REPORT

Lynemouth Bay DfR Scheme: Hydrogeological Risk Assessment

In Support of Environment Agency Deposit for Recovery Environmental Permit Application

Client: Northumberland County Council

Reference: PB9153-RHD-ZZ-XX-RP-Z-0038

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1 Introduction

Northumberland County Council (NCC) 'the Operator' proposes to lead voluntary 'waste management' of the eroding coastal historical landfill at Lynemouth Bay. As part of this, NCC wishes to operate a bespoke deposit for recovery (DfR) Environmental Permit at three locations, referred to from herein as 'Work Areas'. Royal HaskoningDHV has been appointed by NCC to prepare the Environmental Permit application and this Hydrogeological Risk Assessment (HRA) report forms part of the application.

The purpose of the HRA is to present the hydrogeological conceptual site model, summarise baseline conditions that have been established to date, and present future monitoring and sampling proposed to be undertaken.

1.1 Background and Context

NCC is seeking to deliver an overall 'environmental betterment' in Lynemouth Bay by voluntarily undertaking a remediation scheme. The aim of the remediation is to mitigate the risks to the marine environment from the release of the 'contraries' into the North Sea. The scheme entails excavation of soils containing a significant volume of 'contraries' and replacement of the usable material. Some of the objectives of the scheme relate to reinstatement, which is required in order that:

- erosion can continue naturally without causing unacceptable harm to the environment;
- preferential erosion is prevented from occurring, which would alter the physical processes within the bay and especially at the mouth of the River Lyne, potentially altering the morphology of the river's channel in an uncontrolled manner;
- public safety concerns are prevented by avoiding open excavations;
- a substrate is formed to enhance the growth of vegetation to promote stabilisation of the cliff top and to re-establish local flora and fauna.

This report should be read in conjunction with other supporting documents to the Environmental Permit, notably the Environmental Setting and Site Design (ESSD) report, (Royal HaskoningDHV, 2021) and the accompanying figures presented in **Appendix E** of **Lynemouth Bay DfR Scheme: Figures & Drawings**.

The Environment Agency Hydrogeological Risk Assessment template for landfills (2014) has been used in preparation of this report.

1.2 Objectives

The aim of this report is to support the Environmental Permit application by providing:

- information required for assisting in the determination of an DfR scheme in the three Work Areas;
- a hydrogeological risk assessment for the scheme; and
- justification for not undertaking numerical modelling.

1.3 Sources of Information

Key sources of information used in the preparation of this report are:

- Faber Mausell, Lynemouth Bay Reclamation Phase II, Geoenvironmental Interpretive Report, January 2006

- Royal HaskoningDHV's Lynemouth Coastal Landfill, Site Characterisation and Interim Generic Quantitative Risk Assessment (GQRA), (Ref. PB9153-RHD-ZZ-XX-RP-Z-0001), March 2020
- Royal HaskoningDHV's Supplementary Interpretive Ground Investigation and Generic Quantitative Risk Assessment (GQRA) (Ref. PB9153-RHD-ZZ-XX-RP-Z-0018) December 2020
- Royal HaskoningDHV's Waste Recovery Plan, version 4, (Ref. PB9153-RHD-ZZ-XX-RP-Z-0015) 2021

1.4 Layout of this Report

Following this introduction, the conceptual hydrogeological model for the landfill is developed in Section 2. The hydrogeological risk assessment is presented in Section 3. Section 4 sets out the proposed monitoring regime for the DfR scheme. Conclusions are presented in Section 5. Data is summarised in the text and, where appropriate, more detailed information is provided in the recent Royal HaskoningDHV GQRA report noted above, which can be provided upon request.

2 Hydrogeological Conceptual Site Model

The geology, hydrology and hydrogeology baseline information is presented in the ESSD Report, which forms part of the Environmental Permit application, and has been used *inter alia* the controlled waters risk assessment undertaken as part of the generic quantitative risk assessment (Royal HaskoningDHV, 2020b) to construct a hydrogeological conceptual site model for the DfR scheme.

2.1.1 Aquifers

The site is underlain by superficial Marine Deposits (Secondary A Aquifer) and the Pennine Middle Coal Measures Formation (Secondary A Aquifer). They are variable in permeability and are likely to be in close hydraulic connection. Groundwater within the Secondary A Aquifers discharges into the North Sea and locally into the River Lyne.

2.1.2 Water Abstractions

The groundwater underlying the site is affected by saline intrusion. Differences in groundwater elevation between monitoring rounds is indicative of tidal influence. In addition, chloride was recorded at concentrations greater than 250 mg/l within the groundwater samples which is indicative of saline intrusion (WHO, 2003). These results indicate that the aquifers are saline, indicating they are unlikely to be abstracted for potable water.

