FWS Geological & Geo-Environmental Consultants

SIRIUS MINERALS PLC - DISCHARGE OF PLANNING CONDITIONS FOR PLANNING PERMISSION NYM/2014/0676/MEIA (AS VARIED BY NYM/2017/0505/MEIA), NORTH YORKSHIRE POLYHALITE PROJECT

CONDITION	NYMNPA 46
REPORT	HYDROGEOLOGICAL RISK ASSESSMENT (NYMNPA 46 – PHASE 4a)
SITE	PHASE 4a WORKS AT WOODSMITH MINE, NORTH YORKSHIRE
DOCUMENT NUMBER	40-FWS-WS-70-WM-RA-0005 Rev 4

1433DevOR378 Rev 4/April 2018

FWS Consultants Ltd
Merrington House
Merrington Lane Ind Est
Spennymoor
County Durham
DL16 7UT
Company Registration No. 3944252

www.fwsconsultants.com

PROJECT NUMBER	1433Dev	
PROJECT TITLE	NORTH YORKSHIRE POLYHALITE PROJECT	
CLIENT	Sirius Minerals Plc Resolution House Lake View Scarborough YO11 3ZB	
REPORT TITLE	Hydrogeological Risk Assessment (NYMNPA 46 – PHASE 4a)	
REPORT REFERENCE	1433DevOR378 Rev. 4	
DOCUMENT NUMBER	40-FWS-WS-70-WM-RA-0005 Rev. 4	
REVISION	**Date**	**Checked**
Rev. 4	06/04/18	RIL

CONTENTS

HYDROGEOLOGICAL RISK ASSESSMENT (NYMNPA 46 – PHASE 4a)

1 INTRODUCTION

1.1 General Background

This document has been prepared on behalf of Sirius Minerals Plc and provides the Hydrogeological Risk Assessment (HRA) for the Phase 4a Works at Woodsmith Mine. This is required to satisfy Condition 46 of the North York Moors National Park Authority (NYMNPA) planning permission NYM/2014/0676/MEIA (as varied by NYM/2017/0505/MEIA).

Previous documents prepared by FWS on the hydrogeology of the site and the phased construction works have included a revised Hydrogeological Baseline Report (Ref. 1), Hydrogeological Risk Assessments for the Phase 2, 3 and 4 Works (Ref. 2, 3 and 4) and an assessment of the long term cumulative hydrogeological impacts, in support of the s73 application (Ref. 6).

As part of the approved 'Phase 4 Works', groundwater control was to be established within the first 120m of the Mineral Transport System (MTS) shaft using diaphragm walling, as described in the Phase 4 Construction Method Statement (CMS) (40-ARI-WS-71-PA-MS-1051). Sirius Minerals has subsequently identified an opportunity to expedite the excavation of the upper 120m of the MTS shaft at Woodsmith Mine, using a Vertical Shaft Sinking Machine (VSM) (Ref. 5). Use of the VSM offers significant construction programme benefits while not exceeding the environmental parameters that were established at Phase 4. This report is prepared as an addendum to the Phase 4 Hydrogeological Risk Assessment (Ref. 4) and provides a qualitative assessment of the potential effects of the proposed amended construction methodology for the MTS works on groundwater conditions on and adjacent to the site.

1.2 Compliance with Conditions

Table 1 sets out the wording of Planning Condition 46 to Planning Permission Ref No. NYM/2014/0676/MEIA (as varied by NYM/2017/0505/MEIA) that relates for the Hydrogeological Risk Assessment and details where the relevant material, to comply with this condition, has been provided within this report:-

<u>Table 1 - Summary of Planning Condition 46 and Where Relevant Details Are Provided In This Report</u>

NYMNP Condition 46	Compliance with Condition 46
Prior to the Commencement of Development at the Doves Nest Farm Minesite a revised Hydrogeological Risk Assessment based on the most up to date monitoring data shall be undertaken in accordance with the details in the document "York Potash Project: Habitats Regulations Assessment" prepared by Amec Foster Wheeler dated June 2015, with document reference 35190CGos064R and as updated by the HRA prepared by Royal Haskoning dated November 2017 with document reference 40-RHD-WS-83-WM-RP-0001 Rev 4; and submitted for approval in writing by the MPA in consultation with Natural England and the Environment Agency.	1. Details of the Phase 4a Works are presented in Section 3. 2. Up to date monitoring is presented in FWS Consultants Ltd 2016 Hydrogeological Baseline Report for the Doves Nest Farm Minesite, 2012 to 2016 (1975OR01 Ref. 1). 3. Details of the Hydrogeological Risk Assessment are presented in Section 6.

1.3 Objectives

This report provides an addendum to the Phase 4 Hydrogeological Risk Assessment and provides details of the temporary short term impacts and qualitative risk assessment of the VSM system. Based on the findings of this revised qualitative Hydrogeological Risk Assessment, amendments to the construction phase monitoring are provided to demonstrate the effectiveness of the groundwater controls to be adopted within the Phase 4a Works.

All details relating to the "as built" conditions, long term impacts and associated qualitative and quantitative modelling of the completed Service and Production shafts diaphragm walling to 60m below shaft platform level (bspl) and MTS shaft construction to 120m bspl remain unchanged and are as addressed in detail in the Phase 4 Hydrogeological Risk Assessment (Ref. 4) and the Section 73 Works Hydrogeological Risk Assessment (Ref.6).

2 DATA SOURCES

The data considered within this report are from the following sources:-

Hydrogeological Data

- Hydrogeological Baseline Report for the Woodsmith Mine, North Yorkshire 2012 to 2016 (1975OR01; Ref. 1).
- Hydrogeological Risk Assessment Phase 4 Works at Woodsmith Mine, North Yorkshire (1433DevOR205 Rev2 May 2017 Ref. 2).

Development Details of Phase 4a Works

Sirius Minerals Plc NYMNPA 94 - Construction Method Statement (Phase 4a) Document No. 40-SMP-WS-1000-CN-MS-00001.

3 DETAILS OF THE PHASE 4a WORKS

3.1 General Description

Construction of the Phase 2 and 3 works was completed in 2017 and construction of the Phase 4 works, detailed in the Phase 4 Hydrogeological Risk Assessment (Ref 4), is ongoing. Provided below are details of the proposed amendment to the construction methodology for the MTS Shaft from utilising diaphragm walling to a VSM system. All other construction methodologies and final "as built details" relating to the Service and Production Shafts remain unchanged and are as set out in the Phase 4 HRA.

Amendment to the Construction Methodology for the MTS Shaft

- Mobilisation to site.
- Use of a VSM at the MTS Shaft, in place of the previously planned d-walling machines.
- Construction of the guide wall and strand jacks for the operation.
- Installation of ancillary equipment.
- Machine setup and installation of VSM.
- Excavation to -55m below shaft platform level (bspl).

- Excavation to -120m bspl.
- Deposition of limited extractive material from within the first 120m of the MTS shaft into earthworks bunds; and
- Grouting of Annulus.

The following sections present details of the design levels and construction methodology for the Phase 4a Works.

3.2 Construction Methodology

3.2.1 VSM Works – Upper Section

The two staged VSM wall construction will entail the construction elements summarised in Table 2:-

Table 2 - Summary of VSM Wall Construction Elements

Guide walls	The reinforced concrete guide wall will be constructed below the shaft platform surface, to maintain alignment, wall continuity and provide support for the upper soils during VSM operation. These walls act to guide the verticality of the segmental reinforced concrete wall and to aid in the positioning of the final structure. To maintain verticality of the segmental wall and cutter, all hard obstructions and rock to a depth of 3m bspl will be removed within the plan area of the liner, following which the upper 3m of segmental liner will be lowered into position. To construct the guide walls, the following method will be followed: 1. Initial excavation to a depth of approximately 3m using conventional site excavators; 2. Install cutting ring and precast concrete segments to above platform level; 3. Install foam spacer around outside of cutting shoe and precast concrete to just above ground level; 4. Install reinforcement as per design of guide wall; and 5. Pour fresh concrete to ground level and allow to cure.
Installation of Segmental Liner	The VSM system will cut the rock beneath the suspended wall sections to form a circular excavation. This will be undertaken in two depth sections, with an external diameter of between 10.2m to 10.4m to a depth of 55m bspl and with a diameter of 8.2 to 8.4m to a depth of 120m bspl, as shown in Ref. 5. The cutter system will be submerged below groundwater throughout the cutting process and can work below a maximum head of water above the cutting boom assembly of up to 85m. The cutter wheels mix the arisings with the formation water and transport it to the surface by a suction pump located on the radial boom at the cutting head. Following installation of the 9m inner diameter liner to 55m bspl, the annulus between the wall and the rock face will be grouted and a basal mass concrete plug installed to seal off the excavation. An 8m inner diameter segmental liner will then be installed to the top of basal plug and the radial cutting boom reinstalled to cut an 8.2 to 8.4m diameter excavation down to a depth of 120m bspl.
Groundwater Management During Installation of the Segmental Liner	At the MTS shaft location, groundwater levels within the VSM construction depth are anticipated at a depth of 4m bspl (196m AOD) in the Moor Grit aquifer, 9m bspl (191m AOD) in the Scarborough aquifer, 13m bspl (187m AOD) in the Cloughton aquifer, 50m bspl (150m AOD) in the Saltwick aquifer. During installation to a depth of 55m bspl, the head of water within the excavation will be maintained at ambient groundwater level within the relevant aquifer. Should significant fracture zones be encountered causing groundwater loss from the cutting zone, a mains potable water source will be utilised to maintain a minimum 10m head of water above the cutting head.

