STABILITY RISK ASSESSMENT

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DRAWINGS

Drawing SRA1. Side Wall Seal Cross Section
A plan showing construction details of the side wall seal geological barrier.

APPENDICES

Appendix A: GeoSlope model for Geological Barrier

Appendix B: Justification for Input Values

Appendix C: Stability Assessment for soil final layer

1.0 INTRODUCTION

1.1 Report Context

To include details relating to the following :

- H Evason & Co is the operator of the proposed Dorrington Quarry landfill
- Enviroarm Limited were instructed by H Evason & Co, to undertake the Environmental Permit Application for the site including excavating the former landfill and processing this in the inert treatment facility and any inert waste to be brought back to the landfill, in line with the Landfill (England and Wales) Regulations 2016.
- The site entrance is located at National Grid Reference (NGR) SJ 47554 03878, the centre of the recycling area is at SJ 47635 03869 and the centre of the landfill is at SJ 47680 03568, which lies approximately 9km from the south of Shrewsbury on the northern edge of Dorrington.
- Environmental Setting and Installation Design (ESSD/DQ) and Hydrogeological Risk Assessment (HRA/DQ) should be cross referenced with this report.

1.2 Conceptual Stability Site Model

Primary Components

The following sub-sections present a summary of the natural geological, fill materials (the latter to include engineered fill and waste) of the site model, relating to 6 components identified from and from the guidance contained within the Environment Agency R&D Technical Report P1-385/TR2.

- The basal sub-grade; Glaciofluvial Deposit reworked materials which now consist of sand ,silt and clay in base of current landfill permit area and base of extension area.
- The side slopes sub-grade. Glaciofluvial Deposit reworked materials
- View of exposed side walls

- The basal lining system. 1 metre thick mineral engineered geological barrier for application area
- The side slope lining system. 2 metre thick engineered geological barrier to be constructed in

progressive stages so that there is 1 metre perpedicular to slope- Christmas Tree methodology.

- The waste mass. Inert waste accepted in accordance with WAC and within the list WASTE TYPE LIST
- The capping system. None required. The restoration will be 0.7 metres of sub soil and 0.3m of top-soil.

Pore fluid conditions

The pore fluid conditions relevant to each of these components are considered in each sub-section. Such conditions include the following.

- Groundwater pressures acting from below the base and outside the side slopes is zero as the HRA has established at 1.5 metre unsaturated zone beneath the base of the landfill.
- Leachate pressures acting on top of the base of the model. This will be zero.
- Leachate pressures acting behind side slopes of the model (e.g. where leachate recirculation is undertaken in previous landfill cells).None
- Landfill gas pressures will not act on the lining components or within the waste mass itself, Due to the inert nature of the waste the LFGRA has not indicated potential for gas production.
- Excess pore water pressures are not considered likely within the waste mass based on historic landfilling.
- Negative pore water pressures will not be generated as a result of excavation as the base of the quarry, 1 metre above the water table upper limit.

The stability conceptual model has been largely developed from the information contained in the ESSD and HRA reports.

1.2.1 Basal Sub-Grade Model

To include an outline of the following.

- The geology of the basal sub-grade (e.g. types of soils, cohesive, non-cohesive, soft rock, hard rock).Glaciofluvial Deposits re-worked, with at least 1.5 metres unsaturated zone. The base sub grade is reworked clay and silts with a shear strength greater than 100kPa, and is virtually flat with a slope gradient less than1:100.
- The pore fluid pressures which could act on the sub-grade. 0 Groundwater table is 1 metre minimum below base in sand extraction and geological barrier sits on top of this.

1.2.2 Side Slopes Sub-Grade Model

To include an outline of the following.

- The geology of the side slopes sub-grade (e.g. types of soils, cohesive, non-cohesive, soft rock, hard rock and their structure).Glaciofluvial Deposits reworked,. Also see ref from MIRO Report 2 Geodiversity Audit of Active Quarries June 2004"
- The range of inclinations of the slopes. Current landfill side slopes are 1:1 to vertical but all remain stable and the quarry face risk assessment has satisfied under the Quarries Regulations 1999
- Reworking of Phase 2 will allow for new landfill void to be formed. New excavations will be excavated at 1:2.
- The general form of the sub-grade (e.g. areas of rock/soil cut/fill). Hard clay and silt, in excess of 100kPa
- The pore fluid pressures which could act on the sub-grade.0No seepages observed in quarry walls. Groundwater table is 1.5 metres below base of quarry.

1.2.3 Basal Lining System Model

- The proposed mineral lining elements. 1 metre thick engineered mineral liner with a target permeability of 1 x 10^{-7}m/s, 50kPa shear strength and compacted to DTp Highways Specification.
- The proposed groundwater and leachate drainage elements. Not applicable
- The pore fluid pressures which could act on the basal lining system. Not applicable

1.2.4 Side Slope Lining System Model

- The proposed mineral lining elements consists of a 1 metre geological barrier, with a minimum hydraulic conductivity of 1 x 10^{-7} m/s, constructed as a geological barrier in a 'Christmas tree' manner against the side wall. This will be built up with the inert waste with little time when the geological barrier is exposed and unsupported. The slope of the side wall will be typically 1:2.See Drawing SRA 1.

- The geological barrier is at a 1.5 level above the water table and so no groundwater drainage system is required on site.

- No leachate drainage system is required on site due to the inert nature of the waste material.

- The pore fluid pressures will therefore not act on the side slope lining system.

1.2.5 Waste Mass Model

- The type of waste to be deposited, its heterogeneity and physical form. Inert compacted soils effective peak angles between18 and 45kPa. Friction angles between 20-36kPa.Soils tipped in a dry state
- The type and distribution of soils used for cover. All the same
- The general and maximum slopes of the waste during operations and at the end of life of the landfill. Height of working face 2 metres. Final graded slopes in the area will range from 1:7% to 1:12.
- The pore fluid pressures which could act within the waste.0

1.2.6 Capping System Model

To include an outline of the following.

- The proposed mineral and/or geosynthetic lining elements. Not applicable
- The proposed restoration cover elements, including drainage. 1 metres of sub and top soils
- The gas pressure that could act on the underside of the system. Not applicable
- The pore fluid pressure which could act within the capping system.0

2.0 STABILITY RISK ASSESSMENT

2.1 Risk Screening

The SRA for Dorrington Quarry has classified all issues relating to stability or integrity into simple and complex categories. Only those falling within the complex category have been subject to further detailed geotechnical analyses.

- Provision of full justification for issues classified as simple (e.g. sound bedrock forming a sub-grade) and therefore not requiring detailed geotechnical analyses.
- Summary of the reasons for classifying other issues as complex, identifying the governing geotechnical principals behind the decisions.

2.1.1 Basal Sub-Grade Screening

A summary of whether this component is considered to be an issue requiring analytical assessment or an issue which requires no further consideration.

The basal sub grade has been classified on a simple non-complex basis. The overall exposed base is virtually flat with a maximum slope angle of 1:100. The reworked Glaciofluvial Deposits have a shear strength greater than 50kPa and the water table is 1.5 metres below the base of the quarry in Phase 1and 4 metres to 5.5 metres below barrier in Phase 2.

2.1.2 Side Slopes Sub-Grade Screening

A summary of whether this component is considered to be an issue requiring analytical assessment or an issue which requires no further consideration.