There are no licenced groundwater abstractions on site. The nearest licenced groundwater abstraction is located approximately 640 m south-west of the site boundary, operated by The Coal Authority to remediate acid mine drainage for the adjacent former colliery.

2.1.3 Groundwater Source Protection Zones

Groundwater Source Protection Zones (SPZs) are defined around abstraction boreholes used for potable water supply to delineate the area where the release of a contaminant into the aquifer could impact on the abstraction. There are no licenced surface water abstractions identified within the site boundary, or within 1 km of the site.

2.1.4 Hydrology

The nearest surface water receptors are the North Sea and River Lyne. The River Lyne is located to the west of the site, where it flows in a north to south direction before diverting east into the southern part of the site. Within the site it flows in a west to east direction towards the North Sea. The Environment Agency Catchment Data Explorer[1] records the River Lyne from its source to the tidal limit (waterbody ID GB103022076820) as having an overall classification of poor water quality and poor ecological quality (Environment Agency 2016). There is some limited evidence to suggest that groundwater at the site locally discharges into the River Lyne.

This is summarised in Table 2-1 below and illustrated in **Appendix E** of **Lynemouth Bay DfR Scheme: Figures & Drawings**.

[1] *Environment Agency – Catchment Data Explorer (http://environment.data.gov.uk/catchment-planning/WaterBody/GB103022076820)*

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Table 2-1 Conceptual Hydrogeological Site Model

Source	Pathways	Receptors
Substances likely to leach from the reinstated soils and colliery spoil	Leaching and dissolution from unsaturated contaminated soils and vertical migration	Groundwater: Secondary A Aquifer (Coal Measures)
	Leaching and dissolution from unsaturated contaminated soils and vertical migration	Groundwater: Secondary A Aquifer (Marine Deposits)
	Erosion / surface water flooding	River Lyne
	Erosion / surface water flooding	North Sea
	Uncontrolled surface water runoff from soils and colliery spoil during reinstatement earthworks	Groundwater, River Lyne and North Sea

2.2 Justification for Reinstatement without Landfill Engineering

Landfill engineering typically comprises installation of impermeable barriers in order to prevent hydraulic connectivity with the surrounding land and groundwater. As part of the proposed scheme, any back-filled material is currently in situ and will be reinstated to the excavations where it will continue to be eroded (as the surrounding land is), and therefore is 'sacrificial' in purpose.

The reinstated material will comprise the soil matrix that remains following removal of contraries and is considered to be formed from the same material (colliery spoil) which forms the majority of the land currently eroding into Lynemouth Bay and the wider area. Chemical analysis undertaken on the soils and soil-leachate does not indicate any significant difference in the chemical characteristics between the soils identified for reinstatement and the surrounding land. As such, it is not considered necessary to isolate this material from the surrounding land via installation of engineered barriers.

For the same reason that it is considered to be unfeasible to prevent coastal erosion completely in Lynemouth Bay, the reasoning is applicable in the justification for reinstatement without landfill engineering, as any engineered infrastructure would require protection from coastal erosion for the investment to be worthwhile. Prevention of coastal erosion at Lynemouth Bay is considered unfeasible for the following reasons:

- it is financially unviable because NCC has a finite budget which needs to be allocated appropriately and for landfill engineering to be worthwhile, would need to be protected from erosion;
- any largescale engineering coastal defence infrastructure may adversely alter the ecology and landscape of Lynemouth Bay and surrounding areas, a particular concern given the site's location within a local nature reserve and adjacent proximity to sites of national and international conservation designations.

Engineering as part of the DfR scheme is proposed in the form of installation of a cover system, reprofiling the cliff edge to a gentler slope and compaction of the reinstated material. This is considered to either maintain leachate generation potential to be consistent with surrounding soils or potentially reduce leachate generation following reinstatement compaction and angle of the seaward slopes as it may limit rainfall infiltration and a greater amount of rainfall is expected to runoff. The cover system may assist to reduce oxidisation to the reinstated soils.

2.3 Source

The soils proposed to be reinstated in the DfR scheme are considered to be the potential source of pollution. This source is a combination of reinstated colliery spoil and soil identified for reuse following

removal of contraries. Rainfall infiltration through the reinstated soils may leach and mobilise contaminants and erosion of the soils may also mobilise contaminants.

