Sandgate Quarry

Stability Risk Assessment

Environmental Permit

June 2020

inert Recycling (UK) Limited

WYG Environment Planning Transport Limited
Registered Office: 3 Sovereign Square, Leeds, LS1 4ER.

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Checked by:	Paul Brown	Signed:	

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1	March 2020	First Issue
2	June 2020	Updated to incorporate information presented in Hydrogeological Risk Assessment relating to attenuation layer.
3		

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1.0 INTRODUCTION

1.1 Report Context

Inert Recycling (UK) Limited (Inert Recycling) has commissioned WYG Environment Planning and Transport Limited (WYG), to undertake a Stability Risk Assessment (SRA) to support a waste recovery application for Sandgate Quarry, located north of Worthing. This report forms part of supporting information for an Environmental Permit Application for the site.

This report has been completed in conjunction with all relevant documentation, as required by The Environmental Permitting (England and Wales) Regulations 2016 (as amended). It is not a standalone document and factual data related to the site, its setting, and the receiving environment are located in the Application Documents and referred to in this document. All drawings referred to in this SRA are to be found in the Application Document.

This document has been prepared to meet the requirements of the Application Form Part B, Stability Risk Assessment Report and documents the structural and physical stability of the proposed landform.

1.1.1 Site Details

Sandgate Quarry is located off Water Lane, between the A283 (Washington Road) and the B2139 (Thakenham Road), near the village of Storrington. The town of Worthing is situated approximately 7km to the south east. The site is centred at Easting 510300 Northing 114000. The site is situated outside the South Downs National Park with the border of the National Park located on the southern side of Washington Road.

The site covers an area of around 30 hectares and is made up of active and worked out flooded excavations, active lagoon systems along the northern side and landscaping works along the southern slope. The plant and offices are located in the western part of the land. Access to the site is gained via an access road off Water Lane located on the western side of the site.

The site is bounded by Sandgate Country Park to the north, Hampers Lane to the east, Washington Lane to the south and Water Lane to the west.

1.1.2 Proposed Works

In order to restore the site, Inert Recycling seeks to gain a bespoke waste recovery permit for the permanent deposit of inert waste to land at Sandgate Quarry to facilitate the restoration scheme outlined in the planning application (WSCC/044/18/SR).

The proposed development comprises the importation of 1.8 million tonnes of inert waste to infill the void created by the sand extraction. The proposed development changes the original approved restoration to create an enhanced scheme. It seeks to utilise imported inert waste materials rather than using 'virgin' soils for the restoration. The proposed development would use the imported inert waste material to achieve an enhanced restoration over that originally approved. The previously approved restoration scheme included a steep sided large water body. The revised scheme seeks to reduce the steepness of the sides of the void and the area of water by bringing in inert restoration materials. The proposed enhanced scheme includes a smaller lake than currently proposed, as well as a series of shallow ponds, and a causeway between the lake and ponds for increased public access and enjoyment. The proposal also allows for creation of wet heath and reed habitats to improve biodiversity.

The final restoration layout is shown on Dwg No. P4/182/13 and shows a gently undulating profile at around 40 to 44m AOD in the west sloping gently down to a large water body to the east with a water level of around 32m AOD. The proposed waste types will comprise non-waste materials such as soils, sand, stone, gravel etc., and will be capable of being sufficiently compacted so that they can form a stable landform for the medium and long term. The proposed waste types are consistent with those which are considered acceptable for construction and reclamation activities within Standard Rules SR2015 No39: Use of waste in a deposit for recovery operation. The infilling operations will take place in phases following on from each phase of sand extraction.

The base of the workings is proposed to be around 22m AOD and is currently flooded to a level of 27.5m AOD. The slopes are cut into Folkestone Formation and are at an overall gradient of around 30-38°.

1.2 Conceptual Stability Site Model

1.2.1 Historical Information

Information of the ground conditions have been obtained from previous exploratory hole logs (GW01 to 10) from information contained within the Geotechnical Appraisal and Assessment Report produced by CEMEX in April 2013 (Ref 13-S032-SAN-R-001).

