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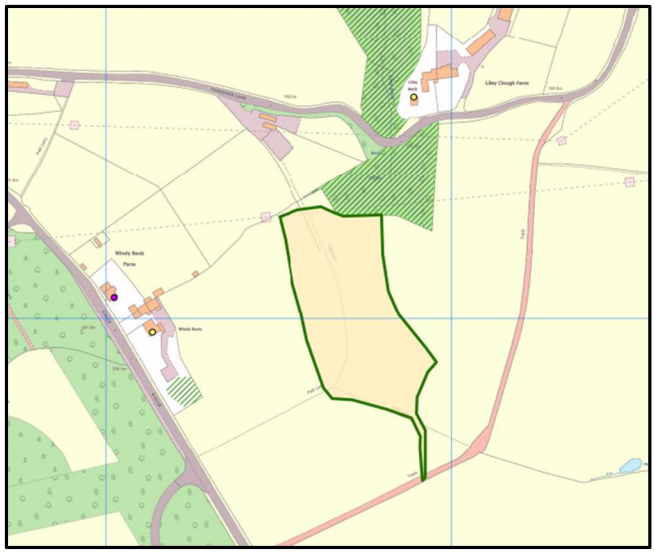
Contaminated Land and Hydrogeology

Emley Fields

Hydrogeological Risk Assessment



Prepared for: WPSCC on behalf of
Liley Clough Environmental Ltd
Liley Lane
Grange Moore
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Contaminated Land and Hydrogeology

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Version History

Version	Author	Approved by	Issue date	Comment
31043R1D1	Roz Cox	Joe Gomme	19/11/2024	Draft report issued to client
31043R1	Roz Cox	Joe Gomme	20/11/2024	Final report issued to client

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1. INTRODUCTION

WPSCC Ltd (WPSCC) has instructed H Fraser Consulting Ltd (HFCL) on behalf of Liley Clough Environmental Ltd (LCEL) to undertake a hydrogeological risk assessment (HRA) in support of an application made to the Environment Agency (EA) for permission to import material under a Deposit for Recovery Permit. The permit application is for land reprofiling at Emley Field, Liley Lane, Grange Moore, Huddersfield, West Yorkshire, WF4 4EN. Planning permission has been granted on appeal; additional pieces of information have been requested by the EA, including this HRA, to support the application.

A number of assessments have been conducted throughout the planning process, including a geotechnical investigation which reported concentrations of contaminants of concern (CoCs) within the soil, mainly made ground at the site; a clear rational for concluding that the CoCs pose no risk to groundwater was not presented.

The EA guidance[1] states that a groundwater risk assessment should be undertaken in a tiered approach as follows:

- Tier 1 – qualitative risk screening – investigate what the risks are, whether more detailed assessment is needed and what that would need to focus on (risk prioritisation)
- Tier 2 – generic quantitative risk assessment – to collect more information so you can make an informed decision on the risk posed by the site – you'll also need to identify your compliance points
- Tier 3 – detailed quantitative risk assessment – to collect more information and formulate a plan if there are clear source-pathway-receptor relationships.

The site is in a location of relatively low sensitivity with respect to controlled waters and a qualitative and semi-quantitative risk assessment is deemed likely to be sufficient.

1.1 Objective

The objective of the work is to provide a HRA to support the application for a Deposit for Recovery Permit.

1.2 Scope of works

The following scope of work is proposed:

- Desk review to compile relevant information about the site (previous reports and plans) as well as using publicly available information such as geological, hydrogeological and topographic mapping. This information will be used to produce a simple conceptual model of the site contaminant linkages for controlled waters.

[1] https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit

- Qualitative risk assessment and reporting - available data will be assessed in a qualitative manner, considering the relevant sources, pathways and controlled waters receptors, and risks to the receptors will be analysed, in accordance with EA guidance.

- The contamination recorded on site will be considered as an additional point in the risk assessment, which will involve some simple contaminant transport assessment for the mobility of any contaminants of concern identified. This will cover any concerns that the EA may have about existing on-site contamination.

- Reporting in general accordance with EA Guidance, Landfill Operators: Environmental Permits[2].

[2] https://www.gov.uk/guidance/landfill-operators-environmental-permits/what-to-include-in-your-hydrogeological-risk-assessment

2 DESK STUDY

The following information sources have been consulted for this desk study:

- Ordnance Survey (OS) mapping
- Historical mapping
- British Geological Survey (BGS) geological and hydrogeological mapping
- Local BGS borehole records
- EA guidance Landfill Operators: Environmental Permits[2]
- Envirotech Ecological Appraisal[3]
- The Coal Authority Consultants Coal Mining Report[4]
- Earth Environmental and Geotechnical Coal Mining Risk Assessment[5]
- JNP Group Flood Risk Assessment[6]
- EA Appeal Document[7]
- RGS Phase 2 Environmental report[8]
- WPS Conceptual Site Model, Environmental Setting and Site Design Report (ESSD)[9]

2.1 Background

The site is approximately 1.4 hectares and known as Emley Field. The south-western boundary is located approximately 130 m north-east of Liley Lane, and the centre of the site is at grid reference SE 21206 17030. It is approximately 6 km east of Huddersfield and approximately 3 km south-east of Mirfield. The site was formerly Whitley Clough Colliery which closed in 1947. Several mine adits and two mine shafts which have been capped to an unknown specification[5] are present on the site and a concrete pad associated with a proposed wormery, located in the centre. The site is currently rough derelict pastureland surrounded by fields with the exception of the northern boundary which lies adjacent to Liley Wood; a bund formed of topsoil lies along the western boundary. Parts of the site have extreme slopes relating to the previous use of the site as part of the wider colliery operation.[9]

A geotechnical investigation was undertaken by RGS[8] during March 2020 which included the excavation of 8 trial pits to depths between 0.8 m and 3.8 m across the site. Exceedances of PAH above ATRISK soil screening values (SSVs) with 6% soil organic matter (SOM) compiled by WS Atkins plc for public open space, based on the end user which are farm workers, were reported in made

[3] Envirotech Ecological Appraisal

[4] The Coal Authority Consultants Coal Mining Report

[5] Earth Environmental and Geotechnical Coal Mining Risk Assessment

[6] JNP Group Flood Risk Assessment

[7] EA Appeal Document

[8] RGS Phase 2 Environmental report

[9] WPS Conceptual Site Model, Environmental Setting and Site Design Report (ESSD)

ground two locations, TP5 (0.1 m – 3.5 m) and TP7 (0.7 m – 2.1 m). Additional contaminants of concern were identified however, these were reported below soil screening values.

Planning permission has been granted on appeal, and an application made to the EA for permission to import material under a Deposit for Recovery Permit. The EA has requested a number of additional pieces of information to support the application, including a Hydrogeological Risk Assessment (HRA).

The site location is shown in Figure 2.1, with the site setting shown in Figure 2.2.