	Following installation of the 9m inner diameter liner to 55m bspl, the annulus between the liner surface and the rock wall will be grouted to seal off hydraulic continuity between the Moor Grit, Scarborough and Cloughton aquifers. This grouting will be installed by an injection system from the base of cutting shoe. A mass concrete floor plug will then be constructed across the base of this upper VSM wall section. The 8m inner diameter segmental liner will them be installed below this basal plug with groundwater ingress from the Saltwick aquifer rising to 50m bspl (150m AOD) during excavation to 120m bspl. Once the segmental lining system has been progressed to 120m bspl, the lower VSM liner section will be grouted up. Following completion of the liner installation to 120m bspl, the construction waters within the lined structure will be pumped out and passed through a VSM construction water treatment system, prior to discharge to the Shaft Platform surface water perimeter drain. Once the lined structure has been pumped dry, proof drilling and grouting will be undertaken, where necessary, of the aquitard sections within the full height of the liner.
Reinforced concrete Segmental Liner	The liner wall will be assembled at the platform surface from reinforced concrete segmental panels. Each panel incorporates rubber side, top and bottom gaskets that form a complete seal to groundwater ingress once assembled. The rings are bolted together at the surface to compress the gasket and form the seal. A steel cutting rim is fixed to the underside of the first segmental ring and consecutive ring sections are then fixed to the upper surface prior to lowering into the excavation. Once the cutter boom assembly has cut the rock section beneath the advancing steel cutter rim, bentonite slurry prepared using fresh potable water will be injected from the base into the 0.1m to 0.2m wide annulus between the rock face and the concrete wall. This slurry will act as a lubricant to enhance the downward movement of the segmental liner assembly.
Management of VSM Cutting Arisings	During VSM wall construction, the ~10,000m^3 of cutting arisings generated will be pumped within a slurry suspension from the rotating cutting heads to a slurry treatment plant at the surface, including screens and hydro vacuum cyclones. The material generated from this process will comprise silt to gravel sized fragments of the host rock. Arisings generated from sandstone units will comprise a free draining sand to gravel sized waste material. Arisings from the siltstone and mudstone units will comprise a rock flour / paste to gravel sized material. It is anticipated that the VSM arisings will require lime stabilisation, to make them geotechnically acceptable for incorporation in the earthworks, which could generate a high pH run-off. As a consequence, drainage from the stabilised material will be collected and passed through a system, to adjust the pH prior to discharge to the main surface water drainage system.
Construction Programme	Works are programmed to run in parallel with Phase 4, commencing in June 2018 and completing in December 2018.
Verification Testing	Verification leachability testing will be undertaken on the arisings generated from the VSM process that are to be placed in the landscape mounds. During construction of the concrete wall, records will be compiled of the grouting to confirm that the completed wall will provide a compliant low permeable structure, as per the design.

3.2.2 Screening Bunds and Stockpiles

As part of the Phase 4a Works, the ~10,000m^3 of VSM cutting arisings generated will be re-used as a non-waste material in the formation of landscape screening mound Bund A , as illustrated in Arup Drawing 40-ARI-WS-71-CI-DR-1082.

4 MINESITE HYDROGEOLOGICAL CONDITIONS

4.1 Introduction

From the development and construction details for the Phase 4a Works, presented in Section 3, and the baseline hydrogeological conditions determined for the site (Ref. 1), the following sections present an overview of the interaction between aquifer conditions and the VSM construction works within the excavation depths proposed.

4.2 Geology

A schematic geological cross-section through the proposed 120m deep VSM works is illustrated in Drawing 1433Dev338 Appendix 1.

4.2.1 Superficial Deposits

The superficial deposits beneath this section of the MTS Shaft Platform comprise 1m of granular structural fill underlain by between 1-2m of lime modified Class 2 cohesive general fill and 0.5m to 1.5m of insitu firm sandy gravelly clay (Glacial Till).

4.2.2 Moor Grit Member

The Moor Grit Member un-conformably overlies the Scarborough Formation and comprises a grey, iron-stained fine to medium grained cross bedded sandstone with occasional medium to coarse gravel to pebble beds, discontinuous argillaceous beds and thin coal laminations within the mid-section of this unit. The upper part of this sandstone unit is distinctly weathered to de-structured, whilst the lower part of the sandstone unit is only partially weathered. This sandstone unit is in the order of 5m thick.

4.2.3 Scarborough Formation

The Scarborough Formation comprises three horizontal to sub-horizontal bedded weak to very weak, partially to distinctly weathered units including an upper moderately to highly fractured mudstone or siltstone, a grey-green sandstone/siltstone mid-section unit and a basal mudstone unit with a combined thickness of around 10m.

4.2.4 Cloughton Formation

The Cloughton Formation comprises a series of interbedded sandstones and mudstones with occasional siltstones of between 23.5m to 52m thick. The upper part of the Cloughton Formation comprises a weak to extremely weak weathered mudstone of between 1 to 5m thick, which thickens to the south. This overlies a medium strong to strong, partially to distinctly weathered, fine to medium grained sandstone, containing interbedded mudstone and occasional coaly and carbonaceous beds, particularly towards the base. The total thickness of this sandstone-dominated Formation ranges from 11.2 to 33.1m. The base of the Cloughton is dominated by an interbedded mudstone/siltstone sequence, of between 20 to 25m thick.

4.2.5 Eller Beck Formation

The Eller Beck Formation comprises 4 to 7 m of fine to medium sandstone, with a basal shale and ironstone unit (Ref. 1). Mud losses recorded during drilling of SM14 between 954 and 23,850 litres/hr indicate a significant fracture zone in the Eller Beck Formation from 141 to 152 m AOD (Ref. 1).

4.2.6 Saltwick Formation

The Saltwick Formation was between 37 to 40 m thick and comprises a series of interbedded sandstones, mudstones and siltstones, with some thin coals, with an upper argillaceous unit, a middle arenaceous unit and then a basal argillaceous unit. The upper argillaceous unit comprises a weak to strong grey, fresh to moderately weathered mudstones with thin sandstone interbeds. This argillaceous unit is less fractured than the mudstones at the base of the Cloughton Formation, and contains numerous, interbedded, thin sandstone/siltstone horizons. The arenaceous unit comprises medium strong, fresh to moderately weathered, fine to medium grained occasionally silty sandstones of between 31 to 34 m thickness. The basal argillaceous unit comprises 7 m of interbedded mudstones, siltstone and fine sandstones and then a 3 to 5 m thick conglomerate, taken to indicate the unconformable contact with the underlying Whitby Mudstone Formation, and may form part of the Dogger Formation.

4.3 Construction of the Segmental Liner

4.3.1 Construction Considerations

During liner installation, ground water is to be maintained between a minimum and maximum level of 10m and 85m respectively above the cutting head. Within the upper 55m bspl, the water level within the excavation is to be maintained at around the ambient water level in the relevant aquifer. On completion of the upper 55m section, to prevent hydraulic continuity developing between the Saltwick and overlying aquifer that could lead to the development of groundwater heads on the cutter unit exceeding 85m, the annulus for the segmental wall will be grouted.

4.3.2 Aquifer Conditions

A summary of the aquifer units and groundwater conditions anticipated within the VSM depth profile at the MTS location is provided in Table 3. This illustrates that four principal groundwater tables exist within the 120m construction depth including independent water tables in the Moor Grit, Scarborough, Cloughton and Saltwick aquifers, as illustrated in Drawing 1433DevOD388. The water levels in these aquifers exhibit significant seasonal fluctuation of between 1m to 6.6m.

The chemical quality of the groundwaters to be encountered in the Ravenscar Formation aquifers may be characterised as freshwater of good quality.