1.2.2 Geology and Ground Conditions

The British Geological Survey, Geology of Britain Viewer shows the site to be underlain by the Folkestone Formation, which are described as: *Medium and coarse grained, well sorted cross bedded sands and weakly bedded sandstones.* The Folkestone Formation is up to 80m thick and overlain by Gault Clay. The base of the Folkestone Formation is marked by its contact with the Marehill Clay Member of the Sandgate Formation, comprising silty clay or clayey silt, or a heterogeneous succession of clays, silts and sands (Sandgate Formation, undifferentiated). At the quarry, the excavation is contained entirely within the Folkestone Formation. The over and underlying formations are not encountered. Based on site observation, there are localised areas made up of gravelly (rounded flint) clay. It is possible that such materials are derived from fluvio-glacial or fluvial processes.

Exploratory drilling and mapping of the materials at Sandgate Quarry have confirmed the published geology. The typical sequence is shown below:

- 0 – 0.5m Soils
- 0 – 2.0m Overburden (sandy gravelly clay)
- >50m Mineral (Folkestone Formation)

1.2.3 Groundwater

The hydrogeology of the site is covered in detail in the Hydrogeological Risk Assessment (HRA) prepared by Stantec (2020) as part of this Permit Application.

The site is currently dewatered in order to be able to work the sand in dry conditions. It is assumed that on the cessation of groundwater pumping that the levels will rebound from the current 28m AOD. The HRA i(Stantec, 2020) indicates groundwater levels will recover to around 40m AOD.

For stability risk assessment purposes, a conservative groundwater level of 28 m AOD is adopted in the ground surrounding the site for current conditions and 40m AOD for long term analysis.

1.2.4 Basal Sub-Grade Model

The proposed quarry will extract Folkestone Formation materials to a level of approximately 22 mOD at the deepest excavation point.

The basal sub-grade is comprised of the sands of the Folkestone Formation and comprises light brown to dark brown and green / grey fine to medium sand, with silt and clay laminate.

The basal subgrade is considered to be relatively non-compressible.

1.2.5 Side Slopes Sub-Grade Model

The walls to the proposed quarry comprise Folkestone Formation. It is proposed to fill against the quarry faces which are to excavated at gradients of around 1V:2H. The side slope sub-grade slope will be in the order of 20.0 m high at its highest point but generally of the order of 10m high.

There is no requirement for a leachate sump within a waste recovery permit.

1.2.6 Waste Mass Model

It is proposed that the new cells shall be used for the placement of inert waste. It is anticipated that an attenuation layer will be installed across the base and up the sides of the excavated area. The HRA (Stantec, 2020) assumes the attenuation layer will be 2m thick with a permeability of 1×10^{-8} m/s.

The maximum temporary waste slope during placement operations will be restricted to 1 in 3 (18.4°) for the full height of the waste. The waste will be compacted in horizontal layers across the base of the cell to the pre-settlement restoration level. The final restored waste height shall be as shown on drawing no. P4/182/13. The waste will be confined by the quarry sidewalls on three sides and a lake on the east on completion.

1.2.7 Capping System Model

A capping system is not a requirement of a waste recovery permit.

2.0 STABILITY RISK ASSESSMENT

2.1 Risk Screening

2.1.1 Basal Sub-Grade Screening

The basal sub-grade shall be formed within the Folkestone Formation, a medium dense sand. Site settlement as a result of compressibility and loading of this material is considered insignificant with no detrimental impact upon the proposed development. Further assessment of this is not required.

2.1.2 Side Slopes Sub-Grade Screening

The side slope sub-grade comprises medium dense sand of the Folkestone Formation. The side slopes will be excavated at maximum gradient of 1:2 (v:h).

The stability of the side slopes has been analysed to identify the factor of safety for the quarry prior to the waste mass being placed.

2.1.3 Waste Mass Screening

Waste is to be placed in phases within the cell resulting in temporary waste slopes. The stability of temporary waste slopes is considered to require further investigation.

2.1.4 Clay Liner Screening

The assessment of the use of an impermeable clay liner on the side slopes of the quarry has been considered and investigated as the Hydrogeological Risk Assessment (Stantec 2020) has indicated it is likely to be required.

2.1.5 Capping System Screening

A capping liner is not required and is therefore not considered further.

Loading other than from the restoration soils and construction plant is not anticipated and therefore consideration of settlement is not considered further.

2.2 Data Summary

The anticipated geotechnical properties for the materials at the site have been determined and used in the appraisal / assessment of excavations and tips. Due to the absence of site specific testing data these are based on published information and engineering experience. The values are presented in Table 1 and Table 2.

