TARMAC Trading Ltd

Wasing Quarry, Wasing Lane, Aldermaston, Reading, RG7 4LY

Stability Risk Assessment

Project no. 11655 - R04 (04)

RSK GEOSCIENCES

MAY 2023

RSK GENERAL NOTES

Project No.: 11655-R04 (03)

Title: Stability Risk Assessment: Wasing Quarry, Wasing Lane, Aldermaston, Reading, RG7 4LY

Client: Tarmac Trading Ltd

Date: May 2023

Office: RSK Environment Limited, 18 Frogmore Road, Hemel Hempstead, HP3 9RT

Status: Final

Author	G Sinnathamby/ Andrea Grossey	**Technical reviewer**	T Navaneethan/ Jon Bailey
Signature		Signature	
Project manager	Andrea Grossey	**Quality reviewer**	Helen Bailey
Signature		Signature	

Revision control sheet				
Revision ref.	**Date**	**Reason for revision**	**Amended by:**	**Approved by:**
Rev 00	29/03/2023	First issue	n/a	see above
Rev 01	13/04/2023	Client comments		see above
Rev 02	26/05/2023	Client comments		see above
Rev 03	30/05/2023	Client comments	Jon Bailey	see above
Rev 04	30/05/2023	Client comments	Jon Bailey	see above

CONTENTS

FIGURES

APPENDICES

1 INTRODUCTION

RSK Environment Limited (RSK) was commissioned by Tarmac Trading Ltd (the ‘Client’) to produce a Stability Risk Assessment (SRA) for the land at Wasing Quarry off Wasing Lane, Aldermaston in Reading, hereafter referred to as the ‘Site’.

This SRA has been produced to form a package of supporting documentation for the application for a Bespoke Environmental Waste Recovery Permit for the Wasing Quarry site, which will be used for the importation of waste materials to restore the land following mineral extraction.

1.1 Background

Land at Wasing Quarry has been considered suitable for the extraction of sand and gravel deposits to meet commercial demand for sand and gravel mineral within the Kennet Valley.

Planning has been approved for the site by West Berkshire Council (in August 2013), which extends to 70 hectares (of which c.50 hectares will be excavated and restored) and includes ancillary buildings located in the east of the Site.

Proposals will comprise the excavation and removal of the sand and gravel across three Phase areas (‘A’, ‘B’ and ‘C’), with timescales for the working of each phase estimated between 3 to 5 years on a progressive basis.

Restoration of the Site will commence with the importation of inert materials following extraction within Phase A, to eventually return the majority of the area back to farmland with some water bodies, contributing to biodiversity and flood storage capacity within the valley.

Planning conditions require that extraction of minerals shall cease no later than the 13 years from the date upon which operations commenced and that the deposit of reclamation materials shall cease no later than 15 years upon which operations commenced.

Site access will be via the construction of a new access road from the A340. Material destined for restoration of the Site will be transported via this route. Once on Site, vehicle movements will be via internal haul roads. Quarry vehicles will cross the River Enborne to Phase B via an existing bridge that will be upgraded if required.

The materials required to restore site levels will comprise the importation of locally sourced waste / natural materials that will be classified under Waste Acceptance Criteria testing as ‘Inert’. As a sustainable approach, the reuse of waste materials is considered environmentally beneficial by reducing the use of virgin material and the need for landfill disposal.

It is estimated that a total output from the three Phase areas will amount to approximately 1,342,600 $m^3$of which approximately 10 % will comprise silt recovered from processing the sand and gravel which can be used as part of the restoration fill.

It is considered that a total import of 1,153,000 m^3 of material will be required to complete the restoration scheme and return the Site to near original levels, whilst providing an additional 15,000 m^3 of flood storage capacity through the lowering of land areas. The total import is estimated at 1.7 million tonnes (based on 1,153,000 m^3 with a mean density of 1,500kg/ m^3).

In order to accommodate this proposal and deposit material at the Site, the Environment Agency (EA) has indicated that an Environmental Permit for waste recovery (Deposit for Recovery or DfR) will be required.

1.2 Report Context and Scope

This document presents a qualitative Stability Risk Assessment (SRA) to accompany the Permit application. Relevant information describing the Site setting (including geological, hydrogeological, Site monitoring data and the development proposed) is detailed in the Environmental Site Setting and Design (ESSD) report which accompanies the Permit application.

The SRA has been prepared as a preliminary assessment of stability and geotechnical risks associated with the proposed inert waste recovery operation at the Site. This assessment has followed the principles outlined in Environment Agency (EA) technical guidance *(How to do a stability risk assessment: landfill sites for inert waste or deposit for recovery activities - Guidance - GOV.UK (www.gov.uk))* and Environment Agency reports 'Stability of Landfill Lining Systems: Report No.1 – *Literature Review* and Report No. 2 – *Guidance*' (Environment Agency, 2003a and 2003b).

Much of the relevant detailed information to support this assessment is provided in various associated reports and correspondence, which are referenced within this report and available as part of the full Permit application. Therefore, it is important that this report is reviewed alongside the relevant permit application reports.

This (SRA report includes a stability Conceptual Site Model (CSM) and considers the following:

a) Primary Components
   - basal sub-grade
   - side slope sub-grade
   - basal engineered system
   - side slope engineered system
   - waste mass

b) Pore fluid pressures relevant to each of the primary components; and

c) Settlement and strain, including the impact of short-term and long-term settlement and the shear strains that may occur for each primary component.

Following development of the CSM the report highlights the potential for issues relating to stability and integrity of each component that may require further geotechnical stability analysis. The preliminary screening review is presented in **Section 5**.

Where further analysis is considered necessary to address the stability of the proposed cut slope forming the restored excavation, the stability assessment(s) are detailed in **Section 6**.