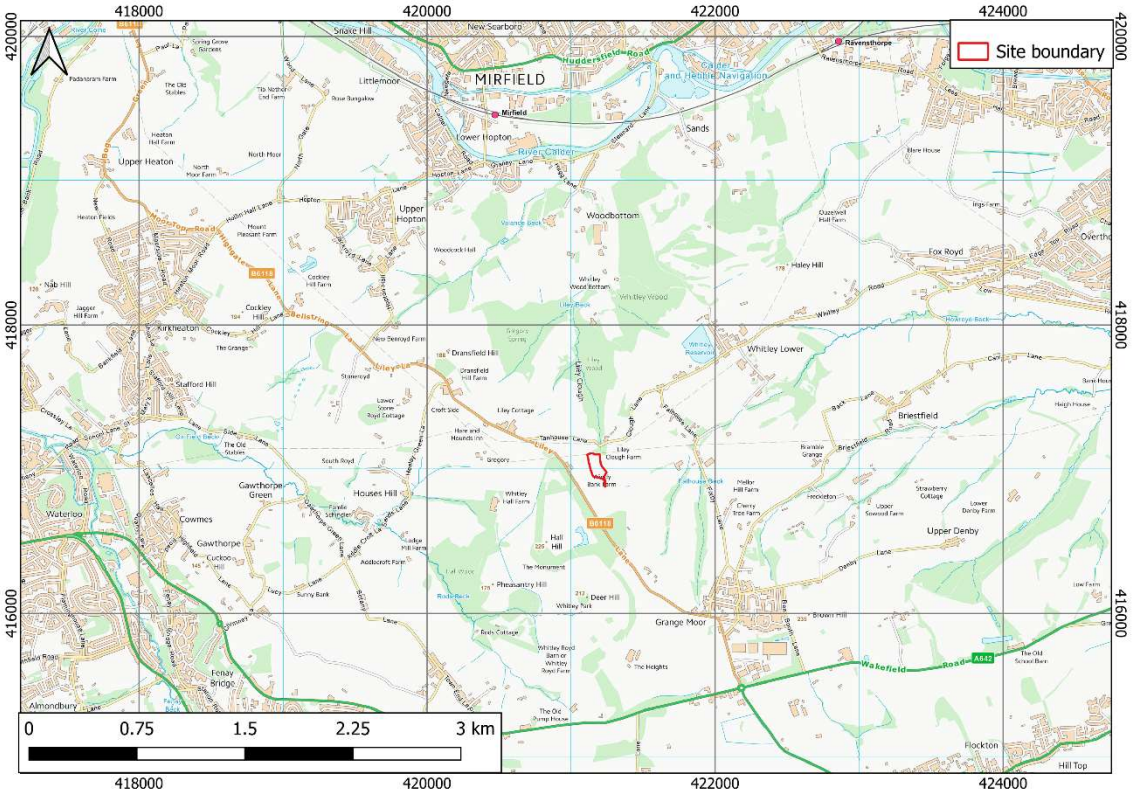

Figure 2.1: Site location

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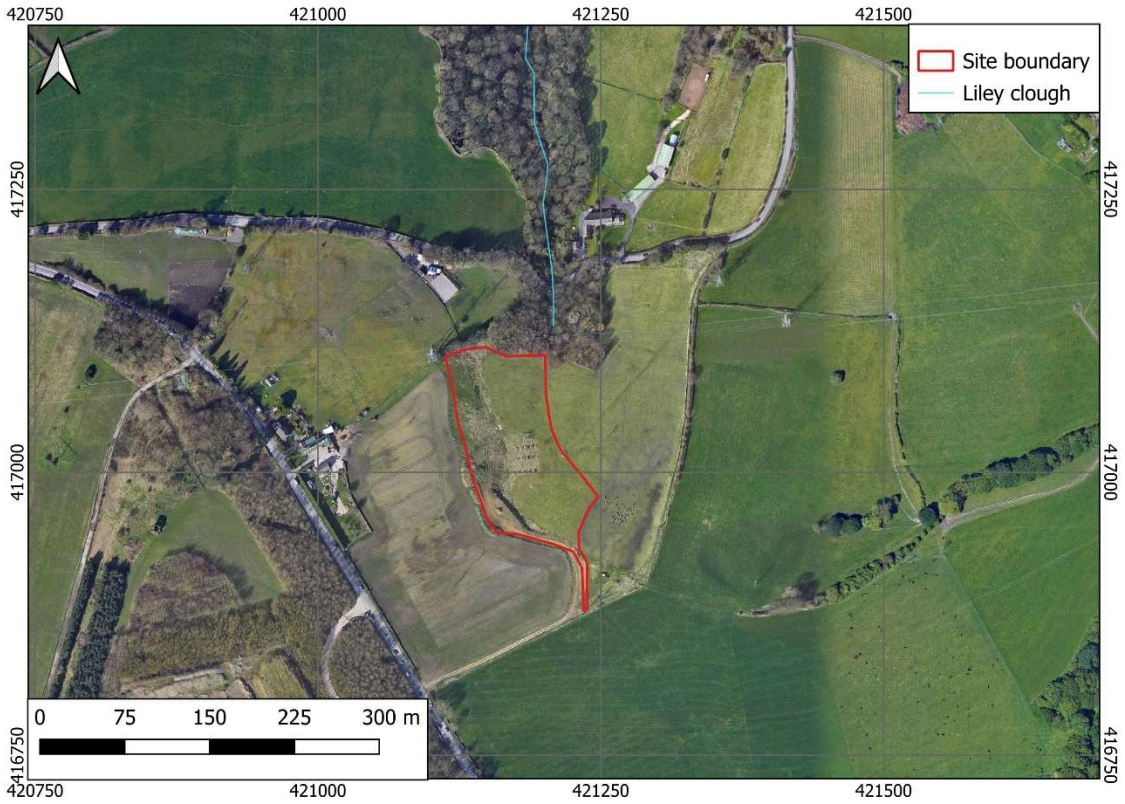


Figure 2.2: Site setting

Contains Ordnance Survey data © Crown copyright and database right 2024

2.2 Site history

A summary of the history from available reports is provided below.

- 1951-56 Whitley Clough Colliery became disused.
- 1960 the coal drift is shown to be disused.
- 1982 no coal mining activities/evidence is shown within the site area or its immediate vicinity. Since the closure of the colliery, the site has become an area of derelict land of rough grassland. The character of the area surrounding the site indicates that the land use is predominantly agricultural.

There are no known previous pollution incidents.

The site is currently in a derelict state with concrete bases of former colliery buildings just below the surface. It also contains the foundations of a proposed wormery with the access commenced in 2005 but not completed.[9]

2.3 Development plans

The proposed plans are to reprofile some of the land that is part of a former colliery area, to fill a man-made hollow and restore the level so that the ground can be used by modern farm machinery. The proposed operation involves the importation of 90,000 tonnes of uncontaminated inert waste comprising subsoil and topsoil over a period of 2 years. The materials, specified in the Waste

Technical Guidance WM3[10] as waste code 17 05 04 *Other Soils and Stones Non-Hazardous* will be sourced from various development sites within the borough of Kirklees in West Yorkshire as and when available, resulting in a smooth slope profile to allow the safe, efficient, productive cultivation of crops using modern farm machinery.[9] The approximate thickness of the fill is 2.4 m at the deepest point (ESSD, Figure 3).

The site will be operated in accordance with a written management system, waste acceptance procedures and by a technically competent operator and therefore the proposed waste infill would not pose an unacceptable risk to human health or the environment.[9]

2.4 Previous site investigations

A site investigation was undertaken by RGS Environmental Geotechnical Specialists (RGS)[8] in March 2020. Fieldwork comprised 8 machine excavated trial pits to depths of between 0.8 m and 3.8 m. Locations are presented in Figure 2.3 below. Topsoil, made ground and clay were logged in the trial pits, this is summarised in Table 2.1. No groundwater strikes were logged. Samples were sent for laboratory testing for the following suite of contaminants:

- Metals – cadmium, chromium VI, copper, mercury, nickel, lead, vanadium and zinc;
- Semi and no-metals – arsenic, selenium, free cyanide and phenols;
- Polycyclic aromatic hydrocarbons (PAHs);
- Others – pH, organic content and total/soluble sulphate;
- Asbestos screen; and
- Total petroleum hydrocarbons (C6-C40).

Samples were screened against ATRISK soil screening values (SSVs) complied by WS Atkins plc with 6% soil organic matter (SOM), based on SOM content of 1.3% to 4.3% for human health in public open space based on the end user being farm workers.

The results identified that the majority of results to be below limit of detection (LOD). Detectable levels of the contaminants were below the SSVs with the exception of three PAHs identified in two samples in two locations (TP5 0.1 m – 3.5 m, TP7 0.7 -2.12m). The contaminants were not screened against controlled water values. This has been assessed in Section 3.2 of this report.

[10] Environment Agency. Waste Classification. 2021

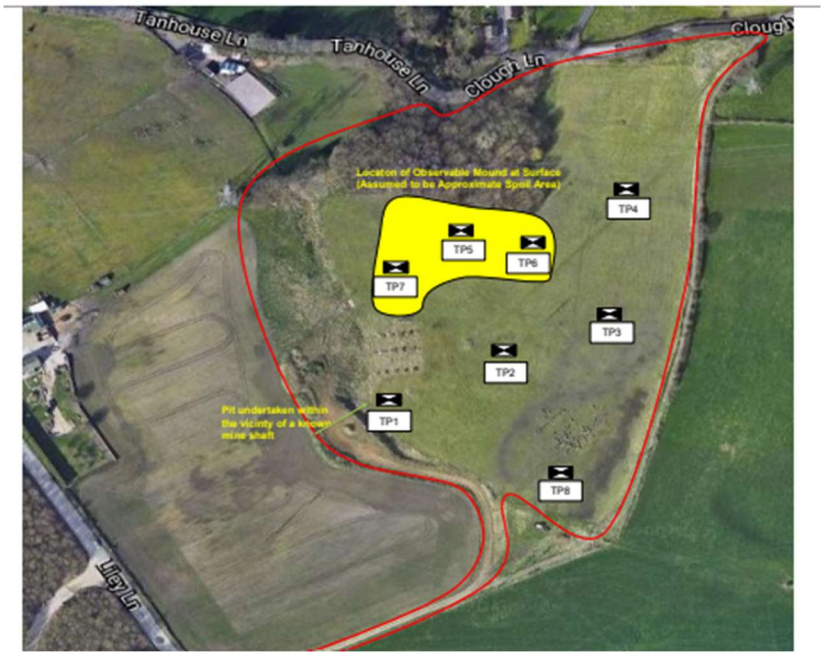


Figure 2.3: Site investigation locations[8]

2.5 Topography

The site is located at an elevation of approximately 197 m aOD along the western boundary, approximately 187 m AOD in the northeastern portion and approximately 195 m AOD in the far southern portion. Parts of the site has extreme slopes relating to the former colliery works. The surrounding land generally slopes down to the northeast across the farm property and rises to the southwest across Liley Lane to an elevation of approximately 222 m AOD. The current topography of the site is shown in Figure 2.4 and a cross section of the current and proposed topography is presented in Figure 2.5.

