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September 2021
Ref: 1776-HRA-01

Hydrogeological Risk Assessment for Lower Hare Farm, Whitestone, Exeter

Contents

Disclaimer

APPENDICES

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1. Introduction

Lower Hare Farm is located in Whitestone, Exeter, EX4 2HW. The area of the site, which is the subject of this report is a field within open farmland, which has had previous import of inert soils, leaving disturbed ground. The proposed landfill will reshape the field and area of disturbed ground to allow an end use of arable production.

This hydrogeological risk assessment is being prepared at the request of AA Environmental Limited (AAe) to support an inert landfill permit application. Reference has been made to JH Groundwater Ltd Hydrogeological Risk Assessment, 2019, which was prepared as part of the planning process.

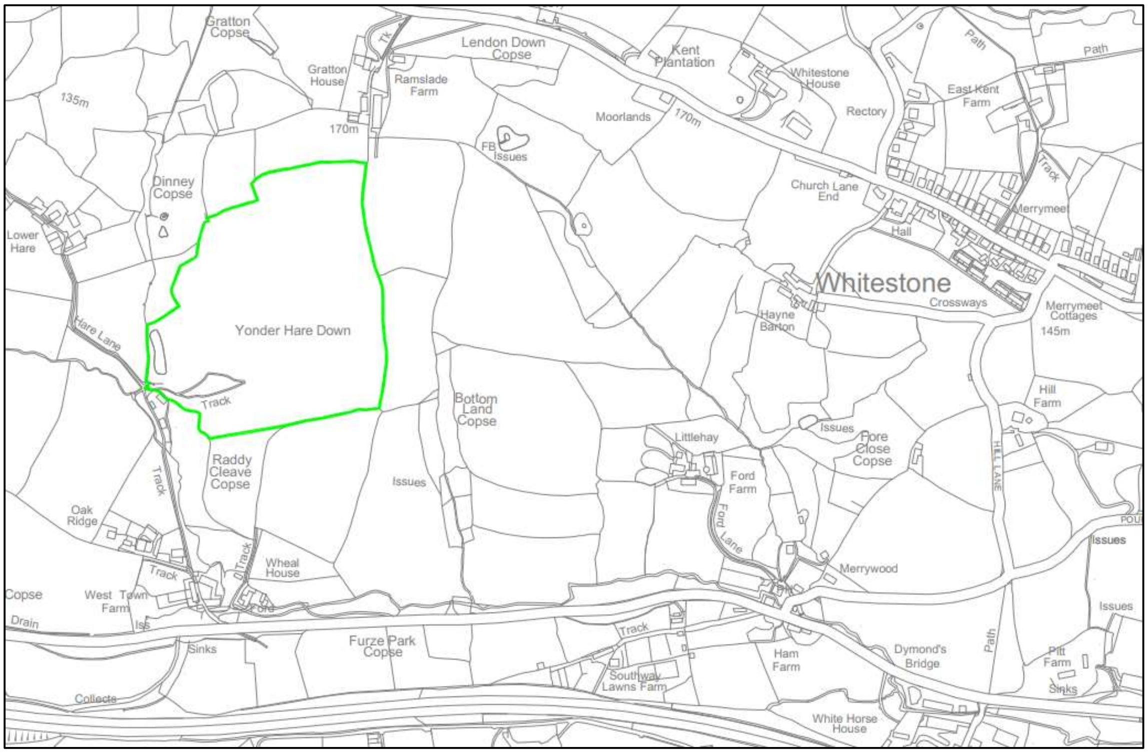
2. The Site

2.1. Location

The site referred to as Lower Hare Farm is an area of sloping field disturbed by the previous import of inert materials. It is centred on approximate National Grid Reference SX 85753 93428. The site lies within rolling farmland north of the A30 and approximately 4km west of Exeter. Whitestone is approximately 800m to the eastnortheast of the site.

On Ordnance Survey maps of the area the site is labelled Yonder Hare Down. The buildings of Lower Hare Farm are positioned to the northwest of the field and on the opposite side of the small north south trending valley, which holds a tributary of the Alphin Brook. The site itself slopes from approximately 170m AOD in the north to approximately 95m AOD in the southwest. The northwestern boundary of the site falls westwards towards Dinney Copse and the valley of the unnamed tributary of Alphin Brook. To the northeast of the site are the buildings of Gratton House and Ramslade Farm. To the east are open fields. A valley feature follows the southern boundary falling from west to east. The access track to the site begins on the west of this valley feature, leaving from Hare Lane. There is a narrow pond of approximately 60m in length towards the centre of the western site boundary.

Figure 1: Site Location Plan (taken from AAe drawing 213189-D-001)



2.2. Environmental Setting

The site is within rolling farmland, underlain by Carboniferous mudstones. The Envirocheck report of the site, refer to AAe Environmental Setting and Site Design report (ESSD), indicates that the local geology supports some groundwater abstractions. An unnamed stream flows to the west of the site, southwards to join the Alphin Brook. The Alphin Brook turns to flow eastwards approximately 300m south of the site. There are no designated habitat sites within 1km of the site. Other local environmental features are presented in Table 1.

Table 1: Local Environmental Features

Receptor	Nature of receptor	Distance from site
Residential/Work-Place/Amenity -Within 50 m	Properties on Hare Lane Ramslade Farm	Adjacent W 50m N
Residential/Work-Place/Amenity - 50 - 250 m	Lower Hare Farm Buildings West Town Farm	150m W 200m S
Residential/Work-	Meadow Croft	380m N

Receptor	Nature of receptor	Distance from site
Place/Amenity > 250 m	Higher Hare Bungalow Properties near Kent Plantation Ford Farm Solar Farm Farms south of the A30 Higher Hare Hayne Barton Alpine Springs Properties off Five Mile Hill Whitestone Farms to E near Pound Lane	450m NW 450m NE 450 ESE 500m SW 500m S 550m NW 600m E 650m NW 700m W 800m ENE 800mESE
Habitats		
Habitats Directive sites	None within 2 km	
CROW Act 2000 sites	None within 2km Closest – Posbury Clump SSSI	6 km NW
Other habitat sites	None within 2 km	
Groundwater		
Aquifer	Ashton Mudstone Secondary A	On site
Groundwater protection zone	None	
Groundwater abstractions (within 1km)	Higher Hare Well West Town Farm Well Whitestone House Well Alphin Springs Pound View Well Brookside Garage – borehole Higher Hare – tapped spring	500m N 600m S 600m NE 750m NW 900m NW 950m SW 950m NW
Surface Water		
Closest	Pond Unnamed tributary of Alphin Brook Alphin Brook	Within boundary on W Adjacent to W 20m SW
Direct runoff from site?	Temporary lagoons in Phase 3. Permanent lagoon to Southwest	
Surface water abstractions	None listed in Envirocheck report	
Nitrate vulnerable zone	No	
Wells and springs		
Wells	Refer to groundwater abstractions	
Springs	Alpine, or Alphin Springs 750m NW "Issues" marked at the head of many local streams	
Air quality management zone	No	
Flood zone	Flood zone 1 – low risk	

2.3. Site History

The site is currently one open field, however, the Ordnance Survey map of 1888 indicates a T-junction of field boundaries at the centre of the site, with a further field boundary closer to the west of the site, appearing to separate the ground as it begins to drop more steeply to the base of the valley. The southwestern field is marked as heath/rough pasture, whereas other parts of the site have no distinguishing markings. Trees are indicated in this area on later maps until the 1970s. By 1974 the field boundaries have been removed and no trees remain. An east to west field boundary has been replaced across the centre of the site by the early 1990s. It is still present in 2006, but removed by 2021.

There is little change to the area surrounding the site, other than the construction of the A30 to the south in the early 1990s. Recontouring to the west of West Town Farm is shown by the early 1990s. This corresponds with an area indicated as EA historic landfill, on the Envirocheck report. The area of Herb's Break, further west, which has a series of ponds, is also indicated as an area of historic landfill.

JH Groundwater Ltd report that the site has been disturbed by the importation of soils, which have not been consolidated. The current owners were advised that soil was imported in the late 1990s.

2.4. Proposed Landfill Design

2.4.1. Environment Agency Guidance

The Environment Agency's (EA) approach to groundwater protection, 2018, gives the following guidance.