Soil-leachate and groundwater samples collected from within and outside of the proposed Work Areas do contain concentrations of some contaminants in exceedance of environmental quality standards. However, most of the exceedances are sporadic. The data obtained indicates the key contaminants of concern are metals (mainly cadmium, nickel and zinc plus others in Work Area (Location) 4) in soil-leachate samples with corresponding elevated concentrations in groundwater samples in some locations. The data suggests that the source of elevated concentrations of metals is the oxidation of pyrite minerals within the colliery spoil waste in some surface areas which is leading to acidic conditions and the release of metals into soil leachate and subsequently groundwater. It should also be noted that due to the aggressive nature of batch leaching tests they are likely to identify all potentially leachable substances but to over-predict the likely leachable mass.

Elevated concentrations of some polycyclic aromatic hydrocarbons (PAHs) above their EQS were recorded in groundwater samples but not in soil leachate. Elevated concentrations of PAHs above EQS were also recorded in samples collected from the River Lyne, however this included samples collected up hydraulic gradient of the site. This suggests these contaminants may be elevated within the local region.

The rate of leachate generation within the reinstated soils is expected to be lower than the current situation due to compaction and the angle of the slope reinstatement is likely to limit rainfall infiltration, and the rainfall will runoff. Weathering of the upper layers of the compacted soils may further reduce its permeability and therefore infiltration. Although it is noted, elevated concentrations of metals were not identified in surface water samples collected from the River Lyne indicating that the metals recorded within site soils is not currently adversely impacting water quality in the river.

2.4 Pathways

The potential pathways for leachate contaminants from the reinstated soils comprise:

- Leaching and dissolution from unsaturated contaminated soils and vertical migration;
- Erosion / surface water flooding with limited lateral migration due to the close proximity of the River Lyne and North Sea receptors; and
- Uncontrolled surface run off from soils proposed for reinstatement during backfilling and compaction operations.

2.5 Receptors

The potential receptors at risk of impact from leachate derived from reinstated soils are as follows:

- Groundwater in the superficial deposits (Secondary A Aquifer);
- Groundwater in the Pennine Middle Coal Measures Formation, which is logged as sandstone (Secondary A Aquifer). The aquifers are likely to be in hydraulic continuity;
- River Lyne, located immediately adjacent to Work Areas 1 and 2, which flows into the North Sea; and
- North Sea, located immediately on the site's eastern boundary.

An important context to this risk assessment is that groundwater sensitivity is considered to be low in this area. This is because groundwater is not abstracted locally is likely to have saline intrusion and likely to have poor quality due to the location within a former industrial setting, being an area of historical waste deposition and within an area of a large volume of colliery spoil deposits. It should be noted that any

hazardous substances entering groundwater or surface water below or adjacent to the Work Areas is doing so currently and the status of this is not considered likely to change in the long term following the reinstatement earthworks.

3 Hydrogeological Risk Assessment

This section provides an assessment of the risks to local groundwater and surface water receptors from the proposed DfR scheme. Numerical modelling has not been undertaken in the preparation of this hydrogeological risk assessment because there is no introduction of a contamination source as the scheme is a reinstatement earthworks project. Assessment of attenuation pathways would not be appropriate due to the coastal location, where dissolved phase contaminants (metals) in groundwater are likely to be discharging into the North Sea on the immediate site boundary.

3.1 Nature of the Hydrogeological Risk Assessment

Environment Agency guidance for landfills states that the level of detail in a risk assessment should be proportionate to the nature and complexity of the risk being addressed, with the three tiers being Risk Screening, Simple Risk Assessment and Complex Risk Assessment. The more sensitive the environmental setting, the greater the level of confidence that is required. A Simple Risk Assessment is considered appropriate for the DfR scheme, as it lies in an area where groundwater and surface water sensitivity is considered to be low due to:

- being underlain by Secondary A Aquifers (Marine Deposits and Pennine Middle Coal Measures) with no licenced or private groundwater or surface water abstractions near the DfR scheme;
- local groundwater quality is likely to be considered as poor due to the location within a former industrial setting, area of historical waste deposition and within an area of a large volume of colliery spoil deposits; and
- the DfR scheme does not lie within or close to a SPZ.

The following is considered with respect to the surrounding environment of the site and the design of the scheme:

- the DfR scheme contains a similar type of material (colliery spoil) with known properties and chemical characteristics similar to the surrounding land. The tipped colliery spoil within Lynemouth Bay is not confined to the site boundary and it is likely that the area surrounding the site is also contributing to dissolved phase contaminants in groundwater currently entering into the North Sea;
- The DfR scheme will involve backfilling within a short period of time, limiting the interaction of reinstatement material with the environment;
- The reinstatement design in simple; and
- There is considered to be a very high potential for dilution in the North Sea compared to the volumes of contaminated groundwater derived from the Work Areas. Dissolved phase contaminant concentrations are also likely to be discharged into the North Sea from the colliery spoil in the wide area of Lynemouth Bay surrounding the Work Areas.