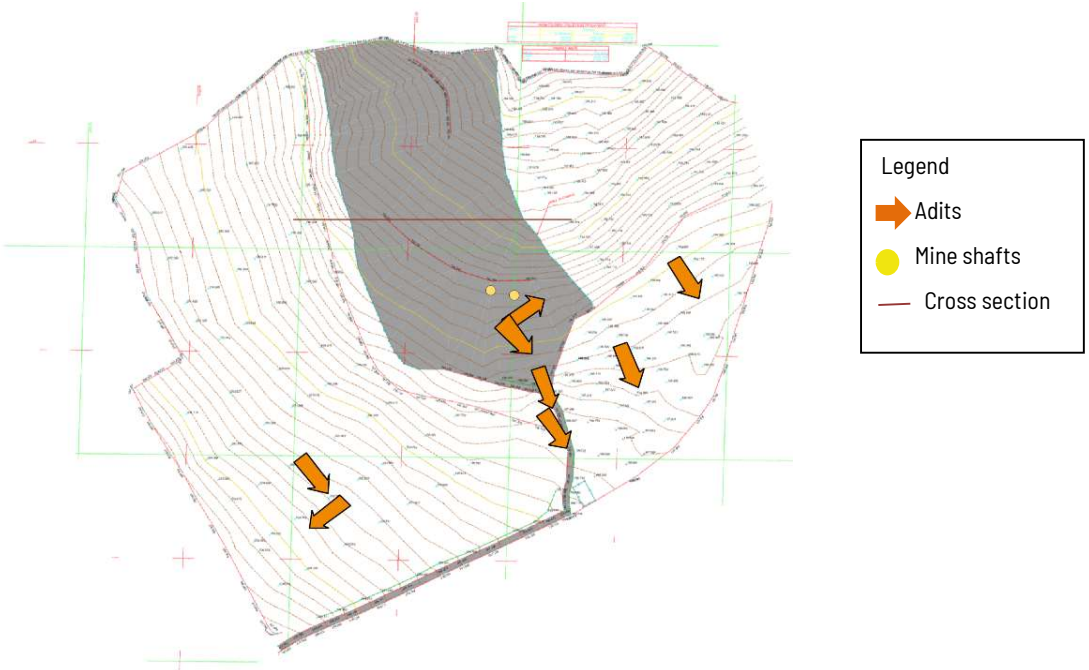


Figure 2.4: Related topography before proposed operation[9]

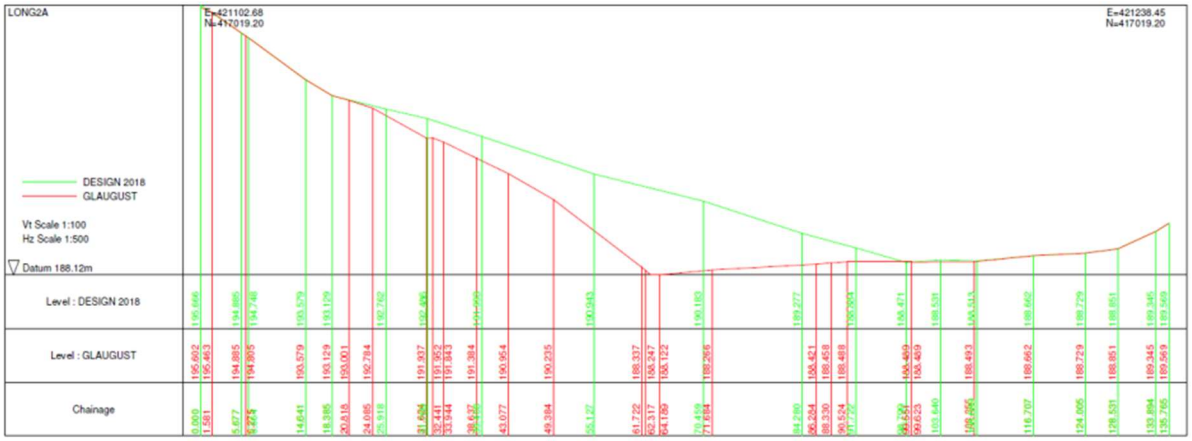


Figure 2.5: Topography after proposed operation[9]

2.6 Geology

The British Geological Survey (BGS) (onshore) Geoindex[11] and BGS viewer[12] were used to provide information on the site geology.

2.6.1 Superficial geology

There are no superficial deposits present on the site. However, information provided by Landis[13] indicate that the soil is *"Freely draining slightly acid loamy soils"*; no data on thickness was available. Additional information on the generalised strata profile obtained during the Phase 2 SI[8] is provided in Table 2.1 below.

Table 2.1: Generalised strata profile

Depth (m bgl) to underside of layer	Thickness (m)	Strata type	Position encountered	Groundwater strikes
0.1 to 0.25	0.1 – 0.25	Topsoil	TP1-TP8	None
0.3 to +3.8	0.55 to +3.7	Made ground (predominantly granular)	TP1, TP2, TP5, TP6, TP7	None
0.8 to +1.8	0.15+	Light brown clay (residual coal measures formation)	TP1, TP2, TP3, TP4, TP8	None

2.6.2 Bedrock geology

The bedrock geology of the property and surrounding area is presented in Figure 2.6. The bedrock geology comprises Pennine Lower Coal Measures Formation – mudstone, siltstone and sandstone

[11] https://mapapps2.bgs.ac.uk/geoindex/home

[12] https://geologyviewer.bgs.ac.uk/

[13] https://www.landis.org.uk/soilscapes/

described as "*Interbedded grey mudstone, siltstone and pale grey sandstone, commonly with mudstones containing marine fossils in the lower part, and more numerous and thicker coal seams in the upper part.*"[11]

According to information in the ESSD "*The Coal Mining Risk Assessment*[5] *shows the strata beneath the site and states it consists of "mudstone potentially with outcropping New Hards Coal Seam, underlain by mudstone with interbedded Wheatley Lime Coal Seam and the Middleton Eleven Yards Coal Seam" (Bennett, 2017). This also identifies a geological fault which crosses north-east to south-west across the centre of the site".*[9]

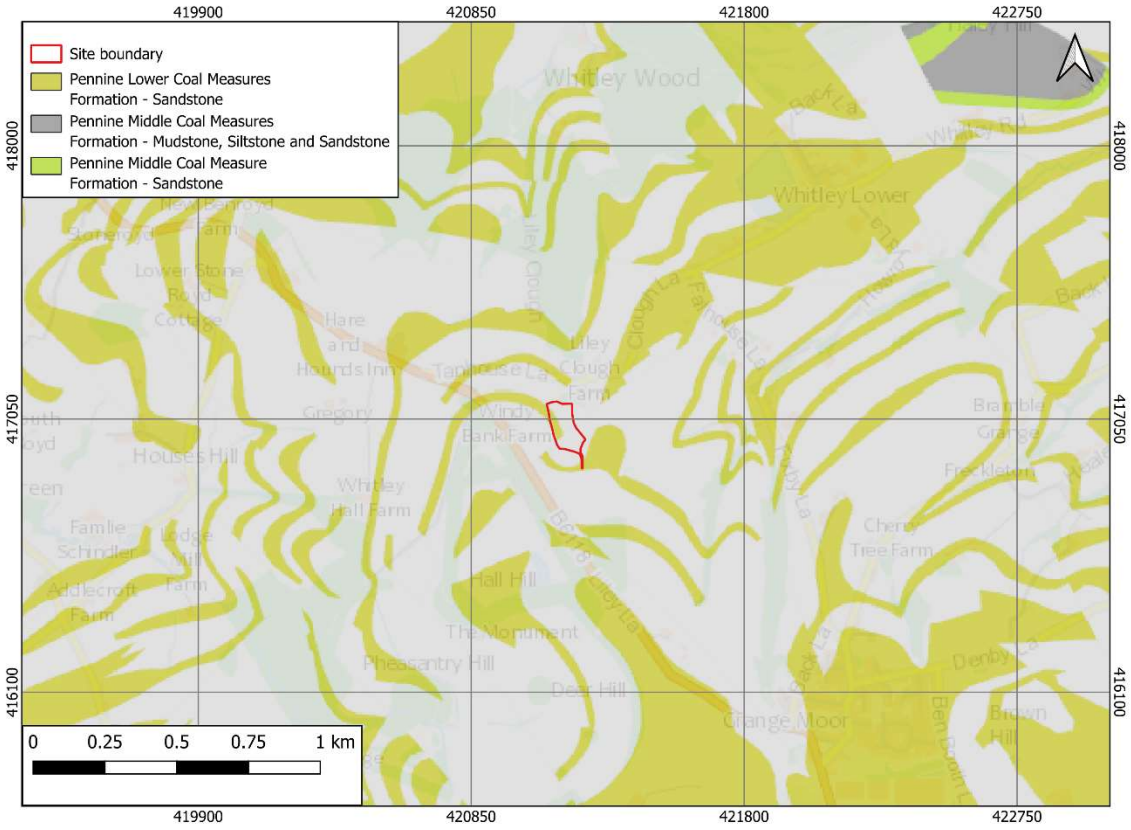


Figure 2.6: Bedrock geology

2.7 Hydrology

The site is located within the River Calder catchment. A small watercourse, Liley Clough, is located north of the site and flows north towards the River Calder, which is located approximately 2.1 km to the north of the site.[11]

