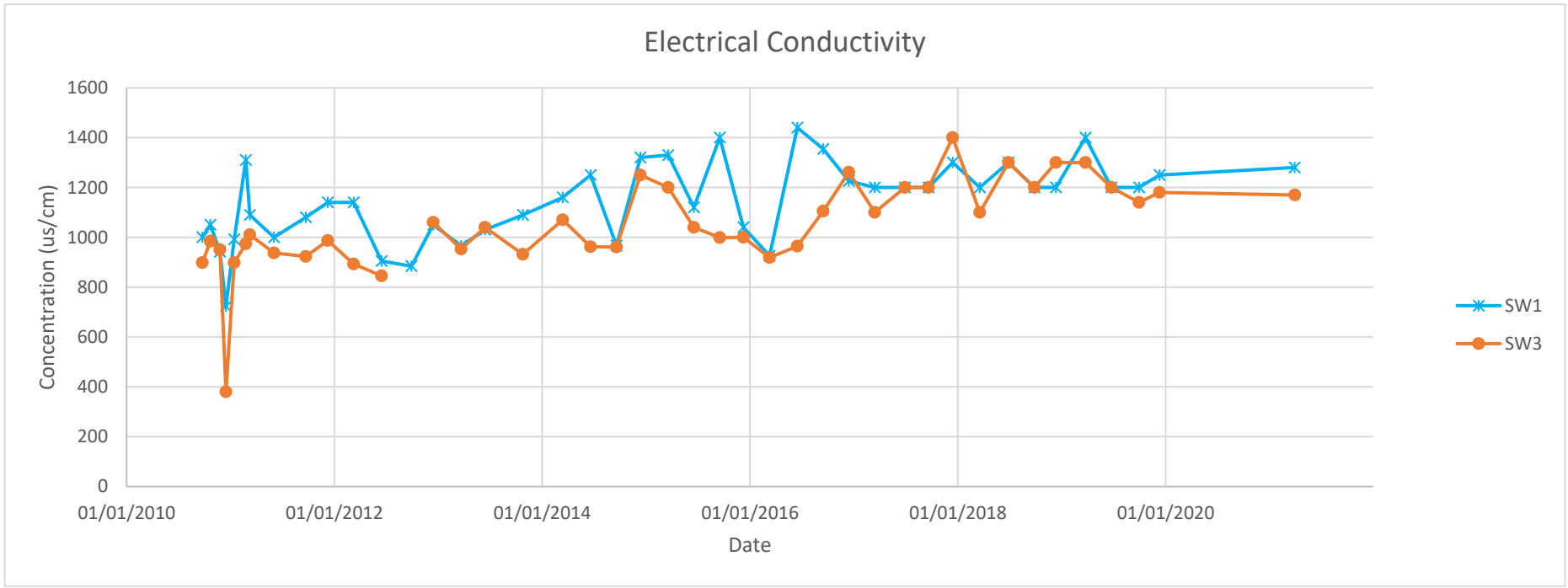
Surface Water Quality Results Graphed

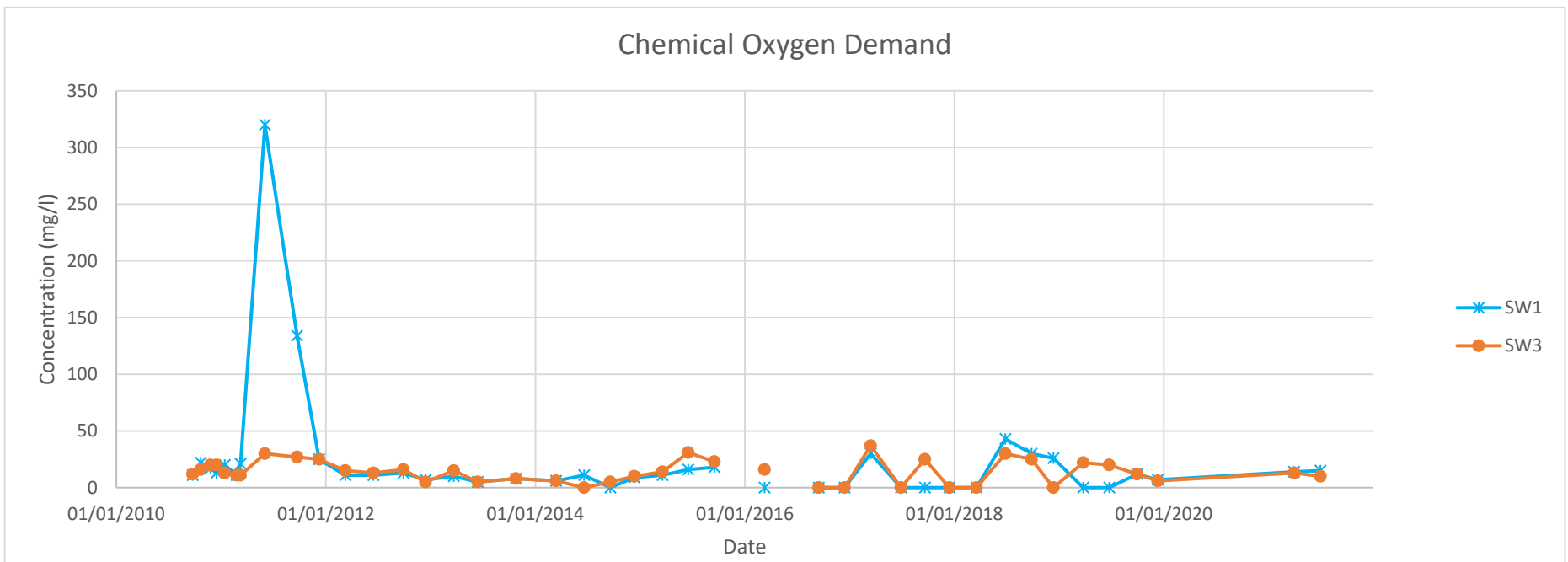


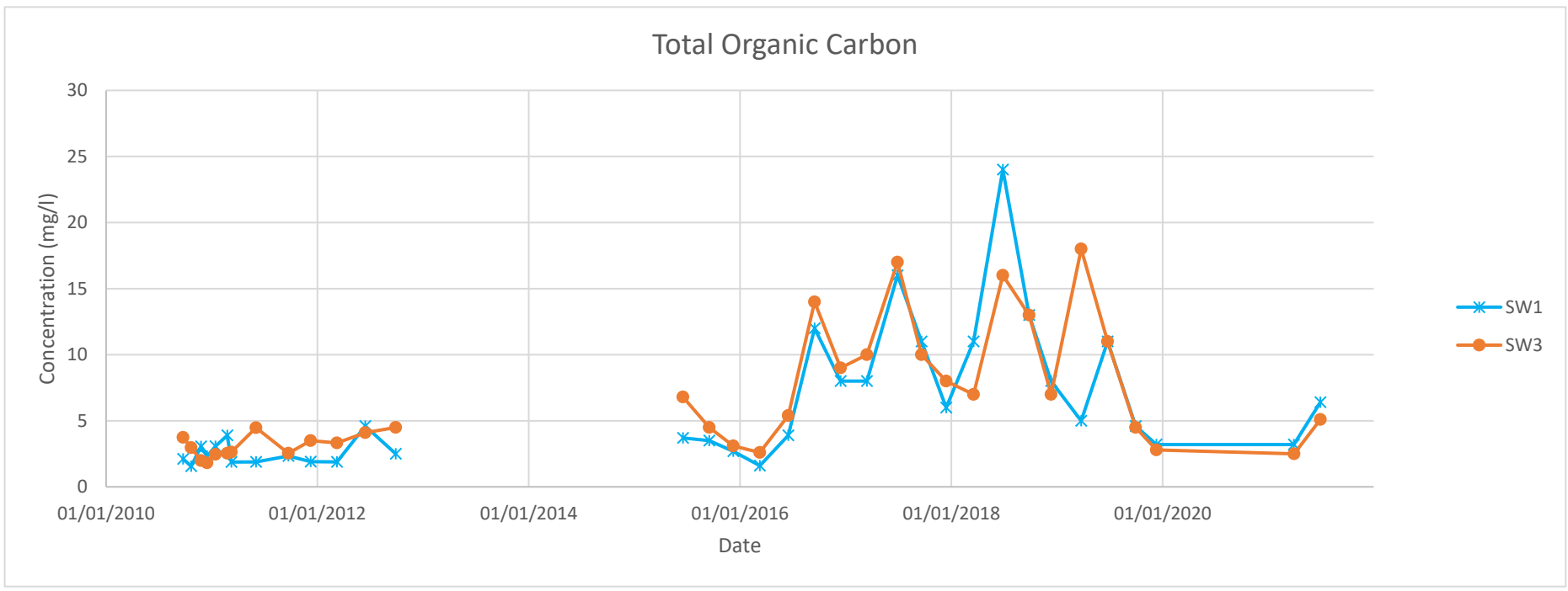




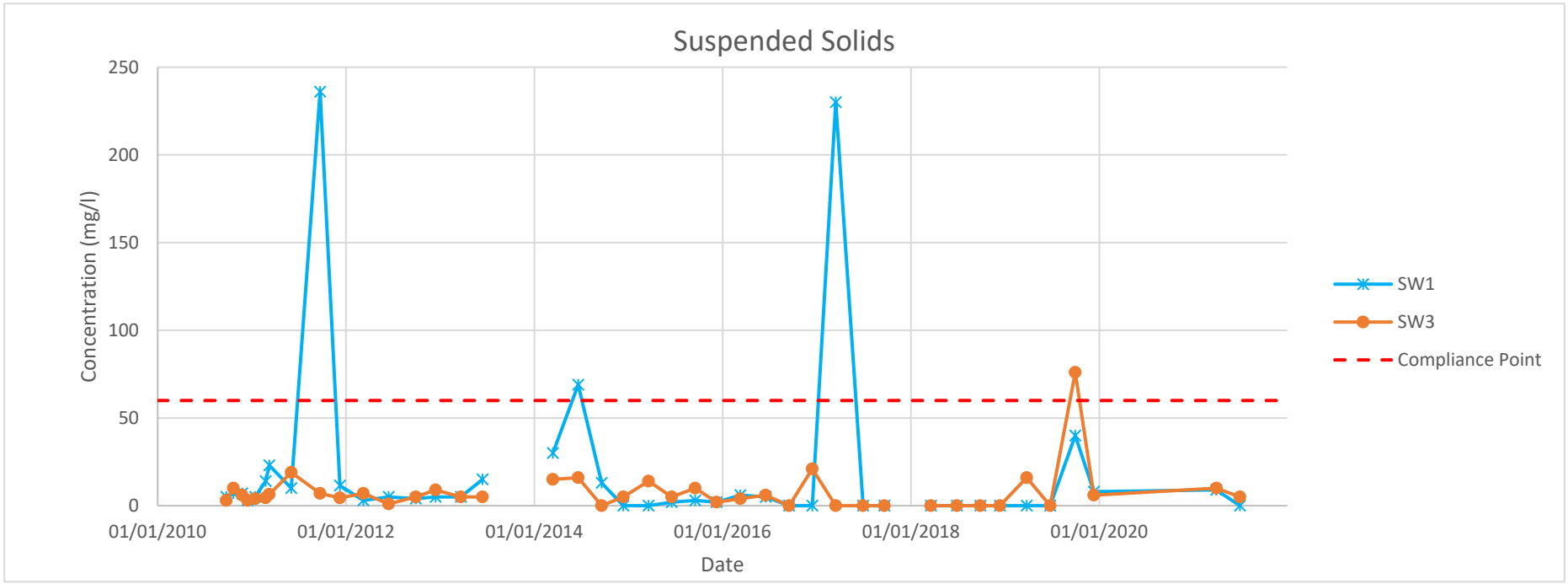
CLIENT	Tarmac Ltd		
PROJECT	**Hydrogeological Risk Assessment Review**		
FIGURE TITLE	**Surface Water Quality Graphs**		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 3	JS	LB	Apr-21

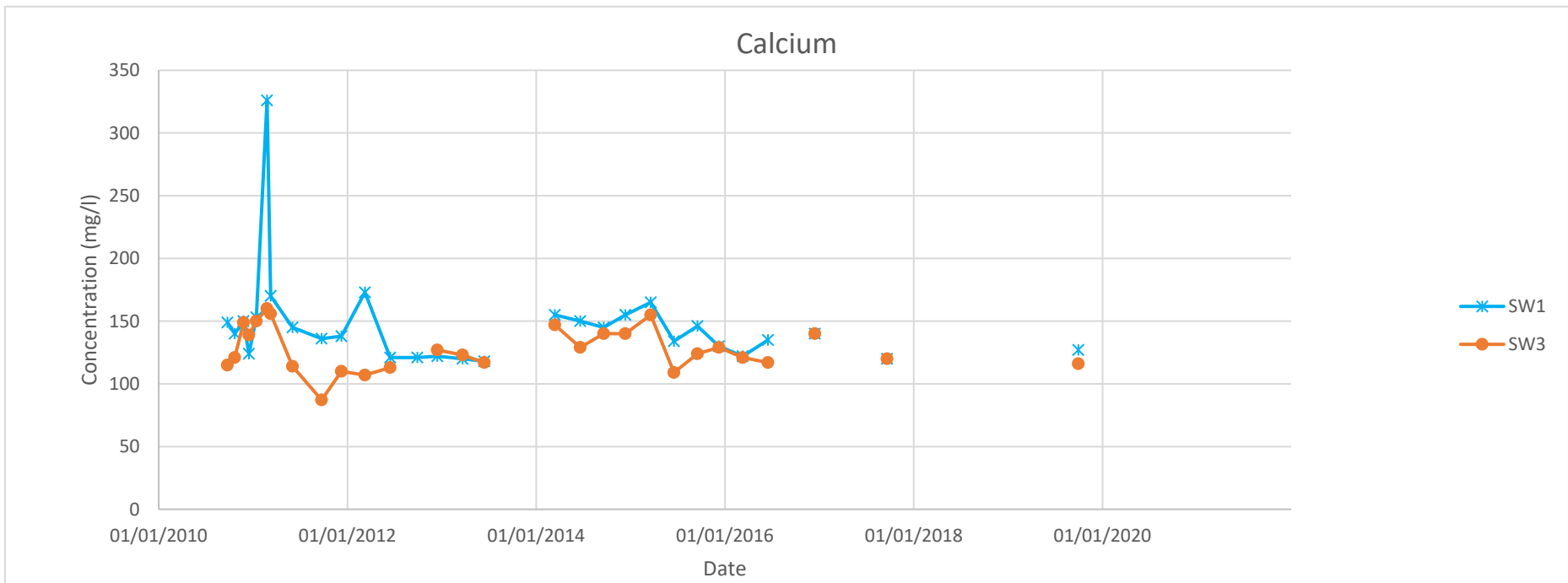


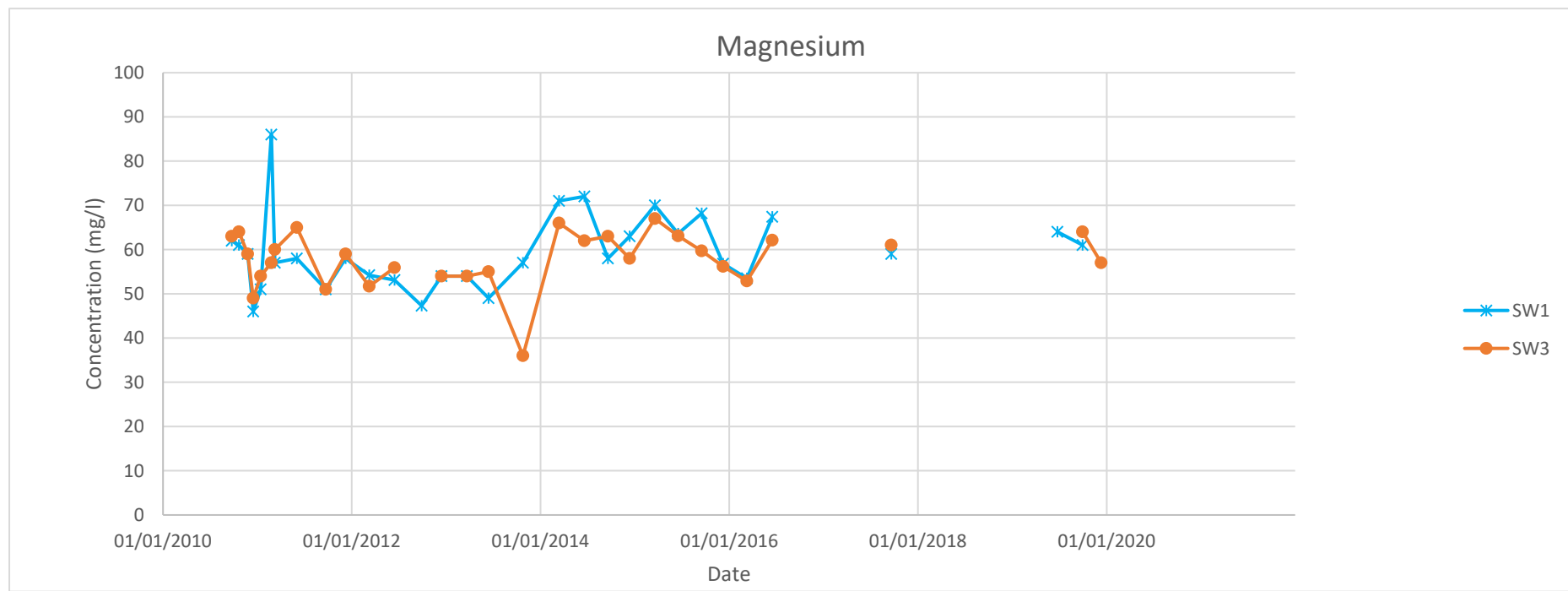




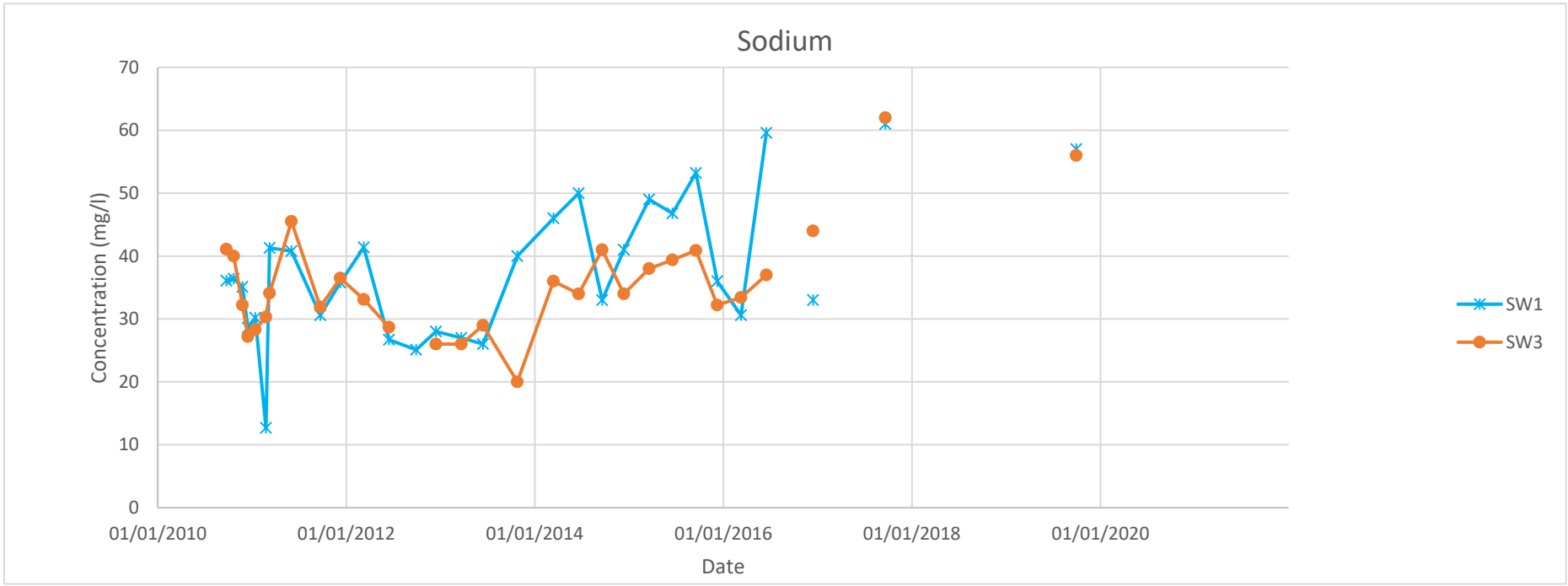
CLIENT	Tarmac Ltd		
PROJECT	**Hydrogeological Risk Assessment Review**		
FIGURE TITLE	**Surface Water Quality Graphs**		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 3	JS	LB	Apr-21

