HYDROGEOLOGICAL ASSESSMENT

For Rand and Asquith (Aceblade) Quarry

at

Elland Edge Quarry, Elland, West Yorkshire

Prepared by: Hart Environmental Limited

Prepared for: Samuel Gledhill & Sons Limited

Date: 29th April 2026

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Contents

Revision History

Revision	Date	Description	Reviewed by	Approved by
Rev 1	28th April 2026	Update and clarification of groundwater plausible pathways		Elizabeth Hart
Rev 2				

1 INTRODUCTION

1.1 Commission

1.1.1 Hart Environmental Ltd were commissioned by Britology Ltd, working on behalf of Samuel Gledhill & Sons Limited to undertake a hydrogeological assessment to support the bespoke deposit for recovery application.

1.1.2 This report includes details on:

- Site environmental setting
- Overview of proposed operations
- Refined conceptual site model following groundwater investigation
- Hydrogeological risk evaluation based on groundwater monitoring data
- Life cycle analysis
- Uncertainties in assessment
- Management & monitoring options

1.1.3 This report forms Appendix E (groundwater assessment) of the deposit for recovery application submission. The report replaces and supersedes the previous hydrogeological risk assessment prepared by Environmental Consulting Ltd, ref 2022-030-012-003, dated 26th September 2022. Where this latter report is referenced in the approved Waste Recovery Plan, ref 22-04-420 Rev B dated April 2022, prepared by Cromwell Mining Consultants, this should be taken to mean this updated report (202413/2a).

1.2 Limitations

1.2.1 This report has been produced by Hart Environmental Ltd with all reasonable skill, care and diligence. The report is for the specific scheme detailed in section 1.1, it is confidential and for the sole use of Samuel Gledhill & Sons Limited. Copies of this report must not be passed to third parties without the express written consent of Hart Environmental Ltd and then no professional liability or warranty will be extended to third parties without the written confirmation of Hart Environmental Ltd.

1.2.2 The report is based on the findings of 3rd party reports. It has been assumed that all reasonable skill, care and diligence has been used when developing these reports and that they were written by competent and qualified professionals. Hart Environmental cannot be held responsible for omissions or inappropriate interpretation of topographical surveys, ground investigation and monitoring data provided by 3rd parties.

2 THE SITE

2.1 Location

2.1.1 The site is located 1.5km west of Rastrick, and 4km southwest of Halifax, centred at NGR SE 129 212 (as shown on Drawing 001 5003/1, in Appendix A of the permit submission). The entire site comprises approximately 8.7ha (equivalent to 87,000m^2) and is accessed from Lower Edge Road.

2.1.2 The site is currently owned by Samuel Gledhill & Sons Ltd and operated by Aceblade Ltd.

2.1.3 The quarry is surrounded on two sides (east and south) by open grassland. To the north is Low Edge Road and residential housing. There is a mix of residential properties, open grass and woodland directly to the west. Beyond this is a large former quarry (approx. 200m to the northwest) which has extracted brickearth, the strata beneath the Elland Flags. This quarry makes up part of Strangstry Wood and remains an open void, providing a full section of strata from the surface, through the Elland Flags to the underlying Halifax Hard Bed.

2.1.4 The site is shown in its setting in Figure 1 below.

Figure 2-1 Site location in relation to surrounding land uses

2.2 Geology

2.2.1 The area is directly underlain by the Elland Flags sandstone, which consist of fine to medium-grained flaggy to thickly bedded blocks or 'leaves' of sandstone, interbedded by mudstones. The Elland Flags are part of the Lower Pennine Coal Measures Formation. The Coal Measures consist of interbedded sandstone, siltstone, mudstone and coal.

2.2.2 Within the quarry depths (upper 35m of Elland Flags) the mudstone bands are no more than 2m thick, however these increase in thickness in the Lower Coal Measure deposits below the base of the Elland Flags. The increased thickness of mudstone can be seen in the quarry face at Strangstry Wood.

2.2.3 The Elland Flags sandstone blocks and underlying mudstone have been quarried extensively in this wider area.

2.2.4 There are no superficial deposits mapped in the local area.

2.3 Hydrogeology

2.3.1 The Elland Flags and the wider Coal Measures are classed as a Secondary A aquifer; a groundwater that can be important for local abstraction and supporting basal flow to rivers.

2.3.2 The site does not lie within a groundwater source protection zone and there are no recorded abstractions within 500m of the quarry.

2.3.3 There are no recorded Environment Agency observational groundwater level or quality boreholes in the area.

2.4 Hydrology

2.4.1 The River Calder is the closest significant water feature to the quarry and lies approx. 580m to the north-west, flowing from west to east. The Calder lies beyond the Strangstry Wood at an elevation of approx. 80mAOD, significantly lower than the base of Elland Edge quarry.

2.5 Current features

2.5.1 The site presently contains two quarry voids where a depth of approx. 30m of stone and clay have been removed, these voids require filling under the deposit for recovery permit. A scaled drawing of the voids is included in the topographical survey in Appendix A of the permit application.

2.5.2 The base of the main void (Void 1) lies at approximately 138mAoD, the 2025 topographical survey (Appendix A) shows this to be approx. 140mAOD. This reduced depth is due to the placement of natural soils to provide a stable tracking platform. Quarrying activity is complete in Void 1 with all available Eland Flags sandstone extracted