Table 3 – MTS VSM Aquifer / Aquitard Conditions to 120m bspl

			MTS Location
Platform Level		mAOD	200.8
MTS Liner Diameter		m	10m
Guide Base		mAOD	~197.8
Base of Stage 1 VSM		mAOD	~145.8
Base of Stage 2 VSM			~80.8
Superficials	Current Ground Level	mAOD	200.8 Shaft Platform construction
	Groundwater Conditions	mAOD	water seepage in sand
Moor Grit	Top & Base Level of Aquifer	mAOD	~199.0 to 190.9
	Inferred Groundwater Surface (Winter, Summer & Mean levels)	mAOD	Winter 195 to 196.8, average 195.9 (BH515)
	Aquifer Design Permeability	m/s	Most Likely 1.3 x10^{-5} m/s
	Water Quality		Good
Scarborough Formation	Top and Base Level of Upper Aquitard Unit	mAOD	190.9 to 189.9
	Upper Aquitard Design Permeability		Most Likely 4.0 x 10^{-6} m/s
	Elevation of Mid-Section Permeable Aquifer	mAOD	189.9 to 187.9
	Inferred Groundwater Surface	mAOD	190.2 to 193.6 (BH515)
	Aquifer Design Permeability	m/s	Most Likely 1.3 x 10^{-5} m/s (Fractures 5.2 x 10^{-4} m/s)
	Water Quality		Good
	Elevation of lower Aquitard Unit	mAOD	187.9 to ~186
	Lower Aquitard Design Permeability		Most Likely K_h 2 x 10^{-6} m/s, K_v 1 x 10^{-8} m/s
Cloughton Formation	Top & Base Level of Upper Aquifer	mAOD	186 to ~160
	Inferred Groundwater Surface (Winter, Summer & Mean levels)	mAOD	~183.3 to ~192.4
	Aquifer Design Permeability	m/s	Most Likely K_v 1 x 10^{-4} m/s
	Water Quality		Good
	Top & Base Level of Lower Aquitard	mAOD	~160 to ~142
	Aquitard Design Permeability	m/s	Most Likely K_h 2 x 10^{-6} m/s, K_v 1 x 10^{-8} m/s
Saltwick Formation	Top & Base Level of Formation	mAOD	~142 to ~96
	Inferred Groundwater Surface (Winter, Summer & Mean levels)	mAOD	~135.7 to ~146.1
	Aquifer Design Permeability	m/s	Most Likely K_h 2 x 10^{-5} m/s
	Water Quality		Good
	Aquiclude Design Permeability	m/s	5.7 x 10^{-7} m/s
Whitby Mudstone		Aquitard	

5 RECEPTORS

The hydrogeological receptors that may be impacted upon by the Phase 4a Works are the discussed in detailed in the Phase 4 Hydrogeological Risk Assessment and summarised below in Table 4.

Table 4 - Receptors

Type	Receptor	Sensitivity
Sensitive Aquifers	Moor Grit Member	Medium
	Scarborough Formation	Medium
	Cloughton Formation	Medium
	Saltwick Formation	Medium
Base Flow Springs	Doves Nest Farm Spring (DNS1)	Very Low
	Ugglebarnby Moor Spring (SP01)	Very Low
	Springs Northwest of Ugglebarnby Moor (SP02, SP03)	Very Low
	Springs North of Woodsmith Mine (SP04)	Very Low
	Springs North of Woodsmith Mine (KHF)	Very Low
Spring Water Supplies	Moorside Farm Spring (MF2)	High
	Soulsgrave Farm Spring (SF2)	High
	Newton House Farm Spring (NHF1)	High
Groundwater Abstractions	Sneaton Low Moor Caravan Park	High
Ecological Receptors	Ugglebarnby Moor Northern Dry Heath Area	Low
	Ugglebarnby Moor Central Wet Heath Area	Low
	Ugglebarnby Moor Southern Dry Heath Area	Low
	Ugglebarnby Moor Southern Spring Flush	Very High
	Sneaton Low Moor Dry Heath Area	Low
Surface Waters	Sneaton Thorpe Beck	Low
	Little Beck	Medium

6 QUALITATIVE HYDROGEOLOGICAL RISK ASSESSMENT

6.1 Conceptual Model

The principal hydrogeological units underlying the MTS location comprise Secondary A aquifers of local importance (Moor Grit, Scarborough, Cloughton and Saltwick) to depths of around 100m. Due to the presence of leaky argillaceous aquitard units between these aquifers, there is limited vertical connectivity between the aquifers. Groundwater levels in all of the four Secondary A Aquifers have been determined to show seasonal variability. In general, the direction of groundwater flow in these aquifers occurs to the north/northeast, with a significant westerly and easterly flow from the hydrogeological divide that is approximately aligned along the B1416 to the west of the Woodsmith Mine. Beneath the Secondary A Aquifers is a major aquiclude of unproductive strata (the Whitby Mudstone Formation) that restricts groundwater interaction between the freshwater groundwaters in the Ravenscar Formation and the sulphatic and saline groundwaters at depth.

Within the minesite area, there are no hydrogeologically-supported terrestrial ecosystems or groundwater abstractions. The shallow Secondary A Aquifers beneath the minesite area are determined as of local importance providing base flow to surface waters.

Offsite, bordering and within close proximity to the minesite, there is flora in the Spring Flush habitat, in the southern areas to Ugglebarnby Moor (Drawing 1433DevOD341), which is intermittently hydrogeologically supported. The dry heath ecosystems in the northern and southern areas of Ugglebarnby Moor, and on Sneaton Low Moor and the wet heath ecosystems in the central area of Ugglebarnby Moor, are not hydrogeologically supported and, as such, are not reliant on the presence of shallow groundwaters in the bedrock aquifers. There are four groundwater abstractions in close proximity to the minesite (Drawing 1433DevOD340); one from a well drilled into the Cloughton Formation at Sneaton Low Moor Caravan Park, and three from spring issues; one associated with Thornhill Farm (and the adjacent property) Moorside Farm Spring (MF2), Soulsgrave Farm Spring (SF2) and Newton House Farm Spring (NHF1). There are three spring discharges that have been determined to contribute low and intermittent volumes to surface water flows to the west of Ugglebarnby Moor (SP01, SP02 and SP03), and two to the north of the Woodsmith Mine (SP04 and KHF), as shown on Drawing 1433DevOD340.

6.2 Groundwater Effects

The physical and chemical groundwater effects that may arise as a result of the Phase 4a Works are summarised in Tables 5 and 6:-

6.2.1 Physical Effects

Table 5 – Physical Effects

Effect	Discussion	Magnitude of Effect at Source
Temporary alteration of groundwater flow paths and levels in the Moor Grit, Scarborough, Cloughton and Saltwick aquifers may arise during VSM construction as a result of water loss from the VSM excavation through fractured zones causing a drop in water level below the ambient groundwater level within each aquifer.	The process of installing the segmental liner to 55m bspl could have a short term (4 – 8 week) effect on groundwater levels immediately adjacent to the excavation in the Moor Grit and Scarborough aquifers. Short term under draining of these aquifers could cause a temporary rise in groundwater levels in the Cloughton aquifer. To manage this risk and to maintain a minimum head above the cutting shoe, water levels are to be supplemented in the event of a water loss from the excavation, by the addition of potable water. Following completion of the Stage 1 to 55m bspl, the segmental liner will be grouted into place to isolate groundwaters in the Moor Grit, Scarborough and Cloughton aquifers from the Stage 2 55m – 120m bspl VSM construction down to the Whitby Mudstone. This grouting will mitigate under draining of the overlying aquifers into the Saltwick.	Low Magnitude of Effect at Source
Localised alteration of groundwater flow paths and levels in the Moor Grit, Scarborough, and Cloughton and Saltwick aquifers may arise after liner construction, if the grout seal between the liner and the rock formation is imperfect.	To manage and verify that a vertical continuous grout seal is achieved across the full height of the liner annulus, thereby providing long term hydraulic separation between the aquifer units, validation testing and pressure grouting is to be adopted through the liner wall.	Very Low Magnitude of Effect at Source

6.2.2 Chemical Effects

Table 6 – Chemical Effects

Effect	Discussion	Magnitude of Effect at Source
Temporary and localised groundwater pollution arising from leakage / spillage of hydraulic fluids and fuel oils from the VSM plant.	A structured maintenance and monitoring regime will be adopted for the VSM operations and plant to ensure that there are no significant leaks or spillages of hydraulic fluids or lubricants within the groundwater surrounding the cutting head or that may enter the excavation.	Very Low Magnitude of Effect at Source
Groundwater pollution from bentonite slurry or grout losses from the annulus between the lining and rock face.	The annulus between the shaft lining and rock is 0.1 to 0.2 m wide. The slurry will not be under pressure and any losses occurring will be managed by the introduction of inert additives.	Very Low Magnitude of Effect at Source
Introduction of pollution from the use of external water to maintain a 10 m head of water above the cutting head.	If the addition of water into the excavation is required to maintain a minimum head during construction, this will be sourced from a potable fresh water supply.	Very Low Magnitude of Effect at Source
Pollution occurring from leachate generated from the spoil arisings	Leachability testing on the Ravenscar and Whitby Mudstone has demonstrated that VSM arisings from these strata have a very low potential to generate acid rock drainage or significant concentrations of pollutants that could present a risk of pollution to groundwaters. The VSM arisings will require lime stabilisation, a standard engineering practice, which may generate high pH run-off. This runoff will be collected and discharged to the main surface water drainage system, where pH control will be managed by a silt-buster, if necessary.	Low Magnitude of Effect at Source

6.3 Hydrogeological Risk Assessment

A qualitative hydrogeological risk assessment has been carried out in accordance with the methodology presented in Appendix 2 to evaluate the potential physical and chemical impacts of the completed Phase 4a Works on the site specific hydrogeological receptors detailed in Section 5.

Evaluation of the Likelihood of Occurrence of an impact has been undertaken by consideration of the Proximity and Connectivity between an activity and the receptor. Appendix 3.1, evaluates the proximity of each activity to each receptor taking account of both horizontal and vertical proximity. To determine the Likelihood of Occurrence of an impact on a receptor, the physical and chemical impacts have been evaluated by consideration of the activity with the worst case proximity (i.e. highest values detailed in Appendix 3.1) to each receptor in conjunction with the worst case connectivity (between an activity and the receptor). The magnitude of the worst case proximity adopted for each receptor and the Likelihood of Occurrence determined are presented in Appendix 3.2.