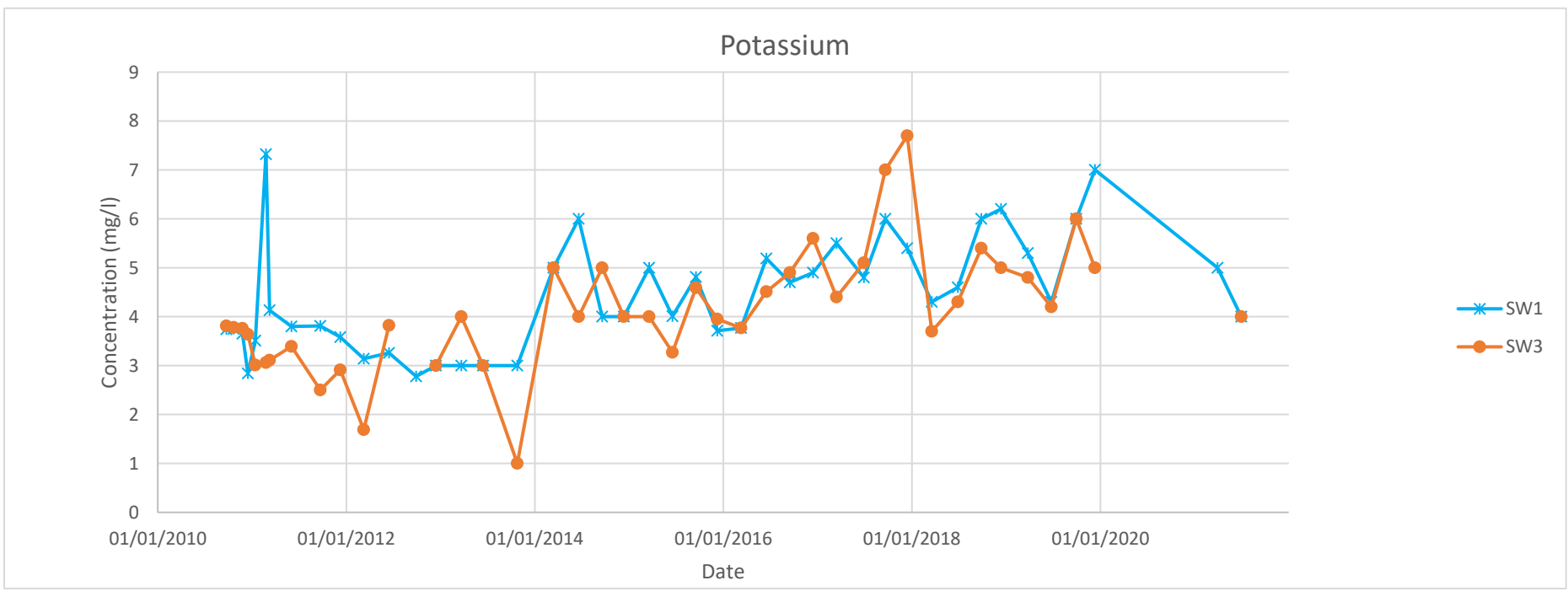


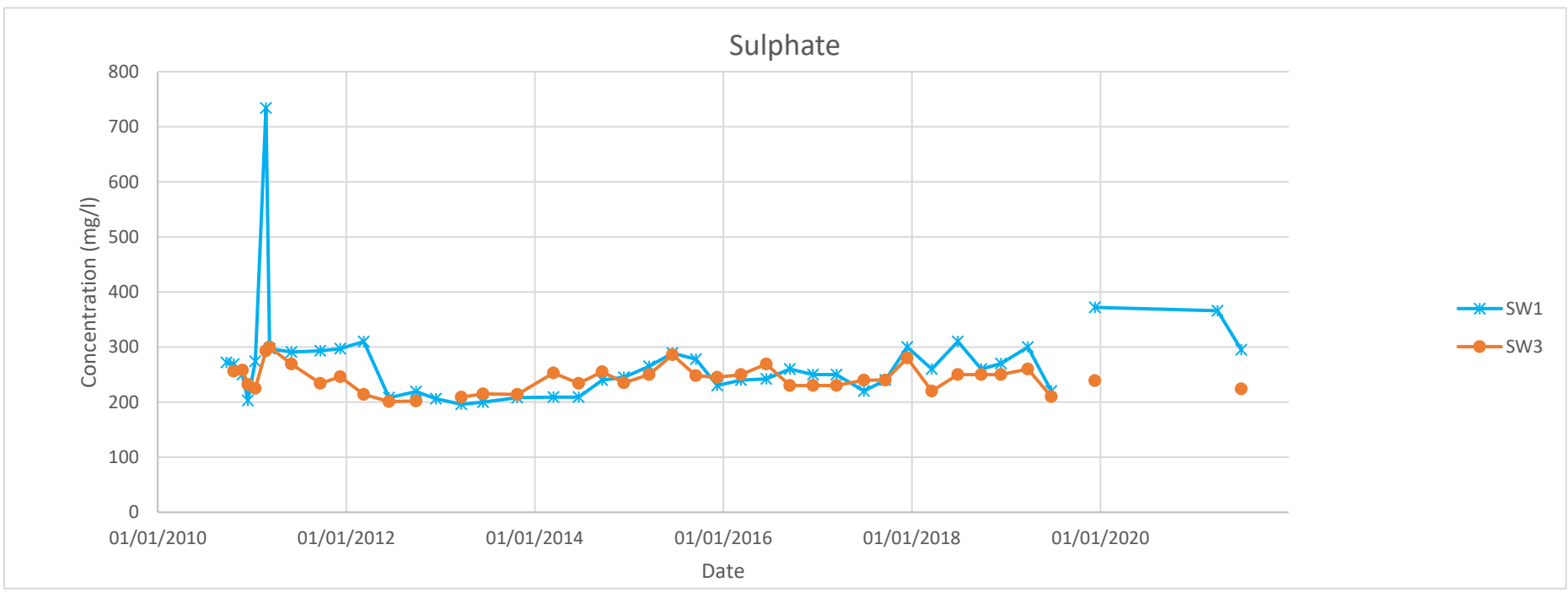




CLIENT	Tarmac Ltd		
PROJECT	**Hydrogeological Risk Assessment Review**		
FIGURE TITLE	**Surface Water Quality Graphs**		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 3	JS	LB	Apr-21



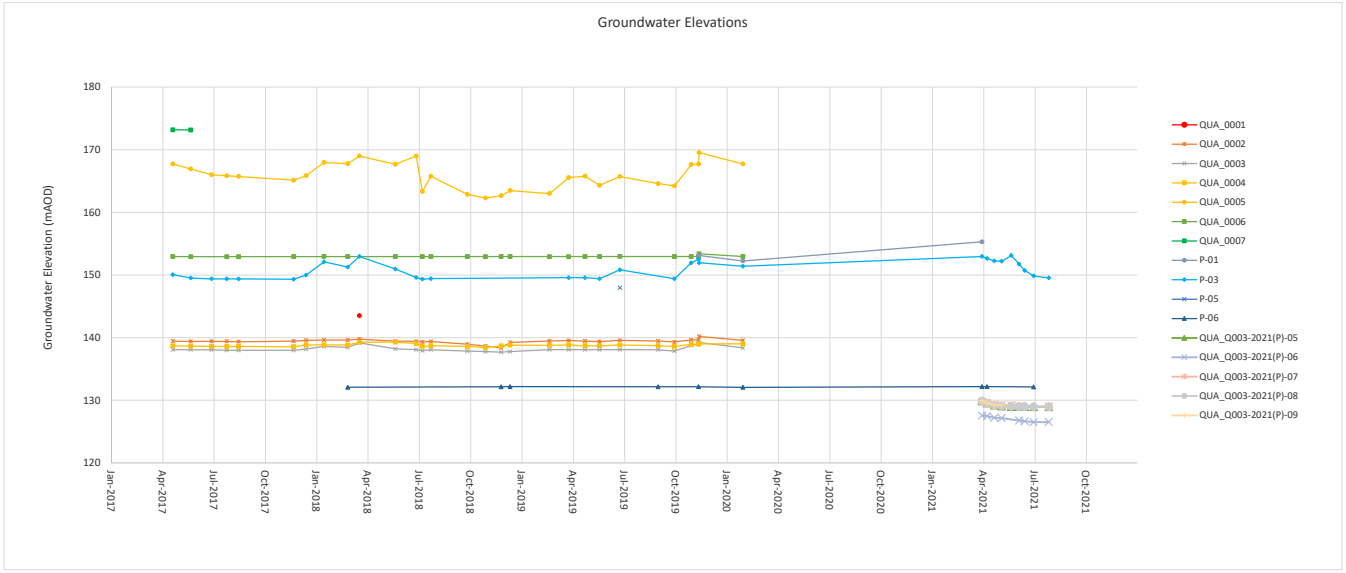


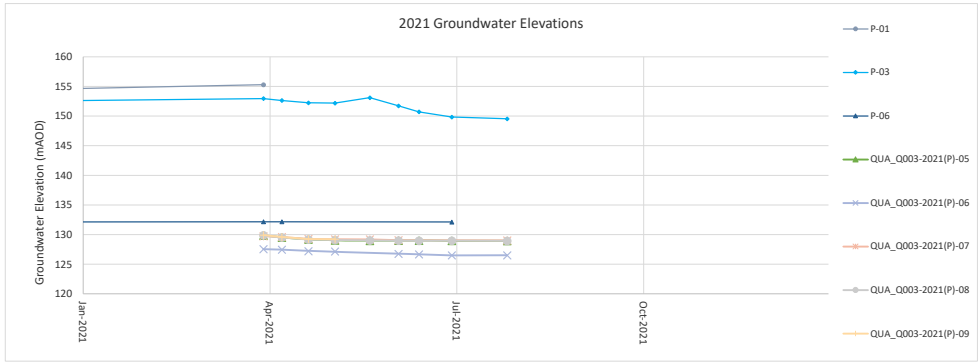


CLIENT	Tarmac Ltd		
PROJECT	**Hydrogeological Risk Assessment Review**		
FIGURE TITLE	**Surface Water Quality Graphs**		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 3	JS	LB	Apr-21

APPENDIX 4

Groundwater Elevation Results





CLIENT	Tarmac Ltd		
PROJECT	Hydrogeological Risk Assessment Review		
FIGURE TITLE	Groundwater Elevations		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 4	JS	LB	19/04/2021

APPENDIX 5

Groundwater and Spring Quality Results

P-03	Unit	Trigger Level	Guideline Values for Environmental Screening Criteria		Date																								
Determindand			UKDWS	Minimum Reporting Values (MRV)	16/12/2010	10/03/2011	15/06/2012	28/09/2012	14/12/2012	14/06/2013	22/03/2013	14/06/2013	14/03/2014	20/06/2014	09/12/2015	10/03/2016	14/12/2016	15/03/2017	14/12/2017	19/03/2018	28/06/2018	25/06/2019	11/12/2019	30/03/2021	08/04/2021	21/04/2021	04/05/2021	21/05/2021	04/06/2021	14/06/2021
Ammoniacal Nitrogen	mg/l	0.39	0.39		0.19	0.19	0.27	0.27	0.03	0.01			0.04	<0.01	<0.41	<0.41	<0.05	<0.05	0.1	<0.05	0.06	<0.05	0.03	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	<0.02
Chloride	mg/l	250	250		293	249	279		23		34	66	104	97	144	76.1	110	170	82	76	100	91	73	22	21	21	30	36	35	42
pH	pH units				7.6	8.4	7.2		8		8.2	7.5	7.4	7.5	7.6	8.7	8.1	7.6	7.7	7.99	7.73	7.84	7.3	7.8	7.3	7.4	7.8	7.4	7.8	7.6
Electrical Conductivity	uS/cm		2500		532	1210	1280			738	736	857	893	902	966	720	1100	1200	1000	940	960	930	927	774	787	876	818	821	803	784
Chemical Oxygen Demand	mg/l				65	59	52		9		17		10	<5		77	<20.0	21	27	<20.0	<20.0	<20.0	9	6	6	6	<5	<5	7	7
Total Organic Carbon	mg/l				1.25	1.09	2.2									4.6	10	9	10	15	18	9	3	3.1	3.2	2.9	2.6	2.6	2.4	2.3
Total Oxidised Nitrogen	mg/l				3.1	3.37	3.67	2.5	4.1			4.8	3.4	1.7	3.1	<0.7	1.9	2.4	0.6	0.7	0.5	0.6	0.8	12.5	12	11.4	10.6	10.3	9.7	8.6
Calcium	mg/l		250		177			278			139		90		166		120	110	120	86	90	92		108	108	112	113	108	106	100
Magnesium	mg/l		50		75			119			56		41		86.2		51	55	49	38	41	36		39	38	40	42	40	42	41
Sodium	mg/l		200		37.7			27.4			16		19		25.5		34	36	37	64	40	48		13	11	14	15	17	17	18
Potassium	mg/l		12		10.9			7.33			3		4		6.92		8.5	6.6	7.3	3.3	4	4		2	2	2	2	2	3	3
Sulphate	mg/l		250		85.2			51.8			24		60		55.1		58	53	66	29	60	48		22	18	19	28	30	40	41
Iron	mg/l		0.2					3.04			4.38		<0.01		1.85		8	0.06	<0.005	<0.005	<0.005	0.033		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	mg/l		0.05					0.595			0.002			0.002	0.269		19	0.005	1	0.001	0.044	0.015		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium	mg/l		0.005	0.0001				0.0006			0.0002		<0.0001		<0.0006		0.00007	0.00009	0.00006	0.00006	0.00004	0.00005		<0.00002	0.00008	0.00005	0.00007	0.00005	0.00007	0.00004
Chromium	mg/l		0.05					0.004			0.002		0.001		0.008		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/l		2					0.016			0.003		0.002				0.0017	0.002	0.0021	0.003	0.0017	0.0043		0.003	0.003	0.002	0.002	0.002	0.002	0.002
Nickel	mg/l		0.02					0.019			0.003		0.002		0.019		0.003	0.003	0.018	0.002	0.008	0.003		0.002	0.002	0.002	0.001	0.001	0.001	0.001
Lead	mg/l		0.01					0.037			0.001		<0.001		0.033		<0.0003	0.0004	<0.0003	<0.0003	<0.0003	0.0004		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	mg/l		5			3.37		0.08			0.018		0.004		0.06		0.012	0.012	0.016	0.011	0.005	0.007		0.005	0.151	0.003	0.006	0.005	0.004	0.122
Antimony	mg/l		0.005								0.02		<0.001				<1.0	<1.0				<1.0		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	mg/l		0.01								0.001													0.001	<0.001	0.001	0.001	0.002	0.002	0.002
Molybdenum	mg/l							0.003			0.001		0.083	<0.003			0.001	<0.001	0.003	0.002	0.003	0.002								

Key
*UKDWS - UK Drinking Water Standards (UKDWS) or Minimum Reporting Value.
**Red highlighted text boxes indicate exceedances of UKDWS.
Groundwater quality sampling was entirely carried out within Coal Measures strata

SW2	Unit	Trigger Level	Guideline Values for Environmental Screening Criteria																	
Determindand			UKDWS	Minimum Recordable Value	24/09/2010	22/10/2010	25/11/2010	16/12/2010	14/01/2011	24/02/2011	10/03/2011	03/06/2011	23/09/2011	09/12/2011	09/03/2012	15/06/2012	28/09/2012	14/12/2012	22/03/2013	14/06/2013	25/10/2013
Ammoniacal Nitrogen	mg/l	0.39	0.39		0.19	0.19	0.28	0.19	0.19	0.19	0.19	0.19	0.2	0.22		0.27	0.27	0.02	0.03	0.07	0.03
Chloride	mg/l	250	250		63.5	76.7	61.1	49.1	53.4	62.6	67	72	65.5	71.8		55	39.8	45	45	53	48
pH	pH units					8.4	8.2	7.8	8.2	8.1	8.4	8.4	8.3	8.1	8.2	8	8	8.2	8.3	7.6	7.7
Electrical Conductivity	uS/cm		2500		1000	1050	934	986	890	947	1030	959	986	1060	981	922	778	1060	962	1050	928
Chemical Oxygen Demand	mg/l				11	15	16	53	39	11	18	26	39	21		18	70	12	13	5	8
Total Organic Carbon	mg/l																				
Total Oxidised Nitrogen	mg/l																				7.6
Suspended Solids					4	1	7	3	2	6	13.5	9	6	2.5		1	5	5	5	5	
Calcium	mg/l		250		152	130	130	133	127	159	147	126	112	134	139	119	105	130	131	122	
Magnesium	mg/l		50		63	64	54	47	46	55	52	64	51	62	51.2	56	40.4	55	56	54	48
Sodium	mg/l		200		36.9	44.6	33.6	30.4	29.2	36.7	36.4	46.2	32.8	40.7	38.1	30.9	22	26	28	28	27
Potassium	mg/l		12		3.87	3.82	3.42	2.78	3.19	3.57	3.24	3.56	3.03	4.94	2.98	4.18	3.07	3	4	3	2
Sulphate	mg/l		250		281	267	233	198	215	254	287	272	253	275		261	204	219	204	215	211
Iron	mg/l		0.2																		0.16
Manganese	mg/l		0.05																		
Cadmium	mg/l		0.005	0.0001									0.0034				0.0006				<0.0001
Chromium	mg/l		0.05										0.0007				0.002				0.001
Copper	mg/l		2										0.006				0.009				<0.001
Nickel	mg/l		0.02										0.002				0.003				0.001
Lead	mg/l		0.01										0.039				0.006				<0.001
Zinc	mg/l		5																		
Antimony	mg/l		0.005																		<0.001
Selenium	mg/l		0.01																		0.006
Molybdenum	mg/l												0.007				0.003				0.001

Key
*UKDWS - UK Drinking Water Standards (UKDWS) or Minimum Reporting Value.
**Red highlighted text boxes indicate exceedances of UKDWS.
Groundwater quality sampling was entirely carried out within Coal Measures strata

Date																												
14/03/2014	20/06/2014	19/09/2014	12/12/2014	20/03/2015	18/06/2015	17/09/2015	09/12/2015	10/03/2016	16/06/2016	15/09/2016	14/12/2016	15/03/2017	29/06/2017	20/09/2017	14/12/2017	19/03/2018	28/06/2018	27/09/2018	12/12/2018	26/03/2019	25/06/2019	30/09/2019	11/12/2019	30/03/2021	08/04/2021	21/04/2021	04/05/2021	21/05/2021
0.08	0.16	0.08	0.03	<0.01	<0.27	<0.41	<0.41	<0.41	0.19	0.15	<0.05	0.08	0.13	0.38	0.09	<0.05	0.1	0.05	0.12	<0.05	0.15	0.07	0.03	0.51	<0.02	0.06	0.05	0.06
57	58	69	68	71	90.8	87.5	70.4	68.2	83.1	92	80	80	92	180	100	110	110	110	94	100	110	109	82	107	108	108	99	97
7.9	7.89	7.9	8.2	7.8	8.7	8.4	8.3	8.41	8.32	8.4	8.6	8.2	8	7.8	8	8	8.3	8.2	8.3	8.3	8	7.9	7.9	7.9	7.8	7.5	8.1	7.7
1080	993	976	1240	1220	1080	1190	1010	991	1230	1200	1284	1200	1200	1500	1400	1200	1300	1300	1300	1300	1200	1150	1160	1160	1160	1280	1120	1100
6	5	8	13	7	29	22		<11.0	<20.0	<20.0	44	<20.0	<20.0	<20.0	<20.0	26	32	<20.0	<20.0	21	12	6		10	9	10	7	13
					5.7	4.1	2.8	2.5	5.4	12	9	11	16	10	8	5	16	13	7	6	11	4.3	2.5	2.4	2.5	3.2	3.3	3.4
										1.1												0.8	5.3	6.2	6.9	6.2	5.8	5.3
5	10	<5	<5	11	2	1	2	7	22		<10.0	<10.0	<10.0	<10.0		<10.0	<10.0	<10.0	<10.0	<10.0	<10.0			13	<5	<5	5	5
151	136	135	145	155	122	121	131	123	126		140			150								108		130	128	131	122	122
65	61	63	59	66	62.1	57.9	55.5	55.7	60.8		60			75								56		53	53	56	53	52
36	33	40	34	40	40.3	40.5	32.2	36.1	37.3		42			92								56		51	49	54	49	49
5	4	5	4	5	3.64	4.62	4.04	3.98	5.33		5.2	4.9	4.9	7	7.7	4.1	4.5	7.7	5.2	5.4	4.2	6		4	4	4	4	3
247	239	250	245	275	297	260	251	250	272		240	230	290	230	330	190	260	260	260	290	230			229	220	221	222	219
														0.09										0.01	0.02	0.03	0.02	0.04
																						0.005		<0.002	<0.002	0.004	0.009	<0.002
														0.00003										<0.00002	<0.00002	0.00003	<0.00002	<0.00002
														<0.001										<0.001	<0.001	<0.001	<0.001	<0.001
														<0.001										<0.001	<0.001	<0.001	<0.001	<0.001
																						<0.001		<0.001	<0.001	<0.001	<0.001	<0.001
																						<0.001		<0.001	<0.001	<0.001	<0.001	<0.001
																						0.002		<0.002	0.003	<0.002	<0.002	<0.002
																						<0.001		<0.001	<0.001	<0.001	<0.001	<0.001
																						0.023		0.022	0.026	0.026	0.029	0.027
																						<0.001						

QUA_Q003-2021(P)-05	Unit	Trigger Level	Guideline Values for Environmental Screening Criteria										
Determindand			UKDWS	Minimum Reporting Values (MRV)	30/03/2021	08/04/2021	21/04/2021	04/05/2021	21/05/2021	04/06/2021	14/06/2021	30/06/2021	27/07/2021
Ammoniacal Nitrogen	mg/l	0.39	0.39		0.26	0.04	0.14	0.12	0.15	0.13	0.1	0.05	0.12
Chloride	mg/l	250	250		218	156	107	68	64	83	84	81	69
pH	pH units				7.7	7.2	7.3	7.5	7.4	7.6	7.4	7.5	7.3
Electrical Conductivity	uS/cm		2500		1500	1430	1370	1330	1310	1330	1330	1280	1310
Chemical Oxygen Demand	mg/l				<5	<5	<5	<5	<5	<5	<5	<5	<5
Total Organic Carbon	mg/l				0.83	0.71	0.54	0.46	0.28	0.7	0.56	0.49	0.36
Total Oxidised Nitrogen	mg/l				3.2	2.8	1.3	<0.2	<0.2	10.7	0.8	0.6	<0.2
Calcium	mg/l		250		140	141	167	183	176	187	181	171	191
Magnesium	mg/l		50		58	59	73	79	76	79	77	73	81
Sodium	mg/l		200		106	76	49	20	24	32	32	29	21
Potassium	mg/l		12		6	5	6	6	5	6	6	6	6
Sulphate	mg/l		250		218	219	249	274	252	287	273	253	274
Iron	mg/l		0.2		<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Manganese	mg/l		0.05		0.081	0.116	0.198	0.282	0.251	0.228	0.227	0.246	0.27
Cadmium	mg/l		0.005	0.0001	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	0.00003	<0.00002	0.00002	<0.00002
Chromium	mg/l		0.05		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/l		2		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	mg/l		0.02		0.002	0.001	0.002	0.002	0.002	0.003	0.002	0.002	0.003
Lead	mg/l		0.01		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	mg/l		5		0.007	0.004	<0.002	0.003	<0.002	0.005	0.003	<0.002	0.003
Antimony	mg/l		0.005		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	mg/l		0.01		0.01	0.008	0.004	<0.001	<0.001	0.003	0.003	0.003	<0.001
Molybdenum	mg/l		-										