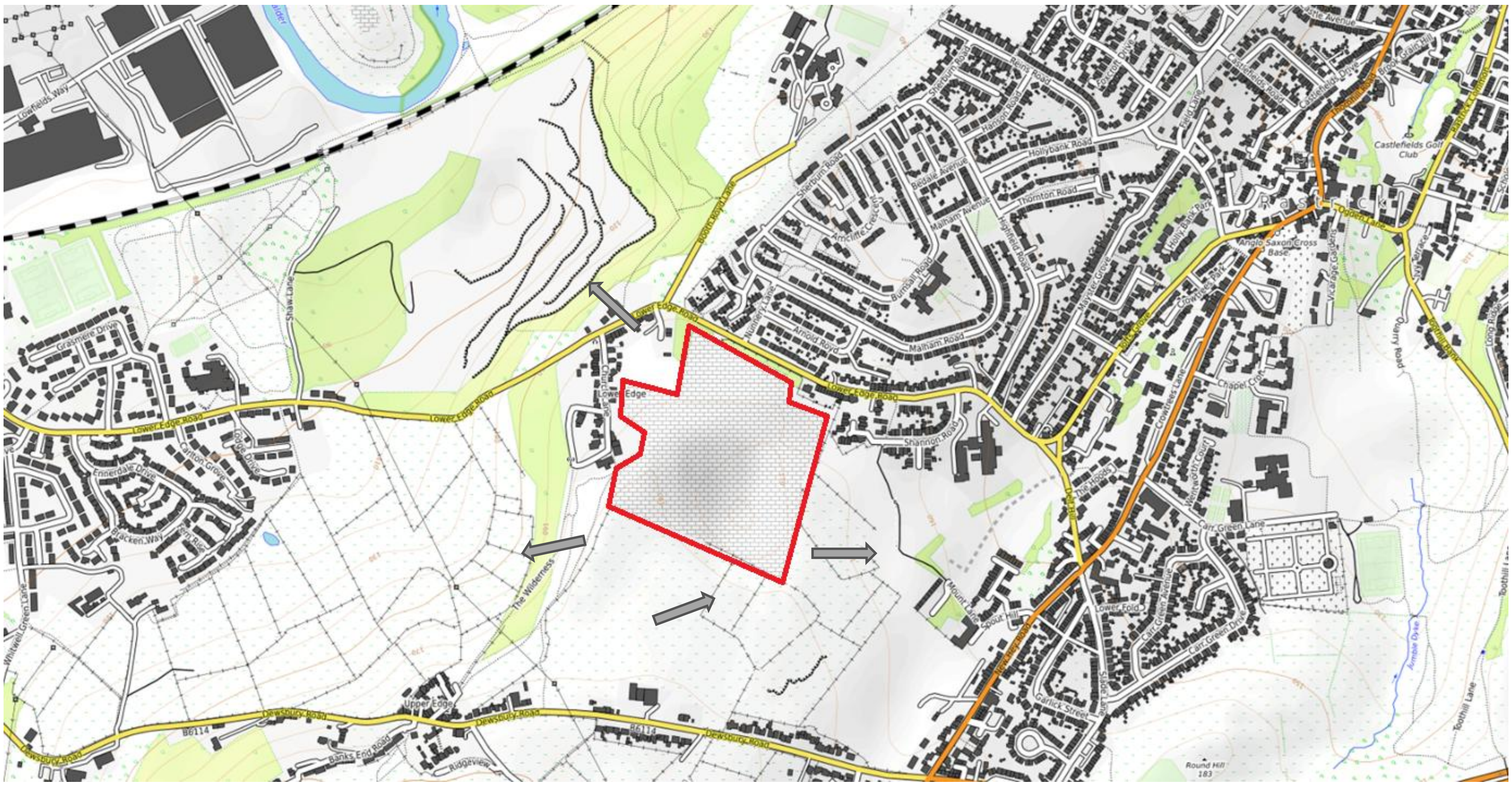
2.5.3 The base of the smaller void (Void 2) is shallower at approx. 150mAoD, having encountered thicker bands of mudstone which limited extraction. Sandstone block is still being extracted from Void 2, this is being worked horizontally towards the south.

2.5.4 The processing area for sandstone aggregates is located on the southeast side of the quarry along with stockpiles of natural overburden and mineral wastes generated from the quarry activity. This material will be used as part of the recovery operation to fill the two void areas, supplemented by imported inert waste, as required under the planning consent. No waste is stockpiled / stored in the voids, all waste stockpiles are located in the permitted treatment area.

Figure 2-2 Site Features.

2.5.5 The overview topographical plan (Figure 3) below shows the site, edged in red, in relation to the surrounding area. The site is located on the crest of a hill at between 180 to 170mAOD, with land levels falling rapidly to approx. 80mAOD to the west, with a shallower drop to the north and east to approx. 130mAOD. The direction of land fall is shown by the grey arrows. Land to the south is slightly elevated at approximately 200mAOD.

Figure 2-3 Area topographical plan scaled to 1:10,000



2.6 Historic activity (site)

2.6.1 The area has been worked for stone since around 1852 and is shown on the first edition county sheet.

2.6.2 The quarry was first opened under planning approval in 1948 to work the Elland Flags sandstone above the Coal Measures. The quarry extracted stone from the surface and also via a series of rectangular shaped tunnels 4 metres wide and 2 metres high to extract the Flags. Evidence of a former shaft can be seen in the eastern working face of the Elland Edge quarry void 1. Quarrying ceased in the 1960's.

2.6.3 A waste management license was issued for the Elland Edge Quarry in approx. 1978 for the infilling of the worked area. The WML was surrendered in 1992 once the void had been infilled. It is understood the historic void was infilled with a mix of quarry arisings and ash from various coal fired power stations.

2.6.4 Since not all areas of Elland Flags sandstone were worked prior to the first closure, and due to the high demand for building materials, the quarry was reopened in the early 1990's, with the northeast area (Void 1) being worked since 2010.

2.6.5 Engineered quarry arisings were used to create buttresses and a haul road to reduce land slippage and facilitate safe access into the void. The buttress lies between the infilled historic quarry and Void 1, the same approach is being taken as works advance in Void 2.

2.6.6 Figure 4 below shows the area infilled under the historic WML and the current void areas, as well as the buttresses and haul road that separates the historic deposited waste from Void 1.

Adjacent land

2.6.7 Land to the south, beyond the site boundary had been quarried for over 100 years and was backfilled with commercial waste and fly ash from Elland Power Station from the 1930's through to closure of the site in 1992. There is understood to be an approximate 6m 'wall' of intact Elland Flag rock separating the Lower Edge quarry and the former infilled quarry to the south (approx. 3m width on each site of the boundary)

2.6.8 Strangstry Wood area, to the west, was used for the Wilkinson Calder Fireclay and Brickworks and extracted and processed the mudstone and Fireclay from the hillside below the Elland Flag horizon.

Figure 2-4 historic filling and buttresses

2.7 Current ground conditions

2.7.1 A ground investigation was commissioned to undertake a series of trial pits at the base of Void 1 to describe the nature of the basal material and to confirm if waste deposits were present. The investigation was undertaken by Vertase FLI and is included in Appendix H of the permit submission.

2.7.2 In summary Vertase advanced 8 trial pits to a maximum depth of 4m and maximum width of 3m. Trial pit locations were limited due to soft ground and standing water in the north-eastern corner of the void.

2.7.3 Soil samples were logged and sent for chemical analysis, focussing specifically on metals and organics often associated with coal ash, since this was the only waste, other than quarry arisings to be recorded as deposited under the WML.

2.7.4 The exploratory logs recorded the base of Void 1 as quarry overburden placed as a protective running layer over Blue Shale (mudstone). Chemical data did not record any elevated concentrations that may indicate the presence of coal ash.

2.7.5 The investigation confirmed the base of Void 1 has not been partially infilled with waste and as such a deposit for recovery permit can be used to support the restoration activity.

