Busta Triangle Quarry Restoration

Proposed Restoration by Inert Landfilling

Hydrogeological Risk Assessment (HRA)

784-B068370

Issued to Collard Environmental

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Contents

Tables

Figures

Appendices

1.0 INTRODUCTION

1.1 REPORT CONTEXT

This report has been prepared by Tetra Tech Limited ('Tetra Tech') on behalf of Collard Environmental to support an environmental permit application for Busta Triangle Quarry (the site), A327, Eversley, Hart, Hampshire, RG27 0QB.

A quantitative Hydrogeological Risk Assessment (HRA) with groundwater modelling is required for a permit and planning approval due to the potential impacts of sub-water table working on the surrounding area. The permit is to permit the backfilling of the site with inert fill material to restore the excavated void.

This quantitative HRA has been prepared to evaluate the potential risks of the proposed development on local surface water and groundwater resources, as well as the wider surrounding environment. Through the development of hydrogeological modeling, opportunities for effective mitigation measures can be established and implemented.

Details regarding other aspects of the proposed waste operation are provided in other supporting documents that have been prepared to support the Environmental Permit Application. This includes the Environmental Setting & Site Design (ESSD) report, Operating Techniques and Environmental Risk Assessment (ERA).

This report is subject to the Terms and Conditions presented within Appendix A.

2.0 ENVIRONMENTAL SITE SETTING

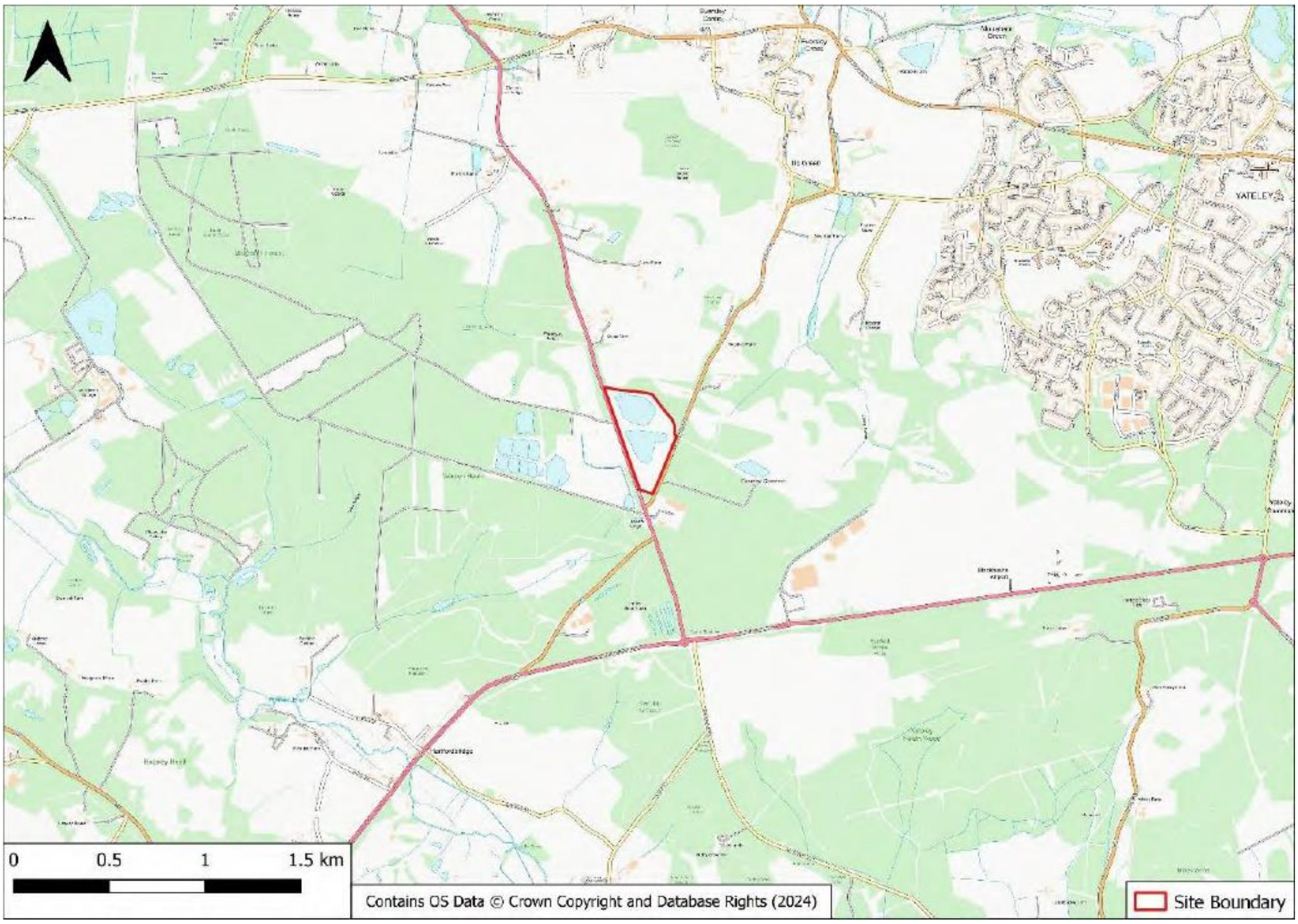
2.1 SITE LOCATION

The site is about 1.5 km west of Yately (NGR: SU 78716 59596/Postcode: RG27 0QB), as shown in Figure 1. It features two ponds, separated by a public bridleway running east-west through the center. The site is bordered by scrub and woodland.

The A327 road lies immediately west, running northwest-southeast, while the B3016 (Cooper's Hill) runs northeast-southwest along the eastern boundary. To the west of the A327 is the Bramshill Concrete Plant and Quarry, and directly south is an office block, both controlled by the applicant. Eversley Quarry is directly east.

The surrounding area includes forest plantations, agricultural land, semi-urban, and industrial uses.

Figure 1: Site Location



2.2 SITE HISTORY

Busta Triangle quarry began operations around 2013, following the Bramshill and Eversley quarries, and continued until about 2017. Initially, the site was covered with forest, bushes, and dwarf shrub/scrub. After the quarrying operations ceased and the site was restored, two ponds formed on the site, separated by a bridleway.

2.3 PROPOSED DEVELOPMENT

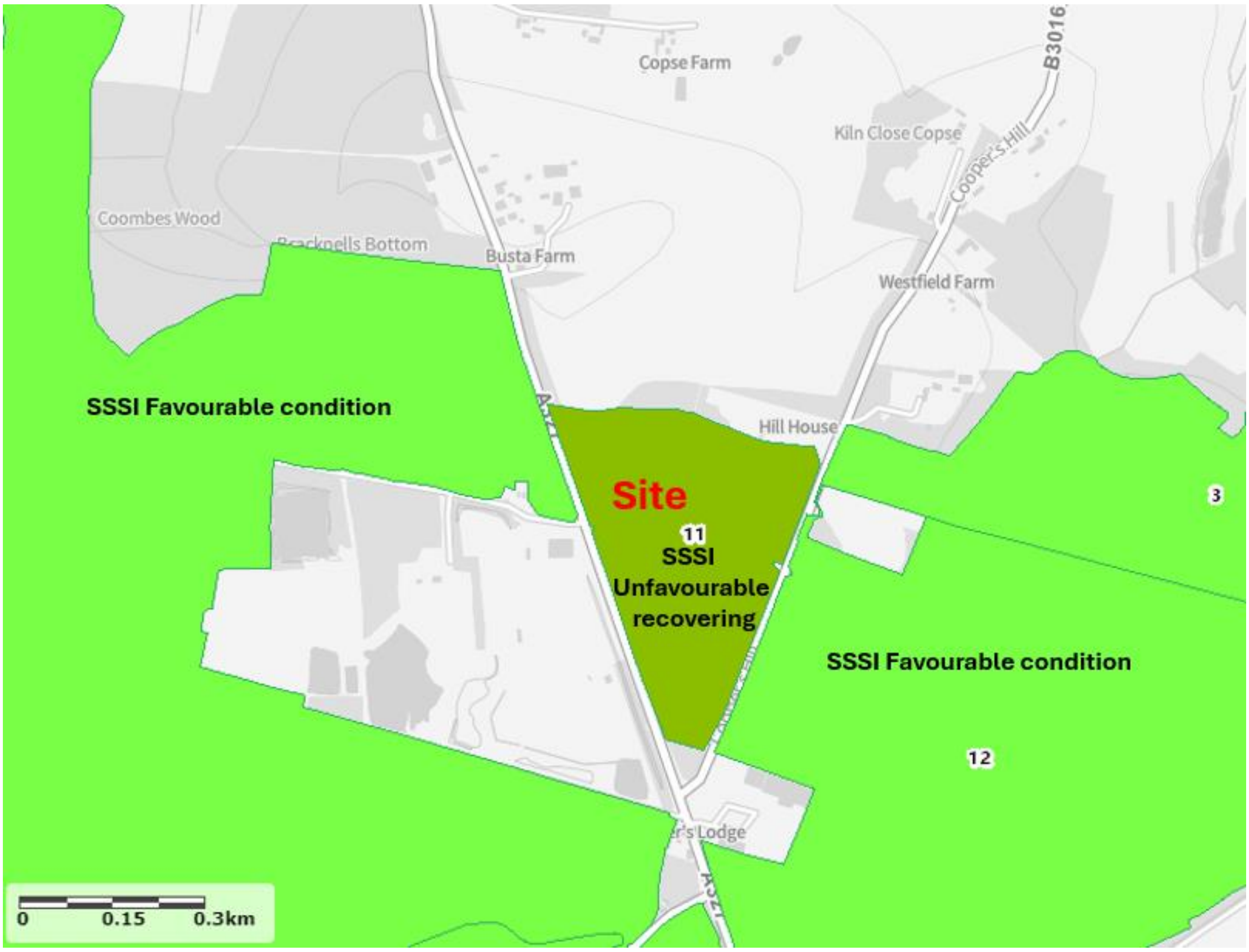
The proposed development involves the importation of inert waste to infill and restore the quarry void that will be created following mineral extraction activities. Works will be completed in accordance with the restoration scheme (Appendix B). It is expected that the site will be completed within three years.

2.4 STATUTORY DESIGNATIONS

There are no scheduled monuments or listed buildings in the immediate vicinity of the site.

The site includes an environmental designation as part of the Castle Bottom to Yateley and Hawley Commons Site of Special Scientific Interest (SSSI) (Figure 2) management Unit 11, which is currently classified as “Unfavourable recovering.” Adjacent areas to the west and east also have SSSI designations but are classified as being in “Favourable condition”.

Figure 2: SSSI Plan



2.5 TOPOGRAPHY

The site slopes northward, with elevations around 95-96m AOD at the southern end and 93m AOD at the northern end, near a local high point. Water levels in the ponds are approximately 92.8m AOD in the southern basin and 93.4m AOD in the northern basin, with basal elevations around 91m AOD.

2.6 PUBLISHED GEOLOGY

2.6.1 Soils

According to the LandIS Soilscapes online viewer (developed by Cranfield University and sponsored by DEFRA), the site is characterized by 'naturally wet, very acid sandy and loamy soils' that drain to shallow groundwater. A 2023 site investigation found that the topsoil and subsoils are less than 0.6m thick (see Table 2-2 in Section 2.2.3.2).

