Two Oaks Quarry: Stability Risk Assessment

Prepared for Mansfield Sand Company Ltd

April 2024

CONFIDENTIAL

Midlands Office
The Bank Chambers
39 Market Place
Melbourne
Derbyshire
DE73 8DS

Tel: 01332 871 882
E mail: info@envireauwater.co.uk
Web: www.envireauwater.co.uk

Quality Control Sheet

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Client	Mansfield Sand Company Ltd
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Authors

	Name	Signed
Prepared by	Chris Woodhouse	
Checked by	Phil Ham	
Approved by	Phil Ham	

Revision History

Revision	Details	Prepared by	Checked by	Approved by	Issue Date
REV01	Draft for comment	CDW	PH		05/03/2024
REV02	Revised draft for comment	CDW	PH	PH	26/03/2024
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1 INTRODUCTION

1.1 Background

Mansfield Sand Company Ltd (Mansfield Sand) has planning permission (ref: 4/2010/0178) to extract silica sand and gravel (referred to as silica sand) in four phases at Two Oaks Quarry (the Site) near Mansfield, Nottinghamshire. Phase 1 workings began in 2015, and it has been divided into 11 units/lagoons, some of which will be restored to agricultural land and heathland using inert and non-hazardous waste restoration materials.

Mansfield Sand proposes to carry out the backfilling and Site restoration under the terms of a Deposit for Recovery Environmental Permit within Phase 1 only. In summary, Lagoons 7, 8, 9 and 10 (see Waste Recovery Boundary in Figure 1) are proposed to be restored to no more than original ground levels by using Site-derived soils/soil forming materials (1,474,362 tonnes silt and 11,600 tonnes of sand) and importing inert and suitable non-hazardous (i.e. chemically inert) restoration materials. Mansfield Sand estimates that up to 296,000 tonnes of imported material will be needed to complete the Site restoration requirements. A Planning Application (ref: LT/2023/128154/01-L01) has been submitted to Nottinghamshire County Council (NCC) for the proposed recovery activity.

Mansfield Sand has engaged Envireau Water to prepare a qualitative Stability Risk Assessment (SRA) to support the Environmental Permit application (this report). Details on the Site setting including geological, hydrogeological, Site monitoring data and the proposed development is detailed in the Environmental Site Setting and Design (ESSD) report (Envireau Water, 2024a). This report should be read in conjunction with the ESSD.

The application for the Environmental Permit is being made by Envireau Water on behalf of Mansfield Sand. This SRA will form part of this application supported by relevant documentation. This SRA follows the principles outlined in Environment Agency technical guidance (Environment Agency, 2023). Details of the components considered in this SRA will be presented in Construction Quality Assurance (CQA) reports that will be submitted to the Environment Agency for approval before any construction commences.

1.2 Scope of Work

The SRA has been prepared to assess the stability and geotechnical risks associated with the proposed restoration at the Site and includes the following:

- Details of the components comprising the Site stability conceptual model (Section 2);
- A stability risk assessment considering each component of the conceptual model (Section 3); and
- A summary of the report findings (Section 4).

1.3 Data Sources

The information and assessments in this report are based on:

- Proposed development and restoration plans provided by Mansfield Sand;
- Geological data provided by Mansfield Sand and from the British Geological Survey (BGS) mapping;
- Ordnance Survey mapping; and
- Site visits undertaken by Envireau Water.