2.7.6 Mudstone is visible at the base of Void 2 and this area is still being extracted to the south and west.

2.7.7 It is understood that any waste arisings in Void 2 along the eastern side wall between the void and the WML area i.e. material that cannot be processed for sale by the quarry, will be removed to the treatment area to be processed. Depending on the nature of the material this will either be treated and retained for recovery on site or disposed off-site.

2.7.8 A further ground investigation was commissioned, undertaken by Lithos Consulting Ltd, to advance 5 boreholes around the perimeter of the quarry. No boreholes could be placed along the northern and eastern boundary of Void 1 due to health and safety constraints associate with sheer quarry face and the need to drill in the highway /private land to allow sufficient step away from the quarry edge.

2.7.9 The boreholes were installed with dual installations to monitor for the possible presence of groundwater and gas.

2.7.10 Details of the drilling and subsequent monitoring to date is included in Appendix H of the permit submission. Monitoring will continue for a full 12 months to provide seasonal baseline data.

2.7.11 Prior to advancing any boreholes, the anticipated depth of the basal mudstone, below the Elland Flags, was calculated from the geologically mapped dip of the strata and the known depth it was encountered in Void 1. This indicated the mudstone below the quarried Elland Flags was likely to lie at approximately 145mAOD in the west falling to 135mAOD in the east.

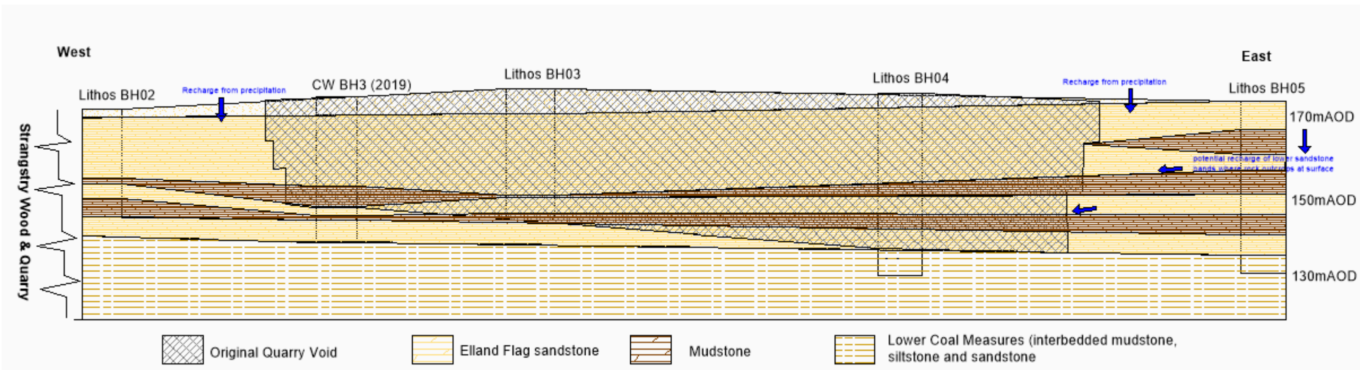
2.7.12 The borehole data has been used to develop the cross section shown in Fig 2-5, this captures geological data along the southern section of the quarry. This includes the intact / unworked rock sequencing on the boundaries of the quarry which provide an indication of the likely layering prior to any quarrying activity.

2.7.13 Lithos BH04 and the previous Cromwell Consulting BH3 advanced in 2019 (log included in Appendix H of the permit submission for completeness) recorded artificial ground associated with the backfill of the original quarry abstraction. Borehole locations are shown in Figure 2-5 below.

Figure 2-5 Borehole locations

2.7.14 This borehole data has been used to provide an indication of the historically worked area. The current Void 1 & 2 are not shown in Fig 2-6 below. However, Void 2 is targeting the intact sandstone bed shown on the west boundary.

Figure 2-6 Geological cross section of the quarry based on borehole logs

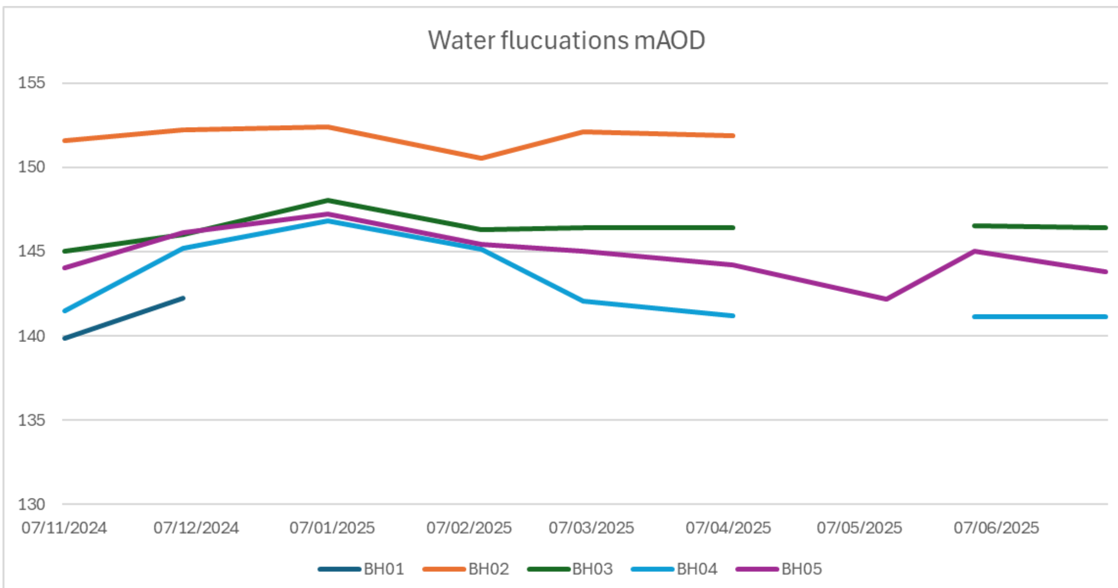


2.7.15 The final depth and installation details for each of the five Lithos boreholes is summarised in Table 2-1 below, along with the most recent groundwater dip data. Groundwater levels are discussed in more detail in section 2.7.22 below.