2.6.2 Superficial deposits

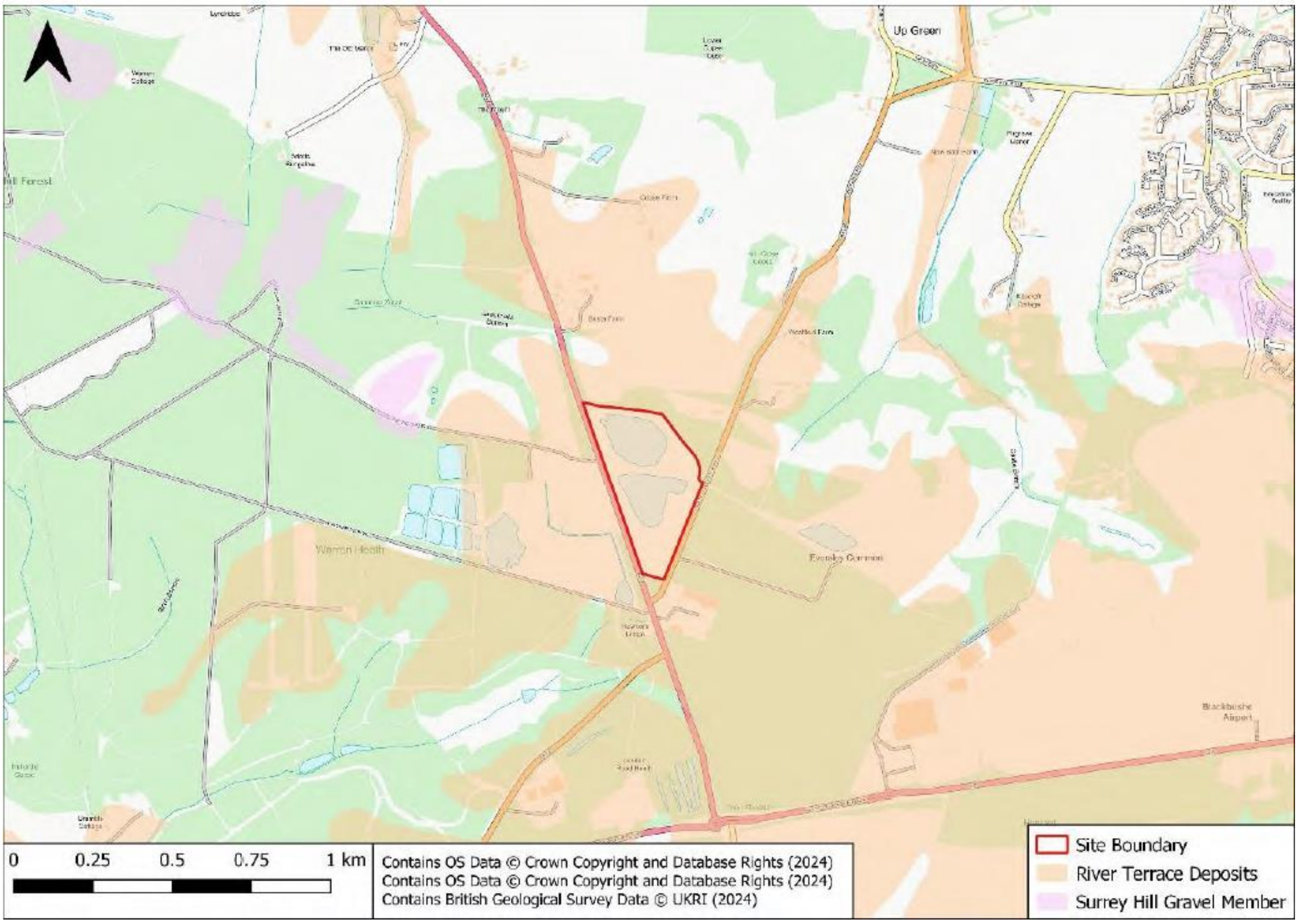
The BGS 1:50k Superficial deposits map indicates that the site is underlain and surrounded by River Terrace deposits, consisting of sand and gravel with localized lenses of silt and clay. It is expected that any superficial deposits within the worked area have been removed, and the void partially backfilled to meet the restoration scheme. The exact materials used for backfilling are unknown but likely include silty or clayey overburden from quarrying, or fines from mineral washing processes.

Remaining in-situ superficial deposits are limited to the site's perimeter, outside the previously worked areas. Site investigations in 2023 show these deposits at depths of 3.4 to 5.5 meters below ground level (mbgl) along the perimeter. LIDAR data and survey elevations suggest basal superficial deposit elevations of 89.6m AOD at the northwestern perimeter, 90.4m AOD at the northeastern section, and 90.3m AOD at the southern perimeter.

A historical plan (Appendix C) indicates the base of mineral deposits (sand and gravel) at approximately 91m AOD in the southern and central parts of the site, and 92m AOD in the northern part. These elevations are similar to the 2023 site investigation depths at the perimeter where deposits remain in-situ.

Figure 3 below shows the regional superficial geology as mapped by the BGS.

Figure 3: Superficial Deposits Map (BGS 1:50k)



2.6.3 Bedrock geology

The bedrock geology, as mapped by the BGS 1:50k and shown in Figure 4 below, indicates that the site is underlain by the Camberley Sand Formation (formerly known as the Barton Beds). This formation overlies the Windlesham Formation, both of which are part of the Bracklesham Group from the Paleogene age. Summary descriptions of the regional bedrock geological units, listed by depth, are provided in Table 1 below.

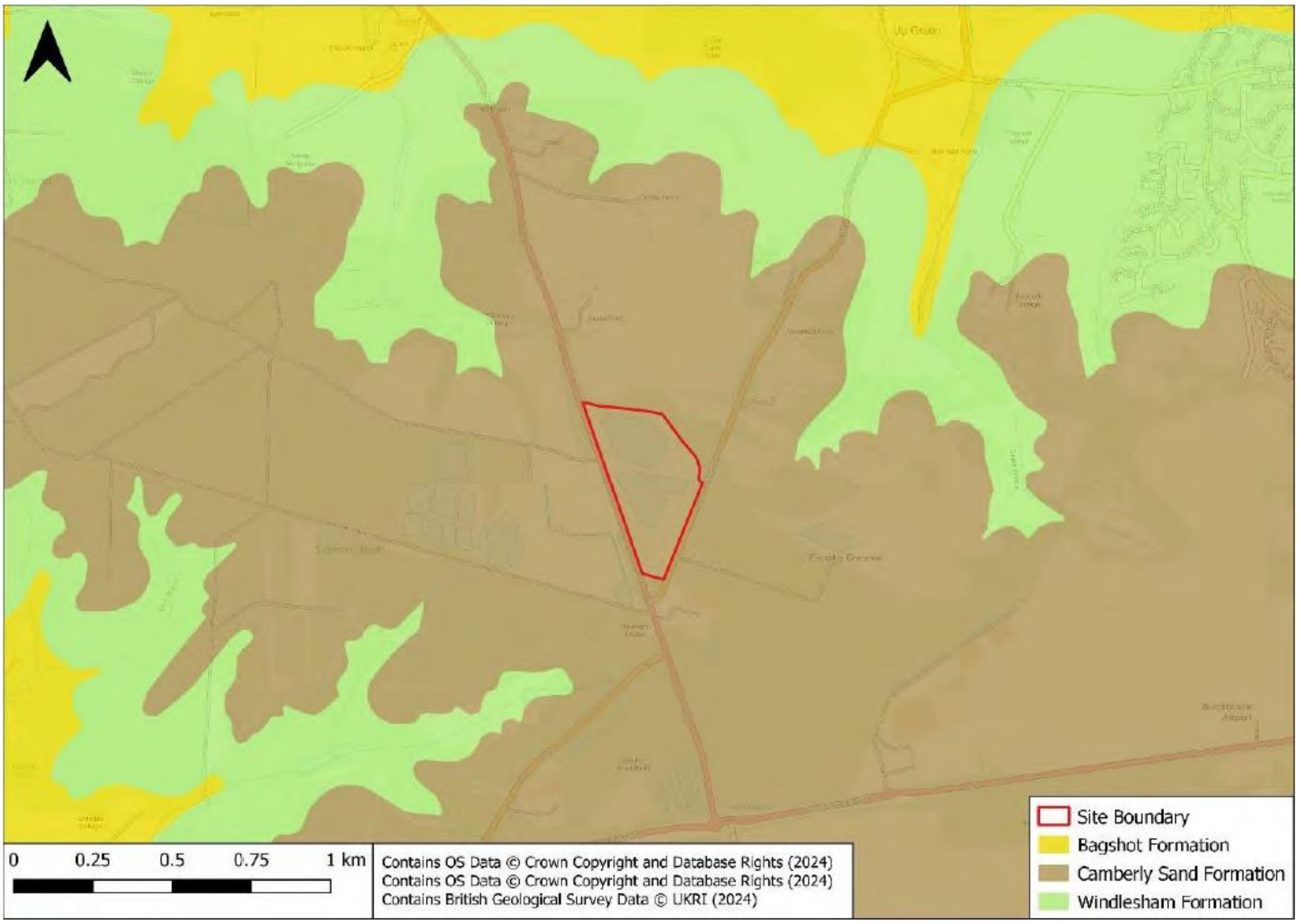
Table 1: Regional Bedrock Geology Summary

Geological Unit	Lithological Description*	Regional Thickness (m)	Upper Boundary	Lower Boundary
Camberly Sand Formation	A fairly uniform sequence of homogeneous, bioturbated, yellow-brown, sparsely to moderately glauconitic silty fine-grained sand or sandy silt, containing some ironstone concretions and masses of white sandstone. Sporadic flint gravel or a gravel bed is present near the base.	Up to 69m**	Youngest bedrock unit, so it is overlain, if at all, only by deposits of Quaternary age.	Windlesham Formation

Windlesham Formation	Bioturbated dark green to brown, fine- to medium-grained sands with sand-sized glauconite grains, silts, and white, yellow, or brown clay. This is overlain by organic dark grey clay with lenticles of fine sand, followed by glauconitic sand and sandy clayey silt. Occasional layers of flint gravel are present, with a prominent gravel bed at the top.	Up to 25m**	Camberly Sand Formation	Swinley Clay Member, or sands of the Bagshot Formation
Bagshot Formation	Most of the Bagshot Formation consists of pale yellow-brown to pale grey or white sand, which can be locally orange or crimson. This sand ranges from fine- to coarse-grained, is frequently micaceous, and can be locally clayey, with sparse glauconite and occasional seams of gravel. The sands are commonly cross-bedded. Thin beds and lenses of laminated pale grey to white sandy or silty clay, also known as 'pipe-clay,' occur sporadically and become thicker towards the top of the formation.	Up to 45m**	Windlesham Formation	Claygate Member (London Clay Formation)

*Summarised description
**From BGS Linked Open Data: https://data.bgs.ac.uk/doc/Lexicon/

Figure 4: Regional Bedrock Geology (BGS 1:50k)



2.6.4 2023 Site Investigations

Borehole logs from the site investigation conducted in 2023, supervised by SLR, are summarized in Table 2-2 below. Draft logs and a plan showing their locations are included in Appendix D. The site and local operations are situated within the parent Bracklesham Group area. Site investigations reveal that the Bracklesham Group extends to depths of at least 12.5 to 15 meters below ground level across the site, overlain by 3.4 to 5.5 meters of sand and gravel superficial deposits. The logged yellowish-brown sands likely represent the Camberley Sands Formation, while the greenish-grey sands likely represent the Windlesham Formation.

Table 2: Summary of On-Site Geology

Geological Unit	Lithological Description	Thickness (m)	Depth (mbgl)
BH01 (drilled to a depth of 12.5m) / E478531 N159781			
Topsoil	Dark brown sandy silty CLAY (with frequent roots up to 0.3mbgl)	0.6	0.0 – 0.6
Superficial	Yellowish brown mottled light grey slightly silty fine to medium SAND	0.65	0.6 – 1.25
	Yellowish brown sandy silty SAND and GRAVEL. (Gravel is chert and sandstone)	2.15	1.25 – 3.4
Bracklesham Group	Yellowish brown (becoming greenish grey from 8mbgl) mottled black slightly clayey / slightly silty fine SAND	9.1	3.4 – 12.5
BH02 (drilled to a depth of 14.5m) / E478780 N159738			
Topsoil / Superficial Deposits	Soft dark brown peaty clayey SILT.	0.35	0.0 – 0.35
Superficial	Yellowish brown mottled light grey slightly gravelly slightly clayey fine to medium SAND	1.35	0.35 – 1.7
	Yellowish brown sandy GRAVEL (Gravel is chert and sandstone)	2.5	1.7 – 4.2
Bracklesham Group	Yellowish brown mottled black very silty fine to medium SAND.	10.3	4.2 – 14.5
BH03 (drilled to a depth of 15m) / E478712 N159280			
Topsoil	Soft organic / peaty black sandy SILT.	0.2	0.0 – 0.2
Superficial	Yellowish brown mottled light grey slightly gravelly silty fine to medium SAND (Gravel is chert and sandstone)	0.5	0.2 – 0.7
	Yellowish brown sandy GRAVEL (Gravel is chert, sandstone and occasional chalk)	4.8	0.7 – 5.5
Bracklesham Group	Yellowish brown mottled black silty fine to medium SAND.	3.0	5.5 – 8.5
	Greenish grey clayey silty fine to medium SAND.	6.5	8.5 – 15.0

It is further noted in the BGS record SU75NE198 that stiff grey clay was present from c.23mbgl, likely representative of the underlying London Clay.