The sub grade side slopes on Phase 1 has not been keyed in, but will be done as part of the on going phasing.Phase 2 will then be done with a 1:2.5 slope.

Also see ref from MIRO Report 2 Geodiversity Audit of Active Quarries June 2004"There is no evidence of Partial failure or complete failures and no stress cracks are visible. Some local quarry faces have now been exposed for well over 20 years and have remained stable.

2.1.3 Basal Lining System Screening

A summary of whether this component is considered to be an issue requiring analytical assessment or an issue which requires no further consideration (full justification given for the latter).

More of Phase 1 requires lining and all of Phase 2 will require lining. The rest of Phase 1 and Phase 2 extension area is to have a 1 metre thick engineered mineral liner placed with a target permeability of 1 x 10^{-7}m/s and placed with a minimum shear strength of 50kPa and placed to a performance specification and a method specification in accordance with DTp Highways Specification. The basal slope angle will not exceed 1:100 and will be more realistically at the current sub base grade of less than 1:100 and is therefore considered stable.

The basal lining system is not considered an issue and the geological base is stable and with an unconfined aquifer below the base will not be subject to basal heave. The base slope is at or less than 1:100 and the friction angles of clays and soils that would be suitable for use as a geological barrier will have greater than 10% clay fraction and would therefore have typical friction angles of 25-36°, thus would be stable at slopes less than 1:14 to 1:25, in addition the matrix of the geological barrier will have sand and gravel within the matrix thus increasing the cohesion of the liner.

The inert nature of the waste is such that no leachate is likely above the liner.

The selected fill will be required to achieve a target permeability value of 1 x 10^{-7}m/s and would be constructed in accordance with an approved Construction Quality Assurance Plan.

2.1.4 Side Slope Lining System Screening

The current phases covered under the Permit do require a side slope lining system. The extension areas of Phases in 1 and all of Phase 2 require a 1 metre thick engineered mineral liner placed with a target permeability of 1 x 10^{-7}m/s and placed with a minimum shear strength of 50kPa and placed to a performance specification and a method specification in accordance with DTp Highways Specification. This will be built up in 2 metre lifts with inert waste placed against it.

The side slope lining system will be constructed in a 'Christmas tree' manner, not exceeding 2 metres in height at a time. It will also be constructed in phases and sub phases so as to minimise the amount of exposure of any one face, and will therefore have inert material deposited against it in a short period of time. There are no groundwater issues in the rock and the water table is reported to be within the rock typically about 2 m below the base of the landfill.

The sequence of events is to construct the first phase of liner up to 2 metres. This is then filled against with inert waste at which point the next 2 metre lift of liner is constructed and so on and so forth until the quarry edge is reached. In the eastern section l the liner will only be 3 metres in depth and in the west up to some 10 metres in depth. This is shown schematically on Drawing SRA 1

The geological barrier lining system has therefore been considered as part of the assessment by way of sliding wedge failure potential, see GeoSlope model at Appendix A.

2.1.5 Waste Mass Screening

A summary of whether this component is considered to be an issue requiring analytical assessment or an issue which requires no further consideration (full justification given for the latter). No consideration needed. The site is and will continue to be an inert landfill site accepting solid inert wastes. The soil is laid in horizontal layers no greater than 2 metres in thickness and compacted.

The type of waste to be deposited, is inert compacted soils with effective peak angles between 18 and 45kPa.Friction angles between will typically be between 20-36kPa. Soils tipped are generally tipped in a dry state. The addition of paving slabs, brick etc will increase the shear strength of the material.

Height of working face will be no greater than 2.0 metres and will be bladed out and rolled.

The waste mass is therefore not considered any further as part of this assessment.

2.1.6 Capping System Screening

A summary of whether this component is considered to be an issue requiring analytical assessment or an issue which requires full justification given for the latter.

Shallow slopes are stable at angles of 1:4 and less. The top area of the will rise at a slope angle of 1:40, and was demonstrated to be stable in the supporting SRA. The slopes for the extension area will range from 1:19 to 1:24.

The pore fluid pressures which could act within the waste are considered negligible due to the low permeability and low porosity of the compacted soils. The nature of the waste is generally impermeable to infiltration indicated by HRA and the final domed landform will encourage surface water runoff from the waste mass.

The restored slopes have been given consideration as part of this assessment to ensure that the final landform is stable.

2.2 Lifecycle Phases

Identification of critical phases during the development of the landfill. In order to ensure that the Stability Risk Assessment fully addresses the key issues throughout the life of the landfill, the following operational factors should be taken into consideration.

- Phasing of Subgrade Slopes. Not applicable
- Phasing of engineered fill and waste placement (rate of construction). Not applicable
- Waste mass geometry (height/outer slope inclination/crest width) vs. time. Not applicable
- Leachate management. Not applicable
- Landfill gas management. Not applicable
- Daily cover characteristics. Not applicable
- Temporary capping characteristics. Not applicable

2.3 Data Summary

Provision of a summary of geotechnical data as follows.

- Site specific data.
- Published data with justification for its use.
- Assumed data with justification for its use.
- Uncertainties in the data to be used and proposals for addressing those uncertainties (e.g. sensitivity analyses).

The geotechnical data used as input for detailed analyses to include the following (where appropriate).

- Material unit weight.1.50-2.00Mg/m^3
- Soil characterisation data (particle size distribution/plasticity index/natural moisture content).Inert soils, generally have a moisture content of between 10% and 20%
- Drained shear strength of soils and rocks.25-40kPa
- Undrained shear strength of cohesive soils.+100kPa
- Shear strength of interfaces.
- Groundwater pressures.0
- Leachate pressures.0
- Potential landfill gas pressures.0
- Excess pore water pressure dissipation characteristics of cohesive soils.
- Consolidation characteristics of soils and waste. Low less than 2%
- Permeability characteristics of soils and waste. Low at base 5.0E-10m/s to 6.5E-10m/s, based on site investigation data obtained at other inert landfill sites and likely to range from1e-6 to 1e-9m/s due to the inert nature of the material to be landfilled, which will also be subject to consolidation and compaction..
- Discontinuity characteristics of rock masses. Not applicable
- Geotechnical parameters for any ground improvement methods adopted (e.g. soil reinforcement).Not required
- Stiffness characteristics of soil and waste. Not applicable

In situ horizontal stresses in waste. Not applicable

2.4 Justification for Modelling Approach and Software

- The side wall geological barrier has been modelled on a wedge type analysis, see Appendix A
- The final landform slopes have been assessed using detailed wedge analysis spread sheets, see Appendix C.

2.5 Justification of Geotechnical Parameters Selected for Analyses

The geotechnical parameters used are based on typical values reported in various texts including Department of the Environment Handbook on the Design of Tips and Related Structures HMSO, Geology for Civil Engineers Unwin Hayman.

2.5.1 Parameters Selected for Basal Sub-Grade Analyses

Not required due to the flat base. Therefore no further assessment is considered necessary for an inert landfill site as discussed in Section 2.1.1

2.5.2 Parameters Selected for Side Slopes Sub-Grade Analyses

A visual assessment has shown the quarry walls to be stable summary and no further assessment has been carried out in the extension area.

2.5.3 Parameters Selected for Basal Liner Analyses

The base is considered stable and no further assessment is required as discussed in Section 2.1.5.

