ENVIRONMENTAL PERMIT VARIATION APPLICATION – HYDROGEOLOGICAL RISK ASSESSMENT

CROFT QUARRY
MARION'S WAY
CROFT
LEICESTERSHIRE
LE9 3GP

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ENVIRONMENTAL PERMIT VARIATION APPLICATION

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1.0 INTRODUCTION

1.1 Scope & Background

1.1.1 Sirius Environmental Limited (Sirius) has been commissioned by Aggregate Industries UK Limited ('AI'), to prepare an application to vary Environmental Permit: EPR/EB3708GW to add a waste recovery activity involving the permanent deposit of wastes to support the restoration of Croft Quarry, Marion's Way, Croft, Leicestershire, LE9 3GP. AI are seeking to commence restoration of the quarry which will bring the final restoration levels to below those of the surrounding natural ground levels. As part of this application, it is necessary to formulate a range of risk assessment documents, including the requirement to undertake a Hydrogeological Risk Assessment.

1.1.2 This assessment includes the development a conceptual site model for the proposed waste recovery operation and identifies the potential source-pathway-receptor linkages and direct and indirect pollution risks to the surrounding hydrogeological environment. This Hydrogeological Risk Assessment has been prepared in accordance with the Environment Agency guidance: Groundwater Risk Assessment for your Environmental Permit (last updated 3rd April 2018).

1.1.3 This report should also be read in conjunction with the Environmental Setting and Site Design report (*Doc. Ref.: AI1009/07*) which accompanies the wider Environmental Permit application.

2.0 CONCEPTUAL HYDROGEOLOGICAL SITE MODEL SUMMARY

2.1 General

2.1.1 The details of the proposed design and the environmental setting of the site are set out in the Environmental Setting and Site Design (ESSD) Report (*Doc. Ref: AI1009/07*) and are summarised below:

- infilling will take place in a void created by the extraction of the igneous diorite intrusion;
- the waste recovery operation will be largely undertaken within the igneous diorite;
- the site will accept selected non-degradable, non-hazardous waste;
- an Artificially Established Geological Barrier will be required to prevent the direct input of any potential hazardous substances present in the waste deposits entering groundwater within the surrounding aquifers.
- due to the nature of the waste streams, leachate collection systems and an artificial sealing liner are not required.

2.1.2 Comprehensive details on the hydrogeological setting of the site are provided within the ESSD report (*Doc Ref.: AI1009/07*), and include the following:

- aquifer characteristics;
- groundwater flow and quality;
- groundwater quality;
- licensed groundwater abstractions; and
- Source Protection Zones.

2.1.3 The conceptual hydrogeological site model is based on the source-pathway-receptor linkages. The conceptual model is shown in **Drawing Nos.: AI1009/14/10 and AI1009/14/13** and key elements of the hydrogeological model are discussed in further detail below.

2.2 Source

2.2.1 The approved scheme of restoration will require the deposit of ~17.2million cubic metres of suitable restoration materials, of which ~3.2million tonnes will be sourced from site-won materials and the remaining ~14million cubic metres (~25.2millions tonnes) being imported materials. For the import portion, the restoration of Croft Quarry will be carried out as a waste recovery operation involving the permeant deposit of non-biodegradable, non-hazardous materials. The majority of these waste streams will comprises the construction, demolition and excavation wastes. The nature of these proposed wastes will offer limited potential to generate landfill gas or leachate. To minimise this potential and account for the scale of the restoration scheme, Waste Acceptance Procedures *(Doc. Ref.: AL1009/13)* have been developed that incorporate stringent verification testing above the testing requirements imposed on the waste producers.

<u>Site Design and Construction</u>

2.2.2 The site design is detailed within the accompanying ESSD (*Doc. Ref.: AI1009/08*). A summary if provided below.

Basal and Sidewall Engineering

2.2.3 Due to the aquifer status and elevation of groundwater within the diorite the base and sidewalls of the quarry will be engineered with an Artificially Established Geological Barrier (AEGB) which will serve the principle aim of preventing any potential for the direct and discernible input of hazardous substances to groundwater, whilst also limiting the input of non-hazardous pollutants. Whilst the characterises of the waste proposed to be deposited will be non-hazardous, the presence of a AEGB will manage the risk associated with the potential deposit of a rogue load at the site.

Groundwater Management Systems

2.2.4 Groundwaters seepages through the diorite and higher faces of the Mercia Mudstone are currently managed by collection in the base of the quarry void and pumping to the surface for initial treated (settlement) ahead of use for the production of mineral and associated products, amenity management practices or discharge to the River Soar.

2.2.5 During infilling operations groundwaters will be continue to seep in through the sidewalls above the top fo the AEGB being contrasted along the sidewalls. These waters will be directed via graded channels to temporary holding lagoon collected formed in the waste surfaces prior to pumping to the surface for use or discharge.

Capping

2.2.6 To maintain separation between the waste deposits and final restoration soils and waters within the wetland habitats, a 500mm capping system will be engineered to achieve maximum permeability of $1x10^{-8}$m/s.

Waste Quality and Priority Contaminants

2.2.7 Under the development proposals, the infilling of Croft Quarry will be achieved by means of the deposition of suitable non-degradable, non-hazardous material into quarry void. The broad scope of wastes to be deposited at the site include:-

- Materials which are not ‘hazardous’ within the meaning of the revised Waste Framework Directive (2008/98/EC).
- Wastes low polluting potential in the landfill environment, whereby the any contaminants are unlikely to become mobile when deposited and any waters produced in the waste has little or no pollution potential, and there are no long term management of any in-waste waters to protect groundwater.