3.1.1 Groundwater and Perched Water Observations

During the two rounds of groundwater elevation monitoring undertaken by Royal HaskoningDHV in 2020, groundwater elevations were measured between 4.85 m bgl (3.52 m AOD) and 10.28 (1.610 m AOD) in monitoring wells located to the north of the River Lyne and 5.55 m bgl (4.37 m AOD) and 9.60 (0.09 m AOD) in exploratory locations to the south of the River Lyne. Groundwater was recorded as resting within the superficial deposits or at the base of the colliery spoil. The groundwater elevation data suggests that the superficial deposits and colliery spoil are in hydraulic continuity with resting groundwater levels recorded at similar elevations within both units. The superficial deposits and colliery spoil also appear to be in hydraulic continuity with the underlying sandstone. Clay layers were recorded overlying the

sandstone in some locations, however the clay is described as gravelly and is absent in some locations indicating that the clay layer has some permeability and does not extend across the entirety of the site.

The groundwater monitoring elevation data collected during the monitoring rounds has been interpreted to determine groundwater flow direction across the site. The groundwater flow direction plots from monitoring rounds undertaken in September 2020 are provided in **Appendix D** of **Lynemouth Bay DfR Scheme: Figures & Drawings**. These indicate that groundwater north of the River Lyne flows to the east towards the North Sea and the groundwater south of the River Lyne flows to the north east towards the River Lyne and North Sea. A similar flow pattern was observed during both monitoring rounds. The data indicates that there is a steep hydraulic gradient towards the North Sea and River Lyne.

The tidal influence on groundwater elevation within the different groundwater bearing strata was not determined as data loggers installed within on-site monitoring wells were stolen and the data lost. However, observations between monitoring rounds indicated that groundwater elevations vary between 12 cm (BH10) and 98 cm (BH05) with an average change in elevation of 36 cm. The changes in groundwater elevation are greater than what would be expected to naturally occur due to rainfall and indicate that groundwater levels are tidally influenced. This is expected given the site's proximity to the North Sea.

The only locations where a change in water level between monitoring rounds was not observed was BH01 located off site in the south and BH08 located within the centre of Location 2. Within BH08 water levels were recorded as being much higher than the surrounding groundwater level, for example water was recorded at 8.25 m AOD within BH08 during the monitoring undertaken on the 7th September 2020 compared with 1.61 m AOD within BH2004, which is located approximately 25 m to the south of BH08. This indicates that the water within BH08 is perched. This is further supported by the fact that the water level within BH08 did not significantly change (0.082 m) between monitoring rounds, unlike that observed in other monitoring wells. This well was also dry during monitoring undertaken as part of Royal HaskoningDHV's 2019 investigation. The exploratory hole log for BH08 does not describe an impervious layer within this monitoring well so it is uncertain why water is perched at this location.

During a topographical survey undertaken at the site in July 2020, the top of the water level within the River Lyne was recorded at four locations, one west of the site near the bridge that crosses the river, three adjacent to the site and one at the mouth of the river before it discharges onto the beach. Water levels ranged from 3.25 m AOD near the bridge to 3.18 m AOD near the mouth of the river. During the groundwater monitoring rounds undertaken by Royal HaskoningDHV in September 2020, groundwater levels in monitoring wells near the river were generally recorded below 3 m bgl, with the exception of BH07 where groundwater was observed between 3.16 and 3.52 m AOD. It is likely that the river is also tidally influenced with water levels fluctuating with the tides and therefore the comparison between data from July and September is unlikely to show the true relationship between the river and groundwater. It is considered likely that there is some local hydraulic connection between groundwater at the site and the river.

3.2 Priority Contaminants

The priority contaminants associated with the material are metals and PAHs:

- Soil-leachate and groundwater samples collected from the site do contain concentrations of some contaminants in exceedance of environmental quality standards. The key contaminants of concern are metals, such as, cadmium, nickel and zinc plus others in Work Area (Location) 4. The data suggests that the source of elevated concentrations of metals is the oxidation of pyrite minerals within the colliery spoil waste in some surface areas which is leading to acidic conditions and the release of metals into soil leachate and subsequently groundwater. Compaction and the cover system following reinstatement of the soils is likely to reduce oxidisation, therefore metals may be of concern during the excavation works and before the reinstatement, rather than be causing an increase in the long term.