2.5.4 Parameters Selected for Side Slope Liner Analyses

The input data for the side slope model is set out as follows;
1
Against quarry slopes at 1:2=45º
Max Slope Length 6m

Angle Of Slope
Worst case is1:2= 45º.

Shear Strength Angle of Friction = 28^0 Average Value

1

2.5.5 Parameters Selected for Waste Analyses

This was not required as discussed in Section 2.1.5

2.5.6 Parameters Selected for Capping Analyses

A summary of data used in the analysis of this component. Infinite slope stability analysis. Cap stability calculations contained as Appendix B.

2.6 Selection of Appropriate Factors of Safety

The factor of safety is the numerical expression of the degree of confidence that exists, for a given set of conditions, against a particular failure mechanism occurring. It also represents the confidence in the input parameters used and analysis method used. It is commonly expressed as the ratio of the load or action which would cause failure against the actual load or actions likely to be applied during service. This is readily determined for some types of analysis (e.g. limit equilibrium slope stability analyses).
Prior to determining appropriate factors of safety for the various components of the model, it is necessary to identify key ‘receptors’ and evaluate the consequences in the event of a failure (relating to both stability and integrity). Consideration of the following receptors is required.

- Groundwater. Beneath base therefore not applicable
- Other environmental receptors. None
- Property - relating to site infrastructure, third party property. None observed
- Human beings (i.e. direct risk). Site staff only

The Factor of Safety adopted for each component of the model would be related to the consequences of a failure.

2.6.1 Factor of Safety for Basal Sub-Grade

A description of the relevant factors involved in the selection of the factor of safety for this component. Not applicable

2.6.2 Factor of Safety for Side Slopes Sub-Grade

A description of the relevant factors involved in the selection of the factor of safety for this component Not applicable

2.6.3 Factor of Safety for Basal Lining System

A description of the relevant factors involved in the selection of the factor of safety for this component. Not applicable

2.6.4 Factor of Safety for Side Slope Lining System

This has been considered as 1.3 for Short Term and 1.5 for Long Term Stability

2.6.5 Factor of Safety for Waste Mass

Not applicable

2.6.6 Factor of Safety for Capping System

A description of the relevant factors involved in the selection of the factor of safety for this component.1.3

2.7 Analyses

This has included details relating to the following.

The completion of a sufficient sensitivity analysis, which may include the use of multiple model runs to simulate different justifiable ranges of input parameter values.

2.7.1 Basal Sub-Grade Analyses

Presentation of the approach to and the results of the analyses undertaken for this component. Not applicable

2.7.2 Side Slopes Sub-Grade Analyses

Presentation of the approach to and the results of the analyses undertaken for this component. Not applicable

2.7.3 Basal Liner Analyses

Presentation of the approach to and the results of the analyses undertaken for this component. Not applicable

2.7.4 Side Slopes Liner Analyses

Presentation of the approach to and the results of the analyses undertaken for this component. Wedge analysis undertaken, though as per photographs, all slopes are stable. Values exceed FOS 1.9

2.7.5 Waste Analyses

Presentation of the approach to and the results of the analyses undertaken for this component. Not applicable

2.7.6 Capping Analyses

Presentation of the approach to and the results of the analyses undertaken for this component. Wedge analysis undertaken, though as per photographs, all slopes are stable.

2.8 Assessment

This comprises a reasoned review of the results of the analyses and takes in to account consideration of analytical limitations, the assessment of uncertainties and the potential effects on Factors of Safety and an overall assessment of risk for each component.

2.8.1 Basal Sub-Grade Assessment

This was not modelled but the basal sub grade is not considered as part of the assessment, due to the unsaturated zone being 1.5 metre below the base of the site based on the findings of Enviroarm Ltd HRA and no lining system in place with the exception of an engineered geological barrier placed on the base of the Glaciofluvial Deposits. The sandstone/silt/clay and the soil have high friction angles and will also exhibit cohesion and the base profile is almost flat, therefore there is no likelihood of and movement or instability. There is no risk of basal heave and the flat profile indicates long term stability. Typical steep faces are worked in local sandstone quarries with medium to long term stability.

2.8.2 Side Slopes Sub-Grade Assessment

Presentation of the approach to and the results of the analyses undertaken for this component shows that the sand and gravel has a large Factor of Safety cut at 1:2 and will be stable for the long term. The faces will be worked progressively and landfilling progressing directly behind thus further reducing the risk of instability.

The Factor of Safety is in excess of 2.18 and complies with guidance issued by the Environment Agency.

2.8.3 Basal Liner Assessment

This was not modelled but the basal sub grade is not considered as part of the assessment, due to the unsaturated zone being 1 metre below the base of the site based on the findings of Enviroarm Ltd HRA and no lining system in place with the exception of an engineered geological barrier placed on the base of the Sherwood Sandstone for the new extension area. The sandstone and the soil have high friction angles and will also exhibit cohesion and the base profile is almost flat, therefore there is no likelihood of and movement or instability. There is no risk of basal heave and the flat profile indicates long term stability. Typical steep faces are worked in local sandstone quarries with medium to long term stability.

2.8.4 Side Slopes Liner Assessment

Presentation of the approach to and the results of the analyses undertaken for this component shows that the side wall geological barrier has a large Factor of Safety when engineered at 1:2 and will be stable for the long term. The engineered barrier will have limited exposure with landfilling progressing directly behind thus further reducing the risk of instability.

The Factor of Safety is in excess of 1.95 and complies with guidance issued by the Environment Agency.

2.8.5 Waste Assessment

Not applicable. The landfill will be worked in horizontal layers which will be stable to vehicles travelling on site.

2.8.6 Capping Assessment

Presentation of the approach to and the results of the analyses undertaken for this component. Capping has been assessed by way of wedge analysis on the steepest slope in the extension area with a slope of 1:19.
The slopes for the extension area will range from 1:19 to 1:24, thus 1:19 is the steepest slope.

Wedge analysis undertaken, all slopes are stable for the placed soils with Factors of Safety ranging from in excess of 200 down to 4.84 for the soils and from 7.30 to 2.17 involving the placement of the cap soils with construction plant even with no residual strength and cohesion values of 0 which are extremely conservative.

All of the results are within the Environment Agency guideline values.

3.0 MONITORING

3.1 The Risk Based Monitoring Scheme

The Stability Risk Assessment has developed risk-based monitoring objectives and schedules. This section provides the technical rationalisation for the design of a monitoring programme, to focus monitoring effort on actual risks.