The EA will normally object to any proposed landfill site in a groundwater SPZ1.
For all other proposed landfill site locations, a risk assessment must be conducted based on the nature and quantity of the wastes and the natural setting and properties of the location. Where this risk assessment demonstrates that active long-term site management is essential to prevent long-term groundwater pollution, the Environment Agency will object to sites:

- *below the water table in any strata where the groundwater provides an important contribution to river flow, or other sensitive receptors*
- *within SPZ2 or 3*
- *on or in a principal aquifer.*

Lower Hare Farm will not be constructed below the water table. It does not fall within an SPZ, or over a principal aquifer.

2.4.2. Imported Waste Types

The permit application is for landfilling of inert wastes. The wastes will meet inert waste acceptance criteria and therefore, there will be no requirement for leachate management. Details of waste acceptance procedures are presented in the Operational Working Plan, AAe reference 213189/OP. The acceptable waste codes for landfilling are given in Table 7.

2.4.3. Basal Construction

The landfill construction will bring an undulating and disturbed topography to a more even surface to promote agriculture. The existing site is underlain by mudstones of the Ashton Mudstone Member. It is proposed to leave all mudstone in situ.

Topsoil will be stripped. Inert materials previously imported as haul road materials, will be levelled and stripped as appropriate to allow engineering of the geological barrier. Any unsuitable material, such as bricks, will be replaced within the engineered landfill cell.

The geological barrier will be engineered from imported inert waste materials. This will be undertaken as a waste recovery activity. The Waste Recovery Plan, AAe reference 213189/WRP, is submitted as part of the environmental permit application. Inert materials for the geological barrier will be selected on the basis of their engineering properties. Waste acceptance procedures will place stricter controls on the organic content of the incoming inert waste than those allowed by the inert Waste Acceptance Criteria (WAC). However, for the purposes of this risk assessment, all incoming wastes are assumed to have the same leaching potential, to add conservatism to the risk assessment.

Figure 2 shows the limit of fill within the site. As there will be no excavation and removal of minerals, the basal footprint will be equal to the top area of the landfill.

2.4.4. Landfill Phasing

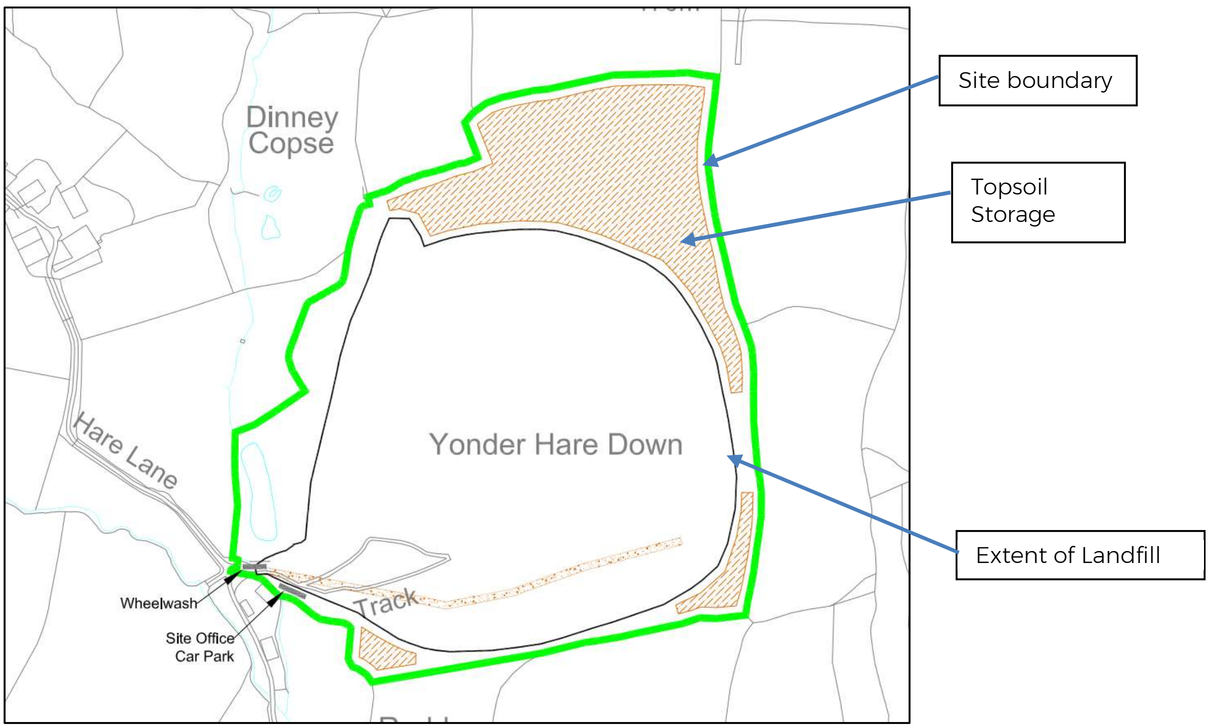
The landfill will be developed in 3 phases. Phase 1 in the northern third of the site (refer to Drawing 213189-D-PH1-001 Phase 1 Overview) principally comprises enabling works. Field habitats will be improved and hedgebanks constructed. Engineering fill, imported as inert waste, will be placed to form the northern boundary of phase 2. No landfill waste will be placed in this phase.

Phase 2 will form the central portion of the site, filled from west to east (refer to Drawing 213189-D-PH2-001A Phase 2 Overview) . Topsoil will be stripped from the existing field. A 1m thick geological barrier will be engineered from suitable waste materials (refer to the Waste Recovery Plan, 213189-WRP) and placed over the stripped area. Landfilled inert waste will be placed to within 1.25m of the final restoration level. The final 1.25m will be restoration soils managed in line with the Restoration Plan as a waste recovery activity.

Phase 3 will initially hold surface water lagoons to assist with management of earlier phases.

These will be removed as Phase 2 reaches completion and infilled with engineered fill as described in the Operational Plan. Specific criteria will apply to this material as it will be placed below the geological barrier. Once this is complete the 1m thick engineered geological barrier will be constructed over the base of Phase 3. Refer to Drawing 213189-D-PH3-001 Phase 3 Overview. The construction and infilling of the lagoons will serve to strengthen ground which has previously been found to soften in wetter periods of the year and will form a more even subgrade for the geological barrier. The final 1.25m of materials will be restoration soils placed as a waste recovery activity.

Figure 2: Landfill Area (taken from AAe drawing 213189/D/004)

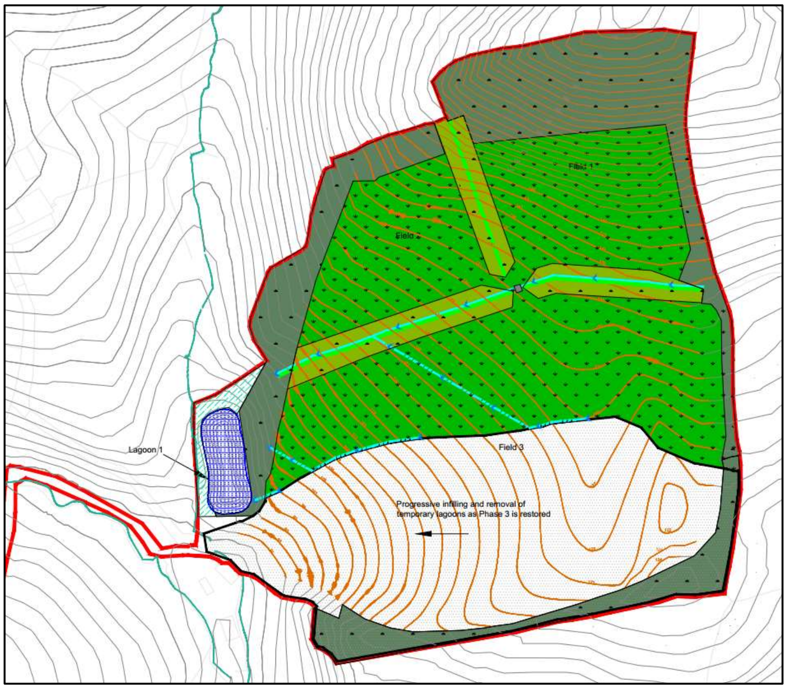


2.4.5. Restoration

Figure 3 presents an overview of the landfill in its final stage of restoration. The restoration contours are shown. Phase 1 has been completed with Fields 1 and 2 and associated hedgebanks. Phase 2 is restored as the central area of agricultural field. Phase 3 is filled progressively from east to west, prior to completion as the southern area of agricultural field.

A Restoration Plan is presented as AAe report reference 213189/RP. A Restoration Controlled Waters Risk Assessment is presented as report reference 213189/RCWRA.

