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CASTLE HILL QUARRY CO. LTD.

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APPLICATION FOR WASTE RECOVERY PERMIT

Stability Risk Assessment Report

GEC JOB NO: GE230291204

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Report Context

1.1 The operator of the installation is Castle Hill Quarry Co. Ltd. (CHQ).

1.2 Land and Mineral Management Ltd. have instructed Geotechnical & Environmental Consulting Ltd. (GEC) to undertake a Stability Risk Assessment (SRA) in support of an application for a bespoke Waste Recovery Permit in respect to the permanent placement of inert waste at Castle Hill Quarry, Cannington, Bridgewater, TA5 2QF.

1.3 This waste recovery permit application is for the permanent deposit of inert waste to land to facilitate the infilling and restoration at two specific areas within the quarry site following the extraction of limestone mineral.

1.4 The following documents have been supplied by the Client and referred to in the compilation of this Report: -

- Castle Hill Quarry Hydrogeological Risk Assessment for Waste Recovery Permit. Tetra Tech Report No. 784-B043634 dated January 2023. Rev. 001 (Draft).

- Castle Hill Quarry-Environmental Setting and Site Design. Tetra Tech , September 2022. Tetra Tech Report No.784- B043634 dated February 2023. (Final).

1.5 This Report has been completed in conjunction with the Environmental Setting and Site Design Report. It is not a standalone document and factual data related to the site, its setting and receiving environment are located in the ESSD and referred to in this document. All drawings referred to in this SRA are to be found in the ESSD unless otherwise stated.

1.6 This document has been prepared in accordance with the Stability Risk Assessment Report Template (Version 1 – March 2010) which addresses the guidance presented at: https://www.gov.uk/guidance/landfill-operators-environmental-permits/how-to-do-a-stability-risk-assessment-landfill-sites-for-inert-waste-or-deposit-for-recovery-activities.

Conceptual Stability Site Model

<u>Location</u>

1.7 The application area is situated within the wider Castle Hill Quarry site, which is located approximately 950m northwest of the village of Cannington in Bridgewater, Somerset. The site is centred at approximate National Grid Reference (NGR) 324834 140637 (Figure SRA1)

1.8 This Stability Risk Assessment refers to two areas within the Castle Hill Quarry site. Details of the site layout are presented in Figure SRA2.

Figure SRA1 Site location plan

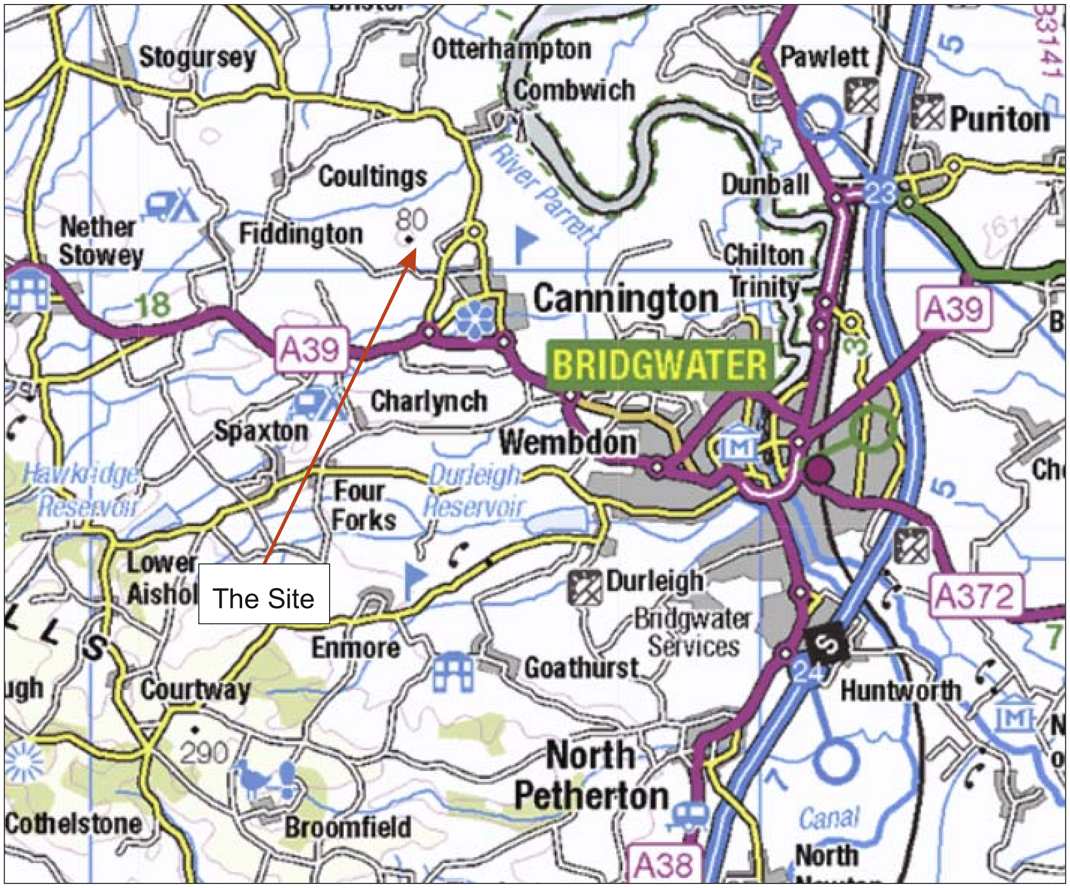
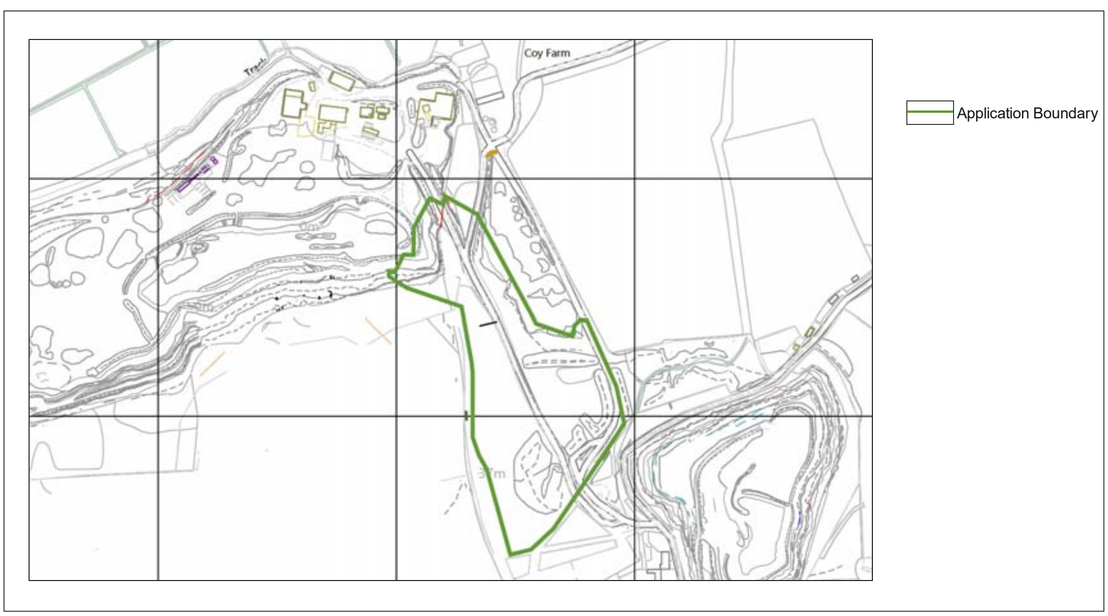


Figure SRA2 Site layout plan



The immediate surroundings of the application site comprise woodland and agricultural land with commercial properties located to the immediate south of the proposed site.

1.9 Access to the site is to the south off of Brymore Way via Chad;s Hill and a dedicated haul road.

1.10 This application relates to two extension areas at the quarry. The first area (known as 'Eastern Extension') is located to the southeast of the existing quarry and is centred at approximate NGR 324834 140637. The second area (known as 'Old Golf Course Extension' is located to the south of the Eastern Extension and is centred at approximate NGR 324834 140637.

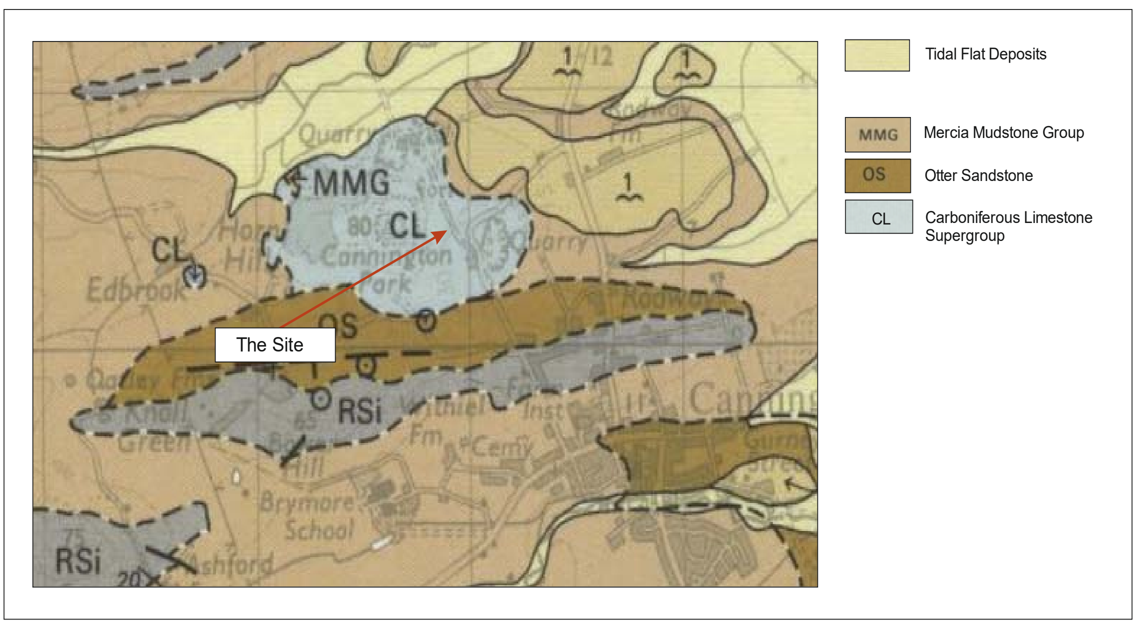
1.11 The proposed Waste Recovery Permit application area covers approximately 4.2ha and is entirely within the existing Castle Hill Quarry area.