1.3 Existing Reports/Data

The following reports for the site have been completed by various consultants. Relevant information from these sources has been gleaned to allow better interpretation of the site and underlying ground conditions:

- Proposed operation/restoration plans of the site by Tarmac (presented in **Appendix B**)
- Geological data from mineral exploration boreholes provided by Tarmac (presented as **Appendix C**)
- Modelled cross sections provided by Tarmac (presented as **Appendix D**)
- Envireau Water, Wasing Quarry: Hydrogeological Impact Assessment (HIA), reference P21-253 Tarmac Wasing/Woolhampton\ RPT Wasing Quarry HIA, dated 31/3/2022
- Envireau Water, Wasing Quarry: Hydrogeological Risk Assessment (HRA), ref: 3490176 Tarmac Wasing/ RPT Wasing Quarry HRA, dated June 2025)
- Envireau Water, Wasing Quarry: Environmental Setting and Site Design (ESSD), reference P22-44 Tarmac Wasing/ RPT Wasing Quarry ESSD dated 22/12/2022 and
- D.K. SYMES Associates, Environmental Statement for Lower Farm Wasing dated May 2012 (including details on previous investigations completed for the site).

Reference to the above reports has been made throughout this SRA where relevant information pertaining to the site has been cited.

1.4 Limitations

This report should be considered in the light of any changes in legislation, statutory requirement or industry practices that may have occurred subsequent to the date of issue.

The comments given in this report and the opinions expressed are based on the ground conditions interpreted from preceding investigations completed by ‘others’ including intrusive site work and on results of tests made in the field and in the laboratory. However, there may be conditions pertaining to the site that have not been disclosed by investigations and therefore could not be taken into account.

The comments given in this report are subject to RSK’s ‘Service Constraints’ provided in **Appendix A.**

2 GEO-ENVIRONMENTAL SETTING

For the purpose of this report it is considered appropriate to provide a concise summary of key aspects of the Site geo-environmental setting, based upon more detailed information, which is presented in the ESSD.

A series of Drawings are included in the ESSD and should be referred to for detail as required, these include namely: Site Setting; Bedrock Geology; Superficial Geology; Local Geology; Hydrological Setting; and Conceptual Hydrogeological Cross Section. **Table 1** provides a summary of the geo-environmental setting for the Site.

Table 1 Site setting

Site Location	The Site is located at Lower Farm on Wasing Lane in Aldermaston in Reading as identified on **Figure 1**. The Environmental Permit application boundary (as outlined in **Figure 1**) extends to 70 hectares, primarily of greenfield arable land. The Site is centred on National Grid Reference (NGR) SU 578658. The River Enborne flows north-eastwards across the centre of the site, with several foot bridge crossing points. One of the bridges is proposed to be used for an internal haul route. The river is joined by several tributaries to the south and north of the Site.
Surrounding Land Uses	**North:** Woodland (designated as a Local Wildlife Site) and marshland areas are present along numerous parts of the northern boundary. The Kennet and Avon canal and River Kennet flow as one watercourse directly north of the site, joined by numerous tributaries. However, 400 m to 500 m up and downstream, the river and canal are separate features. A small marina is present approximately 450 m to the northeast. **East:** Agricultural land bounds the east of the site with residential properties and a garden centre beyond adjacent to Basingstoke Road (A340) and wooded area to the northeast. Aldermaston is located 300m to the southeast including Aldermaston Primary School. **South:** The Brimpton Airfield (a 620 m long airstrip, with associated storage sheds) lies directly south of the southern boundary with residential/farm buildings associated with Wasing Lower Farm and Wasing Lane beyond. Further south-east along Wasing Lane lies Wasing Lodge and a few small residential properties with further agricultural land between. **West:** The River Enborne runs along the western boundary before flowing eastwards through the site and bordering the north-eastern site boundary. Agricultural landforms the remainder of the western boundary with a residential property (c.150 m west) identified as Bottle Cottage. Station Road runs almost adjacent to the Site's western boundary approximately 100 m at its nearest approach. A layout of the Site area is presented as **Figure 2**, which also highlights relevant hydrological features.
Topography	Ordnance Survey Maps and site survey data indicate that Site levels range from c.63 m AOD in the southwest, sloping gently down to c.55 m AOD in the northeast. The highest ground is in the southwest of

	the Site and land slopes generally northeast towards the River Enborne and River Kennet.
Historical Land Use	The Site is greenfield land and has not been subject to previous mineral working, landfilling or built development.
Current Land Use	The Site is currently characterised by agricultural farmland, comprising fields lined by various trees, wooded areas (to the north and northeast) and hedgerows. There are no residential properties or farms present within the site boundary. As part of approved planning, a temporary raised office and small compound with weighbridge has been constructed on the eastern side of the Site, close to an area proposed as a new access route into the Site
Geology	The ground conditions underlying the Site area have been established from both published geological map (BGS online database) and the findings of previous site investigations. Geological data from mineral exploration and groundwater monitoring boreholes provided by Tarmac are presented in **Appendix C**. The following geological strata underlie the Site: **Superficial Deposits**: The site area is located on a River Terrace system of the Kennet Valley Formation. The south of the site (including Phase A) is underlain by the Beenham Grange Gravel (Second Terrace deposits of the River Kennet), whilst Phases B and C (to the north of the site) predominantly comprise Alluvium, which in turn is underlain by the Beenham Grange Gravel Member. Boreholes drilled within the site area indicate that the Beenham Grange Gravel Member (the target economic mineral) comprises sand and gravel, observed as being more silty at shallow depth within the south, with a higher percentage of sand. Alluvium (initially underlying Phases B and C) comprises clayey, silty sand and flinty gravels. Sporadic and discontinuous layers of peat have also been recorded within the superficial deposits. As detailed within the ESSD, these deposits are anticipated to the west of Phase B1b and within the north of Phase B1b, within Phase B2 and encroaching to the north of Phase B3. Peat deposits are also anticipated within C1 (a and b), Phase C2, southern side of Phase C3 and the northern side of Phase C4 The central region of the site where the Beenham Grange Gravel Member and Alluvium meet is much more variable, often with clean gravel being less abundant as a result of the River Enborne. The average thickness of the Beenham Grange Gravel Member across the three Phase areas varies between 2.75 m and 3.28 m. The deposits reach a thickness of almost 6.00 m in the centre and northern parts of Phase B. **Overburden:** Overburden (comprising topsoil and Alluvium layers) vary spatially across the site thickness and composition , averaging between 1.06 m and 2.08 m, with the greatest thickness (of up to 4.00 m) identified within the north of the site (to the north of Phase B and River Enborne) and comprising topsoil and silt with peaty layers. Towards the south of the Site overburden comprises silty clays becoming more gravelly with depth and generally less than 2.00 m in thickness. The Beenham Grange Gravel