3.1.1 Basal Sub-Grade Monitoring

Monitoring scheme. Visual inspection

3.1.2 Side Slopes Sub-Grade Monitoring

Monitoring scheme. Visual inspection

3.1.3 Basal Lining System Monitoring

Monitoring scheme. Visual inspection. Construction Quality Assurance Plan for barrier construction

3.1.4 Side Slope Lining System Monitoring

Monitoring scheme. Visual inspection. Construction Quality Assurance Plan for barrier construction

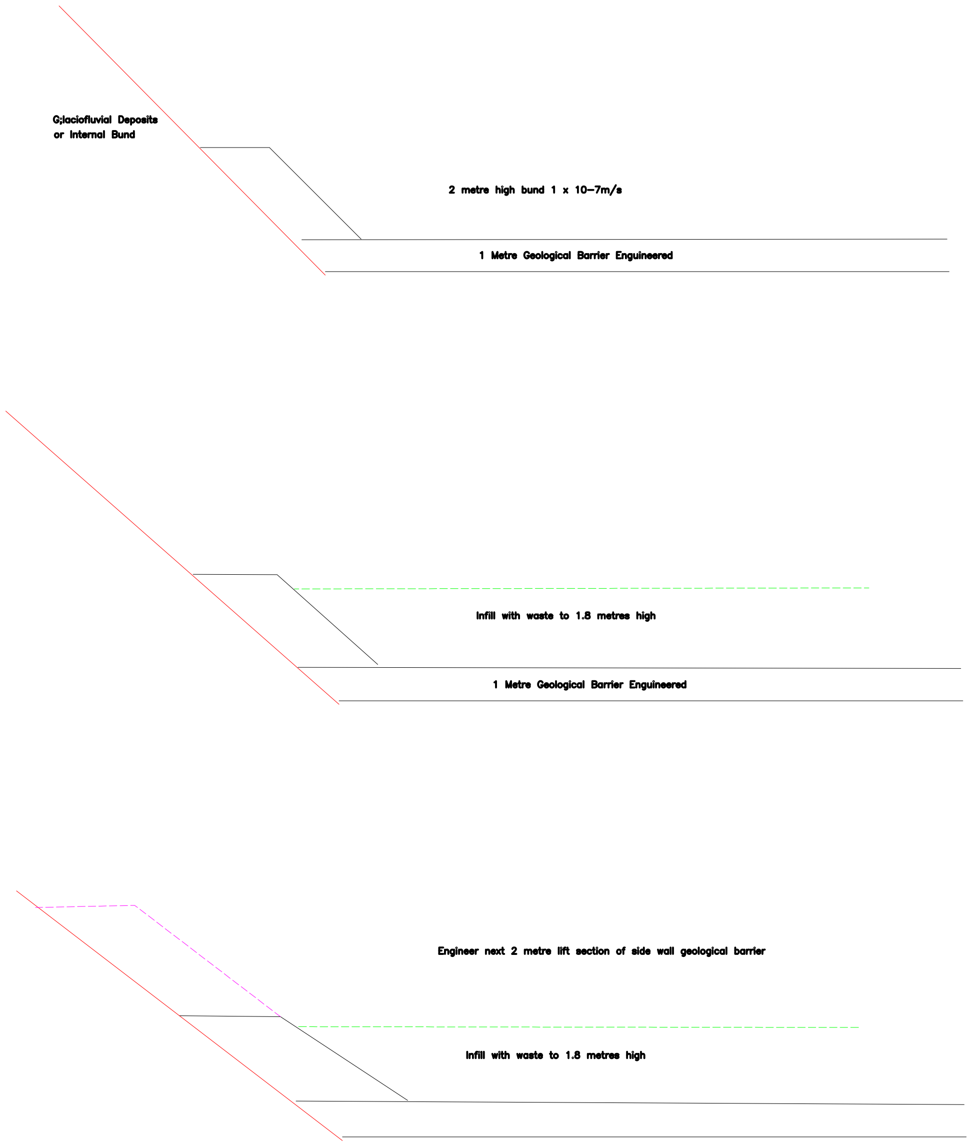
3.1.5 Waste Mass Monitoring

Monitoring scheme. Visual inspection

3.1.6 Capping System Monitoring

Monitoring scheme. Visual inspection

DRAWING



The Contractor is to check and verify all building and site dimensions, levels and sewer invert levels at connection points prior to the commencement of works.

This drawing must be read with and checked against any structural or other specialist drawings provided by the client.

The Contractor is to comply in all respects with the current Building Regulations and CDM regulations whether or not specifically stated on these drawings.

This drawing is not intended to show details of foundations, ground conditions or ground contaminants. Each area of ground relied upon to support the proposed works, including drainage, depicted must be investigated by the contractor, suitable methods of foundation be provided and any suspect contaminents on or within the ground covered by the works be further investigated by a suitable expert.

Notes

ENVIROARM LIMITED

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Tel: 01922-412209 Mobile 07801980984
email: enviroarm@btconnect.com

Client: H Evason & Co

Project: DORRINGTON QUARRY

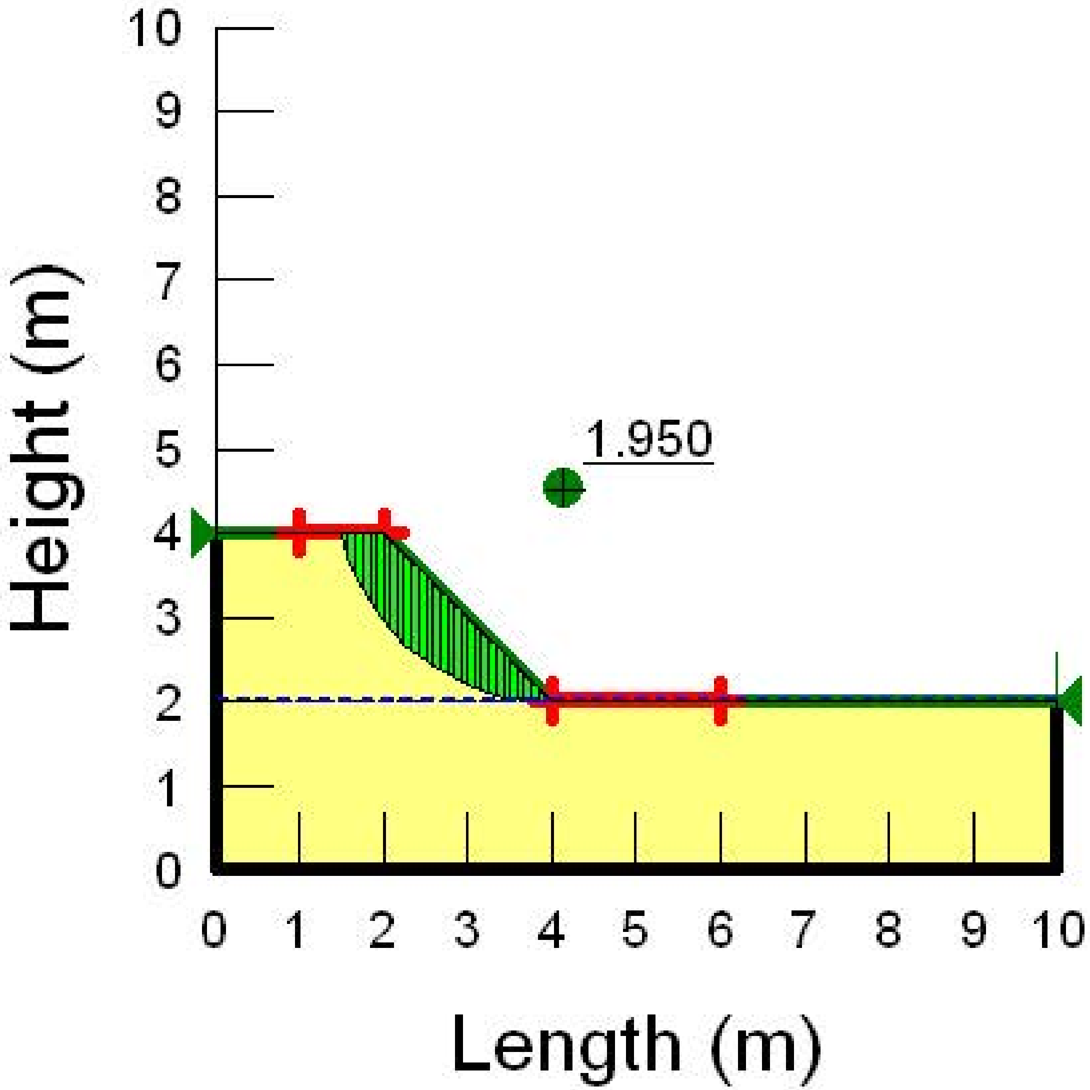
Title: SIDE WALL SEAL SCHEMEATIC CONCEPTUAL MODEL