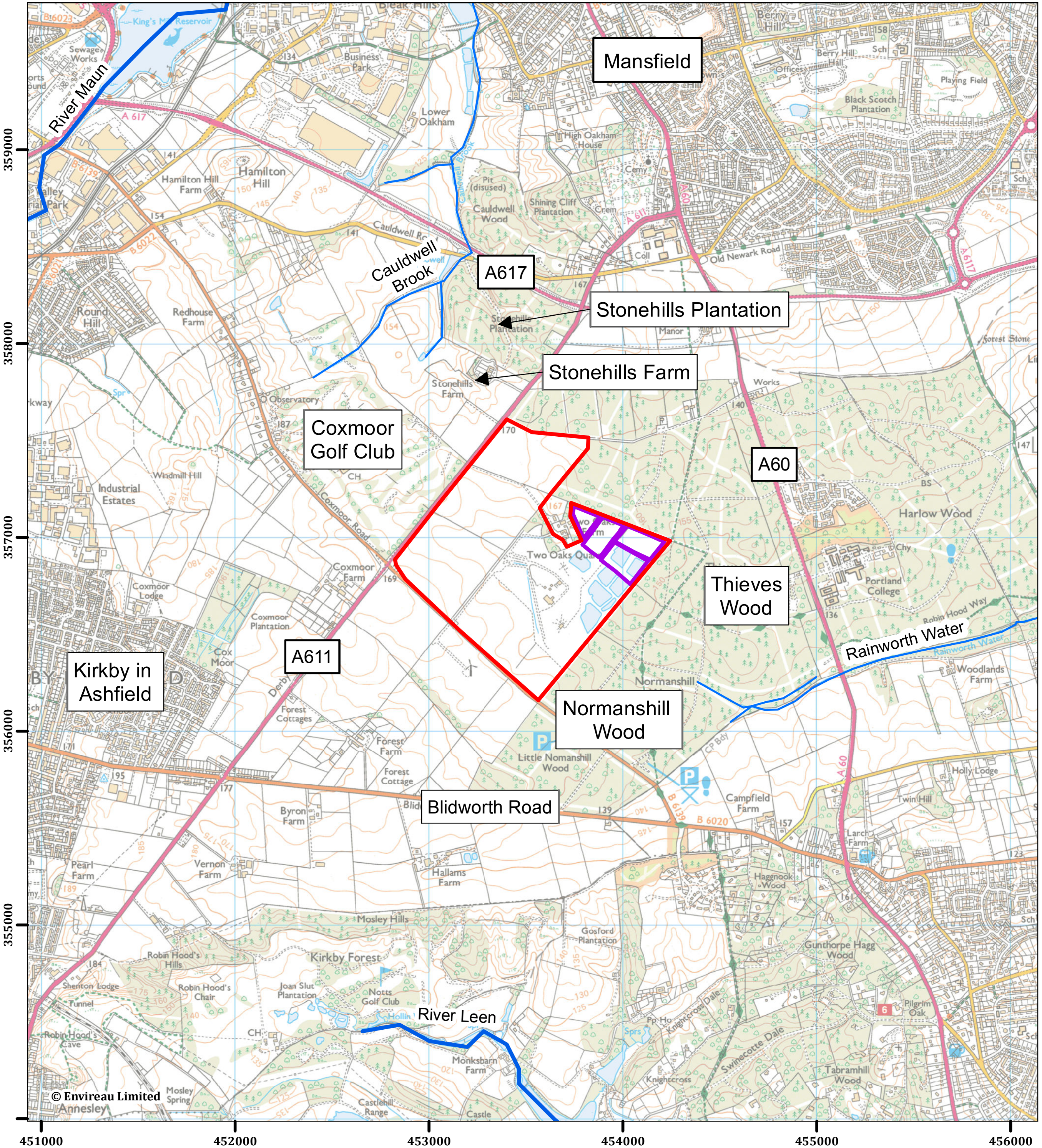

Figure 1: Site Location and Setting

Mansfield, Nottinghamshire

Site Boundary

Waste Recovery Boundary

Notes:

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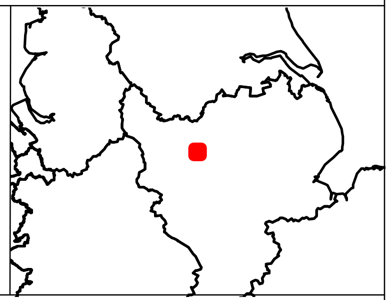


0 250 500 750 1,000 Meters

Scale: 1:30,000 at A4

22 March 2024

NGR: 453,536 E / 356,874 N

Project No. 3490476

Client: Mansfield Sand Company Ltd

Drawn by: JH

Ref: FIG Site Location

envireau WATER

2 STABILITY SITE CONCEPTUAL MODEL

2.1 Overview

Information derived from the ESSD has informed the development of the Stability Site Conceptual Site Model (SSCSM) which is set out in the following sections. The Site Setting is presented on Figure 1. Figure 2 shows a cross section through the restored lagoon system.