Table 2-1 Borehole depths and installation details

BH ID	Ground level mAOD	Base of well mAOD	Response zone	Groundwater level*								
				07/11/24	04/12/24	06/01/25	10/02/25	05/03/25	08/04/25	13/05/25	02/06/25	02/07/25
BH01	160.15	138.15	142 – 138	139.85	142.22	ND	ND	ND	ND	ND	ND	ND
BH02	172.38	146.38	154 – 150	151.56	152.23	152.37	150.55	152.09	151.9	ND	ND	NR
BH03	177.70	145.29	149 – 145	145.05	146.00	148.04	146.32	146.41	146.44	ND	146.55	146.42
BH04	176.32	131.82	140 – 136	141.47	145.21	146.81	145.16	142.06	141.19	ND	141.15	141.11
BH05	173.11	133.61	137 - 133	144.03	146.11	147.24	145.42	145.02	144.21	142.16	145.02	143.82

Fig 2-7 Water fluctuations in monitoring wells over time



Groundwater levels

2.7.16 The groundwater level data presented in Table 2-1 above has been shown graphically in Fig 2-7.

2.7.17 Monitoring well BH02 & 03 were installed in intact undisturbed bedrock at depths intended to target the suspected shallower mudstone band on the west boundary (around Void 2) and capture potential groundwater above this. The difference in water levels between the two locations indicates perched water, rather than one continuous water table and the absence of water during prolonged periods of dry weather indicates the water in these locations is heavily influenced by water infiltration, rather than flow into the site from surrounding ground.

2.7.18 Monitoring wells BH01, 04 & 05 were installed at a depth to correspond to the basal mudstone identified in Void 1. Monitoring well BH05 was installed in intact undisturbed bedrock; BH01 was in quarry backfill and BH04 is believed to be in the WML infilled area. The wells provide representative data to consider the presence and movement of groundwater beyond the site boundary, providing additional information on strata dip and variability.

2.7.19 The area around BH01 appears to have been quarried to a greater depth than Void 1, giving an increased depth of quarry infill; no ash was recorded, and this backfill is not considered to form part of the WML backfill. Natural undisturbed strata were not encountered in BH01 but the depth was extended to correlate with natural bedrock recorded in BH04 & 05.

2.7.20 From the monitoring data presented in Fig 2-7 it can be seen that BH01 is dry on all but the first monitoring event. The water during the first visit is considered to represent trapped drilling waters, not groundwater. Levels in BH01 do not increase following rainfall suggesting infiltrated waters do not reach this depth at this location, conversely the monitoring data in BH04 does appear linked with rainfall, resulting in a dry well after a prolonged period of dry weather, similar to BH02 & 03.

2.7.21 Groundwater was consistently identified in monitoring well BH05 and sufficient recharge occurred during purging to allow water samples to consistently be obtained. Monitoring well BH05 is the only location where a continuous groundwater table is likely to be present, and it is considered likely this is a confined water table in the sandstone recorded between 136 to 134mAOD on the exploratory log. Water was not encountered during drilling and the response zone for the well is sealed below the larger dry band of sandstone between 151 to 137mAOD.

2.7.22 The base of void 1 is recorded as approx. 138mAOD. The groundwater identified in BH05 is located below a low permeable layer approximately 2m below the base of Void 1. However, given the suspected confined nature of the groundwater, with a resting water level of between 142 to 147mAOD, disturbance of the mudstone at the base of Void 1 should be avoided to prevent flooding of the void. Natural fractures and fissures in the mudstone may be the cause of some of the local ponding water identified in Void 1, as confined deeper groundwater using these pathways migrate to surface.

3 OVERVIEW OF PROPOSED OPERATION

3.1.1 The site was granted planning approval as a mineral extraction site in 1948. This consent has been repeatedly reviewed and updated by the Local Planning Authority. The most recent review was completed in 2021 (ref 16/00439/MCO). This planning approval requires the site to be returned to a pre agreed condition and level, following the restoration plan detailed in the recovery plan drawings and cross sections included in Appendix A of the permit submission.

3.1.2 Total restoration of the void cannot be achieved solely with the stockpiles of quarry overburden as around 40% of the geological material has been removed as block and sandstone aggregate product. Therefore, import of material is required.

3.1.3 Under planning condition number 26, restoration material can only include the overburden and mineral waste generated from quarry activity and inert waste imported to site.

3.1.4 Imported waste will be accepted under conditions set out in the Site Management Plan and stored and treated as necessary in the treatment area, shown on Fig 2-2. The quarry already holds a waste treatment permit, this standard rules permit will continue to be operated to support the Deposit for Recovery permit.

4 REFINED GROUNDWATER CONCEPTUAL SITE MODEL

4.1 Groundwater receptors

4.1.1 Evidence indicates that there is no continuous groundwater table in the shallower quarried Elland Flags around the quarry. Groundwater was not abstracted or managed during quarrying and there is no evidence of water seepage from the exposed Elland Flags either at the quarry or 200m to the north-west at Strangstry Wood.

4.1.2 The land around Elland Edge quarry and land immediately to the south form the highest outcrop of Elland Flags sandstone in this local area. As the sandstone is not overlain by any low permeable drift deposits, this area, prior to quarrying, is likely to have formed part of the recharge catchment for the Elland Flags secondary A aquifer.

4.1.3 BGS 1:50,000 geological map (Sheet 77 Huddersfield) suggests the Elland Flags sandstone dips approximately 5 degrees to the northeast. Infiltrated water will generally flow with the geological dip, which on this site is to towards Rastrick.

Groundwater abstractions

4.1.4 A groundwater abstraction borehole is present approximately 1km to the north-west at Ashday Hall. Ashday Hall lies at an elevation of approximately 160mAOD on the opposite side of the valley to the quarry. While at similar ground elevations and both within the Elland Flags sandstone, the quarry and the abstraction lie in distinctly separate geological outcrops. Irrespective of the depth of the groundwater abstraction there are no plausible pathways between the quarry and Ashday Hall abstraction.

4.1.5 There are no other licensed groundwater abstractions recorded. However small-scale abstractions below 20m^3 per day do not require an abstraction license and are not automatically recorded as private abstractions by the Local Authority, so while none have been identified, they cannot be entirely discounted.

4.1.6 Potential risks to any groundwater abstraction from the deposit for recovery activity can only be relevant where plausible pathways exist. As such only assumed abstractions down hydraulic gradient (north-east based on the geological dip) from the quarry should be considered viable receptors.