2.2.8 The qualifying materials include wastes in the following groups:

- Group 1 Rocks and soils
- Group 2 Ceramics or concrete materials
- Group 3 Minerals, processed or prepared
- Group 4 Furnace slags
- Group 5 Ash

2.2.9 Of these the majority of the materials to be landfilled are expected to be:

- Soil (including mixed clays, silts and sands);
- Stones; and
- Concrete based construction materials from development schemes.

2.2.10 A large proportion of the waste for deposits will be sourced from the City and Boroughs of London. These waste streams will consist of a significant quantity of cohesive soils which will significantly limit the generation of a head of water with the waste deposits. This accords with Sirius' experience in the development similar Qualifying Materials facilities across the UK where in-wastes monitoring has indicates limited water infiltration through the wastes deposits.

2.2.11 The quality of any limited waters that do infiltrate the 'Qualifying Materials' will differ significantly from a typical non-hazardous wastes facilities taking degradable wastes as there is not a putrescible component to the waste stream. Consequently, the significant ammoniacal nitrogen and dissolved organic matter as well as other soluble salts will not be present as readily degradable organic matter and soluble salts are specifically excluded from the list of wastes prescribed for deposit at Croft Quarry. Given that the proposed waste types are unlikely to contain a degradable organic content, elevated ammoniacal nitrogen and BOD is not expected to be associated with waste for deposits at the site. Similarly solvents, refined petroleum fuels or other chemical sources will be excluded.

2.2.12 A conservative leachate source term for 'Qualifying Materials' facilities has been derived from a review of source terms from waste soils deposited at a variety of hazardous and non-hazardous soil landfill facilities across the UK. A statistical summary of leachable concentrations derived from wastes accepted at such facilities is present in **Table HRA1.**

Table HRA1: Statistical Summary of Potential Leachate Source Term

Substance	Source term Concentration (mg/l)			EAL	Risk Factor[a]
	Min	Average	Max		
Ammoniacal Nitrogen	0.001	3	22	0.1	30/220
Arsenic	0.001	0.007	0.116	0.005	1.48/23.2
Cadmium	<0.0001	0.002	0.062	0.00012	16.7/516.7
Chloride	9	171	1,040	113	1.5/9.2
Chromium	<0.001	0.004	0.019	0.0015	2.7/12.7
Copper	<0.001	0.006	0.024	0.0085	0.7/2.8
Mercury	<0.00001	0.0001	0.0002	0.000022	4.5/9.1
Lead	<0.001	0.017	0.02	0.00059	28.8/33.9
Nickel	0.002	0.024	0.078	0.0019	12.6/41.1
Sulphate	14	526	1,820	499	1.1/3.7
Zinc	0.002	0.046	0.194	0.024	1.9/8.1

[a] – Average/Maximum concentrations divided by lowest EAL from ***Table HRA2.***

2.3 Pathways

General

2.3.1 Croft Quarry has been worked to a depth of ~136mBOD to exploit one of three large scale groups of quartz diorite outcrops with the region. A lateral extension to the southeast of the existing void is also proposed to be worked of an elevation of *c.* -20mAOD, which will initially require the removal of c. 3.17million m³ of overburden comprising glacially derived diamicton moraines, river terrace deposits, and mudstones and siltstones of the Mercia Mudstone Group.

2.3.2 Restoration of the quarry will return ground levels in the central sections to ~12-15mAOD, increasing to ~17-18mAOD at it edges. These final level will be over 50m below surface levels around the edges of the quarry.

Geology

2.3.3 A full description of the geology within the vicinity of Croft Quarry is provided within the accompanying ESSD (*Doc. Ref.: AI1009/07*). Borehole logs for the gas and groundwater monitoring boreholes installed at Croft Quarry are also presented.

2.3.4 The quarry is located within an igneous diorite intrusion overlain and bounded by the Mercia Mudstone Group strata and superficial deposits. Quarrying operations have proven the presence of the diorite to a depth of c.136mBOD, whilst exploratory drilling has confirmed its continued presence to c.149.5mBOD. However, given the plutonic form of the intrusion, quartz diorite strata are almost certain to be present for many hundreds of metres below the quarry floor of the Site.

2.3.5 The diorite intrusion is extensively buried and concealed by extensive Triassic sedimentary mudstones and siltstones of the Mercia Mudstone Group. At Croft the Mercia Mudstone Group strata is one area with it is seen to thin to absence upon the flanks of South Leicestershire Diorite Complex (SLDC) intrusions, exposing diorite beneath superficial deposits and soils upon the hills of the area.

2.3.6 The Mercia Mudstone forms the upper eastern and southeastern faces of the quarry where it has been stripped to facilitate access to the underlying quartz diorite.

2.3.7 The buried flanks of the SLDC intrusion that form Croft Hill and host Croft Quarry dip steeply away from the hillside such that the quartz diorite becomes overlain by a rapidly increasing thickness of onlapping Mercia Mudstone sediments with distance away from the Site. Summary logs of investigations carried out between 1999 and 2018 in and around the lateral extension area are present in **Appendix ESSD3.** These logs highlight variability and increasing thickness of the Mercia Mudstone away from the main quarry void. At the western tip of the lateral extension area BH2B identified the transition zone between the Mercia Mudstone and Diorite at ~46mAOD. At the northeastern point of the extension area the log fo BH3B identifies the base of the Mercia Mudstone at ~58mAOD. More historic investigation logs located towards the easternmost edges of the extension area log the base of the Mercia Mudstone at between 13mAOD and -13mAOD.