Figure 3: Overview of Landfill Restoration



3. Geology and Hydrogeology

3.1. Geology

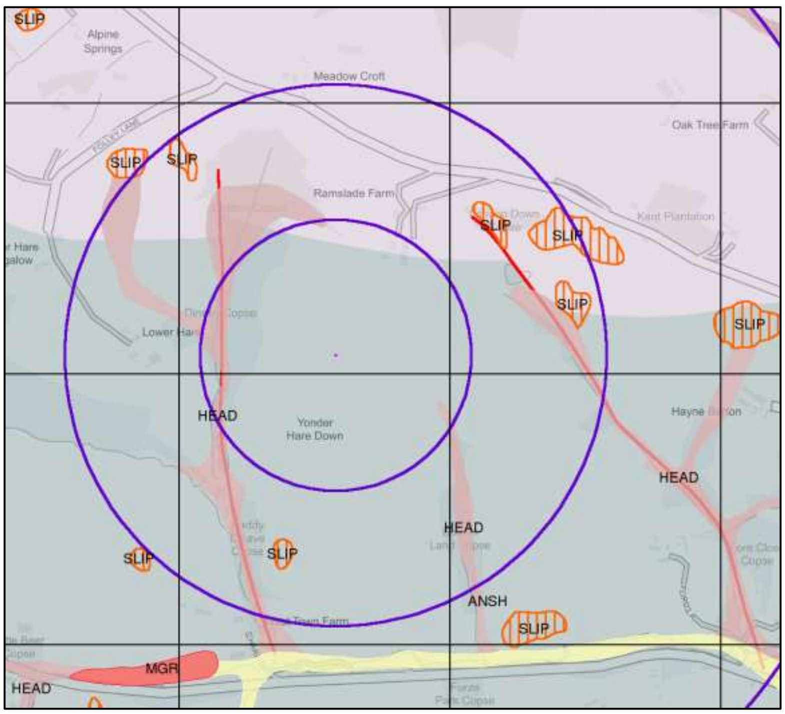
3.1.1. Site Geology

Geological information has been obtained from the British Geological Survey (BGS) Geology of Britain Viewer and an Envirocheck report of the site. Superficial deposits of Head (sand with clay and gravel) are found in narrow deposits within the base of local valleys. This includes the north to south trending valley on the west of the site, which joins the Alphin Brook further south. Head is also found in the shorter valley southeast of the site, which cuts south from Bottom Land Copse to join the Alphin Brook, further south along Five Mile Hill Road.

The underlying bedrock geology is the Carboniferous Ashton Mudstone Member. The BGS Lexicon of Named Rock Units indicates a previous name to be the Ashton Shale Member of the Crackington Formation, with the Ashton Shale being the base of the Crackington Formation. Approximately 50m north of the site, around the location of Gratton House and Ramslade Farm, the now separately named Crackington Formation of interbedded mudstone and sandstone is in outcrop. The contact between the two units trends roughly east to west. There is a fault trending north to south along the valley to the west of the site. There is a further fault beginning southeast of Ramslade Farm and trending southeast along a valley to Landhayes and Pound Lane. The BGS Sheet 325 of Exeter indicates the strata of the Ashton Mudstone member to be sharply folded in this area. Dips of 40 degrees to the north are recorded west of the site and vertical strata are recorded to the east.

Figure 4 presents an extract of the geological information from the Envirocheck report, with faults shown in red.

Figure 4: Geological information.



3.1.2. Site Investigations

In September 2021, AAe installed a series of four boreholes around the perimeter of the site. A dual installation was placed in each location, with a deep 50mm piezometer slotted for the basal 5m and a shallow 50mm standpipe for monitoring of gas conditions above the groundwater level. The ground conditions encountered are summarised in Table 2.

Table 2: Ground Conditions

Stratum	Depth to base (m)	Thickness	Description
Top soil	0.4	0 – 0.4	Topsoil was encountered in BH101 only, described as topsoil with made ground
Clay (Ashton Mudstone Member)	0.8 - 21	0.4 - 21	BH101 – 0.4m grey silty clay BH102 – 4m stiff grey clay BH103 – silty grey clay to 2.5m; clay/mudstone to 6m, stiff grey clay to 21m BH104 – grey silty clay to 0.7m, stiff grey clay to 1.2m
Mudstone (Ashton Mudstone Member)	16 - > 25	4 - >13.8	Grey mudstone, with narrow bands of soft clay in places
Igneous - unknown	> 18	>2	2m of grey igneous rock encountered in BH102 only

All boreholes were found to have clay overlying mudstone. This is assumed to be the weathered Ashton Mudstone Member. The clay was very variable in thickness, with the thickest clay encountered in the deepest, most upgradient borehole. The top of the mudstone was found at 115m AOD in BH103, which was similar to the top of mudstone in BH102 (also upgradient, where it was encountered at 118m AOD. The borehole logs are presented as Appendix 2.

Grey igneous rock was encountered in BH102 only. The full thickness was not penetrated. Basalt is shown by the BGS to be present within Permian rocks on the west of Exeter. No igneous rocks are mapped as being within the boundaries of the site itself.

3.2. Hydrogeology

3.2.1. General Properties

The Ashton Mudstone Member is designated as a Secondary A aquifer. Surface soils are designated as high vulnerability as shown on the Envirocheck report. There are no groundwater source protection zones (SPZs) associated with the site, however, there are a number of licensed local abstractions, refer to Table 1. Many of these are linked to springs and wells. Those north of the site are largely within the outcrop of the Crackington Formation, where the interbedded sandstones and mudstones may cause springs to arise at changes in permeability within the sequence. The BGS have records of one borehole to the northwest of the site, North of Folley Lane and south of Alpine Springs. This is recorded as 40m deep, hard grey and black shales throughout. The well record indicates that the borehole was put down through the base on an existing well shaft. Water was struck at approximately 30m, with a rest water level of 16m below ground level (bgl). The well was pump tested at a rate of approximately 1m^3 per hour.

3.2.2. Hydraulic Conductivity

The Ashton Mudstone Member is not listed as a minor aquifer in the BGS Minor Aquifers technical report of 1997, see references, however, the Crackington Formation is listed. This is assumed to include the Ashton Mudstone Member, as the BGS Memoir for the area (Sheet 325, see references) still refers to the Ashton Shale as part of the Crackington in 1999. The BGS Minor Aquifers report states the following:

There are a total of 26 Crackington Formation sites of which only two have been tested twice. Transmissivities range from 0.2 to 93 m2/d, all but three of the values being below 10 m2/d. This is reflected in the interquartile range of only 1 to 6 m2/d and arithmetic mean, geometric mean and median of 7.7, 2.8 and 3.0 m2/d respectively.

The thickness of the Ashton Mudstone is given as between 250 and 430m on the BGS Sheet for Exeter. However, the BGS Minor Aquifers reports that the effective aquifer thickness is likely to be less than the water-filled borehole depth. Borehole records from the BGS Geology of Britain viewer in the vicinity of the site are between 30 and 60m depth, with rest water levels around 7-8m bgl. This would give an average aquifer thickness of around 40m. Using 40m as the effective thickness with the derived values of transmissivity given by the BGS above, the potential range of hydraulic conductivities for the Ashton Mudstone Member are presented in Table 3.

Table 3: Values for Hydraulic Conductivity of the Ashton Mudstone

Value from BGS Minor Aquifers	Transmissivity (m2/d)	Aquifer thickness (m)	Hydraulic conductivity (m/s)
Minimum	0.2	40	5.79E-08
Lower interquartile (Q1)	1	40	2.89E-07
Geometric mean	2.8	40	8.10E-07
Median (Q2)	3	40	8.68E-07
Upper interquartile (Q3)	6	40	1.74E-06
Arithmetic mean	7.7	40	2.23E-06
Maximum	93	40	2.69E-05

3.2.3. Local Hydrogeology

A site investigation was undertaken by AAe in September 2021. Four groundwater boreholes were constructed, with two up and two downgradient. Borehole BH102, in the southeast, is closest to where the waste will be at its thickest. The borehole was constructed to be approximately 5m below the landfill base, a depth of 18 m. BH103 is on higher ground to the north, so was deepened to 25m. The two downgradient boreholes were taken to a basal elevation of around 80m AOD, to be approximately 10m below the landfill and 5m below the prevailing groundwater level. Groundwater level data is presented in Table 4. Groundwater was found to be between 5.5 and 7.5m below ground level (bgl) in all locations. The monitoring data has been used to draw groundwater contours as presented in Figure 5.