Mansfield Sand has successfully restored some lagoons at the Site for agricultural use, using wholly Site-derived silt and sand. This experience will be applied to the waste to recovery restoration, which will be carried out as follows:

- The bottom 8 m of the lagoon will be filled with Site-derived soils/soil forming materials (settled silt and sand) the top ~5m of which will be above the water table. Experience shows that the materials compact and become effectively incompressible under their own weight, forming a basal barrier; however, the top 1m is likely to remain compressible. This compressible material will be displaced as waste is imported to form a sidewall attenuation layer and restore the remaining void. The restoration material and attenuation layer will be deposited above the water table.
- A sidewall attenuation layer will be engineered using imported (inert, cohesive) waste along the interface between the in-situ, unworked Chester Formation, and the restoration material.
- Imported (inert, cohesive) waste will then be deposited in the remaining ~3.5m deep void and mechanically compacted. The void will be filled progressively, working from one side to the other. This method will displace the compressible material at the top of the basal layer, which is then be extracted once the void is sufficiently filled and compacted.

2.2 Basal sub-grade

The natural base of the lagoon will be the Chester Formation. The lagoon will be formed by the extraction of the in-situ overburden and silica sand mineral deposits.

2.3 Basal Barrier

The Site is underlain by the Chester Formation sandstone which is the mineral being worked at the Site. In the lagoons which are to be filled, the Chester Formation will be removed through quarrying and the lagoons will be partly backfilled by 8 m of silt which will settle out of suspension from wastewater discharged from the mineral processing operation. The settled silt will form the basal barrier to the restoration material. The upper 3.5 m of the basal barrier will be above the water table and no groundwater dewatering will be required during restoration. Prior to the deposition of restoration material and formation of the attenuation layer, the basal settled silt will be compacted using tracked machinery or similar. The basal barrier will be subject to CQA validation of its integrity and permeability prior to restoration materials being deposited.

2.4 Side slope sub-grade

The side slope will be formed by the extraction of the in-situ overburden and silica sand mineral deposits. Side slopes will be formed through quarrying at approximately 55°, which is appropriate for a self-supporting, hard rock subgrade.

2.5 Sidewall Attenuation Layer

A sidewall attenuation layer will be constructed from selected low permeability inert restoration materials (RSK Geosciences, 2024). Restoration material deposited to construct the sidewall attenuation layer will be deposited (and compacted) above the water table. To ensure the attenuation layer remains self-supporting, the slope will be engineered at gradient of 1:2 (or ~26 degrees), resulting in the width towards the base of the attenuation layer being a much greater thickness than that at the top of the attenuation layer.

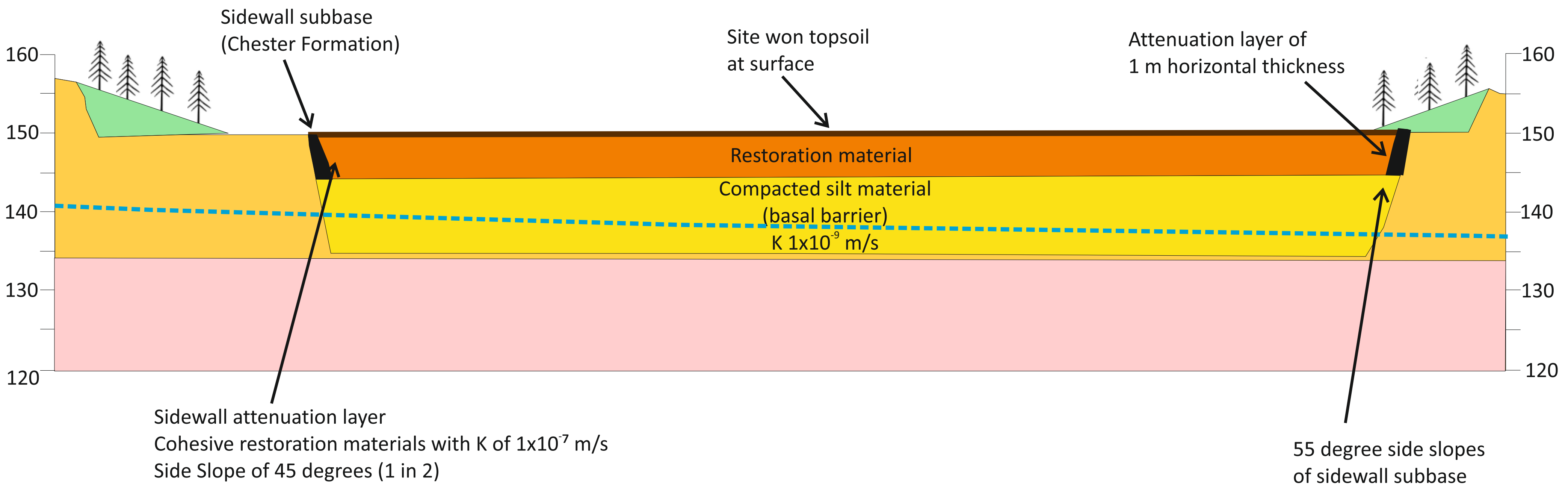
There is no specific guidance for engineering a sidewall attenuation layer as part of a deposit for recovery activity. Therefore, the sidewall attenuation layer will be engineered in accordance with Annex I of the Landfill Directive (1999) for an inert waste landfill. Placement and compaction of the sidewall attenuation layer will therefore aim to achieve a permeability of no more than 1×10^{-7} m/s with a minimum thickness of 1 m. This is also consistent with the requirements of the attenuation layer as modelled by the HRA (Envireau Water, 2024b). Construction Quality Assurance (CQA) of the attenuation layer will be applied to validate that these minimum criteria are achieved. Since the attenuation layer will be engineered using imported waste, CQA Supervision will be carried out during construction in accordance with regulatory guidance (Environment Agency, 2023). No further restoration material will be emplaced until the attenuation layer has met these requirements.