Date : FEB 2021	Scales: 1:25000		
Drawn: ARM	Project No. SRA	Drg No. 1	Rev.
Checked: ARM			

APPENDIX A:

GeoSlope Model for Geological Barrier

Material #: 1
Description: Geological Barrier
Model: MohrCoulomb
Wt: 18
Cohesion: 5
Phi: 32
Piezometric Line: 1

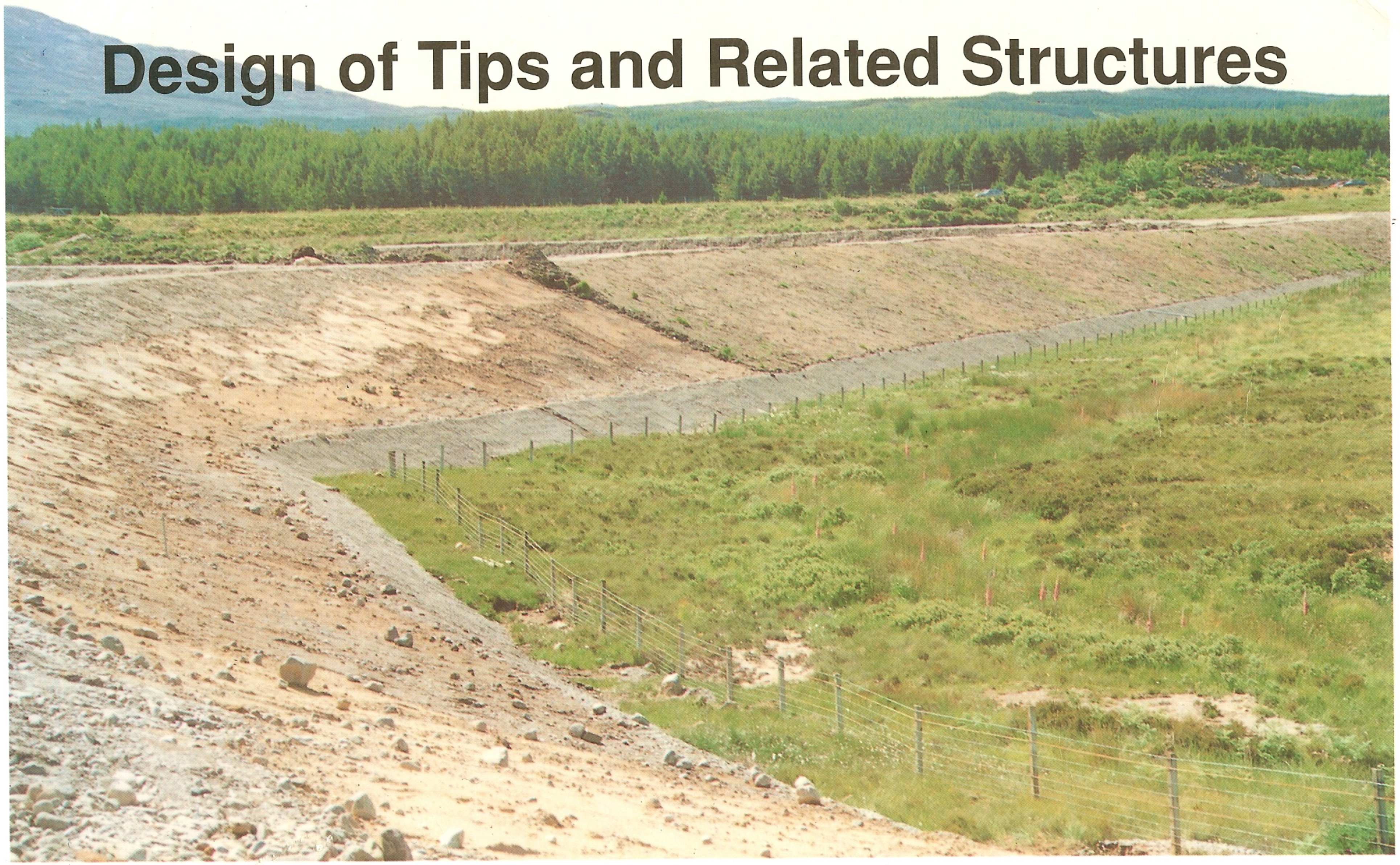


APPENDIX B:

Justification for Input Values

Department of the Environment

Handbook on the Design of Tips and Related Structures



HMSO

Material	Specific Gravity	Bulk Density	Dry Density Mg/m3	Natural Moisture Mg/m3	Void Ratio Content %	Liquid Limit	Plastic Limit %	Plasticity Index %	Cohesion (effective peak) %	Friction (effective peak) kPa	Friction (effective residual) Degrees
Gravel	2.50-2.80	1.45-2.30	1.40-2.10	-	-	NP	NP	NP	0	35-45	32-36
Sand	2.60-2.70	1.40-2.15	1.35-1.90	-	-	-	-	-	0	32-42	30-34
Silt (Non plastic)	-	-	-	-	-	NP	NP	NP	-	28-34	26-30
Silt	2.64-2.66	1.82-2.15	1.45-1.95	-	0.35-0.85	24-35	14-25	-	75	32-36	-
Clay	2.55-2.75	1.50-2.15	1.20-1.75	-	0.42-0.96	>25	>20	-	20-200	-	-
Peat	1.30-1.70	0.91-1.05	0.07-0.11	650-1100	12.7-14.9	-	-	-	20	5	
Keuper Marl I, II (i)	2.30-2.50	1.90-2.40	5-15	25-35	-	17-25	10-15	10-35	40	23-32	-
Keuper Marl II (ii)	2.10-2.30	1.80-2.10	10-12	25-40	-	17-27	10-18	10-35	32-42	22-29	
Keuper Marl IV (iii)	1.80-2.20	1.40-1.80	18-35	35-60	-	17-33	17-35	30-50	25-32	18-24	-
Basal/lodgement	2.50-2.90	1.80-2.40	-	8-25	-	20-45	12-26	9-23	0-55	24-35	23-32
till (iv)									(10)	(32)	(30)
Meltout till (iv)	2.50-2.90	1.60-2.20	-	6-22	-	15-35	8-21	8-20	0-5	31-46	-
										(0)	(36)
Flow till (iv)	2.50-2.90	1.50-1.95	-	8-30	-	18-48	12-30	10-25	0-10	30-36	-
										(0)	(34)
clays (iv)											
									(20)	(20)	(13)
Fluvioglacial	2.50-2.80	1.85-2.00	-	5-20	-	NF-30	NP-18	NP-15	0-5	32-46	
sediments (iv)									(0)	(37)	(36)
Head (iv)	2.30-2.90	1.70-2.20	-	10-35	-	NP-40	NP-20	NP-25	0-27	28-39	-
										(27)	(35)
Collivium (iv)											
										(10)	(35)