<u>Regional Geology</u>

Solid Geology

1.12 With reference to British Geological Survey Sheet 295 Taunton 1::50,000 Solid and Drift, the site is located on an inlier of Carboniferous Limestone surrounded younger Triassic Strata of the Mercia Mudstone Group and the Otter Sandstone.

Figure SRA3 Geology of the site area – after NERC 2022



1.13 The BGS Lexicon of Named Rock Units describes the Carboniferous Limestone Supergroup (CL) as being dominated bioclastic to micritic, bioturbated with common shelly, crinoidal and algal beds of limestone and coral biostromes which are darker grey, and commonly dolomitised in the lower part.

The upper part is dominated by paler grey, thinner-bedded limestones with common palaeokarst surfaces, overlain by clay wayboards, which are possible weathered bentonites. Sandstone is locally common, particularly in the upper part of the Supergroup.

Superficial Geology

1.14 The BGS mapping does not indicate any superficial deposits to be present across the application area. Although Tidal Flat Deposits are shown to outcrop immediately to the north of the existing Castle Hill Quarry workings.

1.15 Structural Geology

1.16 There are no structural features shown within the area of the site. BGS Sheet 295 indicates an apparent regional dip of the stratum to be towards the southwest

Local Geology

1.17 Carboniferous Limestone (Figure SRA3) is anticipated to be present under the entire quarry complex inclusive of the application area, with the overlying Mercia Mudstone outcropping directly to the northeast.

1.18 Exposures of the Carboniferous Limestone within the adjacent quarry workings show it to be massive with orthogonal jointing, comprising two near vertical joint sets forming sub-vertical quarry faces.

1.19 At Cannington Park Quarry, approximately 300m southeast of the Application Area, the bedding of the Carboniferous Limestone has an apparent dip to the east Sedimentary (Red stained (Neptunian) dykes are present however other karstic features are uncommon in the exposed faces. Except for a small cave in the workings near the top of Castle Hill Quarry no large voids have been found within the quarried areas.

1.20 Various boreholes have been undertaken in and around the area of the Castle Hill Quarry site, including 4no.boreholes undertaken as part of an investigation of the quarry complex. Pertinent conclusions that can be drawn from these investigation boreholes are:

- There are no superficial deposits overlying the limestone at the quarry complex location other than a layer of topsoil which varies in thickness from around 0.30 to 3.00m

- Weathered limestone underlies the Topsoil and attains thicknesses of up 4.40m thick, followed by limestone to the base of each borehole which were progressed to depths of up to 55 mbgl.

Hydrology

1.21 2no. (two) surface water features, reported in the Hydrogeological Risk Assessment, were identified within 1km of the centre of the site. Details of these features are summarised in Table SRA1 below.

Table SRA1 Surface water features within 1km of the site

Name	Direction from Site	Distance	Observations
Fiddington Brook	North	0.55km	Northern part of the application area lies within catchment area of Fiddington Brook
Cannington Brook	South	1.00km	

Hydrogeology

1.22 According to the Multi-Agency Geographic Information for the Countryside's (MAGIC) website, the Carboniferous Limestone Supergroup is designated as a Principal Aquifer: which is defined as layers of rock or drift deposits that have high intergranular and / or fracture permeability.

1.23 According to the Multi Agency Geographic Information for the Countryside (MAGIC) website, the proposed site is not situated within a Groundwater Source Protection Zone (GSPZ).

1.24 The Hydrogeological Risk Assessment indicates that groundwater levels will be between 7.00 and 8.05mOD in the area of the application site. The ESSD states that the limestone will be extracted to a basal level of 6.0mOD which means in order to work in a dry environment dewatering of the void will be required.

Deposition Models

1.25 The inert waste placement will comprise the importation of inert waste for infilling the quarry void that has been created from mineral extraction activities at the site.

1.26 Extraction and progressive restoration in the Eastern Extension Area will commence in the northwestern section that adjoins the existing quarry site. Works will proceed progressively in a south easterly direction towards the Old Golf Course Extension Area.

1.27 Extraction and progressive restoration in the Old Golf Course Extension Area will commence from the quarry face in the Eastern Extension Area and progress in a south easterly direction in 3 Phases (as shown on Drawing Numbers CHQOGC2109/6/A, CHQOGC2109/7/A and CHQOGC2109/8/A.

Basal Subgrade Model

1.28 The void associated with this permit application will be created by the extraction of limestone from units of the Carboniferous Limestone Supergroup.

1.29 The basal subgrade will comprise the in-situ limestones of the Carboniferous Limestone Supergroup, which is considered, subject to pre-placement inspection, a competent stratum.

1.30 The ESSD indicates the base of the extraction void will be at 6.00mOD.

1.31 Groundwater monitoring reported in the Hydrogeological Risk Assessment recorded a maximum elevation at 8.05mOD. Groundwater levels post-dewatering are shown on the Client supplied cross-sections to be at 5.5mOD, 0.50m below the base of the extraction void.

Basal Lining System

1.1 A geological barrier (attenuation layer) is a requirement for all landfills according to the Landfill Directive (1999/31/EC) and must provide sufficient attenuation to prevent a risk to soil and groundwater.

1.2 Prior to the commencement of landfilling, a geological barrier will be engineered using suitable imported materials. The geological barrier will be constructed in compliance with the Landfill Directive and will have a hydraulic conductivity of less than 1m at 1 x 10^{-7} m/s or an Environment Agency approved equivalent of 0.5m at 5 x 10^{-8}m/s.

Side Slope Subgrade Model

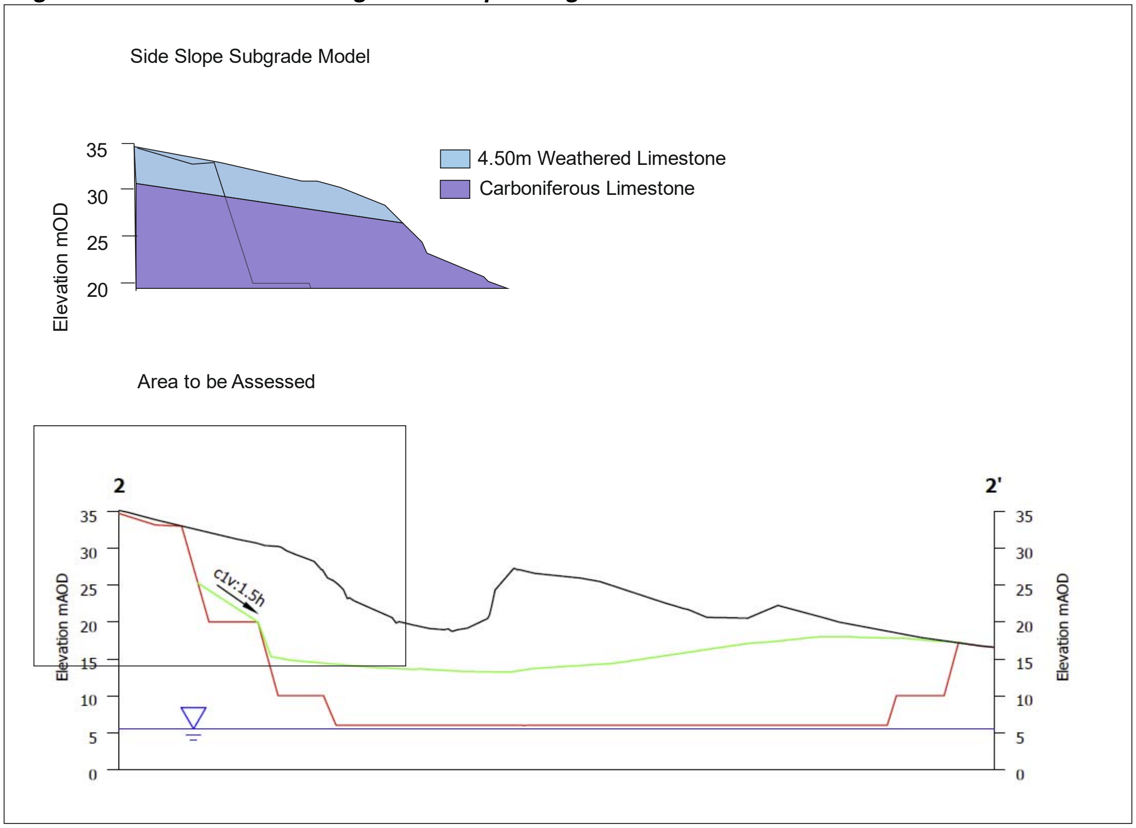
1.3 The side slope subgrade model will comprise the Carboniferous Limestone Supergroup comprising massive bioclastic / micritic limestone. However, local boreholes have shown there to be potentially up to 4.50m of weathered limestone likely comprising rubbly material above the massive limestone beds.

1.4 Based on information supplied by the Client the highest side slope will be approximately 29m with a benched batter angle of 45° (1H : 1V). This represents an average across the slope as some of the massive limestones of the Carboniferous Limestone Supergroup will stand near vertically.

1.5 Dewatering will maintain groundwater 0.50m below the base of the extraction void at 5.50mOD and therefore will not act to destabilise the side slope subgrade.