Table 4: Groundwater Level Data

	BH01	BH02	BH03	BH04
22.09.21	85.118	115.31	130.54	91.888
30.09.21	85.308	115.37	130.64	91.868
05.10.21	85.568	114.37	130.7	91.968
14.10.21	85.328	115.23	130.72	92.078
20.10.21	85.478	115.27	130.77	92.128
03.11.21	85.848	115.34	131.18	92.598
01.12.21	85.418	115.28	131.92	92.438
16.02.22	85.788	115.67	132.03	92.558
16.03.22	86.068	115.81	131.78	92.788
06.04.22	85.418	115.86	131.69	92.568
12.05.22	85.208	115.21	130.93	92.098

Figure 5: Groundwater Contours

Groundwater levels fall by approximately 30m between BH01 and BH02, over a distance of 220m. This gives a hydraulic gradient of 0.136.

A conceptual model of the site is presented as AAe Drawing 213189-CSM-D-001, refer to Appendix 1.

Groundwater quality is summarised in Table 5, based on data from the monitoring events. The full dataset is presented in Appendix 3.

Table 5: Groundwater Quality Monitoring Data

Determinand	Units	BH101 Min	BH101 Max	BH101 Ave	BH102 Min	BH102 Max	BH102 Ave	BH103 Min	BH103 Max	BH103 Ave	BH104 Min	BH104 Max	BH104 Ave
pH		6.7	8.6	7.40	6.8	8.6	7.28	7.1	8.5	7.66	7.1	8.5	7.51
Electrical Conductivity	µS/cm	180	1700	490.00	290	450	378.18	310	520	433.64	250	330	297.00
BOD	mg O2/l	4	6	4.18	4	6	4.18	4	8	4.45	4	6	4.30
COD	mg O2/l	10	42	17.36	10	120	21.55	10	27	12.00	10	15	11.30
Chloride	mg/l	16	61	34.45	26	120	46.18	16	26	19.73	19	27	21.70
Fluoride	mg/l	0.11	0.46	0.16	0.12	2.3	0.34	0.19	0.54	0.45	0.13	2.1	0.34
Ammoniacal Nitrogen	mg/l	0.05	6.5	1.17	0.06	5.5	0.78	0.1	5.8	0.83	0.05	3.9	0.89
Sulphate	mg/l	16	22	18.18	24	79	32.18	22	44	26.73	16	27	19.70
Cyanide (Total)	mg/l	0.05	0.24	0.07	0.05	0.1	0.06	0.05	0.08	0.05	0.05	0.07	0.05
Total Hardness as CaCO3	mg/l	56	100	75.36	86	140	115.45	100	230	194.55	87	120	109.60
Arsenic (Dis)	µg/l	0.2	0.54	0.25	0.2	0.77	0.38	0.2	3.2	1.52	0.2	0.2	0.20
Boron (Dis)	µg/l	10	780	94.73	10	43	28.27	10	93	62.73	11	51	37.00
Cadmium (Dis)	µg/l	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Chromium (Dis)	µg/l	0.5	8	1.18	0.5	4.3	0.85	0.5	5.7	1.03	0.5	5	0.95
Copper (Dis)	µg/l	0.5	2.4	0.71	0.5	1.5	0.59	0.5	1.8	0.68	0.5	1.9	0.74
Mercury (Dis)	µg/l	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nickel (Dis)	µg/l	8.5	19	13.14	19	33	29.00	6.8	17	10.48	22	34	27.50
Lead (Dis)	µg/l	0.5	0.52	0.50	0.5	0.5	0.50	0.5	1.5	0.66	0.5	0.5	0.50
Selenium (Dis)	µg/l	0.5	2	0.64	0.5	23	2.55	0.5	0.85	0.58	0.5	0.5	0.50
Vanadium (Dis)	µg/l	0.5	2.7	0.70	0.5	0.52	0.50	0.5	1.8	0.62	0.5	0.5	0.50
Zinc (Dis)	µg/l	5.3	30	19.19	4	30	10.96	2.5	5.8	3.73	2.5	23	6.44
Chromium vi	µg/l	0.1	20	18.01	0.1	96	25.61	0.1	20	18.01	0.1	20	17.79

Table 5 shows the groundwater chemistry to be largely clean, with chloride and sulphate concentrations around 16 - 120 mg/l, which is much lower than the UK Drinking Water Standard (UKDWS) and the freshwater Environmental Quality Standard (EQS). The average concentration for ammoniacal nitrogen is approximately twice the UKDWS in all boreholes, with maximum concentrations up to 6.5 mg/l. This may be connected to the agricultural setting.

Cyanide has been found to be just above the detection limit in all locations, but this has only occurred once in each location. Metallic determinands are generally below the laboratory limit of detection (LOD). Arsenic and lead are hazardous substances. Arsenic has been detected in BH101- BH103 above LOD (>0.2ug/l). The UKTAG limit of quantification (LOQ) of 5 ug/l has not been exceeded, with the highest recorded concentration of 3.2 ug/l in BH103 upgradient. Lead has been recorded above LOD in BH101 at 0.52 ug/l and in BH103 at 1.3 – 1.5 ug/l. The UKTAG LOQ is 0.2 ug/l.

Of the remaining metallic determinands boron, nickel and zinc are commonly found above LOD. Nickel and zinc exceed the EQS. It is noted that the measured concentrations are dissolved concentrations, whereas the EQS is for the bioavailable nickel and zinc, which will be a lower concentration. Copper and chromium are found to exceed the LOD on one or two occasions in each borehole.

Hydrocarbons are generally found to be below LOD in all boreholes. Traces of total petroleum hydrocarbons (TPH) were found in the May 2022 monitoring, but on retest all results were below LOD. A concentration of 4700 ug/l TPH was recorded in BH103 on one occasion. This appears to be an anomaly. Traces of toluene were found just above the LOD of 1 ug/l in all boreholes except BH103 in April 2022. Occasional traces of polyaromatic hydrocarbons (PAHs) have been found in all boreholes, but these are limited to fluoranthene, pyrene and naphthalene and only on one occasion in each location.

The data used to generate Table 5 is provided in Excel format as part of the permit application process, file reference 1776 HRA Appendix 3 GWQ.

3.3. Hydrology

Ground levels surrounding the site fall from approximately 170m AOD in the north to approximately 95m AOD in the southwest. The western side of the site drains towards the tributary stream of the Alphin Brook. Just north of the site access track there is a narrow pond aligned north to south along the western boundary. The tributary stream joins the Alphin Brook approximately 100m south of the site's access track. From here the Alphin Brook flows south to West Town Farm, where its course turns to flow eastwards, just north of the road named Mile High Hill. Issues to the northeast and southeast of the site mark the head of other streams which flow approximately southwards to join the Alphin Brook. The Alphin Brook flows southeastwards to Alphington, on the outskirts of Exeter, where it joins the course of the River Exe.

There are no surface water abstractions recorded within 2km of the site in the Envirocheck report. There is a spring referred to as Alpine, or Alphin Springs 750m northwest of the site. "Issues" are marked on Ordnance Survey maps at the head of many local streams.

Table 6 presents the average concentrations of the main determinands within the surface waters around the site. The monitoring locations are as shown in Figure 3. The full dataset is presented in Appendix 3. Chloride and sulphate are found at concentrations in the range of approximately 10 – 60mg/l. Ammoniacal nitrogen is often above the UKDWS both up and downgradient of the site. Cyanide has been recorded above LOD in one location upstream. Arsenic, boron, nickel and zinc are above LOD. There is also copper in all samples, which differs to the groundwater chemistry. Hydrocarbons are generally absent from the surface water, with the exception of occasional traces of toluene and naphthalene, both up and downgradient. A retest on TPH in SW4 showed concentrations less than LOD.