2.3.8 The Mercia Mudstone is absent along surface at the northern, western and southwestern edges of quarry, which are instead overlain (except for the highest elevation of Croft Hill) directly by glacially derived diamicton moraines of the Oadby and Thrussington Members; both of which are clay dominated lithologies. The superficial deposits further east and south of the existing quarry void also comprises river terrace deposits associated with the fluvial channels of the River Soar and Thurlaston Brook, which are dominated by sand and gravel but with clay and silt fractions. These fluvial deposits overlie the glacial moraines.

2.3.9 Along the edges of the existing void the base of the superficial deposits typically extend no deeper than ~60mAOD. The rock head elevation in the lateral extension area has been proven to be variable, but superficial deposits with this area increase in thickness through towards the River Soar, with the basal elevation of ~55mAOD proven around the edge of the extension area. The superficial deposits will therefore be elevated above the final restoration levels of the quarry.

Hydrogeology

Sands & Gravels and Sands

2.3.10 The fluvioglacial and / or fluvial sands and gravels and sands comprising the near surface deposits over parts of the lateral extension and over a wide area extending onto the floor of the adjoining Soar Valley comprise a Superficial Aquifer capable of storing and transmitting significant quantities of groundwater. These deposits are designated by the EA as a "Secondary A Superficial Aquifer". This designation implies: *"…permeable layers that can support local water supplies, and may form an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers".*

2.3.11 Groundwater movement within the Superficial Aquifer is made by intergranular flow occurring within the interconnected pore spaces that exist between the sand and gravel matrix of the deposit a characteristic which is termed intergranular permeability.

2.3.12 The Superficial Aquifer forms an unconfined granular aquifer featuring diffuse, intergranular groundwater flow, and is assumed to be largely homogenous and anisotropic.

2.3.13 Recharge to the Superficial Aquifer is diffuse and chiefly autogenic, being sourced directly from effective rainfall.

Glacial & Glaciolacustrine Clays

2.3.14 The glaciolacustrine clays and underlying tills of the Wolston Formation underlying the sands and gravels and sands (where present) currently located within the lateral extension area and its surrounding areas to the east, south and west are designated by the EA as a "Secondary (undifferentiated) Superficial Aquifer". This designation implies: *"Secondary undifferentiated are aquifers where it is not possible to apply either a Secondary A or B definition because of the variable characteristics of the rock type. These have only a minor value."*

2.3.15 Due to an effective absence of any interconnected porosity (i.e. permeability), the glaciolacustrine clays and underlying tills (the Oadby and Thrussington Till) of the Wolston Formation that underlie the sands and gravels and sands (where present) to the south, east and west have negligible ability to store or transmit groundwater. Consequently, notwithstanding the difficulties associated with ascribing a designation within the EA's current classification scheme, the almost entirely argillaceous nature of the clays and tills defines them as a non-aquifer.

2.3.16 These clay deposits thus constitute an aquiclude of substantial thickness that serves to separate groundwater within the overlying sand and gravel from any underlying groundwater bodies that may exist.

Mercia Mudstone Group

2.3.17 The Mercia Mudstone Group is designated as a "Secondary B Bedrock Aquifers" by the EA: *"Secondary B aquifers are mainly lower permeability layers that may store and yield limited amounts of groundwater though characteristics like thin cracks (called fissures) and openings or eroded layers".*

2.3.18 Due to an absence of any effective permeability, the mudstone facies of the Mercia Mudstone Group which underlie the superficial clays and its wider area also have negligible ability to transmit and store any significant volumes of groundwater. Groundwater storage and movement within the Mercia Mudstone Group is therefore limited to the numerous but generally very thin sandstone beds (skerries) contained within it.

2.3.19 Due to the consolidated nature of these sandstone horizons, in addition to possessing intergranular permeability, these strata also have the ability to convey groundwater through the fracture system of the rock (termed fracture permeability or secondary permeability). The Mercia Mudstone Group as a whole thus functions as a series of interbedded aquifers and aquicludes: the aquifers constituted by the sandstone units which are subordinate in the group, and the aquicludes constituted by the mudstone units which dominate the sequence.

2.3.20 Collectively these aquifers and aquicludes form a vertically anisotropic aquifer (the Mercia Mudstone Group Aquifer) in which vertical movement of groundwater is extremely limited. This dictates that recharge to the groundwater systems of the sandstone units occurs chiefly around areas where these units outcrop at or very close to ground surface.

2.3.21 The moderate topographic relief and almost horizontal bedding of the MMG in the region mean that few areas of outcropping sandstone occur, this imposing a further limit on the potential utility of the MMG a viable aquifer unit.

Quartz Diorite

2.3.22 The Diorite is also classified as a “Secondary B Bedrock Aquifer” by the EA:

2.3.23 The Quartz Diorites of the South Leicestershire Diorite Complex are considered to possess very limited aquifer properties. Due to its crystalline nature, the strata possess no effective primary porosity and thus no primary (intergranular) permeability.

2.3.24 That groundwater movement which does occur within the strata will be made entirely within a secondary porosity flow system comprising interconnected factures and joints, albeit that this latter component is likely to be of very limited importance due to mineralisation closure.

2.3.25 It follows that groundwater storage and flow within Quartz Diorite will be greatest where the fracture system is most well developed. Due to stress relief caused by unloading of the rock by mineral extraction and the long history of blasting undertaken at the Site, enhancement of the hydraulic conductivity of strata within proximity of the void (underlying and laterally adjoining) is likely to have occurred.