Table 3.6 Typical Range of Material Properties for Cohesive and Cohesionless Materials (after [24], [25], [26], [38], [45], [48] and [91])

(**) typical values

APPENDIX C:

Stability Assessment for Soil Final Layer

DORRINGTON QUARRY- CAPPING STABILITY & INTEGRITY

Dorrington_v2 Soil Cap1.xls Cap with restoration soils
PSR = 0 (Peak/Remoulded Interface Strengths)

Data Input

Interface details:	upper material		cover soil	sub soil	
	lower material		sub soil	regulating layer	
height of slope base	H	m	6.00	6.00	
lining thickness	T1	m	0.30	0.70	
slope of liner	Cot(alpha)		20.00	20.00	
dry density	Gamdry-1	kN/m3	18.00	18.00	
saturated density	Gamsat-1	kN/m3	20.00	20.00	
saturated thickness	Tw	m	0.00	0.00	
interface cohesion	C1	kN/m2	4.00	4.00	
interface friction angle	Phi-1	deg	28.00	28.00	
soil cohesion	C2	kN/m2	8.00	8.00	
soil friction angle	Phi-2	deg	32.00	32.00	
active thrust at top of slope	Pa	kN	0	0	

Calculations

slope of liner	alpha	rads	0.008	0.008
length of sliding surface	L1	m	133.00	133.00
weight of upper wedge	W1	kN	718.20	1675.80
weight of lower wedge	W2	kN	101.25	551.27
pwp on interface *	U'	kN	0.00	0.00
pwp in cover soil	U"	kN	0.00	0.00
Calculate coefficients for quadratic equation				
A			5.75	13.41
B			-1277.13	-2467.51
C			4.57	7.11
Factor of safety	**Fs**		**222.29**	**184.06**
Maximum shear force on interface	N1	kN	913.86	1423.01
Mobilised shear force on upper interface		kN	4.11	4.11
Maximum shear force on lower interface		kN		1423.01
Tension		kN		-1418.90
				sub soil

N.B. If the tension is negative there is no tension and the shear is transmitted through to the next interface.

DORRINGTON QUARRY - CAPPING STABILITY & INTEGRITY

Dorrington_v2 Soil Cap2.xls Soil cap with restoration soils
PSR = 0.25 (Peak/Remoulded Interface Strengths)

Data Input

Interface details:	upper material		cover soil	sub soil
	lower material		sub soil	regulating layer
height of slope base	H	m	6.00	6.00
lining thickness	T1	m	0.30	0.70
slope of liner	Cot(alpha)		20.00	20.00
dry density	Gamdry-1	kN/m3	18.00	18.00
saturated density	Gamsat-1	kN/m3	20.00	20.00
saturated thickness	Tw	m	0.20	0.20
interface cohesion	C1	kN/m2	4.00	4.00
interface friction angle	Phi-1	deg	28.00	28.00
soil cohesion	C2	kN/m2	8.00	8.00
soil friction angle	Phi-2	deg	32.00	32.00
active thrust at top of slope	Pa	kN	0	0

Calculations

slope of liner	alpha	rads	0.08	0.08
length of sliding surface	L1	m	133.00	133.00
weight of upper wedge	W1	kN	771.40	1729.00
weight of lower wedge	W2	kN	10.67	55.86
pwp on interface *	U'	kN	260.11	260.11
pwp in cover soil	U"	kN	2.45	2.45
Calculate coefficients for quadratic equation				
A			61.45	137.73
B			-838.23	-1416.24
C			40.08	65.42
Factor of safety	**Fs**		**13.59**	**10.24**
Maximum shear force on interface	N1	kN	802.55	1310.08
Mobilised shear force on upper interface		kN	59.04	59.04
Maximum shear force on lower interface		kN		1310.08
Tension		kN		-1251.04
				sub soil

N.B. If the tension is negative there is no tension and the shear is transmitted through to the next interface.

DORRINGTON QUARRY - CAPPING STABILITY & INTEGRITY

Dorrington_v2 Soil Cap3.xls Soil cap with restoration soils
PSR = 0.50 (Peak/Remoulded Interface Strengths)

Data Input

Interface details:	upper material		cover soil	sub soil
	lower material		sub soil	regulating layer
height of slope base	H	m	6.00	6.00
lining thickness	T1	m	0.30	0.70
slope of liner	Cot(alpha)		20.00	20.00
dry density	Gamdry-1	kN/m3	18.00	18.00
saturated density	Gamsat-1	kN/m3	20.00	20.00
saturated thickness	Tw	m	0.15	0.35
interface cohesion	C1	kN/m2	4.00	4.00
interface friction angle	Phi-1	deg	28.00	28.00
soil cohesion	C2	kN/m2	8.00	8.00
soil friction angle	Phi-2	deg	32.00	32.00
active thrust at top of slope	Pa	kN	0	0
Calculations				
slope of liner	alpha	rads	0.08	0.08
length of sliding surface	L1	m	133.00	133.00
weight of upper wedge	W1	kN	758.10	1768.90
weight of lower wedge	W2	kN	10.45	56.90
pwp on interface *	U'	kN	195.08	455.19
pwp in cover soil	U"	kN	1.38	7.49
Calculate coefficients for quadratic equation				
A			60.39	140.91
B			-866.14	-1331.58
C			41.45	61.30
Factor of safety	**Fs**		**14.29**	**9.40**
Maximum shear force on interface	N1	kN	830.07	1227.50
Mobilised shear force on upper interface		kN	58.07	58.07
Maximum shear force on lower interface		kN		1227.50
Tension		kN		-1169.43
				sub soil

N.B. If the tension is negative there is no tension and the shear is transmitted through to the next interface.

DORRINGTON QUARRY - CAPPING STABILITY & INTEGRITY

Dorrington_v2 Soil Cap4.x Soil cap with restoration soils
PSR = 0 (Residual Interface Strengths)

Data Input

Interface details:	upper material		cover soil	sub soil
	lower material		sub soil	regulating layer
height of slope base	H	m	6.00	6.00
lining thickness	T1	m	0.30	0.70
slope of liner	Cot(alpha)		20.00	20.00
dry density	Gamdry-1	kN/m3	18.00	18.00
saturated density	Gamsat-1	kN/m3	20.00	20.00
saturated thickness	Tw	m	0.00	0.00
interface cohesion	C1	kN/m2	0.00	0.00
interface friction angle	Phi-1	deg	26.00	26.00
soil cohesion	C2	kN/m2	4.00	4.00
soil friction angle	Phi-2	deg	28.00	28.00
active thrust at top of slope	Pa	kN	0	0

Calculations

slope of liner	alpha	rads	0.08	0.08
length of sliding surface	L1	m	133.00	133.00
weight of upper wedge	W1	kN	718.20	1675.80
weight of lower wedge	W2	kN	10.17	55.36
pwp on interface *	U'	kN	0.00	0.00
pwp in cover soil	U"	kN	0.00	0.00
Calculate coefficients for quadratic equation				
A			57.21	133.49
B			-370.91	-882.29
C			14.84	34.62
Factor of safety	**Fs**		**6.44**	**6.57**
Maximum shear force on interface	N1	kN	349.17	814.73
Mobilised shear force on upper interface		kN	54.19	54.19
Maximum shear force on lower interface		kN		814.73
Tension		kN		-760.53
				sub soil

N.B. If the tension is negative there is no tension and the shear is transmitted through to the next interface.