Key
*UKDWS - UK Drinking Water Standards (UKDWS) or Minimum Reporting Value.
**Red highlighted text boxes indicate exceedances of UKDWS.
Groundwater quality sampling was entirely carried out within Coal Measures strata

QUA_Q003-2021(P)-06	Unit	Trigger Level	Guideline Values for Environmental Screening Criteria										
Determindand			UKDWS	Minimum Reporting Values (MRV)	30/03/2021	08/04/2021	21/04/2021	04/05/2021	21/05/2021	04/06/2021	14/06/2021	30/06/2021	27/07/2021
Ammoniacal Nitrogen	mg/l	0.39	0.39		0.39	0.08	0.12	0.09		0.1	0.1	0.05	0.09
Chloride	mg/l	250	250		21	20	20	21		18	19	21	20
pH	pH units				7.7	7.4	7.4	7.7		7.8	7.6	7.8	7.5
Electrical Conductivity	uS/cm		2500		1030	1020	1070	1050		1030	1030	975	1030
Chemical Oxygen Demand	mg/l				<5	<5	<5	<5		<5	<5	<5	<5
Total Organic Carbon	mg/l				0.34	0.23	0.24	0.38		0.36	0.43	0.35	0.25
Total Oxidised Nitrogen	mg/l				<0.2	<0.2	5	<0.2		<0.2	<0.2	<0.2	<0.2
Calcium	mg/l		250		140	137	145	143		139	144	138	151
Magnesium	mg/l		50		65	62	66	66		63	66	63	68
Sodium	mg/l		200		13	12	14	13		12	12	12	13
Potassium	mg/l		12		4	4	4	5		4	4	4	4
Sulphate	mg/l		250		214	210	203	209		204	216	203	219
Iron	mg/l		0.2		<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01
Manganese	mg/l		0.05		0.112	0.11	0.119	0.105		0.099	0.102	0.11	0.107
Cadmium	mg/l		0.005	0.0001	<0.00002	<0.00002	0.00004	<0.00002		0.00004	<0.00002	<0.00002	<0.00002
Chromium	mg/l		0.05		<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Copper	mg/l		2		<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Nickel	mg/l		0.02		0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Lead	mg/l		0.01		<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Zinc	mg/l		5		<0.002	<0.002	0.012	<0.002		0.002	<0.002	<0.002	<0.002
Antimony	mg/l		0.005		<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Selenium	mg/l		0.01		<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Molybdenum	mg/l		-										

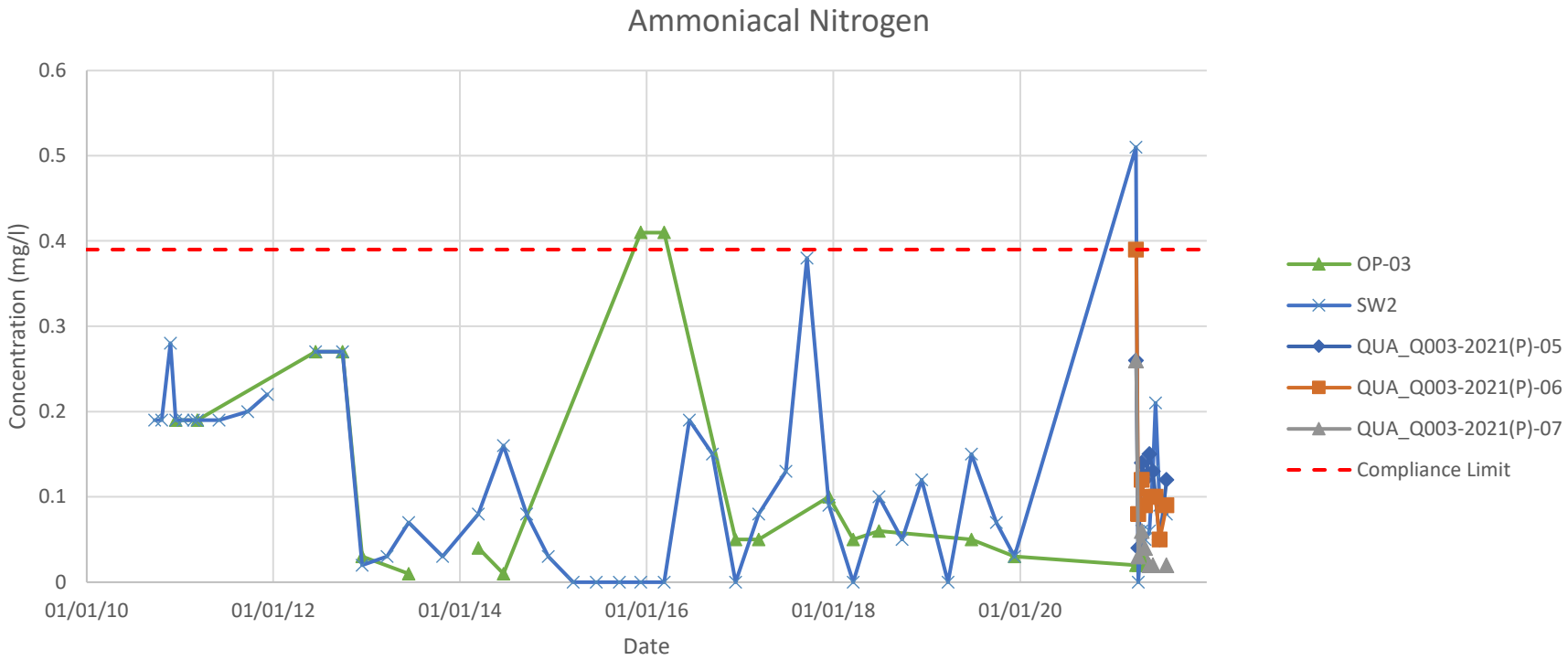
Key
*UKDWS - UK Drinking Water Standards (UKDWS) or Minimum Reporting Value.
**Red highlighted text boxes indicate exceedances of UKDWS.
Groundwater quality sampling was entirely carried out within Coal Measures strata

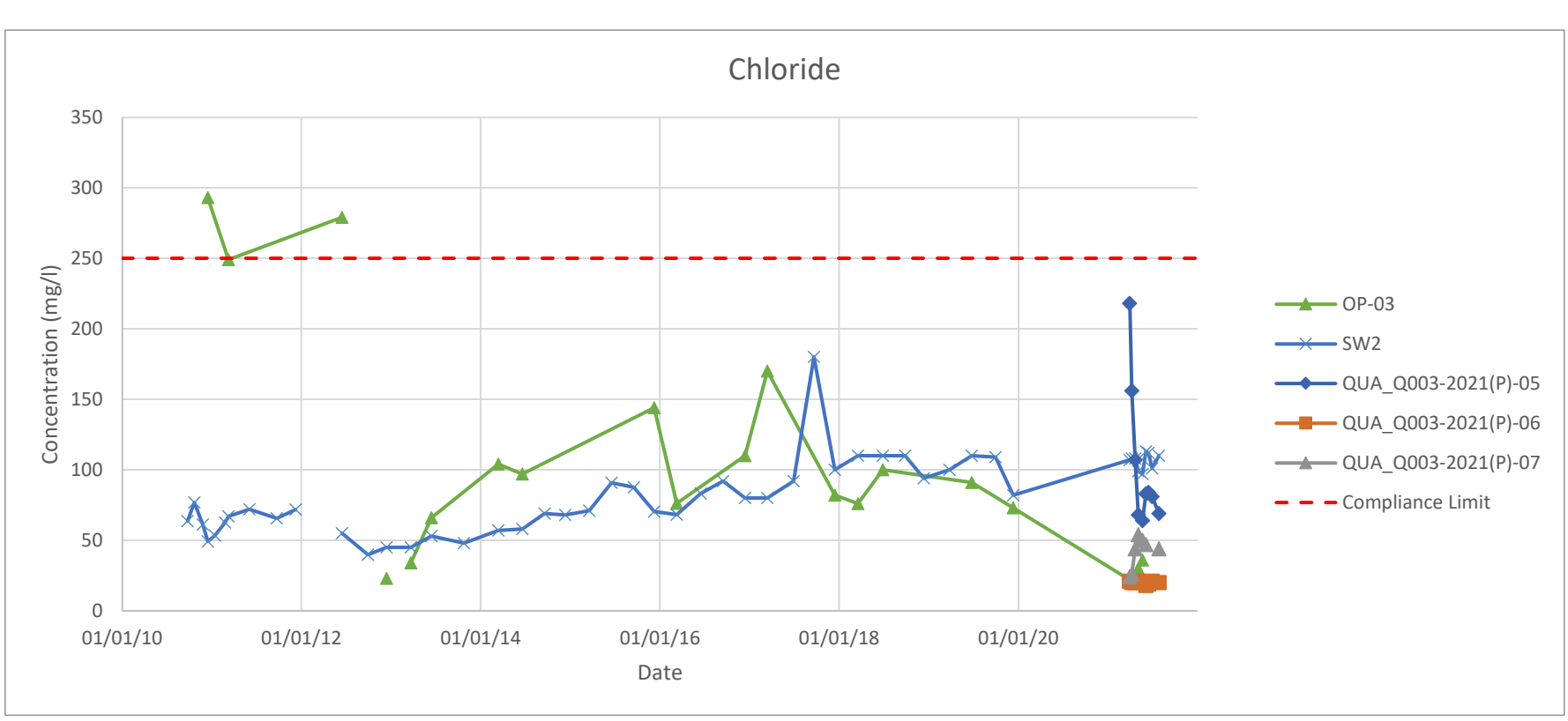
QUA_Q003-2021(P)-07	Unit	Trigger Level	Guideline Values for Environmental Screening Criteria										
Determindand			UKDWS	Minimum Reporting Values (MRV)	30/03/2021	08/04/2021	21/04/2021	04/05/2021	21/05/2021	04/06/2021	14/06/2021	30/06/2021	27/07/2021
Ammoniacal Nitrogen	mg/l	0.39	0.39		0.26	0.03	0.06	0.04	<0.02	<0.02			<0.02
Chloride	mg/l	250	250		24	26	44	54	50	47			44
pH	pH units				7.8	7.6	7.7	7.9	7.7	7.9			7.7
Electrical Conductivity	uS/cm		2500		593	572	671	731	703	702			681
Chemical Oxygen Demand	mg/l				<5	<5	<5	<5	<5	<5			<5
Total Organic Carbon	mg/l				0.51	0.35	0.34	0.36	0.38	0.4			0.21
Total Oxidised Nitrogen	mg/l				11.4	7.5	8.8	11.1	11.5	11			10.2
Calcium	mg/l		250		75	70	81	83	84	82			82
Magnesium	mg/l		50		31	28	32	33	33	32			32
Sodium	mg/l		200		10	10	18	21	21	19			17
Potassium	mg/l		12		2	1	2	2	2	2			2
Sulphate	mg/l		250		69	55	65	75	71	74			70
Iron	mg/l		0.2		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01
Manganese	mg/l		0.05		0.02	0.012	0.015	0.013	0.007	0.006			<0.002
Cadmium	mg/l		0.005	0.0001	<0.00002	0.00005	<0.00002	0.00004	<0.00002	0.00008			<0.00002
Chromium	mg/l		0.05		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			<0.001
Copper	mg/l		2		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			<0.001
Nickel	mg/l		0.02		0.002	0.002	0.002	0.003	0.002	0.002			0.002
Lead	mg/l		0.01		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			<0.001
Zinc	mg/l		5		<0.002	0.002	<0.002	<0.002	<0.002	0.003			0.003
Antimony	mg/l		0.005		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			<0.001
Selenium	mg/l		0.01		0.011	0.003	0.002	0.003	0.002	0.002			0.002
Molybdenum	mg/l		-										

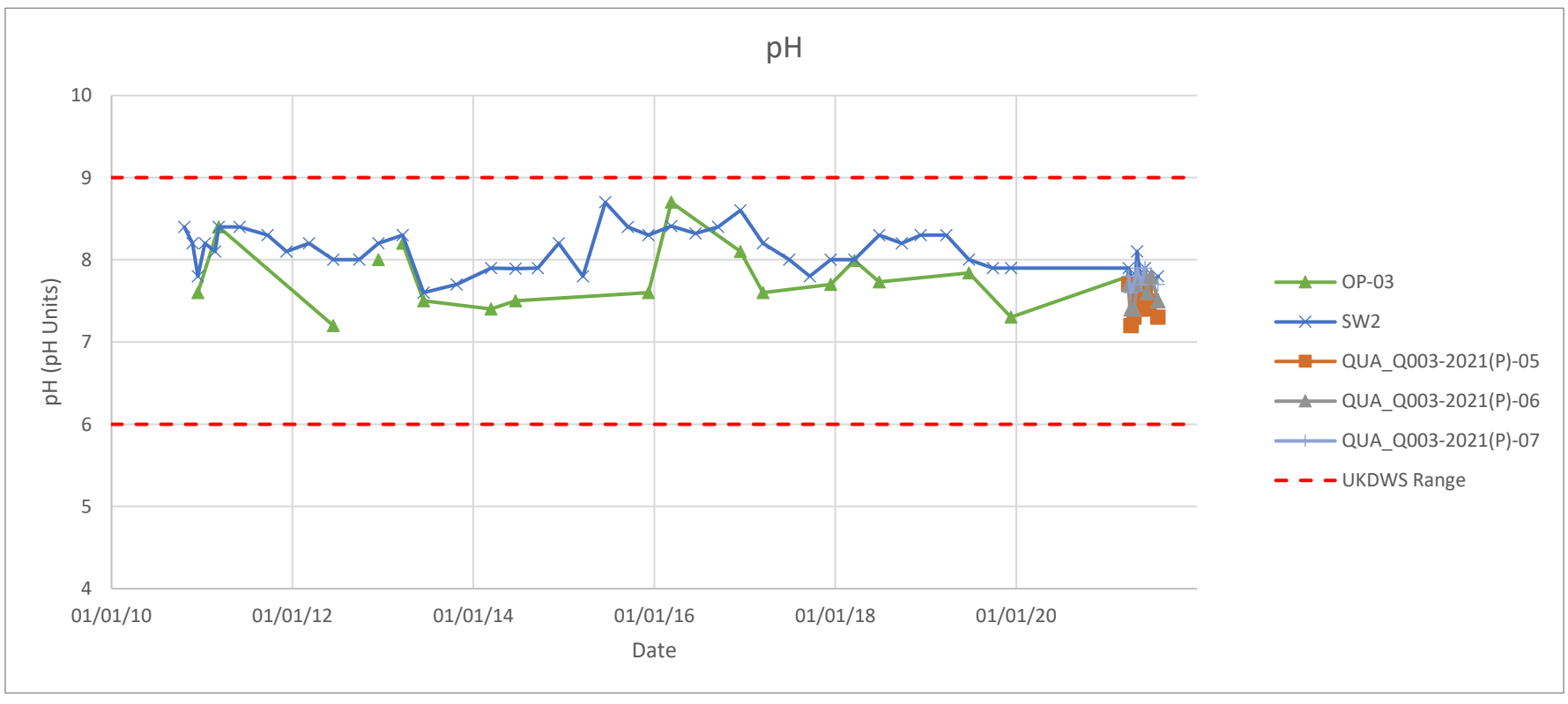
Key
*UKDWS - UK Drinking Water Standards (UKDWS) or Minimum Reporting Value.
**Red highlighted text boxes indicate exceedances of UKDWS.
Groundwater quality sampling was entirely carried out within Coal Measures strata

APPENDIX 6

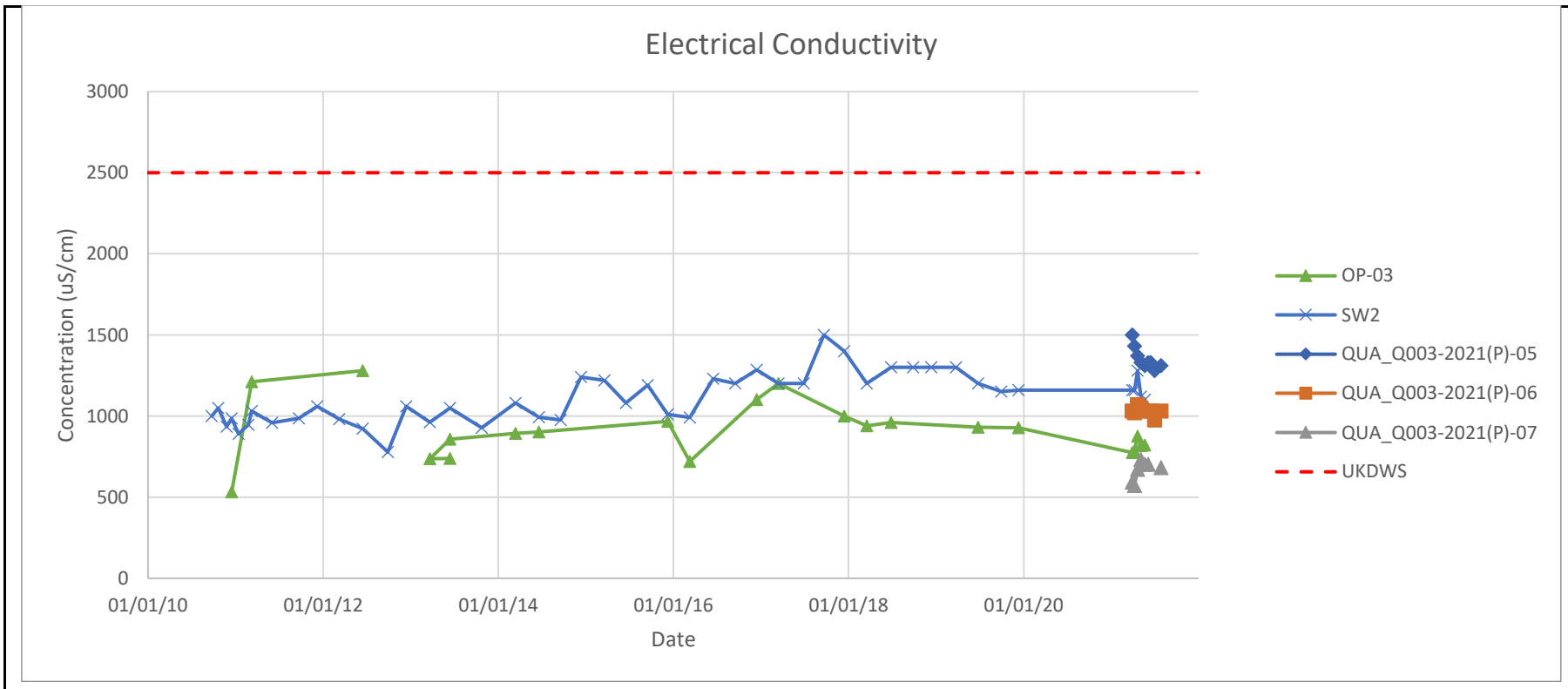
Groundwater and Spring Quality Results Graphed