Groundwater Levels & Flow

2.3.26 The monitoring of groundwater levels at Croft Quarry only commence in April 2918, thus there is no direct evidence regarding the evolution of any changes that might have occurred to local groundwater levels as a result of the history of quarrying at the site. Monitoring datasets from each piezometer installed at the site in 2017 is presented and summarised in the ESSD Report that supports this application *(Doc. Ref.: AI1009/07).*

2.3.27 The base of the superficial aquifer is over 45m above the final restoration levels for the quarry any will not be in hydraulic continuity with the waste deposits. There is no direct pathway for pollutants to discharge into the superficial aquifer.

2.3.28 Groundwater levels recorded within the Merica Mustone to the immediate north of the lateral extension area (BH3B) is recorded at between ~19 and 22mAOD between 2018 and 2022, increasing to ~38.5-42mAOD further north at BH4A. The significant difference between water levels is considered to be a facet of the high degree of vertical and horizontal anisotropy, which is evidenced by examination of the borehole logs: piezometer BH03B intercepts a 3m thick layer of sandstone within the upper profile of the Mercia Mudstone, whereas no significant sandstone horizons were encountered within piezometer BH04A.

2.3.29 Groundwater levels with the Mercia Mudstone are being drawn down by the long history of dewatering in the at the quarry, with recharge of the aquifer severely limited by total recharge area and the low permeability of the mudstone facies. As infilling of the void progresses groundwater levels within the Mercia Mudstone Group will remain above the final restoration levels of the quarry and maintain an inward hydraulic gradient in areas where the Mercia Mudstone outcrops on the sidewalls below the final waste levels on the eastern edge of the lateral extension area.

2.3.30 Groundwater levels within the Diorite Aquifer are consistently and substantially below those within the overlying Mercia Mudstone Aquifer, with head differences of between c. 56-70m.

2.3.31 The water level contained within the quarry sump is currently c.136 mBOD; average groundwater elevations measured at piezometers BH01, BH02B, BH3C and BH4B, all positioned at increasing distance from the void, are 65.6 mBOD, 53.6 mBOD, 47.9 mBOD and 16.2 mBOD respectively. The large depth to groundwater within the Diorite Aquifer compared to the River Soar level strongly suggests that groundwater levels within this aquifer have been drawn-down over the many years of dewatering undertaken at the quarry. Interpretation of the available data - alongside application of simple hydrogeological principles - indicates that groundwater within the Diorite Aquifer near the Quarry is flowing radially towards the void via the interconnected parts of the rock's fracture network.

2.3.32 The results of a water balance present in accompanying ESSD (Doc. Ref.: AI1009/07) suggests a total groundwater input to the quarry of between c.8 l/s and 12 l/s. Despite the considerable area and great depth of the void, relatively little groundwater interception occurs. This then demonstrates that the volumes of groundwater flowing within the Diorite Aquifer are very small. This implies that the Diorite possesses both limited transmissivity and limited recharge, both factors which accord with the general hydraulic nature of the strata and its geological setting beneath low permeability Triassic and Superficial cover. In turn this implies that the limit of discernible groundwater level drawdown attributable to the quarry dewatering operation (i.e. the radius of influence) will most likely be contained within a radius measurable in hundreds of metres rather than several kilometres away from the quarry sump.

2.3.33 As with the flooded nature of other abandoned quarries in the South Leicestershire Diorite Complex, prior to the commencement of dewatering at Croft Quarry the groundwater level within the Quartz Diorite would have been close to ground surface. It follows that the natural undisturbed mode of discharge from the Diorite Aquifer at Croft prior to quarrying and dewatering was made as lateral recharge to adjoining permeable fluvial and glaciofluvial deposits and thence to the River Soar and Thurlaston Brook. Therefore the mass effect of dewatering, wherein groundwater and rainfall ingress to the quarry are pumped to the adjoining River Soar, is largely that of a simple short-circuiting of the pre-existing natural system.

2.3.34 Final restoration levels will result in a waste depth of over 120m in the existing main quarry, whilst remaining over 55m below that of surrounding surface levels. As infilling progresses vertically, waters will infill the enhanced fracture networks close to the quarry faces and any interconnecting fractures, with water levels generally keeping pace with vertical filling rates. Due to the low rate of infiltration into the wastes deposits, the rate of groundwater rebound in the Diorite will result in an inward hydraulic head throughout the restoration works. Upon achieving final levels, long-term pumping will be necessary to manage groundwaters infiltration from the remaining exposures of the Diorite and Mercia Mudstone, together as surface water runoff. Consequently groundwaters levels within the Diorite and Mercia Mudstone will continue to be drawn down relative to pre-quarry levels within these aquifers.

2.4 Receptor

2.4.1 The Site is not located within a Source Protection Zone, however, the Environment Agency classifies the superficial deposits and Mercia Mudstone Group as a Secondary B Aquifers (permeable layers that can support local water supplies, and may form an important source of base flow to rivers) and a Secondary B Aquifer (a lower permeability layer which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering), respectively.

2.4.2 As previously mentioned, the proposed infill materials will be largely be contained within the South Leicestershire Diorite Complex together with a small exposure of the Mercia Mudstone Group long the eastern sidewall of the lateral extension area. These aquifers will be primary receptors to the quarry restoration activity.

2.4.3 Waters managed from the wastes and capped and restored surfaces will also be pumped and discharged to surface level for use in the processing of wastes and minerals, amenity management or the production of construction products (e.g. concrete and concrete products).