- Elevated concentrations of some PAHs above their EQS were recorded in groundwater samples but not in soil leachate. Elevated concentrations of PAHs above EQS were also recorded in samples collected from the River Lyne, however this included samples collected up hydraulic gradient of the site. This suggests these contaminants may be elevated within the local region. PAHs may be mobilised in the early stage leachate and may, therefore be impersistent in the long term and the current baseline is unlikely to be altered long term.

3.3 Qualitative Risk Assessment

3.4 Approach

For each possible source-pathway-receptor linkage identified, the potential risk was evaluated qualitatively based upon the probability and consequence risk matrix. This is based on based on CIRIA C552 (2001) Contaminated Land Risk Assessment – A Guide to Good Practice, this methodology is presented as Appendix A of this report.

3.5 Results

The results of the risk assessment for each source-pathway-receptor linkage are presented in Table 3-1 and discussed below:

Table 3-1 Conceptual Site Model

Source	Pathway	Receptor	Potential Consequence of Contaminant Linkage	Likelihood of contaminant Linkage	Risk Classification	Discussion
Substances likely to leach from the reinstated soils and colliery spoil	Leaching and dissolution from unsaturated contaminated soils and vertical migration	Groundwater: Secondary A Aquifer (Coal Measures)	Minor	Likely	Low risk	Groundwater samples identified the following widespread exceedances of the EQS in both groundwater and soil-leachate samples: cadmium, nickel, zinc. Fluoranthene and benzo(a)pyrene were not detected in soil -leachate samples above the EQS.
	Leaching and dissolution from unsaturated contaminated soils and vertical migration	Groundwater: Secondary A Aquifer (Marine Deposits)	Minor	Likely	Low risk	
	Erosion / surface water flooding	River Lyne	Minor	Likely	Low risk	Groundwater samples identified the following widespread exceedances of the EQS: cadmium, nickel, zinc (and other metals in Location 4). However, these

Source	Pathway	Receptor	Potential Consequence of Contaminant Linkage	Likelihood of contaminant Linkage	Risk Classification	Discussion
						were not recorded in the River Lyne.
	Erosion / surface water flooding	North Sea	Minor	Likely	Low risk	The qualitative understanding is dilution in the North Sea is likely to be vast.
	Uncontrolled surface water runoff from soils and colliery spoil during reinstatement earthworks	River Lyne, North Sea and Groundwater	Minor	Low likelihood	Very low risk	Soil movement and stockpiling will be adequately managed during the scheme to avoid uncontrolled run off.

4 Requisite Surveillance

4.1 Risk Based Monitoring Scheme

Appropriate monitoring, or requisite surveillance, is proposed to be undertaken in the form of groundwater and surface water monitoring. An appropriate level of monitoring is required in order to demonstrate that site management requirements are being met and to provide warning of any adverse impacts.

Monitoring is proposed up to a point where it is no longer practical or meaningful to monitor boreholes any further; i.e. where monitoring wells have been lost due to excavation of material containing 'contraries', or where boreholes and land have been eroded into the sea.

Sampling and analysis of the North Sea for the site monitoring programme is not considered likely to obtain any meaningful data to determine that any particular Work Area in isolation is causing pollution or provide data that could be used in any future hydrogeological risk assessment. Therefore, sampling of the North Sea is not proposed to be undertaken.

A leachate collection system or basal drainage layer is not proposed within this scheme, therefore leachate monitoring is not proposed.

4.1.1 Sampling Undertaken to Date

Groundwater and surface waste samples have been taken from monitoring wells across the site in addition to soil and soil-leachate samples. The samples obtained during the post ground investigation groundwater sampling exercise were scheduled for the following laboratory chemical analysis:

- pH, sulphate, ammoniacal nitrogen and total alkalinity as $CaCO_3$;
- unionised ammonia;
- metals: arsenic, hexavalent chromium, chromium III, cadmium, copper, mercury, lead, nickel, vanadium, selenium and zinc;
- TPH CWG with aromatic / aliphatic split and carbon banding;
- PAHs; and,
- VOCs and SVOCs.

Eight of the surface water samples obtained during the post SI groundwater sampling exercise from the River Lyne were scheduled for the following laboratory chemical analysis:

- Metals Bioavailability Assessment Tool (MBAT) suite of analysis;
- pH, sulphate, ammoniacal nitrogen, total alkalinity as $CaCO_3$;
- unionised ammonia;
- metals: arsenic, hexavalent chromium, chromium III, cadmium, copper, mercury, lead, nickel, vanadium, selenium and zinc;
- TPH CWG with aromatic / aliphatic split and carbon banding;
- PAHs; and,
- VOCs and SVOCs.