2.6 Restoration Material Mass

The restoration material will comprise construction inert waste. This will be predominantly cohesive clays but may include some demolition waste, wastes from extractive industries and other suitable wastes as set out in the waste acceptance procedures document (RSK Geosciences, 2024).

2.7 Capping and Restoration System

Due to the nature of the restoration material to be placed at the Site, no formal capping system is required or proposed. In-situ subsoil and topsoil will be stripped, stored, and used elsewhere on-Site. The lagoons to be filled The top 300 mm of fill will be restored using site-won sand material and restored to heathland.



Not to Scale

Figure 2: Cross Section of Restored Lagoon

Orange	Restoration material
Yellow	Silt material
Light orange	Chester Formation (Sherwood Sandstone)
Pink	Lenton Sandstone Formation (Sherwood Sandstone)
Blue dashed line	Maximum groundwater elevation (mAOD)

Date:	06 March 2024
Project No.	3490476
Client:	Mansfield Sand
Ref:	FIG Restored Lagoon
Drawn by:	SS

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3 STABILITY RISK ASSESSMENT

3.1 Risk Screening

3.1.1 Overview

Each of the six components of the stability SSCSM have been considered and risk assessed. Potential risks relating to stability and integrity of each component have been assessed to determine whether further geotechnical stability analysis is required. The SRA is presented below.

3.1.2 Basal Barrier

Settled silt will form the basal barrier. Table 1 presents a screening assessment of the basal barrier against each aspect of stability and deformability in accordance with Section 3.3.1 of Dixon & Jones (2003). Based on the preliminary screening set out in Table 1, the basal barrier does not require further consideration or assessment.

Table 1 Basal barrier stability components

Category	Stability Component	Assessment
Excessive Deformation	Compression	The settled silt will be compact prior to restoration material being deposited in the lagoon and will, therefore, form a solid, largely incompressible base. The top ~1m is compressible and will be removed through the restoration (filling) method. As such, there will be no deformation of the compacted basal layer and this component does not require further consideration.
	Basal heave	The basal layer of the lagoons will lie above the natural water table and, in this hydrogeological setting, there is no plausible mechanism by which heave of the settled silt could occur. Therefore, this component does not require further consideration.
	Cavities in the barrier	Settled silt is not capable of supporting cavities and in the unlikely event that any cavities are present, these will be removed through the compaction process.
Filling on Waste		The settled silt is site-derived and is not waste material.

3.1.3 Side Slope Sub-Grade

The basal sub-grade of the side slopes will be formed by in-situ overburden (subsoil and topsoils) and silica sand mineral of the Chester Formation. The Chester Formation is competent sandstone bedrock and experience with the other quarry voids on-site demonstrates that slopes at angles of 55° are stable and not at risk of failure. Table 2 presents a screening assessment of side slope subgrade stability and deformability as detailed in Section 3.3.1 of Dixon & Jones (2003). Based on the preliminary screening set out in, the side slope sub-grade does not require further consideration or assessment.