Compliance Points

2.4.4 In line with current EA guidance, the point of compliance for Hazardous Substances and Non-Hazardous Pollutants is the down-gradient boundary of the site relative to the direction of groundwater flow beneath the site within the vertical mixing depth.

Groundwater Quality

2.4.5 As previously indicated, prior to the installation of the groundwater monitoring boreholes around the periphery of Croft Quarry, no groundwater monitoring had been undertaken. As such groundwater quality data has been collected since November 2018 to establish baseline groundwater quality conditions. A statistical summary and full datasets of groundwater quality within the Diorite and Mercia Mudstone are presented in the ESSD (*Doc. Ref.: AI1009/07*).

2.4.6 Collection of groundwater samples from BH01 and BH02/A was not feasible as such groundwater quality analysis has been undertaken using the remaining six monitoring boreholes.

2.4.7 The statistical analysis of individual boreholes indicates that for a large number of the monitored determinands, no significant variations in recorded concentrations are observed. However, variation in recorded concentrations was noted in a small number of the recorded parameters, namely, chloride, molybdenum, nickel and sulphate. It was observed that BH02/B and BH03/C contained elevated concentrations of all these parameters relative to the other groundwater boreholes and that BH04/B contained elevated concentrations of chloride molybdenum and nickel. The proposals regarding why these elevated levels are observed are discussed further below.

2.4.8 In addition to analysing the geochemical profiles of each individual borehole, individual groundwater monitoring boreholes were grouped together depending on which of the two major lithologies surrounding the quarry void in which they are situated (i.e. Diorite or Mercia Mudstone). These summaries were created to allow for direct comparison between these two units and identify any differences in baseline geochemical composition. Upon comparison, the geochemical profiles for both units are broadly comparable with average concentrations for all determinands, however, a few exceptions are observed in chloride, molybdenum, nickel, and sulphate. In these instances, it was identified that concentrations within the Diorite were elevated compared to the levels recorded within the Mercia Mudstone, these elevated concentrations within the Diorite are attributed to the igneous origin of the lithology and the presence of low solubility metal compounds within the secondary mineralisation. It is proposed that a small proportion of these metal compounds are dissolved into the water where they dissociate into their constituent ions, hence increasing the concentration recorded in the Diorite relative to the Mercia Mudstone which contains a lower proportion of such compounds.

2.4.9 Additionally, the results indicate that there is no negative impact on the local groundwater quality from the historic Croft Landfill which is located to the southeast of the quarry void.

2.4.10 The statistical methodology utilised in analysing the recorded background groundwater quality is outlined in the Environment Agency Research and Development document "Techniques for the Interpretation of Landfill Monitoring Data Guidance Notes, Report No. P1-471"; Accordingly, the groundwater quality monitoring records were screened utilising the P1-471 outlier test methodology discussed in Section A.3 of Report No. P1-471 and the critical values (P=1%) for the statistical Tmax presented in Table A.1 of Report No. P1-471.

Environmental Assessment Levels

2.4.11 The setting of Environmental Assessment Levels (EALs) is necessary in order to assess whether the requirements of Schedule 22 to the Environmental Permitting Regulations 2016 are likely to be met.

2.4.12 As previously indicated, the development proposal for Croft Quarry seeks to infill the existing quarry void with selected non-degradable, non-hazardous materials or wastes.

2.4.13 To ensure that EALs representative to the Site are selected and that the subsequent Hydrogeological Risk Assessment provides a site assessment of groundwater pollution potential, the following selection criteria shall be employed.

2.4.14 For Hazardous Substances, the EALs shall be derived by comparing a monitored baseline concentration value for each of the Hazardous Substances identified as a "Priority Contaminant" in **Section 2.0** of this document and comparing this monitored baseline against Limit of Quantification (LoQ) values as defined in UKTAG (2016). Upon comparison, if the monitored baseline concentration is lower than the LoQ value the monitored baseline concentration will be selected as the EAL. If the monitored baseline concentration is higher than the relevant LoQ then the maximum statistically valid concentration will be selected as the EAL. Where LoQ values are not available, the appropriate laboratory limits of detection will be selected.

2.4.15 The derivation of EALs for Non-Hazardous Pollutants shall follow a similar process to that described for Hazardous Substance, however, instead of utilising LoQ values, the monitored baseline concentrations will be compared against the corresponding UK Drinking Water Standards (DWS) or the UK Environmental Quality Standards (EQS) for freshwaters. Additionally, in situations where the monitored baseline concentration is significantly below the corresponding DWS the EAL will be set at 25% or 50% above the maximum recorded baseline concentration.

2.4.16 Details of the EALs to be taken forward for consideration are presented in **Table HRA2**.

Table HRA2: Proposed Environmental Assessment Levels (mg/l)