No. 16 of samples were also tested for chloride during the second round of sampling.

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4.2 Visual Monitoring

Visual and olfactory monitoring of material to be reinstated is proposed in order to ensure, for example, no material grossly contaminated with oil, which is unsuitable, is used within the DfR scheme. Further details in relation to this monitoring is provided in the Remediation Strategy (Royal HaskoningDHV, 2021). The Remediation Strategy can be provided upon request.

4.3 Groundwater Monitoring

4.3.1 Monitoring Regime

The Environment Agency Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water requires groundwater monitoring to be undertaken up and downgradient of the landfill where there is a pathway from the landfill to the groundwater.

The deposit of soils by reinstatement is not considered likely to create a pathway which has not been identified as an existing contaminant linkage already on the site. As such, there are no plans to drill boreholes as monitoring wells for the specific purpose of monitoring with respect to the DfR Environmental Permit. Pre-existing monitoring wells will be utilised to establish baseline conditions and obtain quarterly monitoring data for as long as practicable.

The following monitoring wells have been identified as suitable for future monitoring as part of this scheme:

Table 4-1 On-site Boreholes Selected for Groundwater Monitoring

Borehole	Monitoring Well Response Zone Strata	Groundwater Sampled previously	Work Area Location	Upgradient / Downgradient / within Work Area (WA)	Unit groundwater / perched water level is resting
BH01	Made Ground	Yes	Outside WA1	Down gradient	Colliery spoil
BH04	Made Ground	Yes (0.30 m)	WA2	Within WA	Colliery spoil
BH07	Made Ground	Yes	WA2	Within WA	Colliery spoil
BH2001	Sandstone	Yes	WA2	Within WA	Superficial deposits, gravelly CLAY
BH2002	Sandstone	Yes	WA2	Within WA	Colliery spoil
BH2003	Sandstone	Yes	WA2	Within WA	Superficial deposits, gravelly CLAY
BH2004	Sandstone	Yes	WA2	Within WA	Colliery spoil
BH2005	Sandstone	Yes	WA1	Up gradient	Superficial deposits, gravelly CLAY
BH2006	Sandstone	Yes	WA1	Within WA	Colliery spoil
BH2007	Sandstone	Yes	Outside WA1	Down gradient	Colliery spoil

The location of exploratory holes is presented in **Appendix B** of **Lynemouth Bay DfR Scheme: Figures & Drawings**.

Chemical testing undertaken so far has been for a broad range of determinands and the chemical analysis proposed to be undertaken in forthcoming quarterly monitoring is based on priority contaminants

Table 4-2 Water Testing Suite

Determinands
MBAT Analysis (surface water only)
Metals (arsenic, aluminium, barium, beryllium, boron, cadmium, chloride, chromium III and VI, copper, iron, lead, mercury, manganese, nickel, nitrate, selenium, vanadium and zinc)
pH
Total organic carbon (TOC)
Ammoniacal Nitrogen (as N)
Unionised ammonia
Total oxidised nitrogen (as N)
Sulphate (soluble)
Total Alkalinity as CaCO3
Speciated polycyclic aromatic hydrocarbons (USEPA 16)
Petroleum hydrocarbons (speciated as per TPH-CWG)

Sampling and data screening undertaken so far is summarised in Table 4-3 below. This summarises the exceedance against EQS with respect to the monitoring wells selected for future monitoring:

Table 4-3 Groundwater Data EQS Assessment to Date

Determinand	EQS (µg/l)	Monitoring well recording exceedance of the EQS (round)	Work Area
pH	7 – 9 (pH units)	BH01 (R1)	1
		BH04 (R2 and R3)	2
		BH07 (R2 and R3)	2
		BH2002 (R3)	2
Hexavalent Chromium	0.6	BH04 (R3)	2
		BH07 (R3)	2
		BH2003 (R3)	2
		BH2004 (R3)	2
Cadmium	0.25	BH04 (R1 and R3)	2
		BH07 (R1)	2
		BH2002 (R2 and R3)	2
Nickel	28.16	BH01 (R1, R2 and R3)	1
		BH04 (R1, R2 and R3)	2
		BH2002 (R2 and R3)	2
Zinc	57.02	BH01 (R1)	1
		BH04 (R1, R2 and R3)	2
		BH2002 (R2 and R3)	2