2.6.5 Permitted Waste Sites and Historic Landfill Sites

With reference to the EA dataset on authorized landfill site boundaries, there are no permitted waste sites within a 2 km radius of the site.

With reference to the EA dataset on historic landfill sites, the following sites have been identified within 2km of the site:

Table 3 - Historic landfill sites within 2km

Site Reference	Distance and Direction	Name	License Issue	License Surrender	Waste Types
EAHLD12713	650m east	Warren Heath	14/11/1991	-	Not given
EAHLD12702	1060m north	Copse Farm	12/08/1977	-	Inert, industrial, commercial, household
EAHLD12708	1300m east	Blackbushe Airport	28/09/1983	-	Inert, commercial, household, special, liquid/sludge

2.7 HYDROGEOLOGY

2.7.1 Rainfall and Evapotranspiration

The Met Office climate summary (1991 – 2020) for Odiham[1], situated approximately 11 km southwest of the site, indicates that the average annual rainfall for the area is around 780 mm. A summary of the rainfall data from this monitoring station is provided in 4 below.

Table 4: Average Monthly and Annual Rainfall (mm) at Odiham Climate Station (April 1991 – October 2020)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
83.7	61.1	50.75	54.51	48.94	53.26	50.82	58.44	61.03	87.51	90.82	82.39	783.27

[1] MetOffice Website *https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climateaverages/gcp76x8dg* (Accessed 30th January 2024)

Met office MORECS data for the period 1960 to 2015 indicates that average annual evapotranspiration of the site is around 420mm per year, leading to around an annual average recharge of approximately 360mm.

Due to the previous excavation and subsequent replacement of sands and gravels with low permeability overburden, topped with a thin soil layer, direct recharge from the site is minimal. This is evidenced by the presence of on-site ponds, which are likely caused by surface flooding rather than groundwater inflows (as further discussed in Section 2.7.3 below).

2.7.2 Aquifer Characteristics and Groundwater Vulnerability

The Environment Agency (EA) classifies the underlying bedrock aquifer unit as Secondary A, described as:

"permeable strata 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, lakes or wetlands."

The superficial deposits mapped at and near the site also have a Secondary A aquifer designation.

The superficial deposits and strata of the Bracklesham group are considered to form a series of semi-discrete minor aquifers, aquitards, and aquicludes. The sandy/gravel-rich, more permeable strata form minor aquifers, while the clay-dominated, likely discontinuous strata act as aquitards and aquicludes. Due to the variable geology observed, the in-situ aquifer units are expected to exhibit highly variable hydrogeological properties, with hydraulic conductivity ranging from $2x10^{-7}$ m/s to $3x10^{-4}$ m/s.

This aligns with the 2005 Hydrological and Hydrogeological assessment for the quarry extension, which states:

'Hydraulic conductivity field tests undertaken for Eversley Quarry, combined with Hazen analysis of Particle Size Distribution tests, suggest that aquifer permeability in the Barton Sands may be approximately 10^{-5} m/s (0.86m/day). Hazen Analysis of Particle Size Distribution data from samples taken from the River Terrace Deposits of the Busta Triangle Extension area showed a permeability range of 0.23m/day to 1.8m/day, with an average of 0.63m/day'.

2.7.3 Groundwater Levels and Flows

Groundwater level monitoring data is available for the three boreholes (BH01, BH02, and BH03) installed at the application site in October-November 2023. Water strike and level data were recorded during these site investigations and are summarized in Table 5 below.

Table 5: Summary of Water Strike and Level Data During 2023 Site Investigations

Borehole ID	Water Strike / Level Info.	Relevant Geological Unit
BH01	5.3 mbgl	Bracklesham Group
	6.5 rising to 6.3 mbgl	
	8.0 rising to 7.5 mbgl	
	Standing water level of 5.3 mbgl the day after drilling completion (01/11/2023)	
BH02	7.2 mbgl	
	10.3 rising to 9 mbgl	
	Standing water level of 7.2 mbgl the day after drilling completion (02/11/2023)	
BH03	6.5 mbgl	
	9.8 rising to 8.5 mbgl	
	10.5 mbgl	
	Standing water level of 6.55 mbgl the day after drilling completion (31/10/2023)	

The water strike data indicates that the shallowest groundwater encounter is over 5 meters below ground level. Updated assessments of borehole elevations show groundwater levels of approximately 87.5-88 meters Above Ordnance Datum (mAOD) in the north of the site and 89.3 mAOD in the south.

Groundwater levels within the three monitoring boreholes have been dipped on a monthly basis, with level measurements available for ten rounds from January 2024 to October 2024.

Groundwater level measurements in metres below ground level (mbgl) and metres above ordnance datum (mAOD) are summarised in Table 6andTable 7. A groundwater hydrograph of measurements to date is presented in

Insert 1.

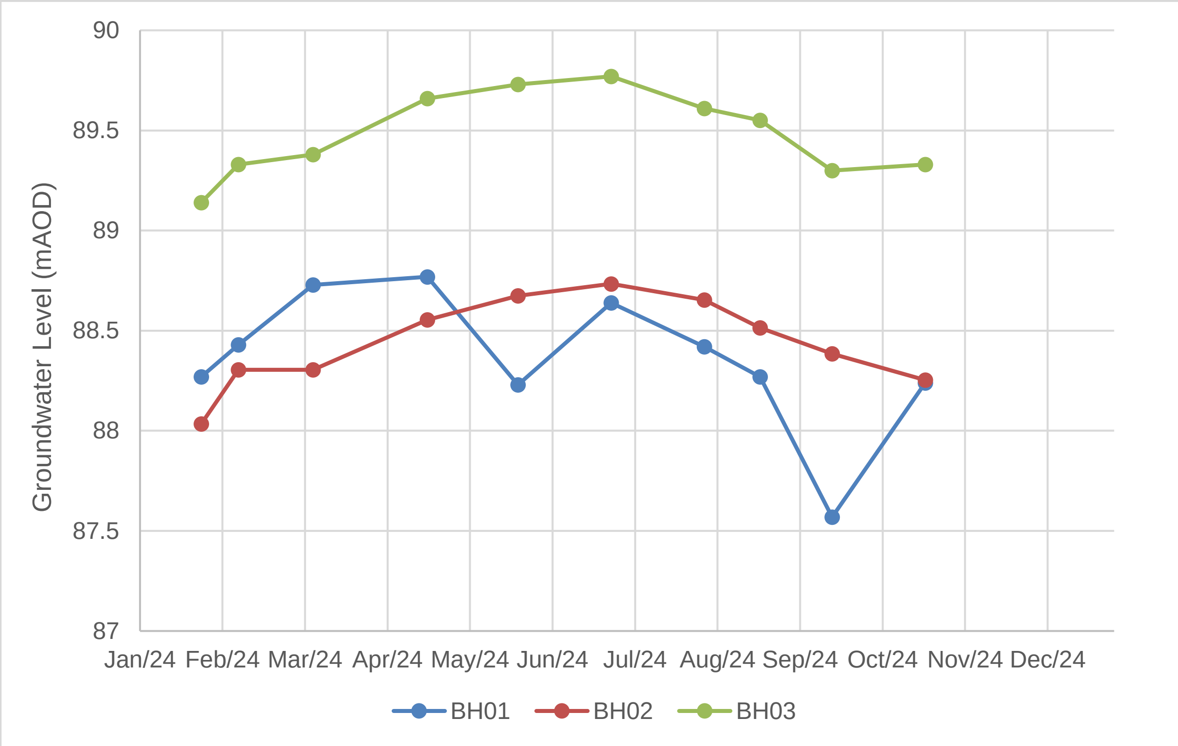
Table 6 - Groundwater levels in mbgl, Jan to Oct 2024

Date	BH01, DTW (mbgl)	BH02, DTW (mbgl)	BH03, DTW (mbgl)
24/01/2024	5.22	6.71	6.68
07/02/2024	5.00	6.44	6.49
06/03/2024	4.76	6.42	6.44
18/04/2024	4.71	6.17	6.16
22/05/2024	5.26	6.06	6.10
26/06/2024	4.85	6.00	6.05
31/07/2024	5.06	6.08	6.21
21/08/2024	5.22	6.22	6.27

Table 7 - Groundwater levels in mAOD, Jan to Oct 2024

Date	BH01, GWL (mAOD)	BH02, GWL (mAOD)	BH03, GWL (mAOD)
24/01/2024	88.269	88.034	89.14
07/02/2024	88.429	88.304	89.33
06/03/2024	88.729	88.304	89.38
18/04/2024	88.769	88.554	89.66
22/05/2024	88.229	88.674	89.73
26/06/2024	88.639	88.734	89.77
31/07/2024	88.419	88.654	89.61
21/08/2024	88.269	88.514	89.55

Insert 1 - Groundwater Hydrograph, Jan to Oct 2024



Groundwater levels display seasonal variation during the monitoring period. Water levels in the boreholes increased by approximately 0.5 metres from the beginning of the year, peaking in the early summer months in June. Following this peak, by October water levels gradually declined to similar levels to those recorded in February.

Up until April, groundwater levels in BH01 are higher than those recorded in BH02. However, after April, groundwater levels in BH02 are higher.

Error! Reference source not found. and **Error! Reference source not found.** display the groundwater contours for March 2024 and September 2024, respectively. Groundwater levels are shown to flow towards the northeast in March, and towards the northwest in September. The reason for the change in flow direction is due to the variability in which of BH01 or BH02 demonstrates higher groundwater levels, noted above. However, generally a northwards regional flow direction is assumed, based upon the local topography, and the presence of the River Blackwater 2.7km to the north.

Based on the groundwater levels discussed above, the ponds on the site are not in hydraulic connectivity with the regional groundwater table. Water within the on-site ponds results from direct rainfall and surface water runoff entering the depressions left by former quarry workings. The base of the excavations comprises finer grained material than the extracted River Terrace Deposits, leading to ponding of water.