Table 2 Side Slope sub-grade stability components

Stability Component	Assessment
Stability	With the exception of relatively thin subsoil and topsoil, the side slope sub-grade will be formed by quarrying of the Chester Formation. The side slope subbase will be extracted at a gradient of 55°. This is appropriate for the geological strata at the Site (Mansfield Sand, 2024) and allows for an appropriate factor of safety (Mansfield Sand, 2022) and is consistent with regulatory guidance (Dixon & Jones, 2003). Therefore, this component does not require further consideration.
Deformability	The side slope sub-grade of the Chester Formation is effectively incompressible, and as such this component does not require further consideration.
Groundwater	The lagoon above the settled silt will be formed entirely within the unsaturated zone. Therefore, this component does not require further consideration.
Fill Slope	Refer to Table 3

3.1.4 Sidewall Attenuation Layer

The side slope attenuation layer system will be formed by the placement of imported cohesive restoration materials to achieve a layer of no less than 1 m in thickness and permeability no less than 1×10^{-7} m/s.

Table 3 presents the side slope geological barrier stability and integrity screening analysis, which has been considered in accordance with Section 3.3.1 of Dixon & Jones (2003). Based on the preliminary screening set out in Table 3, the side slope sub-grade does not require further consideration or assessment.

Table 3 Sidewall attenuation layer stability/integrity components

Timing	Stability Component	Assessment
During Construction	Waste - Stability	The side slope attenuation layer will be formed by imported inert cohesive materials which will achieve a FoS >1.3 with slope gradients of less than 1 in 2 in each lagoon in-line with prevailing guidance Dixon & Jones (2003). FoS values of this magnitude are obtained by following best practice and industry guidance for the minerals and waste sector and as such, long-term stability will be assured. Accordingly, this component does not require further consideration.
	Waste – Integrity	The sidewall attenuation layer will be formed using inert cohesive restoration materials, which are considered to be effectively incompressible under the limited stresses imposed by the proposed mass of restoration material. The HRA shows that heads in the restoration material are likely to reach the ground surface (Envireau Water, 2024b). This additional pressure will further ensure the long-term integrity of the attenuation layer. As such, this component does not require further consideration.
Following restoration material placement	Mineral - stability	The sidewall attenuation layer will be permanently subject to the pressure of the emplaced mass of restoration material which will wholly comprise cohesive waste types. This pressure will ensure stability of the attenuation layer and will ensure that this component does not require further consideration.
	Mineral - integrity	The sidewall attenuation layer will be formed using inert cohesive restoration materials, which will be effectively incompressible under the stresses imposed by overlying

Timing	Stability Component	Assessment
		saturated restoration material. There is no risk of basal heave as the underlying strata will be unsaturated. As such this component does not require further consideration.

3.1.5 Restoration Material Mass

The restoration material that will be deposited will largely be homogeneous, comprising predominantly low permeability cohesive soils.

Table 4 presents the restoration material stability and integrity screening analysis, which has been considered in accordance with Section 3.3.1 of Dixon & Jones (2003). Based on the preliminary screening set out in Table 4, the restoration material does not require further consideration or assessment.

Table 4 Restoration material mass stability/integrity components

Mechanism	Stability Component	Assessment
Failure within the restoration material - stability	Stability	Restoration material will be compacted by tracking of Site plant to an engineering specification. Due to the cohesive nature of the imported restoration material, it is anticipated that temporary waste faces will be able to exist at a natural angle of repose, likely 1 in 2. Exposed slopes will be maintained in each operational phase with a slope angle no steeper than 1 in 2. For cohesive, unsaturated material being deposited above the water table) this should readily achieve a FOS of at least 1.3 to 1.5. Dixon & Jones (2003) considers factors of this magnitude are obtained by following good-practice and industry guidance for the minerals and waste sector and as such, general case long-term stability should be assured. The restoration material will be emplaced dry (above the water table). Therefore, there is no risk of pore fluid pressures reducing the stability of any temporary faces. As such this component does not require further consideration.
Failure involving geological barrier and waste	Mineral - stability	The assessment for the scenario set out in Table 3 is considered equally applicable to the restoration material and, accordingly, this component does not require further consideration.
	Mineral - integrity	

3.1.6 In-waste Infrastructure

As the restoration material to be deposited at the Site will be chemically inert and controlled by strict waste acceptance procedures, leachate will not be generated within the waste mass. This has been further assessed through the HRA which accompanies the Permit application. In-waste leachate monitoring or collection is, therefore, not required.

Similarly, landfill gas will not be generated as discussed in the accompanying ESSD. As such in-waste gas extraction infrastructure will not be required.