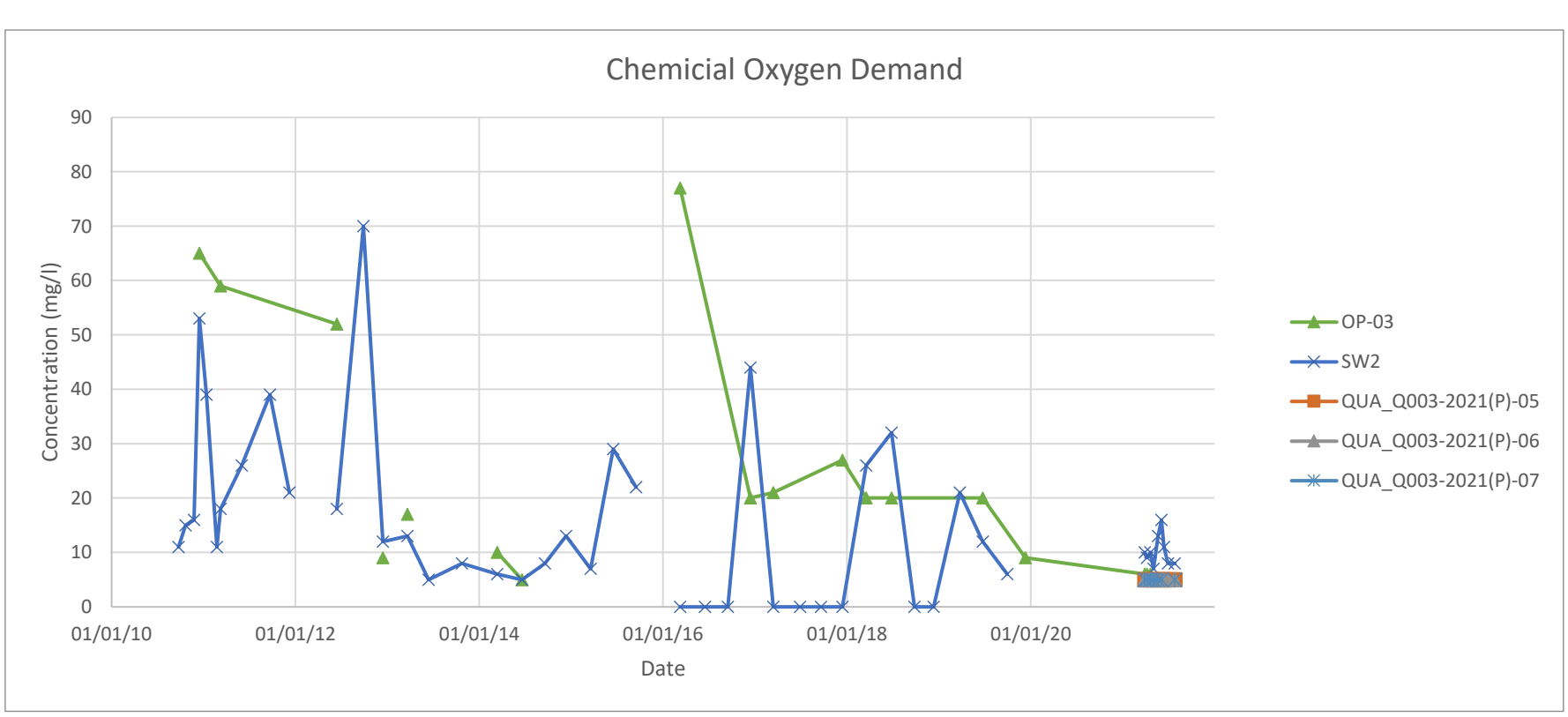


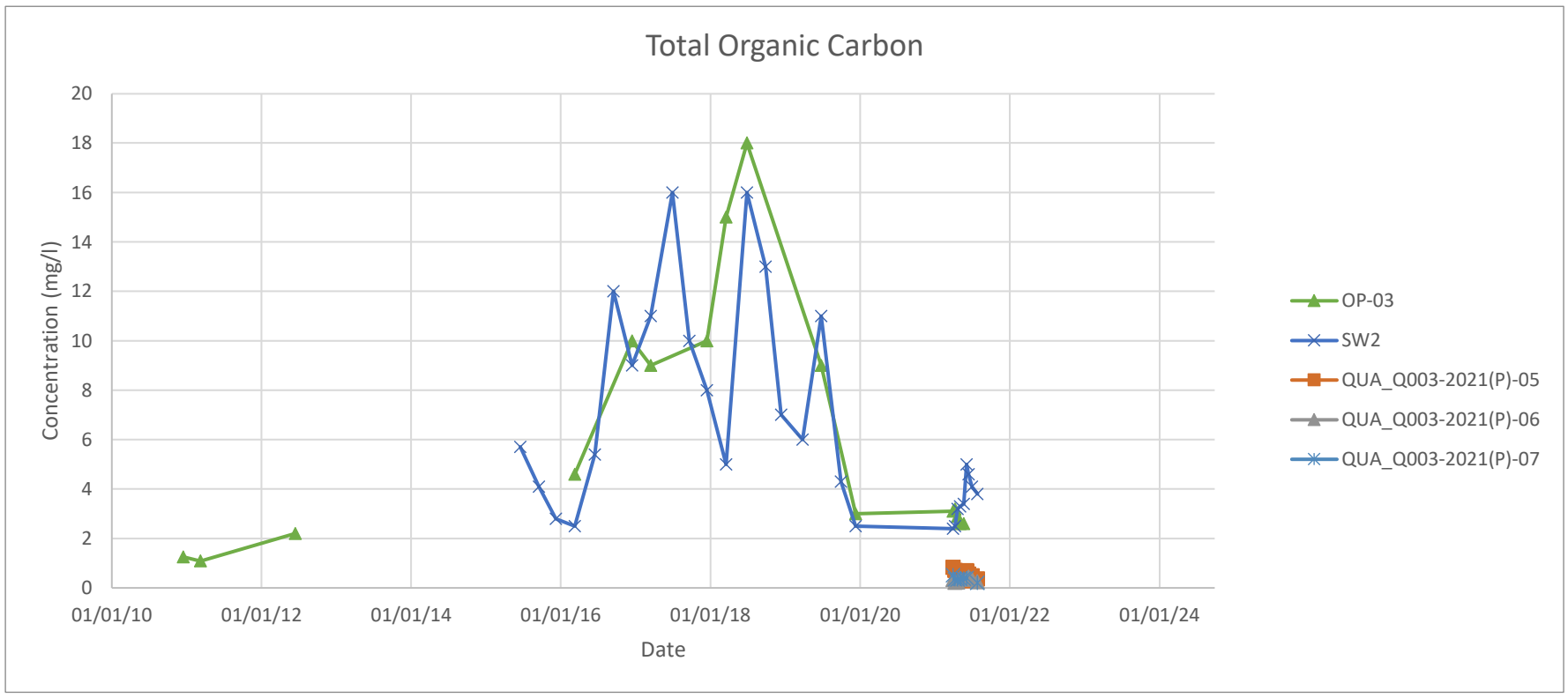




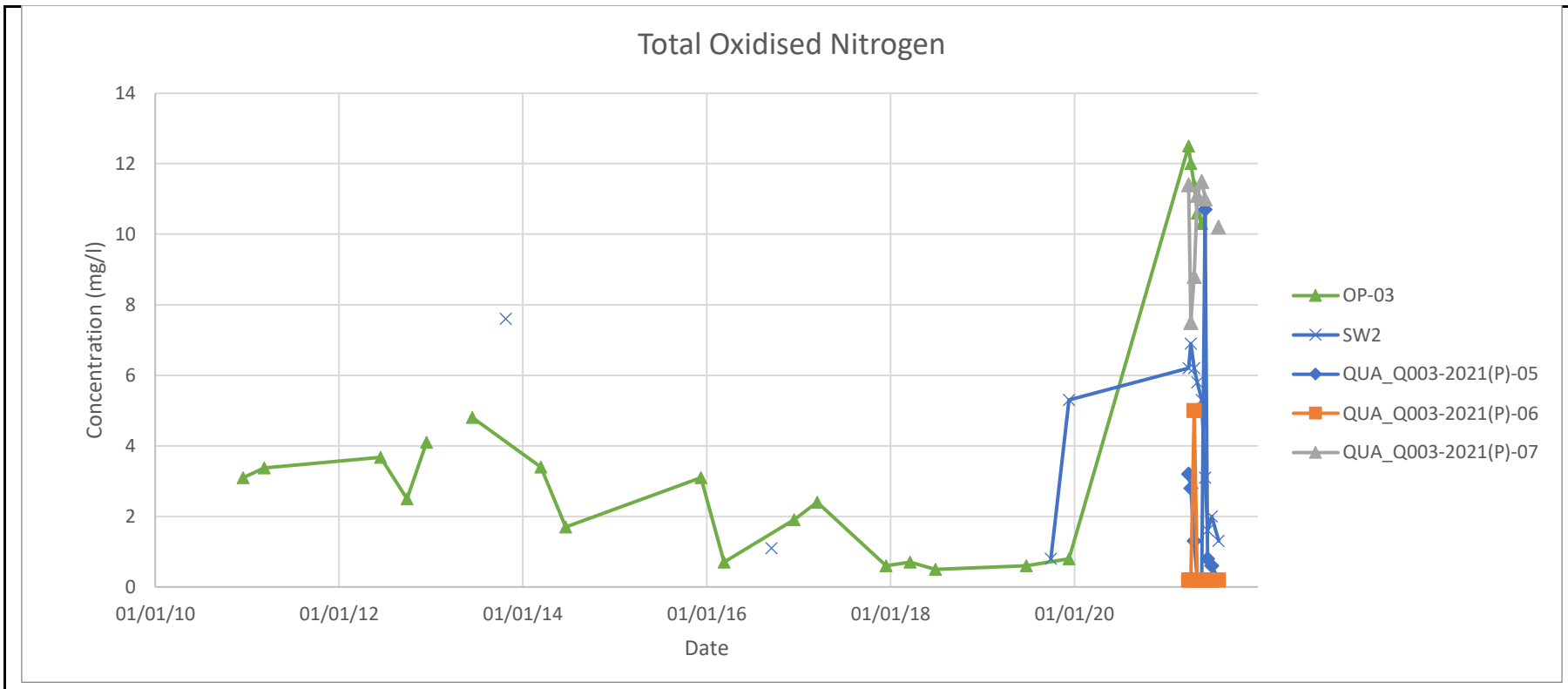
CLIENT	**Tarmac Ltd**		
PROJECT	**Hydrogeological Risk Assessment Review**		
FIGURE TITLE	**Groundwater and Spring Quality Results**		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 6	JS	LB	Sep-21

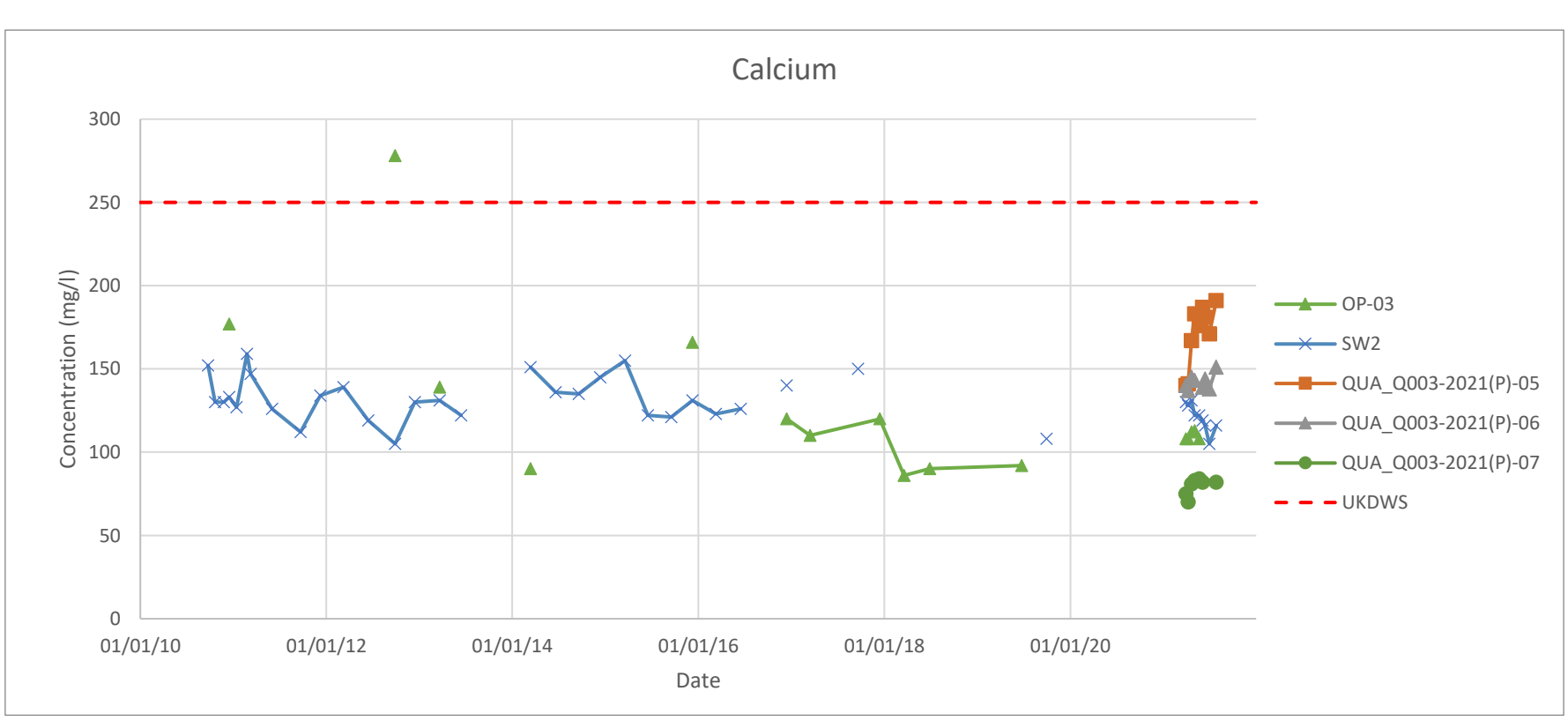


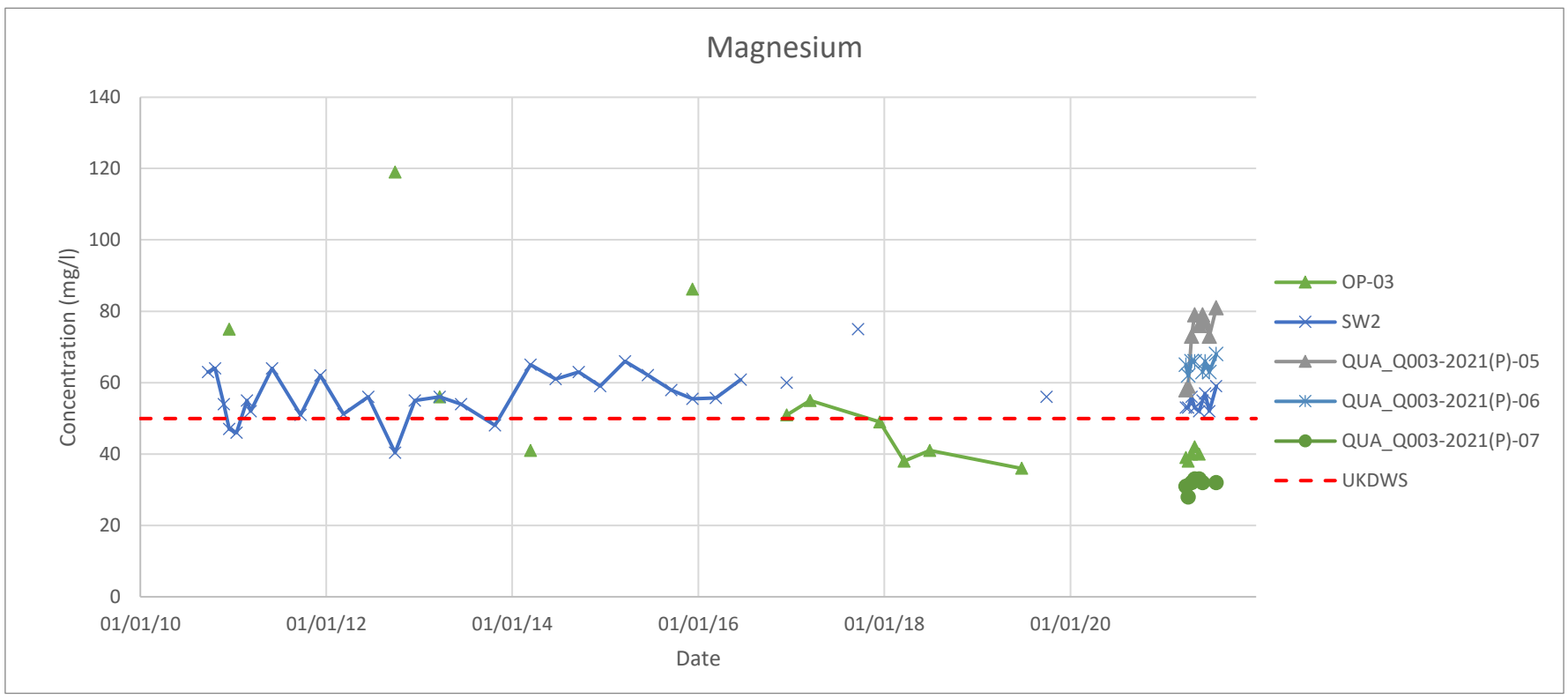




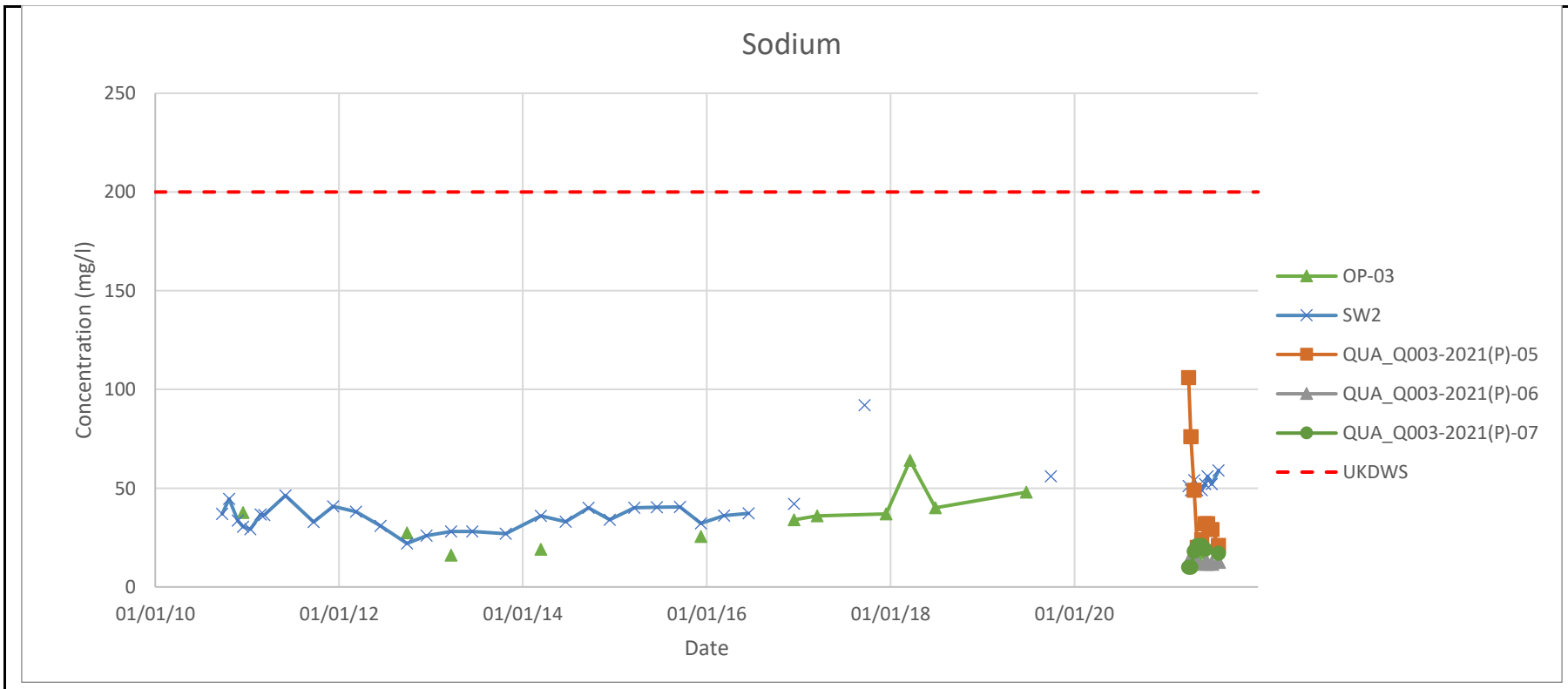
CLIENT	**Tarmac Ltd**		
PROJECT	**Hydrogeological Risk Assessment Review**		
FIGURE TITLE	**Groundwater and Spring Quality Results**		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 6	JS	LB	Sep-21