Figure 5: Groundwater contours for March 2024

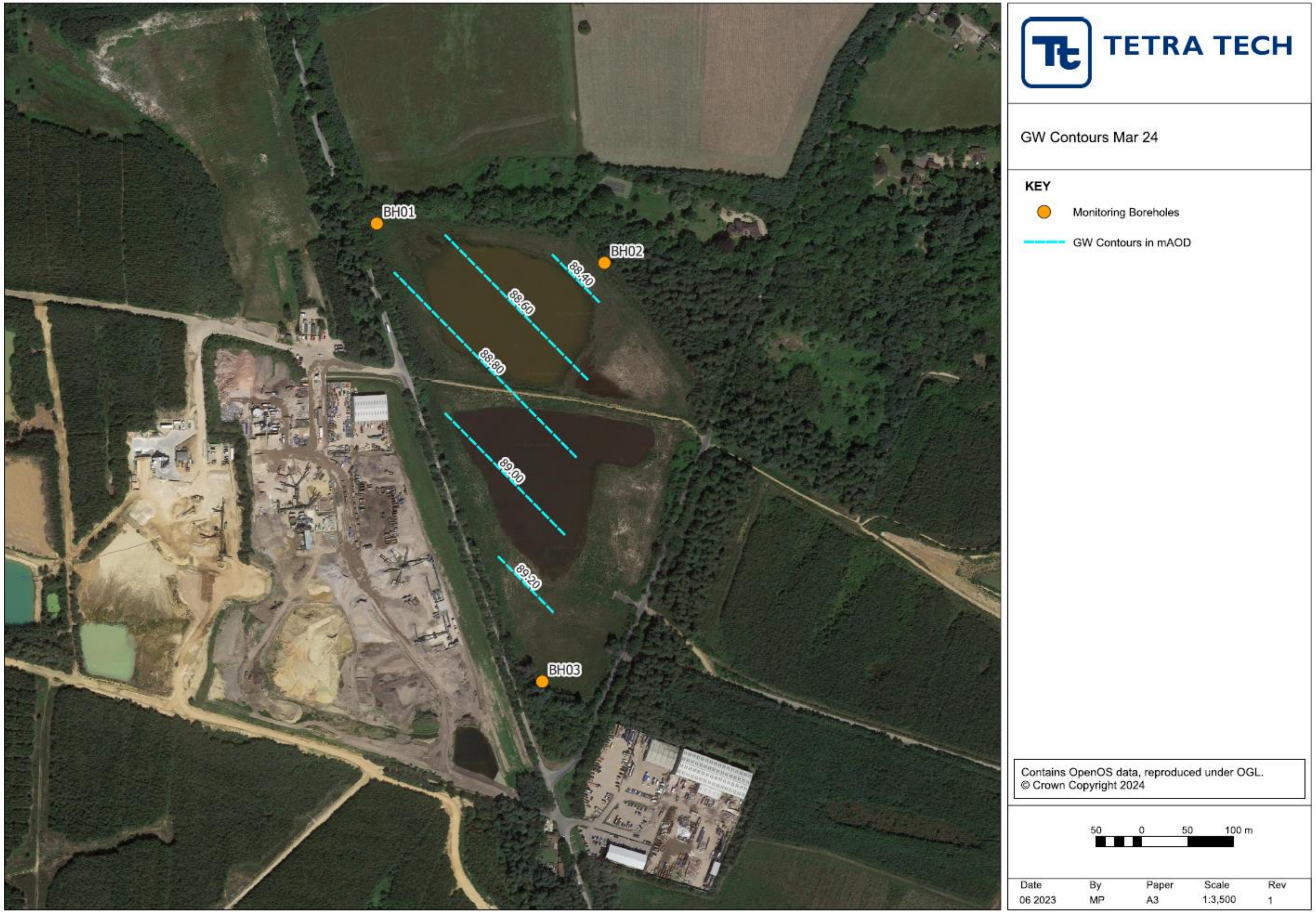
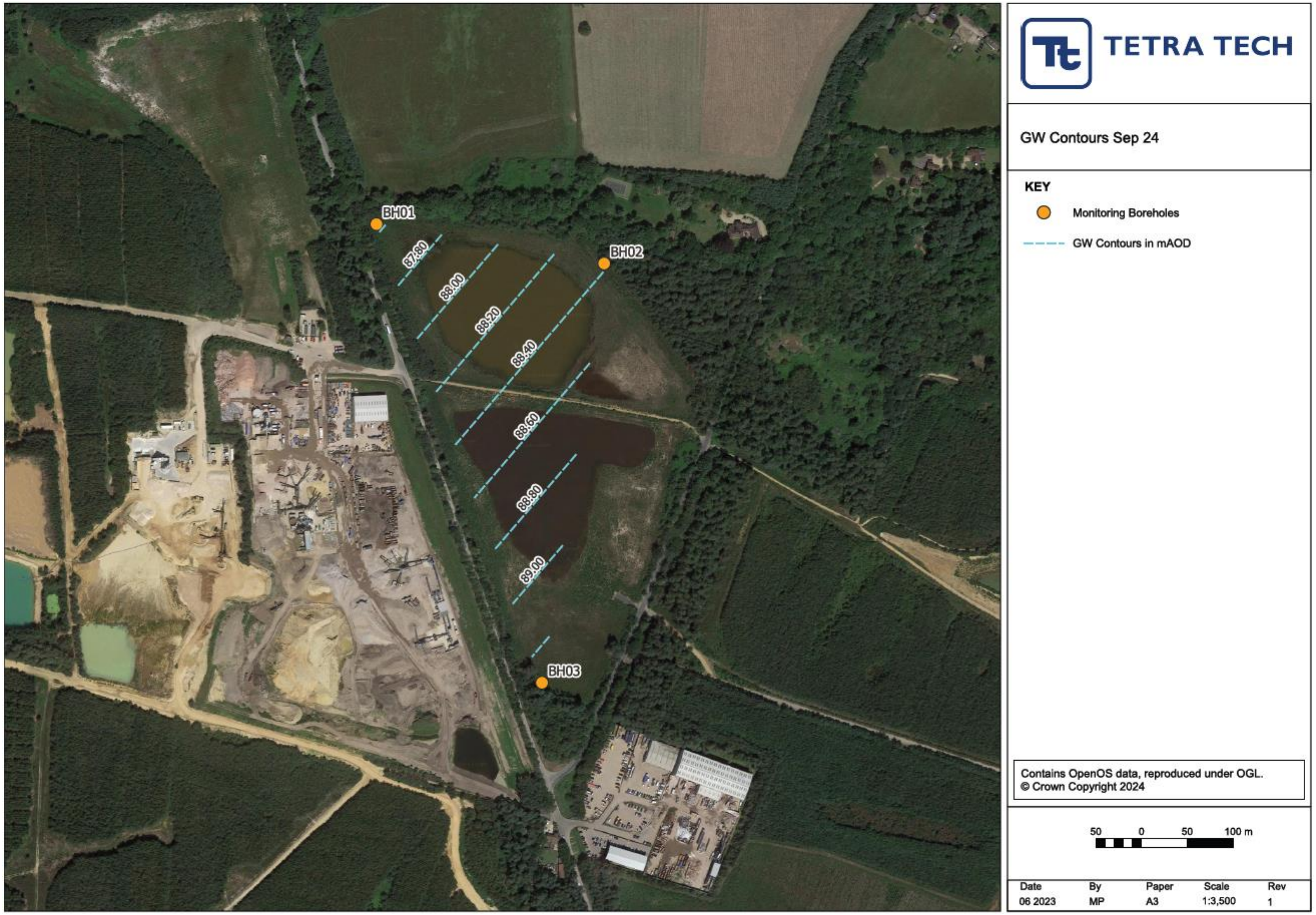


Figure 6: Groundwater contours for September 2024



2.7.4 Abstractions and Source Protection Zones

A review of the Defra Magic Map website indicates that the proposed development is not located within a groundwater Source Protection Zone (SPZ). The nearest SPZ, an Outer Protection Zone II, is approximately 8 km southwest of the site.

The Environment Agency were contacted on 05/11/2024 and asked for details of groundwater and surface water abstractions local to the site; no additional abstractions within 2km of the site were noted.

The closest abstraction to the site is a multipoint groundwater abstraction of five boreholes, located 2.2km north-west of the site. The license is held by *EU Plant's Ltd* to abstract up to 957m^3/day for trickle irrigation from the Bagshot Beds (i.e. the Bracklesham Group)

2.7.5 Private Water Supplies

Hart District Council were contacted on 05/11/2024 and asked for details of any Private Water Supplies within a 10km radius of the site.

There are no registered Private Water Supplies within 2km of the site. The closest private water supply is located 4.8km west of the site, towards Heckfield.

2.7.6 Groundwater Vulnerability and Water Body Quality Rating

The units underlying the site are classified as having medium groundwater vulnerability. The area directly east of the site is classified as having medium to high groundwater vulnerability.
The WFD rating[3] for the on-site groundwater body (Farnborough Bagshot Beds) is as follows:

- Overall rating: Good
- Chemical Rating: Good
- Quantitative Rating: Good

2.7.7 Groundwater Quality

Between January 2024 and October 2024, ten monthly groundwater sampling rounds have been conducted to provide a baseline dataset of groundwater quality data for the site.

Resultant samples have been screened against Threshold Screening Values (TSV), which comprise the minimum of the UK Drinking Water Standard (DWS) or Environmental Quality Standard (EQS) for the substance. For the substances cadmium, lead and mercury, the Minimum Reporting Value (MRV) as defined by the Environment Agency has been set as the TSV.

Potential outliers within the dataset have been noted:

- Average electrical conductivity values across all groundwater samples was 546 us/cm, excluding a reading of 6100 us/cm in BH01 during the April round which is assumed to be an outlier.
- High concentrations were noted for calcium (713.2 mg/l), Potassium (90.3mg/l) and Magnesium (74mg/l) for June at BH03. These concentrations are much higher than in previous rounds with BH03 (and BH01 and BH02), and are therefore considered to be outliers.

The following exceedances of the TSVs were noted:

- All samples (21 no.) exceeded the TSV for nickel, which is based upon the DWS of 0.02 mg/l. The average recorded concentration was 0.0087mg/l, and the maximum was 0.013mg/L. Note that the freshwater annual average EQS for Nickel is 0.02mg/l, meaning that none of the samples exceeded the EQS.
- Fifteen of 21 samples exceeded the 0.0129 mg/l TSV for Zinc, which is based upon the freshwater EQS1. The average recorded concentration was 0.0239 mg/l, and the maximum was 0.0570mg/l.

Elevated naturally occurring nickel is known to occur within some groundwater of the Bracklesham Group within the Thames Basin, due to oxidation of pyrite within the sands of the aquifer; concentrations can occur with a 5th to 95th percentile range of a 0.007 to 0.0374 mg/l[2]

With the exception of the exceedances for nickel and zinc noted above, groundwater within the Bracklesham Group at the site is of fairly good quality:

- Cadmium, mercury and lead were below the limit of detection in all boreholes in all rounds. However, it should be noted that the LOD for the testing carried out to date is above the Minimum Reporting Values presented by UKTAG (see also section 6.1.3. for recommendations on future monitoring).
- Arsenic was detected just above the limit of detection (0.0025 mg/l) on two occasions. During the June round 0.0026 mg/l was recorded in BH01, and during the October round 0.0028 mg/l was recorded in BH03. Both of these detections were below the TSV of 0.01mg/l, which is based on the DWS.
- Chloride and Sulphate levels were generally low, respectively averaging 20.5 mg/l and 61.8mg/l across all samples.
- Concentrations of Ammoniacal Nitrogen were also generally low, with four samples below the LOD, and the remaining samples averaging 0.065 mg/l, well below the TSV of 0.30mg/l.
- Analysis for an extended suite including PCBs, Speciated PAHS, Phenol and Mineral Oils and BTEX was scheduled during the June monitoring round. All of these substances were below their respective limits of detection.

A summary table of the groundwater analysis conducted to date is presented in Table 8.

[1] Set at 10.9ug/L plus the Thames catchment background, which is 2ug/L.
[2] Baseline groundwater chemistry : the Palaeogene of the Thames Basin, BGS, 2010.

Table 8 - Summary of Groundwater Quality Data, BH01, BH02 and BH03, Jan to Oct '24

Substance	Units	LoD	Sample Count	No. Above LoD?	Min	Average	Max	TSV	TSV Source	Exceedances?
Dissolved Antimony	mg/l	<0.002	21	0	-	-	-	0.005	DWS	0
Dissolved Arsenic	mg/l	<0.0025	21	2	0.0026	0.0027	0.0028	0.01	DWS	0
Dissolved Barium	mg/l	<0.003	21	21	0.014	0.025	0.035	1.3	DWS	0
Dissolved Cadmium	mg/l	<0.0005	21	0	-	-	-	0.0001	MRV	0
Dissolved Calcium	mg/l	<0.2	30	27	3.8	43.8	713.2			
Dissolved Chromium (Total)	mg/l	<0.0015	21	0	-	-	-	0.0047	EQS	0
Dissolved Copper	mg/l	<0.007	21	0	-	-	-	0.001	EQS	0
Dissolved Iron (Total)	mg/l	<0.02	21	3	0.02	0.067	0.15	0.2	DWS	0
Dissolved Lead	mg/l	<0.005	21	0	-	-	-	0.0002	MRV	0
Dissolved Magnesium	mg/l	<0.1	30	27	1.1	5.887	74			
Dissolved Mercury	mg/l	<0.001	21	0	-	-	-	0.00001	MRV	0
Dissolved Molybdenum	mg/l	<0.002	21	0	-	-	-	0.07	DWS	0
Dissolved Nickel	mg/l	<0.002	21	21	0.005	0.0087	0.013	0.004	DWS	21
Dissolved Potassium	mg/l	<0.1	30	27	2	6.16	90.3			
Dissolved Selenium	mg/l	<0.003	21	0	-	-	-	0.01	DWS	0
Dissolved Vanadium	mg/l	<0.0015	21	1	0.0018	0.0018	0.0018	0.02	EQS	0
Dissolved Zinc	mg/l	<0.003	21	21	0.007	0.0239	0.057	0.0129	EQS	15
pH	pH units	<0.01	30	27	3.8	6.32	7.4			
Total Alkalinity as CaCO3	mg/l	<1	30	26	18	93.6	390			
Electrical Conductivity @25C	uS/cm	<2	30	27	165	546.4	6100			
Chloride	mg/l	<0.3	30	27	9.9	20.5	35	250	DWS	0
Sulphate as SO4	mg/l	<0.5	30	26	7.5	61.8	160	250	DWS	0
Ammoniacal Nitrogen as N	mg/l	<0.03	30	23	0.03	0.065	0.16	0.3	EQS	0

2.8 HYDROLOGY

The site is located within the catchment of the River Blackwater (Hawley to Whitewater confluence at Bramshill sub catchment). The River Blackwater is a tributary of the Loddon and sub-tributary of the Thames. It rises at two springs in Rowhill Nature Reserve between Aldershot, Hampshire and Farnham, Surrey. It curves a course north then west to join the Loddon in Swallowfield civil parish. The Blackwater is located 2.7km north of the site.