The Magnitude of Effect at the Receptor has been evaluated by consideration of the qualitative assessment of the Magnitude of Effect at Source, as presented in Section 6.2 and the Likelihood of Occurrence as presented in Appendix 3.2.

Assessment of the Significance of Impact of the physical and chemical effects on the specific hydrogeological receptors have been evaluated by consideration of the Magnitude of Effect at Receptor and the Receptor Sensitivity and the results are presented in Appendix 3.2 and evaluated in Section 6.4.

6.4 Results of the Qualitative Hydrogeological Risk Assessment

The qualitative risk assessment, presented in Appendix 3.2, has determined that although the Phase 4a Works have the potential to cause a short term Minor Significance of Physical Impact on groundwater levels immediately adjacent to the VSM excavation in the Ravenscar aquifers, these Works have a Negligible Significance of Physical and Chemical Impact on all other hydrogeological receptors, including to the Spring Flush habitat and drinking water supplies from Moorside and Soulsgrave Farm springs. As detailed in the Section 73 Hydrogeological Risk Assessment (Ref.6), this development will have a negligible cumulative long term hydrogeological impact on all hydrogeological receptors.

6.5 Consideration of Mitigation Measures

As part of this assessment, consideration has been given as to whether the recharge trench and groundwater drainage beneath Bunds E and F are necessary mitigation measures to be initiated as part of these Phase 4a Works. This qualitative risk assessment has demonstrated that these measures are not warranted at this stage of the construction process.

R IZATT-LOWRY
DIRECTOR

7 REFERENCES

1 FWS Consultants Ltd, 2016. Hydrogeological Baseline Report for the Doves Nest Farm Minesite, North Yorkshire 2012 to 2016 (1975OR01).

2 FWS Consultants Ltd, 2017 Hydrogeological Risk Assessment for the Phase 2 Works at Doves Nest Farm Minesite, North Yorkshire (1433OR27).

3 FWS Consultants Ltd, 2017 Hydrogeological Risk Assessment for the Phase 3 Works at Doves Nest Farm Minesite, North Yorkshire (1433OR175).

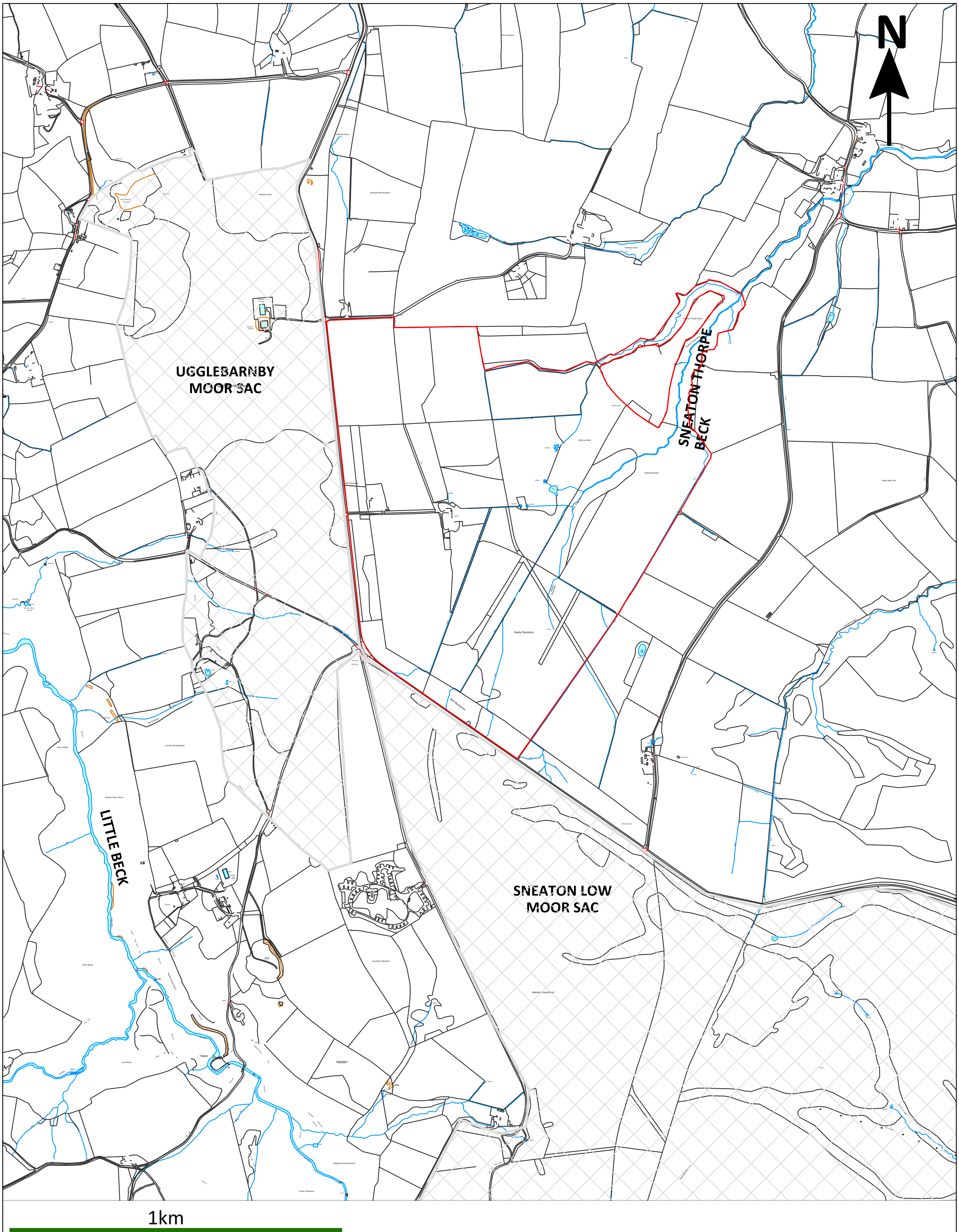
4 FWS Consultants Ltd, 2017 Hydrogeological Risk Assessment for the Phase 4 Works at Doves Nest Farm Minesite, North Yorkshire (1433OR205).

5 Sirius Minerals Plc NYMNPA 94 - Construction Method Statement (Phase 4a) Document No. 40-SMP-WS-1000-CN-MS-00001.

6 FWS Consultants Ltd, 2017 Hydrogeological Risk Assessment Section 73 Works At Woodsmith Mine, North Yorkshire (1433OR226).

APPENDIX 1

DRAWINGS



NOTES / KEY

SITE OWNERSHIP BOUNDARY

NYM SAC

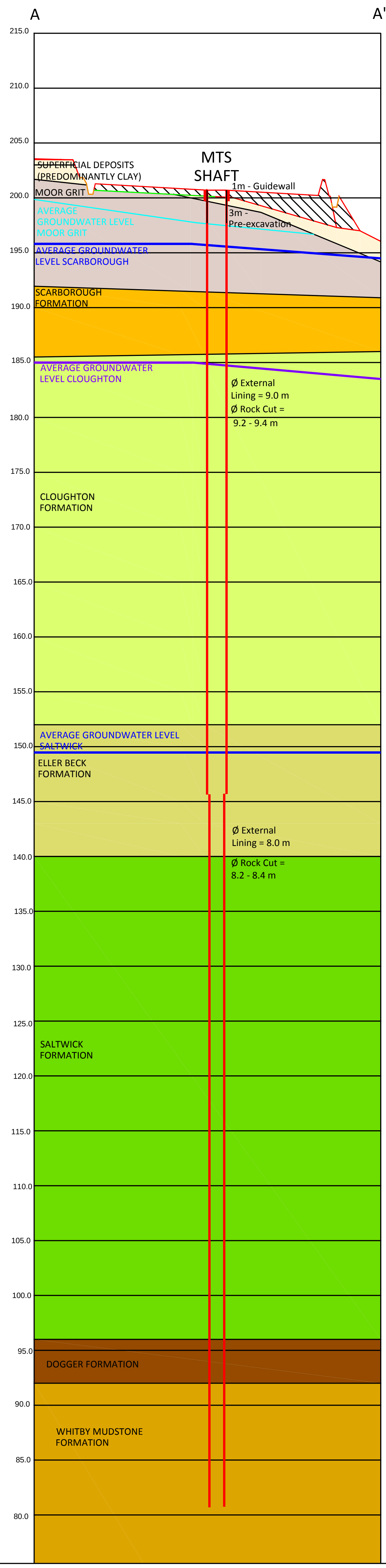
SURFACE WATER

DRAWING TITLE
WOODSMITH MINE
LOCATION PLAN

PROJECT TITLE
THE NORTH YORKSHIRE
POLYHALITE PROJECT

CLIENT SIRIUS MINERALS PLC	
STATUS FINAL	PROJECT NUMBER 1433
DRAWN BY CB	DATE March 2017
SCALE 1:10,000 @ A3	DRG. No. 1433DevOD215Rev2

Merrington House
Merrington Lane Industrial Estate
Spennymoor
County Durham
DL16 7UT



NOTES / KEY

PHASE 2&3 WORKS
GEOMEMBRANE
LINED DRAINAGE DITCH

GEOLOGY
EXISTING GRANULAR PLATFORM CONSTRUCTION
NEW GRANULAR PLATFORM CONSTRUCTION
COHESIVE SUPERFICIAL DEPOSITS
MOOR GRIT
SCARBOROUGH FORMATION
CLOUGHTON FORMATION
ELLER BECK
SALTWICK FORMATION
DOGGER FORMATION
WHITBY MUDSTONE FORMATION