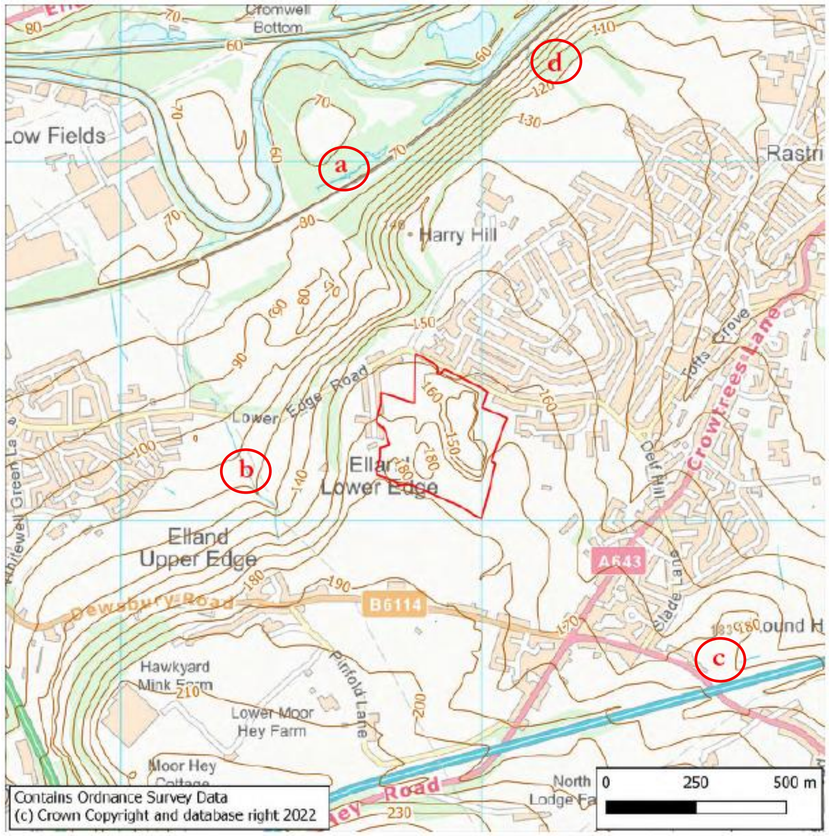
Groundwater springs

4.1.7 Groundwater springs are mapped in the wider area, the closest four to the quarry are described in the table below and the location of each shown in Figure 4-1.

Table 4-1 summary of groundwater springs

<table>
<tr><th>Id on Fig 6</th><th>Descriptions</th><th>Comments</th></tr>
<tr><td>A</td><td>Suspected spring fed ponds at the edge of the Calder flood plain, about 600m north northwest of the quarry, at an elevation of c. 62mAOD. These are associated with the local nature reserve</td><td rowspan="2">Springs a & b are located up geological gradient from the quarry according to the geological dip recorded on the BGS map. Water infiltration at the quarry has no plausible migration pathway to these locations.</td></tr>
<tr><td>b</td><td>A small stream that rises about 500m to the west of the quarry. This rises at a spring in the base of the Elland Flag Rock at an elevation of about 150mAOD and runs in a shallow valley down to the River Calder.</td></tr>
<tr><td>C</td><td>A spring rises about 950m to the southeast of the quarry, at an elevation of c. 140mAOD, near a small mound called Round Hill, at the head of a small valley. It quickly becomes culverted under Rastrick</td><td>The spring may be fed by confined deeper groundwater that would be distinctly separate from any infiltrated water at the quarry. However, given the elevation of 140mAOD is similar to the elevation of the base of the sandstone extracted in the quarry. The 'spring' could be a result of unconfined discharge of water draining through this band of sandstone, as opposed to a confined groundwater source. However, the geological dip is toward the northeast, which would suggest water 'draining' from the quarry is unlikely to contribute to the springs flow.</td></tr>
<tr><td>D</td><td>A spring rises about 900m north of the site, at an elevation of c. 105mAOD and flows steeply downhill to the Brookfoot Loop of the River Calder.</td><td>The Spring issues at 105mAOD. This is well below the base of the quarry (approx. 138mAOD), it is highly unlikely there exists a plausible pathway between the quarry and the confined groundwater creating the spring.</td></tr>
</table>

Figure 4-1 Approximate location of springs and abstractions



4.1.9 Based on ground elevations and geological topography it is considered unlikely that the springs detailed in table 4-1 could be viable receptors when considering the deposit for recovery activity.

4.1.10 However, the location and prevalence of springs can change over time and with varying rainfall rates, it is not unreasonable to consider a groundwater spring could exist at some point to the northeast at approx. 140mAOD where the quarried sandstone band outcrops at surface.

Groundwater as basal flow

4.1.11 The River Calder lies approx. 580m to the north-west, flowing from west to east. The Calder lies beyond the Strangstry Wood at an elevation of approx. 80mAOD, significantly lower than the base of Elland Edge quarry. There is no plausible direct flow pathway between groundwater at the quarry and the River Calder.

Secondary A aquifer

4.1.12 The Elland Flags are classified as a secondary A aquifer; a groundwater that can be important for local abstraction and supporting basal flow to rivers. Groundwater within the Elland Flags sandstone must be considered a receptor irrespective of current active abstractions or springs directly down gradient. This assumption links to any assumed future changes in activity and changes in groundwater levels.

4.1.13 However, the designation does not confirm that all Elland Flag sandstone bands include a water table, or a usable volume of water. The designation is for the geological unit. Additionally, the Elland Flag sandstone beds are separated by beds of low permeable mudstones and these mudstones can act as confining layers, creating distinctly separate groundwater tables within the sandstone bands.

4.1.14 Evidence on site, as detailed in section 4.1.1 & 4.1.2, indicates that there is no continuous groundwater table in the quarried Elland Flag beds. Groundwater in deeper beds of sandstone is indicated, but these appear confined and are currently discretely separate from the deposit for recovery area (the open void is not being flooded by confined groundwater).

Aquifer recharge area

4.1.15 The area around the quarry, prior to extraction, formed the highest outcrop of Elland Flags in the surrounding area and, given the absence of any superficial deposits would have been an important groundwater recharge area for the upper sandstone beds.

4.1.16 Sandstone extends off site to the west and south-west around Strangstry Wood, and to the south, now agricultural grazing land. These areas would also historically have provided some recharge for Elland Flags groundwater; however, these have also been extensively quarried. In the case of Strangstry Wood, quarrying reduced levels to a point significantly lower than the Elland Edge site and this remains an open void. The quarry to the south was excavated to a depth similar to Elland Edge quarry and has been backfilled and restored.

4.1.17 There is little remaining intact sandstone located up hydraulic gradient that could generate sufficient recharge to sustain a groundwater flow through the deposit for recovery area. Again, such a flow into the open void has not been observed in the time the quarry has been operational.

4.2 Precautionary migration pathways

4.2.1 Based on the review of the hydrogeological setting, both on site and in the wider area, and in the absence of a continuous groundwater table intersecting the quarry voids, it is considered that the main ways in which water may enter the void and/or recovered waste mass is via the following scenarios:

1. Water seeping from the WML area draining through the base of void 1.
2. Rainwater infiltration through the deposit for recovery area (void 1 & 2)
3. Confined groundwater in the lower beds of sandstone migrating into the infilled void 1 via fractures and fissures in the mudstone, draining to the northeast with the geological dip.