1.6 A Geological cross section, compiled from information supplied by the Client, is presented as Figure SRA4 overleaf.

Figure SRA4 Section through side slope subgrade



Side Slope Lining Model

1.32 The Environmental Permitting Regulations (England and Wales) 2016 (as amended) specify that an attenuation layer to prevent leachate migration must be present at the base and sides of sites which accept inert materials for deposition. Therefore, a geological barrier (attenuation layer) will be installed on top of the Carboniferous Limestone across the base of the extraction void.

1.33 The barrier will be constructed using suitable imported materials which will either be 1m in thickness a permeability no greater than $1x10^{-7}$m/s or its EA approved equivalent of 0.5m with a permeability of no greater than $5x10^{-8}$m/s. In situ testing and sampling will be undertaken to ensure that the imported material is suitable for this purpose.

1.34 The proposed construction of the clay liner would be to the specification detailed in the Construction Quality Assurance (CQA) Plan that will be submitted to the Agency for approval prior to engineering taking place.

Inert Waste Mass Model

1.35 It is proposed that the Castle Hill Quarry extensions will be used for the placement of inert materials only.

1.36 The inert material is liable to comprise locally derived arisings from earthworks, foundation construction works and demolition debris.

1.37 The geology of the local area is variable and comprises both coarse- and fine-grained materials. Most of the inert materials are likely to comprise locally derived materials. With respect to stability the worst case would be a waste mass comprised entirely of fine-grained materials. Therefore, the inert material model will comprise a generic fine-grained material and the characteristic geotechnical parameters attributed to this material will be based on a number of sources.

Table SRA2 Bibliography of Published sources used in the determination of the characteristic geotechnical parameters of the inert waste

Author	*Date*	*Title*
Carter M., & Bentley S.P.	*2016*	*Soil Properties and Correlations 2nd. Ed.*
Look B.	*2007*	*Handbook of Geotechnical Investigation and Design Tables*
Duncan J.M., & Wright, S.G.	*2005*	*Soil Strength & Slope Stability*
CIRIA C583	*2004*	*Engineering in the Lambeth Group[1]*
Hight D.W., McMillan, F, Powell, J.J.M., Jardine, R.J., & Allenou, C.P.	*2003*	*Some Characteristics of the London Clay: In Tan et al. (Eds.) Characterisation and Engineering Properties of Natural Soils.[1]*

[1] the inclusion of these two strata specific references should not be taken as a suggestion of the Inert Waste content.

1.38 The maximum inert waste slope will be restricted to 1(v):2(h).

1.39 The waste will be compacted in horizontal layers across the base of the cell to the approved pre-settlement restoration level.

Capping System Model

1.7 On completion of filling to final levels, the site will be capped with restoration soils and not less than 0.30m of topsoil. In accordance with the requirements of the Landfill Directive, an engineered cap (clay or plastic) is not required.

2.0 STABILITY RISK ASSESSMENT

Risk Screening

Basal Subgrade Screening

2.1 The basal subgrade will be formed of the in-situ Carboniferous Limestone Supergroup. This Stratum is considered to be a competent rock which will not undergo any noticeable settlement during or post placement of the inert waste.

2.2 Provided careful inspection of the basal subgrade is carried, with particular attention to any karstic features, prior to the placement and compaction of the basal liner, further consideration of this component is not considered necessary.

Basal Lining System Screening

2.3 An engineered basal lining system (attenuation layer) is to be installed across the inert landfill area at approximately 6mOD.

2.4 Where the liner is placed on the competent materials of the Carboniferous Limestone Supergroup no further analysis of this component is considered necessary.

2.5 Standing groundwater has been recorded between 7.00 and 8.05mOD which is above the base of the extraction void and level of the basal liner. Although dewatering of the site is proposed, consideration of the hydrostatic uplift forces that may be generated on the underside of the basal liner will require further investigation.

Side Slope Subgrade Screening

2.6 The side slopes will be formed as part of the extraction process which has been carried out by a competent quarrying company. These works will be subject to ongoing inspection (Regulation 33) part of which would be to assess the stability of the side slope subgrade. Therefore, the side slope subgrade will be in a stable configuration at the onset of inert waste placement and given the stratigraphy and description of the side slope subgrade it is unlikely that the materials will become unstable during the inert waste placement phases of the works. However, a stability check of the side slope subgrade will be carried out for completeness and to determine a long-term stable angle of repose.

2.7 Side slope subgrade instability is likely to be limited to the upper weathered Carboniferous Limestone which will be considered as a 4.50m thick superficial layer. Therefore, the stability analyses will focus on these potentially loose granular materials.

Side Slope Lining System Screening

2.8 An artificially established side-slope lining system, comprising either 1.00m of fine-grained material with a hydraulic conductivity of less than 10^{-7}m/s or its Environment Agency approved equivalent, is to be placed on the side slopes of the extraction void. Given the gradient of the side slope subgrade it is probable that the side slope lining system will be placed in sections; such that the side slope liner will not achieve fully drained conditions prior to the placement of inert waste.

2.9 Groundwater outflows into the void are not expected as standing groundwater level is a minimum of 8.00mOD and dewatering is to be undertaken to lower it to 5.50mOD.

2.10 Analysis of this component is considered necessary to investigate the short-term and long term stability of this element prior to the placement of the inert waste.

Waste Mass Screening

2.11 This component is considered to be an issue that will require a detailed geotechnical analysis in order to assess the stability of the waste mass.

Capping System Screening

2.12 As detailed on the restoration scheme (Drawing Number 2109_006.012_CHILL025_OGC Rest Plan) the site will be restored to woodland calcareous grassland with some native hedgerows.

2.13 The proposed finished contours indicate a maximum slope at 1(V) : 3(H) in the north of the site adjacent to the existing quarry. Provided a maximum gradient of 1(V) : 3(H) (17°) is not exceeded the finished restoration profile will remain stable under all foreseeable conditions and requires no specific stability analysis.

Justification of Modelling Approach and Software

2.14 Two-dimensional limiting equilibrium stability analyses will be used in the assessment of the stability of the various components of the proposed landfill facility at Coombefield North Quarry. The method of analysis used in each particular case was determined from an examination of the form of failure being considered.

2.15 The stability analyses were carried out using the Slope/W computer programme.

2.16 The Morgenstern and Price Method was used in the analyses to determine the Degree of Utilisation against instability for both total stress and effective stress conditions.

Justification of Geotechnical Parameters Selected for Analyses

Parameters Selected for Side Slope Subgrade Analyses

2.17 The side slope subgrade will comprise both the Weathered Carboniferous Limestone / overburden and the massive limestones of the Carboniferous Limestone Supergroup. During the site walkover, no evidence of kinematic failure (toppling, sliding and wedge) was seen in the adjacent Castle Hill Quarry . Therefore, for the purposes of the stability assessment the Carboniferous Limestone Supergroup will be considered as bedrock and the stability analyses limited to the overlying weathered material. It is assumed that all Topsoil will be stripped and stockpiled prior to the onset of excavation works.

2.18 Considering the worst case, where 4,50m of weathered Carboniferous Limestone is present above the intact material, the following characteristic geotechnical parameters are considered appropriate (Table SRA3).

Table SRA3 Side Slope Subgrade Stability – Summary of Characteristic Geotechnical Data

Material	Description	Unit Weight	Total Stress		Effective Stress	
		γ (kN/m^3)	c_u (kN/m^2)	ϕ_u (°)	c′ (kN/m^2)	ϕ' (°)
Weathered Carboniferous Limestone	slightly silty sandy GRAVEL/gravelly SAND	18	Not Applicable Granular Material		5	36
Carboniferous Limestone Supergroup	Impenetrable Bedrock					

Parameters Selected for Side Slope Liner Analyses

2.19 The side slope liner is to be constructed using an appropriate imported fine-grained material. Typical values for a fine-grained material have been used to define the characteristic geotechnical values of the side slope liner material (Table SRA4).

Table SRA4 Side Slope Liner Stability – Summary of Characteristic Geotechnical Data

Material	Unit Weight	Total Stress		Effective Stress	
	γ (kN/m^3)	c_u (kN/m^2)	ϕ_u (°)	c′ (kN/m^2)	ϕ' (°)
Side Liner	19	50	0	5	25

Parameters Selected for Waste Analyses

2.20 The Parameters of the inert waste appropriate for this site were selected on the basis of the information presented in the various publications listed in Table SRA2. As stated previously the inclusion of stratum-specific references should not be taken as guidance to what may be included within the Inert Waste but purely as another source to help define a generic fine-grained material. In reality, it is likely to comprise a mixture of fine-and coarse-grained materials and demolition materials. Therefore, the treatment of the inert waste as fine-grained will be the worst-case as the inclusion of any coarse-grained material will increase its characteristic angle of shearing resistance.

Table SRA5 Waste Mass Stability - Summary of Characteristic Geotechnical Data

Material	Unit Weight	Total Stress		Effective Stress	
	γ_k (kN/m^3)	c_u (kN/m^2)	ϕ_{uk} (°)	c'_k (kN/m^2)	ϕ'_k (°)
Waste Mass	17	50	0	5	25

Selection of Appropriate Factors of Safety

2.21 The stability analyses have been carried out in accordance with EC7. The United Kingdom have adopted Design Approach 1 (DA1) Combination 1 & 2 (C 1 & 2) whereby partial factors are applied to either the actions or the material properties and a resultant factor of safety of 1.00 is required.