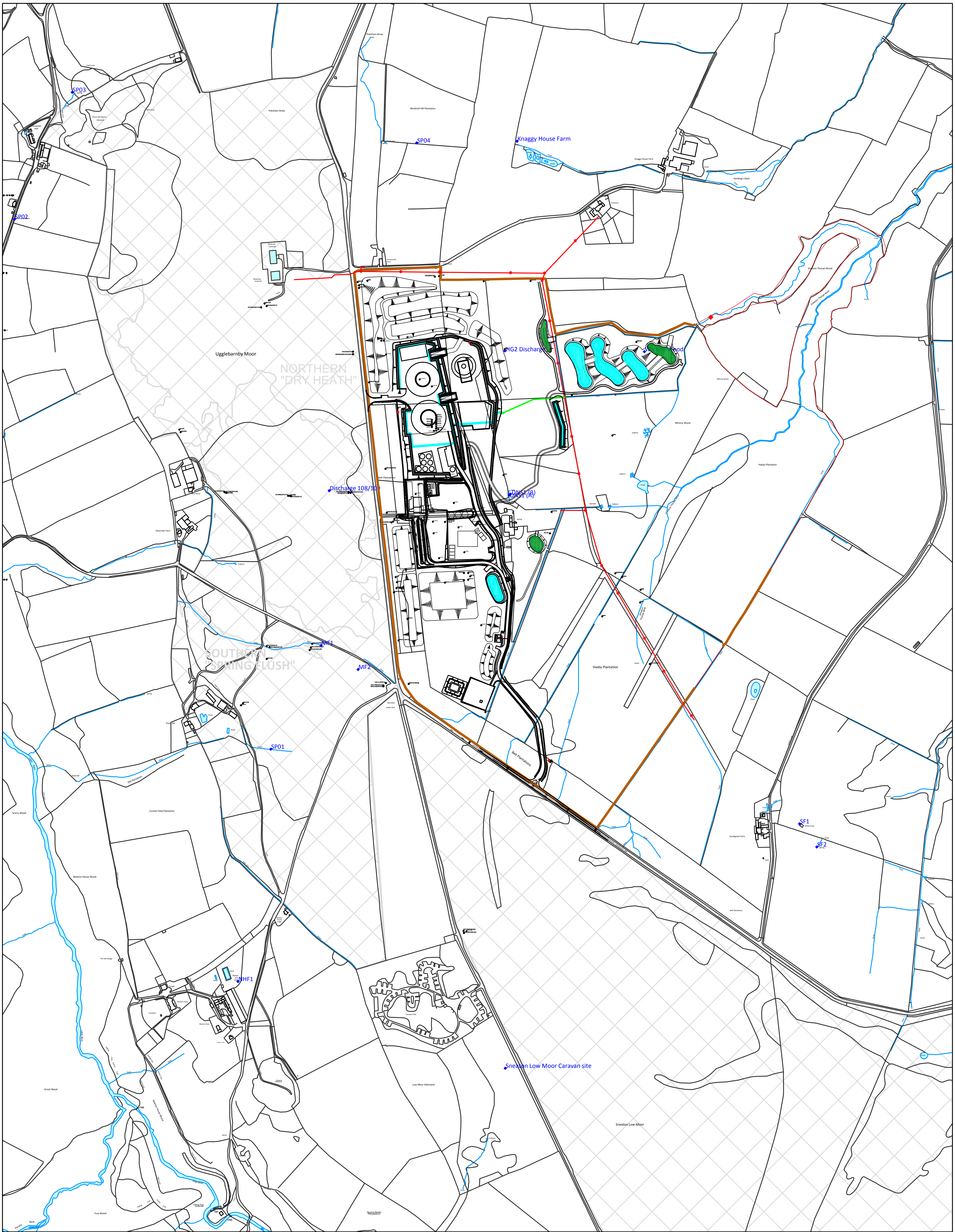
DRAWING TITLE
SCHEMATIC DRAWING OF VSM EXCAVATION FOR MTS SHAFT

PROJECT TITLE
NORTH YORKSHIRE POLYHALITE PROJECT

CLIENT
SIRIUS MINERALS PLC

STATUS FINAL	PROJECT NUMBER 1433Dev
DRAWN BY CB	DATE March 2018
SCALE AS SHOWN	DRG. No. 1433DevOD338

FWS Geological & Geo-Environmental Consultants
Merrington House
Merrington Lane Industrial Estate
Spennymoor
County Durham
DL16 7UT



NOTES / KEY

SITE OWNERSHIP BOUNDARY	
NYM SAC	
SURFACE WATER	
BOREHOLES	GCBH01
HYDROGEOLOGICAL RECEPTORS	MF2

DRAWING TITLE
HYDROGEOLOGICAL RECEPTORS - PHASE 4A

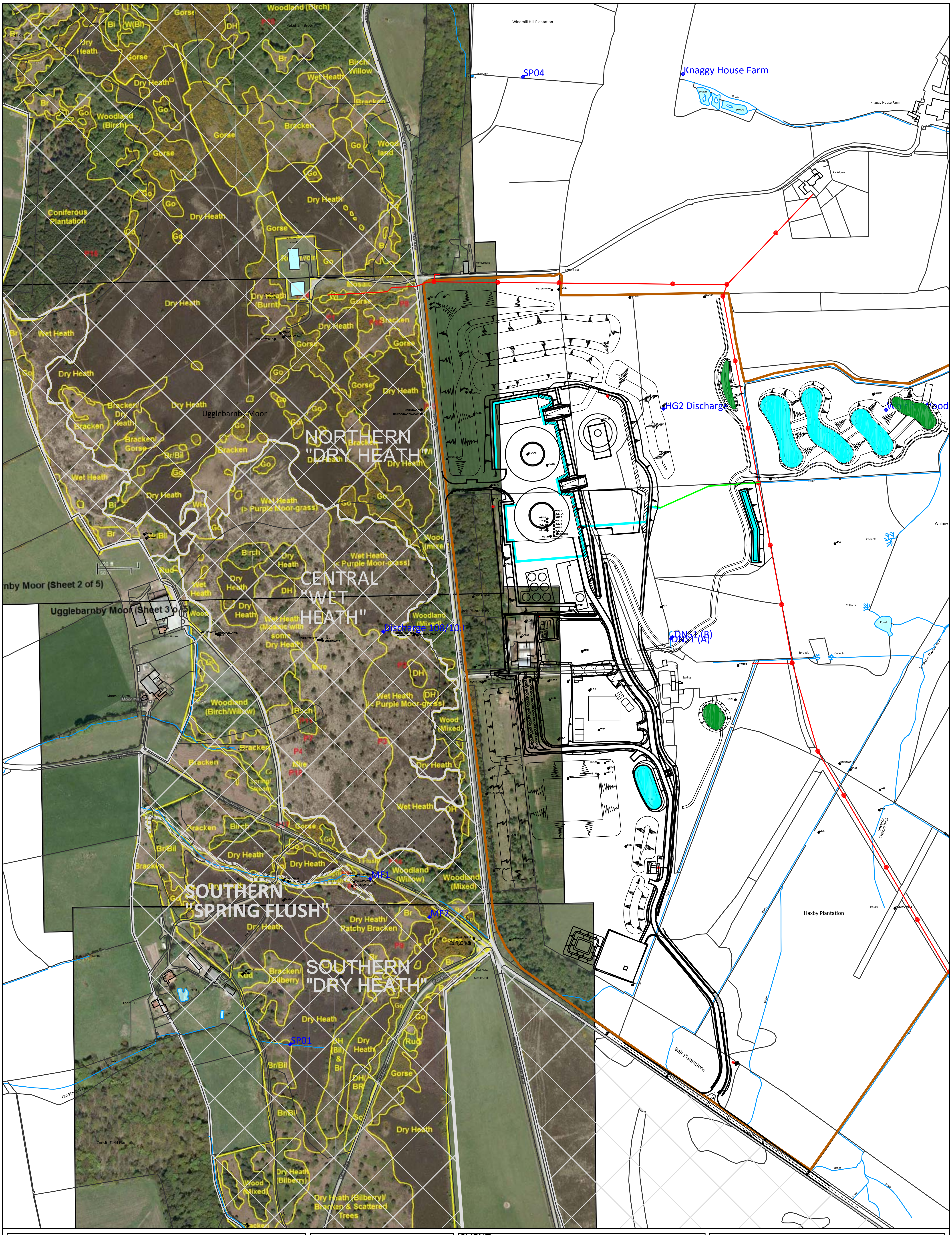
PROJECT TITLE
NORTH YORKSHIRE POLYHALITE PROJECT

CLIENT
SIRIUS MINERALS PLC

STATUS FINAL	PROJECT NUMBER 1433Dev
DRAWN BY CB	DATE April 2018
SCALE 1:8,000@A3/1:4,000@A1	DRG. No. 1433DevOD340

FWS Geological & Geo-Environmental Consultants

Merrington House
Merrington Lane Industrial Estate
Spennymoor
County Durham
DL16 7UT