Table 1. Geotechnical Description of Material Types

Material	Description (BS5930)
Soils	Brown sandy organic clay and silt.
Overburden	Brown sandy slightly gravelly CLAY. Gravel is rounded fine to medium of flint.
Folkestone Formation (sandstone)	Weak brown sandstone.
Folkestone Formation (sand)	Medium dense to dense fine to medium SAND.
Silt (settled)	Soft grey sandy silt

Table 2. Geotechnical Properties

Material	Strength Parameters						Permeability
	Unit Weight (kN/m³)	**UCS (MPa)**	**c_u (kPa)**	**c' (kPa)**	**φ' (°)**	**Ψ (°)**	**k (m/s)**
Overburden*	18	-	40	0	25	-	10^{-7}
Folkestone Formation (sandstone†)	18	200	-	60	46	27*	10^{-5}
Folkestone Formation (sand†)	18	-	-	0	33	-	10^{-4}
Settled Silt	18	-	15	0	20	-	10^{-6}
Site specific parameters not available. Based on reference to *Look (2007) and † Richards & Barton (1999)							

2.2.1 Geotechnical Properties of the Folkestone Formation

A description of the geotechnical characteristics is provided by Richards and Barton (1999), where they describe the Folkestone Formation as a marine shallow-water deposit of Cretaceous age (100-125 million years). Consisting of mostly poorly lithified sands, which classify onto the sand/sandstone borderline, the sand has properties neither akin to the classical concept of an engineering soil nor being strong enough to be labelled a rock (an important consideration with regards to excavations and tips at the quarry).

It has also been observed by Richards and Barton (1999) and noted by a number of studies that the strength of the sandstone is reduced by saturation. An explanation for the loss of strength has yet to be determined but it is suggested that the presence of clay particles within the matrix (which are susceptible to softening) and the loss of the suctions that occur in semi-saturated / dry samples are mechanisms to explain the observations.

2.2.2 Structural Geology

The trends of the main discontinuity sets at the quarry were measured at a number of locations during the site visit. The results are summarised in Table 3.

Table 3. Summary of the orientation of the main discontinuity sets

Discontinuity	Dip / Dip Direction	Comment
Bedding	7° / south	Bed thickness of 0.5-2.0m
Joint Set 1	Sub-vertical / NE-SW	Widely Spaced
Joint Set 2	Sub-vertical / NE-SW	Widely Spaced

Due to the nature of the material (i.e. prone to erosion and surface disturbance) is quite possible that there may be other discontinuities present that were not observed.

2.3 Justification for Modelling Approach and Software

The method of analysis was based on limit equilibrium principles and included checks on global slope stability, predominantly passing through the toe and shallow circular failures affecting only the surface.

For analysis the programme Slide (Rocscience Inc., Version 8.00) was used which incorporates a search routine for identifying the critical surface with the lowest factors of safety against instability.

There are several analysis methods available within the Slide program, including “rigorous” methods such as GLE/Morgenstern and Price and simplified methods such as Bishops or Janbu methods. For this stability review it was considered that GLE/Morgenstern and Price method was appropriate for analysis.

Groundwater levels around the quarry excavation have been modelled at several ranges, representing the upper and lower ranges expected at the site and the design for general groundwater conditions as displayed in Table 4.

Table 4. Groundwater modelling conditions

Model	Water Level
Dry Excavation	22m AOD
Average Conditions	28m AOD
Worst Case	40m AOD

The computer programme Slide was used to calculate the factor of safety of the full height of the slope for a range of unconfined circular failures under effective stress conditions.

2.3.1 Geological Sections

The succession at the site has been based on the available records. There appears to be reasonable consistency in the strata present, overburden over Folkestone Formation.

A maximum slope gradient of 1(v) in 2(h) has been used to assess the stability of the proposed side slope. This is the steepest anticipated from the proposed working plans. A slope gradient of 1(v) in 3(h) (18º) was modelled for the proposed full height temporary waste slopes.

2.4 Justification of Geotechnical Parameters Selected for Analyses

To allow for a conservative situation to be developed, the worst-case situation for the slope has been undertaken, with a 20m high, 1v:2h (27º) face with reduced friction angle beneath the water table representing disaggregated sandstone.