The site is located within Flood Zone 1 which has a low probability of flooding from rivers and the sea.[14]

A detailed Flood Risk Assessment was undertaken by JNP Group[6] and concluded the following:

[14] https://flood-map-for-planning.service.gov.uk/

- *"Limited surface water flooding is predicted forming an overland flow route across the site which feed into the headwaters of the Liley Clough.*
- *The flooding risks to the proposed development from fluvial, surface water, tidal, groundwater sewer or reservoir sources are predicted to be low or very low. Mitigation is not required.*
- *Off-site flood risks are not considered to be increased by the proposed development.*
- *During construction, control of run-off will be required to prevent turbid water entering Liley Clough.*
- *In conclusion the proposed development has an acceptable flood risk within the terms and requirements of the National Planning Policy Framework (NPPF)."*[6]

2.8 Hydrogeology

DEFRA's Magic Map Application[15] was viewed and shows that the site is located on a Secondary A aquifer, defined are defined by the EA as "*aquifers (that) comprise permeable layers that can support local water supplies, and may form an important source of base flow to rivers*".[16]

Permeability of the lower coal measures in the east Pennines ranges between 3.8 x 10^{-5} m/d and 9.4 x 10^{-4} m/d.[17]

According to information in the ESSD "*The underlying bedrock is therefore underlain by permeable rocks and the proposed operation of filling in the hollow will increase the permeability than the existing Coal Measures strata. Therefore, infiltration will be greater and run-off from the site will be reduced.*" The bedrock consists partly of sandstone and the nature of the import material is unknown therefore, if the import materials are clay for example, the permeability will be lower than that of the bedrock.

The site is not located close to a source protection zone. However, it is located in a high groundwater vulnerability area.[15]

Information provided in the flood risk assessment states that "*the infilling of the site may alter groundwater flow paths and associated surface water flow paths from groundwater issues to Liley Clough. The imported material will increase the length of the flow path and increase the groundwater storage capacity of the site, in the imported fill. The volume of groundwater flowing through the site, or generated via recharge on the site, will not be altered by the works so the increased flow paths and groundwater storage should act to increase flow times, smoothing out the peaks in groundwater discharge which would become less intense but over a longer period of time. As the site is towards an interfluve, the groundwater catchment for the site is likely to be small and these affects minimal. The works are therefore not predicted to significantly alter the groundwater regime at or emanating from the site.*"

There are no BGS-recorded boreholes located within 250 m of the site.

No groundwater was intercepted during the Phase 2 SI works.

[15] https://magic.defra.gov.uk/magicmap.aspx

[16] https://www.gov.uk/government/publications/protect-groundwater-and-prevent-groundwater-pollution/

[17] The Physical Properties of Minor Aquifer in England and Wales

3 CONCEPTUAL MODEL

A conceptual model describes the potential environmental impacts associated with the site, and any uncertainties in how the activity will interact with the hydrogeological setting.

For a risk to exist due to any contamination, there needs to be one or more contaminant- pathway-receptor linkages – "contaminant linkage" – by which a relevant receptor might be affected by the contaminants in question. In other words, there must be contaminants present in, on or under the land in a form and quantity that pose a hazard, and one or more pathways by which they might impact as receptor. Defra[18] provides the following definitions:

> (a) A "contaminant" is a substance which is in, on or under the land and which has the potential to cause significant harm to a relevant receptor, or to cause significant pollution of controlled waters.
>
> (b) A "receptor" is something that could be adversely affected by a contaminant, for example a person, an organism, an ecosystem, property, or controlled waters.
>
> (c) A "pathway" is a route by which a receptor is or might be affected by a contaminant. The term "contaminant linkage" means the relationship between a contaminant, a pathway and a receptor. All three elements of a contaminant linkage must exist for there to be a risk to the identified receptor.

The conceptual site model summarises what is known about the ground conditions at the site, then goes on to describe potential sources, pathways, and receptors. Section 4 presents the preliminary risk assessment.

3.1 Ground model

It is proposed to reprofile agricultural land due to extreme slopes in part of the site from a former colliery via the importation of 90,000 tonnes of uncontaminated inert waste comprising topsoil and subsoil. There are no superficial deposits however, a site investigation showed topsoil of thicknesses up to 0.25 m and made ground between 0.55 m and thicker than 3.7 m however, this was not present in all trial pits. The bedrock geology comprises the secondary A aquifer of the Pennine Lower Coal Measures Formation, formed of mudstone, siltstone and sandstone.

3.2 Contaminant sources

The source of contamination considered here are contaminants of concern identified above LOD from the soil samples taken during the SI undertaken by RGS[8]. These include:

- Metals – copper, mercury, nickel, lead, vanadium and zinc;
- Semi- and non-metals – arsenic and selenium;
- PAHs – naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene pyrene, benzo[a]anthracene, chrysene; benzo[b]fluoranthene, benzo[k] fluoranthene, benzo[a]pyrene, indeno(1,2,3-c,d)pyrene, Dibenzo(a,h)anthracene, Benzo[g,h,i]perylene;
- Asbestos screen – none detected; and
- Total petroleum hydrocarbons (C6-C40).

[18] DEFRA. Environmental Protection Act 1990. Part 2A

As these contaminant concentrations are for soil, the likely concentrations in water for these contaminants have been calculated. The following assumption / parameters have been used for the calculations:

- soil organic matter has been taken as 1.3% to be conservative;
- full saturation of the soil i.e. Henrys constant not taken into account;
- average soil density for a uniform silty clay with gravel has been used.

Calculations and relevant data are provided in Appendix A.

The resulting contaminant concentration in groundwater have been screened against controlled water screening values including Environmental Quality standards (EQS) for both annual averages (AA) and maximum accepted criteria (MAC) due to surface water receptors and drinking water standards (DWS) due to potential drinking water receptors. Any contaminants for which EQS or DWS have been exceeded are presented in Table 3.1 below. No screening value for TPH is available.

.

Table 3.1: Contaminant concentrations compared to DWS and EQS

Contaminant of concern	Location	Depth (m)	Soil description	Min soil conc. (mg/kg)	Max soil conc. (mg/kg)	Min water conc. (Cgw) (mg/l)	Max water conc. Cgw (mg/l)	EQS AA* (mg/l)	EQS MAC* (mg/l)	DWS (mg/l)
Copper	All	0.1 to 3.8	TS, MG, C	17	61	0.001700	0.006100	**0.001**	N/A	2
Mercury	TP7	0.1 to 2.1	MG	0.12	0.19	0.000120	0.000190	N/A	**$7x10^{-5}$**	1
Nickel	All	0.1 to 3.8	TS, MG, C	8.4	55	0.128908	0.844039	**0.004**	**0.034**	**0.02**
Lead	All	0.1 to 3.8	TS, MG, C	15	68	0.016664	0.075542	**0.0012**	**0.014**	**0.01**
Vanadium	All	0.1 to 3.8	TS, MG, C	11	15	N/A	N/A	0.02 – 0.06	N/A	N/A
Zinc	All	0.1 to 3.8	TS, MG, C	18	95	0.289562	1.528244	**0.0109**	N/A	N/A
Arsenic	All	0.1 to 3.8	TS, MG, C	4.7	68	0.161164	2.331732	**0.05**	N/A	**0.01**
Selenium	All except TP3	0.1 to 3.8	TS, MG, C	0.25	1.5	0.048423	0.290536	N/A	N/A	**0.01**
Naphthalene	TP7	0.7-2.1	MG	1.2	1.2	0.103425	0.103425	**0.002**	0.13	**$1x10^{-4**}$**
Acenaphthylene	TP7	0.7-2.1	MG	0.82	0.82	0.003274	0.003274	N/A	N/A	**$1x10^{-4**}$**
Acenaphthene	TP7	0.7-2.1	MG	1	1	0.007097	0.007097	N/A	N/A	**$1x10^{-4**}$**
Fluorene	TP7	0.7-2.1	MG	2.4	2.4	0.010507	0.010507	N/A	N/A	**$1x10^{-4**}$**