NOTES / KEY	
NYM SAC	
SURFACE WATER	
BOREHOLES	GCBH01
HYDROGEOLOGICAL RECEPTORS	MF2

DRAWING TITLE
ECOLOGICALLY SENSITIVE HABITATS ON UGGLEBARNBY MOOR - PHASE 4A

PROJECT TITLE
NORTH YORKSHIRE POLYHALITE PROJECT

CLIENT
SIRIUS MINERALS PLC

STATUS	PROJECT NUMBER
FINAL	1433Dev
DRAWN BY	**DATE**
CB	April 2018
SCALE	**DRG. No.**
1:5,000@A3/1:2,500@A1	1433DevOD341

FWS Geological & Geo-Environmental Consultants
Merrington House
Merrington Lane Industrial Estate
Spennymoor
County Durham
DL16 7UT

APPENDIX 2

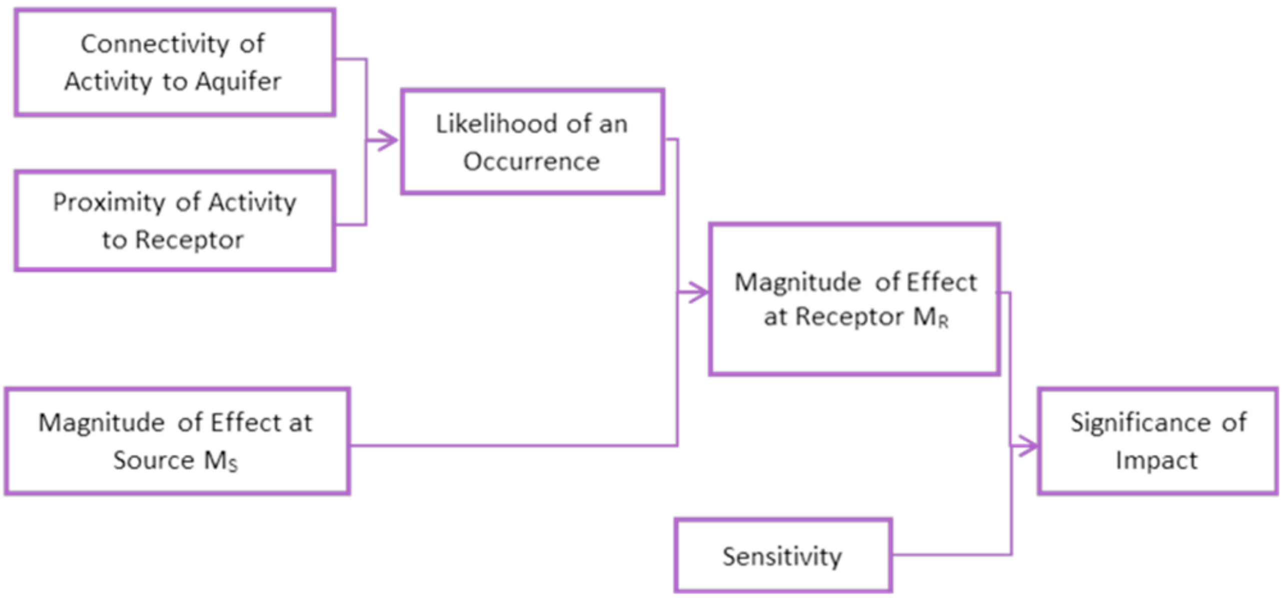
RISK ASSESSMENT METHODOLOGY

APPENDIX 2

1 RISK ASSESSMENT METHODOLOGY

The revised qualitative hydrogeological risk assessment presented in this report evaluates the "Significance of Impact" of the Phase 2 and 3 Works on hydrogeologically sensitive receptors, and follows a source-pathway-receptor approach to meet regulatory requirements.

In order to evaluate the physical and chemical hydrogeological impacts, the following criteria, and the linkages between them, have been considered:-



Two criteria have been used to assess the "Likelihood" of an effect propagating through the hydrogeological system to a receptor. These are the Connectivity and Proximity of an activity to a receptor. Therefore, the closer and more directly connected an activity is to a receptor, the more likely it is that a pathway will exist between an activity and that receptor.

The Magnitude of Effect at Source (MS) has been considered in terms of the worst-case physical and chemical changes to baseline conditions that might occur.

Combining the Likelihood of an Occurrence with the Magnitude of Effect at Source provides a qualitative evaluation for the Magnitude of Effect at Receptor (MR), which is the effect that a particular activity will have on a specific receptor.

The Magnitude of Effect at Receptor is then combined with the Sensitivity of the Receptor to provide an estimate of the Significance of Impact.

Five categories are used to describe the Connectivity, the Proximity, the Likelihood of an Occurrence, the Magnitude of Effect at Source (MS), the Magnitude of Effect at Receptor (MR); and the Sensitivity of a Receptor:-

- Very High
- High
- Medium

- Low
- Very Low

Four categories are then used to describe the overall "Significance of Impact":-

- Major
- Moderate
- Minor
- Negligible

The results of the revised qualitative assessment are given in risk matrices presented in Appendix 3 that identify which of the five categories above apply to specific activities and receptors during the Phase 3 Works and, from this, it has been assessed which of the four categories of "Significance of Impact" they belong.

The following sections provide descriptions and definitions for each of these categories as they apply to each of the components of the qualitative risk assessment.

1.1 Likelihood of Occurrence

The Likelihood of Occurrence of a physical or chemical effect is evaluated by combining Connectivity and Proximity of an activity to a receptor, as detailed below.

Likelihood	**Connectivity between Activity and Receptor**					
		Very Low	**Low**	**Medium**	**High**	**Very High**
Receptor Proximity to Activity	**Very Low**	Very Low	Low	Low	Medium	Medium
	Low	Low	Low	Medium	Medium	High
	Medium	Low	Medium	Medium	High	High
	High	Medium	Medium	High	High	Very High
	Very High	Medium	High	High	Very High	Very High

1.1.1 Connectivity

Very High Connectivity	Activity and receptor occur in the same aquifer unit, with a direct or known pathway between them. For chemical impacts, the receptor is also down hydraulic gradient from the activity and on the same flow path (determined as being a line of flow between the source and the receptor that is perpendicular to groundwater contours).
High Connectivity	Activity and receptor occur in the same aquifer unit but the pathway is indirect as a result of the presence of a very thin (<1 m) or discontinuous aquitard. For chemical impacts, the receptor is down hydraulic gradient from the activity and is slightly oblique to the flow path.
Medium Connectivity	Activity and receptor occur in adjacent aquifer units that are in hydraulic continuity but are separated by a thin (>1 m), fractured or leaky aquitard. For chemical impacts the receptor is down hydraulic gradient from the activity and is strongly oblique to a flow path.
Low Connectivity	Activity and receptor are in adjacent aquifer units with no or very limited hydraulic continuity between them due to the presence of a natural or man-made aquitard. For chemical impacts the receptor is down hydraulic gradient from the activity and is on a different flow path.
Very Low Connectivity	There is no hydraulic continuity between the activity and the receptor due to the presence of a laterally and vertically continuous, or multiple thin (>1 m) aquitard units, an aquiclude

	unit or an engineered barrier unit. For chemical impacts, the receptor is up hydraulic gradient from the activity.

1.1.2 Proximity

In accordance with Environment Agency guidance on groundwater protection (Ref. 12), the minimum permitted distance for the proximity of a potentially polluting activity to a water abstraction is 50 m (equivalent to Source Protection Zone I). As such, for the purpose of this qualitative risk assessment a distance of <50 m has been used to define the condition of Very High Proximity. By consideration of Environment Agency guidance for the minimum distance of 250 m to a Source Protection Zone II this distance has been used to define the condition of High Proximity. Moderate and a Low Proximity limits have been set equally spaced from the 250 m zone, at 500 and 750 m respectively, and a Very Low Proximity has been defined as >750 m. The following absolute values have, therefore, been used to evaluate the Proximity of an activity to a receptor.

Very high proximity	< 50 m
High proximity	51 – 250 m
Medium proximity	251 – 500 m
Low proximity	501 – 750 m
Very low proximity	>750 m

A multi-layered aquifer system also requires consideration of vertical proximity. In order to take this into account, the proximity between aquifers moving down vertically through a sequence is reduced by one category for each aquifer to be consistent with the concept of connectivity.

1.2 Magnitude of Effect at Source (M_S)

The Magnitude of Effect at Source of a physical or chemical impact is categorised, as detailed below:-

Very High Magnitude of Effect at Source	A very high degree of physical change is a change in groundwater level that is >150% of the regional natural annual groundwater level variation for an aquifer, or >150% of the natural variation in flowrate from a spring. A very high degree of chemical change is a change of >150% of the natural baseline chemical quality variation that could cause a risk of harm or give rise to a pollution risk.
High Magnitude of Effect at Source	A high degree of physical change is a change in groundwater level that is between 100 and 150% of the regional natural annual groundwater level variation for an aquifer, or between 100 and 150% of the natural variation in flowrate from a spring. A high degree of chemical change is a change of between 100 and 150% of the natural baseline chemical quality variation that could cause a risk of harm or give rise to a pollution risk.
Medium Magnitude of Effect at Source	A moderate degree of physical change is a change in groundwater level that is between 50 and 100% of the local natural annual groundwater level variation for an aquifer, or between 50 and 100% of the natural variation in flowrate from a spring. A high degree of chemical change is a local change of between 50 and 100% of the natural baseline chemical quality variation that could cause a risk of harm or give rise to a pollution risk.
Low Magnitude of Effect at Source	A low degree of physical change is a change in groundwater level that is between 20 and 50% of the local natural annual groundwater level variation for an aquifer, or between 20 and 50% of the natural variation in flowrate from a spring. A low degree of chemical change is a local change of between 20 and 50% of the natural baseline chemical quality variation.
Very Low Magnitude	A very low degree of physical change is a change in groundwater level that is <20% of the

of Effect at Source.	local natural annual groundwater level variation for an aquifer, or <20% of the flow from a spring. A very low degree of chemical change is a local change of <20% of the local natural baseline chemical variation.