Table 6: Surface Water Quality

Date		Upstream N	Upstream W	Downstream	Pond
		SW1	SW2	SW3	SW4
Determinand	Units				
pH		7.93	8.08	8.05	7.85
Electrical Conductivity	µS/cm	386.67	300.00	340.00	338.33
Suspended Solids At 105C	mg/l	112.20	32.40	72.80	67.00
BOD (mg O2/l)	mg/l	4.00	4.00	4.00	4.00
COD (mg O2/l)	mg/l	18.00	17.83	18.33	34.50
Chloride	mg/l	30.50	32.00	28.33	36.33
Fluoride	mg/l	0.19	0.17	0.18	0.23
Ammoniacal Nitrogen	mg/l	0.55	2.29	1.15	1.30
Sulphate	mg/l	25.33	25.67	26.17	16.60
Cyanide (Total)	mg/l	0.05	0.10	0.05	0.05
Total Hardness as CaCO3	mg/l	112.67	105.17	124.50	134.50
Arsenic (Dissolved)	µg/l	0.30	0.29	0.33	0.72
Boron (Dissolved)	µg/l	30.17	27.50	27.50	34.17
Cadmium (Dissolved)	µg/l	0.11	0.11	0.11	0.11
Chromium (Dissolved)	µg/l	4.63	5.75	5.35	4.05
Copper (Dissolved)	µg/l	2.68	2.59	2.63	3.18
Mercury (Dissolved)	µg/l	0.05	0.05	0.05	0.05
Nickel (Dissolved)	µg/l	3.63	3.88	3.80	10.97
Lead (Dissolved)	µg/l	0.50	0.50	0.55	0.65
Selenium (Dissolved)	µg/l	0.50	0.50	0.50	0.50
Vanadium (Dissolved)	µg/l	0.50	0.51	0.52	0.67
Zinc (Dissolved)	µg/l	3.55	3.43	3.03	9.15
Chromium (Hexavalent)	µg/l	17.53	17.69	17.70	17.37

During the construction of the landfill additional temporary surface water management lagoons (lagoons 2 and 3) will be constructed in Phase 3. The design is described in AAe: 2022: Detailed Drainage Design, Report reference 213189/DC/001. These lagoons will drain west into the existing western pond. There will also be an ecological pond constructed as part of the permanent restoration in the southeast of the site.

4. Conceptual Hydrogeological Site Model

4.1. Sources

The source in this assessment is inert wastes imported to reprofile disturbed ground. Wastes will be placed above the original ground level and therefore, above groundwater level. Inert waste will be imported as a recovery activity to form the preparatory/enabling engineering works in Phase 1. There will be slight reprofiling of Fields 1 and 2 in the north of the site and the engineering of a hedgebank between Phase 1 and 2. Inert waste will also be imported as a recovery activity to form the geological barrier. The waste imported for engineering works as a recovery activity will be selected on the basis of its engineering properties and organic content below that of inert WAC.

The construction of the geological barrier will allow the landfilling of inert wastes in Phases 2 and 3. The restoration profile, refer to Figure 3, together with the original ground levels are used to derive waste thickness. The thickness of the source will vary across the site.

- In Phase 1 there will be very little thickness of waste in the north, increasing to around 4m where the engineered fill will be placed to support the geological barrier in Phase 2. Refer to Drawing 213189-D-PH1-002 Phase 1 Detail.
- The waste thickness in Phase 2 will be up to approximately 8m. Refer to Drawing 213189-D-PH2-002 Phase 2 Detail.
- In Phase 3 the waste will reach up to 14m, where a shallow dry valley feature is infilled. Refer to Drawing 213189-D-PH2-002 Phase 3 Detail.

The waste acceptance criteria for inert waste to be used in the enabling works for Phase 1 and in the geological barrier will be more restrictive than for the landfilled wastes. However, to add conservatism to this risk assessment it is assumed that all inert waste used in Phases 1 to 3 will constitute the source. The attenuation properties for the engineered liner are halved for all determinands to add conservatism into the assessment and differentiate the liner from the underlying natural ground.

It is noted that in Drawing 213189-D-PH2-002 Phase 3 Detail, the line of section A-AA goes through the temporary drainage lagoons, which will be constructed in this phase to assist with surface water management in the earlier phases of the site. Prior to construction of the geological barrier in Phase 3, these ponds will be emptied and backfilled with engineered fill.

The fill will be selected such that it has a pollution potential less than, or equal to, the natural quality of the surrounding geology and water. This is described in more detail in the Operational Plan. As such, the pond infill material is not considered part of the source in this assessment.

Council Directive 2003/33/EC lists those wastes which may be accepted at inert landfills without testing. The proposed codes for the inert landfill are presented in Table 7, which includes wastes that are considered inert without testing and wastes which will be subjected to testing in accordance with the site's waste acceptance procedures, refer to the Operational Working Plan, AAe report reference 213189/OP and Importation Protocol 213189/IP.

Table 7: Proposed Inert Waste Codes

Description	EWC code
Acceptable Inert Materials	
Wastes from glass-based fibrous material	10 11 03
Glass packaging	15 01 07
Concrete	17 01 01
Bricks	17 01 02
Tiles and ceramics	17 01 03
Mixtures of concrete, bricks, tiles and ceramics	17 01 07
Glass	17 02 02
Soils and stones (natural arisings confirmed by inspection, not including peat and topsoil and not from contaminated sites)	17 05 04 20 02 02
Potentially Acceptable Materials	
Wastes from mineral non-metalliferous excavation	01 01 02
Waste gravel and crushed rocks	01 04 08
Waste sand and clays	01 04 09
Waste ceramics, bricks, tiles and construction products (after thermal processing)	10 12 08
Track ballast	17 05 08
Soil and stones from brownfield land	17 05 04 or 20 02 02
Sludges from physical treatment (limited to soil washing silts only)	19 02 06
Minerals from waste facilities	19 12 09
Soils from waste treatment process	19 12 12
Solids from soil remediation	19 13 02

Waste Acceptance Criteria (WAC) are expressed as mg/kg within the incoming wastes, but the majority of determinands are tested for their potential to leach from the waste. An equivalent leachate concentration in mg/l is 10% of the WAC concentration expressed in mg/kg. Council Directive 2003/33/EC also presents "first flush" leachate concentrations (C_o) and these are incorporated into the leachate source term. For organic determinands an equivalent leachability and C_o concentration is available for phenol. Other organics are limited by a total soil concentration.

Table 8: Waste Acceptance Criteria for Leachates

Determinand	WAC Leachate Criteria (LS=10l/kg) (mg/kg)	Equivalent leachability (mg/l)	Co concentration 2.1.2.1 2003/33/EC (mg/l)	EAL (mg/l) Lower of UKDWS and EQS
Arsenic (total)	0.5	0.05	0.06	0.01 UKDWS
Barium (total)	20	2	4	0.7 [1]
Cadmium (total)	0.04	0.004	0.02	0.00009 EQS
Chromium (total)	0.5	0.05	0.1	0.0047 EQS
Copper (total)	2.0	0.2	0.6	0.001 EQS
Mercury (inorganic)	0.01	0.001	0.002	0.00007 EQS
Molybdenum (total)	0.5	0.05	0.2	0.07 [1]
Nickel (total)	0.4	0.04	0.12	0.004 EQS
Lead (total)	0.5	0.05	0.15	0.0012 EQS
Antimony (total)	0.06	0.006	0.1	0.005 UKDWS
Selenium (total)	0.1	0.01	0.04	0.01 UKDWS
Zinc (total)	4.0	0.4	1.2	0.0109 2 EQS
Chloride (total)	800	80	460	250 UKDWS/EQS
Fluoride (total)	10	1	2.5	1.5 UKDWS
Sulphate (as SO4)*	1000	100	1500	250 UKDWS
TDS	4000	n/a	n/a	n/a
Phenol Index	1.0	0.1	0.3	0.0077 EQS

1- World Health Organisation (WHO) Molybdenum is a health-based value as no guideline available
The values of TDS can be used instead of Cl or SO4.

In most instances, as demonstrated by Table 8 the equivalent leachability, or Co concentration exceeds the EAL (see highlighted cells) and therefore, it must be demonstrated that sufficient attenuation is available below the wastes.

4.2. Pathway

A geological barrier of thickness 1m and maximum permeability 1 x 10^{-7} m/s will be engineered from suitable inert waste prior to the receipt of general inert wastes. The engineered geological barrier will be included within the Landsim model. However, to add conservatism, the retardation properties of the geological barrier will be set to half that of the natural strata.

Below the geological barrier will be a thickness of Ashton Mudstone, which has been recorded as clay close to surface and to substantial depth in the north of the site, becoming mudstone with depth. Boreholes have recorded groundwater at depths of between approximately 5 and 7.5m bgl. The permeability of the unsaturated zone will be relatively low in predominantly clay strata. Permeability will be governed by the presence of fissures and fractures, which are likely to be few close to surface, where the mudstone is weathered to clay.

The Ashton Mudstone is classed as a secondary aquifer locally, indicating that hydraulic conductivity is enhanced due to fissures and fractures. The range of likely values for hydraulic conductivity are presented in Table 3.