	Member is often present immediately below the soil layer within the south of the site. **Bedrock:** consisting of London Clay Formation proven locally to a minimum thickness of 10 m due to the southerly inclination of the underlying Reading Formation (part of the Lambeth Group and Thanet Sands. These in turn overlie the Upper Chalk at depth (c.35 m – 40 m depth). **Man-made Deposits:** There is unlikely to be any made ground present within the areas proposed for excavation/restoration, however there may be a small amount of made ground within areas of the site associated with trackways
Hydrogeology	The site is underlain by a Secondary 'A' Aquifer (comprising both the Beenham Grange Gravel Member and Alluvium). The Lambeth Group and Upper Chalk are designated a Secondary 'A' aquifer and Principal aquifer respectively and are likely to be in hydraulic continuity. The site is located within a Source Protection Zone (SPZ). Further details on the SPZ and aquifer designations beneath the site are details in the ESSD. The solid geology of the London Clay Formation is considered 'unproductive' with the London Clay acting as an aquitard between the superficial deposits and underlying aquifers. The two aquifers are considered to be hydraulically separated. Beneath the site area the London Clay Formation is understood to be at least 10 m thick, which affords significant protection to the underlying Principal Chalk, aquifer at depth. Groundwater levels are monitored on a monthly basis by Tarmac in 22 boreholes screened across the sand and gravel deposits that are installed at and around the Site (including the former Woolhampton Quarry situated to the west). Groundwater levels in the area range from 52.10 to 62.80 m AOD. The groundwater flow direction is inferred to be northward and north-eastward, towards the River Kennet and Spring Ditch.
Hydrology	The River Enborne, present on the site's southwestern border, flows in a north-eastward's direction across the centre of the site area towards its confluence with the River Kennet (some 600 m downstream of the site boundary). There are several tributaries of the River Enborne that flow through the Site. The largest of these originate on land to the south and flow northwards east of excavation Phase A and along the south-eastern Site boundary. These are referred to as Stream A and Stream B, respectively. Approximately 100m to the north of the site is the Kennet & Avon Canal (incorporating the River Kennet), flows eastward (commencing from Woolhampton Lock 500 m northeast). Approximately 400 m north-east of the Site, the Canal and River Kennet spilt with the canal branching off to the northeast and river branching off more towards the southeast. To the north, around Woolhampton, several tributaries flow southwards to join the River Kennet/Kennet & Avon Canal.

Hydrology	Towards the north and west, there are six waterbodies located within the former quarry workings of Woolhampton, the closest being c.200 m from the site boundary. The drainage system to the north of the site between Phase B, C and the Kennet & Avon Canal were created in the 1950/60s as an overflow catchment to Kennet & Avon Canal. The main drainage feature in this area is Spring Ditch, this flows westwards from the former Woolhampton Quarry and heads across the north of Phase B to its confluence with the River Enborne, 310 m east of the Site.

3 PROPOSED DEVELOPMENT

The site was awarded planning permission by West Berkshire Council for mineral processing in August 2013.

As detailed in the ESSD, the planning consent allows for the winning and working of minerals, the erection of a site office, welfare unit, weighbridge, wheel cleaner and other ancillary buildings with restoration of the site using imported suitable inert materials to return the land to agricultural use.

A summary of key development considerations is presented in **Table 2.**

Table 2 Proposed Development

Operational Phasing	The site has been divided into three phase areas (designated 'A', 'B' and 'C') as detailed on **Figure 3**. The scheme treats each phase as a separate area of mineral extraction, linked by internal roads. There will be an initial transfer of overburden material between phases with extraction commencing in the southwest within Phase A1 and A2. Topsoil will be stripped and stored in 2 m to 3 m high bunds during mineral extraction and restoration to the southeast of the phase. Phases A3 and A4 would be worked in conjunction with Phase B during periods where dewatering discharge (from B) will be prohibited by high flow rates in the River Kennet and Enborne. Phase C would also be worked on a campaign basis. Extraction in Phase C4 (1-4) will be undertaken when dewatering is not possible in Phases C1-C3. Topsoil storage mounds for Phases B and C will be located in the southeast of the site, outside of Flood Zones 2 and 3. These will also provide visual screening from Wasing Lane. The stored soils will be replaced as each phase is completed to return the land back to agricultural land use at original ground levels Design drawings detailing the proposed extraction and restoration operations across Phases A, B and C are presented in A1, B1 and C1 in **Appendix B.** Timescales for each phase are estimated between 3 to 5 years, providing an overall working of these three phases as approximately 13 years, as shown on illustrative 'Progressive Operations' drawings 'PO Y1' to 'PO Y14' (in **Appendix B**), with a further 4 years to complete restoration by infilling as shown on illustrative Restoration Plan 'R2' (in **Appendix B**).
Access and Plant	A new purposed access route (onto the A340) from site has been incorporated into the design of the site to allow transportation of materials on and off site.