1.3 Magnitude of Effect at Receptor (MR)

The Magnitude of Effect at any Receptor is estimated by combining the Magnitude of Effect at Source and the Likelihood of a hydrogeological "effect" occurring, as detailed in the matrix below:-

Magnitude of Effect at the Receptor		**Likelihood**				
		Very Low	**Low**	**Medium**	**High**	**Very High**
Magnitude of Effect at Source	**Very Low**	Very Low	Very Low	Very Low	Very Low	Very Low
	Low	Very Low	Very Low	Low	Low	Low
	Medium	Very Low	Low	Low	Medium	Medium
	High	Very Low	Low	Medium	High	High
	Very High	Very Low	Low	Medium	High	Very High

A description of the five categories of hydrogeological "Magnitude of Effect at the Receptor" that have been used in this report are presented below:-

Magnitude of Effect at Receptor	**Description**
Very High	Loss of resource and/or integrity of the resource; severe damage to key characteristics or features and permanent/ irreplaceable change is certain to occur.
High	Loss of resource, but not affecting the overall integrity of the resource; partial loss of or damage to key characteristics or features and permanent/irreplaceable change is likely to occur.
Medium	Minor loss of, or alteration to, key characteristics of a resource; measurable change in attributes, quality or vulnerability. Long term, though reversible change, is likely to occur.
Low	Very minor loss of, or alteration to, key characteristics of a resource; noticeable change in attributes, quality or vulnerability. Short to medium term, though reversible, change could possibly occur.
Very Low	Temporary or intermittent very minor loss of, or alteration to, key characteristics of a resource; noticeable change in attributes, quality or vulnerability. Short to medium term change is unlikely to occur, and when does is likely to be intermittent and reversible.

1.4 Receptor Sensitivity

The sensitivity of groundwater receptors in the qualitative risk assessment has been assessed in terms of their ability to accommodate physical or chemical change and on the impact any change may have on a regional or local ecological or other environmental system. By adopting this approach to the qualitative assessment, the most sensitive receptors are determined to be those with very limited or no capacity to accommodate physical and/or chemical change that are of very high importance as a groundwater resource. Conversely very low sensitivity receptors are those that can generally tolerate physical and/or chemical changes and are of low importance as a groundwater resource. Groundwater receptor characteristics and receptor examples are detailed in the table overleaf:-

Sensitivity	Groundwater Receptor Characteristics	Receptor Examples
Very High	• Has very limited or no capacity to accommodate physical or chemical changes. • Supports internationally important ecological, amenity or landscape features.	• Licensed public water supply or major industrial abstractions (e.g. SPZ 1/2). • Licensed/unlicensed abstractions and springs providing potable water supply, for which there is no alternative source (e.g. mains water). • Designated SAC, SPA, or Ramsar site with fauna or flora that are hydrogeologically supported from groundwaters within rock aquifers. • Surface water bodies supporting the above.
High	• Has limited capacity to accommodate physical or chemical changes. • Supports nationally important ecological amenity or landscape features.	• Designated 'Principal Aquifer'. • Licensed/unlicensed abstractions and springs providing potable water supply, for which an alternative source (e.g. mains water) is available. • SSSI, NNR with fauna or flora that are hydrogeologically supported from groundwaters within rock aquifers. • Surface water bodies supporting the above.
Medium	• Has limited capacity to accommodate physical or chemical changes. • Supports regionally important ecological, amenity or landscape features.	• Designated 'Secondary A (or Undifferentiated) Aquifer'. • Regionally important wildlife sites with fauna or flora that are hydrogeologically supported from groundwaters within rock aquifers. • Non-potable licensed abstractions. • Surface water bodies supporting the above or classified as Good under Water Framework Directive.
Low	• Has moderate capacity to accommodate physical or chemical changes. • Supports locally important ecological, amenity or landscape features.	• Non-potable unlicensed abstractions. • Local wildlife sites (LNR, SNCI, RIGS), country parks with flora hydrogeologically supported from groundwaters within rock aquifers. • Designated SAC, SPA, or Ramsar site with fauna or flora that are not hydrogeologically supported from groundwaters within rock aquifers. • Surface water bodies supporting the above or classified as Moderate under Water Framework Directive.
Very Low	• Generally tolerant of and can accommodate physical or chemical changes. • Supports no features of significant ecological, amenity or landscape value.	• Designated 'Secondary B Aquifer' or 'Unproductive Strata'. • Surface waters with no important, dependent receptors. • SSSI, NNR with fauna or flora that are not hydrogeologically supported from groundwaters within rock aquifers.

1.5 Significance of Impact

The significance of the impact that changes will have on a hydrogeological receptor is assessed by comparing the Magnitude of Effect at Receptor with the receptor Sensitivity. This is assessed using the following matrix.

Receptor Sensitivity	**Magnitude Of Effect At Receptor**				
	Very Low	**Low**	**Medium**	**High**	**Very High**
Very Low	Negligible	Negligible	Negligible	Negligible	Minor
Low	Negligible	Negligible	Minor	Minor	Minor
Medium	Negligible	Minor	Minor	Moderate	Moderate
High	Negligible	Minor	Moderate	Moderate	Major
Very High	Negligible	Minor	Moderate	Major	Major

The four categories assigned to the Significance of Impact above relate to a Major, Moderate, Minor or negligible (as identified below) against which the necessity to implement mitigation measures is evaluated.

Significance of Impact	**Description**	**Necessity Of Mitigation Measures**
Major	Major risk of unacceptable change to a sensitive hydrogeological receptor.	Mitigation measures required.
Moderate	Moderate risk with measurable change to a sensitive hydrogeological receptor.	Mitigation measures required.
Minor	Minor risk with local minor change to a sensitive hydrogeological receptor.	Mitigation measures may be required.
Negligible	No risk and no discernible change to a sensitive hydrogeological receptor.	No mitigation measures required.

APPENDIX 3

QUALITATIVE RISK ASSESSMENT

APPENDIX 3.1

EVALUATION OF PROXIMITY OF RECEPTOR TO THE PHYSICAL AND CHEMICAL EFFECTS OF CONSTRUCTION WORKS ASSOCIATED WITH SPECIFIC SITE PREPARATORY WORKS ACTIVITIES

APPENDIX 3.1

EVALUATION OF PROXIMITY OF RECEPTOR TO THE PHYSICAL AND CHEMICAL EFFECTS

OF CONSTUCTION WORKS ASSOCIATED WITH SPECIFIC SITE PREPARATORY WORKS ACTIVITIES

Receptor and Associated Geology		() = overlying	Phase 4a Works Activities And Associated Geology
			MTS Shaft
			Moor Grit, Scarborough, Cloughton, Saltwick
Ugglebarnby Moor Northern Dry Heath Area	**Dry Heath Ecology**	Distance (m) Horizontal Proximity **Calculated Proximity**	245 High **High**
Ugglebarnby Moor Central Wet Heath Area	**Wetland Ecology**	Distance (m) Horizontal Proximity **Calculated Proximity**	315 Medium **Medium**
Ugglebarnby Moor Southern Dry Heath Area	**Dry Heath Ecology**	Distance (m) Horizontal Proximity **Calculated Proximity**	650 Low **Medium**
Ugglebarny Moor Southern Spring Flush	**Wetland Ecology**	Distance (m) Horizontal Proximity **Calculated Proximity**	750 Low **Low**
Sneaton Low Moor Dry Heath Area	**Dry Heath Ecology**	Distance (m) Horizontal Proximity **Calculated Proximity**	820 Low **Low**
Sneaton Thorpe Beck	**Surface Water**	Distance (m) Horizontal Proximity **Calculated Proximity**	560 Low **Low**
Little Beck	**Surface Water**	Distance (m) Horizontal Proximity **Calculated Proximity**	1370 Very Low **Very Low**
Sneaton Low Moor Caravan Park Cloughton Fm	**Drinking Water**	Distance (m) Horizontal Proximity **Calculated Proximity**	1670 Very Low **Very Low**
MF2 Moor Grit	**Drinking Water**	Distance (m) Horizontal Proximity **Calculated Proximity**	760 Very Low **Very Low**
SF1 Scarborough Fm	**Drinking Water**	Distance (m) Horizontal Proximity **Calculated Proximity**	1350 Very Low **Very Low**
NHF Cloughton Fm	**Drinking Water**	Distance (m) Horizontal Proximity **Calculated Proximity**	1550 Very Low **Very Low**
SP01 Moor Grit	**Baseflow**	Distance (m) Horizontal Proximity **Calculated Proximity**	1020 Very Low **Very Low**
SP02, SP03 Cloughton Fm	**Baseflow**	Distance (m) Horizontal Proximity **Calculated Proximity**	1125 Very Low **Very Low**
SP04 Moor Grit	**Baseflow**	Distance (m) Horizontal Proximity **Calculated Proximity**	550 Low **Low**
DNS1 Moor Grit	**Baseflow**	Distance (m) Horizontal Proximity **Calculated Proximity**	330 Medium **Medium**