Determinand	EQS (µg/l)	Monitoring well recording exceedance of the EQS (round)	Work Area
		BH2003 (R3)	2
TPH Aliphatics >C16-21	8	BH07 (R3)	2
TPH Aliphatics >C21-35	8	BH01 (R1)	1
		BH2001 (R3)	2
Fluoranthene	0.0063	BH01 (R2)	1
		BH2005 (R2 and R3)	1
		BH2006 (R2 and R3)	1
		BH2007 (R2)	1
Anthracene	0.1	BH2003 (R1)	2
Benzo(a)pyrene	0.00017	BH01 (R2)	1
		BH2005 (R2 and R3)	1
		BH2006 (R2 and R3)	1
		BH2007 (R3)	1
		BH07 (R2 and R3)	2
		BH2001 (R2 and R3)	2
		BH2003 (R2 and R3)	2

Note: The assessment criteria are lower than the laboratory LoD for determinands such as hexavalent chromium, fluoranthene, benzo(a)pyrene analysis and a number of volatile and semi volatile determinands.
Note: Only samples that exceed the laboratory LoD have been included in this assessment.

4.4 Groundwater Baseline Monitoring

Monitoring of pH levels is intended to draw attention to any adverse or unanticipated trends in monitoring data or groundwater impacts. They are intended to provide an early warning system. They should allow for natural variations in groundwater quality and allow sufficient time for any necessary actions and settlement from the reinstatement works to take place prior to the consideration of additional management.

Specific compliance limits or regulatory standards such as EQS are not proposed to be used as compliance limits for the DfR scheme and reference is made to the screening exercise previously undertaken to present the fact that exceedances have been encountered ahead of the remediation and reinstatement scheme.

4.5 Surface Water Monitoring

To date three rounds of surface water monitoring have been undertaken. Assessment of the surface water results obtained from the River Lyne at the site has identified three determinands above the assessment criteria. Table 4-4 summarises the surface water assessment with respect to data recorded above the EQS.

Table 4-4 Surface Water Data Assessment EQS to Date

Determinands	EQS (µg/l)	Data Range (min – max) µg/l	No. of results above EQS	Location of exceedance of the EQS (Round)
Fluoranthene	0.0063	<0.005 – 0.0454	10	SW02 (R1, R2 and R3)

				SW03 (R1, R2 and R3)
				SW05 (R1 and R2)
Benzo(a)pyrene	0.00017	<0.002 – 0.03	6	SW02 (R2 and R3)
				SW03 (R2 and R3)
				SW05 (R1 and R2)
TPH Aromatics >C21-35	8	<10 - 11	1	SW05 (R1)

Note: The assessment criteria are lower than the laboratory LoD for determinands such as hexavalent chromium, fluoranthene, benzo(a)pyrene analysis and a number of volatile and semi volatile determinands.
Note: Only samples that exceed the laboratory LoD have been included in this assessment.

The Environment Agency Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water requires surface water monitoring up and downstream of a deposit of waste where there is a pathway from the deposit to the surface water. This is to track changes in surface water quality that may be attributed to the deposit.

It is noted that there is limited evidence to suggest that groundwater at the Works Areas locally discharges into the River Lyne. However due to the close proximity of Work Areas 1 and 2, monitoring of the River Lyne is proposed to be undertaken.

5 Conclusion

This hydrogeological risk assessment provides a hydrogeological conceptual site model and an assessment of the risks to local groundwater and surface water from the proposed DfR scheme. An important context to this risk assessment is that the scheme involves reinstatement of material already in place, and the DfR scheme is unlikely to adversely alter the current site conditions. Groundwater and surface water sensitivity is also considered to be low in this area. This is because the site is not within or close to a SPZ, there are no water abstractions within the site or surrounding area, and groundwater quality is likely to be considered as poor due to the location within a former industrial nature, area of historical waste deposition and within an area of a large volume of colliery spoil deposits.

Leachate generation is considered to be lower than that which is currently occurring following reinstatement due to compaction and a cover system which are likely to reduce rainfall infiltration and promote run off. Short term increases in pH levels and metal concentrations are anticipated upon exposure to atmosphere, however this exposure time is proposed to be kept to a minimum to reduce oxidation. PAHs are not considered likely to be readily mobilised via leaching as data obtained to date records elevated PAHs above the EQS in groundwater samples but not in soil leachate. However, if PAHs are mobilised during the earthworks it is likely to be impersistent in the long term. It is important to note that the laboratory leaching tests are likely to overestimate leaching concentrations in the reinstatement material due to the aggressive nature and limitations of the tests. This hydrogeological risk assessment therefore assesses the worst case scenario.