The shear strength parameters for the Folkestone Formation have been derived from the properties provided within Table 5. The Folkestone Formation have been assessed using a dry or saturated unit weight based upon whether they occur above or below the water table.

For conservative analysis the effect of cohesion has been discounted from the analysis. The clay liner has been determined for a thickness of 2m that will be stable on a 1:2 slope, with analysis in table 6. Conservative shear strength parameters for the inert waste fill have been assumed based on previous similar stability analyses; the chosen drained shear strength parameter of 20º is considered very low. Bulk unit weights are based on published literature and on experience of material properties encountered on similar analyses carried out by WYG. The analysis for the inert waste fill is summarised in Table 7.

A distributed surcharge load of 5kPa at the top of the slope has been added to the analysis to allow for conservative design.

2.4.1 Parameter Selected for Side Slopes Sub-Grade Analyses

Table 5. Geotechnical Parameters – Side Slope Sub-Grade

Material		Bulk Density (kN/m³)	Effective Stress		Source
			c′ (kN/m²)	ϕ' (°)	
Unsaturated Folkestone Formation	Weak brown sandstone	18	0	46	Table 3.
Saturated Folkestone Formation	Fine-medium sand*	18	0	33	Table 3.

Table Notes: *Material beneath the water table has been described as disaggregated leading to the description of sand, rather than sandstone above.

Due to the nature of the modelling within SLIDE, the parameters for the unsaturated Folkestone Formation are not shown on the material table within the analysis outputs.

2.4.2 Parameters Selected for Clay Liner

It is understood that the clay liner to be used is to have a permeability of less than 1x10-8 m/s, a maximum thickness of 2m on the side slope and basal layers, with a maximum slope gradient of 1(v): 2(h).

Table 6. Geotechnical Parameters – Clay Liner

Material	Bulk Density (kN/m³)	Effective Stress		Source
		c′ (kN/m²)	ϕ' (°)	
Clay Liner	20	0	36	Minimum value required to enable a 2m thickness to have a FOS greater than 1 on the side slope. This is considered unrealistically high and will need to be re-evaluated once a source of clay is established

2.4.3 Parameters Selected for Waste Analyses

It is understood that the waste shall be classified as inert waste comprising heterogeneous soils and subordinate inert inclusions including fine grained and coarse-grained soils, concrete and brick.

Table 7. Geotechnical Parameters – Inert Waste

Material	Bulk Density (kN/m^3)	Effective Stress		Source
		c′ (kN/m^2)	φ' (°)	
Inert Waste Soils	17	0	20	Conservative value

2.5 Selection of Appropriate Factors of Safety

Global factors of safety (FOS) for long term stability of excavated slopes of between 1.35 and 1.5 are proposed. Short term FOS exceeding 1 is appropriate during construction. All analysis is undertaken using effective stress parameters to model slopes that may be required to stand for limited periods following initial profiling.

2.6 Analyses

Table 8. Summary of Stability Analysis for Side Slope Sub-Grade – 1 (v): 2 (h) gradient Effective Stress Circular for drained conditions

Method	Slope	Stratum	GWL maOD	F of S	Comment
Effective Stress Circular	1 in 2	Folkestone Formation	22	1.527	Deep Slope Failure

2.6.1 Clay Liner Analyses

The results of the clay liner stability analysis are presented within Appendix B and summarised in Table 9 below.

Table 9. Summary of Stability Analysis for Clay Liner – 1 (v): 2 (h) gradient Effective Stress Circular for drained conditions

Method	Slope	Stratum	GWL maOD	F of S	Comment
Effective Stress Circular	1 in 2	Clay Liner	22	1.159	Failure within liner

2.6.2 Waste Analyses

The results of the temporary waste mass stability analyses are presented in Appendix C and summarised in Table 10 below.

Table 10. Summary of Stability Analysis for Temporary Waste Slope – 1 (v): 3 (h) gradient

Method	Slope	Stratum	GWL maOD	F of S	Comment
Effective Stress Circular	1 in 3	Inert Waste	22	1.161	Shallow Failure in clay liner above level of fill
			28	1.161	Shallow Failure in clay liner above level of fill
			32	1.112	Shallow Failure in clay liner above level of fill
			40	1.031	Shallow failure in fill
			40 Outside 32 Within	1.003	Deep failure within waste

SLIDE analyses of the above are presented in Appendix A (Side Slopes), Appendix B (Clay Liner), Appendix C (Waste).