4.2.2 Whilst unlikely, each possible scenario and the likely impact these could have on groundwater quality is considered below to determine the need for further detailed risk assessment.

4.3 Potential sources of contamination

1) Contaminated water seeping from the infilled WML area

4.3.1 Visual observations recorded in Environmental Consulting Ltd HRA report, sourced from Cromwell Mining Consultants Ltd indicates:

there is seasonal inflow of water in to void 1 from the south. In January 2013 this took the form of two rivulets that emerged from the WML area. On 13 January 2014 the flow was estimated in the order of 1 l/s. The flow rate can be slightly higher with high precipitation or snow melts.

It is reported that before the former quarries were infilled, the flows emerged in the voids as groundwater springs approximately 20m below the top of the quarry.

4.3.2 Assuming this report is accurate it would suggest historic migration of water related to precipitation and a possible groundwater spring within the WML area at approximately 150mAOD (assuming the top of Void 1 lies at approx. 170mAOD). However, it is considered based on the available geological data that rather than a natural spring, this is more likely a consequence of quarrying activity disturbing the confining layer.

4.3.3 If impacted water leaching from the WML area migrates through the infilled void area, this may present a source of contamination associated with waste deposited under the WML. Such water will only seep from the base of the WML, as described above. This would enter the drainage base and disperse. There is currently no evidence the flow has been sufficient to drain into sandstone to the north even in an open void, collecting instead in a small, ponded area in the void. However, this potential source of contamination is attributed to the WML area already infilled, not the deposit for recovery activity and should be managed as a background source of potential contamination, not managed through the deposit activity.

2) Infiltrated rainwater passing through the deposit for recovery infilled void

4.3.4 During infilling work surface water will be managed to avoid pooling or excessive 'wetting' of recovered waste as increased moisture could affect the ability to engineer the waste to the necessary geotechnical specification. The method of water management is set out in section 5 of the Site Management Plan (Appendix J of the Waste Recovery Plan).

4.3.5 It is likely that much of the collected rainwater will be used for dust suppression and there is no proposed formal discharge from site via sewer or to surface water. Management of surplus collected rainwater is set out in the Site Management Plan.

4.3.6 Following completion of the infilling, a surface water management system comprising channels and ponds is proposed to collect and manage rainwater, this is set out in the planning consent. The engineering and compaction of the recovered waste will result in the backfilled quarry having a permeability significantly less than the surrounding ground; it is unlikely there would be any discernible infiltration through the waste mass.

4.3.7 Rainwater infiltration through the recovered waste is not considered to present a plausible migration pathway.

3) Contamination leaching from recovered waste into confined groundwater migrating upward through the mudstone.

4.3.8 The absence of a source of contamination in the waste being recovered will be confirmed by chemical testing either on site (for site won arisings that are not natural overburden) or during waste acceptance procedures before waste is accepted into the void. Further details on waste acceptance procedures are summarised in section 6 of the Site Management Plan (Appendix J of the Waste Recovery Plan).

4.3.9 Waste intended for reuse in the voids align with the waste permitted in standard rules permit SR2015 No.39. 'Use of waste in a deposit for recovery operation (Construction, reclamation, restoration or improvement of land other than by mobile plant)' to increase confidence that the waste is inert and does not present a leachable risk to the environment.

4.3.10 The Waste Recovery Plan sets out the lower fill sequencing as follows:

1) A drainage base across the mudstone at the base and sides of the quarry to prevent pooling and encourage dispersion of water, comprising 250 to 500mm gravel;

2) shale and mudstone that has been stored on site for restoration to be placed over the drainage base to approx. 4m thickness, placed in a maximum of 1m layers (more typically 0.5m) and compacted by excavator to achieve a permeability of at least 10^{-7}m/s

3) shale and mudstone overburden used to form 1:1.5 slopes as buttresses around the edge of the quarry to stabilise the slopes before any waste is deposited.

4.3.11 If confined groundwater migrates upward through fractions and fissures in the mudstone, this will encounter the drainage layer and natural basal layers. There will be no intermixing of groundwater with deposited waste in the deposit for recovery area.

4.4 Groundwater monitoring data

4.4.1 There has been insufficient recharge in BH01, 02 and 03 to obtain a water sample on any of the monitoring visits. Water samples have been collected from BH04 and BH05. Samples were scheduled for a range of inorganic and organic determinants.

4.4.2 A sample of the ponded water in Void 1 was collected historically in 2015 and subject to chemical analysis for a range of organic and inorganic determinants.

4.4.3 A further sample was collected in February and March 2025 during the borehole monitoring visits. This was again tested for a range of organic and inorganic determinants.

4.4.4 Key indicator compounds from the 2025 chemical data are presented in Table 4-2. All monitoring data collected by Lithos Consulting are included in Appendix H of the permit submission. Indicator compounds have been identified based on a review of the chemical data and consideration of priority and hazardous substances.

4.4.5 Concentrations of the indicator compounds in the ponded area are very similar to concentrations recorded in water collected from BH04, installed in the former WML area. Based on this similarity it is likely the water at the base of Void 1 originated from water leaching from the waste management area, as opposed to confined water in the sandstone below the base of the quarry.

Table 4-2 Water chemical data

Sample location	Indicator compound (units as stated)						
	Chloride (mg/L)	Ammoniacal Nitrogen (mg/L)	Arsenic (µg/L)	Boron (µg/L)	Lead (µg/L)	Selenium (µg/L)	Benzo(a)pyrene (µg/L)
DWS	250	0.5	10	1000	10	10	0.01
UK TAG	-	-	5	-	5	-	0.005
BH05 (confined groundwater	146	0.31	0.48	108	0.94	2.82	10.16
BH04 (water in the WML area)	62	0.07	0.78	397	3.10	9.32	0.21
Ponded water in void 1	54	3	0.73	262	0.63	10	0.03

NB concentrations represent mean across all monitoring visits

4.4.6 With the exception of benzo(a)pyrene (and other PAHs), where the drinking water standard and groundwater quality standard are both very low due to the recognised health implications around polycyclic aromatic hydrocarbons (PAH's), the indicator compounds detected on site are all below respective UKTAG hazardous substances thresholds and Water Supply thresholds[1], confirming that even if a plausible contaminant linkage were identified the concentrations currently on site would not present a viable risk to the water environment.

4.4.7 Concentrations of PAHs are higher in BH05 than in the WML area or the ponded water in void 1. Given the high degree of landfilling on surrounding land, the chemical data from BH05 is likely to reflect wider off-site sources of contamination; it is unlikely to be indicative of natural levels associated with geological sequencing but is likely representative of background conditions of the wider area.