The Environmental Permitting Regulations 2016 require that there is no discernible discharge of hazardous substances to groundwater and therefore, the pathway for hazardous substances is limited to the base of the unsaturated zone. For non-hazardous pollutants it is required that input is limited to ensure there is no pollution. Non-hazardous pollutants are, therefore, assessed once they have entered the aquifer, but the length of pathway will be limited to a position on the downgradient boundary of the site. Refer to section 5 for more details of the risk assessment modelling.

4.3. Receptor

The relevant receptors for this assessment are the groundwaters of the Ashton Mudstone Member and the surface waters of the Alphin Brook, which is approximately 20m downgradient of the site at its closest point. The modelled receptor will be a theoretical receptor on the boundary of the site.

Based on these receptors, the lower value of either the UK Drinking Water Standards (UKDWS), given in the Water Supply (Water Quality) Regulations 2018, or the freshwater Environmental Quality Standards (EQS) is considered to be the appropriate Environmental Assessment level (EAL).

5. Hydrogeological Risk Assessment

5.1. The Nature of the Hydrogeological Risk Assessment

Environment Agency guidance on landfill developments (EA webpage accessed November 2021 https://www.gov.uk/guidance/landfill-operators-environmental-permits/landfills-for-inert-waste) indicates that, if an inert waste landfill is in a sensitive area, such as in an aquifer, source protection zone (SPZ), or below the water table, then a simple risk assessment is insufficient and a more detailed risk assessment is required. Lower Hare Farm is located above a secondary aquifer. A more detailed risk assessment is required and Environment Agency approved Landsim is proposed as the assessment tool.

5.2. The proposed assessment scenarios

It is proposed that the site will be an inert landfill, with a geological barrier engineered as a waste recovery activity. There will be no requirement for long-term management controls. The geological barrier will have an engineered permeability of 1 x 10-7 m/s within the Landsim model. The underlying unsaturated zone will be assessed to determine the degree to which attenuation can be provided before potential contaminants reach the saturated zone. Scenario 1 will assess the site as it is designed to operate. Incoming landfilled waste and inert waste for engineering will be assumed to meet inert WAC. Additional modelled scenarios (models RLA1 and RLA2) will examine the potential for wastes to be received unknowingly in exceedance of the inert WAC. This is often referred to as a rogue load assessment.

5.3. The Priority Contaminants

The selected priority contaminants are derived from those listed within the inert waste acceptance criteria to which a leachate limit is applied and where this limit exceeds the EAL as presented in Table 6. These determinands are listed below:

Non-hazardous pollutants: Barium, Cadmium, Chromium, Nickel, Selenium, Zinc, Chloride, Fluoride, Sulphate,
Hazardous substances: Arsenic, Lead and Mercury
Organic contaminant: Phenol

5.4. Review of Technical Precautions

The technical precautions appropriate to an inert landfill are:

- A geological barrier, of 1m thickness and a maximum permeability of 1 x 10^{-7} m/s;
- Suitable capping to support the designated end use.

A leachate containment system is not required. The permeability of the geological barrier will control the rate of release of any leachate, but prevent a build-up, which would require long term management. The Landsim model confirms that at the end of the management control period the water balance within the model generates zero head of leachate. This is illustrated manually as follows:

The surface area of the landfill is approximately 6.45 ha (64500 m^2).
The effective rainfall is 521 mm per annum (1.65×10^{-8} m/s).
Therefore, the rainfall infiltration is 1.11×10^{-3} m^3/s.. Q_{rain}

The base of the landfill, is the same as the surface/cap = 64500m^2.
The maximum permeability is 1×10^{-7} m/s.
Therefore, the basal seepage is 6.45×10^{-3} m^3/s... Q_{seep}

The basal seepage (Q_{seep}) is 6 times greater than the rainfall infiltration (Q_{rain}). Therefore, it is unlikely that there will be a build-up of leachate at the base of the landfill.

5.5. Justification for Modelling Approach and Software

Landsim has been selected as the assessment tool for the inert landfill. This is also an Environment Agency approved assessment tool. The Landsim model allows the selection of properties for the geological barrier separate to those of the rest of the unsaturated zone.

5.6. Model Parameterisation

Input parameters are sourced from site information where possible. Where there is insufficient site specific data, values are sourced from literature, much of which is described in the preceding sections of this report. The leachate source term is derived from inert waste acceptance criteria and includes the higher Co values, to include conservatism to the leachate concentration. The leachate source chemistry is presented in Table 9. For metals, which are generally more easily attenuated, the Co concentration is used as the source concentration. For other determinands a range is used between the inert WAC equivalent leachability (EL) and the higher EQS, or Co values. General input parameters are presented in Table 10.

Table 9: Landsim Input Criteria, Leachate

Determinand	Modelled concentration (mg/l)	Comment	* Partition coefficient (ml/g)	Justification
Arsenic	0.06	Co	Uni (117, 249.6) [1]	Consim – unspecified-glacial till
Barium	4	Co	Uni (11,52) [2]	Range from USEPA as no value for sand, or unspecified in Consim

Determinand	Modelled concentration (mg/l)	Comment	* Partition coefficient (ml/g)	Justification
Cadmium	0.02	Co	Uni (222.2, 240) [1]	Consim – glacial till - unspecified
Chromium	0.1	Co	Uni (35, 965.6) [1]	Consim unspecified – glacial till
Copper	0.6	Co	Uni (126.8, 295)	Consim (glacial till – unspecified)
Mercury	0.002	Co	3835.4 [1]	Consim glacial till
Nickel	0.12	Co	Uni (66, 85.7) [1]	Consim unspecified – glacial till
Lead	0.15	Co	434.6 [1]	Consim – glacial till
Selenium	0.04	Co	9.5 [1]	Consim unspecified
Zinc	1.2	Co	Uni (20.7, 26) [1]	Consim glacial till - unspecified
Chloride	460	Co	-	No retardation assumed
Fluoride	2.5	Co	0.8 [1]	Consim glacial till
Sulphate (as SO4)	Tri (100, 750, 1500)	Tri (EL,0.5Co, Co)	-	No retardation assumed
Phenol	0.3	Co	Koc=27, foc for clay / Mst = 0.01 [1]	From Consim ranges for clay and Mercia Mst
Phenol half life	Engineered barrier: Uni (0.03, 0.82) [1]			Aerobic to anaerobic
Phenol half life	Unsaturated: Uni (0.03, 0.27) [1]			Aerobic- as less compacted
Notes	Phenol half life: potential anaerobic conditions allowed for at base of waste in engineered barrier			

1 = Consim Help File
2 = US EPA : 1996 : Soil Screening Guidelines: Technical Background Document
*Is it also noted that the partition coefficient is halved within the geological barrier, to add conservatism to the assessment, as the barrier will be made from waste materials.

Table 10: Landsim Input Parameters

Parameter	Unit	Value	Source
Waste			
Infiltration to open waste	mm/yr	Norm (521,52)	Effective rainfall: ADAS 1982. Area 43S
Cap design infiltration	mm/yr	Norm (250,25)	Low permeability capping not required. Value half of effective rainfall as restored profile will encourage runoff
End of filling	yr	10	Operational life of the site assumed to be 10 years
Cell dimensions	ha	6.45	Top is same as base, but Landsim requires base to be smaller. Base = 300 x 215 = 6.45ha Top – auto calculated as 6.72 ha