2.7 Assessment

2.7.1 Side Slopes Sub-Grade Assessment

The analysis has shown that the stability of the side slope sub-grade is acceptable under long term (effective stress) conditions with a gradient of 1(v):2(h) when the water level within the quarry is pumped out to 22mAOD as the factor of safety (FOS) is well above 1. This suggests that side slopes of 1v:2h or flatter area stable. It is recommended that slopes that are required to stand in the short term at varying levels of groundwater entry and ponding water are evaluated in terms of steady state and rapid drawdown situations.

2.7.2 Clay Liner Assessment

The stability of the clay liner is such that at a maximum thickness of 2m a minimum friction angle of 36° is required. If this friction angle is unobtainable, consideration should be made to the overall slope angle of the clay liner and a reduction in slope angle may be required to enable a suitable clay liner to be produced.

The clay liner should be protected from drying in the intermediate situation prior to equilibrium conditions being met in the landfill cell.

2.7.3 Waste Assessment

The stability of the waste mass has been considered and is deemed satisfactory when placed with temporary waste slopes no greater than 1(v) in 3(h).

As long as the waste mass meets the requirements of SR2015 No39 and do not exceed a slope angle of 1(v):3 (h), then the slopes are considered to be stable.

2.8 Monitoring

2.8.1 General

Where appropriate each element of construction: subgrade and fill will be subject of an independent Construction Quality Assurance (CQA) regime during construction. This will ensure that all materials are stable and to specification at the time of construction.

2.8.2 Basal Sub-Grade Monitoring

The local geology has been assumed to follow that recorded on the available published geological information and the available ground investigation data. Should significantly different conditions be encountered at the proposed sub-grade level (e.g. absence of strata associated with the Folkestone Formation) then advice on the impact on the design should be sought from the works designer. Any variations to the proposed design should be agreed / approved by the Environment Agency prior to execution on site.

2.8.3 Side Slopes Sub-Grade Monitoring

The anticipated sequence of materials within the side slopes of the excavation has been derived from consideration of the available ground investigation data. Should significantly different conditions be encountered in the side slopes then advice on the impact on the design should be sought from the works designer. Any variations to the proposed design should be agreed / approved by the Environment Agency prior to execution on site.

2.8.4 Waste Monitoring

The risk of failure to temporary slopes within the waste mass is considered low. The site operator should ensure that waste is suitably compacted and temporary waste slopes do not exceed the maximum allowable gradient of 1:3 to the full height (6.0 m). In the event of a slope failure the Environment Agency should be informed and remedial action agreed.