Knaggy House Farm Spring Scarborough Fm	**Baseflow**	Distance (m) Horizontal Proximity **Calculated Proximity**	550 Low **Low**
Moor Grit Secondary A Aquifer	**"Shallow aquifer/ Drinking water/ Baseflow"**	Distance (m) Horizontal Proximity **Calculated Proximity**	0 Very High **Very High**
Scarborough Fm Secondary A Aquifer	**"Shallow aquifer/ Drinking water/ Baseflow"**	Distance (m) Horizontal Proximity **Calculated Proximity**	0 Very High **Very High**
Cloughton Fm Secondary A Aquifer	**"Moderate depth aquifer/ Drinking water/ Baseflow"**	Distance (m) Horizontal Proximity **Calculated Proximity**	0 Very High **Very High**
Saltwick Fm Secondary A Aquifer	**Moderate depth aquifer**	Distance (m) Horizontal Proximity **Calculated Proximity**	0 Very High **Very High**

Note: Calculated Proximity is determined from the Horizontal Proximity and the Vertical Proximity as detailed in Appendix 3.

APPENDIX 3.2

QUALITATIVE HYDROGEOLOGICAL RISK ASSESSMENT – PHASE 4a WORKS

APPENDIX 3.2 - Qualitative Hydrogeological Risk Assessment - Phase 4a Works

			Ugglebarnby Moor Northern Dry Heath Area	Ugglebarnby Moor Central Wet Heath Area	Ugglebarnby Moor Southern Dry Heath Area	Ugglebarny Moor Southern Spring Flush	Sneaton Low Moor Dry Heath Area	Sneaton Thorpe Beck	Little Beck	Caravan Park	MF2	SF1	NHF	SP01	SP02, SP03	SP04	DNS1	Knaggy House Farm Spring	Moor Grit Secondary A Aquifer	Scarborough Fm Secondary A Aquifer	Cloughton Fm Secondary A Aquifer	Saltwick Fm Secondary A Aquifer
			Dry Heath Ecology	Wetland Ecology	Dry Heath Ecology	Wetland Ecology	Dry Heath Ecology	Surface Water	Surface Water	Drinking Water	Drinking Water	Drinking Water	Drinking Water	Baseflow	Baseflow	Baseflow	Baseflow	Baseflow	Shallow aquifer/ Drinking water/ Baseflow	Shallow aquifer/ Drinking water/ Baseflow	Moderate depth aquifer/ Drinking water/ Baseflow	Moderate depth aquifer
PHYSICAL IMPACTS	Alteration of groundwater flow paths and levels in the Moor Grit, Scarborough, Cloughton and Saltwick aquifers may arise during construction if a drop in water head within the shaft excavation occurs below the ambient groundwater level within each aquifer.	Connectivity between Activity and Receptor	Low	Low	Low	Low	Low	Low	Very Low	Very Low	Low	Low	Low	Low	Low	Low	Low	Low	Very High	Very High	Very High	Very High
		Receptor Proximity to Activity	High	Medium	Low	Low	Very Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Low	Medium	Low	Very High	Very High	Very High	Very High
		Likelihood	Medium	Medium	Low	Low	Low	Low	Very Low	Very Low	Low	Low	Low	Low	Low	Low	Medium	Low	Very High	Very High	Very High	Very High
		Magnitude of Effect at Source	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
		Magnitude of Effect at Receptor	**Low**	**Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Low**	**Very Low**	**Low**	**Low**	**Low**	**Low**
		Sensitivity (Value of Resource)	**Low**	**Low**	**Low**	**Very High**	**Low**	**Low**	**Medium**	**High**	**High**	**High**	**High**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Medium**	**Medium**	**Medium**	**Medium**
		Significance of Impact	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Minor**	**Minor**	**Minor**	**Minor**
	Alteration of groundwater flow paths and levels in the Moor Grit, Scarborough, Cloughton and Saltwick aquifers may arise after construction, if the grout seal between the liner and the rock formation is imperfect.	Connectivity between Activity and Receptor	Low	Low	Low	Low	Low	Low	Very Low	Very Low	Low	Low	Low	Low	Low	Low	Low	Low	Very High	Very High	Very High	Very High
		Receptor Proximity to Activity	High	Medium	Low	Low	Very Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Low	Medium	Low	Very High	Very High	Very High	Very High
		Likelihood	Medium	Medium	Low	Low	Low	Low	Very Low	Very Low	Low	Low	Low	Low	Low	Low	Medium	Low	Very High	Very High	Very High	Very High
		Magnitude of Effect at Source	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
		Magnitude of Effect at Receptor	**Low**	**Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Low**	**Very Low**	**Low**	**Low**	**Low**	**Low**
		Sensitivity (Value of Resource)	**Low**	**Low**	**Low**	**Very High**	**Low**	**Low**	**Medium**	**High**	**High**	**High**	**High**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Medium**	**Medium**	**Medium**	**Medium**
		Significance of Impact	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Minor**	**Minor**	**Minor**	**Minor**
CHEMICAL IMPACTS	Groundwater pollution from normal VSM operation.	Connectivity between Activity and Receptor	Low	Low	Low	Low	Low	High	Very Low	Very Low	Low	Low	Low	Low	Low	Low	Low	Low	Very High	Very High	Very High	Very High
		Receptor Proximity to Activity	High	Medium	Low	Low	Very Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Low	Medium	Low	Very High	Very High	Very High	Very High
		Likelihood	Medium	Medium	Low	Low	Low	Medium	Very Low	Very Low	Low	Low	Low	Low	Low	Low	Medium	Low	Very High	Very High	Very High	Very High
		Magnitude of Effect at Source	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
		Magnitude of Effect at Receptor	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**
		Sensitivity (Value of Resource)	**Low**	**Low**	**Low**	**Very High**	**Low**	**Low**	**Medium**	**High**	**High**	**High**	**High**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Medium**	**Medium**	**Medium**	**Medium**
		Significance of Impact	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**
	Groundwater pollution from bentonite slurry or grout losses within the annulus between the shaft lining and rock.	Connectivity between Activity and Receptor	Low	Low	Low	Low	Low	High	Very Low	Very Low	Low	Low	Low	Low	Low	Low	Low	Low	Very High	Very High	Very High	Very High
		Receptor Proximity to Activity	High	Medium	Low	Low	Very Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Low	Medium	Low	Very High	Very High	Very High	Very High
		Likelihood	Medium	Medium	Low	Low	Low	Medium	Very Low	Very Low	Low	Low	Low	Low	Low	Low	Medium	Low	Very High	Very High	Very High	Very High
		Magnitude of Effect at Source	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
		Magnitude of Effect at Receptor	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**
		Sensitivity (Value of Resource)	**Low**	**Low**	**Low**	**Very High**	**Low**	**Low**	**Medium**	**High**	**High**	**High**	**High**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Medium**	**Medium**	**Medium**	**Medium**
		Significance of Impact	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**
	Introduction of pollution from the use of external water to maintain a 10 m head of water above the cutting head.	Connectivity between Activity and Receptor	Low	Low	Low	Low	Low	High	Very Low	Very Low	Low	Low	Low	Low	Low	Low	Low	Low	Very High	Very High	Very High	Very High
		Receptor Proximity to Activity	High	Medium	Low	Low	Very Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Low	Medium	Low	Very High	Very High	Very High	Very High
		Likelihood	Medium	Medium	Low	Low	Low	Medium	Very Low	Very Low	Low	Low	Low	Low	Low	Low	Medium	Low	Very High	Very High	Very High	Very High
		Magnitude of Effect at Source	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
		Magnitude of Effect at Receptor	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**
		Sensitivity (Value of Resource)	**Low**	**Low**	**Low**	**Very High**	**Low**	**Low**	**Medium**	**High**	**High**	**High**	**High**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Medium**	**Medium**	**Medium**	**Medium**
		Significance of Impact	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**
	Pollution occurring from leachate generated from the spoil arisings	Connectivity between Activity and Receptor	Low	Low	Low	Low	Low	High	Very Low	Very Low	Low	Low	Low	Low	Low	Low	Low	Low	Very High	Very High	Very High	Very High
		Receptor Proximity to Activity	High	Medium	Very Low	Low	Very Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Low	Medium	Low	High	Medium	Low	Very Low
		Likelihood	Medium	Medium	Low	Low	Low	Medium	Very Low	Very Low	Low	Low	Low	Low	Low	Low	Medium	Low	Very High	High	High	Medium
		Magnitude of Effect at Source	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
		Magnitude of Effect at Receptor	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**
		Sensitivity (Value of Resource)	**Low**	**Low**	**Low**	**Very High**	**Low**	**Low**	**Medium**	**High**	**High**	**High**	**High**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Very Low**	**Medium**	**Medium**	**Medium**	**Medium**
		Significance of Impact	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**	**Negligible**