Access and Plant	A surface mounted weighbridge, wheel-wash and Site offices will be installed at the Site for the duration of all quarrying and restoration works.
Water Management	Groundwater beneath the site can be relatively high (within 1 m of ground surface within Phase B and C) and therefore, to maximise the recovery of the sand and gravel and to facilitate the recovery operation it is proposed to dewater the excavation areas. Dewatering will also be required to allow for a geological barrier to be engineered prior to restoration by inert landfilling. In accordance with approved planning, it is intended to pump shallow groundwater from sumps formed in the base of excavations into one of three settlement/balancing ponds on site before being discharged to nearby watercourses.
Restoration	The Site will be progressively restored by the importation of inert waste in accordance with approved plans (**Appendix C** of the ESSD). Restoration materials will be strictly limited to inert wastes prior to replacement of indigenous subsoil and topsoil to return the Site to agricultural use. Excavation of the sand and gravels from each phase area, will expose the underling London Clay Formation (which has a very low permeability) that will act as a natural basal geological barrier (protecting the underlying chalk strata, a designated Principal Aquifer) as required to satisfy the requirements of the Landfill Directive. In addition to the basal geological barrier, a 1.00 m thick sidewall geological barrier (side wall attenuation layer) will be constructed from suitable imported waste materials around the perimeter of each phase which will have sufficient clay content to provide permeability characteristics of no more than 1 x 10^{-7} m/s as specified within the HRA.

4 STABILITY SITE CONCEPTUAL MODEL

Information derived from the ESSD, as summarised in **Table 1** and **Table 2**, has informed the development of a Conceptual Site Model (CSM) relating to the physical site setting (the ground model) in the context of this SRA.

4.1 Basal Subgrade Model

Based on intrusive investigations at the Site, which are discussed in more detail in the ESSD, the depth to the base of sand and gravel (and the top of the London Clay Formation) at the Site generally ranges between 4.50 m bgl (metres below ground level) and 5.50 m bgl.

Topsoil/subsoil (overburden) across the three Phase areas has been proven to a depth averaging between 1.25 m bgl and 2.08 m bgl, with the thickest present in Phase B (up to c. 4.27 m thick).

The Sand and Gravel mineral to be extracted across each of the three Phase areas is anticipated to average between 2.75 m and 3.28 m in thickness. The maximum thickness is anticipated to be within Phase B (up to c.5.90 m in thick).

The basal subgrade to the inert landfill will be formed by the London Clay Formation, the upper surface of which will be exposed as the Sand and Gravel mineral is fully worked to depth in each operational phase.

Shallow groundwater is present across the Site within the superficial Sand and Gravel deposits (the mineral to be extracted). The Site will be subject to dewatering (by pumping of shallow groundwater) during the operational phases to allow the mineral to be extracted, and the void isolated from surrounding groundwater prior to filling by means of a side slope geological barrier. Groundwater in each operational phase will continue to be supressed until each void has been filled sufficiently to counter the risk of any hydrostatic heave against the basal and side slope geological barriers.

4.2 Side Slope Subgrade Model

The side slope subgrade will be formed by the regraded side slopes of the in-situ overburden and Sand and Gravel mineral of the Beenham Grange Gravel Member and Alluvium.

As detailed in **Section 4.1**, mean overburden topsoil and subsoil are anticipated to a depth of between 1.25 m bgl and 2.08 m bgl, with mean Sand and Gravel mineral to be extracted anticipated to be between 2.75 m and 3.28 m thick.

The quarry side slope stability will be subject to on-going geotechnical assessment during quarrying operations under the Quarries Regulations 1999.

In accordance with Environment Agency (2003b), restoration side slopes will be formed no steeper than 1:2 to facilitate placement of the geological barrier.

4.3 Basal Geological Barrier Model

Operational phases of the Site will be progressively restored with inert waste materials to be controlled by strict waste acceptance procedures detailed in the accompanying Waste Acceptance Plan and information supporting the Permit application.

As detailed in **Section 4.1**, the mineral to be extracted is underlain by London Clay which has been proven locally to a minimum thickness of 10 m and increasing in thickness to the south (**Table 1**). The London Clay will provide a natural low permeability attenuation layer between the inert waste and Chalk aquifer at depth. The characteristic permeability of intact London Clay bedrock is typically less than 1 x 10^{-7} m/s required by the HRA and as such, no CQA testing is necessary.

The minimum thickness of London Clay is such that hydrostatic heave poses a low risk.

4.4 Side Slope Geological Barrier Model

The side slope geological barrier (or side wall attenuation layer) will be constructed from site won or imported waste materials placed around the perimeter of each phase which will have sufficient clay content to provide permeability characteristics of no more than 1 x 10^{-7} m/s, as detailed in the HRA.

In accordance with the HRA and guidance from Annex I of the Landfill Directive (1999) for inert waste landfill, placement and compaction of cohesive materials/clay will achieve a maximum permeability of 1 x 10^{-7} m/s with a minimum 1 m barrier thickness (or equivalent permeability for increased/reduced thickness).

CQA testing of the side slope geological barrier will be applied to ensure that these minimum criteria are achieved and meet with a design specification that will be produce for the proposed works.

Restored side slopes will be formed no steeper than 1:2 to facilitate placement of the geological barrier.

Groundwater in each operational phase will continue to be supressed until each void has been filled sufficiently to counter the risk of any hydrostatic heave against the side slope geological barrier and such that waste materials can continue to be emplaced dry.

4.5 Waste Mass Model

Operational phases of the Site will be filled with suitable imported inert wastes placed directly above the basal and side slope geological barrier. The waste mass will be placed ‘dry’ as operational phases will be dewatered.

As detailed in the planning conditions relating to Reclamation Operations for the proposed scheme, imported inert waste will be treated by physical means to ensure that prior to placement, *no rocks/large stones or other materials exceeding 150 mm in any dimension or other deleterious materials likely to cause physical obstruction to cultivation and maintenance of the surface to be restored are placed within one metre of the surface*. As such it is anticipated that the material to be deposited will be generally homogeneous comprising inert predominantly cohesive soils and clays limited to European Waste Codes – 01 04 09, 17 05 04 and 20 02 02 as detailed in the WAP.