2.8.5 Clay Liner Monitoring

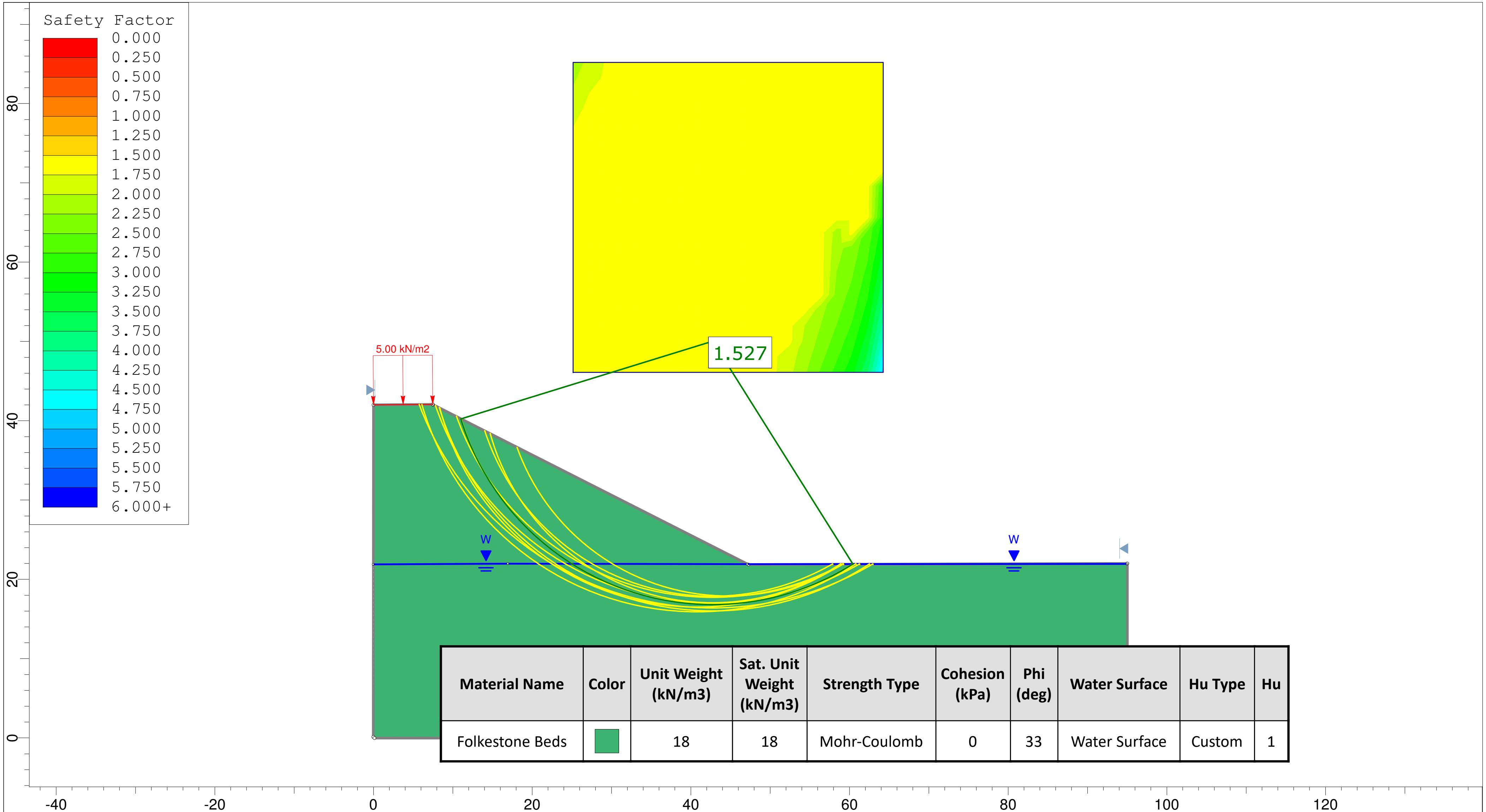
The risk of failure within the clay liner is considered to be low, if the material used has the required friction angle of greater than 36° and does not exceed a maximum of 2m in thickness on a 1:2 gradient slope. If this is unobtainable consideration should be made to changing the angle of the clay liner slope. Once the clay liner is constrained by the fill, it drastically increases the FOS within the unit. In the event of a slope failure the Environment Agency should be informed and remedial action agreed.

REFERENCES

Stantec, 2020. Sandgate Quarry, Hydrogeological Risk Assessment. Ref: 66671AAR2.