Parameter	Unit	Value	Source
Thickness	m	Tri (0,8,14)	Conservative – derived from restoration contours and sections.
Waste porosity	fraction	Uni (0.2, 0.4)	Inert waste
Waste Dry Density	g/cm³	Uni (1.15, 1.25)	Inert waste
Waste field capacity	fraction	Uni (0.2, 0.4)	Inert waste
Head of leachate when breakout occurs	m	1	Conservative – the base of the landfill slopes to the W-E valley feature, which is 5 – 14 m below the surrounding ground level. A head of 1m could apply on the north and west perimeters as worst case.
Drainage System			
Head on EBS	m	Tri (0.079, 0.15, 0.4)	Initial starting point as leachate build up unlikely – refer to water balance calculations, section 5.4 and model results for head on EBS after management control ceases
Waste hydraulic conductivity	m/s	Uni ($1e^{-7}$, $1e^{-3}$)	Silt to gravel
Primary drainage system		None	No leachate drainage required for inert landfills
Sump diameter	m	300	No sump. Value input to represent whole cell base.
Geological barrier			
Thickness	m	1	Landfill design requirement
Moisture content	fraction	0.15	Assumed for imported inert waste
Hydraulic conductivity	m/s	$1e^{-7}$	Landfill design requirement
Longitudinal dispersivity	m	0.1	10% pathway length
Density	kg/l	1.8	Assumed for imported inert waste engineered to meet requirements of CQA Plan
Unsaturated zone – Ashton Mudstone Member			
Thickness	m	Uni (5, 7.5)	Based on monitoring data.
Moisture content	fraction	0.15	Assumed for mudstone
Hydraulic conductivity	m/s	2.89e-7	Refer to Table 3
Longitudinal dispersivity	m	Uni (0.5, 0.75)	10% of path length
Aquifer Pathway			
Pathway width	m	215	Site width perpendicular to flow
Thickness	m	170	BGS Sheet 325 gives thickness of 250m. 80m topographical difference across site suggests removal by erosion likely
Density	kg/l	1.8	Assumed for mudstone
Mixing zone thickness	m	40	Effective aquifer thickness, refer to BGS Minor aquifers.
Relative vertical dispersivity	-	1	1% of pathway length

Parameter	Unit	Value	Source
Hydraulic conductivity	m/s	Tri (1.74e-6, 2.23e-6, 2.69e-5)	Refer to Table 3
Hydraulic gradient	-	0.136	Groundwater level falls from 115 to 85m AOD over 300m
Pathway porosity	fraction	0.1	Mudstone/shale
Distance to receptor	m	5	Distance to default receptor
Longitudinal dispersivity	m	0.5	10% of pathway length
Lateral dispersivity	m	0.05	10% of longitudinal

5.7. Landsim Sensitivity Analysis and Results

5.7.1. Results

Modelled outputs are presented in Table 11. Results are displayed for arsenic, lead and mercury at the base of the unsaturated zone. Results for all other determinands are assessed at the monitor well. The position of the monitor well is fixed by Landsim to be 5 m downgradient of each landfill phase. In the instance of, Lower Hare Farm the whole site is represented as one cell and therefore, the monitor well is the appropriate point of assessment. The results presented are the 95th percentile peak concentrations, as determined from Landsim graphical outputs.

In addition to the main modelled scenario the sensitivity of two parameters is assessed.

- The cap design infiltration is increased by 20% to 300mm (LHF Sensitivity 1)
- The thickness of the unsaturated zone is halved to a uniform range of 2.5 to 3.5m (LHF Sensitivity 2).

The results show with an increase in the cap design infiltration there is little change to the results. With a decrease in the thickness of the unsaturated zone most results stay the same. There is an increase in concentrations for phenol, but results are still below the EAL.

Table 11: Landsim Model Results and Sensitivity Analysis (mg/l)

Determinand	Scenario 1	Sensitivity 1 Cap design rain increase to 300mm	Sensitivity 2 Unsat thickness 2.5 – 3.5 m	EAL (mg/l) Lower of UKDWS and EQS	LOQ (mg/l)
Arsenic	<1e-8	<1e-8	<1e-8	0.01 [UKDWS]	0.005
Barium	0.006	0.0033	0.0067	0.7 [1]	
Cadmium	<1e-8	<1e-8	<1e-8	0.00009 [EQS]	
Chromium	5.75e-8	<1e-8	<1e-8	0.0047 [EQS]	
Copper	<1e-8	<1e-8	<1e-8	0.001 [EQS]	
Mercury	<1e-8	<1e-8	<1e-8	0.00007 [EQS]	0.00002
Nickel	<1e-8	<1e-8	<1e-8	0.004 [EQS]	
Lead	<1e-8	<1e-8	<1e-8	0.0012 [EQS]	0.0002
Selenium	0.0011	0.001	0.0013	0.01 [UKDWS]	
Zinc	3e-3	1.1e-3	3e-3	0.0109 [2 EQS]	
Chloride	103	105	103	250 [UKDWS/EQS]	
Fluoride	0.6	0.6	0.67	1.5 [UKDWS]	
Sulphate (as SO4)	185	185	198	250 [UKDWS]	
Phenol	4.5e-4	6.5e-4	0.0027	0.0077 [EQS]	

(shaded)	Hazardous substance

[1] – WHO;

Results for hazardous substances are assessed at the base of the unsaturated zone. Results for non-hazardous pollutants are assessed at the monitor well

5.7.2. Model Validation

The model suggests that there will be very little potential for build up of leachate within the wastes. Ongoing visual inspections of the site once operational will be used to validated this assumption.

The model predicts a low likelihood of deterioration in groundwater quality relative to the existing background conditions. Future groundwater monitoring of the site will be used to validate these predictions.

5.7.3. Accidents and their consequences

An accident which requires assessment within an inert landfill is the potential for the site to receive non-inert waste. In order to assess the consequence of such a scenario the Landsim model has been run iteratively to determine the increase in concentrations within the leachate which could be tolerated without adverse impact at the appropriate point of assessment. Leachate concentrations used in the initial scenario have been varied by a factor of up to 2 in rogue load assessment one (RLA1) and up to 10 in RLA2. The increased leachate source concentrations and results are presented in Table 12 below.

It should be noted that, for many determinands, these increases in leachate concentrations for the rogue load assessment are increases above the Co leachate concentration, which is already higher than inert WAC.

The results indicate no exceedances of the EAL for most metallic determinands for an increase in concentration of a factor of 10. Zinc concentrations could be increased 4 or 5 times.

For the non-metallic determinands the following increase in concentrations can be tolerated without exceedance of the EAL at the monitor well:

- Chloride – > 2 x Co concentration;
- Fluoride – > 2 x Co concentration;
- Sulphate – most likely concentration = 1200 mg/l;
- Phenol – 10 x Co concentration.

It should be noted that this is a whole site assessment and therefore, a worst case scenario, as the waste acceptance procedures on site will minimise the likelihood that non-inert waste is accepted and should this occur it is unlikely to affect the entire waste mass. Leachate concentrations used in all models have included the C_o concentrations, which are much higher than the inert WAC criteria. This builds further conservatism into the assessment.

Table 12: Assessment of receipt of non-inert waste

Determinand	Initial Modelled concentration = Co	RLA1 input Source x 2, or as stated	RLA2 input Source x 10, or as stated	RLA1 results	RLA2 results	EAL (mg/l) UKDWS unless stated	LOQ (mg/l)
Arsenic	0.06	0.12	0.6	<1e-8	<1e-8	0.01	0.005
Barium	4	8	40	0.01	0.041	0.7 [1]	
Cadmium	0.02	0.04	0.2	<1e-8	<1e-8	0.005	
Chromium	0.1	0.2	1	<1e-8	<1e-8	0.05	
Copper	0.6	1.2	6	<1e-8	<1e-8		
Mercury	0.002	0.004	0.02	<1e-8	<1e-8	0.001	0.00002
Nickel	0.12	0.24	1.2	<1e-8	<1e-8	0.02	
Lead	0.15	0.3	1.5	<1e-8	<1e-8	0.01	0.0002
Selenium	0.04	0.08	0.4	0.002	0.0094	0.01	
Zinc	1.2	2.4	5	0.0055	0.0085	0.0109 [2] bioavailable + background	
Chloride	460	920	1000	210	242	250	
Fluoride	2.5	5	6	1.2	1.5	1.5	
Sulphate (as SO4)	Tri (100, 750, 1500)	Most likely = 800	Most likely 1200	190	242	250	
Phenol	0.3	0.6	3	9e-4	0.0044	0.0077 [2]	
	Hazardous substance						

[1] – WHO; [2] - EQS

Results for hazardous substances are assessed at the base of the unsaturated zone. Results for non-hazardous pollutants are assessed at the monitor well.

5.8. Emissions to Groundwater

5.8.1. Hazardous Substances

The Landsim modelling and sensitivity analysis shows that the acceptance of inert waste to landfill at Lower Hare Farm should not release discernible concentrations of hazardous substances in to the groundwater. The assessment of accidents in the form of receipt of non-inert waste indicates that there is some tolerance in the inert waste acceptance criteria in relation to this site and the accidental receipt of non-inert waste may not cause discernible discharge of hazardous substances.

5.8.2. Non-hazardous pollutants

The Landsim modelling and sensitivity analysis shows that the acceptance of inert waste at Lower Hare Farm should not cause pollution of groundwater by non-hazardous pollutants. The assessment of accidents in the form of receipt of non-inert waste indicates that there is some tolerance in the inert waste acceptance criteria in relation to this site and the accidental receipt of non-inert waste will not automatically lead to pollution, depending on the volume and concentration of contaminants in the rogue load.