In the most recent WFD cycle, the Blackwater was assessed as having generally Good to High physico-chemical quality elements, but only mostly Moderate Biological quality elements. The overall classification for the water body was Moderate.

There are several small watercourses locally that either flow north/northeast towards the River Blackwater or southwest towards the River Hart. Observations from a site walkover noted in the Hydrological and Hydrogeological Assessment[3] undertaken as part of the original quarry extension identify a small channel adjacent to the northern site boundary, which conveys flow east towards a tributary of the River Blackwater. This channel was largely dry, suggesting it is not in continuity with groundwater and would only receive runoff during storm events.

A tributary of the River Blackwater, sourced from Camberly Kart Club, is located approximately 850 m east of the site and is designated by the Environment Agency as a Main River. The watercourse flows north past the site, draining an upstream catchment area of approximately 2.1 km².

There are no further Main Rivers within 1km of the site.

Based on the hydrogeological context discussed in the above reporting the ponds on the site are not in hydraulic connectivity with the regional groundwater table. Water within the on-site ponds is the result of direct rainfall and surface water flows from the site. Ponded water will then evaporate over time. Overland flows which do not drain to the ponds would predominately be to the north and northwest, where it would be captured by drainage channels and / or provide local groundwater recharge.

2.8.1 Surface Water Quality

Surface water quality sampling has been undertaken on the northern pond on a monthly basis for a range of parameters. The sample location (Grid reference: SU 78728 59603) for surface water sampling is along the southern bank of the northern of the two on-site ponds.

The surface water samples have been screened against Threshold Screening Values (TSV), based upon the lowest of DWS, EQS or MRV (see Section 2.7.7). The following exceedances were noted:

- Eight exceedances from ten samples against the TSV for iron of 0.2mg/l, which is based upon the DWS. The average recorded concentration was 0.455mg/l, and the maximum 0.89mg/L. All samples were below the EQS for iron, at 2 mg/l.
- One exceedance against the TSV for zinc, with a maximum of 0.017 mg/l recorded against a TSV of 0.0129 mg/l.

With the exception of these exceedances, surface water within the ponds is generally of good quality:

- The average electrical conductivity value across all samples was 123 us/cm, lower than the values measured within the monitoring boreholes.

[3] Capita Symonds, Eversley Quarry, Busta Triangle Extension, Hydrological and Hydrogeological Assessment, August 2005

- No detections above the LOD were noted for cadmium, arsenic or lead.
- Analysis for an extended suite including PCBs, Speciated PAHS, Phenol and Mineral Oils and BTEX was scheduled during the June monitoring round. Several PAH's were detected above the limit of detection, but below their respective TSVs, where available. No PCBs, mineral oils or BTEX were detected.

Table 9 - Summary of Surface Water Quality Data, SW01 (Northern Pond), Jan to Oct '24

Substance	Units	LoD	Sample Count	No. Above LoD?	Min	Average	Max	TSV	TSV Source	Exceedances?
Dissolved Antimony	mg/l	<0.002	10	1	0.003	-	-	0.005	DWS	0
Dissolved Arsenic	mg/l	<0.0025	10	0	-	-	-	0.01	DWS	0
Dissolved Barium	mg/l	<0.003	10	7	0.004	0.006	0.013	1.3	DWS	0
Dissolved Cadmium	mg/l	<0.0005	10	0	-	-	-	0.0001	MRV	0
Dissolved Calcium	mg/l	<0.2	7	7	3.1	4.09	5.7			
Dissolved Chromium (Total)	mg/l	<0.0015	10	0	-	-	-	0.0047	EQS	0
Dissolved Copper	mg/l	<0.007	10	0	-	-	-	0.001	EQS	0
Dissolved Iron (Total)	mg/l	<0.02	10	10	0.08	0.455	0.89	0.2	DWS	8
Dissolved Lead	mg/l	<0.005	10	0	-	-	-	0.0002	MRV	0
Dissolved Magnesium	mg/l	<0.1	7	7	0.7	0.87	1			
Dissolved Mercury	mg/l	<0.001	10	0	-	-	-	0.00001	MRV	0
Dissolved Molybdenum	mg/l	<0.002	10	0	-	-	-	0.07	DWS	0
Dissolved Nickel	mg/l	<0.002	10	0	-	-	-	0.004	DWS	0
Dissolved Potassium	mg/l	<0.1	7	7	1.1	1.79	2.4			
Dissolved Selenium	mg/l	<0.003	10	0	-	-	-	0.01	DWS	0
Dissolved Vanadium	mg/l	<0.0015	10	1	0.0016	-	-	0.02	EQS	0
Dissolved Zinc	mg/l	<0.003	10	10	0.004	0.0077	0.017	0.0129	EQS	1
pH	pH units	<0.01	7	7	6.1	6.24	6.51			
Total Alkalinity as CaCO3	mg/l	<1	7	7	20	34.57	54			
Electrical Conductivity @25C	uS/cm	<2	7	7	57	123.86	410			
Chloride	mg/l	<0.3	7	7	6.4	7.79	10	250	DWS	0
Sulphate as SO4	mg/l	<0.5	7	3	0.9	1.47	2	250	DWS	0
Ammoniacal Nitrogen as N	mg/l	<0.03	7	7	0.04	0.0733	0.15	0.3	EQS	0

3.0 CONCEPTUAL SITE MODEL

3.1 CSM OVERVIEW

This section sets out the Conceptual Site Model (CSM), which describes the potential contaminant sources associated with the proposed development the receptors upon which contaminants could potentially have an impact and also pathways that may exist to allow contaminants to impact upon the identified receptors.

The CSM development has focussed on characterising the hydrogeological model for groundwater beneath the site, both in its current condition and post restoration of the site following infilling with inert materials. A conceptual understanding of the hydrogeological regime in the vicinity of Busta Triangle Quarry and the proposed restoration has been derived from an assessment of published and site-specific information.

To assess the potential impact of any contamination identified at the site on any water dependant receptors, a risk assessment has been progressed. For a risk to be present at the site, three components must exist:

- Contaminant(s) must be present at concentrations capable of causing adverse effects on groundwater (Source);
- There must be exposure migration pathway by which the receptor encounters the contaminant (Pathway); and,
- A groundwater dependent receptor must be present, (Receptor).

The source-pathway-receptor scenario is used to generate a conceptual site model (CSM), which can be used to identify potentially significant pollutant linkages, to inform the decision whether a more detailed quantitative analysis of risk is required. The first stage of the process is to determine the presence or absence of any contaminant(s) of concern (source) at the site, followed by the most likely pathways that these contaminants would take in the environment and finally the potential receptors of concern.

3.2 SOURCE TERM CHARACTERISTICS

3.2.1 Waste Types

It is proposed to complete the restoration with inert material as defined in Article 2 of the Landfill Directive 1999/31/EC as follows:

'Inert waste' means waste that does not undergo any significant physical, chemical or biological transformations. Inert waste will not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to human health. The total leachability and pollutant content and the ecotoxicity of its leachate are insignificant and, in particular, do not endanger the quality of any surface water and/or groundwater. Table 4-1 lists those wastes that may be accepted at the site which do not require Waste Acceptance Criteria (WAC) testing under Council Decision (2003/33/EC), provided that they are inert and from a single source only (mixed loads from more than one site cannot be accepted without testing).'

Permitted wastes accepted at the site will be strictly inert as classified under the Landfill Directive (1999/31/EC) and Council Decision (2003/33/EC) of 19th December 2002 'establishing criteria and procedures for the acceptance of waste landfills…'

Any suspected non-compliant material will not be accepted onto site and will be dealt with in accordance with the site's Waste Acceptance Procedures.

Table 10 lists those wastes that may be accepted at the site which do not require Waste Acceptance Criteria (WAC) testing under Council Decision (2003/33/EC), provided that they are inert and from a single source only (mixed loads from more than one site cannot be accepted without testing).

Table 10: Proposed Waste Types

EWC Code	Description	Restriction
01	**WASTE RESULTING FROM EXPLORATION, MINING, QUARRYING AND PHYSICAL AND CHEMICAL TREATMENT OF MINERALS**	
01 01	**Wastes from mineral excavation**	
01 01 02	Waste glass-based fibrous materials	Restricted to waste overburden and interburden only
01 04	**Wastes from physical and chemical processing of non-metafillerous minerals**	
01 04 08	Waste gravel and crushed rocks other than those mentioned in 04 04 06	
01 04 09	Waste sand and clay	
10	**WASTES FROM THERMAL PROCESSES**	
10 12	**Wastes from manufacture of ceramic goods, bricks, tiles and construction products**	
10 12 08	Waste ceramics, brick, tiles and construction products (after thermal processing)	
17	**CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATED SOIL FROM CONTAMINATED SITES)**	
17 01	**Concrete, bricks, tiles and ceramics**	
17 01 01	Concrete	Selected C&D waste only
17 01 02	Bricks	Selected C&D waste only
17 01 03	Tiles and ceramics	Selected C&D waste only
17 01 07	Mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06	Selected C&D waste only. Metal from reinforced concrete must have been removed.
17 05	**Soil (including excavated soil from contaminated sites), stones and dredging spoil**	
17 05 04	Soil and stones other than those mentioned in 17 05 03	Excluding topsoil, peat; excluding soil and stones from contaminated sites
19	**WASTES FROM WASTE MANAGEMENT FACILITIES, OFF-SITE WASTE WATER TREATMENT PLANTS AND THE PREPARATION OF WATER INTENDED FOR HUMAN CONSUMPTION AND WATER FOR INDUSTRIAL USE**	
19 12	**Wastes from the mechanical treatment of waste (for example sorting, crushing, compacting, pelletising) not otherwise specified**	
19 12 09	Minerals only	Wastes from the treatment of waste aggregates that are otherwise naturally occurring minerals. Does not include fines from treatment of any non-hazardous waste or gypsum from recovered plasterboard.

20	**MUNICIPAL WASTES (HOUSEHOLD WASTE AND SIMILAR COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL WASTES) INCLUDING SEPARATELY COLLECTED FRACTIONS**	
20 02	**Garden and park wastes (including cemetery waste)**	
20 02 02	Soil and stones	Only from garden and parks waste; excluding topsoil, peat.

In addition to the wastes that are listed in Table 10, Collard proposes to accept the waste codes listed in Table 11 below which will be subject to WAC testing.

Table 11: Proposed Waste Types that Will Require WAC Testing

EWC Code	Description	Restriction
10	**WASTES FROM THERMAL PROCESSES**	
10 13	**Wastes from manufacture of cement, lime and plaster and articles and products made from them**	
10 13 14	Waste concrete	
19	**WASTES FROM WASTE MANAGEMENT FACILITIES, OFF-SITE WASTEWATER TREATMENT PLANTS AND THE PREPARATION OF WATER INTENDED FOR HUMAN CONSUMPTION AND WATER FOR INDUSTRIAL USE**	
19 12	**Wastes from the mechanical treatment of waste (for example sorting, crushing, compacting, pelletising) not otherwise specified**	
19 12 12	Other wastes from mechanical treatment of wastes other than those mentioned in 19 12 12	Restricted to crushed bricks, tiles, concrete and ceramics only. Metal from reinforced concrete must be removed. Does not include fines from treatment of any non-hazardous waste or gypsum from recovered plasterboard.