Contaminant of concern	Location	Depth (m)	Soil description	Min soil conc. (mg/kg)	Max soil conc. (mg/kg)	Min water conc. (Cgw) (mg/l)	Max water conc. Cgw (mg/l)	EQS AA* (mg/l)	EQS MAC* (mg/l)	DWS (mg/l)
Phenanthrene	TP7	0.7-2.1	MG	5.4	5.4	0.000258	0.000258	N/A	N/A	**$1x10^{-4}$****
Anthracene	TP7	0.7-2.1	MG	0.5	0.5	0.001739	0.001739	**$1x10^{-4}$**	**$1x10^{-4}$**	**$1x10^{-4}$****
Fluoranthene	TP5 & TP7	0.1 to 3.8	MG	0.2	2.8	0.000225	0.003153	**$6.3x10^{-6}$**	**$1.2x10^{-4}$**	**$1x10^{-4}$****
Pyrene	TP5 & TP7	0.1 to 3.8	MG	0.11	3.2	0.000171	0.004973	N/A	N/A	**$1x10^{-4}$****
benzo[a]anthracene	TP5 & TP7	0.1 to 3.5	MG	0.16	1.3	0.000031	0.000254	N/A	N/A	**$1x10^{-4}$****
Chrysene	TP5 & TP7	0.1 to 3.5	MG	0.37	1.7	0.000071	0.000325	N/A	N/A	**$1x10^{-4}$****
benzo[b]anthracene	TP5 & TP7	0.1 to 3.5	MG	0.22	1.3	0.000013	0.000077	N/A	N/A	$1x10^{-4}$**
benzo[k]anthracene	TP5 & TP7	0.1 to 3.5	MG	0.18	0.52	0.000007	0.000021	N/A	N/A	$1x10^{-4}$**
benzo[a]pyrene	TP5 & TP7	0.1 to 3.5	MG	0.18	0.61	0.000056	0.000189	**$1.7x10^{-7}$**	N/A	**$1x10^{-5}$**

Contaminant of concern	Location	Depth (m)	Soil description	Min soil conc. (mg/kg)	Max soil conc. (mg/kg)	Min water conc. (Cgw) (mg/l)	Max water conc. Cgw (mg/l)	EQS AA* (mg/l)	EQS MAC* (mg/l)	DWS (mg/l)
indeno(1,2,3-c,d)pyrene	TP5 & TP7	0.1 to 3.5	MG	0.15	0.33	0.000001	0.000003	**$1.7x10^{-7}$***	N/A	$1x10^{-4}$**
Dibenzo(a,h)anthracene	TP7	0.7 to 2.1	MG	0.2	0.2	0.000028	0.000028	N/A	N/A	$1x10^{-4}$**
Benzo[g,h,i]perylene	TP5 & TP7	0.1 to 3.5	MG	0.22	0.44	0.000003	0.000007	**$1.7x10^{-7}$***	N/A	$1x10^{-4}$**
TPH	TP1 & TP7	0.1 to 2.1	MG	110	200	N/A	N/A	N/A	N/A	N/A

All – no samples were taken from TP2 or TP6

Text in **Bold** exceeded screening concentrations

*Screening value for Benzo(a)pyrene (BaP) as BaP is considered as a marker for other PAHs.

**Value for polyaromatic hydrocarbons used where no specific screening values is available

TS – Topsoil, MG – Made ground, C - clay

All contaminants reported above LOD exceed either the EQS or DWS (or both) screening values where available. The majority of the contamination was identified within made ground in TP5 and TP7. No samples were taken from TP2 or TP4.

An additional potential source of contamination is from the import of subsoil and topsoil from various sources. However, these materials will be uncontaminated inert waste and should therefore pose no risk to controlled waters. It will be essential for the site owner to ensure that the quality of the imported materials is validated appropriately in advance of bringing the materials to site.

3.3 Pathways

The following potential pathways for transport of pollutants to controlled waters have been identified:

- Direct run off of surface water to streams and rivers
- Infiltration to Secondary A aquifer via permeable unsaturated strata
- Lateral migration via groundwater to surface waters
- Infiltration via rapid pathways (e.g. mine shafts / fault) to the Secondary A aquifer

3.4 Receptors

The following receptors have been identified near the site:

- Liley Clough stream
- Pennine Lower Coal Formation aquifer

4 QUALITATIVE RISK ASSESSMENT

A qualitative risk assessment has been undertaken on the likely risks to the identified receptors at the site. Table 4.1 presents the potential contaminant linkages which may exist at the site.

Table 4.1: Potential contaminant linkages and generic assessment

Source	Pathway	Receptor	Assessment
Contaminated soil within the unsaturated zone	Direct run off of surface water to streams and rivers	Liley Clough stream	The contaminated materials are located approximately 50 m from the stream head. All contaminants exceed either the EQS, DWS or both. However, they will be covered with inert non-hazardous topsoil and subsoil. Permeability of the imported materials are unknown. Flood risk at the site is low. **Risks are considered to be medium; further assessment is required.**
	Infiltration to Secondary A aquifer via permeable unsaturated strata Infiltration via rapid pathways (e.g. mine shafts/ fault) to the Secondary A aquifer	Pennine Lower Coal Formation aquifer	The contaminated materials will be covered with inert non-hazardous topsoil and subsoil. The permeability of the imported materials is unknown. However, based on the proposed infill profile, the depth of fill will be highest above the location of the test pits with the highest contamination levels. The contaminant concentrations calculated from the soil exceed either the EQS, DWS or both. The state of the mine shaft capping and the extent of the adits is unknown. **Risks are considered to be medium. Further assessment is required.**
	Lateral migration via groundwater to surface waters	Liley Clough stream	
Imported topsoil and subsoil	Direct run off of surface water to streams and rivers	Liley Clough stream	All topsoil and subsoil imported to the site will be classified as waste code 17 05 04 Other Soils and Stones Non-Hazardous and will be sourced from various development sites locally. All materials should have been chemically

Source	Pathway	Receptor	Assessment
	Infiltration to Secondary A aquifer via permeable unsaturated strata Infiltration via rapid pathways (e.g. mine shafts) to the Secondary A aquifer	Pennine Lower Coal Formation aquifer	tested prior to site import to ensure suitability. The site will be operated in accordance with a written management system. **Risks are considered to be low as long as correct procedures are followed.**
	Lateral migration via groundwater to surface waters	Liley Clough stream	

5 QUANTITATIVE RISK ASSESSMENT FOR CONTAMINANT TRANSPORT

Further assessment of the CoCs was required due to exceedances of the controlled water screening criteria (EQS/DWS) as presented in Table 3.1 and subsequent qualitative risk analysis (Table 4.1), identifying potential risks to the Liley Clough stream and the aquifer.

5.1 Modelling approach

A quantitative assessment for contaminant transport has been undertaken using RAM3 software. This is a bespoke spreadsheet-based software package built by ESI Ltd (now Stantec). The software adopts the Source->Pathway->Receptor approach and can model multiple segments along the pathway. A constant or declining source term can be selected, and attenuation can be applied along the pathway, whilst dilution can be applied along the pathway and at the receptor. The software also allows site-specific waterbalance to be applied. It is used for contaminant transport calculation and widely used for contaminated land and landfill modelling. It applies the same algorithms as the Environment Agency's RTM spreadsheet but allows multiple contaminants to be assessed on the same spreadsheet.

5.2 Model structure

The model source is taken to be the Made Ground on site, with the contaminant concentrations observed in the site investigation.

The modelled pathway is a 1 m vertical pathway through unsaturated LCM clay (demonstrated at the base of all trial pits undertaken), followed by assumed sub-horizontal movement within an assumed LCM sandstone bed beneath.

The receptor is the spring head presumed to be at the head of the stream at Liley Clough, with the assumption that groundwater from the possible sandstone bed discharges at that point.

The following CoCs were selected for modelling based on their mobility, toxicity and observed concentrations.

- Metals and semi-metals - mercury, nickel and arsenic
- PAHs – naphthalene and phenanthrene
- TPH - benzene

5.3 Model input values

The criteria used in the modelling are presented in Table 5.1 and Table 5.2 .