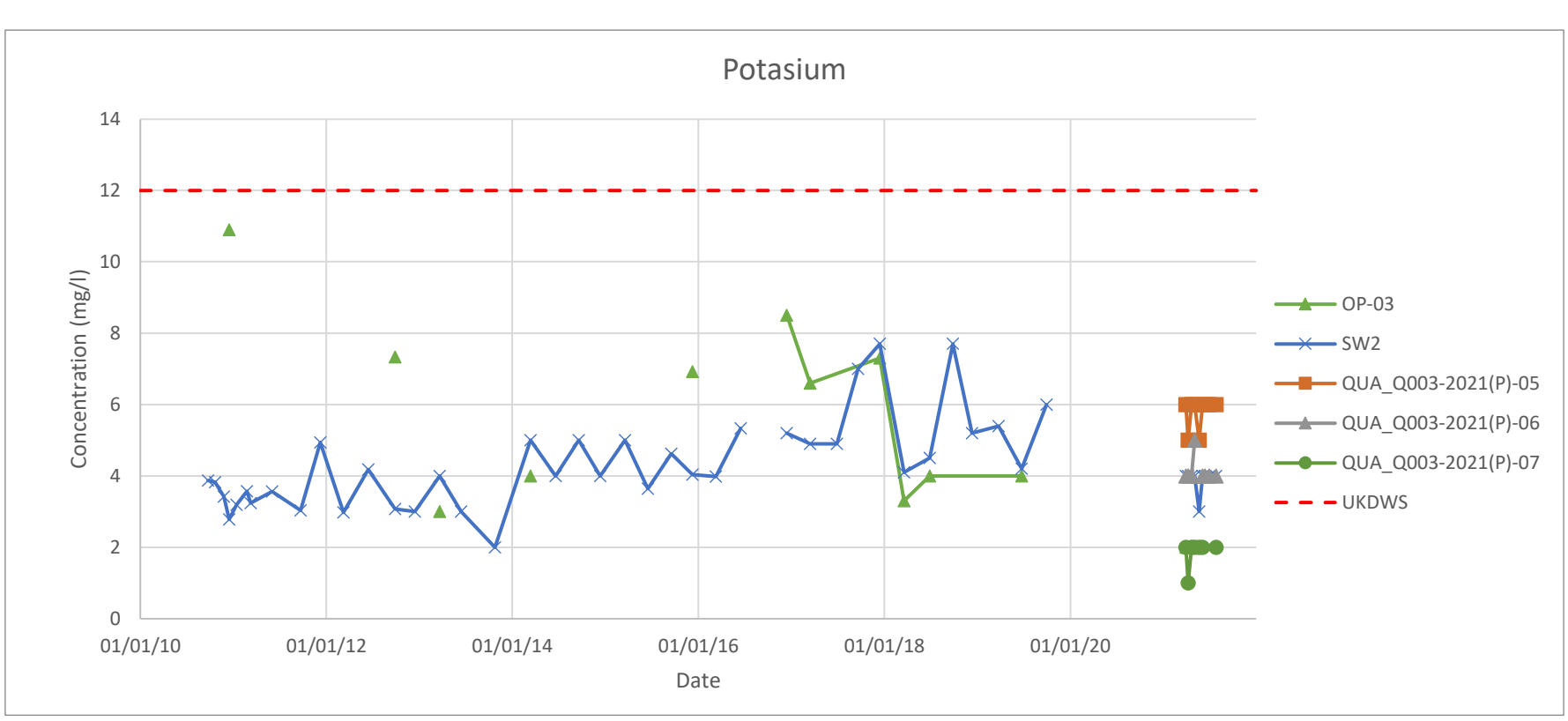


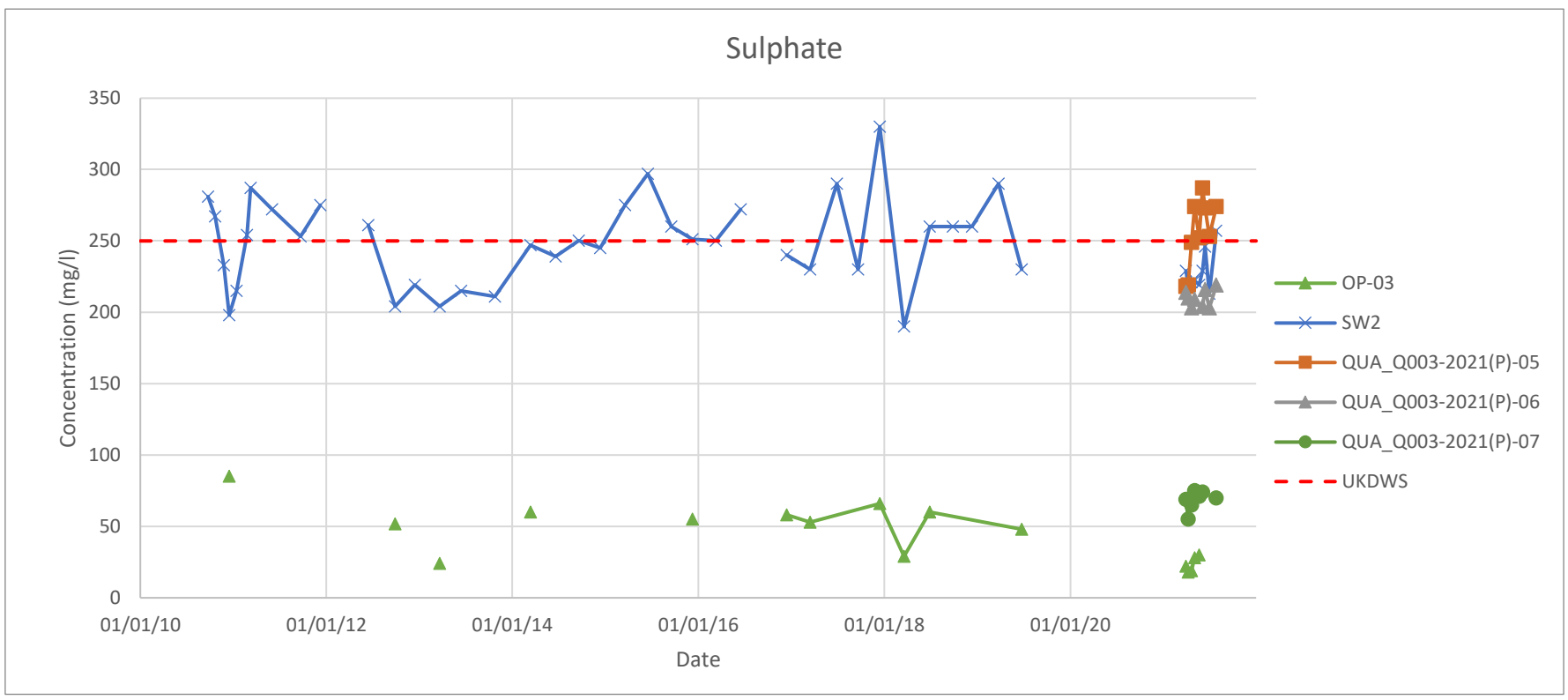




CLIENT	**Tarmac Ltd**		
PROJECT	**Hydrogeological Risk Assessment Review**		
FIGURE TITLE	**Groundwater and Spring Quality Results**		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 6	JS	LB	Sep-21

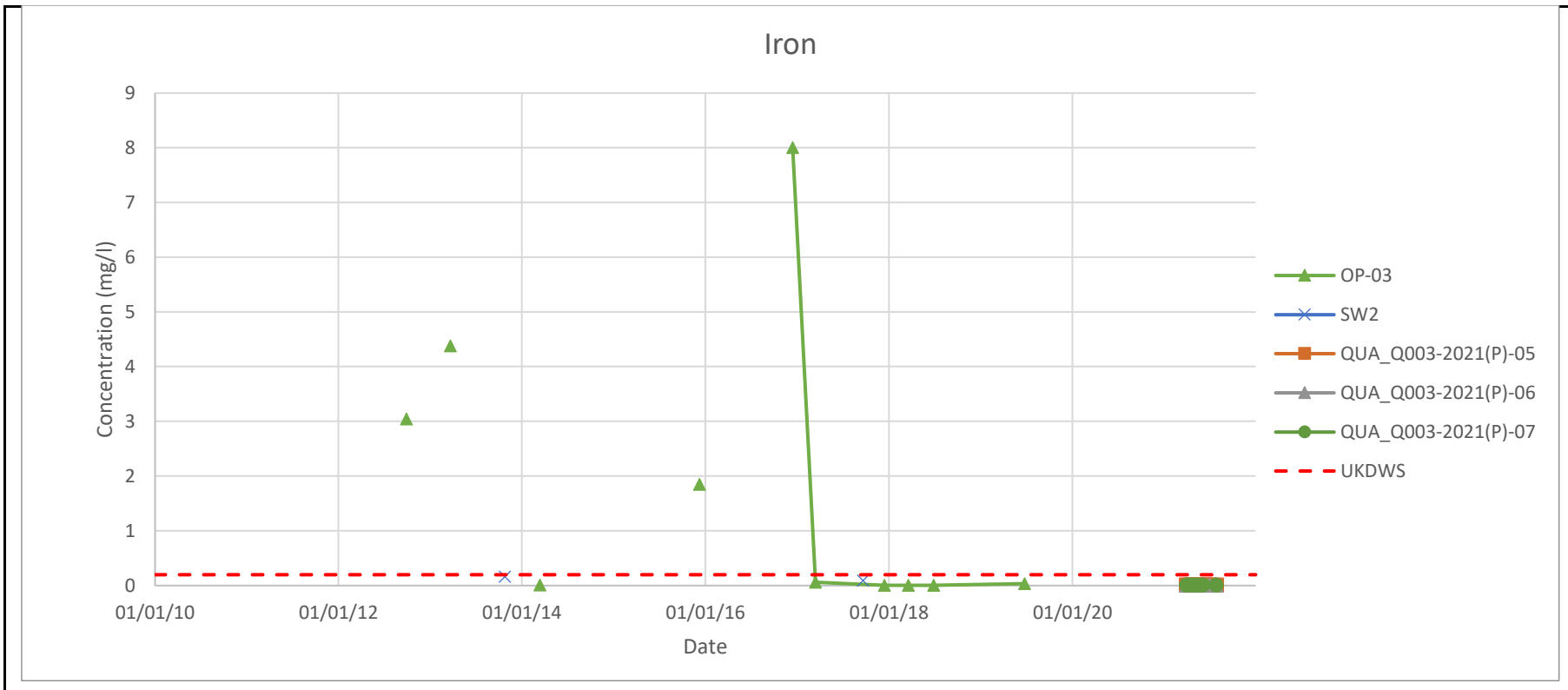


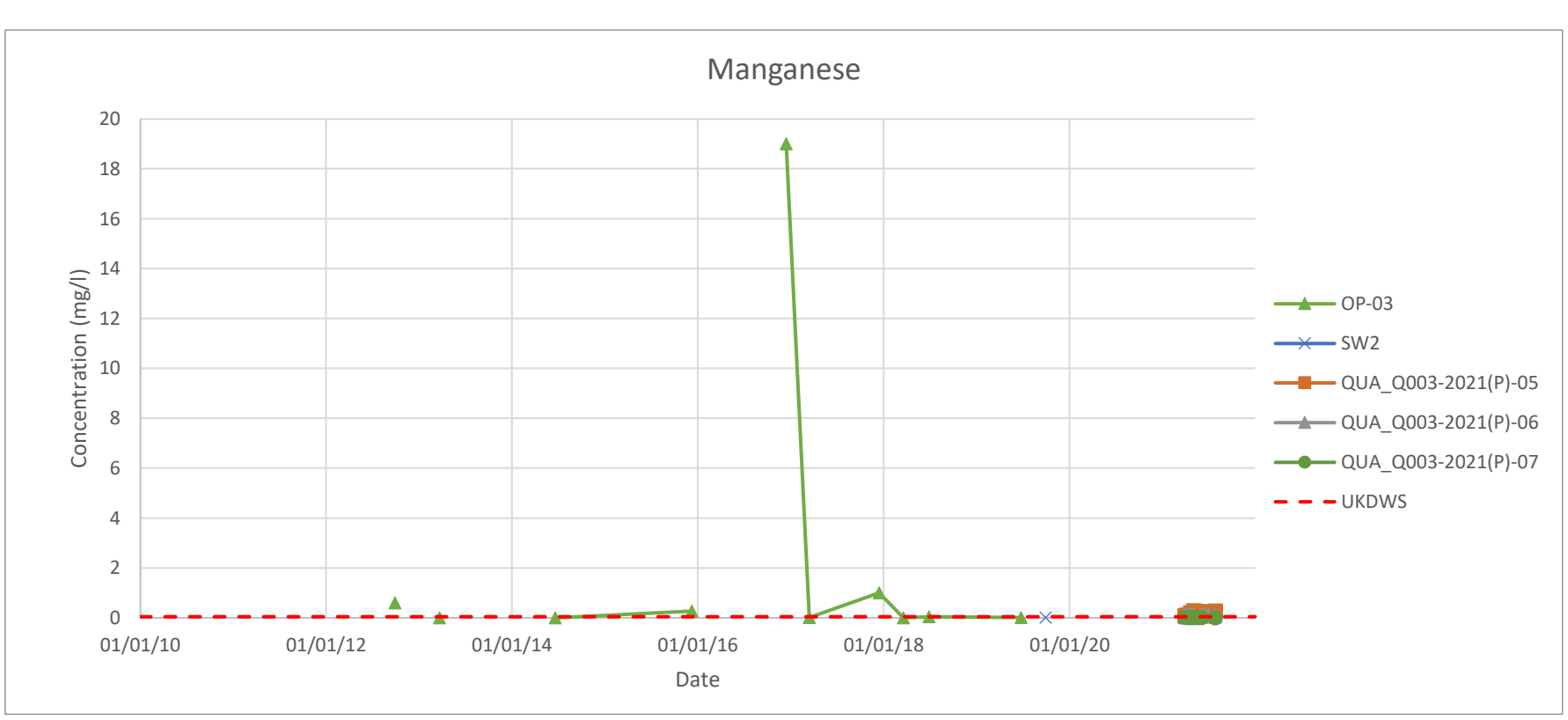


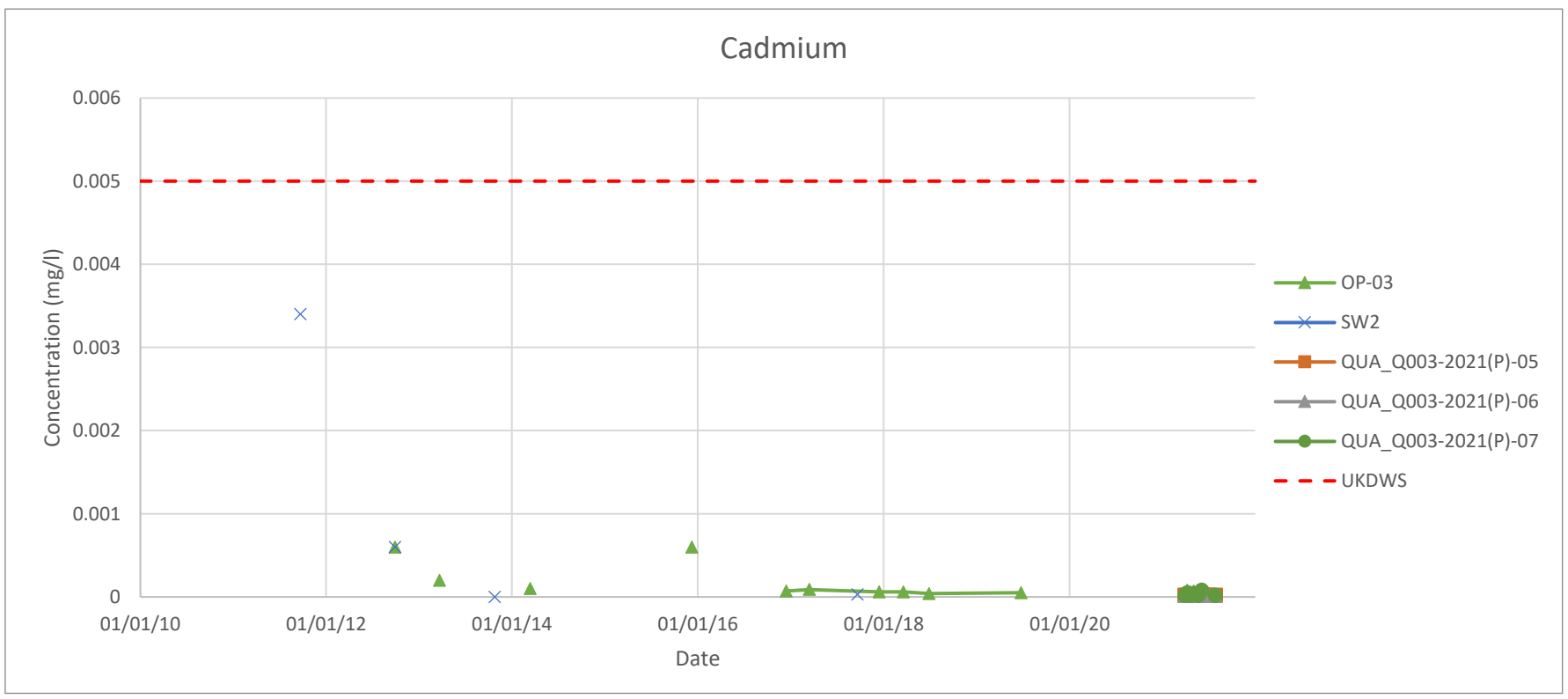


wardell armstrong

CLIENT	**Tarmac Ltd**		
PROJECT	**Hydrogeological Risk Assessment Review**		
FIGURE TITLE	**Groundwater and Spring Quality Results**		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 6	JS	LB	Sep-21