4.4.8 A full excel data set of monitoring results is included in Appendix E. Original laboratory certificates are included in the monitoring letters in Appendix H.

[1] UKTAG_Technical report_GW_Haz-Subs_ForWebfinal.pdf & The Water Supply (Water Quality) Regulations 2010

4.5 Conceptual site model summary

4.5.1 Section 4 of this report has considered various source, pathways and receptors associated with the site, surrounding area and the proposed deposit for recovery activity. The outcome of this review is summarised in Table 4-3 below.

Table 4-3 summary of risk assessment

Source	Pathway	Receptor	Probability
Contaminants associated with the WML area	Leaching from the infilled area into the base of Void 1	Secondary A aquifer to the northeast	**Low** – there is evidence that water infiltration from the WML area drains towards Void 1. However, sampling confirms concentrations of indictor compounds are low and the pooled water in Void 1 has never required pumping to dewater the open Void. This suggests the flow rate of water from the WML area is very low. This water would enter the drainage base and disperse; it could not migrate upwards into the recovered waste. This potential source of contamination is attributed to the WML area already infilled, not the deposit for recovery activity and should be managed as a background source of potential contamination, not managed through the deposit activity.
Contamination in the recovered waste deposits	Leaching within the lower deposits via confined groundwater moving upwards into the infilled void through fractures and fissures in the basal mudstone.		**Very Low** – If confined groundwater migrates upward through fractions and fissures in the mudstone, this will encounter the drainage layer and natural basal layers. There will be no intermixing of groundwater with deposited waste in the deposit for recovery area.

4.5.2 Contamination has been identified in BH05, in groundwater upgradient of the deposit for recovery area. Conditions in BH05 should form the basis of the critical concentrations in the permit. There should be no increase in loading between that recorded in upgradient borehole BH05 and downgradient monitoring wells.

5 HYDROGEOLOGICAL RISK EVALUATION

5.1.1 Based on the data collected during the ground investigations, considered within the context of the wider environmental setting, the nature of the waste to be used in the recovery operation and design of the infill operation, the deposit for recovery activity is not considered to present a risk to the groundwater. No detailed quantitative risk assessment is required, nor are any engineering mitigation measures proposed, beyond the infill sequencing set out in the Waste Recovery Plan.

6 LIFE CYCLE ANALYSIS AND CLIMATE CHANGE

6.1 Life cycle analysis

6.1.1 Life cycle analysis on the Deposit for Recovery operation would include a comprehensive evaluation of the environmental impacts associated with the entire lifecycle of waste used to infill the quarry voids, from the waste generation, potential to recycle and reuse in an alternative setting, treatment required and its final disposal and long-term stability / suitability. This analysis should also consider all stages, including waste transportation to and from the quarry.

6.1.2 Completing a full life cycle analysis is highly complex and can include a high degree of subjectivity, a full life cycle assessment has not been undertaken for this site.

6.1.3 However, there are key considerations that should always be included in a Deposit for Recovery operation in terms of waste stability and suitability, and these considerations support the wider life cycle analysis concept.

6.1.4 The quarry can only accept inert waste to infill the voids. This will be explicit in the Deposit for Recovery permit and is also a clear planning condition in the mineral extraction restoration planning consent.

6.1.5 There is a wide range if wastes that fall under the inert definition and the waste codes proposed for this activity. Consideration should be given when selecting a source whether firstly the material is waste or secondly could be treated to form a useful and sought after end of waste product, such as creation of aggregate under the quality protocol.

6.1.6 As most of the material sourced is likely to be generated from the quarry arisings and construction sites there may be wider uses of the resource rather than using it for void infill. Much of this decision may lie with the waste producer, but good practice should ensure waste sources used to fill the voids have limited, if any, wider use. Once used in the backfilling operation these materials will be removed permanently as an available resource.

6.1.7 There is the possibility the site will in the future be developed for residential housing, if the planning authority agrees to this change in land use. Pre-empting this change in land use and incorporating the likely geotechnical and geochemical obligations in the final earthworks design, site management plan and validation/verification monitoring and testing would ensure the waste, once recovered in the infill, does not need to be removed or reengineered to support the change of use. This consideration should extent to foundation design, introduction of potential new pathways and changes in land use behaviour following restoration i.e public open space compared to a garden setting.

6.2 Climate change

6.2.1 Climate change means that extreme weather incidents are becoming more common and more severe and climate projections show that over the coming decades we will face an increased risk of climate change impacts, including:

- extreme rainfall, leading to more frequent and severe floods;
- heat waves;
- drought;
- rise in sea levels and tidal surges;
- storms; and
- wildfires.

6.2.2 Table 6-1 below considers each potential consequence of climate change and the potential impacts on the applicability of assumptions and outputs from this risk assessment. The table does not cover issues which should be controlled as part of the management of the recovery operation, these should be addressed in the Site Management Plan.

Table 6-1 Climate change considerations

Impact	Possible consequence	Action
Extreme changes in temperature	Greater potential for increased waste reactions and fires causing possible leaching of contamination to ground.	• make sure heat-sensitive wastes are removed from site (only inert waste should be stored) • make sure there is appropriate segregation and separation of wastes in the treatment area • check waste suitability prior to import rather than after import to the treatment area • Ensure waste is used in the operation in a timely manner to avoid prolonged stockpiling or build up of waste in the treatment area • regularly inspect waste storage areas • provide, test and maintain appropriate fire detection and firefighting measures and consider where firefighting waters will migrate/drain.
	Freezing of waste could affect the geotechnical properties and increase the moisture content after placement	• Increase validation testing and adjust waste management to consider implications. This is connected to final confidence in the engineered waste mass rather than potential to cause contamination
Extremes in rainfall (both increase and decrease)	increased site surface water and flooding	• Unlikely to affect the sites potential to cause groundwater contamination provided the site only stores inert waste and good surface water management is in place during the recovery operation. • No soakaways should be permitted in either the Voids or on the WML /treatment area. • Any increased need for dewatering should not affect the contaminant linkages discussed in this risk assessment. • A obligation and design of a surface water management system in the final restored voids is set out in the approved WRP.
	Increased pressure in the confined groundwater due to high recharge following increased rainfall, leading to a breach in the low permeable mudstones	• Use of clean natural overburden to form a compacted machine running layer prior to infilling activities should provide increased integrity of the mudstone • A granular drainage layer at the base of the void, with the additional c.4m quarry overburden as set out in the WRP design section, will increase dispersion and prevent groundwater ponding at the base of the infilled void or rising up into the recovered waste.
Storms: there could be a change in frequency and intensity	combination of increased wind speeds, increased rainfall, and lightning	• Covered in consideration of high rainfall above.