Table 5.1: Parameter input values for modelling

RAM section (for reference)	Criteria	Value	Unit	Reference
	Made Ground			
Made ground	Source length	160	**m**	Site plans
Made ground	Source width	100	**m**	Site plans
Made ground	Source thickness	1.2	**m**	Half of maximum ESSD Fig 3
Made ground	Total porosity	0.25	-	

RAM section (for reference)	Criteria	Value	Unit	Reference
Made ground	Water-filled porosity	0.1	-	Assumed for granular material reported
Made ground	Air-filled porosity	0.15	-	
Made ground	Bulk density	1200	kg/m^3	
Made ground	Fraction of organic carbon	0.05	-	
	LCM Clay			
Hydrogeology	Unit_Thickness	1	m	Assumed
Hydrogeology	Hydraulic_Conductivity	1x10^{-9}	m/s	Assumed for clay
Hydrogeology	Hydraulic_Gradient	1	-	For vertical unsaturated flow
Hydrogeology	Effective porosity	0.05	-	Estimate for clay
Hydrogeology	Tortuosity	5		Assumed
Attenuation	Dry_bulk_density	1300	kg/m^3	Assumed
Attenuation	Fraction_organic_carbon	0.0217	-	Steventon-Barnes, table 19, mean value
Pathways	Travel distance	1	m	Assumed small value
Pathways	Dispersivity	0.1	m	10% of travel distance
	LCM Sandstone			
Hydrogeology	Unit_Thickness	10	m	Assumed for minor sandstone unit
Hydrogeology	Hydraulic_Conductivity	1.97x10^{-7}	m/s	BGS Table 8.10 (MCM)
Hydrogeology	Hydraulic_Gradient	0.091		Assumed to match topographic gradient
Hydrogeology	Porosity	0.1		Average from BGS Table 8.10
Hydrogeology	Tortuosity	5		Assumed
Attenuation	Dry_bulk_density	1850	kg/m^3	Estimate for sandstone
Attenuation	Fraction_organic_carbon	0.0217		Steventon-Barnes, table 19, mean value
	Pathway characteristics			
Water balance	Effective rainfall	300	mm/yr	Assumed
Pathways	Travel distance	86	m	Centre of site to stream head
Pathways	Dispersivity	8.6	m	10% of travel distance
Pathways	Mixing depth	8.6	m	10% of travel distance

RAM section (for reference)	Criteria	Value	Unit	Reference
Pathways	Mixing width	100	m	Source width

Table 5.2: Contaminant parameter input values for modelling

Criteria	Units	Contaminant of concern						Reference
		Mercury	Nickel	Arsenic	Naphthalene	Phenanthrene	Benzene	
Contaminant characteristics								
MG soil concentrations	mg/kg	0.19	55	68	1.2	5.4	10	Max values from RGS (2020)
DWS	mg/l	1.00E-03	0.02	0.01	0.002	N/A	0.001	Defra
EQS	mg/l	7.00E-05	0.004	0.05	1.00E-04	1.00E-04	0.01	Defra
Kd*	l/kg	1000	65	29	-	-	-	USEPA (neutral pH)
KoC*	l/kg	-	-	-	1,514	30,200	27	
Henry's law constant	-	1	1	1	0.017	0.0013	0.182	EA/Atkins (2003)
Free water diffusion coefficient	m^2/s	2.00E-09						Assumed low value
RAM - Attenuation								
Half-life	days	No decay	No decay	No decay	258	401.5	730	Howard et al, high values

* Contaminant solid-water partition coefficient (kd) or organic carbon-water partition coefficient (koc)

A number of significant conservative assumptions have been made in selecting the input values, to ensure that the predicted outputs are also conservative. These include the following.

- Clay has been demonstrated beneath the site in the trial pits however, its thickness is unknown. From the mapped geology it is likely that the clay units in the LCM are considerably thicker than the sandstone units; a thickness of only 1 m has been assumed for this model.
- The hydraulic conductivity value noted in BGS[17] for the LCM sandstone in the East Pennines region is very low (maximum $9x10^{-4}$ m/d). The maximum value ($4x10^{-2}$ m/d) quoted from the

range in BGS Table 8.10 for the Middle Coal Measures has therefore been used in this instance.

- An estimated the infiltration at 300 mm/yr has been applied. This is probably high for an area with a significant ground slope and a presumed clayey infill.
- In all cases the conservative estimates for attenuation characteristics of the modelled species have been used – maximum values for the decay half-lives of organic species and minimum values for the partition coefficients.
- Given the nature of the Made Ground (colliery spoil) and the length of time that it has been in situ, it is unlikely that there is a significant benzene concentration as part of the total petroleum hydrocarbon analysis (TPH). However, it has been assumed that 10 mg/kg of the TPH total is benzene and have modelled this since benzene is both noxious and mobile.

5.4 Model results

Model results are presented in Table 5.3.

Table 5.3: Potential contaminant linkages and generic assessment

Time (years)	Mercury	Nickel	Arsenic	Naphthalene	Phenanthrene	Benzene
10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	<1.000E-15
20	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	<1.000E-15
25	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.419E-15
30	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.755E-13
500	0.000E+00	<1.000E-15	0.000E+00	0.000E+00	0.000E+00	<1.000E-15
2000	0.000E+00	<1.000E-15	3.431E-06	0.000E+00	0.000E+00	0.000E+00
3000	0.000E+00	2.090E-10	7.339E-04	0.000E+00	0.000E+00	0.000E+00
4000	0.000E+00	1.584E-07	6.983E-03	0.000E+00	0.000E+00	0.000E+00
5000	0.000E+00	7.159E-06	1.997E-02	0.000E+00	0.000E+00	0.000E+00

As the table shows, none of the contaminants are predicted to break through to the receptor within 5,000 years. We consider that this demonstrates that there is no significant risk.

6 CONCLUSIONS

WPSCC instructed HFCL on behalf of LCEL to undertake an HRA in support of an application made to the Environment Agency (EA) for permission to import material under a Deposit for Recovery Permit for land reprofiling.

A number of assessments have been conducted throughout the planning process, including a geotechnical investigation which reported concentrations of CoCs within the soil, mainly made ground at the site; a clear rational for concluding that the CoCs pose no risk to groundwater was not presented. These CoCs were screened against relevant standards and presented potential risks to controlled waters, further assessment was required.

Contaminants representative of different contaminant groups (metals, non-metals and organics) were selected for modelling, based on their relative toxicity, mobility and concentrations in the site soils. Stantec RAM3 modelling software was used to predict concentrations at a downstream receptor under a set of very conservative assumptions. Even under these assumptions none of the modelled contaminants is predicted to reach the receptor within 5,000 years.

We therefore conclude that the proposed deposit for recovery poses no significant risk to controlled waters.

7 REFERENCES

- https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit
- https://www.gov.uk/guidance/landfill-operators-environmental-permits/what-to-include-in-your-hydrogeological-risk-assessment
- Envirotech, 2018. Ecological Appraisal. Land off Liley Lane, Grage Moor. Report reference 5428.
- The Coal Authority, 2019. Consultants Coal Mining Report. Report reference 51001982237001.
- Earth Environmental and Geotechnical,2019. Coal Mining Risk Assessment. Report No. A2893/G1
- JNP Group, 2019. Flood Risk Assessment. Reference S10750.
- The Planning Inspectorate, 2019. Appeal Decision. Appeal Ref: APP/Z4718/W/19/3232011
- RGS, 2020 Phase 2 Environmental report. Reference C447/20/E/661.
- WPS, 2023. Conceptual Site Model, Environmental Setting and Site Design Report (ESSD)
- Environment Agency, 2021. Waste Classification. Guidance on the classification and assessment of waste (1st Edition v1.2.GB) Technical Guidance WM3
- https://mapapps2.bgs.ac.uk/geoindex/home
- https://geologyviewer.bgs.ac.uk/
- https://flood-map-for-planning.service.gov.uk/
- https://magic.defra.gov.uk/magicmap.aspx
- The British Geological Survey in partnership with the Environment Agency, 2000. The Physical Properties of Minor Aquifer in England and Wales. H K Jones, B L Morris, C S Cheney, L J Brewerton, P D Merrin, M A Lewis, A M MacDonald, L M Coleby, J C Talbot, A A McKenzie, M J Bird, J Cunningham and V K Robinson
- https://www.gov.uk/government/publications/protect-groundwater-and-prevent-groundwater-pollution/
- DEFRA, 2023. Environmental Protection Act 1990. Part 2A. Contaminated Land Statutory Guidance.
- USEPA, 1999. Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities
- Howard et al, 1991. Handbook of Environmental Degradation Rates
- Steventon-Barnes, 2000. Solid organic matter in UK aquifers: its role in sorption of organic contaminants
- Environment Agency and Atkins, 2003. Review of the Fate and Transport of Selected Contaminants in the Soil Environment. Tables 2.4, 3.2 & 4.3.