The qualitative risk assessment for each possible source-pathway-receptor linkage identified indicates a very low risk of pollution. It is therefore concluded that the DfR scheme will not pose an unacceptable risk to groundwater and surface water. A risk-based programme of surface water and groundwater monitoring has been proposed to act as an early warning for identification of conditions which have the potential to cause deterioration to the quality of these receptors in the long term.

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Appendix A - Qualitative Risk Assessment Methodology

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Qualitative Methodology

The risk assessment considers the sources and potential receptors identified, together with linking pathways. These linkages are summarised in the Preliminary Conceptual Site Model and Qualitative Risk Assessment within the report, where the associated environmental risk is assessed for a given source and the end-use of the site. This assessment also takes account of specific chemicals of concern or groups of similar chemicals of concern. The column designated as 'Potential Consequence of Source- Pathway – Receptor-Linkage' in the Preliminary Conceptual Site Model and Qualitative Risk Assessment gives an indication of the sensitivity of a given receptor to a particular source/chemical of concern being considered. It is a worst case classification and is based on full exposure via the particular linkage being examined. The derivation of the classes used to rank this particular aspect is as follows based on CIRIA 552 'Contaminated Land Risk Assessment, A Guide to Good Practice' 2001:

Classification	Human Health	Controlled Water	Ecological	Built Environment	Amenity
Severe	Acute risk to human health likely to result in 'significant harm' as defined by the Environmental Protection Act 1990, Part 2A	Substantial pollution of sensitive water resources	Significant change to the number of one or more species or ecosystems	Catastrophic damage to buildings, structures or the environment	Irreversible damage to human health
Moderate	Chronic damage to human health ('significant harm').	Pollution of sensitive water resources	Change to population densities of non-sensitive species	Damage to sensitive buildings, structures or the environment	Non-permanent health effects to humans
Mild	Harm but not necessarily significant harm to humans	Pollution to non-sensitive water resources	Some change to population densities but with no negative effects on the function of the ecosystem	Easily repairable effects of damage to buildings or structures	Slight short term health effects to humans
Minor	Harm but not necessarily significant harm to humans which can easily be prevented with the use of PPE.	Slight pollution to non-sensitive water resources	No significant changes to population densities in the environment or in any ecosystem	Very slight non-structural damage or cosmetic harm to buildings or structures	No measurable effects on humans

Subsequently, in the column designated 'Likelihood of PCL, an assessment is made of the probability of the selected source and receptor being linked by the identified pathway. This assessment is ranked based on-site specific conditions as follows:

Classification of probability	Definition
High likelihood	There is a pollution linkage and an event that either appears very likely in the short term and almost inevitable over the long term, or there is evidence at the receptor of harm or pollution
Likely	There is a pollution linkage and all the elements are present and in the right place, which means that it is probable that an event will occur Circumstances are such that an event is not inevitable, but possible in the short term and likely over the long term
Low likelihood	There is a pollution linkage and circumstances are possible under which an even could occur. However, it is by no means certain that even over a longer period such event would take place, and is less likely in the shorter term
Unlikely	There is a pollution linkage, but circumstances are such that it is improbable that an event would occur in the very long term

The ‘Risk Classification’ column is an overall assessment of the actual risk, which considers the likely consequence of a given risk being realised and the likelihood of that risk being realised. The risk classifications are assigned using the following consequence/likelihood matrix:

Matrix				
Severe	Moderate to low	Moderate	High	Very High
Medium	Low	Moderate to Low	Moderate	High
Mild	Very Low	Low	Moderate to Low	Moderate
Minor	Very Low	Very Low	Low	Moderate to Low
Likelihood	**Unlikely**	**Low likelihood**	**Likely**	**High likelihood**

Overall risks are described as follows:

Very Low	The presence of the identified source does not give rise to the potential to cause unacceptable harm.
Low	It is possible that harm could arise to a designated receptor from an identified source, however, this is unlikely to be unacceptable.
Moderate	It is possible that harm could arise to a designated receptor from an identified source, but it is likely that such harm would be relatively localised or non-permanent - remedial action may be necessary.
High	A designated receptor is likely to experience unacceptable harm from an identified source without remedial action.
Very High	There is a high probability that severe unacceptable harm could arise to a designated receptor from an identified source without appropriate remedial action.

In cases of physical features, such as foundations and underground services, harm is defined as impact which would result in non-serviceability of the identified receptor or extra over build costs associated with redevelopment.

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