Substance	Limit of Quantification	Laboratory Limits of Detection	DWS	Max. Baseline Concentration	Proposed EAL
Diorite					
Hazardous Substances					
Arsenic	0.005	0.0005	50	0.0039	0.005
Lead	0.0002	0.0002	-	0.00062	0.00062
Mercury	0.00001	0.00001	0.001	0.00003	0.00003
Non-Hazardous Pollutants					
Amm-N	-	0.04	0.39	N/A	0.1[d]
Cadmium	-	0.00008	0.005	<0.00008	0.00012[b]
Chloride	-	1	250	172	215[c]
Chromium	-	0.001	0.005	<0.001	0.0015[b]
Copper	-	0.0003	2	0.00565	0.0085[b]
Nickel	-	0.0004	0.02	0.00129	0.0019[b]
Sulphate	-	1	400	1,870	1,870
Zinc	-	0.001	5	0.0161	0.024[b]
Mercia Mudstone Group					
Hazardous Substances					
Arsenic	0.005	0.0005	-	0.0053	0.0053
Lead	0.0002	0.0002	-	0.00059	0.00059
Mercury	0.00001	0.00001	0.001	0.000022	0.000022
Non-Hazardous Pollutants					
Amm-N	-	0.04	0.39	N/A	0.1[c]
Cadmium	-	0.00008	0.005	<0.00008	0.00012[b]
Chloride	-	1	250	90	113[c]
Chromium	-	0.001	0.005	<0.001	0.0015[b]
Copper	-	0.0003	2	0.00648	0.0097[b]
Nickel	-	0.0004	0.02	0.000871	0.0013[b]
Sulphate	-	1	400	499	499
Zinc	-	0.001	5	0.0206	0.031[b]

[a] - applies to hazardous substances only
[b] - Maximum baseline concentration + 50%
[c] – maximum baseline concentration +25%
[d] – set at 25% of Drinking Water Standard

3.0 HYDROGEOLOGICAL RISK ASSESSMENT

3.1 Nature of the Hydrogeological Risk Assessment

3.1.1 In lieu of the sub-water table placement of the wastes directly with the aquifer at Croft Quarry a quantitative risk assessment has been carried out.

3.2 Assessment Scenarios

3.2.1 As a consequence of the infilling of the quarry void groundwater levels within the Diorite and Mercia Mudstone aquifers units will rebound. As the waste levels will be restricted to ~14-15mAOD within the central section of the quarry, extending to 17-18mAOD at the edges groundwater will continue to be prevented from rebounding to pre-quarrying levels, which based on evidence from other quarries located within the South Leicestershire Diorite Complex would typically close to surface level. Nonetheless, with the long-term management of water levels within the void required to be maintained at up to ~14mAOD, groundwater levels will be present at a higher elevation than potential in-waste water levels. This will maintain an inward hydraulic gradient throughout operational and post-completion phases of the development generating a hydraulic containment scenario where the potential movement of pollutants out of the waste will be via diffuse flux through the AEGB against the hydraulic gradient.

3.2.2 For hydraulic containment conditions to be lost in-waste water levels would be required to exceed that of groundwater levels within the surrounding strata. Given the anticipated final rebound level being over 50m above final wastes such the advective transfer of leachate from the waste mass will not occur.

3.3 Priority Contaminants

3.3.1 Based on the leachate source term and risk factors present in Table HRA1 the following priority contaminants have been selected for assessment:-

- Hazardous Substances
  - *Arsenic*
  - *Lead*
- Non-Hazardous Pollutants
  - *Ammoniacal Nitrogen*
  - *Cadmium*
  - *Chloride*
  - *Sulphate*

3.4 Review of Technical Precautions

Capping

3.4.1 To maintain separation between the waste deposits and final restoration soils and waters within the wetland habitats, a 500mm capping system will be engineered to achieve maximum permeability of $1x10^{-8}$m/s. The cap will be subsequently covered with up to 1m of restoration soils.

Basal and Sidewall Lining Systems

3.4.2 In accordance with the requirements of Schedule 22 to the EPR2016, to prevent the potential for any direct discharges of hazardous substances to groundwater and limit the potential discharge of non-hazardous substances to groundwater within the Diorite base and sidewalls of the quarry will be lined with a Artificially

Established Geological Barrier (AEGB) comprising suitable clay materials. The basal lining system will be engineered to a minimum thickness of 500mm and maximum permeability of $1x10^{-8}$ m/s.

3.4.3 Due to the near vertical gradients of the quarry sidewalls, the minimum thickness of the AEGB will be increased to 1m, whilst still achieving a maximum permeability of $1x10^{-8}$ m/s. The sidewall AEGB will also be constructed 2m high incremental lifted, buttressed internally by wastes to maintain stability. The buttress materials height will also be maintained ~1m below the top of each AEGB lift to form a rock trap, which will also redirect groundwaters and surface waters to a collection point for subsequent pumping to surface level.

Water Management

3.4.4 Surface waters and groundwaters seepages through the Diorite and higher faces of the Mercia Mudstone are currently managed by collection in the base of the quarry void and pumping to the surface for initial treated (settlement) ahead of use for the production of mineral and associated products, amenity management practices or discharge to the River Soar.

3.4.5 During infilling operations groundwaters will be continue to seep in through the sidewalls above the top of the AEGB being constructed along the sidewalls. These waters will be directed via graded channels to temporary holding lagoon formed in the waste surfaces prior to pumping to the surface for use or discharge.

3.4.6 There will no management of in-waste waters.

3.5 Numerical Modelling

Justification for Modelling Approach and Software

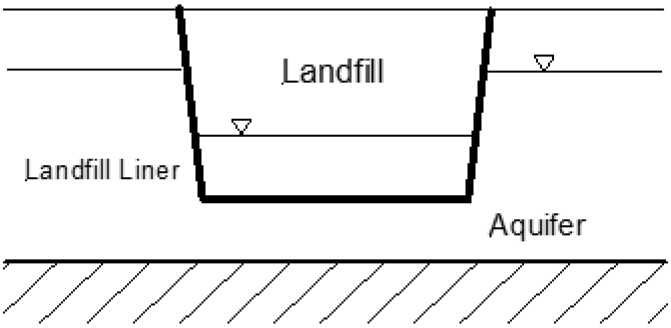
3.5.1 As assessment of the risk from the diffusive flux of potential contamination through the AEGB has been performed using the Environment Agency spreadsheet tool “Contaminant Fluxes from Hydraulic Containment Landfills Worksheet Version 1.0”.