APPENDIX A

Controlled Water Screening Calculations

KMg checked- 14/11/2024

Total porosity	phi_tot	0.3
Watr filled porosite	phi_w	0.3
air filled porosity	phi_a	0

KMG Changed to use SOM as fraction

USEPA data

Contaminant of concern	Contaminant concentration (mg/kg)	Min concenrtration (mg/kg)	Max concentration (mg/kg)	Kd (L/kg)	Kd Comment	Source	SOM (%)	Koc	Source	Foc (-)	Soil density (kg/m3)	Cgw (mg/l)***	Location	Depth (m)	Soil description	EQS AA* (mg/l)	EQS MAC* (mg/l)	DWS (mg/l)
Copper	17 to 61	17	61	10000	(based on pH 6.8)	USEPA data	N/A	N/A	N/A	N/A	1842	6.10E-03	All	0.1 to 3.8	TS, MG, C	**0.001**	N/A	2
Mercury	0.12-0.19	0.12	0.19	1000		USEPA data	N/A	N/A	N/A	N/A	1842	1.90E-04	TP7	0.1 to 2.1	MG	N/A	$7x10^{-5}$	0.001
Nickel	8.4-55	8.4	55	65	(based on pH 6.8)	USEPA data	N/A	N/A	N/A	N/A	1842	8.44E-01	All	0.1 to 3.8	TS, MG, C	**0.004**	0.034	0.02
Lead	15-68	15	68	900		USEPA data	N/A	N/A	N/A	N/A	1842	7.55E-02	All	0.1 to 3.8	TS, MG, C	**0.0012**	0.014	0.01
Vanadium	11 to 54	11	15	N/A			N/A	N/A	N/A	N/A	1842	N/A	All	0.1 to 3.8	TS, MG, C	0.02 – 0.06	N/A	N/A
Zinc	18-95	18	95	62		USEPA data	N/A	N/A	N/A	N/A	1842	1.53E+00	All	0.1 to 3.8	TS, MG, C	**0.0109**	N/A	5
Arsenic	4.7-68	4.7	68	29	(based on pH 6.8)	USEPA data	N/A	N/A	N/A	N/A	1842	2.33E+00	All	0.1 to 3.8	TS, MG, C	**0.05**	N/A	0.01
Selenium	0.25-1.5	0.25	1.5	5	(based on pH 6.8)	USEPA data	N/A	N/A	N/A	N/A	1842	2.91E-01	All except TP3	0.1 to 3.8	TS, MG, C	N/A	N/A	0.01
Naphthalene	1.2	1.2	1.2	11.43970711		USEPA data	1.3	1514	15	0.0076	1842	1.03E-01	TP7	0.7-2.1	MG	0.002	0.13	$1x10^{-4}$**
Acenaphthylene	0.82	0.82	0.82	250.2735221		koc*foc	1.3	33113	15	0.0076	1842.00	3.27E-03	TP7	0.7-2.1	MG	N/A	N/A	$1x10^{-4}$**
Acenaphthene	1	1	1	140.7391441		koc*foc	1.3	18621	15	0.0076	1842.00	7.10E-03	TP7	0.7-2.1	MG	N/A	N/A	$1x10^{-4}$**
Fluorene	2.4	2.4	2.4	228.2521649		koc*foc	1.3	30200	15	0.0076	1842.00	1.05E-02	TP7	0.7-2.1	MG	N/A	N/A	$1x10^{-4}$**
Phenanthrene	5.4	5.4	5.4	20900		USEPA data	1.3	30200	15	0.0076	1842.00	2.58E-04	TP7	0.7-2.1	MG	N/A	N/A	$1x10^{-4}$**
Anthracene	0.5	0.5	0.5	287.3524507		koc*foc	1.3	38019	15	0.0076	1842.00	1.74E-03	TP7	0.7-2.1	MG	$1x10^{-4}$	$1x10^{-4}$	$1x10^{-4}$**
Fluoranthene	0.2-2.8	0.2	2.8	888.0039659		koc*foc	1.3	117490	15	0.0076	1842.00	3.15E-03	TP5 & TP7	0.1 to 3.8	MG	**$6.3x10^{-6}$**	$1.2x10^{-4}$	$1x10^{-4}$**
Pyrene	0.11-3.2	0.11	3.2	643.3020056		koc*foc	1.3	85114	15	0.0076	1842.00	4.97E-03	TP5 & TP7	0.1 to 3.8	MG	N/A	N/A	$1x10^{-4}$**
benzo[a]anthracene	0.16-1.3	0.16	1.3	5109.929465		koc*foc	1.3	676083	15	0.0076	1842.00	2.54E-04	TP5 & TP7	0.1 to 3.5	MG	N/A	N/A	$1x10^{-4}$**
Chrysene	0.37-1.7	0.37	1.7	5228.955013		koc*foc	1.3	691831	15	0.0076	1842.00	3.25E-04	TP5 & TP7	0.1 to 3.5	MG	N/A	N/A	$1x10^{-4}$**
benzo[b]fluoranthene	0.22-1.3	0.22	1.3	16920.56674		koc*foc	1.3	2238721	15	0.0076	1842.00	7.68E-05	TP5 & TP7	0.1 to 3.5	MG	N/A	N/A	$1x10^{-4}$**
benzo[k]fluoranthene	0.18-0.52	0.18	0.52	25027.35221		koc*foc	1.3	3311311	15	0.0076	1842.00	2.08E-05	TP5 & TP7	0.1 to 3.5	MG	N/A	N/A	$1x10^{-4}$**
benzo[a]pyrene	0.18-0.61	0.18	0.61	3224.147526		koc*foc	1.3	426580	15	0.0076	1842.00	1.89E-04	TP5 & TP7	0.1 to 3.5	MG	$1.7x10^{-7}$	N/A	$1x10^{-5}$
indeno(1,2,3-c,d)pyrene	0.15-0.33	0.15	0.33	125433.8942		koc*foc	1.3	16595869	15	0.0076	1842.00	2.63E-06	TP5 & TP7	0.1 to 3.5	MG	$1.7x10^{-7}$*	N/A	$1x10^{-4}$**
Dibenzo(a,h)anthracene	0.2	0.2	0.2	7053.666227		koc*foc	1.3	933254	15	0.0076	1842.00	2.84E-05	TP7	0.7 to 2.1	MG	N/A	N/A	$1x10^{-4}$**
Benzo[g,h,i]perylene	0.22-0.44	0.22	0.44	65828.64343		koc*foc	1.3	8709636	15	0.0076	1842.00	6.68E-06	TP5 & TP7	0.1 to 3.5	MG	$1.7x10^{-7}$*	N/A	$1x10^{-4}$**
TPH	110-200	110	200				1.3						TP1 & TP7	0.1 to 2.1	MG	N/A	N/A	N/A

All – no samples were taken from TP2 or TP6

Text in **Bold** are exceeded screening concentrations

*Screening value for Benzo(a)pyrene (BaP) as BaP is considered as a marker for other PAHs.

**Value for polyaromatic hydrocarbons used where no specific screening values is available

TS – Topsoil, MG – Made ground, C - clay

12 - Environment Agency/Atkins, 2003. Review of the Fate and Transport of Selected Contaminants in the Soil Environment. Tables 2.4, 3.2 & 4.3.

15 - Koc values from Geometric mean of koc values from Physical-Chemical Properties and Environmental Fate for Organic Chemicals, Mackay et. al. 2006. 2nd Ed.

Soil density based on granualr made ground equation from . https://soilquality knowledgebase.org.au/measuring-soil-organic-carbon/ soil organic matter % = soil organic carbon % x 1.72

***RAM manual is ESI (2008) Guide to using RAM Risk Assessment Model

APPENDIX B

RAM Modelling Data

Source Type

☑ Soil Source ☐ Groundwater Source

Level Number

- ○ Level One
- ○ Level Two
- ◉ Level Three
- ○ Level Four
- ○ Advanced

Parameter Values

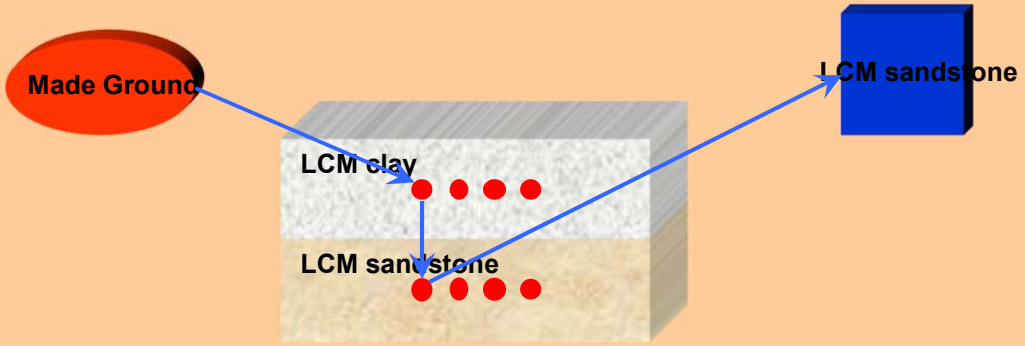
◉ Deterministic ○ Probabilistic

Created: 18/11/2024 13:20:52

by: Joe Gomme

Version: 3.40.51x Adv

Site: Liley Lane



Numerical value
Suggested formula
Probabilistic parameters
Data specified elsewhere
Suggested formula edited

CONTAMINANT INFORMATION

		Species1	Species2	Species3	Species4	Species5	Species6
Source determinand names	6	Mercury	Nickel	Arsenic	Naphthaler	Phenanthre	Benzene