7 MANAGING UNCERTAINTY

7.1 Uncertainty in the conceptual site model

7.1.1 The conceptualisation of the site is based on currently available data and concludes that there is a very low probability of water from the deposit for recovery activity migrating beyond the site boundary. Also, that the leachable fraction from the previously deposited waste adjacent to void 1 is not exceeding drinking water standards or environmental quality standards.

7.1.2 However, site conditions can change over time, both seasonally and over years. While monitoring data has been collected over varying seasons and varying rainfall events it is not possible to accurately confirm that these are the extremes the site could experience.

7.1.3 Considering the possible implications of deviation from the assumptions made in this risk assessment and possible future environmental changes allows uncertainty in the conceptualisation and ultimately the conclusions of the risk assessment to be challenged. This is an essential part of assessing the uncertainty in the conceptualisation and provides a sensitivity assessment on the overall predicted risk.

7.1.4 The following three scenarios have been identified in this report as being critical uncertainties that need exploring. Where possible mitigation is required to manage the uncertainty, these are included in the site management plan:

- Deposit of contaminated 'unsuitable' waste i.e. waste with a leached concentrations that exceed the inert thresholds (unauthorised loads).
- Failure of water management systems, prolonged and intense rainfall leading to increased standing water / flooding within the deposit for recovery area / chance of release from site
- Persistent high rainfall causing increased recharge and increased pressure in the confined aquifer.

7.1.5 Scenarios 1 & 2 above are interrelated. Increase in surface water infiltration/surface flooding, within the context of this hydrogeological assessment, only presents a risk if it mobilises contamination off site. Leachable contamination should only be present in waste if non-inert waste has been deposited in the void or from silt / mud run-off (see section 6 of the management plan regarding waste acceptance and management of unauthorised loads).

7.1.6 Scenario 3 could contribute to a theoretical migration pathway. However, this can be discounted by considering the actual piezometric head that could be achieved by the groundwater in the confined sandstone and the placement of drainage layer and c.4m of compacted natural overburden at the base and sides of the void (drainage base, fill layers 1 & 2).

7.1.7 The piezometric head can only reach a maximum height of a saturated recharge area. This can be significant if the recharge area is several meters higher than the top of the confined sandstone band. However, Elland quarry is located at the highest elevation for the recharge area, the maximum piezometric head anticipated for BH5 was approx. 47mAOD, which would at worse only be approx. 2m above the natural overburden form fill layers 1 & 2 (base of void 1 is currently recorded at 40mAOD, drainage layer and c.4m fill would bring this to approx. 45mAOD), and this would only be if flow pathways could be established though the compacted natural strata. The compaction is aiming to achieve permeability rates of 10^{-7}m/s which is equivalent to an inert landfill liner in the Landfill Directive.

7.2 Priority and hazardous substances

7.2.1 There should be no input of priority or hazardous substance to groundwater from the infilling recovery activity. Waste used in the recovery operation should only be inert.

7.2.2 However, it is recommended that a selection of plausible priority and hazardous substances that could reasonably be associated with construction site wastes be included in the completion monitoring scheme. An groundwater monitoring plan is included in section 15 of the management plan.

8 RISK ASSESSMENT CONCLUSIONS

8.1 Summary

8.1.1 Based on the data collected during the ground investigations and considered within the context of the wider environmental setting, the proposed deposit for recovery activity is not considered to interact with a groundwater table and no migration beyond the site boundary is anticipated. No detailed quantitative groundwater modelling is considered necessary.

8.1.2 Waste acceptance criteria should consider the need to reduce any pollutant input to the environment; only inert waste included in the standard rules permit will be accepted. The design and management of the deposit activity should ensure that only clean natural arisings generated from the site are placed in the lower section of the Voids and quarry sides, as per the fill sequence.

8.1.3 Placed natural arisings and inert wastes should be suitably engineered and compacted to limit the infiltration of surface water, as required in the Waste Recovery Plan. This reduced permeability throughout the infilled void will also reduce the possibility of interactions with waste deposited in the historic WML area or migration of infiltrated water beyond the wider site boundary.

8.2 Management and monitoring options

8.2.1 The management of waste recovery should be detailed in the site waste management plan, and this should align with the agreed waste recovery plan.

8.2.2 This risk assessment has been developed with the assumption that the fill sequence in the waste recovery plan is followed and only natural quarry overburden, mineral processing wastes and inert imported waste will be used to infill the voids under the Deposit for Recovery permit and that suitable sampling and waste management procedures will be in place to ensure this.

8.2.3 Consideration of the environmental implications of contaminated 'unsuitable / non-conforming' wastes has been included in this assessment and management of this is detailed in the waste acceptance procedures in the site management plan. Such wastes should be avoided, however the absence of a sustained flow of groundwater through the waste mass indicates that should contaminated waste be inadvertently deposited in the voids this would not present any increased environmental risk.

8.2.4 Monitoring boreholes BH01 to 05 should continue to be monitored during the deposit activity and for a period of not less than 12months on completion of all earthworks. This timeframe should allow for seasonal fluctuations to be captured.

8.2.5 It was unsafe to install a borehole downgradient of void 1, as the quarry face extends to the boundary of the land ownership. Beyond this is public highway and private residential properties, neither are suitable for the installation of a long-term monitoring borehole.

8.2.6 It is therefore proposed that once engineering works to place the drainage layer and fill sequences 1 & 2 (placement of natural soils over the drainage layer and creation of side buttresses) are completed, two groundwater monitoring wells are installed along the northern boundary of void 1, installed to the base of the void into the drainage layer (approx. 38mAOD). Monitoring of these wells could commence prior to any imported waste placement (i.e. wells should be installed and sealed in overburden and drainage layer at the base do the void) and plain pipe should be used to increase well lengths as waste is placed, ensuring the response zone remains sealed in the natural overburden.

8.2.7 While these wells would be within the quarry area, provided they are placed as close to the northern quarry edge as possible they would provide validation monitoring for any groundwater migrating to this downgradient area.

8.2.8 This approach would provide BH2 and BH5 as up gradient monitoring wells, with BH1 and the new BH6 & BH7 as downgradient monitoring wells. Monitoring in BH3 & BH4 can continue to be monitored and will provide useful information on any changes to the WML condition. However, these have previously been dry on all monitoring events so data collection may be limited.

8.2.9 Validation monitoring should compare water quality data collected from up gradient boreholes to water collected in the downgradient boundary monitoring wells.

8.2.10 A plan showing suggested groundwater monitoring location is included below, a more detailed schematic is included in Appendix A of the WRP.

Fig 8-1 proposed monitoring locations