Table SRA6 Partial Factors used in Design in Accordance with the UK National Annex to EC7

Design Approach	Combination	Partial Factor Sets	Partial Factor Value			
1	1	A1 + M1 + R1	Actions A1			
			Permanent (G)	Unfavourable	$\gamma_{G;dst}$	1.35
				Favourable	$\gamma_{G;stb}$	1.00
			Variable (Q)	Unfavourable	$\gamma_{Q;dst}$	1.50
				Favourable	$\gamma_{G;dst}$	0
			Materials M1			
			Coefficient of shearing resistance (*tanϕ*)		$\gamma_{\phi'}$	1.00
			Effective cohesion (*c'*)		$\gamma_{c'}$	1.00
			Undrained shear strength (c_u)		γ_{cu}	1.00
			Resistance R1			
			Resistance		$\gamma_{R;e}$	1.00
	2	A2 + M2 + R1	Actions A2			
			Permanent (G)	Unfavourable	$\gamma_{G;dst}$	1.00
				Favourable	$\gamma_{G;stb}$	1.00
			Variable (Q)	Unfavourable	$\gamma_{Q;dst}$	1.30
				Favourable	$\gamma_{G;dst}$	0
			Materials M2			
			Coefficient of shearing resistance (*tanϕ*)		$\gamma_{\phi'}$	1.25
			Effective cohesion (*c'*)		$\gamma_{c'}$	1.25
			Undrained shear strength (c_u)		γ_{cu}	1.40
			Resistance R1			
			Resistance		$\gamma_{R;e}$	1.00

2.22 The values of the partial factors used are termed “nationally determined parameters” and EC7 (as published by CEN) allows these to be specified in National Annexes which recognise regional variations in design philosophy.

2.23 LFE4 – Earthworks in Landfill Engineering – Chapter 2 confirms the adoption of Design Approach 1 Combinations 1 and 2, and the nationally adopted partial factors.

Analyses

Basal Subgrade and Basal Liner

2.24 The base of the of the inert waste landfill will be formed at 6mOD within the Carboniferous Limestone Supergroup which is considered a competent rock material.

2.25 Groundwater levels presented in the Hydrogeological Risk Assessment indicate that standing groundwater level are between 7.00 and 8.05mOD. Whilst cross section through the void shows the dewatered level to at 5.50mOD, 0.50m below the base of the void.

2.26 Using a simple hydrostatic balance equation, if dewatering was to cease the uplift force on the underside of the basal liner will be :

height of groundwater above base of void x unit weight of water

$$(8.05-6.00) \times 9.81 = 20kN/m^2$$

The thickness of material required to overcome the hydrostatic uplift would be:

(thickness of basal attenuation layer x unit weight) + (thickness of inert waste x unit weight)>20kN/m^2).

Assuming worst case:

20 – (0.5 x19) = 10.5kN/m^2.
10.5/17 = 0.62m inert waste

Therefore, it is recommended that to avoid uplift of the basal attenuation layer dewatering of the void is continued until a minimum of 1.00m of inert waste is place above the basal attenuation layer.

<u>Side Slope Subgrade</u>

2.27 The side slopes of the void will have been formed during the mineral extraction phase of the works and have been subject to ongoing stability assessment and inspection. However, for completeness a stability assessment of the side slope subgrade has been carried out.

2.28 Groundwater monitoring has shown a maximum elevation of the standing groundwater to be at between 7.00 and 8.05mOD prior to dewatering which is shown on the cross-section supplied by the Client to be at 5.50mOD. Therefore, provided dewatering is maintained during inert waste placement, groundwater will not adversely affect the stability of the side slope subgrade.

2.29 The highest side slope subgrade will be ca 29m formed with a benched profile at a maximum overall gradient of 1(v):1(h). As discussed previously, only the upper 4.50m of the side slopes subgrade (weathered Carboniferous Limestone) is considered to be at risk of instability with the lower 24.5m of the side slope subgrade comprising massive and bedded micritic limestones of the Carboniferous Limestone Supergroup.

2.30 The results of the side slope subgrade stability analyses are shown in Table SRA7 and the SlopeW worksheets presented in Appendix 1.

Table SRA7 Side Slope Subgrade Stability – Summary of Results

Run	File Name	Degree of Utilisation		Notes
		C1	C2	
As shown in Client Supplied Section 2-2'				
01	SSG1		4.32	Weathered limestone unstable at the gradient shown in Section 2-2'
Slacken Batter to 1(h): 1 (V)				
02	SSG2	0.88		Total & Effective Stress Analysis (Granular Material)
03	SSG3		0.98	

Side Slope Liner Analyses

2.31 A side slope liner will be placed against the side slope subgrade. Based on the results of the side slope subgrade analyses presented in Table SRA7 it is assumed that the side slopes are at 1(v) : 1(h) within the massive Carboniferous Limestone and battered back to 1(v) : 2(h) within the upper weathered Carboniferous Limestone. The liner will be modelled as a 1.00m thick layer applied to the side slope subgrade as this poses a more critical case than the 0.50m thick option.

2.32 The results of the side slope liner stability analyses are shown in Table SRA8 and the SlopeW worksheets presented in Appendix 2.

Table SRA8 Side Slope Liner Stability – Summary of Results

Run	File Name	Characteristic Shear Strength		Degree of Utilisation		Liner Thickness (m)	Notes
		c	ϕ	C1	C2		
Rotational Failure Entirely within Side Slope Liner							
01	SSL1	50	0	0.26		1.00	Total stress
02	SSL2				0.24		
03	SSL3	5	25	0.89		1.00	Full effective stress conditions
04	SSL4				0.99		
05	SSL5	5	25		0.25	1.00	5m lift buttressed with inert waste

Waste Mass Analyses

2.33 The post extraction void may be up to 30m deep; although it cross sections through the backfilled void show a maximum inert waste height of ca 24m (Section 4-4'). Although it is considered unlikely that a 24m high temporary waste face would be created given the phasing and placement of the inert waste in layers, to represent the worst case, a 24m high temporary waste slope will be considered in this analysis with waste faces during placement operations being restricted to 1(v) : 2(h).

2.34 Leachate pore fluid pressures may develop in the waste mass during filling due to infiltration. It is noteworthy that the term leachate as applied refers to direct precipitation or groundwater present within the inert waste at time of placement.

2.35 Given the composition (inert materials), landfill gas pressures are unlikely to develop within the waste mass.

2.36 Waste stability must be assessed as part of the design process for the temporary waste slope configuration. A Stability assessment is required for failure modes wholly within the waste body. The analyses of the failures wholly within the waste were based on Table 3.43 "Failure Wholly within the Waste" of the Environmental Agency R&D Technical Report P1-385/TR2.

2.37 Slope/W has been used to undertake the investigation into failures wholly within the waste mass for both total and effective stress conditions.

2.38 The effects of saturation of the waste mass have been modelled by reducing the cohesion to 0kN/m^2 and representing the waste mass as fully softened.

2.39 Results of the analyses are presented in Appendix 3 and are summarised in Table SRA9.

Table SRA9 Waste Mass Stability – Summary of Results

Run	File Name	Waste Strength	Leachate Condition	Degree of Utilization		Notes
				C1	C2	
1	WM1	Total	Dry	0.33		Total Stress
2	WM2				0.31	
3	WM3	Effective	Dry	0.43		Effective Stress
4	WM4				0.49	
5	WM5		Saturated	0.49		Cohesion = 0kN/m^2
6	WM6				0.58	

Assessment

Basal Subgrade

2.40 The basal subgrade is to comprise the in-situ limestones of the Carboniferous Limestone Supergroup which is considered competent rock stratum and therefore no settlement other than short term elastic recompression is expected, which will be built out during inert waste placement.

2.41 Therefore, subject to careful inspection prior to the placement of basal liner, the basal subgrade is considered appropriate without any significant re-engineering.

Basal Liner

2.42 The basal liner will consist of imported fine-grained materials comprising a 1m thick layer with a hydraulic conductivity of less than 10^{-7} m/s or its Environment Agency approved direct equivalent of 0.5m thick layer with a hydraulic conductivity 5 x 10^{-8} m/s.

2.43 The extraction void will be dewatered during waste placement to create a dry working environment. In order to avoid uplift and liner separation, this dewatering must continue until a a minimum of 1.00m of inert waste is placed above the basal liner.

2.44 No further assessment of the basal liner is considered necessary and the design presented herein is considered appropriate for the basal attenuation layer.

Side Slope Subgrade

2.45 The side slopes of the void have been formed as part of the mineral extraction works. It is appropriate to assume that the extraction works will be subject to geotechnical appraisal and as part of this appraisal it will be demonstrated that the side slope subgrade is stable at the angle of excavation.

2.46 However, a stability assessment of the side slope subgrade has been carried out. The stability of massive limestone subgrade is controlled by the orientation of the discontinuities in their rock masses and not by stresses as seen in the upper weathered beds of the side slope subgrade. Therefore, the side slope stability assessment has been limited to the upper beds of the side slope subgrade.

2.47 The results of the stability assessments indicate the side slope subgrade is unstable at the gradients shown on the Client supplied cross-sections. To ensure the stability of the upper slopes the weathered limestone beds will need to be battered back to a safe gradient.

2.48 The side slope stability analysis has shown that provided the side slope subgrade batter does not exceed 1(v) : 2 (h) in the weathered limestone, the side slope subgrade will remain stable under all foreseeable conditions.

Side Slope Liner

2.49 For the purposes of this stability assessment, initially the full height of the side slope liner has been modelled.

2.50 The 1.00m thick side slope liner has been analysed and shown to be stable in the short term under total stress conditions with a maximum degree of utilisation of 0.36 being returned under Combination 1 factoring.

2.51 If left unsupported in the long-term such that fully drained effective stress conditions are achieved the liner remains stable albeit with a degree of utilisation of 0.99 under Combination 2 factoring. Therefore, it is recommended that the liner is placed in advance of the inert waste placement and not left unsupported for long periods without buttressing with inert waste.(SLL5).

2.52 Dewatering will lower the groundwater below the base of the extraction void such that hydrostatic forces on the back of low permeability liner will not occur.

2.53 It can be concluded that side slope liner will remain stable under operational conditions provided it is not left exposed to become fully saturated. Visual monitoring of the side slope liner will be required in the form laid out in Section 3 of this SRA.