3.5.2 The spreadsheet tool was devised by the Environment Agency to support groundwater risk assessment performed for existing and proposed landfill sites operated in settings where there is hydraulic containment and to help indicate whether a landfill can be engineered to comply with current regulatory regimes. This model can also be used to asses the risk posed to similar facilities involving the permanent deposit of waste below the wate table.

3.5.3 The Hydraulic Containment Model is a steady-state model, which calculates the diffusion of contaminants through a geological strata or liner that does not take leachate depletion into account. Therefore, unlike models such as LandSim, the effects of the source depletion as contaminants are removed, such as by abstraction, are not considered within the model conclusions and any conclusions drawn are therefore conservative with regards to the intermediate and long term.

3.5.4 Based on wastes being deposited in lined void in a permeable formation above a finite distance above the base of the aquifer, water and contaminative fluxes can occur through the base and sides of the quarry. on this conceptualisation, the Hydraulic Containment Model Scenario 2 would be the appropriate scenario for the site. This model scenario is conceptualised in Figure HRA1.

Figure HRA1: Hydraulically Contained Landfill – Scenario 2



Model Parameterisation

3.5.5 The model parameters and justifications for the values selected as presented in spreadsheet model files presented in **Appendix HRA1.**

3.5.6 The model uses single input parameters and assumes a constant source concentration; therefore the model has been run for a fixed period of 20,000years.

3.5.7 The models have also been run in 'List I' mode for all substances which predicts the concentration at the outer edge of the AEGB.

Accidents and their Consequences

3.5.8 Details of accidental occurrences at the site that could present a potential risk to groundwater adjacent to the site are provided in **Table HRA3**.

Table HRA3: Accident Risk Assessment

Hazard	Risk to Groundwater	Likelihood	Mitigation and Corrective Measures
Deposition of hazardous wastes	Generation of leachate containing Hazardous Substances and Non-Hazardous Pollutants	**Low** – due to the essential and technical precautions	Appropriate characterisation of wastes prior to delivery to the site will be provided by the customer, with the appropriate verification checks/tests performed wastes by the operator. Any incorrectly accepted wastes will be immediately returned to the customer or moved to a suitable storage area prior to removal to a suitable site.
Spillage of fuels from storage tanks or vehicles	Release of hydrocarbons (Hazardous Substances) into the ground and migration into groundwater	**Low** – fuel stores will be bunded in accordance with regulation requirements. A traffic management system and speed limit will be imposed at the site to reduce both the risk of accidents and the likelihood of spillage occurring.	Any spillage will be cleaned up immediately and any resulting contaminated soils removed to a suitable installation.

1.1.1 With respect to the deposition of potentially contaminated wastes, it is considered that the risks and potential consequences of such accidents are extremely low for the following reasons:

- all waste deliveries will be pre-arranged and come from known sources to ensure no contaminated material is delivered;
- if deemed necessary, characterisation testing will be undertaken to demonstrate that the waste will not give rise to polluting leachate, prior to the acceptance of waste at the site;
- if deemed necessary compliance testing will be undertaken to ensure the continued acceptability of the waste stream;
- visual inspection will be undertaken of every waste load deposited at the site; and
- in the event of suspicion regarding the acceptability of the waste, quarantine procedures will be enforced.

1.1.2 In the unlikely event of contaminants from a rogue load being deposited at the site, attenuation processes will occur within the waste body, and most organic Hazardous Substances are very likely to be degraded and/or retarded during migration through the surrounding wastes within the quarry void.

1.1.3 Other processes such as volatilisation can also be expected for volatile and semi-volatile organic substances resulting in a loss of contaminant from the waste.

3.6 Emissions to Groundwater

3.6.1 The results of the diffusive flux calculations for Croft Quarry are presented in **Table HRA4**. The result indicate that their will be no discernible breakthrough of hazardous Substances and Non-Hazardous Pollutants through the

Table HRA4: Summary of results of contaminant fluxes from Croft Quarry as modelled at the edge of the liner/AEGB

Priority Contaminant	EAL	Peak Concentration at Edge of AEGB (mg/l)
Hazardous Substances		
Arsenic	0.005	No discernible break through
Lead	0.00012	No discernible break through
Non-Hazardous Pollutants		
Ammoniacal Nitrogen	0.1	No discernible break through
Cadmium	0.00012	No discernible break through
Chloride	215	No discernible break through

4.0 REQUISITE SURVEILLANCE

4.1 In-Waste Monitoring

1.1.4 No in-waste monitoring is proposed to be carried out. Stringent Waste Acceptance Procedures (Doc. Ref.: AI1009/13) have bene developed to ensure that waste deposits will be non-degradable and non-hazardous in nature.

4.2 Groundwater Monitoring

1.1.5 The groundwater monitoring schedule during the operational phase of the infilling activities of Croft Quarry presented in **Table HRA5**. The location of the proposed groundwater monitoring points for Croft Quarry are presented in **Drawing No.: AI1009/14/05**.