Receptor Target Concentrations

	Name	Values in mg/L					
Quality Standard 1	DWS	1.00E-03	0.02	0.01	0.002		0.001
Quality Standard 2	EQS	7.00E-05	0.004	0.05	1.00E-04	1.00E-04	0.01
Quality Standard 3							
Quality Standard 4							

Generic Contaminant Properties

Contaminants_Solubility	**mg/L**	10	10	10	10	10	10
Contaminants_Henrys_Law_Constant	**[-]**	1	1	1	0.017	0.0013	0.182
Contaminants_Organic_Carbon_Water_Partition_Coefficient_Koc	**L/kg**	0	0	0	1514	30200	27
Contaminants_Free_Water_Diffusion_Coefficient	**m2/s**	2.00E-09	2.00E-09	2.00E-09	2.00E-09	2.00E-09	2.00E-09

HYDROGEOLOGICAL UNITS

Hydrogeological Units		LCM clay	LCM sandstone	
Hydrogeology_Unit_Thickness	m	1	10	
		assumed	assumed	
Hydrogeology_Log_Hydraulic_Conductivity	log(m/s)	0.00E+00	0	
Hydrogeology_Hydraulic_Conductivity	m/s	1.00E-09	1.96759E-07	6.3e-3 for L&MCM sandstone in text from minaq p181; 1.7e-2 for MCM east pennines, 6 sites
		estimate fc	Max for LCM east pennines minaq table 8.10 * 100	
Hydrogeology_Hydraulic_Gradient	[-]	1	0.091	
		unsaturate	15m elevation difference site centre to stream head, distance 164m	
Hydrogeology_Porosity	[-]	0.05	0.1	
		estimate fc	8-13% LCM east pennines minaq table 8.10	
Hydrogeology_Velocity	m/s	2E-08	1.79051E-07	
Hydrogeology_Tortuosity	[-]	5	5	

ATTENUATION PARAMETERS

Hydrogeological Units		LCM clay	LCM sandstone
General properties			
Attenuation_Dry_bulk_density	**kg/m3**	1300	1850
		estimated	estimated
Attenuation_Fraction_organic_carbon	**[-]**	0.0217	0.0217
		Steventon-Barnes, 2000 (Solid organic matter in UK aquifers: its role in sorption of organic contaminants) Table 19 has mean 2.17%, max 7.26% and min 0.38% in LCM	
Contaminant specific parameters			
Mercury			
Attenuation_Partition_Coefficient_Kd_Species_1	**L/kg**	1000	1000
		USEPA	
Attenuation_Retardation_Species_1	**[-]**	26001	18501
Attenuation_Half_Life_Species_1	**days**	No Decay	No Decay
Attenuation_Decay_Coefficient_Species_1	**1/s**	0	0
Nickel			
Attenuation_Partition_Coefficient_Kd_Species_2	**L/kg**	65	65
		USEPA (for neutral pH)	
Attenuation_Retardation_Species_2	**[-]**	1691	1203.5
Attenuation_Half_Life_Species_2	**days**	No Decay	No Decay
Attenuation_Decay_Coefficient_Species_2	**1/s**	0	0
Arsenic			
Attenuation_Partition_Coefficient_Kd_Species_3	**L/kg**	29	29
		USEPA (for neutral pH)	
Attenuation_Retardation_Species_3	**[-]**	755	537.5
Attenuation_Half_Life_Species_3	**days**	No Decay	No Decay
Attenuation_Decay_Coefficient_Species_3	**1/s**	0	0
Naphthalene			
Attenuation_Partition_Coefficient_Kd_Species_4	**L/kg**	32.8538	32.8538
Attenuation_Retardation_Species_4	**[-]**	855.1988	608.7953

Attenuation_Half_Life_Species_4	**days**	258	258
		High estimate for groundwater half-life - Howard et al	
Attenuation_Decay_Coefficient_Species_4	**1/s**	3.11E-08	3.11E-08

Phenanthrene

Attenuation_Partition_Coefficient_Kd_Species_5	**L/kg**	655.34	655.34
Attenuation_Retardation_Species_5	**[-]**	17039.84	12124.79
Attenuation_Half_Life_Species_5	**days**	401.5	401.5
		High estimate for groundwater half-life - Howard et al	
Attenuation_Decay_Coefficient_Species_5	**1/s**	2E-08	2E-08

Benzene

Attenuation_Partition_Coefficient_Kd_Species_6	**L/kg**	0.5859	0.5859
Attenuation_Retardation_Species_6	**[-]**	16.2334	11.83915
Attenuation_Half_Life_Species_6	**days**	730	730
		High estimate for groundwater half-life - Howard et al	
Attenuation_Decay_Coefficient_Species_6	**1/s**	1.1E-08	1.1E-08

SOURCE CONCENTRATIONS: Made Ground

SOIL SOURCE

Source Data Options

- ○ Pore water concentrations
- ○ Leaching test
- ◉ Soil contaminant concentrations

Source Type

- ◉ Constant source
- ○ Declining source

Source Geometry

Made_Ground_Source_length	160	**m**	approximated from plans
Made_Ground_Source_width	100	**m**	approximated from plans
Made_Ground_Source_area	16000	**m2**	
Made_Ground_Source_thickness	1.2	**m**	estimated average based on maximum of
Made_Ground_Source_volume	19200	**m3**	2.4m from proposed section drawing

General Source Properties

Made_Ground_Source_porosity_total	**[-]**	0.25
Made_Ground_Source_porosity_water_filled	**[-]**	0.1
Made_Ground_Source_porosity_air_filled	**[-]**	0.15
Made_Ground_Source_dry_bulk_density	**kg/m3**	1200
Made_Ground_Source_fraction_organic_carbon	**[-]**	0.05

Source Contaminant Information

Source determinand names		Mercury	Nickel	Arsenic	Naphthaler	Phenanthre	Benzene
Made_Ground_Soil_contaminant_concentration	**mg/kg**	0.19	55	68	1.2	5.4	10
Made_Ground_Source_solid_water_partitioning_coefficient_Kd	**L/kg**	1000	65	29	32.8538	655.34	0.5859
Made_Ground_Input_concentration	**mg/L**	0.00019	0.84345	2.328103	0.036431	0.008239	10

WATER BALANCE

Infiltration through the soil zone source

Source Name: Made Ground

Effective_Rainfall	300	**mm/year**
Infiltration_Factor	1	**[-]**
Infiltration_Rate	300	**mm/year**
Infiltration_Area	16000	**m2**
Q_Infiltration	0.000152	**m3/s**

PATHWAY SUMMARY

Path 1		Section 1		Section 2		Section 3		Section 4	
Path 1 Type		Source		Unit		Unit		Receptor	
Path 1 Name		**Made Ground**		**LCM clay: Node 1**		**LCM sandstone: Node 1**		**LCM sandstone**	
Path 1 Process		Declining source		ADRD (1D)		ADRD (1D) + Dilution		Monitoring Borehole	
Path 1 Standards								Target Standard	EQS
Path 1	Parameter1	**Q_managed [m3/s]**	0.000E+00	**Velocity [m/s]**	2.000E-08	**Velocity [m/s]**	1.791E-07		
Path 1	Parameter2	**Managed time [years]**	0.000E+00	**Dispersivity [m]**	0.1	**Dispersivity [m]**	8.6		
Path 1	Parameter3	**Q_path [m3/s]**	1.521E-04	**Travel Distance [m]**	1.0	**Travel Distance [m]**	86.0		
Path 1	Parameter4	**Q_decline [m3/s]**	1.521E-04			**Mixing Depth [m]**	8.6		
Path 1	Parameter5					**Mixing Width [m]**	100.0		
Path 1	Parameter6			**Q_Dilute [m3/s]**	0	**Q_Dilute [m3/s]**	1.540E-05	**Q_dilute [m3/s]**	0.000E+00

SIMULATION PARAMETERS

Monte Carlo Analysis with Crystal Ball

Reported Percentile	95
Number of simulations	10000

☐ Stop on calculation error

☐ Use same sequence of random numbers

Minimise while running:

◉ Nothing

○ All Spreadsheets (faster)

○ Microsoft Excel (fastest)

Named Constants

s_per_year	31557600
s_per_day	86400

Laplace Transform Solution Parameters

sigma	0
nu	1
nsum	16
omega	11

Reporting Options

☐ Include Remedial Targets and Attenuation Factors on the results sheets in Advanced level

☐ Use the array form of the RAM function

☐ Include a set of timeslices for each contaminant in each pathway

Number of timeslices for breakthrough curves: 10

The timeslices specified on the results sheets are saved below.

Path1 timeslices in years

TS_Path1
10
20
25
30
500
2000
3000
4000
5000
10000

RECEPTOR: LCM sandstone

Receptor Options

◉ Monitoring Borehole

No further dilution along pathway

No data requirement