Wastes will be placed in layers of typically 0.25 m thickness before compaction by tracking of Site plant. All works will be undertaken in accordance with a CQA plan to be submitted to the EA for approval before any construction commences.

Groundwater in each operational phase will continue to be supressed until each void has been filled sufficiently to counter the risk of any pore fluid pressures within the placed soils which may reduce the stability of any temporary waste faces.

4.6 Capping System Model

Due to the inert nature of the waste mass to be placed in restoration of the Site there is no formal capping system required. As detailed in **Table 2**, in-situ subsoil and topsoil will be stripped, stored and replaced upon completion of each phase. This will ensure that the Site is fully restored to original levels and returned to productive agricultural use in accordance with planning.

5 STABILITY RISK ASSESSMENT

5.1 Risk Screening

Each of the six principal components of the Stability Conceptual Site Model (**Section 4**) have been considered and assessed.

Issues relating to stability and integrity of each component are considered by means of preliminary screening review to determine whether further geotechnical stability analysis may be required. The preliminary screening review is presented in the following sub-sections.

5.1.1 Basal Subgrade Screening

As detailed in **Section 4.1,** the basal sub-grade will be formed by the London Clay bedrock. Each aspect of the stability and deformability of the basal subgrade has been considered in accordance with Section 3.3.1 of Environment Agency report 'Stability of Landfill Lining Systems: Report No. 2 – *Guidance*' (Environment Agency, 2003b) and discussed in **Table 3** below.

Table 3 Basal Sub-grade Stability Components

<table>
<tr><td rowspan="3">Excessive deformation</td><td>Compression</td><td>It is considered that the basal subgrade (London Clay) will be essentially incompressible in its in-situ condition as the stresses applied by the restoration fill will be no greater than those currently applied by the existing in-situ mineral. As such, this component does not require further consideration.</td></tr>
<tr><td>Basal Heave</td><td>The basal subgrade (London Clay) is naturally of very low permeability and extends to a thickness of at least 10.00 m above underlying aquifer strata. Operational phases will be actively dewatered, with dewatering drawing water from the overlying superficial deposits. It is not considered that there is any likely mechanism by which heave of the basal subgrade may occur and therefore this component does not require further consideration.</td></tr>
<tr><td>Cavities</td><td>Natural cavities are not anticipated within the in-situ London Clay. As such, this component does not require further consideration.</td></tr>
<tr><td>Filling on Waste</td><td colspan="2">Not Applicable</td></tr>
</table>

Based on the preliminary stability screening of the basal subgrade presented in **Table 3**, it is considered that the basal subgrade system does not require further consideration or assessment.

5.1.2 Side Slope Subgrade Screening

As detailed in **Section 4.2**, the basal sub-grade of the side slopes will be formed in in-situ overburden (subsoil and topsoil where not stripped and Alluvium) and Sand and Gravel mineral of the Beenham Grange Gravel Member.

The indicative quarry slope geometries are shown on cross sections provided by Tarmac (drawing ref: W335-00006-1, dated August 2022) presented in **Appendix D**). Temporary cut slopes presented in the drawings indicate provisional slope gradients in the range as 1V:1.5H to 1V:1.2H with maximum depth of cut of up to circa 8.00 m.

The restoration side slope subgrade stability and deformability has been considered in accordance with the requirements for cut slopes of granular soil as detailed in Section 3.3.1 of Environment Agency (2003b) and discussed in **Table 4** below.

Table 4 Side Slope Sub-grade Stability Components

Cut Slope:	**Stability**	The side slope sub-grade will predominantly be formed by mineral extraction of the Beenham Grange Gravel Member. A variable thickness of overlying soft clay is also present across areas of the site. The operational quarry side slope geometries will be subject to on-going geotechnical assessment under the Quarries Regulations 1999 to ensure their stability. The restored side slopes sub-grade shall be no steeper than that recommended by EA guidance (typically 1 in 2) in order allow construction of the geological side slope barrier. In the prevailing ground conditions (mixed superficial soils and groundwater present) it is not considered possible to qualitatively assess the side slope stability and a preliminary stability assessment has been undertaken to assess the side slope sub-grade stability for the restoration stage, as provided in **Section 6.**
	Deformability	The predominant side slope sub-grade materials of the Beenham Grange Gravel Member are considered essentially incompressible and the potentially compressible Alluvium are only of limited extent, as such this component does not require further consideration.
	Groundwater	Each operation phase will be actively dewatered during mineral extraction. This will continue until restoration materials have been placed to sufficiently counter any

Cut Slope:	**Groundwater**	increase in pore pressure or hydrostatic heave against the side slope barrier. An abstraction (transfer) licence has been obtained to authorise dewatering. Groundwater dewatering in each operational phase will also ensure that pore water pressures are limited to ensure an adequate ODF.
Fill Slope		Refer to **Table 6**

The Site will be operated by Tarmac, an experienced operator, with particular experience working in the local area and with experience of side slope sub grade conditions anticipated at the Site. The operational quarry side slopes will be subject to on-going geotechnical assessment under the Quarries Regulations 1999 to ensure their stability.

In accordance with prevailing guidance (Environment Agency, 2003b), Tarmac will ensure that restoration side slopes are designed and maintained in each operational phase to have sufficient Over Design Factor (ODF as per Eurocode EC 7). These would be 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.

Based on the preliminary stability screening of the side slope subgrade presented in **Table 4**, it is considered that the side slope subgrade system does require further consideration in respect to the global slope which has been addressed in **Section 6**.

5.1.3 Basal Geological Barrier System Screening

As detailed in **Section 4.3**, no basal geological barrier is required because low permeability London Clay bedrock is present at and below the basal sub-grade level.

5.1.4 Side Slope Geological Barrier System Screening

As detailed in **Section 4.4**, the side slope barrier system will be formed by placement of site won or imported cohesive waste materials to achieve a barrier of no less than 1.00 m in thickness and permeability no greater than 1 x 10^{-7} m/s.