Table HRA5: Groundwater Monitoring Schedule

Monitoring Point Reference	Parameter	Monitoring Frequency	Monitoring Standard or Method
BH03/B and BH04/B, and any replacement monitoring boreholes	Water Level, pH, Electrical Conductivity, ammoniacal nitrogen, arsenic, cadmium, chloride and lead	Quarterly	As specified in Environment Agency Guidance LFTGN02 'Monitoring of Landfill Leachate, Groundwater and Surface Water' (February 2003), risk assessments for your environmental permit (www.gov.uk) or such other subsequent guidance as may be agrees in writing with the Environment Agency
	As above, and: Alkalinity, chromium, copper, mercury, nickel, antimony, calcium, iron, magnesium, manganese, potassium, selenium, sodium, sulphate, zinc, base of Monitoring Point (mAOD)	Annually	
	Benzene, Toluene, Ethyl Benzene, Xylene, Polycyclic Aromatic Hydrocarbons (PAH)	Annually for the first six years then every two years	PAH analysis must include all the substances listed in EPR 2016, schedule 10, paragraph 2(d)

[a] *- all metal and metalloids parameters to be based on the dissolved fractions*

4.2.1 Groundwater compliance limits for boreholes installed in the Diorite are presented in **Table HRA6.** As groundwater levels throughout the active and post-completion phase of the quarry restoration scheme will be permanent drawn down relative to pre-quarry development levels. Groundwaters will therefore continue flow into the quarry through the exposed sidewalls for the foreseeable future. The likelihood of any contaminants migrating away from the quarry is negligible. Consequently, it is not proposed to install additional groundwater monitoring boreholes to supplement the existing infrastructure.

Table HRA6: Groundwater Compliance Limits

Parameter	Monitoring Point Ref.	Limit (mg/l)
Ammoniacal Nitrogen (as N)	BH02/B	TBC[a]
	BH03/C	
	BH04/B	
Arsenic	BH02/B	0.005[b]
	BH03/C	0.005[b]
	BH04/B	0.0089[c]

Parameter	Monitoring Point Ref.	Limit (mg/l)
Cadmium	BH02/B	0.00012[d]
	BH03/C	0.00023[c]
	BH04/B	0.00012[d]
Chloride	BH02/B	215[e]
	BH03/C	92[e]
	BH04/B	42[e]

[a] – suitable period of baseline monitoring to be carried out
[b] – Limit of Quantification (UKTAG, 2016)
[c] – 2 standard deviations above the mean recorded baseline concentration
[d] – 50% above Limit of Detection
[e] – 25% above maximum baseline concentration

4.3 Surface Water Monitoring

1.1.8 During the operational phase of the infilling activities waters managed with the quarry void will be frequently sampled and monitored within the managed ponds formed on the waste surface. Monitoring will also be undertaken on waters discharged from Croft Quarry via the exiting consented discharge points (Ref.: T/50/08259/T and Ref.: T/50/45029/T). This monitoring will entail monthly or annual chemical analysis of selected parameters and visual inspections for hydrocarbon contamination.

4.3.1 The proposed surface water monitoring schedule for Croft Quarry is presented in **Table HRA7.**

Table HRA7: Surface Water Monitoring Schedule

Monitoring Point Reference	Parameter	Monitoring Frequency
Lagoons 1 & 2	Ammoniacal Nitrogen, chloride, sulphate, Electrical Conductivity, Visual Oil and Grease, pH	Monthly
	As above plus: Arsenic, cadmium, calcium, lead, DOC, chromium (III & IV), copper, nickel, PAHs, BTEX compounds	Annually
SW1 (Discharge Consent Ref.: T/50/08259/T) & SW2 (Discharge Consent Ref.: T/50/45029)	Ammoniacal nitrogen, chloride, sulphate, Electrical Conductivity, Visual Oil and Grease, pH, Flow Rate	Monthly
	Arsenic, cadmium, calcium, lead, DOC, chromium (III & IV), copper, nickel, PAHs, BTEX compounds	Annually

4.3.2 A H1 screening assessment is included in **Appendix HRA2**. This considers the risk to the fluvial environment of the River Soar from the discharge of waters managed within the quarry void during active infilling and post-completion. The quality of the discharge parameters have been conservatively set at the maximum potential leachable concentrations presented in **Table HRA1.** The results illustrate that there is sufficient dilution available within the River Soar taking into account the potential maximum source term concentrations of the wastes and current discharge consent limits.

5.0 CONCLUSIONS

5.1 Compliance with the Schedule 22 of the EPR2016

1.1.9 The results of this risk assessment have established that the proposed permanent deposit of waste will comply with the relevant requirements of the Groundwater Regulations 2009 as follows:

- the waste recovery operation poses a potential hazard to ground and surface water quality. Consequently, it falls within the scope of the Schedule 22 of the EPR2016;
- this assessment forms a review of the "prior investigation" that must be carried out for this type of development;
- the proposed technical precautions are considered appropriate and reasonable to avoid the entry of Hazardous Substances into groundwater throughout the lifecycle of the facility
- the proposed technical precautions will limit the introduction of Non-hazardous Pollutants into groundwater to avoid pollution throughout the lifecycle of the facility; and
- groundwater and surface water monitoring schedules have been derived in accordance with the requisite surveillance requirements of Schedule 22 to the EPR2016.

6.0 REFERENCES

Environment Agency (2003). *Guidance on the Monitoring of Landfill Leachate, Groundwater, and Surface Water*. Doc. Ref.: LFTGN02.

UKTAG (2016). *Technical Report on Groundwater Hazardous Substances*

APPENDIX HRA1
Hydraulic Containment Model Files

(Refer to Electronic Spreadsheets Refs: AI1009_08_A1a to e)

APPENDIX HRA2
H1 Database (Surface Water Discharge Screening Assessment *[File Ref: AI1009_08_A2.R0]*)