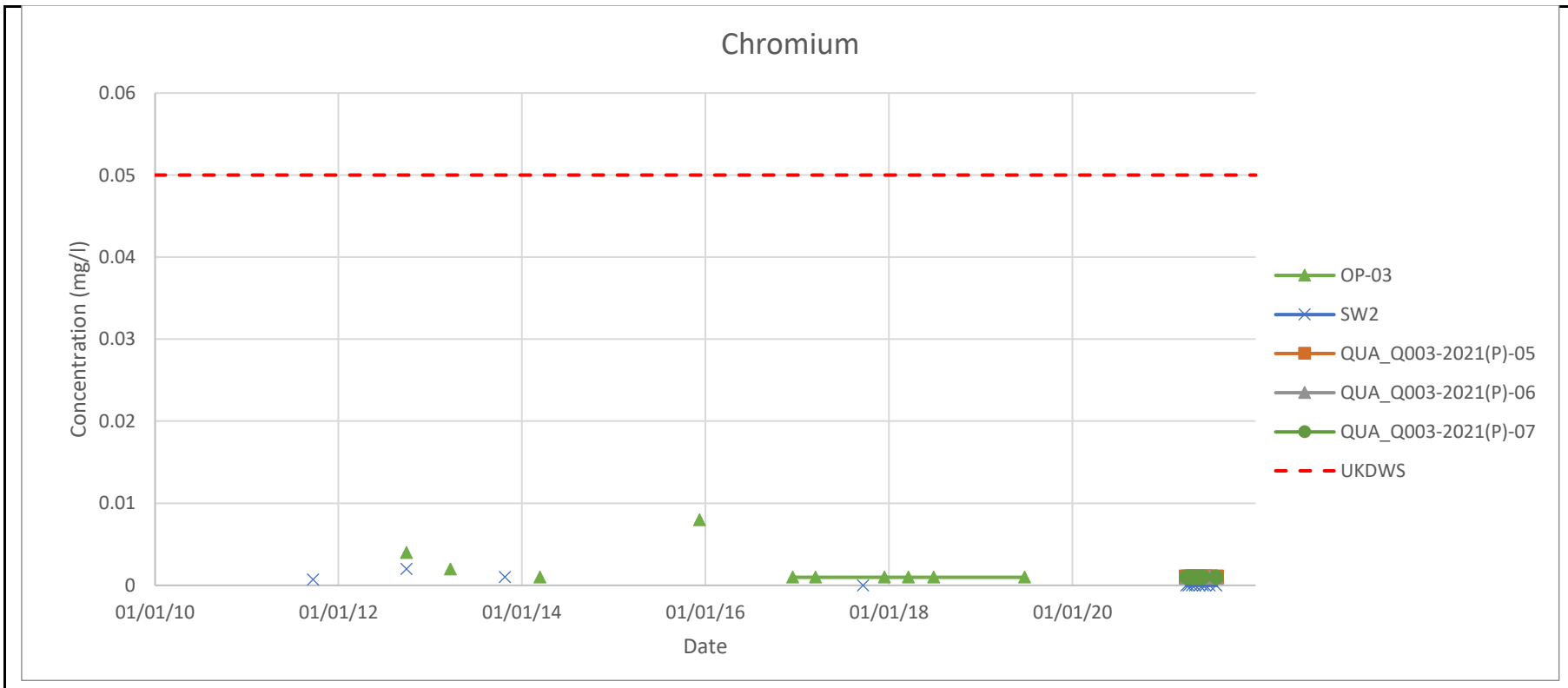


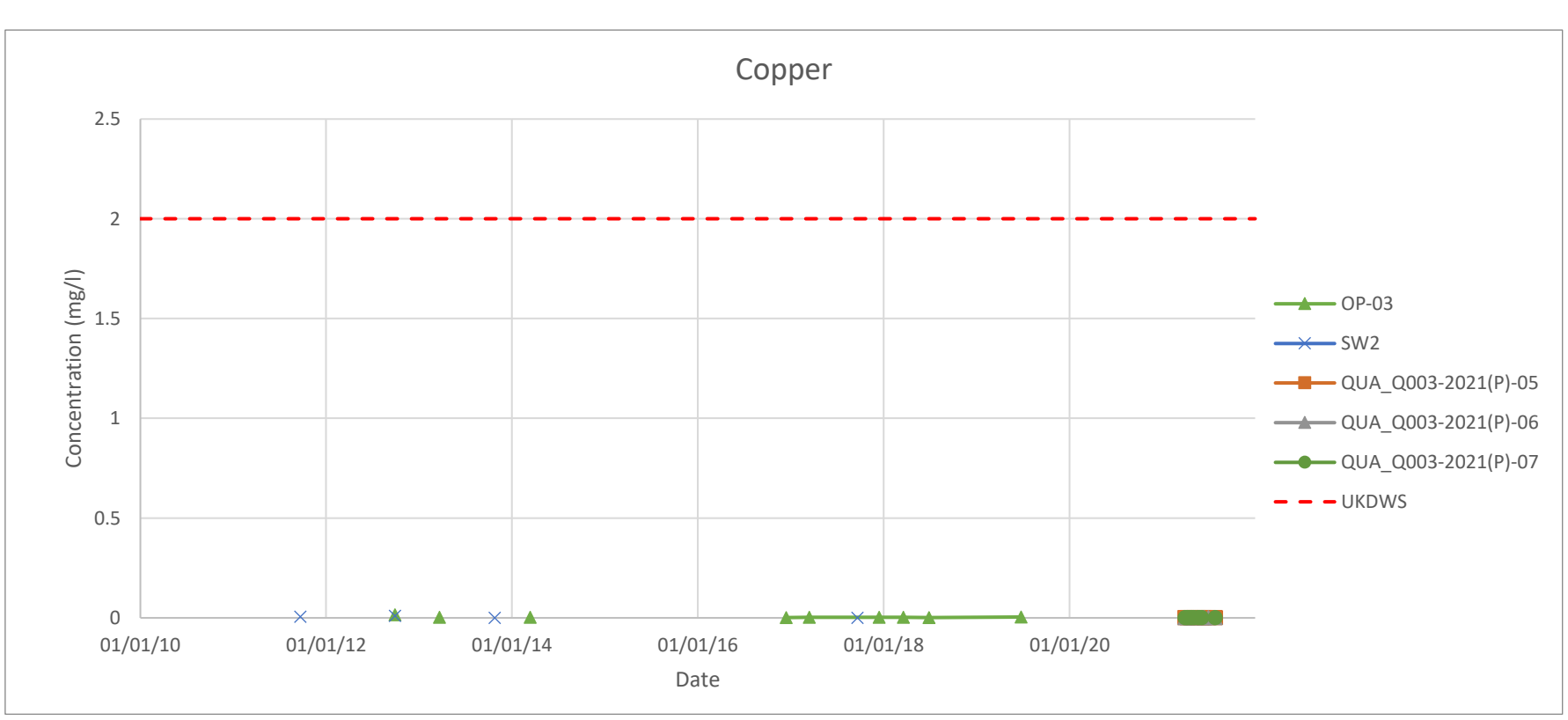


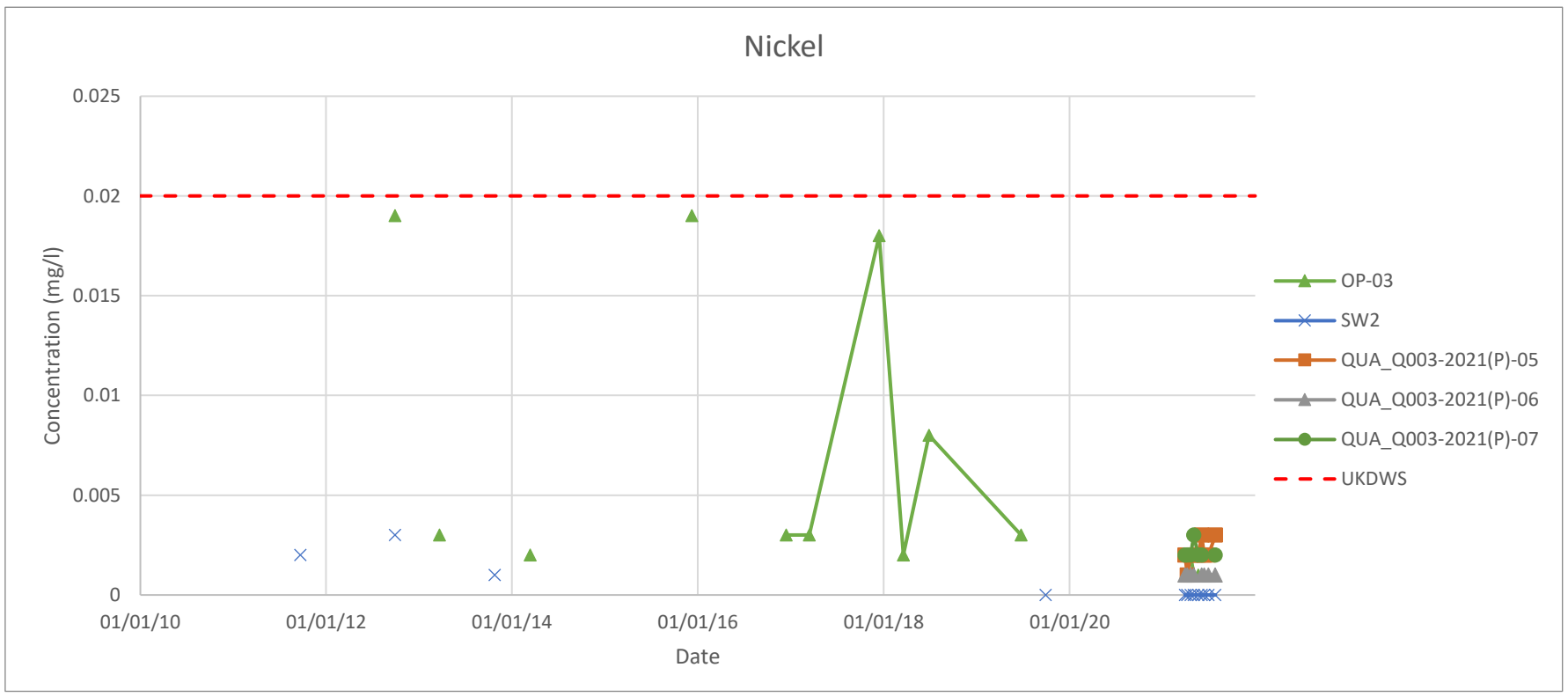


wardell armstrong

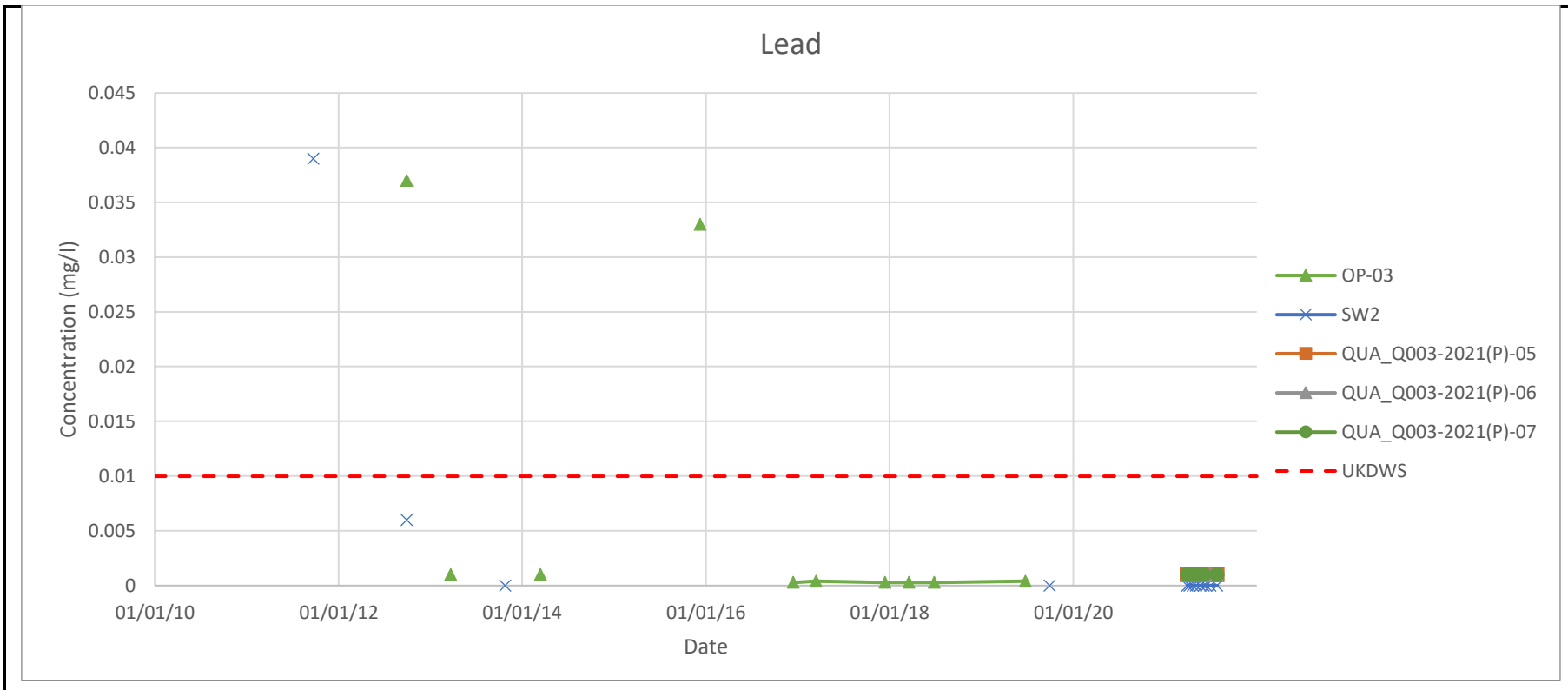
CLIENT	**Tarmac Ltd**		
PROJECT	**Hydrogeological Risk Assessment Review**		
FIGURE TITLE	**Groundwater and Spring Quality Results**		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 6	JS	LB	Sep-21

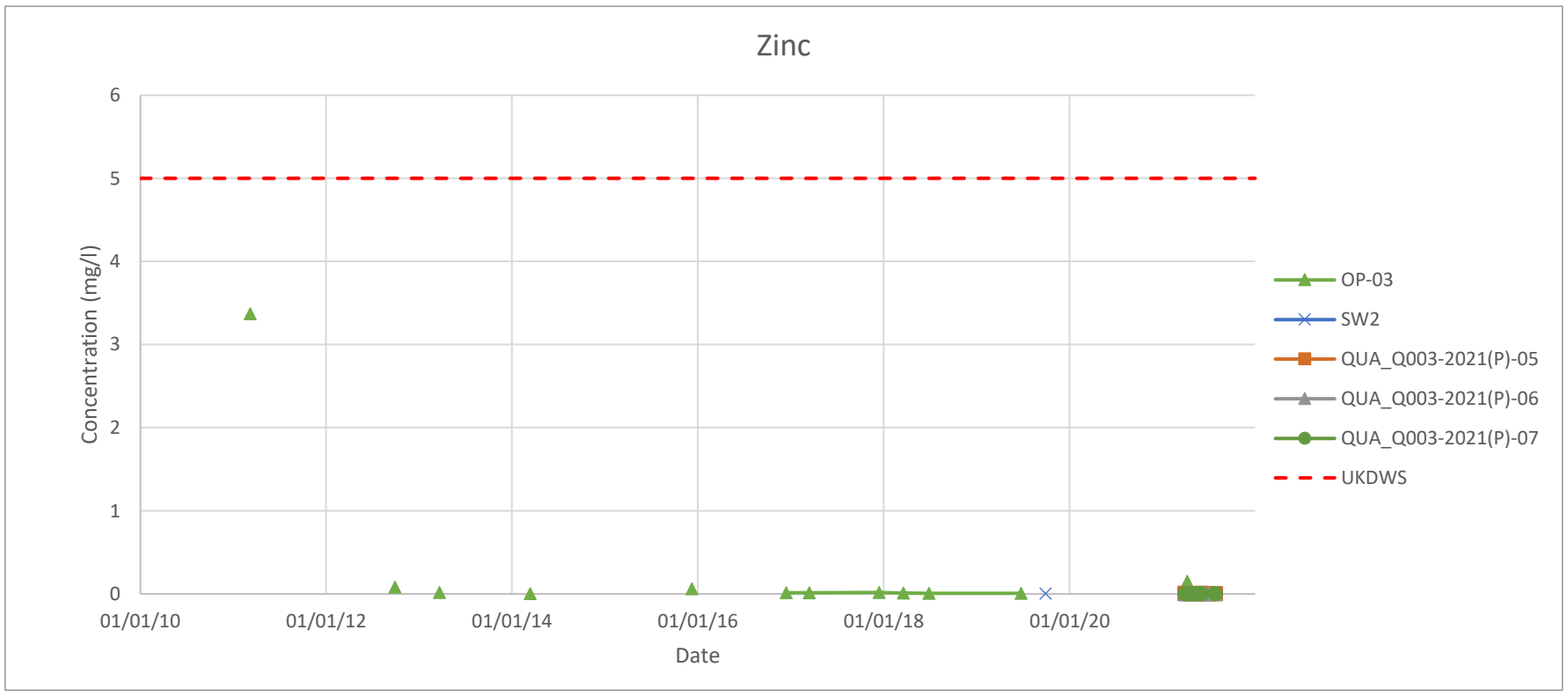


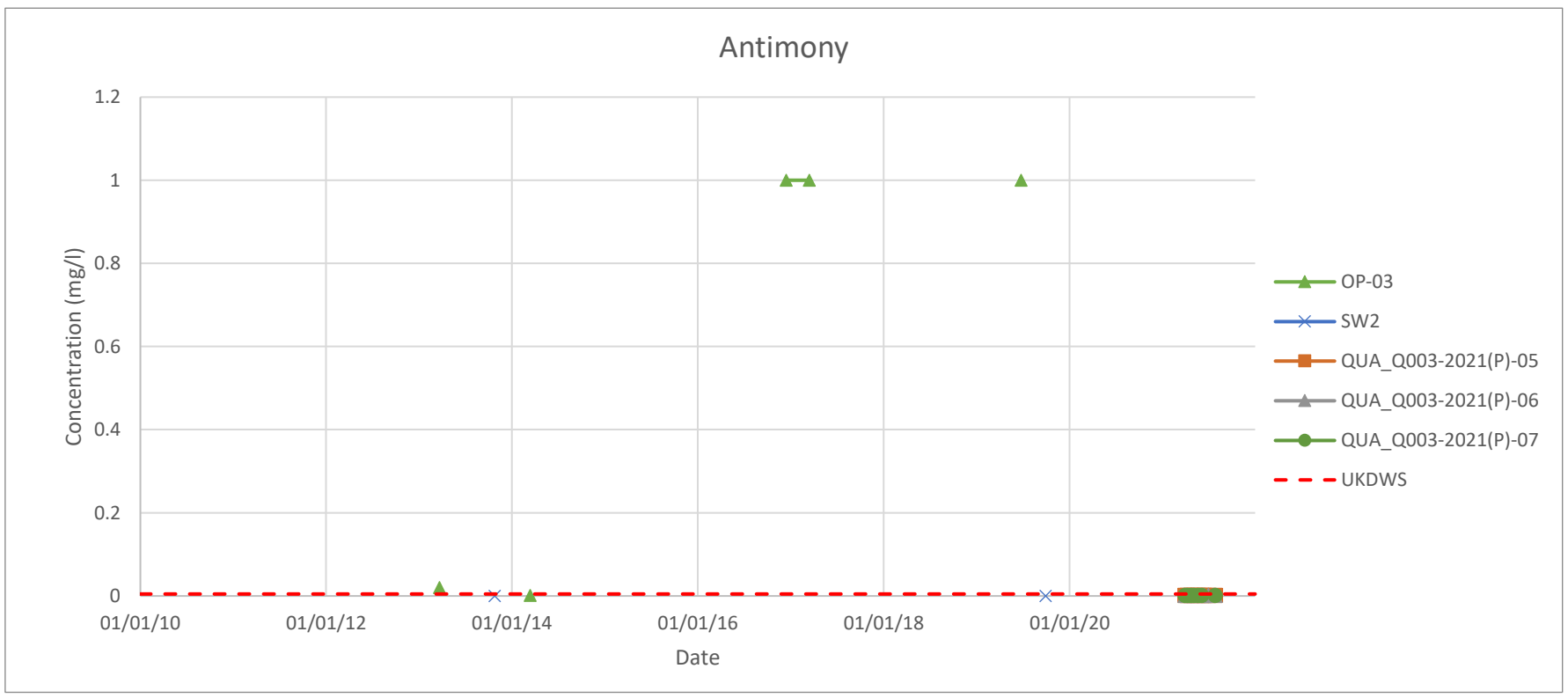




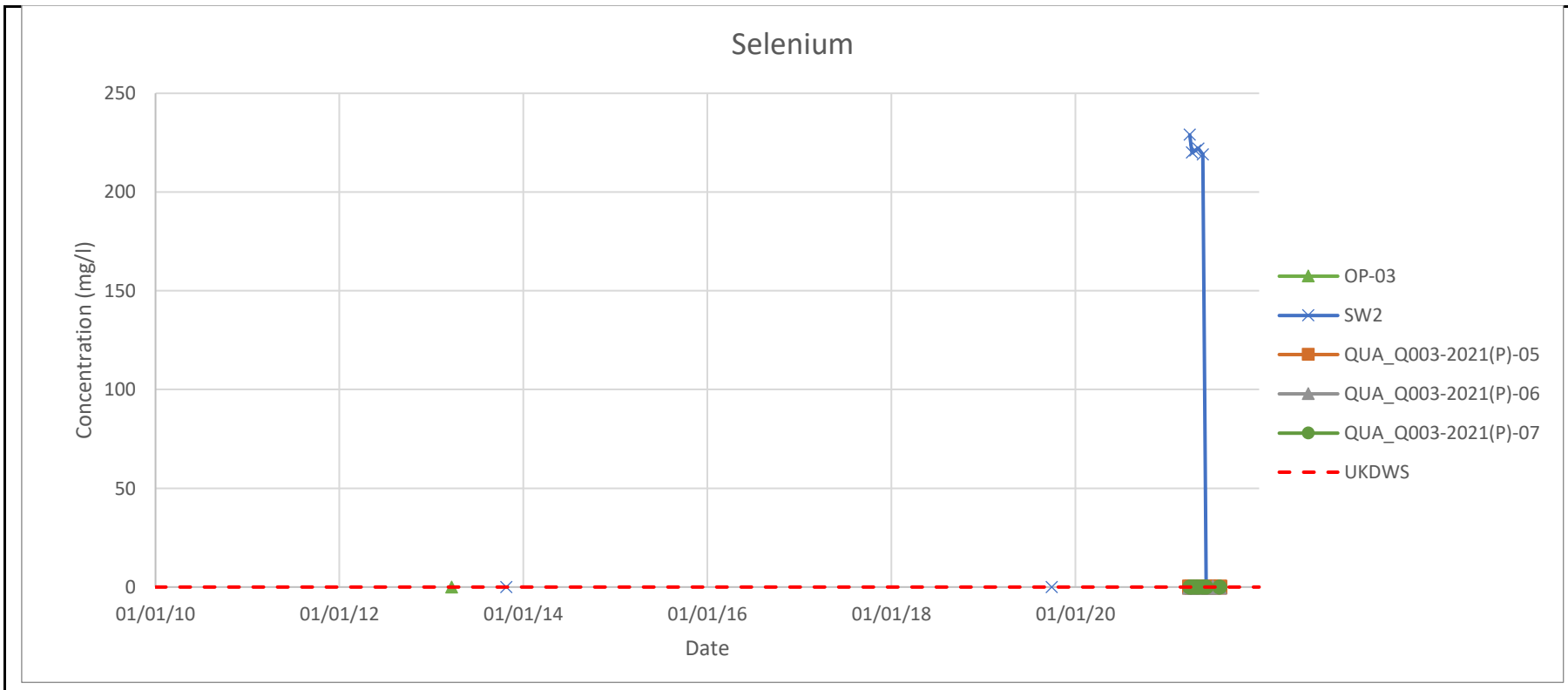
CLIENT	**Tarmac Ltd**		
PROJECT	**Hydrogeological Risk Assessment Review**		
FIGURE TITLE	**Groundwater and Spring Quality Results**		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 5	JS	LB	Sep-21

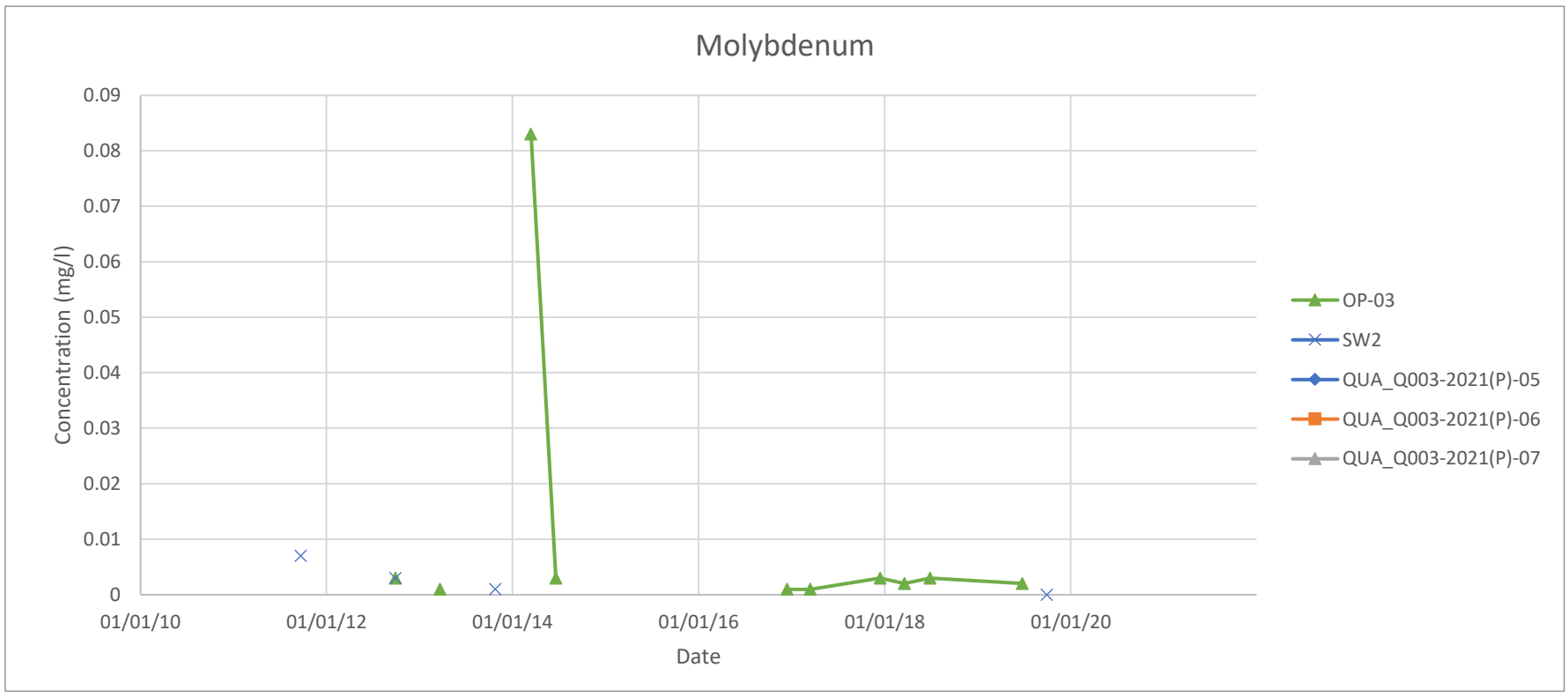






CLIENT	**Tarmac Ltd**		
PROJECT	**Hydrogeological Risk Assessment Review**		
FIGURE TITLE	**Groundwater and Spring Quality Results**		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 6	JS	LB	Sep-21





CLIENT	**Tarmac Ltd**		
PROJECT	**Hydrogeological Risk Assessment Review**		
FIGURE TITLE	**Groundwater and Spring Quality Results**		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 6	JS	LB	Sep-21