Waste Mass

2.54 The stability of the inert waste face was analysed using the computer programme SLOPE/W to calculate the degree of utilisation of the restoring forces to prevent failure through the waste body for a range of circular failure surfaces using Morgenstern and Price’s method.

2.55 The waste slope has a Degree of Utilisation of <1.00 (<100%) for both short term total stress conditions and long term effective stress conditions.

2.56 The waste slope continues to have a Degree of Utilisation of < 1.00 even when the material becomes fully softened and the value of the cohesion intercept reduces from 5kN/m^2 to 0kN/m^2.

2.57 It is concluded that a 1(v) : 2(h) waste slope will be stable for the range of conditions anticipated.

Capping System

2.58 Not a consideration at this site.

3.0 MONITORING

The Risk-Based Monitoring Scheme

3.1 Monitoring of the stability of the site is proposed in the form set out below. The objectives are to identify any instances of overall settlement of the structure, identify instability of the waste mass itself and instability of the side slope subgrade and lining system at the earliest possible juncture.

Basal Subgrade Monitoring

3.2 Prior to the placement any inert waste, it is recommended that the basal subgrade is carefully inspected. Special attention should be paid to the presence of any karstic solution features. If evidence of such features is observed, they should be remediated by the placement of a compacted granular fill to base of void level prior to the placement of the basal liner.

Basal Liner Monitoring

3.3 The basal liner is to comprise either 1.00m or 0.50m of imported fine-grained material.

3.4 Careful inspection of the basal liner should be carried out prior to inert waste placement to ensure the fine-grained material has not become cracked as a result of drying out.

3.5 To avoid shrinkage and cracking in hot weather a layer of inert waste should be placed over the basal liner or in the absence of suitable waste material a protective geotextile could be used.

Side Slope Subgrade + Lining Monitoring

3.6 The side slopes should be visually monitored for instability during the waste placement operations with special attention being paid to the upper slopes where and if weathered limestone is present. In the event of any instances of instability, appropriate action should be taken which may include battering back the upper slopes or buttressing the slope using inert waste material or undertaking minor dentition works.

3.7 Provided the side slope liner is properly compacted and not left exposed for extended periods of time the side slope lining system will remain stable in the short term. However, this does not preclude the need for regular inspection with particular attention being paid to separation between the liner and the side slope subgrade. If this, or any other instability is identified in the side slope liner, it should be buttressed with Inert Waste.

Waste Mass Monitoring

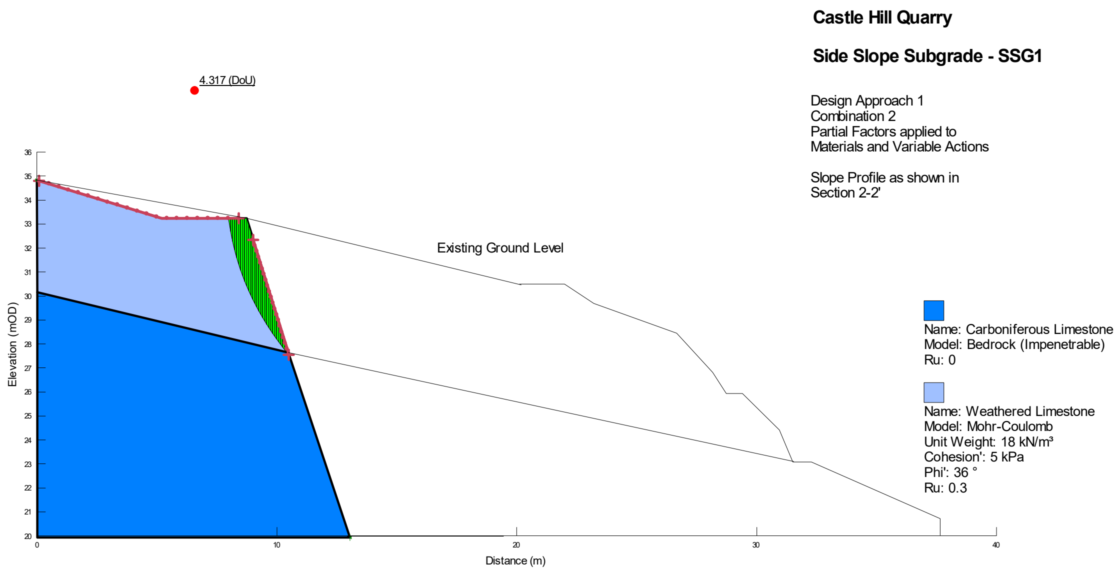
3.8 The temporary slopes in the waste should be visually monitored and appropriate actions taken on any sign of instability. This would typically include a reduction in slope angle of the temporary waste slopes.

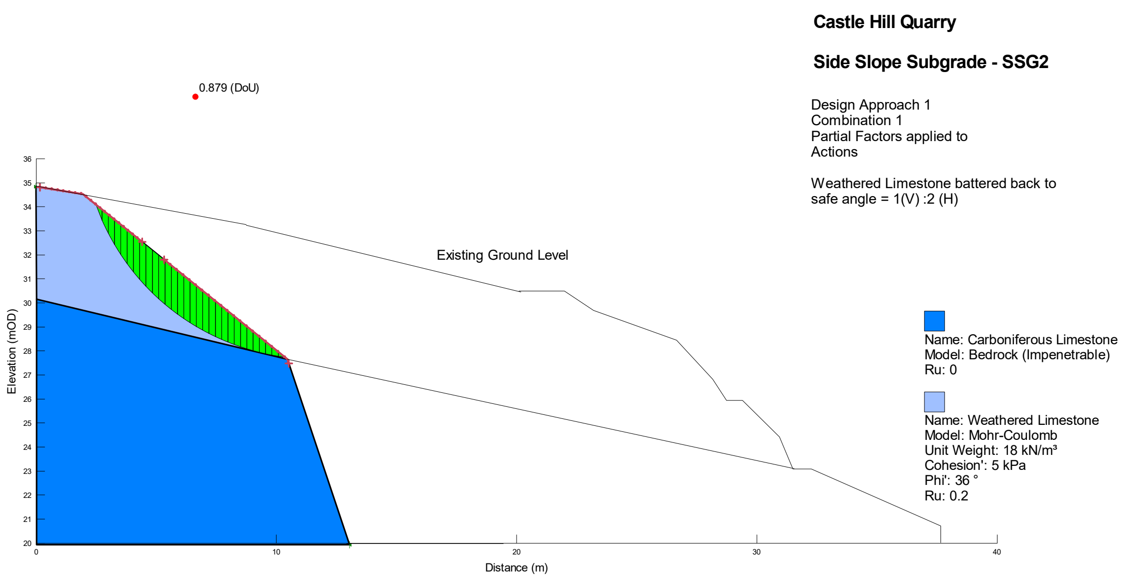
Restoration Soils and Finished Surface Monitoring

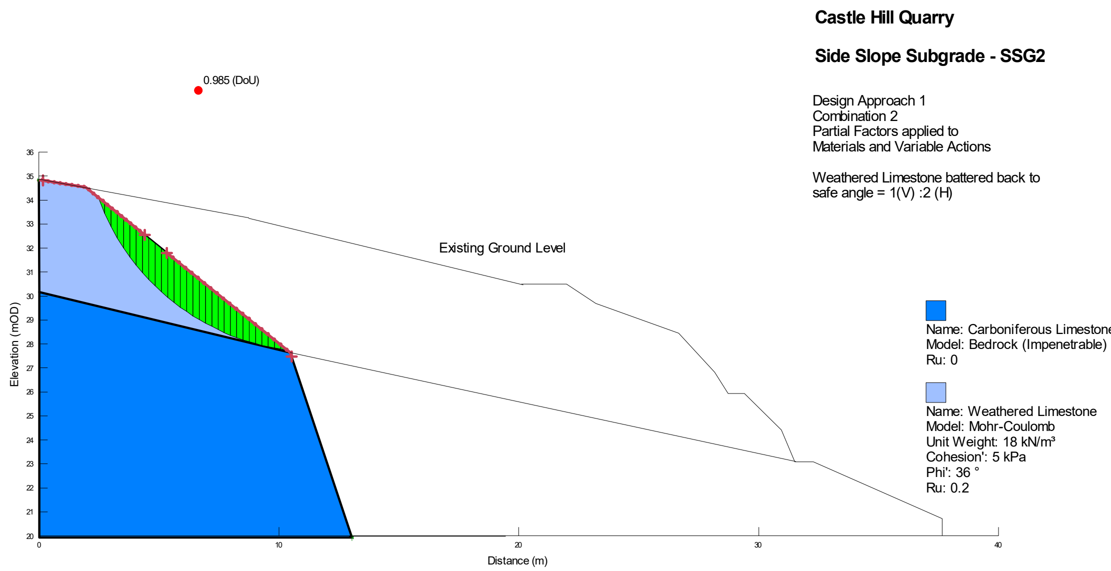
3.9 EA Guidance 'Landfill and deposit for recovery: aftercare and permit surrender' indicates that where records demonstrate that a recovery site has accepted only inert wastes during its lifetime, the site is applicable for a low risk surrender based on records alone. As such no further monitoring or post closure monitoring is deemed necessary. However, a site specific closure and aftercare plan has been complied and has been issued under separate cover.