Waste types for the construction of the Attenuation Layer will be restricted to the following waste codes in Table 12 below. The attenuation layer will be constructed with a minimum thickness of 1m with a hydraulic permeability of 1 x 10-7m/s.

Table 12: Proposed Waste Types in the Attenuation Layer Only

EWC Code	Description	Restriction
17	**CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATED SOIL FROM CONTAMINATED SITES)**	
17 05	**Soil (including excavated soil from contaminated sites), stones and dredging spoil**	
17 05 04	Soil and stones other than those mentioned in 17 05 03*	* This specifically excludes excavated soil from contaminated sites.

3.2.2 Leachate Generation

Due to the inert nature of the material to be used to restore the site, it is considered highly unlikely that water encountering the material will generate high concentrations of pollutants. The operator will make sure that this is the case by restricting the source waste materials allowed on to the site and by adopting stringent Waste Acceptance Procedures. Hazardous substances are not expected to be present and non-hazardous substances are expected to be very low with respect to the background groundwater quality.

The decline in leachate concentrations is controlled by water inputs to the fill material at the site. The site is to be restored progressively in a phased approach and therefore will be open to rainfall infiltration. Rainfall falling on the inert materials will either run-off over the waste and be subject to evapotranspiration and / or infiltrate through waste mass as effective rainfall.

Effective rainwater which does infiltrate through the restoration soils will migrate vertically through the inert waste materials. Leachate generated will be subject to attenuation and retardation processes.

Given the inert nature of the emplaced materials and reference to EA guidance ‘Standards and Measures for the Deposit of Inert Waste on Land’, it is not necessary to manage and monitor leachate at sites which comprise the recovery or disposal of inert waste. The site will fall outside the scope of the EPR 2016 (as amended) and therefore, no leachate management and monitoring infrastructure is proposed for the site.

3.2.3 Leachate Contaminants of Concern

Waste types listed above are assumed to meet the definition of inert waste. The standard WAC threshold values for inert landfills and the equivalent leachate quality are summarised in Table 13 for ease of reference.

Table 13: Waste Stream & Inert WAC Limit Leachate Quality

Pollutant	WAC Inert Limit (mg/kg to 10 l/kg)*	Equivalent Leachability (µg/l)	EQS (µg/l)	UKDWS (µg/l)
Arsenic	0.5	**50**	50	10
Barium	20	**2,000**	-	700
Cadmium	0.04	**4**	0.15	50
Chromium	0.5	**50**	4.7	-
Copper	2	**200**	1	2,000
Mercury	0.01	**1**	0.07	1
Molybdenum	0.5	50	-	70
Nickel	0.4	**40**	4	20
Lead	0.5	**50**	1.2	10
Antimony	0.06	**6**	-	5
Selenium	0.1	10	-	10
Zinc	4	**400**	14**	-
Chloride	800	80,000	-	250,000
Fluoride	10	1,000	-	1,500
Sulphate	1000	100,000	-	250,000
Phenol	1	**100**	7.7	-

*Limit values (mg/kg) for compliance leachate testing using BS EN 12457-3 at L/S 10 l/kg

**Zinc 10.9µg/l + 3.1µg/l in accordance with 2015 Environmental Quality Standards (EQS) Guidance.

Text in bold **green** text highlights an exceedance of the UKDWS

Text in bold **orange** text highlights an exceedance of the EQS

This view that 10: L:S ratio tests are useful for establishing waste mass behaviour is supported by the Environment Agency (2013) report[4] on waste sampling and testing for disposal to landfill (page 27), which states:-

'…*for most wastes destined for disposal in landfill sites government consider that a single step leaching test at a Liquid to Solids (L:S) ratio of 10:1 l/kg is adequate for establishing and monitoring the cumulative mass leached and general leaching behaviour*'.

Equivalent leachability concentrations for the Inert WAC values have been calculated and screened against EQS/UKDWS.

Please note that the inert WAC limit values represent the maximum values (worst case scenario) and the majority of imported waste is expected to be significantly below these levels. It is considered that a risk assessment based upon a source term set at the inert WAC limits will be highly conservative.

3.3 PATHWAYS

A conceptual understanding of the hydrogeological regime in the vicinity of the Site has been derived from an assessment of both published and site-specific information.

The site is mapped as being underlain by the Camberly Sand Formation of the Bracklesham Group, classified as a bedrock Secondary A Aquifer. The Secondary A Aquifer has been proven to be partially saturated. Superficial River Terrace Deposits were formerly present on site but have largely been removed due to quarrying activities.

Standing water is present on site in the form two ponds, but based upon groundwater level measurements, these are not in continuity with groundwater in the Camberley Sands and are instead the result of incident rainfall. The ponds will be dewatered prior to any infilling taking place.

3.3.1 Groundwater Levels

Groundwater flow is thought to be broadly to the north. Groundwater flow within the Bracklesham Group is via intergranular flow (primary flow) within the sandier sequences.

Measured groundwater levels within boreholes indicate that the saturated thickness of the Bracklesham Group at the site ranges from around 87.57mOAD (5.56m bgl) in the north-west, to around 89.77mAOD (5.6m bgl) in the south. Additionally, groundwater levels and flows at site fluctuate during seasonal variations.

3.3.2 Baseline Groundwater Quality

Baseline hydrogeological analysis has demonstrated that the quality of groundwater in the Bracklesham Group aquifer at Site is generally good and generally consistent with DWS and EQS, with the exception of Nickel and Zinc.

Consideration of background groundwater quality within the modelling is detailed in Section 4.6.8.

3.4 RECEPTORS

The following are considered to represent potential local receptors for any leachate generated from the proposed infilling at Busta Triangle Quarry:

(i) Groundwater present in the Camberley Sands of the Bracklesham Group (Secondary A Aquifer);

(ii) Local surface watercourses via groundwater baseflow.

[4] Environment Agency, Waste Sampling and Testing for Disposal to Landfill EBPRI 11507B,l March 2013.

A review of licensed abstractions and private water supplies shows that none are present within 2km of the site. No main rivers or significant water features are located down hydraulic gradient of the site to the north.

Modelling protective of groundwater within the Bracklesham Group at appropriate compliance points will also be protective of any surface water or groundwater receptors beyond the compliance points.

3.5 CONCEPTUAL HYDROGEOLOGICAL SITE MODEL SUMMARY

The conceptual site model for the site is summarised below:-

- The primary potential source of concern is considered to be the import of inert material which will be used to restore the quarry void;
- Given the inert nature of the fill material, it is considered that there is a very low potential for generating significant volumes of leachate and pollutant concentrations. This can be ensured by the adoption of strict compliance with Waste Acceptance procedures at the site;
- A review of groundwater levels demonstrates that groundwater is currently present at depths of around 4 to 6mbgl within the Camberley sands beneath the site.
- Prior to infilling of the existing depressions, the ponds will be dewatered and discharged off site under an appropriate permit.
- Contaminants from the site will be able to migrate through the base of the restoration soils and already in place overburden / interburden, into the Bracklesham Group, which is classified as a Secondary A Aquifer.
- Groundwater flow is anticipated to be towards the north-west or north-east (seasonal variation), primarily via intergranular flow through the sands of the Bracklesham Group, providing baseflow to water courses.
- The site is not located within a groundwater source protection zone (SPZ); no licensed abstractions or PWS are located within 2km of the site.
- The most sensitive receptor with respect to the proposed development is considered to be groundwater resource immediately beneath the site, within the Bracklesham Group Secondary A Aquifer.

4.0 QUALITATIVE HYDROGEOLOGICAL RISK ASSESSMENT

4.1 INTRODUCTION

The hydrogeological risk assessment has been carried out using conservative assumptions regarding the source, pathways and receptors. Site specific data have been used wherever possible to parameterise the risk assessment.

As previously discussed, the quarry void at the site is proposed to be restored using inert material. Based on the definition of inert waste, the site should not produce any leachate that could result in any significant discharge of hazardous substances or non-hazardous pollutants throughout the lifecycle of the site.

However, notwithstanding this, a risk assessment is required for an inert landfill where the receiving environment is particularly sensitive, for example where waste is located below the water table, or a direct pathway exists to a sensitive surface water receptor.

4.2 PROPOSED ASSESSMENT SCENARIO

One assessment scenario is necessary for the site, namely the closure of the site following the completion of the infilling activities. The modelling for the site considered the impact for all phases of the site in conjunction.

4.3 RISK ASSESSMENT MODEL

The site conceptual model has been developed based on quantifying contaminant migration from a source along the pathway identified. This follows the Agency's recommended approach to landfill risk assessment. This approach has been implemented in a using the probabilistic ConSim 2.5 software.

This software is based upon the EA's Remedial Target Methodology. The source of contaminant is then defined in terms of a contaminant inventory and the release of contaminants from the source is modelled. Receptors are placed down hydraulic gradient of the source, and the impact upon these receptors is quantified. Dilution in groundwater and attenuation, dispersion, decay and retardation in both the unsaturated and saturated pathways can be modelled. The model assumes that the source is located above the water table, and an unsaturated zone is present.

One advantage of ConSim is that probabilistic modelling or Monte Carlo modelling can be undertaken. This is useful when a range of possible parameters may be selected, due to uncertainty or natural variability. Instead of entering a single value for a model parameter, a range of parameters may be entered as a probability distribution. The model is then run for many iterations, and the results of the model are presented as a probability distribution. For example, the 50th percentile results could be considered the average or most likely result, whereas the 95th percentile results can be considered a worst-case result.

4.4 THE PRIORITY CONTAMINANTS TO BE MODELLED

The priority contaminants which are to be modelled are a selection of the determinants presented in the screening exercise in Table 13, based on the Waste Acceptance Criteria (WAC) for inert landfills.

The representative contaminants that are modelled in the assessment are as follows:

- The non-hazardous contaminants chloride, chromium, copper, nickel, cadmium, sulphate and zinc; plus Ammoniacal Nitrogen and phenol;
- Hazardous inorganic contaminants: arsenic, lead and mercury;

This selection of contaminants presents several hazardous and non-hazardous heavy metals, the conservative anions chloride and sulphate, plus phenol, an organic contaminant.

4.5 MODEL ASSUMPTIONS

It is assumed that the entire material mass is present at the start of the simulation. Since filling of the site will be progressed over several years, the actual source term will begin to decline during this time and will subsequently be smaller than that represented in the model by the time filling is complete, which thus represents a conservative approximation of the system.

For simplicity, it has also been assumed that the thickness of the restoration soils within the source area is constant.

4.6 MODEL PARAMETERISATION – SCENARIO 1, BASELINE

4.6.1 Site Geometry

The site has been split into two source areas:

- Source 1, covering the northern portion of the site; and
- Source 2, covering the southern portion of the site.

The total tonnage of material required to restore the site is 165,000m^3. The surface area of Source Area 1 and 2 is presented below. Based upon the CSM sections presented in Section 3 of this report, a thickness of 1.4m and 2.4m for the respective source areas sums to 167,000m^{3,} a close approximation of the total volume.

Table 14 – Source Parameterisation

Description	Source Area 1 (North)	Source Area 2 (South)	Data Source / Justification
Surface area, m^2	37,000 m^2	48,000 m^2	From surveyed plans, measured in GIS
Thickness, m	Single(1.4)	Single (2.4)	Average estimated
Volume, m^3	51,000 m^3	115,200 m^3	Thickness times area, checked with cut/fill volume
Dry bulk density, g/cm^3	Uniform(1.2,2.2)		ConSim suggested range of values inclusive of clay and sand.
Water Filled Porosity	Single(0.27)		Based on RTM porosity calculator
Airm Filled Porosity	Single(0.051)		Based on RTM porosity calculator

4.6.2 Source Term Values

Source term values have been set to pore water concentration equivalent to the inert WAC leachability limits, converted to mg/l. This is highly conservative assumption, as it assumes that all material within the site will be at the Inert WAC limit, with the exception of Ammoniacal Nitrogen.