Appendices

Appendix A – Results of the Side Slope Stability Analyses



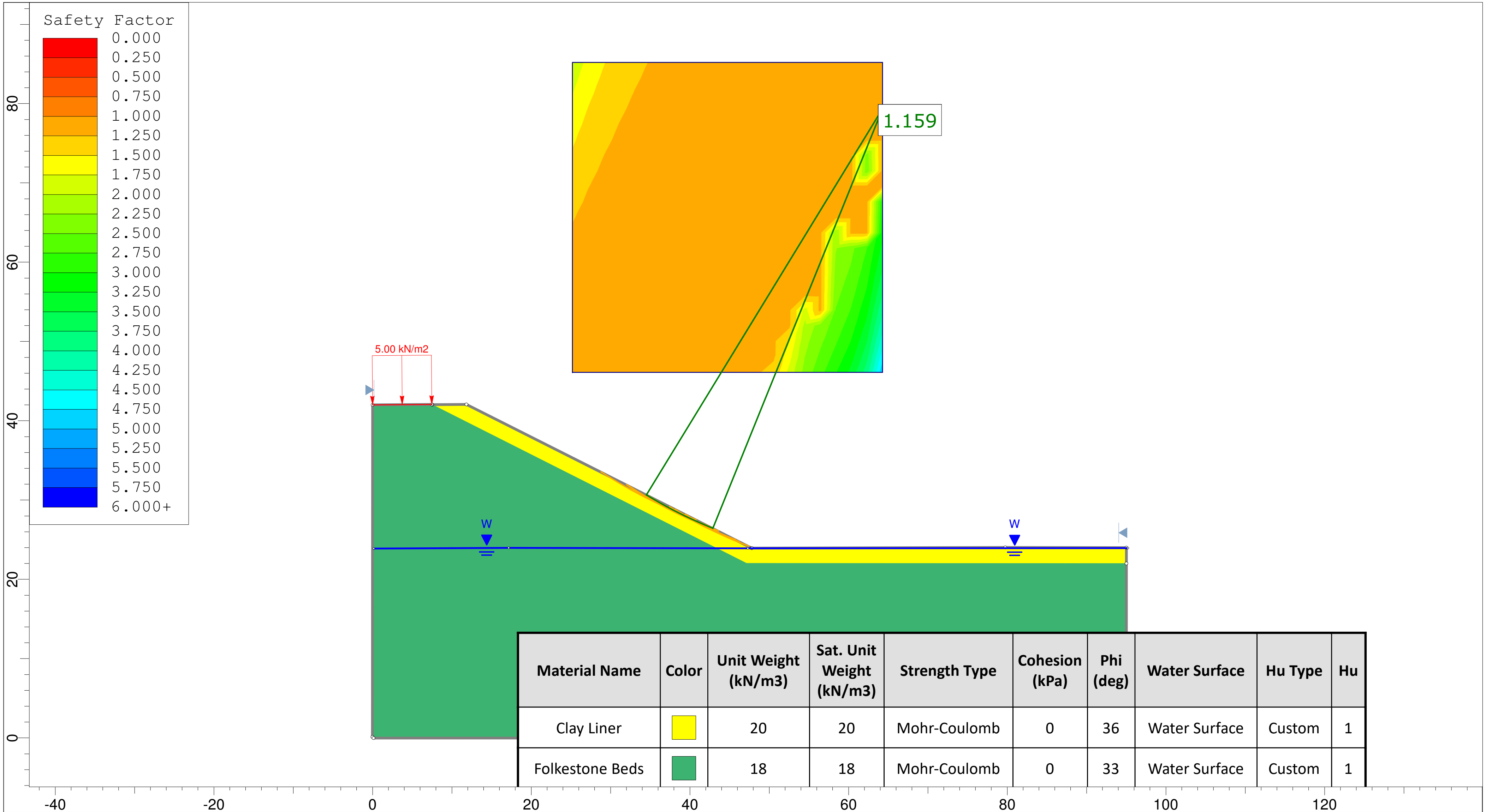
Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Folkestone Beds		18	18	Mohr-Coulomb	0	33	Water Surface	Custom	1

rocscience

SLIDEINTERPRET 8.016

Project	Sandgate Quarry		
Analysis Description	No liner Water Level at 22m AOD		
Drawn By JO	*Scale* 1:673	10 lowest factors of safety	
June 2020		DA1 C2	