Appendix 1

SlopeW Worksheets – Side Slope Subgrade

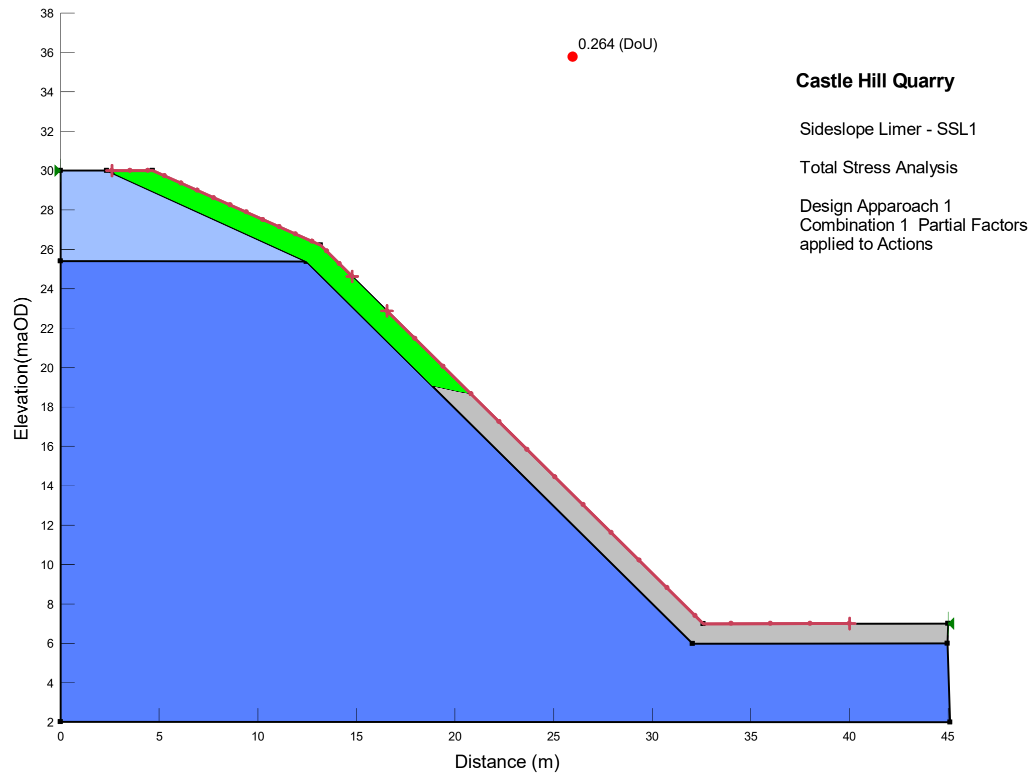

Castle Hill Quarry
Side Slope Subgrade - SSG1
Design Approach 1
Combination 2
Partial Factors applied to
Materials and Variable Actions
Slope Profile as shown in
Section 2-2'
4.317 (DoU)
Existing Ground Level
Name: Carboniferous Limestone
Model: Bedrock (Impenetrable)
Ru: 0
Name: Weathered Limestone
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 5 kPa
Phi': 36 °
Ru: 0.3
Elevation (mOD)
Distance (m)

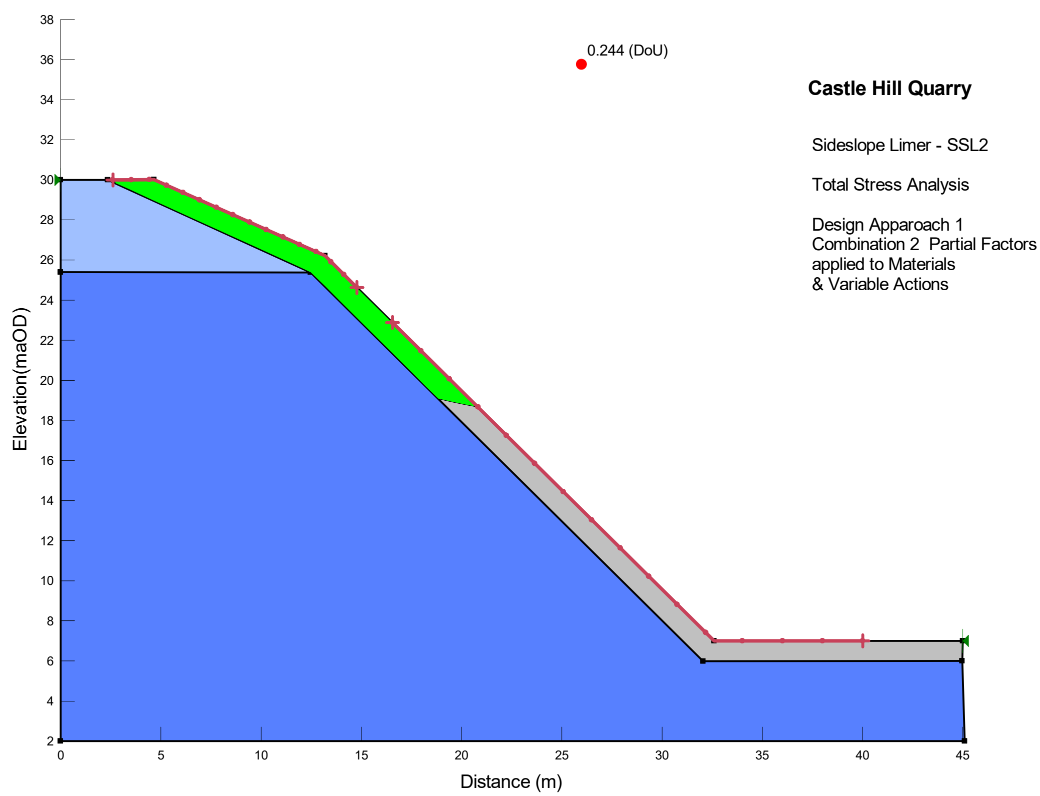

Castle Hill Quarry
Side Slope Subgrade - SSG2
Design Approach 1
Combination 1
Partial Factors applied to
Actions
Weathered Limestone battered back to
safe angle = 1(V) :2 (H)
0.879 (DoU)
Existing Ground Level
Name: Carboniferous Limestone
Model: Bedrock (Impenetrable)
Ru: 0
Name: Weathered Limestone
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 5 kPa
Phi': 36 °
Ru: 0.2
Elevation (mOD)
Distance (m)

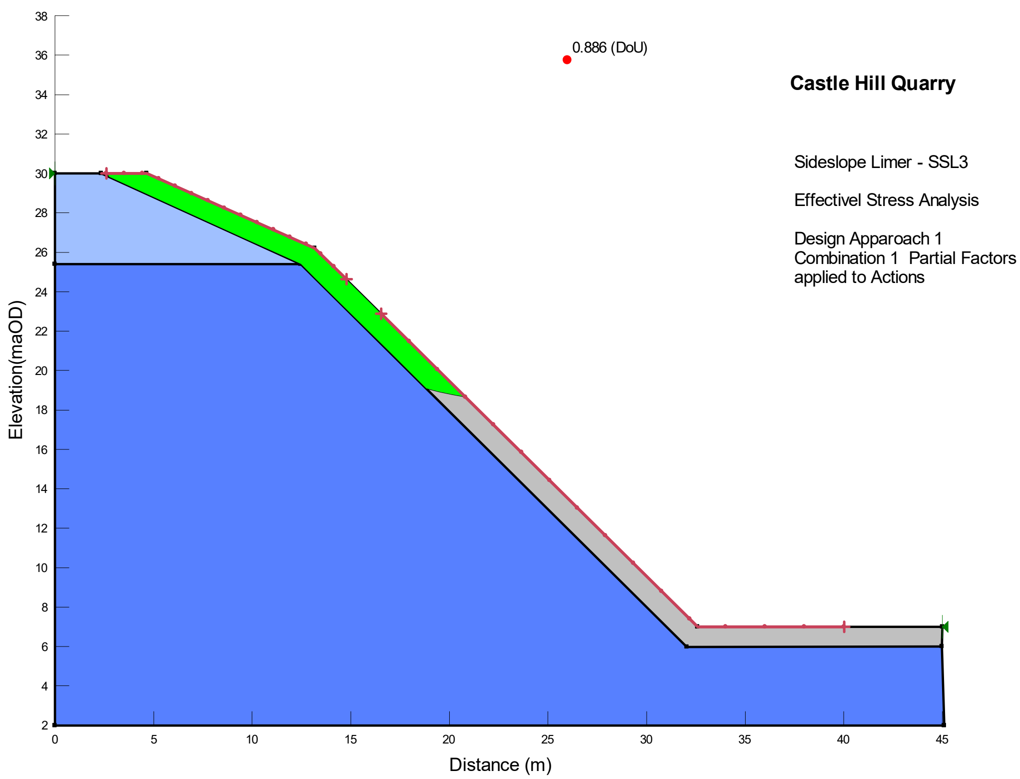

Castle Hill Quarry
Side Slope Subgrade - SSG2
Design Approach 1
Combination 2
Partial Factors applied to
Materials and Variable Actions
Weathered Limestone battered back to
safe angle = 1(V) :2 (H)
0.985 (DoU)
Existing Ground Level
Name: Carboniferous Limestone
Model: Bedrock (Impenetrable)
Ru: 0
Name: Weathered Limestone
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 5 kPa
Phi': 36 °
Ru: 0.2
Elevation (mOD)
Distance (m)