Side slope geological barrier stability and integrity has been considered, for both the Unconfined and Confined scenarios in accordance with the requirements for mineral only geological barrier systems as detailed in Section 3.3.1 of Environment Agency (2003b). as discussed in **Table 5** below.

Table 5 Side Slope Barrier Stability/Integrity Components

During Construction (Unconfined)	**Mineral Only**	**Stability**	As detailed in **Section 4.2,** the side slope geological barrier will be formed of site won or imported cohesive waste materials and should achieve an Over Design Factor (ODF as per Eurocode EC 7) >1.0 or with slope gradients no steeper than 1 in 2 (1V:2H) (Environment Agency (2003b). The side slope geological barrier system will be maintained in each operational

During Construction (Unconfined)	**Mineral Only**	**Stability**	phase with a slope angle no steeper than 1 in 2 (1V:2H). This can be 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. As such, this component does not require further consideration, and it will be subject to CQA checks following installation
		Integrity	Groundwater in each operational phase will continue to be supressed until each void has been filled sufficiently to counter the risk of any hydrostatic heave against the side slope barrier. It is considered that there are no other factors which may affect the integrity of the proposed side slope barrier system assuming low permeability cohesive Clay is used for this purpose. As such, this component does not require further consideration.
	Geosynthetic mineral	**Stability**	Not Applicable
		Integrity	
Following placement of waste (Confined)	**Mineral Only**	**Stability**	The assumptions presented for the unconfined scenario are presented above which are assumed to apply to the confined phase. However, in the confined scenario the side slope barrier will be permanently subject to the pressure of the placed waste mass which will wholly comprise inert, cohesive and homogeneous soils. This confining pressure means that this component does not require further consideration.
		Integrity	As indicated for the unconfined scenario, groundwater will be supressed until each void has been filled sufficiently. In the confined scenario groundwater rebound will occur however the confining pressure of the waste mass will ensure the long-term integrity of the basal geological barrier as groundwater levels and porewater

Following placement of waste (Confined)	**Mineral Only**	**Integrity**	pressures equilibrate with surrounding strata.
	Geosynthetic mineral	**Stability**	Not Applicable
		Integrity	

The Site will be operated by Tarmac, an experienced Operator, with particular experience working in the local area and of side slope sub grade conditions anticipated at the Site.

In accordance with prevailing guidance (Environment Agency, 2003b), Tarmac will ensure that side slopes barriers are designed and maintained in each operational phase to ODF of >1. This can be 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.

Based on the preliminary stability screening of the side slope subgrade presented in **Table5,** it considered that the side slope geological barrier system does not require further consideration or assessment.

5.1.5 Waste Mass Screening

As detailed in **Section 4.5**, the waste mass will be placed in operational phases which will be dewatered. The waste will be generally homogeneous comprising predominantly low permeability cohesive soils.

Each aspect of the stability of the waste mass and stability and integrity of the waste mass/barrier has been considered in accordance with Section 3.3.1 of Environment Agency (2003b) as discussed in **Table 6** below.

Table 6 Waste Slope Stability/Integrity Components

Failure wholly in waste	**Stability**	As discussed in **Section 4.5,** waste materials will be placed in layers of typically 0.25 m thickness before compaction by tracking of Site plant to an engineering specification. The side slope geological barrier works will be undertaken in accordance with a CQA plan to be submitted to the EA for approval before any construction commences. Due to the anticipated cohesive nature of waste soils, it is anticipated that temporary waste faces will be able to exist at an angle of 1 in 2 (1V:2H). Exposed waste slopes will be maintained in each operational phase with a slope angle no steeper than 1 in 2.5 (1V:2.5H). For cohesive, unsaturated material this should achieve an Over Design Factor (ODF as per Eurocode EC 7) >1.0.

Failure wholly in waste	**Stability**		Environment Agency (2003b) considers an ODF of this magnitude is 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. This will be subject to on-going assessment during the restoration phase and steeper gradients may be achievable subject to the characteristics of the waste mass. Groundwater in each operational phase will continue to be supressed until each cell has been filled sufficiently to counter the risk of any pore fluid pressures within the placed soils which may reduce the stability of any temporary waste faces. As such this component does not require further consideration.
Failure involving geological barrier and waste	**Mineral only**	**Stability**	Assumptions for the confined scenario presented in **Table 5** are considered to be equally applicable. As such, this component does not require further consideration.
		Integrity	Assumptions for the confined scenario presented in **Table 4** are considered to be equally applicable. As such, this component does not require further consideration.
	Geosynthetic mineral	**Stability**	Not applicable
		Integrity	Not applicable

Based on the preliminary stability screening of waste slopes presented in **Table 6**, it considered that the waste mass slope system does not require further consideration or assessment.

5.1.6 In-waste Infrastructure

As the waste to be deposited at the Site will be inert and controlled by strict waste acceptance procedures, to ensure long term high quality agricultural land use, it is not anticipated that leachate will be generated within the waste mass. This has been further assessed through appropriate Hydrogeological Risk Assessment (HRA) which accompanies the Permit application. In-waste leachate monitoring or collection is therefore not required.

Similarly, as the waste to be deposited will be inert, landfill gas will not be generated from strict adherence to Waste Acceptance Procedures and waste characterisation and compliance monitoring. 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. Any new or replacement infrastructure will be installed in accordance with prevailing EA guidance.

5.1.7 Capping System Screening

As detailed in **Section 4.6,** there is no formal capping system required for deposit for recovery activities.

In situ subsoil and topsoil will be stripped, stored and replaced upon completion of each phase. This will ensure that the Site is fully restored to original levels, which will tie in with the local landscape and ensure that the Site is returned to productive agricultural use in accordance with planning permission.