APPENDIX 7

Monitoring Borehole Information

Borehole (PO/OP)	Year	Current Groundwater Elevation Monitoring Borehole	Borehole Log	Location (NGR)		Ground Level (mAOD)	Base of Borehole		Top of Screened Section		Base of Screened Section		Geology / Depth (m BGL)	Install geology	Notes	Average Groundwater Level (mAOD)
				Easting	Northing		mbgl	mAOD	mbgl	mAOD	mbgl	mAOD				
P-0 Borehole Series																
P-01	2021	**Yes**	Yes	433418	538105	185.2	63	122.2	56	129.2	59	126.2	0 - 1.0 - Top Soil 1- 36.0 - Permian Limestone 36.0 - 38.6 - Permian Marl 38.6 - 61.3 - Permian Sand 61.3 - 63.0 - Coal Measures	Permian Sand	Used for Mont Scheme	152.7
P-02	2021	No	Yes	432733	537973	156.1	13.9	142.2	10.9	145.2	13.9	142.2	0 - 6.2 - Fill and Made Ground 6.2 - 9.05 - Permian Sand 9.05 - 13.9 - Coal Measures	Coal Measures	BH Destroyed	-
P-03	2021	**Yes**	Yes	432505	538142	155.9	6.7	149.2	3.7	152.2	6.7	149.2	0 - 1.5 - Permian Limestone/Marl 1.5 - 2.75 - Permian Sand 2.75 - 6.7 - Coal Measures	Coal Measures	Used for Mont Scheme	150.4
P-04	2021	No	Yes	432745	537966	155.1	11.5	143.6	6.95	148.2	9.95	145.2	0 - 1.0 - Fill Material 1.0 - 4.5 - Permian Marl 4.5 - 10 - Permian Sand 10 - 11.5 - Coal Measures	Permian Sand	BH Destroyed	-
P-05	2021	**Yes**	No	433364	538102	185.0	38	147.0	35	150.0	38	147.0	0 - 36.8 Limestone 36.8 - 38 Marl Slate	limestone	Used for Mont Scheme	148.0
P-06	2021	No	No	433384	538074	185.0	56.2	128.8	53	132.0	56	129.0	0 - 36.7 Limetone 36.7 - 38.7 Marl Slate 38.7 - 55.3 Permian Sands 55.3 - 56.2 Coal Measures	Sand and CM Interface	Used for Mont Scheme	132.0
QUA Borehole Series																
QUA_0001	2021	No	No	432560	538093	154.7	n/a	142.9	Information Not Held						Dry	143.5
QUA_0002	2021	No	No	432576	538015	151.7	n/a	138.3	Information Not Held							138.2
QUA_0003	2021	No	No	432585	537947	149.6	n/a	135.4	Information Not Held							138.8
QUA_0004	2021	No	No	432603	537895	150.9	n/a	136.6	Information Not Held							165.9
QUA_0005	2021	No	No	432654	538187	179.1	n/a	160.2	Information Not Held							153.0
QUA_0006	2021	No	No	432599	538130	179.0	n/a	152.8	Information Not Held							173.2
QUA_0007	2021	No	No	432684	538061	177.9	n/a	173.3	Information Not Held						Dry	Dry / Occassionally wet at base
QUA_0008	2021	No	No	BH too steep access												
QUA_0009	2021	No	No	BH Missing												
QUA_0010	2021	No	No	BH Missing												
QUA_0011	2021	No	No	BH Missing												
QUA_0012	2021	No	No	Buried/Destroyed												
QUA_0012	2021	No	No	Buried/Destroyed												

APPENDIX 8

WAC for Inert Waste Sites and Risk Factor Analysis

Limit values (mg/kg) for compliance leaching test using BS EN 12457 at L/S 10 l/kg

Parameter	mg/kg	mg/l*	Hazardous substance?	MRV for hazardous substances	UKDWS (mg/l)	Risk Factor***	Rank***
As (arsenic)	0.5	0.05	Yes	0.01**	0.01	5	1
Ba (barium)	20	2	No	-	1	2	3
Cd (cadmium)	0.04	0.004	No	-	0.005	0.8	9
Cr (chromium (total))	0.5	0.05	Yes	0.01**	0.05	1	6
Cu (copper)	2	0.2	No	-	2	0.1	13
Hg (mercury)	0.01	0.001	Yes	0.01	0.001	1	6
Mo (molybdenum)	0.5	0.05	No	-	-	-	-
Ni (nickel)	0.4	0.04	No	-	0.02	2	3
Pb (lead)	0.5	0.05	Yes	0.01**	0.01	5	1
Sb (antimony)	0.06	0.006	No	-	0.005	1.2	5
Se (selenium)	0.1	0.01	No	-	0.01	1	6
Zn (zinc)	4	0.4	No	-	5	0.08	14
Cl (chloride)	800	80	No	-	250	0.32	12
F (fluoride)	10	1	No	-	1.5	0.67	10
SO4 (sulphate)	1000	100	No	-	250	0.4	11
Total dissolved solids (TDS)	4000	400	No	-	-	-	-
Phenol index	1	0.1	No	-	-	-	-
Dissolved organic carbon	500	50	No	-	-	-	-

MRV = minimum reporting value from:
https://www.gov.uk/government/publications/values-for-groundwater-risk-assessments/hazardous-substances-to-groundwater-minimum-reporting-values
* WAC data (in mg/kg) converted to leachate concentrations (in mg/l) by a 10:1 conversion factor
** Laboratory method limit of detection as no published MRV
*** "Risk factor" is the inert waste WAC divided by the UKDWS. Rank based on calculated risk factor

APPENDIX 9

LandSim Model Parameterisation and Input Parameters

Input Parameters for LandSim Model				
Parameter		**Unit**	**Value**	**Derivation**
Location				
Location (x,y)		m	1000, 1000	Nominal location
Length and width (x,y)		m	700, 375	Length of proposed landfill parallel to groundwater flow direction and width perpendicular to groundwater flow direction
Monitoring Point (x,y)		m	1400, 1000	Nominal 50m down gradient
Source				
Management Control Duration		years	26	No leachate management
Infiltration to waste		mm/year	622.4	MORECS rainfall (Sq. 80)
Infiltration to grassland		mm/year	111.8	MORECS HER (Sq. 80)
End of Filling (from start of waste disposal)		Years	26	Value based on planning permission to 2031 (DCC committee report) Starting in 2005.
Cap Area		Ha	20	Based on landfill design. Assumed slighly larger than the landfill basal area
Basal Area		Ha	19	Based on landfill design
Final Waste Thickness		m	Single(30)	Based on landfill design - 40m in central parts 20m in extension area.
Waste Porosity		Fraction	Uniform(0.001,0.1)	Assumed value
Waste Density		kg/l	Uniform(0.8,1.5)	Assumed value
Waste Field Capacity		Fraction	Uniform(0.01,0.5)	Assumed value
Head of Leachate when Surface Water		m	Single(25)	Based on landfill design
Values of m and c used to calculate the Kappa Value	Arsenic	kg/l	M = 0.0415	LandSim defaults
			C = -0.0862	
	Lead	kg/l	M = 0.0443	
			C = 0.0171	
	Nickel	kg/l	M = 0.0987	
			C = -0.1479	
Half Lives	Arsenic	years	Single(1E+9)	No degradation
	Lead	years	Single(1E+9)	
	Nickel		Single(1E+9)	
Leachate Quality Data	Arsenic	mg/l	Single(0.05)	As per WAC for inert Sites.
	Lead	mg/l	Single(0.05)	
	Nickel	mg/l	Single(0.06)	
Primary Drainage System				
Head on EBS		m	0.1	Nominal leachate head
Engineered Geological Barrier				
Barrier Type		-	Clay	Based on landfill design
Thickness		m	1	Assumed value
Density		kg/l	Single(1.8)	Assumed value
Moisture Content		Fraction	Single(0.15)	Assumed value
Longitudinal Dispersion		m	Single(0.1)	LandSim approach (10% of pathway length)
Hydraulic Conductivity		m/s	Single(0.0000001)	Based on landfill design (geo barrier 1x10-7m/s)
Biodegradation and Retardation Parameters within the Engineered Geological Barrier				
Partition Coefficient	Arsenic	l/kg	Single(25)	Landsim default value (minimum)
	Lead	l/kg	Single(27)	Landsim default value (minimum)
	Nickel	l/kg	Single(20)	Landsim default value (minimum)
Unsaturated Zone				
Thickness		m	Uniform (0, 4)	As per site-specific groundwater elevation results.
Aquifer pathway				
Pathway Length		m	Uniform(55,745)	Landsim
Pathway Width		-	Single(400)	Width of pathway perpendicular to groundwater flow. Groundwater flow direction based on baseline groundwater montioring
Hydraulic Conductivity		m/s	Uniform(9.95x10-8, 9.9x10-7)	Average hydraulic conductivity of Coal Measures strata within the north-east of England as quoted within Minor Aquifer Handbook 2014.
Regional Gradient		-	Single(0.02)	Based on baseline groundwater monitoring (based on new boreholes (2021 - P05 and P06))
Mixing Zone Thickness		m	Single(6.4)	Based on geology and groundwater elevations
Pathway Porosity		Fraction	Single(0.25)	Assumed value
Longitudinal Dispersivity		m	Uniform(5,75)	LandSim approach (10% of pathway length)
Transverse Dispersivity		m	Single(21)	LandSim approach (3% of pathway length)

APPENDIX 10

LandSim Results

Project: Old Quarrington

Project Number: NT14345

Customer: TARMAC LTD

Write Project Notes Here

Phase: Phase 1

Concentration of Arsenic at base of Unsaturated Zone [mg/l]

At 30 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 100 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 300 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 1000 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

Phase: Phase 1

Concentration of Arsenic at base of Unsaturated Zone [mg/l]

At infinity

01% of values less than 0

05% of values less than 0

10% of values less than 0

50% of values less than 0

90% of values less than 0

95% of values less than 0

99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

Phase: Phase 1

Concentration of Lead at base of Unsaturated Zone [mg/l]

At 30 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 100 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 300 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 1000 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

Phase: Phase 1

Concentration of Lead at base of Unsaturated Zone [mg/l]

At infinity

01% of values less than 0

05% of values less than 0

10% of values less than 0

50% of values less than 0

90% of values less than 0

95% of values less than 0

99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

Phase: Phase 1

Concentration of Nickel at base of Unsaturated Zone [mg/l]

At 30 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 100 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 300 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 1000 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

Phase: Phase 1

Concentration of Nickel at base of Unsaturated Zone [mg/l]

At infinity

01% of values less than 0

05% of values less than 0

10% of values less than 0

50% of values less than 0

90% of values less than 0

95% of values less than 0

99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

Phase: Phase 1

Flow to Leachate Treatment Plant [l/day]

At 30 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 100 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 300 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 1000 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

Phase: Phase 1

Flow to Leachate Treatment Plant [l/day]

At infinity

01% of values less than 0

05% of values less than 0

10% of values less than 0

50% of values less than 0

90% of values less than 0

95% of values less than 0

99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

Phase: Phase 1

Head on EBS [m]

At 1000 years

01% of values less than 1.001E-010
05% of values less than 1.001E-010
10% of values less than 1.001E-010
50% of values less than 1.001E-010
90% of values less than 1.001E-010
95% of values less than 1.001E-010
99% of values less than 1.001E-010

Minimum 1.001E-010	Maximum 1.001E-010	
Mean 1.001E-010	Std. Dev. 1.15746E-017	Variance 1.33972E-034

At infinity

01% of values less than 1.001E-010
05% of values less than 1.001E-010
10% of values less than 1.001E-010
50% of values less than 1.001E-010
90% of values less than 1.001E-010
95% of values less than 1.001E-010
99% of values less than 1.001E-010

Minimum 1.001E-010	Maximum 1.001E-010	
Mean 1.001E-010	Std. Dev. 1.15746E-017	Variance 1.33972E-034

Phase: Phase 1

Surface Breakout [l/day]

At 300 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At 1000 years

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

At infinity

01% of values less than 0
05% of values less than 0
10% of values less than 0
50% of values less than 0
90% of values less than 0
95% of values less than 0
99% of values less than 0

Minimum 0	Maximum 0	
Mean 0	Std. Dev. 0	Variance 0

Phase: Phase 1

Leakage through EBS [l/day]

At 100 years

01% of values less than 61218.3
05% of values less than 61218.3
10% of values less than 61218.3
50% of values less than 61218.3
90% of values less than 61218.3
95% of values less than 61218.3
99% of values less than 61218.3

Minimum 61218.3	Maximum 61218.3	
Mean 61218.3	Std. Dev. 0.00494727	Variance 2.44755E-005

At 300 years

01% of values less than 61218.3
05% of values less than 61218.3
10% of values less than 61218.3
50% of values less than 61218.3
90% of values less than 61218.3
95% of values less than 61218.3
99% of values less than 61218.3

Minimum 61218.3	Maximum 61218.3	
Mean 61218.3	Std. Dev. 0.00494727	Variance 2.44755E-005

At 1000 years

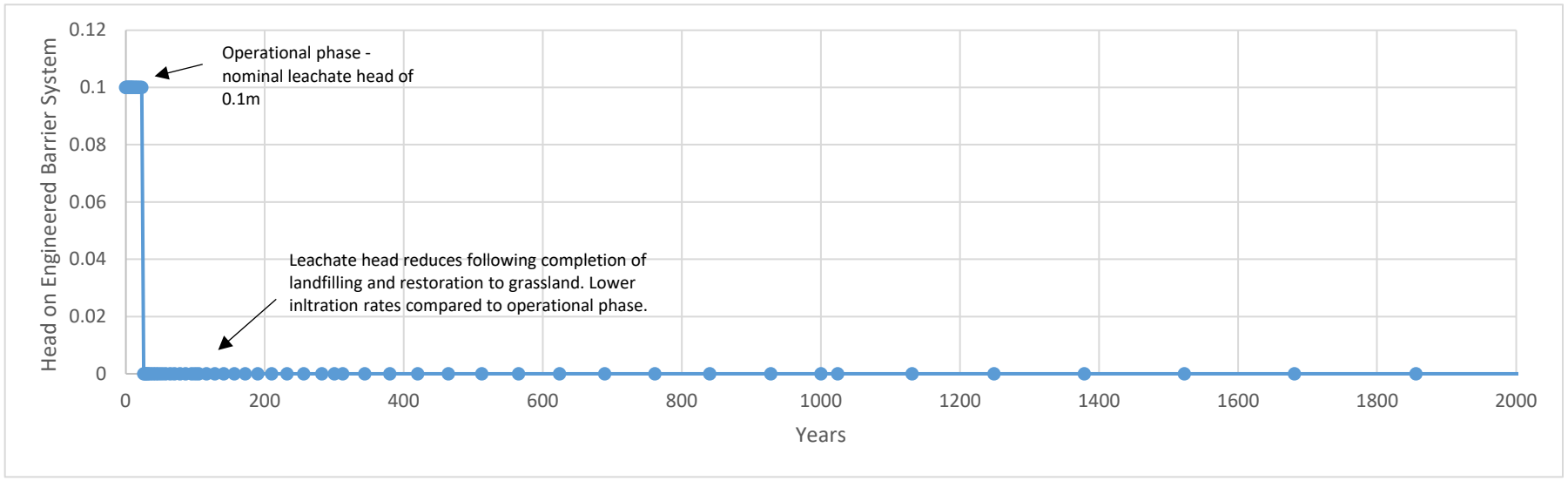
01% of values less than 61218.3
05% of values less than 61218.3
10% of values less than 61218.3
50% of values less than 61218.3
90% of values less than 61218.3
95% of values less than 61218.3
99% of values less than 61218.3

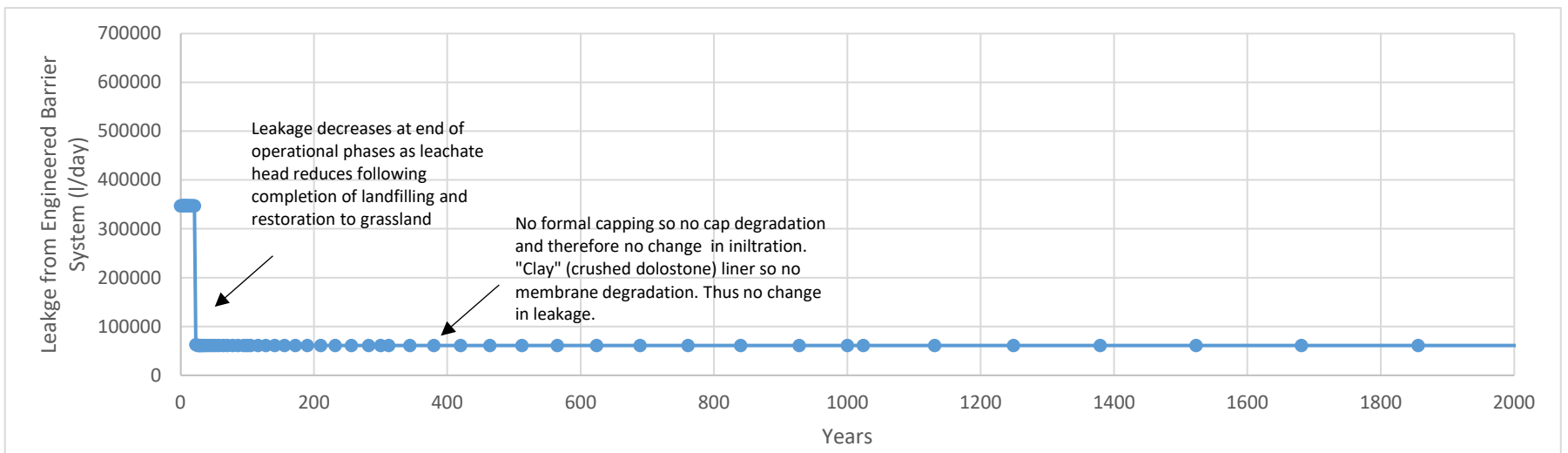
Minimum 61218.3	Maximum 61218.3	
Mean 61218.3	Std. Dev. 0.00494727	Variance 2.44755E-005

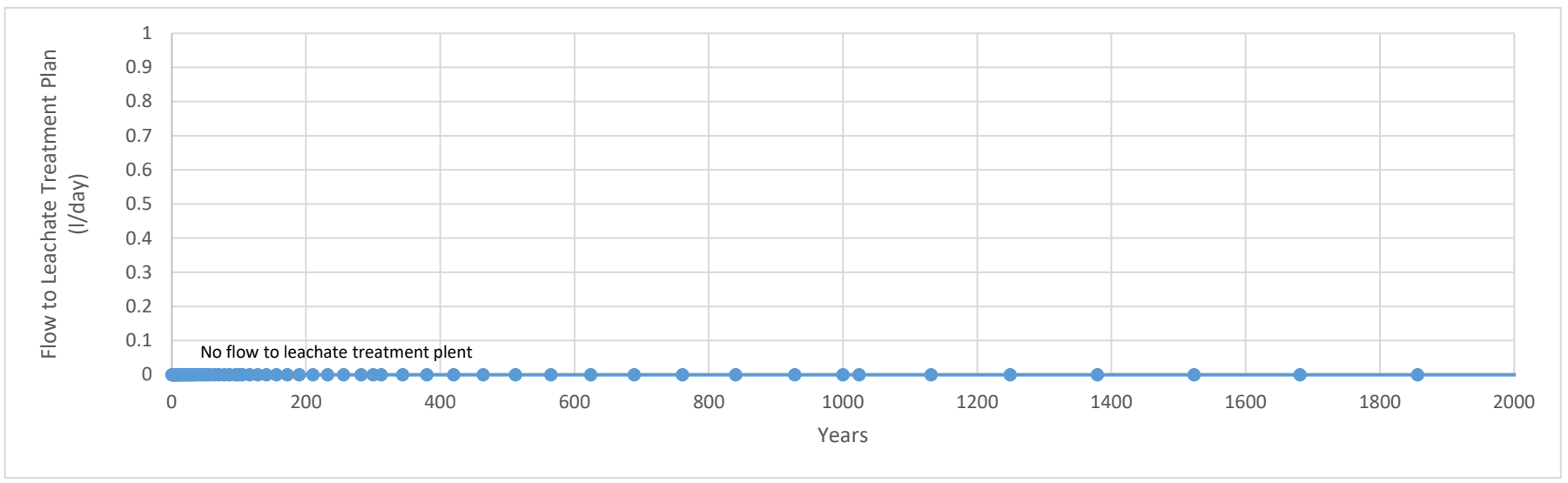
At infinity

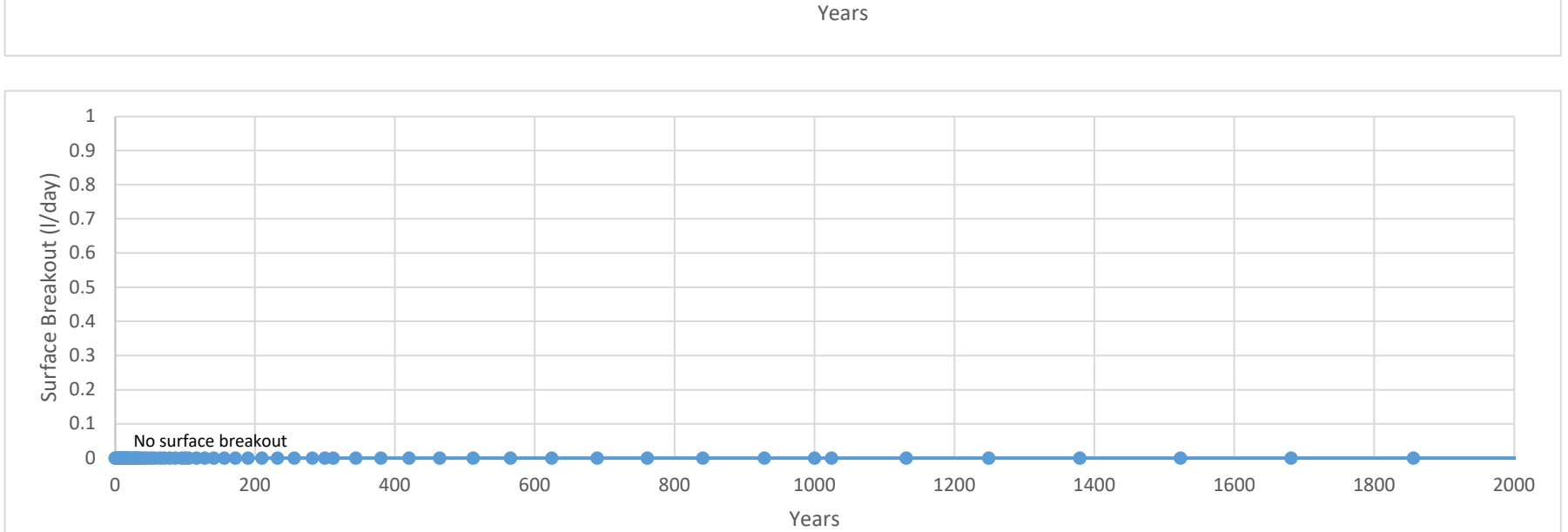
01% of values less than 612183
05% of values less than 612183
10% of values less than 612183
50% of values less than 612183
90% of values less than 612183
95% of values less than 612183
99% of values less than 612183