Ammoniacal nitrogen is not detailed in Section 2.1.2.1 of Council Decision 2033/33/EC but has been included in case small quantities of wood or other biodegradable material are accidentally placed into the Site. Although biodegradable material will not be deliberately disposed of at the Site, it is possible that some residual biodegradable material may be placed. Therefore, it is possible that some degradation products, such as ammoniacal nitrogen, may be produced. The value of 1mg/L is considered to be a high value for the generation and leachability of ammoniacal nitrogen from inert wastes and is therefore conservative.

Table 15 – Source Term Values

CoPC	Source Term Value – Pore Water Concentration / Equivalent Leachability (mg/l)
Ammoniacal Nitrogen	Single(1.00)
Arsenic	Single(0.05)
Cadmium	Single(0.004)
Chloride	Single(80)
Chromium	Single(0.050)
Copper	Single(0.200)
Lead	Single(0.050)
Mercury	Single(0.001)
Nickel	Single(0.040)
Phenol	Single(0.1)
Sulphate	Single(100)
Zinc	Single(0.4)

Source partition coefficients have been input using ConSim suggested input parameters from the ConSim help files.

Table 16 - Soil partition coefficients, inorganic parameters

CoPC	Soil water partition coefficients, Kd
Ammoniacal Nitrogen	Uniform(0.5,3.2)
Arsenic	Uniform(117,249.6)
Cadmium	Single(240)
Chloride	Single(0)
Chromium	Uniform(30,999)
Copper	Single(295)
Lead	Logtriangular(27,270,27000)
Mercury	Uniform(145,1500)
Nickel	Logtriangular(20,400,8100)
Sulphate	Single(0)
Zinc	Logtriangular(20.7,200,36000)

Table 17 - Soil partition coefficient parameters, phenol

Parameter	Value	Justification
Henry's law constant	Single(1.89E-5)	ConSim suggested value
KoC, ml/g	Single(27)	ConSim suggested value
Fraction Organic Carbon (%)	Uniform(0.01,0.1)	ConSim suggested value for clay

4.6.3 Infiltration

Infiltration has been set to the estimated effective rainfall for the site, 360mm per year, which is the total annual average rainfall minus evapotranspiration. It has been set to a normal distribution with standard deviation equivalent to 10% of the total value.

4.6.4 Unsaturated Pathway Definition

The unsaturated pathway has been defined as two layers. A low permeability attenuation layer will be emplaced at the base of the site, at least one meter thick and with a hydraulic conductivity of less than 1 x 10-7 m/s (or equivalent), as per the Landfill Directive. This attenuation layer has been modelled as a separate unsaturated zone pathway, 'Unsaturated Pathway 1 – Attenuation Layer'.

Underlying this is the material which is currently present at surface on the site – mainly comprising silts remaining from the previous mineral workings – 'Unsaturated Pathway 2'.

For the unsaturated pathways, the parameters given in Table 20 and Table 19 are used for modelling. For partition coefficients, values have been set to the same as those used for the source.

Table 18 - Unsaturated Pathway 1 - Attenuation Layer

Parameter	Value	Justification
Thickness m	Single(1.0)	Based upon requirements of Landfill Directive.
Water Filled Porosity fraction	(0.15, 0.25)	ConSim suggested values for Clay. Assuming 50% saturated.
Dry Bulk Density g/cm^3	Uniform(1.82, 2.15)	
Unsaturated Conductivity m/s	Single(1E-7)	Based upon requirements of Landfill Directive.
Vertical Dispersivity	Single(0.1)	10% of pathway length

Table 19 - Unsaturated Pathway 2 - Silts

Parameter	Value	Justification
Thickness m	Uniform(3,5.2)	Based upon range in site sections and June GW levels (highest measured).
Water Filled Porosity fraction	(0.15, 0.25)	ConSim suggested values for Silt. Assuming 50% saturated.
Dry Bulk Density g/cm^3	Uniform(1.82, 2.15)	
Unsaturated Conductivity m/s	Loguniform(2E-7,3E-4)	Based upon values provided in HIA. Within ConSim suggested range for silts to sands.
Vertical Dispersivity	Uniform(0.3,0.52)	10% of pathway length

4.6.5 Aquifer Pathway Definition

The aquifer pathway has been defined based upon the parameters shown in Table 20.

Table 20 - Aquifer Parameters

Description	Value	Data Source
Unit Thickness, m	Uniform(60,70)	Based upon nearby BGS borehole records.
Hydraulic gradient	Uniform(0.0029,0.0037)	Range from GW contours.
Porosity	Uniform(0.26,0.53)	ConSim suggested value for fine sands.
Hydraulic Conductivity, m/s	Loguniform(2E-7,3E-4)	Based upon values provided in HIA. Within ConSim suggested range for silts to sands.
Dry bulk density, g/cm3	Uniform(1.22,2.04)	"Distribution of landslides and geotechnical properties within the Hampshire Basin ", values for Bracklesham Gorup
Mixing Depth, m	Calculated	Calculated by software

Groundwater contouring has shown seasonal variation in the flow direction beneath the site from the north-west to the north-east, based on the dataset collected to date. To provide for a conservative assessment, it is assumed that groundwater flow has a bearing of 0 degrees, i.e. due north. Due to the shape of the site, this results in a maximum length of the restoration soils parallel to groundwater flow, for compliance points placed centrally and north of the source areas.

For ammoniacal nitrogen and phenol, which are assumed to undergo degradation within the aquifer, the parameters presented within Table 21 apply.

Table 21 - Contaminant parameters for Ammoniacal Nitrogen and Phenol

Parameter	Value	Justification
Half life, Phenol, years	Single(0.273)	Upper ConSim suggested value3
Half Life, Ammoniacal Nitrogen, years	Single(6)	Upper value given in 2003 EA publication[5]
FoC in Aquifer, %	Uniform(0.41,0.57)	Range of values provided in 2012 EA report[6] for Bracklesham Group

It should also be noted that biodegradation has also been applied within the unsaturated zone, but within the dissolved phase only.

4.6.6 Receptor Definition

Two receptors have been defined within the model:

- For the non-hazardous contaminants Ammoniacal Nitrogen, Cadmium, Chloride, Chromium, Copper, Nickel, Phenol, Sulphate and Zinc, the compliance point has been set 50m downgradient of the most downgradient edge of Source 1 (the northern source).
- For the hazardous contaminants Arsenic, Lead, Mercury, the compliance point is set immediately downgradient of Source 1. Hazardous contaminants must not be discernible in groundwater beyond this point, as per EA guidance on the discernability of hazardous substances in groundwater.

4.6.7 Environmental Assessment Levels

As groundwater quality beneath the site is relatively good, Environmental Assessment Levels (EALs) have not been set at Environmental Quality Standards or Drinking Water standards, as this may allow for unacceptable deterioration in groundwater quality at the site.

Instead, EALs been set for the receptors accounting for both existing baseline ground quality within the aquifer, where available, and with reference to Minimum Reporting Values, and Threshold Screening Values.

- Where a sufficient dataset of detections is available for statistical analysis of a contaminant, the EAL has been set at the average of the baseline groundwater quality in boreholes BH01, BH02 and BH03, plus three standard deviations to account for variation. The model then also includes background groundwater quality (Section 4.6.8). This includes ammoniacal nitrogen, arsenic, chloride, nickel, sulphate and zinc.
- For Chromium, where no samples were analysed above the limit of detection, the EAL has been set as the midpoint between the LOD and the EQS, as the LOD is below the EQS.
- For Phenol and copper, where no samples were analysed above the limit of detection, the EAL has been set at half of the EQS for the substance.

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[5] Buss, S.R., Herbert, A.W., Morgan, P. and Thornton, S.F., 2003. Review of ammonium attenuation in soil and groundwater. NGWCLC report NC/02/49. Environment Agency.
[6] Geochemical properties of aquifers and other geological formations in the UK, Environment Agency Science Report SC030110/SR, 2012

- For Lead, Cadmium and Mercury, the EAL has been set at the minimum reporting value, to ensure that no discernible amount of these substances enters groundwater.

The EALs utilised are presented in Table 22.

Table 22 – Environmental Assessment Levels

Sustance	EAL (mg/l)	Note
Amm. Nitrogen	0.154	Set at av. of background groundwater quality plus three standard deviations.
Arsenic	0.00270	Set at av. of background groundwater quality plus three standard deviations.
Cadmium	0.0001	Set at MRV
Chloride	47.9	Set at av. of background groundwater quality plus three standard deviations.
Chromium	0.0031	Set at midpoint of LOD and EQS
Copper	0.0005	Set at 50%of EQS
Lead	0.0002	Set at MRV
Mercury	0.00001	Set at MRV
Nickel	0.0153	Set at av. of background groundwater quality plus three standard deviations.
Sulphate	176.96	Set at av. of background groundwater quality plus three standard deviations.
Zinc	0.0712	Set at av. of background groundwater quality plus three standard deviations.
Phenol	0.00385	Set at 50%of EQS

4.6.8 Background Groundwater Concentrations

For those substances where the EAL been based upon the average of background quality plus three standard deviations, the background groundwater quality has been entered into the model as a probability distribution, shown in Table 23. A log triangular distribution has been selected, with minimum, average and maximum of groundwater quality data to date used to set the distribution.

For the remaining substances where the EAL has been set at either the MRV or a midpoint below the EQS, the background groundwater concentration is set to zero.

Table 23 - Modelled background groundwater concentrations

CoPC	Input Distribution (mg/L)
Ammoniacal Nitrogen	Logtriangular(0.015,0.0583,0.16)
Arsenic	Logtriangular(0.00125,0.00139,0.0028)
Chloride	Logtriangular(9.9,20.49,35)
Nickel	Logtriangular(0.005,0.0087,0.013)
Sulphate	Logtriangular(0.25,59.783,160)
Zinc	Logtriangular(0.007,0.0239,0.057)

4.7 MODEL RESULTS

The model was run probabilistically using the input parameters defined in previous sections. An electronic copy of the model is included in Appendix F.

The model is run for a maximum time period of 1,000 years, with time slices at 1, 5, 10, 50, 100 and 500 and 1,000 years. This is significantly longer than the time period that is likely to be required to achieve permit surrender and is considered to be a conservative upper time limit for an inert simulation. The model was run for 1001 iterations, allowing 95th percentile predicted concentrations to be calculated.

For the non-hazardous substances, peak concentrations for the 50th and 95th percentile and the time to peak concentrations at the 50m compliance point are presented inTable 24, alongside the relevant EAL. Note that these results are based on the total input from both Source 1 and Source 2 at the receptor.

Table 24 - Scenario 1, Predicted Concentrations, Non-hazardous Compliance Point

Substance	50th Percentile		95th Percentile		EAL (mg/l)
	Max predicted (mg/l)	Time to peak (years)	Max predicted (mg/l)	Time to peak (years)	
Amm. Nitrogen	0.056	100	0.117	100	0.154
Cadmium	No Breakthrough	-	No Breakthrough	-	1.00E-4
Chloride	19.69	10	30.47	100	47.9
Chromium	No Breakthrough	-	No Breakthrough	-	0.0031
Copper	No Breakthrough	-	No Breakthrough	-	0.0005
Nickel	No Breakthrough	-	No Breakthrough	-	0.0153
Sulphate	19.1	10	92.78	No peak	176.96
Zinc	No Breakthrough	-	No Breakthrough	-	0.0712
Phenol	No Breakthrough	-	No Breakthrough	-	0.00385

For the majority of non-hazardous substances including the metals and phenol, no breakthrough is predicted within the model. Sulphate, chloride and nitrogen are predicted to breakthrough within the first 100 years with a slight rise above baseline concentrations predicted at the 50m compliance point; however, the predicted concentrations are well below the EALs and should lead to no significant deterioration of groundwater quality downgradient of the site.

For the hazardous substances, peak concentrations for the 50th and 95th percentile and the time to peak concentrations at the hazardous compliance point (immediately downgradient of the northern source) are presented in Table 25, alongside the relevant EAL.