DORRINGTON QUARRY - CAPPING STABILITY & INTEGRITY

Dorrington_v2 Cap5.xls Restoration soils
PSR = 0.25 (Residual Interface Strengths)

Data Input

Interface details:	upper material		cover soil	sub soil
	lower material		sub soil	regulating layer
height of slope base	H	m	6.00	6.00
lining thickness	T1	m	0.30	0.70
slope of liner	Cot(alpha)		200.00	6.31
dry density	Gamdry-1	kN/m3	18.00	18.00
saturated density	Gamsat-1	kN/m3	20.00	20.00
saturated thickness	Tw	m	0.08	0.18
interface cohesion	C1	kN/m2	0.00	0.00
interface friction angle	Phi-1	deg	26.00	26.00
soil cohesion	C2	kN/m2	4.00	4.00
soil friction angle	Phi-2	deg	28.00	28.00
active thrust at top of slope	Pa	kN	0	0

Calculations

slope of liner	alpha	rads	0.08	0.08
length of sliding surface	L1	m	133.00	133.00
weight of upper wedge	W1	kN	738.15	1722.35
weight of lower wedge	W2	kN	10.24	55.75
pwp on interface *	U'	kN	97.54	227.60
pwp in cover soil	U''	kN	0.34	1.87
Calculate coefficients for quadratic equation				
A			58.80	137.20
B			-333.08	-793.56
C			13.23	30.86
Factor of safety	**Fs**		**5.62**	**5.74**
Maximum shear force on interface	N1	kN	311.29	726.35
Mobilised shear force on upper interface		kN	55.34	55.34
Maximum shear force on lower interface		kN		726.35
Tension		kN		-671.01
				sub soil

N.B. If the tension is negative there is no tension and the shear is transmitted through to the next interface.

DORRINGTON QUARRY - CAPPING STABILITY & INTEGRITY

Dorrington_v2 Cap6.xls Restoration soils
PSR = 0.50 (Residual Interface Strengths)

Data Input

Interface details:	upper material		cover soil	sub soil
	lower material		sub soil	regulating layer
height of slope base	H	m	6.00	6.00
lining thickness	T1	m	0.30	0.70
slope of liner	Cot(alpha)		20.00	20.00
dry density	Gamdry-1	kN/m3	18.00	18.00
saturated density	Gamsat-1	kN/m3	20.00	20.00
saturated thickness	Tw	m	0.15	0.35
interface cohesion	C1	kN/m2	0.00	0.00
interface friction angle	Phi-1	deg	26.00	26.00
soil cohesion	C2	kN/m2	4.00	4.00
soil friction angle	Phi-2	deg	28.00	28.00
active thrust at top of slope	Pa	kN	0	0

Calculations

slope of liner	alpha	rads	0.08	0.08
length of sliding surface	L1	m	133.00	133.00
weight of upper wedge	W1	kN	758.10	1768.90
weight of lower wedge	W2	kN	10.45	56.90
pwp on interface *	U'	kN	195.08	455.19
pwp in cover soil	U"	kN	1.38	7.49
Calculate coefficients for quadratic equation				
A			60.39	140.91
B			-294.96	-703.25
C			11.62	27.11
Factor of safety	**Fs**		**4.84**	**4.95**
Maximum shear force on interface	N1	kN	273.42	637.98
Mobilised shear force on upper interface		kN	56.44	56.44
Maximum shear force on lower interface		kN		637.98
Tension		kN		-581.54
				sub soil

N.B. If the tension is negative there is no tension and the shear is transmitted through to the next interface.

DORRINGTON QUARRY - CAPPING STABILITY & INTEGRITY

Dorrington_v2 Cap7.xls Restoration soils
PSR = 0 (Construction Plant - Peak/Remoulded Interface Strengths)

Data Input

Interface details:	upper material		cover soil	sub soil
	lower material		sub soil	regulating layer
height of slope base	H	m	6.00	6.00
lining thickness	T1	m	0.30	0.70
slope of liner	Cot(alpha)		20.00	20.00
dry density	Gamdry-1	kN/m3	18.00	18.00
saturated density	Gamsat-1	kN/m3	20.00	20.00
saturated thickness	Tw	m	0.00	0.00
interface cohesion	C1	kN/m2	4.00	4.00
interface friction angle	Phi-1	deg	28.00	28.00
soil cohesion	C2	kN/m2	8.00	8.00
soil friction angle	Phi-2	deg	32.00	32.00
active thrust at top of slope	Pa	kN	75	75

Calculations

slope of liner	alpha	rads	0.08	0.08
length of sliding surface	L1	m	133.00	133.00
weight of upper wedge	W1	kN	718.20	1675.80
weight of lower wedge	W2	kN	10.17	55.36
pwp on interface *	U'	kN	0.00	0.00
pwp in cover soil	U"	kN	0.00	0.00
Calculate coefficients for quadratic equation				
A			131.97	208.25
B			-952.73	-1530.75
C			45.57	70.92
Factor of safety	**Fs**		**7.17**	**7.30**
Maximum shear force on interface	N1	kN	912.65	1420.19
Mobilised shear force on upper interface		kN	127.27	127.27
Maximum shear force on lower interface		kN		1420.19
Tension		kN		-1292.92
				sub soil

N.B. If the tension is negative there is no tension and the shear is transmitted through to the next interface.

DORRINGTON QUARRY - CAPPING STABILITY & INTEGRITY

Dorrington_v2 Soil Cap8.xls Restoration soils
PSR = 0.25 (Construction Plant - Peak/Remoulded Interface Strengths)

Data Input

Interface details:	upper material		cover soil	sub soil
	lower material		sub soil	regulating layer
height of slope base	H	m	6.00	6.00
lining thickness	T1	m	0.30	0.70
slope of liner	Cot(alpha)		20.00	20.00
dry density	Gamdry-1	kN/m3	18.00	18.00
saturated density	Gamsat-1	kN/m3	20.00	20.00
saturated thickness	Tw	m	0.08	0.18
interface cohesion	C1	kN/m2	4.00	4.00
interface friction angle	Phi-1	deg	28.00	28.00
soil cohesion	C2	kN/m2	8.00	8.00
soil friction angle	Phi-2	deg	32.00	32.00
active thrust at top of slope	Pa	kN	75	75
Calculations				
slope of liner	alpha	rads	0.08	0.08
length of sliding surface	L1	m	133.00	133.00
weight of upper wedge	W1	kN	738.15	1722.35
weight of lower wedge	W2	kN	10.24	55.75
pwp on interface *	U'	kN	97.54	227.60
pwp in cover soil	U"	kN	0.34	1.87
Calculate coefficients for quadratic equation				
A			133.56	211.96
B			-911.48	-1433.97
C			43.51	66.11
Factor of safety	**Fs**		**6.78**	**6.72**
Maximum shear force on interface	N1	kN	871.36	1323.85
Mobilised shear force on upper interface		kN	128.59	128.59
Maximum shear force on lower interface		kN		1323.85
Tension		kN		-1195.26
				sub soil

N.B. If the tension is negative there is no tension and the shear is transmitted through to the next interface.