The waste mass will be inert and therefore it is considered highly unlikely that any significant settlement due to biodegradation of organic material will occur. Any oversized materials will be removed prior to placement to ensure homogeneity of the waste mass, lack of cavities and limit compressibility and therefore long term settlement.

In light of the above, each aspect of capping system stability defined in Section 3.3.1 and Table 3.39 of Environment Agency (2003b) has been considered and it is therefore considered that stability of the capping system does not require further consideration or assessment.

5.1.8 Lifecycle Phases

As detailed in **Table 2** Proposed Development and plans appended to the accompanying ESSD, the Site will be progressively worked across the three phases over 13 years and restored over a further 4 years.

The infilling of the mineral void with pre-treated inert waste soils 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 EA 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

5.1.9 Monitoring

Based upon the assessments and screening provided in this SRA, a simple risk-based monitoring scheme is considered appropriate as summarised in **Table 7**.

Table 7 Monitoring

Basal subgrade	None applicable
Side Slope subgrade	Exposed faces within operational phases to be inspected on a daily basis for any signs of failure. Appropriate remedial action will be taken if evident.
Basal lining/ geological barrier	N/A
Side Slope geological barrier system	Construction will apply with CQA requirements
Waste mass	Non proposed
Capping monitoring	None proposed. As detailed in the ESSD, the Site will be returned to agriculture and subject to a 5 year aftercare programme to ensure the Site meets the requirements of the approved planning consent and restoration scheme.

It is also noted that the Site will be operated by an experienced Operator and the Conceptual Site Model components described are not considered to be ‘atypical’ and very similar to other landfill sites constructed and operated by Tarmac.

6 DETAILED STABILITY ASSESSMENTS

6.1 Introduction

The results of the qualitative risk screening exercise in **Section 5** concluded that only the side slope subgrade component requires further assessment. This is because a qualitative assessment alone was not considered appropriate in the prevailing ground conditions.

A preliminary stability analysis of the side slope stability is outlined in the following sections.

6.2 Side Slope Subgrade Stability Analysis

6.2.1 Side slope geometry

The side slope stability assessment considers the following restored characteristic slope geometries:

- Slope Section AA within north-eastern corner of Phase B is considered to be the most critical due to its greater depth (circa. 8.0 m) and more extensive surface layer of clay/silt Alluvium (circa 1.8 m). A restored slope gradient of at Slope Section AA of approximately 1V:2H is considered initially.
- Slope Section B’ is located at the eastern side of Phase A. Slope B’ is approximately 4.0 m in height and has a reduced thickness of clay/silt Alluvium of <1.0 m. A restored slope gradient of at Slope Section BB of approximately 1V:2H is considered initially.
- Where a suitable over design factor (ODF) was not been obtained for the above cases, additional analysis has been undertaken to determine the maximum safe gradient required to satisfy an ODF >1 for the slope height and prevailing ground conditions.

Given the anticipated extraction and reinstatement period (i.e. 1-2 years), the long-term stability of the above slopes has been assessed utilising appropriate drained strength parameters. Stratigraphy considered for the assessment is presented in **Table 9**.

6.2.2 Ground Model and Geotechnical Parameters

The ground conditions and ground models associated with the proposed extraction cutting slopes have been derived from existing reports and data as detailed in **Section 1.3**.

Neither in-situ nor laboratory geotechnical tests were carried out on any of the strata. Therefore, the geotechnical parameters used in this slope stability assessment have been derived from professional experience and through engineering judgement as presented in **Table 8** and **Table 9**.

Table 8 Stratigraphy Used in Cross Sections

Stratum	Top of Strata Elevation (m BGL)	
	Section AA	Section B'
Alluvium (Clay/silt)	0.0	0.0
Gravel (Beenham Grange Gravel)	1.8	0.9
Interbedded Clay/silt (Beenham Grange Gravel)	4.5	-
Gravel (Beenham Grange Gravel)	5.0	-
London Clay Formation	~8.0	~4.0

Table 9 Geotechnical Parameters Adopted for Slope Stability Analyses

Stratum	Bulk Density, γ (kN/m^3)	Undrained Shear Strength, cu (kN/m^2)	Effective Angle of Shearing Resistance, φ' (Degrees)	Effective Cohesion c´(kN/m^2)
Alluvium / Clay/silt Layer Beenham Grange Gravel	17.0	-	28.0	0.0
Gravel (Beenham Grange Gravel)	19.0	-	32.0	0.0
London Clay Formation (Drained)	19.0	-	24.0	3.0

Note: A pore-pressure ratio (ru) of 0.15 has been assigned the upper Alluvial Clay; Geological units underlying London Clay Formation have been ignored in this assessment due to their depth in relation to the slope geometries in question.

6.2.3 Groundwater

Dewatering will be carried out during quarrying and filling to keep the extraction area dry and this will remain in operation until such time that sufficient waste has been placed to counter hydraulic failure of the side slope geological barrier. For the purposes of the analyses, a hydrostatic groundwater level is assumed to be present at the base of the excavation and gradual draw down within the side slopes rising to approximately 1.00 m bgl a short distance back from the excavation.

6.2.4 Loading

No external loadings have been considered at this time.

If there is a requirement for any temporary loading of the side slopes during the operational phase this will be subject to geotechnical assessment under the Quarries Regulations 1999.

6.2.5 Method of Analysis

The software used by RSK for Slope Stability Assessments is Oasys Slope developed by Ove Arup. Circular slip analyses were carried out for the slope profiles, using Bishop's Simplified Method of Slices with variably inclined interslice forces. This is the industry-standard method of analysis. In this method, a large number of theoretical computer-generated slip circles are drawn, relative to a predetermined grid of centres.

The slope stability analyses have been undertaken using the partial factors provided in BS EN 1997-1:2004 Eurocode 7 Design, General rules (+A1:2013) Approach 1 Combination 2 (EC7 DA1-2) to determine an Over Design Factor (ODF), whereby an ODF≥1.00 is required to demonstrate satisfactory stability. This approach is in accordance with current UK design standards.