Table 25 - Scenario 1, Predicted Concentrations, Hazardous Compliance Point

Substance	50th Percentile		95th Percentile		EAL (mg/l)
	Max predicted (mg/l)	Time to peak (years)	Max predicted (mg/l)	Time to peak (years)	
Arsenic	0.0017	No peak	0.0024	No peak	0.00270
Lead	No Breakthrough	-	No Breakthrough	-	0.0002
Mercury	No Breakthrough	-	No Breakthrough	-	0.00001

Arsenic is predicted at a concentration beneath the EAL, but with no peak – this reflects a background concentration being set for arsenic in the model. No breakthrough is predicted for arsenic, lead and mercury at the hazardous compliance point.

4.8 MODEL PARAMETERISATION – SCENARIO 2, ROGUE LOAD

While the starting point for an inert restoration site is that residual leachate quality should be close to that of inert Waste Acceptance Criteria (WAC), the site is located on a Secondary A Aquifer, which presents a moderately sensitive groundwater receptor.

The Environment Agency requires a robust Rogue Load Assessment considering the potential contaminants representative of non-compliant waste potentially accepted under mirror non-hazardous waste codes (e.g. 19 12 12).

The Environment Agency has undertaken preliminary review of leachate from soil waste deposits and has provided a note about the values that could be considered in the assessment. A consistent approach to rogue load modelling is also expected to enable risk assessment of the more soluble and mobile contaminants that could arise from the deposition of more variable soils wastes. Table 26, below, present the values which the Environment Agency are currently recommending for rogue load assessment of ammoniacal nitrogen, chloride and sulphate.

Table 26 - EA Recommended values for rogue load assessment

Substance	Minimum (mg/l)	Most Likely (mg/l)	Maximum (mg/l)
Ammoniacal Nitrogen	0.3	8	25
Chloride	100	300	800
Sulphate	200	1200	1800

Scenario 2, the rogue load assessment model, has been parameterised by utilising the values presented in Table 26 as a log triangular distribution within the model. All other model parameters remain the same as those presented in 4.6 for Scenario 1.

The results of Scenario 2 as peak concentrations for the 50th and 95th percentile and the time to peak concentrations at the 50m compliance point are presented in are presented in Table 27, alongside the relevant EAL.

Table 27 - Scenario 2, Predicted Concentrations, Non-hazardous Compliance Point

Substance	50th Percentile		95th Percentile		EAL (mg/l)
	Max predicted (mg/l)	Time to peak (years)	Max predicted (mg/l)	Time to peak (years)	
Amm. Nitrogen	0.062	100	0.147	100	0.154
Chloride	20.19	10	33.48	10	47.9
Sulphate	21.79	10	102.27	50	176.96

With the increased source concentrations to account for potential rogue loads, the predicted concentrations for ammoniacal nitrogen, chloride and sulphate are increased when compared with Scenario 1 but are still expected to remain below the relevant EALs.

Note also that these EALs are set well beneath the relevant EQS, to prevent unacceptable degradation of current groundwater quality on site.

5.0 REQUISTE SURVEILLANCE

The requisite surveillance for groundwater and surface water that is considered necessary and appropriate for the site is presented in the following sections. A comprehensive monitoring infrastructure is currently in place such that no additional monitoring boreholes are required.

5.1 GROUNDWATER MONITORING

Monitoring infrastructure is already present on site. The monitoring boreholes BH01 and BH02 are present downgradient to the proposed source areas and are screened within the Bracklesham Group. They are proposed as downgradient monitoring boreholes for the site.

BH03 is located upgradient of the source area and should also be monitored to detect any potential changes in background groundwater quality flowing on to the site.

The proposed groundwater monitoring schedule is presented in Table 24.

Table 28 - Proposed groundwater monitoring schedule

Monitoring Location	Parameter	Frequency
Downgradient Boreholes **BH01** and **BH02** Upgradient Borehole **BH03**	Groundwater level and dip to base, in mbgl and mAOD. pH, Electrical Conductivity, Alkalinity Ammoniacal Nitrogen, Cadmium, Chloride, Chromium, Copper, Nickel, Sulphate, Zinc, Phenol Arsenic Low Level, Lead Low Level, Mercury Low Level	Quarterly

5.2 SURFACE WATER MONITORING

The ponds present on site will be dewatered and infilled as part of the site restoration. There are no other perennial surface water features in the immediate vicinity of the quarry which are thought to be in hydraulic continuity with groundwater, and therefore surface water monitoring is not proposed.

5.3 PROPOSED COMPLIANCE LIMITS

Compliance Limits for groundwater are proposed within Table 29. Quantitative modelling of the site predicts minimal breakthrough of contaminants to groundwater. The compliance limits for the site are therefore based upon the EALs utilised within the modelling, which are either set well below the relevant EQS, or take into account background groundwater quality to prevent the deterioration of the groundwater resource.

Specific compliance limits are proposed for ammoniacal nitrogen, arsenic, chloride, lead, nickel, sulphate, and phenol, to provide a range of contaminant behaviours within the subsurface.

Table 29 – Proposed Groundwater Compliance Limits

Substance	Proposed CL (mg/l)
Ammoniacal Nitrogen	0.154
Arsenic	0.00270
Chloride	47.9
Lead	0.0002
Nickel	0.0153
Sulphate	176.96
Phenol	0.00385

It should be noted that groundwater monitoring conducted at the site to date for arsenic, lead, and mercury has not been carried out with a low-level Limit of Detection (LoD) corresponding to the Minimum Reporting Values (MRV) recommended by UKTAG. Whilst arsenic has been detected within groundwater above the limit of detection on one round, there have been no detections of lead and mercury.

It is recommended that future groundwater analysis at the site is carried out with low level testing for arsenic, lead and mercury, and that this testing take place prior to the commencement of infilling on site. Results of this testing should be reviewed to determine if the EAL's for lead and mercury presented above and utilised within the modelling are appropriate, or whether these substances are already present within groundwater at low levels.

5.4 ATTENUATION LAYER – WASTE ACCEPTANCE

As per the landfill directive, a low permeability clay attenuation layer will be emplaced at the base and sides of the southern extension area (Source Area 1), at least one meter thick and with a hydraulic conductivity of less than 1 x 10-7m/s (or equivalent).

As it is proposed to utilise imported waste soils within the attenuation layer, the material must be physically and chemically suitable. As per Environment Agency guide Landfills for inert waste, it is a requirement that where waste be utilised within the attenuation layer for the site, it meets the following criteria:

1. *making sure that the waste is from a single source or waste type* – Materials used in the attenuation layer will consist exclusively of waste code 17-05-04 - Other soil and stones -Non-hazardous.
2. *making sure it meets the definition of inert waste* – Material to meet Inert WAC criteria, and comprise material that will not dissolve, burn or otherwise physically or chemically react.
3. *making sure the waste has a pollution potential less than, or equal to, the natural quality of the surrounding geology and water* – Modelled concentrations in groundwater immediately have been compared with EALs based upon either background groundwater concentrations, or set well below the relevant EQS. No significant deterioration of present groundwater quality is predicted.
4. *using suitable cohesive material in the attenuation layer (you must test this waste as part of your material assessment)* – Material to comprise entirely cohesive material, with CQA testing to confirm required permeability.
5. *confirming that the attenuation material will not leach non-hazardous pollutants into groundwater* – Modelling has confirmed that setting the entire proposed site to the inert WAC limits does not result in a significant impact on existing groundwater quality.

6. *including evidence that the material contains no hazardous substances at sites over a principal aquifer or below the water table* – The site is not located on a principal aquifer and based upon a review of monitored groundwater levels no sub water table deposition of waste will take place.

6.0 CONCLUSIONS

This report presents an assessment of the hydrogeological regime at Busta Triangle as the basis of a risk assessment. The assessment uses an accurate model of the relevant flow mechanisms and contaminant transport theory and is based on detailed knowledge of the hydrogeology and hydrology of the area surrounding the proposed restoration site.

A conceptual model of the proposal was developed through the interpretation of data in the vicinity of the site to provide detailed information on the local geology, hydrogeology and hydrology. A conceptual model has been formulated for the site, and a number of possible source, pathway, receptor linkages have been identified.

The quantitative risk assessment approach is presented, along with data input parameters. A simple risk assessment model was constructed. The model considers the fate of the leachate determinands derived in the source along the transport pathway and the effects of attenuation, decay, retardation, dispersion, and dilution.

6.1 COMPLIANCE WITH THE ENVIRONMENTAL PERMITTING REGULATIONS (ENGLAND AND WALES) 2016

Compliance of the Busta Triangle site with the relevant parts of the Environmental Permitting Regulations 2016 (as amended) is discussed in the following sections.

6.1.1 Accidents and their consequences

In the event of the site contributing unacceptable contamination to the groundwater the source should be capped to reduce rainwater infiltration. However, given the quantities of listed substances expected to be placed at the site, this is considered an unlikely requirement.

6.1.2 Acceptance of Simulated Contaminants

It is conceivable that the recovery materials may unintentionally contain levels of substances not acceptable by sites classed as inert, in spite of strict waste acceptance criteria being adhered to. The HRA shows that, even if rogue loads were tipped at the site, there is sufficient attenuation within the subsurface to protect groundwater receptors. Therefore, the risk assessment model predicts that substances from the Site will not impact on the wider groundwater or surface water environment.

6.1.3 Compliance Limits

Technical precautions including requisite surveillance and proposed compliance limits have been proposed for the site. Groundwater compliance limits are presented and are conservative and are either based upon observed background groundwater quality at the site, or are set well below relevant screening standards so as to not allow a significant deterioration in the existing water quality.

6.1.4 Groundwater quality

The risk assessment model shows that the site is unlikely to impact upon groundwater quality. The maximum concentrations that may result from the site are based on a theoretical source term. Given that the actual source term concentrations in the site are likely to be much smaller than simulated here, as strict adherence to the Waste Acceptance Criteria procedures will be applied, the actual resultant concentrations are likely to be much lower. It is considered extremely unlikely that a breach of the EP Regulations will occur.

Appendices

Appendix A: Standard Terms & Conditions

This report is produced solely for the benefit of Collard Environmental and no liability is accepted for any reliance placed on it by any other party unless specifically agreed in writing otherwise.

This report refers, within the limitations stated, to the condition of the site at the time of the inspections. No warranty is given as to the possibility of future changes in the condition of the site. This report is based on a visual site inspection, reference to accessible referenced historical records, information supplied by those parties referenced in the text and preliminary discussions with local and Statutory Authorities.

Some of the opinions are based on unconfirmed data and information and are presented as the best that can be obtained without further extensive research. Where ground contamination is suspected but no physical site test results are available to confirm this, the report must be regarded as initial advice only, and further assessment should be undertaken prior to activities related to the site. Where test results undertaken by others have been made available these can only be regarded as a limited sample. The possibility of the presence of contaminants, perhaps in higher concentrations, elsewhere on the site cannot be discounted.

Whilst confident in the findings detailed within this report because there are no exact UK definitions of these matters, being subject to risk analysis, we are unable to give categoric assurances that they will be accepted by Authorities or Funds etc. without question as such bodies often have unpublished, more stringent objectives. This report is prepared for the proposed uses stated in the report and should not be used in a different context without reference to WYG. In time, improved practices or amended legislation may necessitate a re-assessment.

The assessment of ground conditions within this report is based upon the findings of the study undertaken. We have interpreted the ground conditions in between locations on the assumption that conditions do not vary significantly. However, no investigation can inspect each and every part of the site and therefore changes or variances in the physical and chemical site conditions as described in this report cannot be discounted.

The report is limited to those aspects of land contamination specifically reported on and is necessarily restricted and no liability is accepted for any other aspect especially concerning gradual or sudden pollution incidents. The opinions expressed cannot be absolute due to the limitations of time and resources imposed by the agreed brief and the possibility of unrecorded previous use and abuse of the site and adjacent sites. The report concentrates on the site as defined in the report and provides an opinion on surrounding sites. If migrating pollution or contamination (past or present) exists further extensive research will be required before the effects can be better determined.

Appendix B – Restoration Plan

Appendix C – Mineral Contours

Appendix D – Borehole Logs

Appendix E – Site Conceptual Model

Appendix F – ConSim Model Files

Water Quality Dataset (Excel)

(DIGITAL APPENDIX ONLY)