Appendix 2

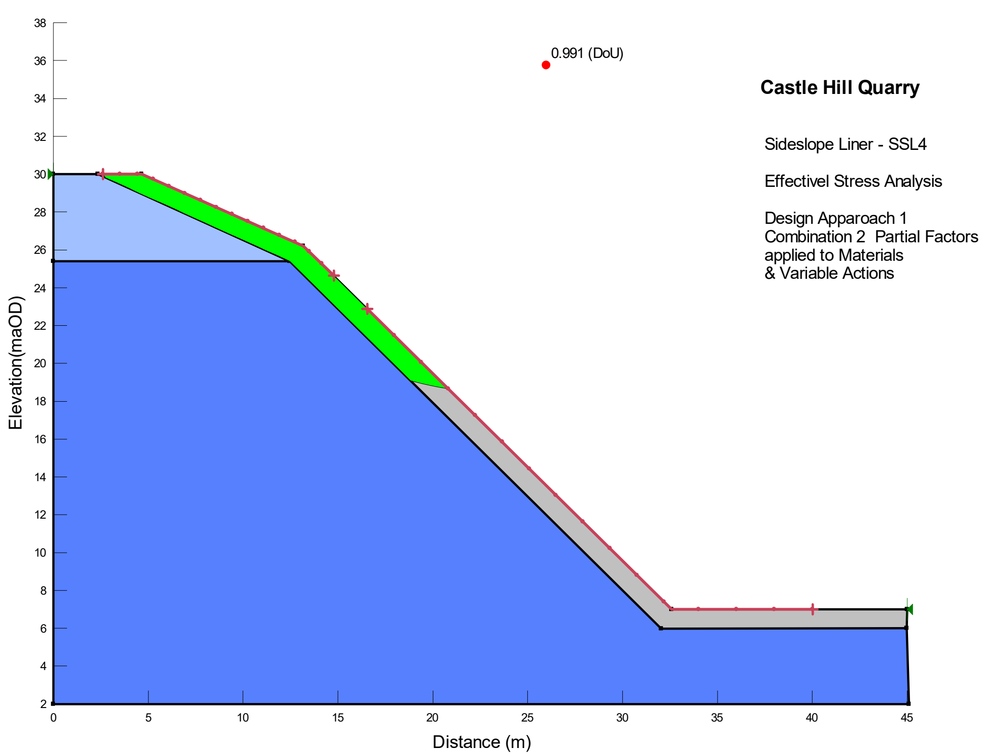
SlopeW Worksheets - Side Liner & Terminal Bund Stability


0.264 (DoU)
Castle Hill Quarry
Sideslope Limer - SSL1
Total Stress Analysis
Design Apparoach 1
Combination 1 Partial Factors
applied to Actions
Elevation(maOD)
Distance (m)

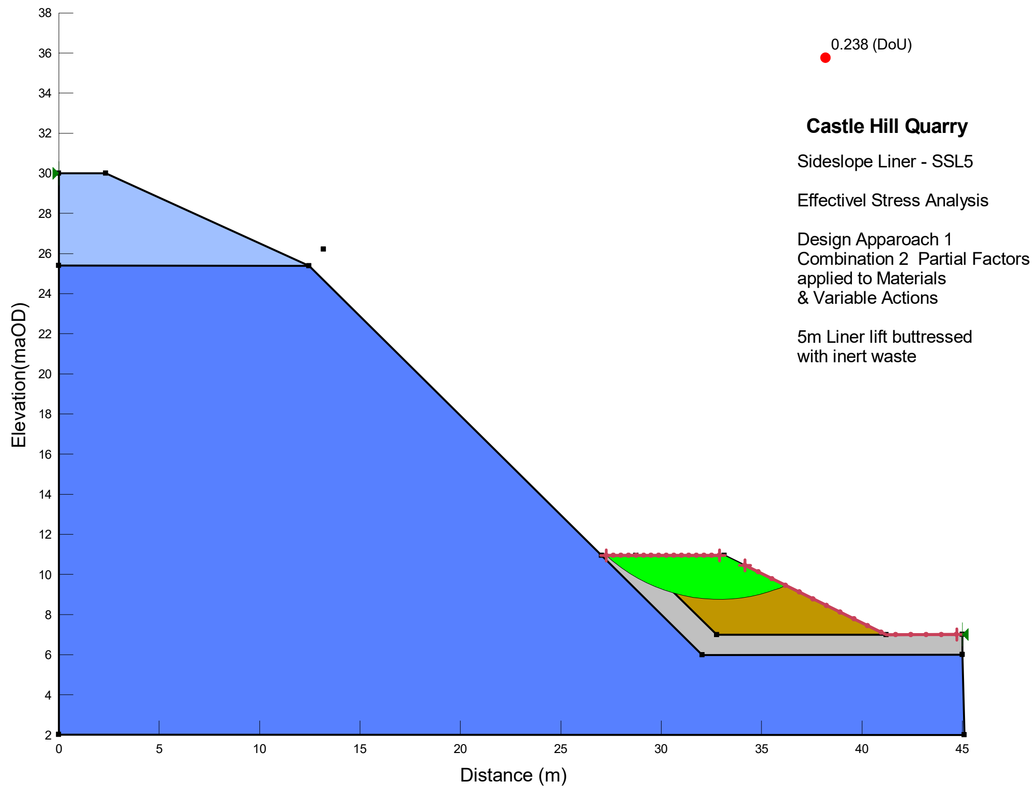

0.244 (DoU)
Castle Hill Quarry
Sideslope Limer - SSL2
Total Stress Analysis
Design Apparoach 1
Combination 2 Partial Factors
applied to Materials
& Variable Actions
Elevation(maOD)
Distance (m)



0.886 (DoU)
Castle Hill Quarry
Sideslope Limer - SSL3
Effectivel Stress Analysis
Design Apparoach 1
Combination 1 Partial Factors
applied to Actions
Elevation(maOD)
Distance (m)



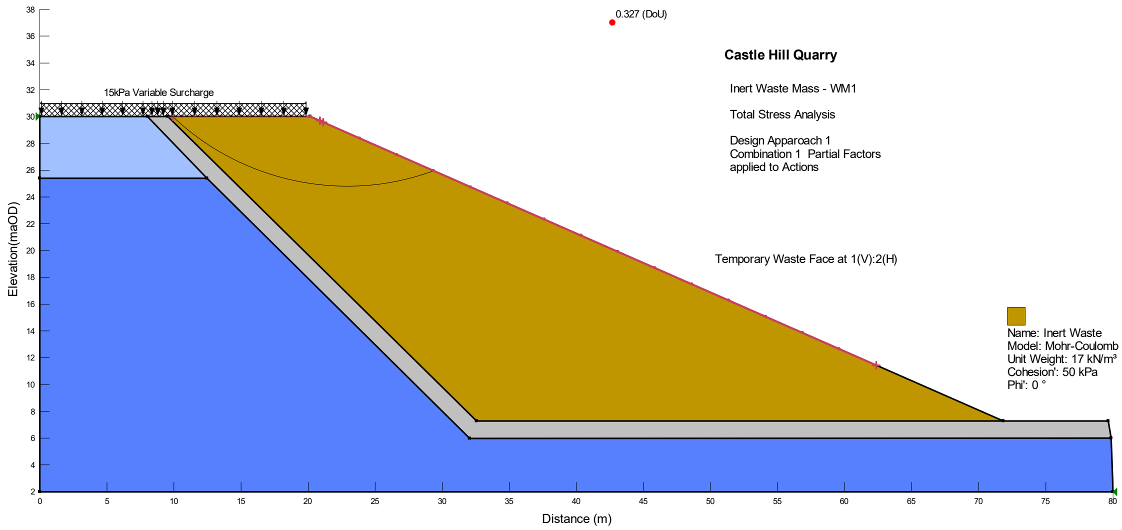
0.991 (DoU)
Castle Hill Quarry
Sideslope Liner - SSL4
Effectivel Stress Analysis
Design Apparoach 1
Combination 2 Partial Factors
applied to Materials
& Variable Actions
Elevation(maOD)
Distance (m)

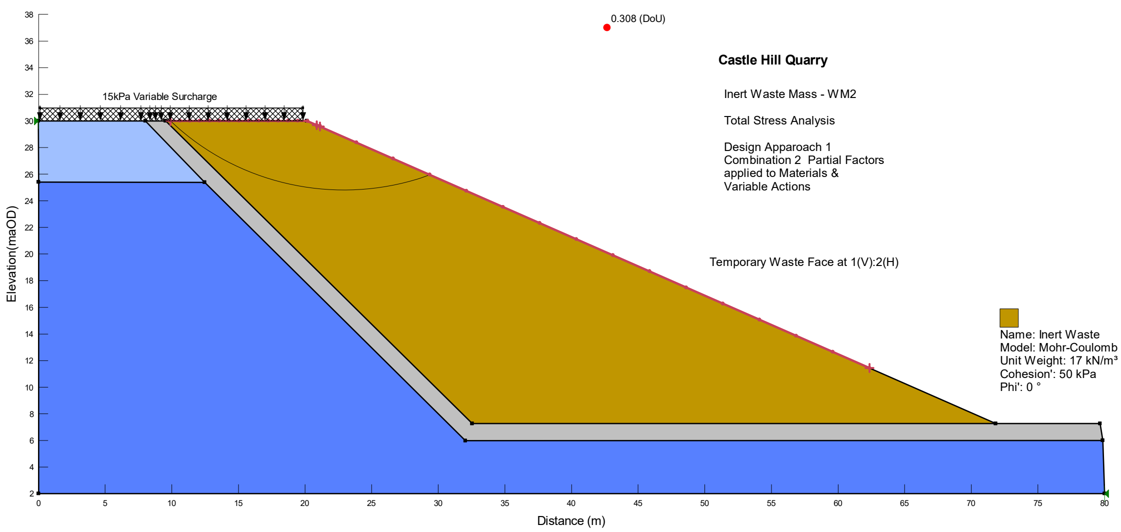


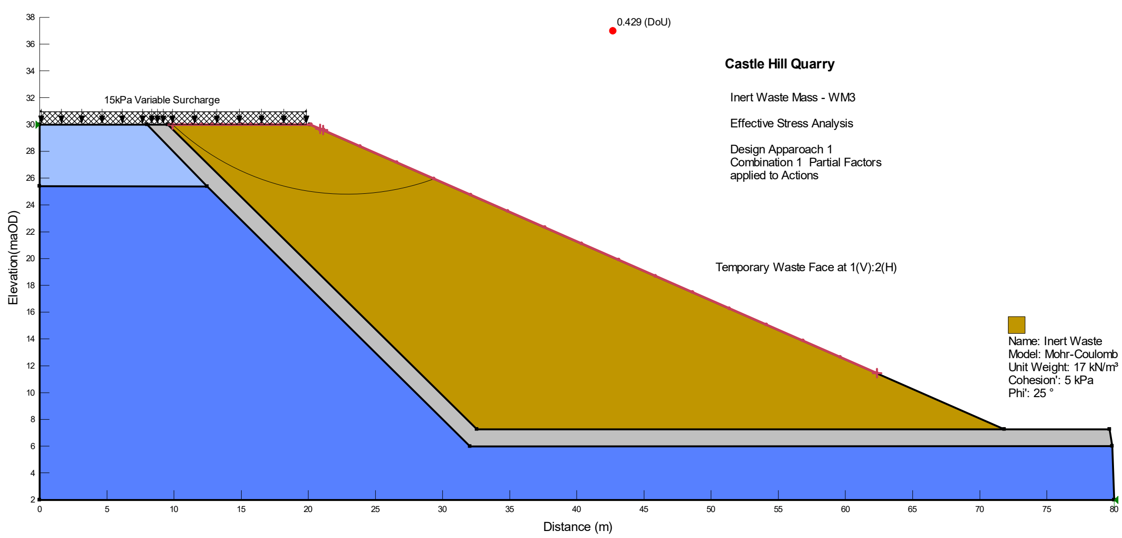
0.238 (DoU)
Castle Hill Quarry
Sideslope Liner - SSL5
Effectivel Stress Analysis
Design Apparoach 1
Combination 2 Partial Factors
applied to Materials
& Variable Actions
5m Liner lift buttressed
with inert waste
Elevation(maOD)
Distance (m)