By default, the programme draws the slip circle with a minimum Over Design Factor ('ODF').

6.2.6 Results of analysis

The results of the slope stability analyses for Slope Section AA and B' are presented in **Table 10** to **Table 12** below. Graphical outputs of analysis results are presented in **Appendix E**.

Table 10 Stability Results for Section AA - 1V:2H Slope Profile

Case	Analysis Method	Over Design Factor (ODF)	Stability Condition
Long-term	BS EN 1997-1:2011 DA1-2	0.730	Unsatisfactory

Table 11 Stability Results for Section AA – 1V:2.5H Slope Profile

Case	Analysis Method	Over Design Factor (ODF)	Stability Condition
Long-term	BS EN 1997-1:2011 DA1-2	1.032	Satisfactory

Table 12 Stability Results for Section B' – 1V:2H Slope Profile

Case	Analysis Method	Over Design Factor (ODF)	Stability Condition
Long-term	BS EN 1997-1:2011 DA1-2	1.061	Satisfactory

6.2.7 Summary

The results of the slope stability analysis indicate the following:

- A restored side slope gradient of 1V:2H should remain stable for slope heights up to circa 4.00 m in height and where a <1.00 m surface layer of soft clay Alluvium is present.
- A slackened restored side slope gradient of 1V:2.5H should remain stable for slope heights up to circa 8.00 m in height and/or where a surface layer of soft clay Alluvium >1.00 m and up to 1.80 m in thickness is present.

7 CONCLUSIONS

The conclusions of the SRA are summarised below:

1. The conceptual ground model derived for the Site comprises a surface layer of soft clay Alluvium over the Beenham Grange Gravel Member, which in turn is underlain by the London Clay Formation to depth.
2. Groundwater beneath the site is indicated to be relatively high within 1 m of ground surface) and therefore, to maximise the recovery of the sand and gravel and to ensure stability during the recovery operation it is proposed to dewater the excavation areas. Dewatering will also be required to allow for a geological barrier to be engineered prior to restoration by inert landfilling.
3. The basal subgrade model comprises competent London Clay bedrock and this extends to a thickness of at least 10 m above underlying deep aquifer. Hydraulic failure of the basal sub-grade is assessed as a low risk and no further consideration or assessment is required.
4. The side slope subgrade model is characterised by the conceptual ground model and groundwater conditions discussed above. Provisional temporary side slope gradients during the operational phases are indicated to be in the range of 1V:1.5H to 1V:1.2H with maximum depth of cut of up to circa 8.00 m. In the operational phase the mineral excavations will be subject to on-going geotechnical assessment under the Quarries Regulations 1999.
5. In accordance with Environment Agency (2003b), restoration side slopes should be formed no steeper than 1:2 to facilitate placement of the geological barrier. In the prevailing ground conditions it was not considered possible to qualitatively assess the side slope stability and a preliminary stability assessment has been undertaken, as detailed in **Section 6**. The stability assessment indicates the following:
   - A side slope gradient of 1V:2H should remain stable for slope heights up to circa 4.00 m in height and <1.00 m surface layer of soft clay Alluvium.
   - A slackened side slope gradient of 1V:2.5H should remain stable for slope heights up to circa 8.00 m in height and/or a surface layer of soft clay Alluvium >1.00 m and up to 1.80 m in thickness.
6. No basal geological barrier is required because a significant thickness of low permeability London Clay bedrock is present at and below the basal sub-grade level.
7. The side slope barrier system will be formed by placement of site won or imported cohesive waste materials to achieve a barrier of no less than 1 m in thickness and permeability no greater than 1 x 10-7 m/s. It will be placed under dry conditions and on a stable side slope subgrade restored to the gradients indicated by the preliminary stability assessment above or revised as needed by a later revaluation once more information is available. The side slope geological barrier works will be undertaken in accordance with a CQA plan to be submitted to the EA for approval before any construction commences.
8. The waste mass will comprise predominantly low permeability cohesive soils, which will be placed in dry conditions and in accordance with a CQA plan to be submitted to

the EA for approval before any physical work commences. It is considered that exposed waste slopes should remain stable up to slope gradients of 1 in 2.5 (1V:2.5H), but this should be subject to on-going assessment during the restoration phase and steeper gradients may be achievable subject to the characteristics of the waste mass. Further, in view of the inert and cohesive nature of the proposed waste mass, the risk of cavities forming and long term surface settlement occurring is considered low and no further stability assessment is required.

9. Due to the inert nature of the waste mass no formal capping system is required. On completion the Site will be fully restored with site derived subsoil and topsoil to original levels and returned to productive agricultural use in accordance with planning permission.

10. To summarise, the findings of the SRA demonstrate that the stability of the recovery activity can be achieved over its entire life cycle providing the works are managed and undertaken in line with this SRA and subject to on-going assessment of extractive faces in accordance with Quarries Regulations 1999 and approved CQA plan.

REFERENCES

Environment Agency, 2003a. Stability of Landfill Lining Systems: Report No. 1 Literature Review. R&D Technical Report P1-385/TR1, January 2003.

Environment Agency, 2003b. Stability of Landfill Lining Systems: Report No. 2 Guidance. R&D Technical Report P1-385/TR2, January 2003.

Environment Agency, LFE4 - Earthworks in landfill engineering, Design, construction and quality assurance of earthworks in landfill engineering.

Official Journal of the European Communities, 1999. Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste (Landfill Directive).

FIGURES

APPENDICES

Appendix A
RSK SERVICE CONSTRAINTS

Appendix B
EXTRACTION AND RESTORATION DESIGN DRAWINGS

Appendix C
GEOLOGICAL DATA FROM MINERAL EXPLORATION BOREHOLES

Appendix D
PROPOSED EXTRACTION LEVEL CROSS SECTIONS

Appendix E
SLOPE STABILITY ANALYSIS OUTPUTS