Any monitoring infrastructure (i.e. boreholes) which are installed at the Site, including existing infrastructure will be monitored and managed in accordance with the accompanying Site Monitoring Plan (Envireau Water, 2024c).

3.1.7 Capping System Screening

There is no formal capping system required for deposit for recovery activities.

The restoration material will be chemically inert and, therefore, settlement due to biodegradation of organic material will not occur. Prior to deposition, any oversized material will be removed from the restoration material to ensure homogeneity of the restoration material mass, lack of cavities and ensure a low risk of compressibility and therefore long term settlement.

In light of the above, each aspect of capping system stability defined in Section 3.3.6 Dixon & Jones (2003) has been considered and it is therefore considered that stability of the capping system does not require further consideration or assessment.

3.2 Lifecycle Phases

As detailed in the accompanying ESSD, lagoons will be progressively restored through filling over the 15 year lifespan of the quarry.

The infilling of the lagoon with chemically inert restoration material will be undertaken in layers of typically 0.25 m thickness before compaction by tracking of Site plant to an engineering specification. All works will be undertaken in accordance with a CQA plan to be submitted to the Environment Agency for approval before any construction commences.

Daily monitoring of all exposed slopes will be maintained to allow appropriate remedial action to be taken if necessary.

3.3 Monitoring

Based on the assessments and screening provided in this SRA, a simple risk-based monitoring scheme is considered appropriate as summarised in Table 5.

Table 5 Proposed monitoring measures

Component	Monitoring
Basal barrier	CQA Validation to ensure that the basal settled silt is geotechnically sound and suitable for accepting restoration material. No deposition of restoration material to be carried out until the CQA validation is completed.
Side Slope subgrade	Exposed faces within the lagoons will be inspected on a daily basis for any signs of failure. Appropriate remedial action will be taken if evident.
Side Slope attenuation layer	Construction will be carried out in-line with CQA requirements
Restoration material mass	CQA supervision will be carried out in accordance with regulatory guidance. Exposed faces within will be inspected on a daily basis for any signs of failure. Appropriate remedial action will be taken if evident.

Component	Monitoring
Capping monitoring	None proposed. As detailed in the ESSD, the Site will be returned to heathland and subject to an aftercare programme to ensure the Site meets the requirements of the approved planning consent and restoration scheme.
Groundwater monitoring	A groundwater monitoring network is in place. Routine water level monitoring and sampling will be carried out in accordance with the final permit.

4 SUMMARY

This SRA has provided a preliminary assessment of the six principal components of the stability Site conceptual model in accordance with Environment Agency guidance (Dixon & Jones, 2003). The Site will be operated by an experienced operator experienced with working with the Chester Formation strata at the Site and restoration using site won materials. Monitoring will be carried out during the Site operation, including CQA validation and supervision in accordance with regulatory guidance. Based on the preliminary screening, the restoration material does not require further consideration and a quantitative assessment is not required.

REFERENCES

Dixon N and Jones DRV. *Stability of Landfill Lining Systems: Report No. 2 Guidance. Environment Agency R&D Technical Report P1-385/TR2.*

Dixon, N., & Jones, D. (2003). *Stability of Landfill Lining Systems: Report No. 2 Guidance R&D Technical Report P1-385/TR2.* Bristol: Environment Agency.

Envireau Water. (2024a). *Two Oaks Quarry: Environmental Site Setting and Design.*

Envireau Water. (2024b). *Two Oaks Quarry: Hydrogeological Risk Assessment.*

Envireau Water. (2024c). *Two Oaks Quarry: Site Monitoring Plan.*

Environment Agency. (2023, June 29). *Engineering construction proposals for deposit for recovery*. Retrieved from GOV.UK: https://www.gov.uk/government/publications/deposit-for-recovery-operators-environmental-permits/engineering-construction-proposals-for-deposit-for-recovery#construction-quality-assurance-supervision

Environment Agency. (2023). *Stability of Landfill Lining Systems: Report No. 2 Guidance. R&D Technical Report P1-385/TR2.*

Mansfield Sand. (2022). *Two Oaks Quarry Geotechnical Assessment.* Mansfield: Mansfield Sand.

Mansfield Sand. (2024). *Excavation Rules in Pursuance of Regulation 31, Quarries Regulations 1999.* Mansfield: Mansfield Sand.

RSK Geosciences. (2024). *Two Oaks Quarry: Waste Acceptance Procedures.*