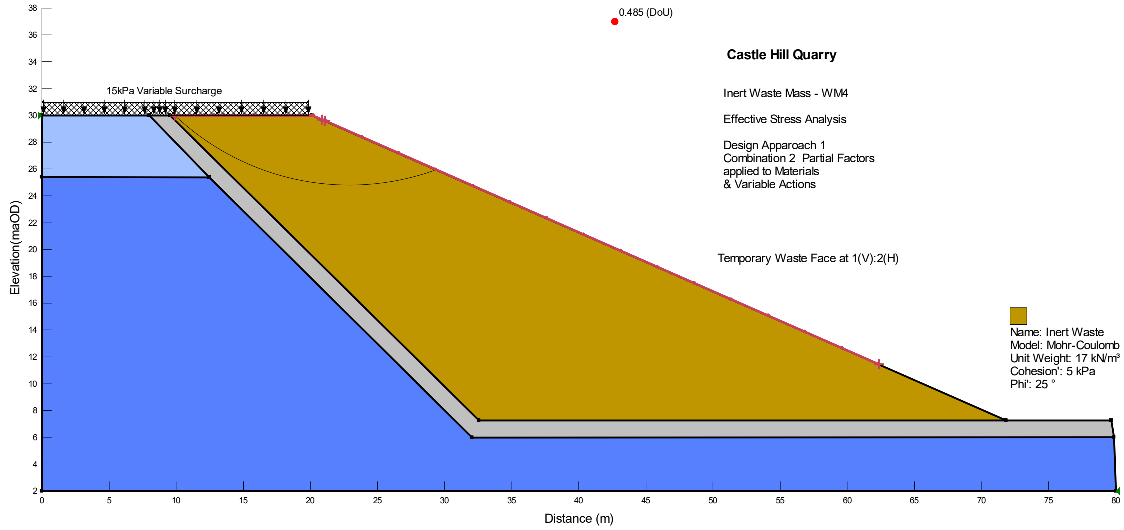
Appendix 3

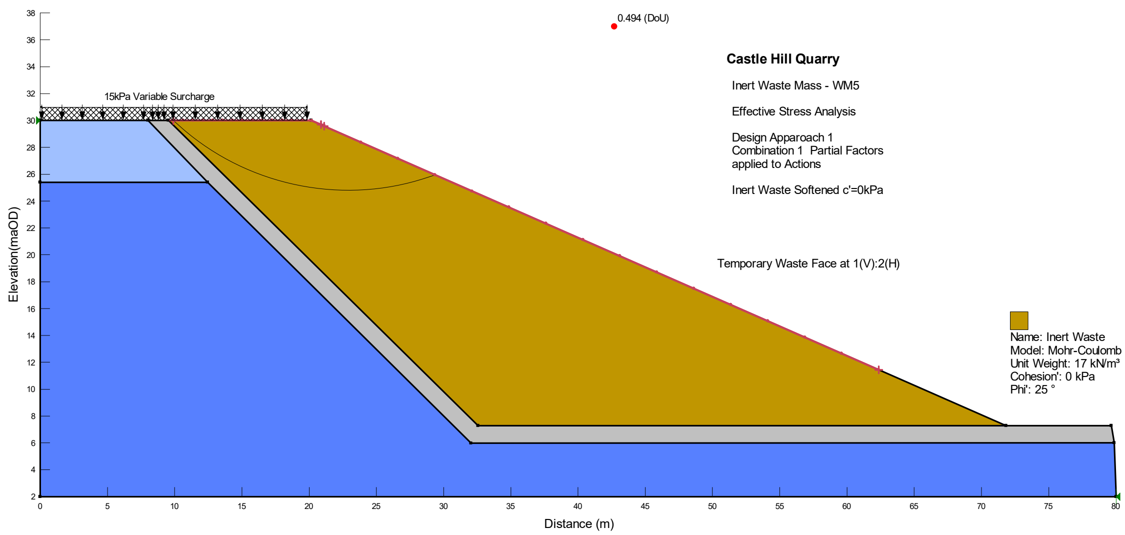
SlopeW Worksheets – Waste Mass

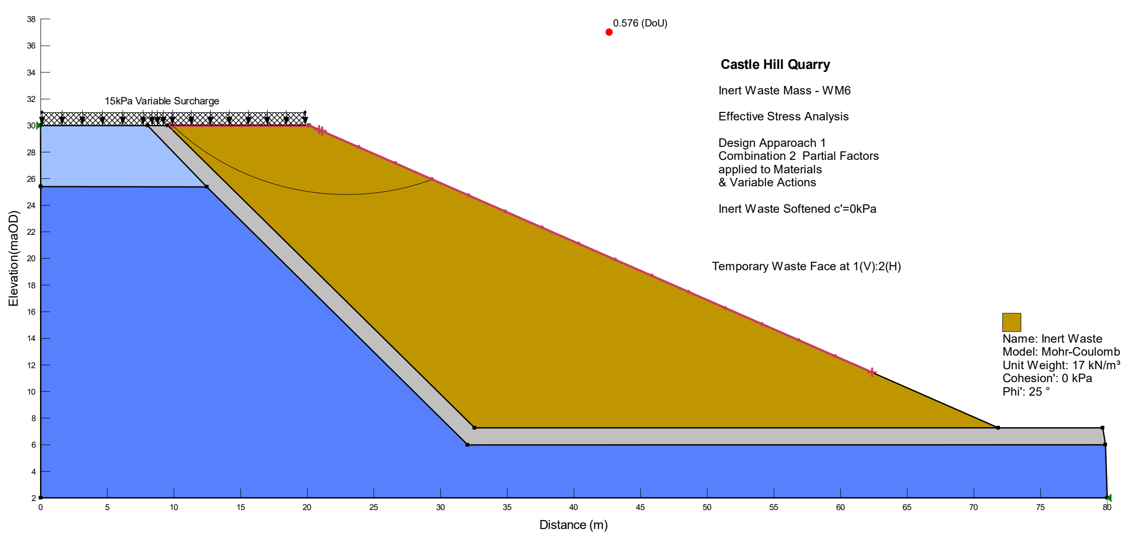

0.327 (DoU)
Castle Hill Quarry
Inert Waste Mass - WM1
Total Stress Analysis
Design Apparoach 1
Combination 1 Partial Factors
applied to Actions
15kPa Variable Surcharge
Temporary Waste Face at 1(V):2(H)
Name: Inert Waste
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 50 kPa
Phi': 0 °
Elevation(maOD)
Distance (m)


0.308 (DoU)
Castle Hill Quarry
Inert Waste Mass - WM2
Total Stress Analysis
Design Apparoach 1
Combination 2 Partial Factors
applied to Materials &
Variable Actions
15kPa Variable Surcharge
Temporary Waste Face at 1(V):2(H)
Name: Inert Waste
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 50 kPa
Phi': 0 °
Elevation(maOD)
Distance (m)


0.429 (DoU)
Castle Hill Quarry
Inert Waste Mass - WM3
Effective Stress Analysis
Design Apparoach 1
Combination 1 Partial Factors
applied to Actions
15kPa Variable Surcharge
Temporary Waste Face at 1(V):2(H)
Name: Inert Waste
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 25 °
Elevation(maOD)
Distance (m)


0.485 (DoU)
Castle Hill Quarry
Inert Waste Mass - WM4
Effective Stress Analysis
Design Apparoach 1
Combination 2 Partial Factors
applied to Materials
& Variable Actions
15kPa Variable Surcharge
Temporary Waste Face at 1(V):2(H)
Name: Inert Waste
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 25 °
Elevation(maOD)
Distance (m)


0.494 (DoU)
Castle Hill Quarry
Inert Waste Mass - WM5
Effective Stress Analysis
Design Apparoach 1
Combination 1 Partial Factors
applied to Actions
Inert Waste Softened c'=0kPa
15kPa Variable Surcharge
Temporary Waste Face at 1(V):2(H)
Name: Inert Waste
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 0 kPa
Phi': 25 °
Elevation(maOD)
Distance (m)


0.576 (DoU)
Castle Hill Quarry
Inert Waste Mass - WM6
Effective Stress Analysis
Design Apparoach 1
Combination 2 Partial Factors
applied to Materials
& Variable Actions
Inert Waste Softened c'=0kPa
15kPa Variable Surcharge
Temporary Waste Face at 1(V):2(H)
Name: Inert Waste
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 0 kPa
Phi': 25 °
Elevation(maOD)
Distance (m)