Minimum 612183	Maximum 612183	
Mean 612183	Std. Dev. 0.111084	Variance 0.0123397









CLIENT	Tarmac Ltd		
PROJECT	Hydrogeological Risk Assessment Review		
FIGURE TITLE	Hydraulic Results		
FIGURE NO.	DRAWN BY	APPROVED BY	DATE
Appendix 10	AS	LB	Sep-21

APPENDIX 11

LandSim Model Files

Project: Old Quarrington

Project Number: NT14345

Customer: TARMAC LTD

Write Project Notes Here

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

No Biodegradation

Unsaturated Pathway:

Unretarded values used for simulation

No Biodegradation

Saturated Vertical Pathway:

No Vertical Pathway

Aquifer Pathway:

Unretarded values used for simulation

No Biodegradation

Timeslices at: 30, 100, 300, 1000

Decline in Contaminant Concentration in Leachate

Arsenic	Non-Volatile
c (kg/l): -0.0862	m (kg/l): 0.0415
Lead	Non-Volatile
c (kg/l): 0.0171	m (kg/l): 0.0443
Nickel	Non-Volatile
c (kg/l): -0.1479	m (kg/l): 0.0987

Project: Old Quarrington

Project Number: NT14345

Customer: TARMAC LTD

Write Project Notes Here

Background Concentrations of Contaminants

Justification for Contaminant Properties

Unjustified value

All units in milligrams per litre

Phase: Phase 1

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(111.8)
Infiltration to waste (mm/year):	SINGLE(633.4)
End of filling (years from start of waste deposit):	26

Justification for Specified Infiltration

Duration of management control (years from the start of waste disposal): 26

Cell dimensions

Cell width (m):	300
Cell length (m):	633.333
Cell top area (ha):	20
Cell base area (ha):	19
Number of cells:	1
Total base area (ha):	19
Total top area (ha):	20
Head of Leachate when surface water breakout occurs (m)	SINGLE(25)
Waste porosity (fraction)	UNIFORM(0.001,0.1)
Final waste thickness (m):	SINGLE(30)
Field capacity (fraction):	UNIFORM(0.01,0.5)
Waste dry density (kg/l)	UNIFORM(0.8,1.5)

Justification for Landfill Geometry

Unjustified value

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Arsenic	SINGLE(0.05)
	Data are spot measurements of Leachate Quality
Lead	SINGLE(0.05)
	Data are spot measurements of Leachate Quality
Nickel	SINGLE(0.04)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate
Unjustified value

Drainage Information

Fixed Head.

Head on EBS is given as (m):	SINGLE(0.1)

Justification for Specified Head
Unjustified value

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
Unjustified value

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	SINGLE(1.8)
Pathway moisture content (fraction):	SINGLE(0.15)

Justification for Clay: Liner Thickness
Unjustified value

Hydraulic conductivity of liner (m/s):	SINGLE(1e-007)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
Unjustified value

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Arsenic	SINGLE(25)
Lead	SINGLE(27)
Nickel	SINGLE(20)

Justification for Liner Kd Values by Species
Unjustified value

Permian LMST and Sands pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(0,4)
Flow Model:	porous medium
Pathway moisture content (fraction):	SINGLE(0)
Pathway Density (kg/l):	UNDEFINED

Justification for Unsat Zone Geometry
Unjustified value

Pathway hydraulic conductivity values (m/s):	SINGLE(1e-008)

Justification for Unsat Zone Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	SINGLE(0.3)

Justification for Unsat Zone Dispersion Properties
Unjustified value

Retardation parameters for Permian LMST and Sands pathway

Modelled as unsaturated pathway
No retardation values used in this simulation.
Check 'Unretarded Contaminant Transport' setting under simulation preferences.

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(50,750)
Pathway width (m):	SINGLE(400)

Coal Measures pathway parameters

No Vertical Pathway

Coal Measures pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	SINGLE(6.4)

Justification for Aquifer Geometry
Unjustified value

Pathway regional gradient (-):	SINGLE(0.02)
Pathway hydraulic conductivity values (m/s):	UNIFORM(9.95e-008,9.95e-007)
Pathway porosity (fraction):	SINGLE(0.25)

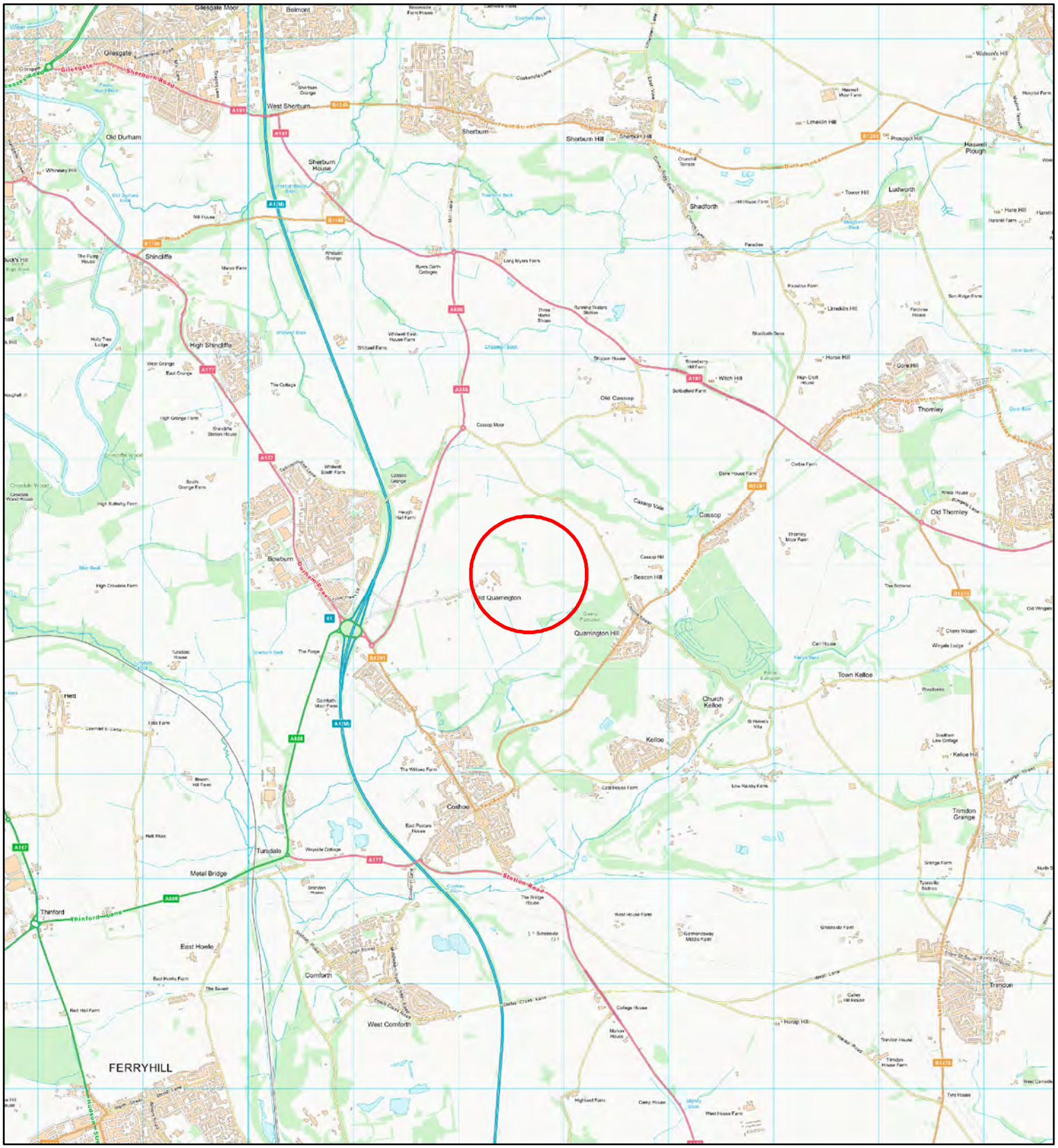
Justification for Aquifer Hydraulics Properties
Unjustified value

Pathway longitudinal dispersivity (m):	UNIFORM(5.5,74.5)
Pathway transverse dispersivity (m):	SINGLE(21)

Justification for Aquifer Dispersion Details
Unjustified value

Retardation parameters for Coal Measures pathway
Modelled as aquifer pathway.
No retardation values used in this simulation.
Check 'Unretarded Contaminant Transport' setting under simulation preferences.

DRAWINGS



wardell armstrong

TARMAC
A CRH COMPANY

Site Name:
Q003 -
Old Quarrington and Cold Knuckle Quarry

Drawing Name:
Scoping Figure 1
Site Location

Drawn By:	***Scale @ A4:***
SW	*1:50,000*
Date:	***Drawing No:***
11/09/2019	*Q003 - 00197 - 1*

N

DO NOT SCALE FROM THIS DRAWING

Legend

- Planning Boundary
- Extant Permit Boundary (EPR/BB3007CA)
- Proposed Permit Extension Area

Bing Satellite Imagery
Boundaries are indicative. Aerial imagery shown for context purposes only.

REVISION	DETAILS	DATE	DR'N	CH'K'D	APP'D

CLIENT

TARMAC LTD.

PROJECT

OLD QUARRINGTON AND COLD KNUCKLE QUARRY

DRAWING TITLE

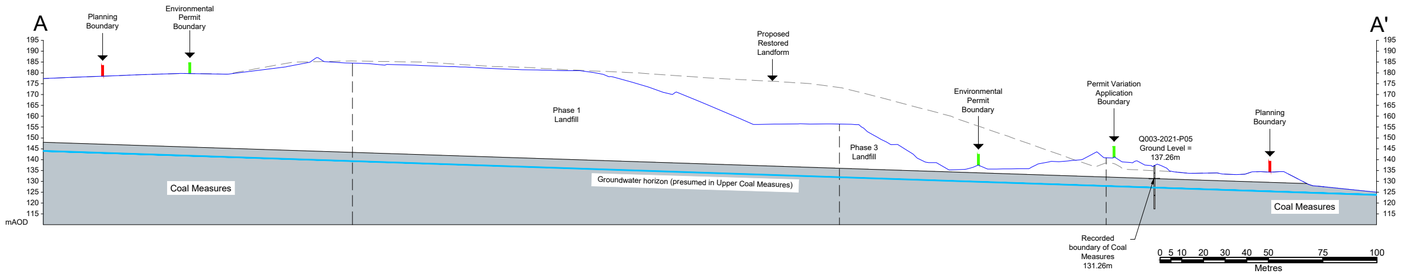
Extant Permit Boundary (EPR/BB3007CA) and Proposed Permit Extension Area

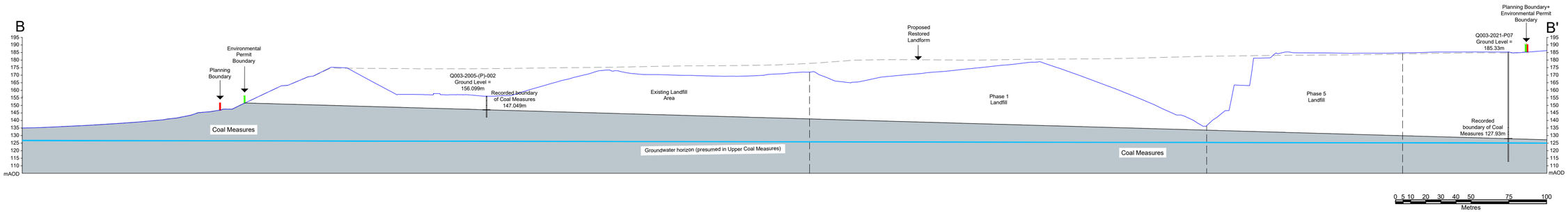
DRG No.		REV
NT14345-012		A
DRG SIZE	SCALE	DATE
A3	1 : 4100	January 2021
DRAWN	CHECKED BY	APPROVED BY
JS	LB	LB

wardell armstrong
TRURO | TEL 0187 256 0738
WWW.WARDELL-ARMSTRONG.COM
STOKE, BIRMINGHAM, BOLTON, CARDIFF, CARLISLE, EDINBURGH, GLASGOW, LEEDS, LONDON, NEWCASTLE, ALMATY, MOSCOW

N:\NT\NT14345 - OLD QUARRINGTON LANDFILL EXTEN\03 - DESIGN\QGIS\HYDRO\HYDRO MASTER.QGS

Cross Sections
Scale @ 1:2000

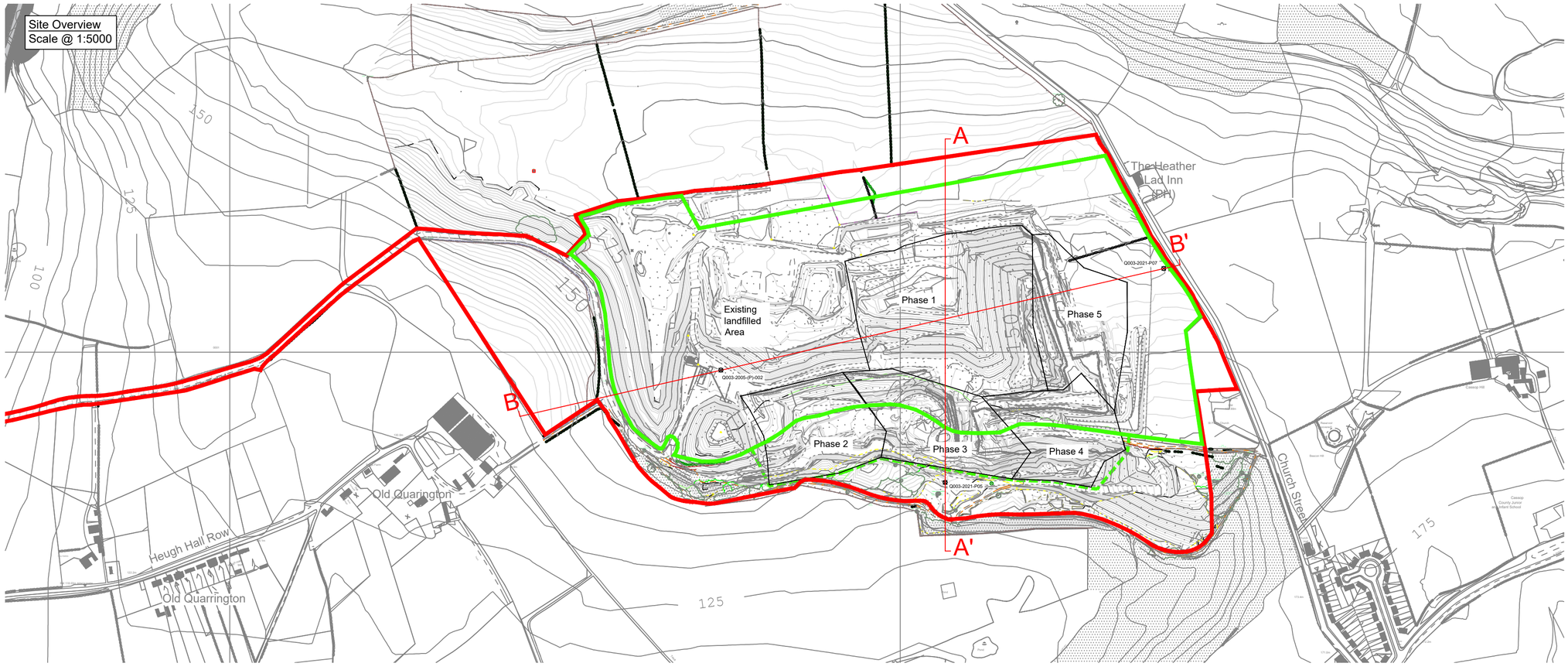




Legend

- Planning Boundary
- Quarry Extraction Boundary
- Environmental Permit Boundary
- Permit Variation Application Boundary
- Phase 1 — Landfill Phasing Boundary
- Groundwater Monitoring Borehole

Site Overview
Scale @ 1:5000



wardell armstrong

TARMAC
A CRH COMPANY

Site Name:
Q003- Old Quarrington Quarry

Drawing Name:
Proposed Permit Extension Area and Cross Section

Drawn By:	***Scale @ A2:***
P Gill	As Shown
Date:	***Drawing Number:***
August 2021	Q003-00197-48

N

DO NOT SCALE FROM THIS DRAWING

Legend

- Planning Boundary
- Extant Permit Boundary (EPR/BB3007CA)
- Proposed Permit Extension Area
- 2021 Borehole Series (Q0003-2021(P))

Bing Satellite Imagery
Boundaries are indicative. Aerial imagery shown for context purposes only.

REVISION	DETAILS	DATE	DR'N	CH'K'D	APP'D

CLIENT

TARMAC LTD.

PROJECT

OLD QUARRINGTON AND COLD KNUCKLE QUARRY

DRAWING TITLE

LOCATION OF 2021 BOREHOLE SERIES

DRG No.		REV
NT14345-015		A
DRG SIZE	SCALE	DATE
A3	1 : 4100	April 2021
DRAWN	CHECKED BY	APPROVED BY
JS	LB	LB

wardell armstrong
TRURO | TEL 0187 256 0738
WWW.WARDELL-ARMSTRONG.COM
STOKE · BIRMINGHAM · BOLTON · CARDIFF · CARLISLE · EDINBURGH · GLASGOW · LEEDS · LONDON · NEWCASTLE · ALMATY · MOSCOW

N:\NT\NT14345 - OLD QUARRINGTON LANDFILL EXTEN\03 - DESIGN\QGIS\HYDRO\HYDRO MASTER.QGS

DO NOT SCALE FROM THIS DRAWING

Legend

- Planning Boundary
- Extant Permit Boundary (EPR/BB3007CA)
- Proposed Permit Extension Area
- 2021 Borehole Series (Q0003-2021(P))
- P-0 Borehole Locations
- Surface Water Monitroing Locations
- Spring Monitoring Locations

Bing Satellite Imagery
Boundaries are indicative. Aerial imagery shown for context purposes only.

REVISION	DETAILS	DATE	DR'N	CH'K'D	APP'D

CLIENT

TARMAC LTD.

PROJECT

OLD QUARRINGTON AND COLD KNUCKLE QUARRY

DRAWING TITLE

REQUISITE SURVEILLANCE MONITORING ARRAY

DRG No.	REV
NT14345-016	A

DRG SIZE	SCALE	DATE
A3	1 : 4100	April 2021

DRAWN	CHECKED BY	APPROVED BY
JS	LB	LB

wardell armstrong
TRURO | TEL 0187 256 0738
WWW.WARDELL-ARMSTRONG.COM
STOKE, BIRMINGHAM, BOLTON, CARDIFF, CARLISLE, EDINBURGH, GLASGOW, LEEDS, LONDON, NEWCASTLE, ALMATY, MOSCOW

N:\NT\NT14345 - OLD QUARRINGTON LANDFILL EXTEN\03 - DESIGN\QGIS\HYDRO\HYDRO MASTER.QGS

wardell-armstrong.com

STOKE-ON-TRENT
Sir Henry Doulton House
Forge Lane
Etruria
Stoke-on-Trent
ST1 5BD
Tel: +44 (0)1782 276 700

BIRMINGHAM
Two Devon Way
Longbridge Technology Park
Longbridge
Birmingham
B31 2TS
Tel: +44 (0)121 580 0909

BOLTON
41-50 Futura Park
Aspinall Way
Middlebrook
Bolton
BL6 6SU
Tel: +44 (0)1204 227 227

BRISTOL
Desklodge
2 Redcliffe Way
Bristol
BS1 6NL

BURY ST EDMUNDS
6 Brunel Business Court
Eastern Way
Bury St Edmunds
Suffolk
IP32 7AJ
Tel: +44 (0)1284 765 210

CARDIFF
Tudor House
16 Cathedral Road
Cardiff
CF11 9LJ
Tel: +44 (0)292 072 9191

CARLISLE
Marconi Road
Burgh Road Industrial
Estate Carlisle
Cumbria
CA2 7NA
Tel: +44 (0)1228 550 575

EDINBURGH
Great Michael House
14 Links Place
Edinburgh
EH6 7EZ
Tel: +44 (0)131 555 3311

GLASGOW
2 West Regent Street
Glasgow
G2 1RW
Tel: +44 (0)141 433 7210

LEEDS
36 Park Row
Leeds
LS1 5JL
Tel: +44 (0)113 831 5533

LONDON
Third Floor
46 Chancery Lane
London
WC2A 1JE
Tel: +44 (0)207 242 3243

NEWCASTLE UPON TYNE
City Quadrant
11 Waterloo Square
Newcastle upon Tyne
NE1 4DP
Tel: +44 (0)191 232 0943

TRURO
Baldhu House
Wheal Jane Earth Science Park
Baldhu
Truro
TR3 6EH
Tel: +44 (0)187 256 0738

International offices:

ALMATY
29/6 Satpaev Avenue
Hyatt Regency Hotel
Office Tower
Almaty
Kazakhstan
050040
Tel: +7(727) 334 1310

MOSCOW
21/5 Kuznetskiy Most St.
Moscow
Russia
Tel: +7(495) 626 07 67

wardell armstrong