A further assessment has been made in relation to sulphate, which can be high in concentration, above that of the inert WAC, in naturally occurring soils. The initial Landsim model (LHF Scenario 1) has considered a source concentration of (100, 750, 1500) to take into account the Co concentration. It is considered more likely that most leachate will be less than 400 mg/l. The Landsim model has, therefore, been rerun with 400 mg/l sulphate (the EQS) as the maximum concentration, 250 mg/l (the UKDWS) as the most likely concentration and 100 mg/l (the inert WAC) as the minimum concentration. The resulting concentration in the groundwater at the monitor well on the boundary of the site is 64 mg/l. This is much lower than the UKDWS and lower than the maximum concentration recorded in the upgradient groundwater boreholes of 79 mg/l. The 50th percentile concentration is 23 mg/l, which is comparable to the site wide average concentration in groundwater and surface water. It is considered, therefore, that the leachate criterion for sulphate in incoming wastes can be increased above the inert WAC to 250 mg/l on average, with the maximum not exceeding 400 mg/l.

5.9. Emissions to Surface Water

Perimeter ditches will be used to direct rainfall away from the open waste during filling. Temporary lagoons will be constructed in Phase 3 to which surface water will be directed. This is as described in AAe: 2022: Detailed Drainage Design, Report reference 213189/DC/001. These will outfall to the existing pond in the west of the site. The ponds give a point of control prior to any direct release to the tributary of the Alphin Brook.

The Landsim modelling has indicated that there is unlikely to be exceedance of the EQS in the groundwater on the downgradient boundary of the site. If groundwater seepage enters the tributary stream there will be further dilution and therefore, the EQS is less likely to be exceeded.

5.10. Hydrogeological Completion Criteria

The site will receive inert waste and will have no active leachate controls. The Landsim modelling indicates that the site is unlikely to fail to comply with the requirement of the Environmental Permitting Regulations in the absence of leachate control. Therefore, no hydrogeological completion criteria are required.

6. Requisite Surveillance

6.1. The Risk Based Monitoring Scheme

6.1.1. Leachate Monitoring

Leachate infrastructure is not required for an inert landfill and therefore, no leachate monitoring will be undertaken. Visual inspections of the site will be made on a regular basis as good working practice. This will include checks for any unusual seepages, or discolouration in low lying areas of the site that might indicate the landfill is generating unexpected leachate. This will enable investigation and any corrective measures to be undertaken. While this is an unlikely scenario, routine inspections should include such checks rather than assume that the potential for leachate generation is so low as to be disregarded.

6.1.2. Groundwater Monitoring – control and compliance levels

Groundwater monitoring has been undertaken on eleven occasions since September 2021. This data has been used to derive groundwater quality control and compliance levels. The following substances are selected:

Hazardous substances – arsenic, toluene
Non-hazardous pollutants – chloride, nickel, sulphate

The groundwater quality has been assessed using the ESI Soil and Groundwater Statistics Calculator version 2, to determine whether there are outliers in the data. This uses the same techniques as the Environment Agency R+D technical report P1-471, A.3 Statistical Analysis. The outputs are summarised in Appendix 4. The mean and standard deviation are derived after excluding outliers. Control and compliance levels are derived as described below.

Non-hazardous substances
The derived control levels are set at the mean + 2 x standard deviation.
The derived compliance levels are set at the mean + 3 x standard deviation.

Hazardous substances
The selected hazardous substances for compliance are arsenic and toluene. The UK Technical Advisory Group on the Water Framework Directive (UKTAG) gives the limit of quantification (LOQ) for arsenic as 5ug/l. For toluene the LOQ is 0.2 ug/l. All measured concentrations of arsenic are below the LOQ. Therefore, the control level has been set as the maximum. The compliance level has been set as the LOQ.

For toluene there has been one result above LOD in three of the four groundwater boreholes, with a maximum concentration of 1.3 ug/l. These results are considered to be outliers. The current LOD is 1 ug/l. It is proposed that this is used as the compliance level as a review of major laboratories suggests that this is the lowest LOD typically available. There is no UKDWS for toluene and the EQS is 74 ug/l.

The compliance levels are applicable to boreholes BH101 and BH104 on the downgradient side of the site. It is noted, however, that the maximum concentrations of chloride and sulphate have been observed in BH102 upgradient. This borehole encounters different geological conditions to elsewhere on site, with igneous rock encountered at the base of the borehole. Where the maximum concentration in BH102 exceeds the calculated compliance level downgradient, the compliance level will become the maximum concentration upgradient (after outliers have been excluded).

Table 13: Control and Compliance Levels

		As (ug/l)	Toluene (ug/l)		Chloride (mg/l)	Ni (ug/l)	Sulphate (mg/l)
BH101	Min	0.2	1		16	8.5	16
	Max	0.2	1		61	19	22
	Average	0.2	1		34.455	13.136	18.182
	STDEV	0	0		13.441	3.522	2.089
	Control	0.2	1		61.337	20.18	22.36
	Compliance	5	1		74.778	23.702	35
BH102 [1]	Min	0.2	1		26	19	24
	Max	0.77	1		52	33	35
	Average	0.385	1		38.8	29	27.5
	STDEV	0.192	0		8.854	3.768	3.749
BH103 [1]	Min	0.2	1		16	6.8	22
	Max	3.2	1		22	17	29
	Average	1.522	1		19.1	10.482	25
	STDEV	0.985	0		1.912	3.802	2.667
BH104	Min	0.2	1		19	22	16
	Max	0.2	1		23	34	27
	Average	0.2	1		21.111	27.5	19.7
	STDEV	0	0		1.537	4.327	3.945
	Control	0.2	1		24.185	36.154	27.59
	Compliance	5	1		52	40.481	35

1 – upgradient borehole – data for information only

6.1.3. Surface Water Monitoring

Surface water quality monitoring has been undertaken on 6 occasions. Use of the ESI tool for assessment of outliers requires a minimum of 8 samples, therefore, the data has been assessed manually. SW3 represents surface water conditions down gradient of the site and is the location to which compliance limits should be assigned. It is noted that the sampling point SW3 is downgradient of the confluence with the brook from the west, which is sampled by SW2. The summary of surface water quality given in Table 6, however, indicates there is little variation between sample locations. The proposed compliance limits are presented in Table 14.

Table 14: Surface Water Compliance Limits

		As (ug/l)	Toluene (ug/l)		Chloride (mg/l)	Ni (ug/l)	Sulphate (mg/l)
SW3	**Min**	0.22	1.00		23.00	2.80	19.00
	Max	0.48	1.10		31.00	7.00	35.00
	Average	0.33	1.02		28.33	3.80	26.17
	STDEV	0.09	0.04		2.56	1.45	4.84
	Control	0.50	1.09		33.45	6.69	35.86
	Compliance	0.59	1.13		36.01	8.14	40.70

7. Summary and Conclusions

7.1. Conceptual Model of the Site

The conceptual model of the site comprises an inert waste deposit over natural strata, with the geological barrier and enabling works engineered from inert waste as a recovery activity. The risk assessment assumes that both the waste for deposit and engineered waste for recovery forms the source. The infilling of the temporary lagoons below the level of the geological barrier does not form part of this assessment. Separate waste acceptance criteria will be applied to this material, as described in the Operational Plan. There will be less potential for attenuation of any seepage from the infilled ponds due to the lower elevation and therefore, certain criteria will be more restrictive than inert WAC.

The impact of the source on the hydrogeological regime is assessed using Landsim. The footprint of the landfill is taken to be the whole of Phases 1 to 3. In practice there will only be waste used for recovery activities in Phase 1. The waste for deposit will be limited to Phases 2 and 3. The attenuation properties of the geological barrier are halved in relation to the natural strata to add conservatism to the assessment.

7.2. Compliance with the Environmental Permitting Regulations

A quantitative hydrogeological risk assessment of the proposed new landfill has been undertaken using the Environment Agency approved assessment tool. This indicates that the new landfill is unlikely to cause discernible discharge of hazardous substances, or pollution by non-hazardous pollutants. The new landfill will be engineered with a 1m geological barrier to a maximum permeability of 1×10^{-7} m/s. This is, therefore, considered to be compliant with the Environmental Permitting Regulations, 2016.

Compliance levels have been derived for downgradient boreholes and surface water.

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