DORRINGTON QUARRY - CAPPING STABILITY & INTEGRITY

Dorrington_v2 Cap9.xls Restoration soils

PSR = 0.50 (Construction Plant - Peak/Remoulded Interface Strengths)

Data Input

Interface details:	upper material		cover soil	sub soil
	lower material		sub soil	regulating layer
height of slope base	H	m	6.00	6.00
lining thickness	T1	m	0.30	0.70
slope of liner	Cot(alpha)		20.00	20.00
dry density	Gamdry-1	kN/m3	18.00	18.00
saturated density	Gamsat-1	kN/m3	20.00	20.00
saturated thickness	Tw	m	0.15	0.35
interface cohesion	C1	kN/m2	4.00	4.00
interface friction angle	Phi-1	deg	28.00	28.00
soil cohesion	C2	kN/m2	8.00	8.00
soil friction angle	Phi-2	deg	32.00	32.00
active thrust at top of slope	Pa	kN	75	75

Calculations

slope of liner	alpha	rads	0.08	0.08
length of sliding surface	L1	m	133.00	133.00
weight of upper wedge	W1	kN	758.10	1768.90
weight of lower wedge	W2	kN	10.45	56.90
pwp on interface *	U'	kN	195.08	455.19
pwp in cover soil	U"	kN	1.38	7.49
Calculate coefficients for quadratic equation				
A			135.15	215.67
B			-869.89	-1335.33
C			41.45	61.30
Factor of safety	**Fs**		**6.39**	**6.15**
Maximum shear force on interface	N1	kN	830.07	1227.50
Mobilised shear force on upper interface		kN	129.93	129.93
Maximum shear force on lower interface		kN		1227.50
Tension		kN		-1097.57
				sub soil

N.B. If the tension is negative there is no tension and the shear is transmitted through to the next interface.

DORRINGTON QUARRY - CAPPING STABILITY & INTEGRITY

Dorrington_v2 Cap10.xls Restoration soils
PSR = 0 (Construction Plant - Residual Interface Strengths)

Data Input

Interface details:	upper material		cover soil	sub soil
	lower material		sub soil	regulating layer
height of slope base	H	m	6.00	6.00
lining thickness	T1	m	0.30	0.70
slope of liner	Cot(alpha)		1.00	1.00
dry density	Gamdry-1	kN/m3	18.00	18.00
saturated density	Gamsat-1	kN/m3	20.00	20.00
saturated thickness	Tw	m	0.00	0.00
interface cohesion	C1	kN/m2	0.00	0.00
interface friction angle	Phi-1	deg	26.00	26.00
soil cohesion	C2	kN/m2	4.00	4.00
soil friction angle	Phi-2	deg	28.00	28.00
active thrust at top of slope	Pa	kN	75	75

Calculations

slope of liner	alpha	rads	0.08	0.08
length of sliding surface	L1	m	133.00	133.00
weight of upper wedge	W1	kN	718.20	1675.80
weight of lower wedge	W2	kN	10.17	55.36
pwp on interface *	U'	kN	0.00	0.00
pwp in cover soil	U"	kN	0.00	0.00
Calculate coefficients for quadratic equation				
A			131.97	208.25
B			-374.10	-885.47
C			14.84	34.62
Factor of safety	**Fs**		**2.79**	**4.21**
Maximum shear force on interface	N1	kN	349.17	814.73
Mobilised shear force on upper interface		kN	124.95	124.95
Maximum shear force on lower interface		kN		814.73
Tension		kN		-689.78
				sub soil

N.B. If the tension is negative there is no tension and the shear is transmitted through to the next interface.

DORRINGTON QUARRY - CAPPING STABILITY & INTEGRITY

Dorrington_v2 Cap11.xls Restoration soils
PSR = 0.25 (Construction Plant - Residual Interface Strengths)

Data Input

Interface details:	upper material		cover soil	sub soil
	lower material		sub soil	regulating layer
height of slope base	H	m	7.00	7.00
lining thickness	T1	m	0.30	0.70
slope of liner	Cot(alpha)		20.00	20.00
dry density	Gamdry-1	kN/m3	18.00	18.00
saturated density	Gamsat-1	kN/m3	20.00	20.00
saturated thickness	Tw	m	0.08	0.18
interface cohesion	C1	kN/m2	0.00	0.00
interface friction angle	Phi-1	deg	26.00	26.00
soil cohesion	C2	kN/m2	4.00	4.00
soil friction angle	Phi-2	deg	28.00	28.00
active thrust at top of slope	Pa	kN	75	75

Calculations

slope of liner	alpha	rads	0.08	0.08
length of sliding surface	L1	m	133.00	133.00
weight of upper wedge	W1	kN	738.15	1722.35
weight of lower wedge	W2	kN	10.24	55.75
pwp on interface *	U'	kN	97.54	227.60
pwp in cover soil	U"	kN	0.34	1.87
Calculate coefficients for quadratic equation				
A			133.56	211.96
B			-336.27	-796.75
C			13.23	30.86
Factor of safety	**Fs**		**2.48**	**3.72**
Maximum shear force on interface	N1	kN	311.29	726.35
Mobilised shear force on upper interface		kN	125.64	125.64
Maximum shear force on lower interface		kN		726.35
Tension		kN		-600.72
				sub soil

N.B. If the tension is negative there is no tension and the shear is transmitted through to the next interface.

DORRINGTON QUARRY - CAPPING STABILITY & INTEGRITY

Dorrington_v2 Cap12.xls Restoration soils
PSR = 0.50 (Construction Plant - Residual Interface Strengths)

<u>Data Input</u>				
Interface details:	upper material		cover soil	sub soil
	lower material		sub soil	regulating layer
height of slope base	H	m	6.00	6.00
lining thickness	T1	m	0.30	0.70
slope of liner	Cot(alpha)		20.00	20.00
dry density	Gamdry-1	kN/m3	18.00	18.00
saturated density	Gamsat-1	kN/m3	20.00	20.00
saturated thickness	Tw	m	0.15	0.35
interface cohesion	C1	kN/m2	0.00	0.00
interface friction angle	Phi-1	deg	26.00	26.00
soil cohesion	C2	kN/m2	4.00	4.00
soil friction angle	Phi-2	deg	28.00	28.00
active thrust at top of slope	Pa	kN	75	75
<u>Calculations</u>				
slope of liner	alpha	rads	0.08	0.08
length of sliding surface	L1	m	133.00	133.00
weight of upper wedge	W1	kN	758.10	1768.90
weight of lower wedge	W2	kN	10.45	56.90
pwp on interface *	U'	kN	195.08	455.19
pwp in cover soil	U"	kN	1.38	7.49
<u>Calculate coefficients for quadratic equation</u>				
A			135.15	215.67
B			-298.15	-706.44
C			11.62	27.11
Factor of safety	**Fs**		**2.17**	**3.24**
Maximum shear force on interface	N1	kN	273.42	637.98
Mobilised shear force on upper interface		kN	126.21	126.21
Maximum shear force on lower interface		kN		637.98
Tension		kN		-511.77
				sub soil

N.B. If the tension is negative there is no tension and the shear is transmitted through to the next interface.