Appendix B - Results of the Clay Liner Slope Stability Analyses



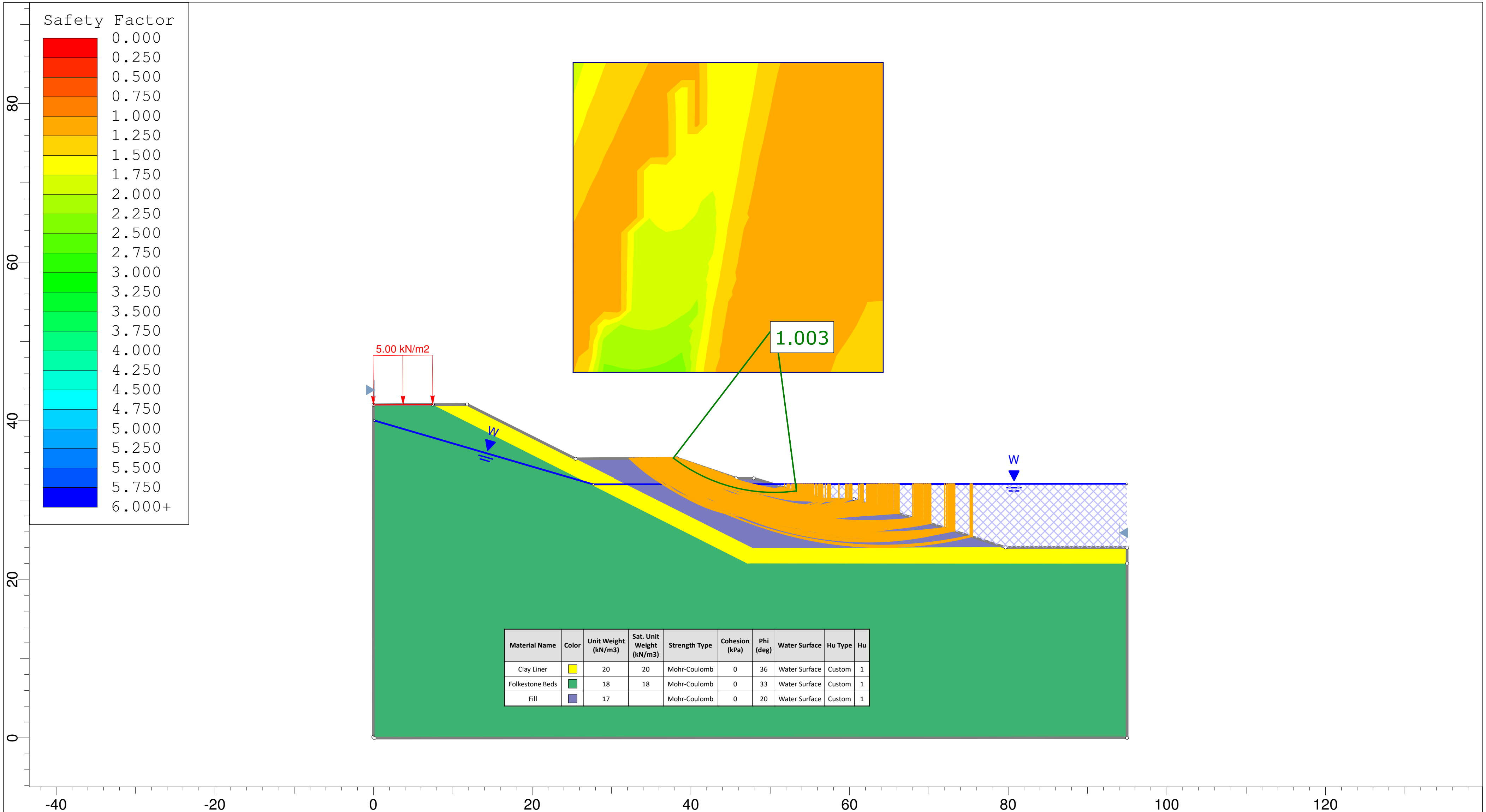
Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Clay Liner		20	20	Mohr-Coulomb	0	36	Water Surface	Custom	1
Folkestone Beds		18	18	Mohr-Coulomb	0	33	Water Surface	Custom	1

rocscience

SLIDEINTERPRET 8.016

Project	Sandgate Quarry		
Analysis Description	Liner with Water Level at 22m AOD		
Drawn By JO	*Scale* 1:673	10 lowest factors of safety	
June 2020		DA1 C2	

Appendix C - Results of the Waste Mass Slope Stability Analyses



Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Clay Liner		20	20	Mohr-Coulomb	0	36	Water Surface	Custom	1
Folkestone Beds		18	18	Mohr-Coulomb	0	33	Water Surface	Custom	1
Fill		17		Mohr-Coulomb	0	20	Water Surface	Custom	1

rocscience	*Project*	Sandgate Quarry	
	Analysis Description	2m Clay liner with fill Water Level at 40m AOD outside quarry 32mAOD within	
	Drawn By JO	*Scale* 1:673	factors of safety from 1.0 to 1.1
SLIDEINTERPRET 8.016	June 2020		DA1 C2

Appendix D – Report Conditions

REPORT CONDITIONS

This report is produced solely for the benefit of **Inert Recycling (UK) Limited** and no liability is accepted for any reliance placed on it by any other party unless specifically agreed in writing otherwise.

This report is prepared for the proposed uses stated in the report and should not be used in a different context without reference to WYG. In time improved practices, fresh information or amended legislation may necessitate a re-assessment. Opinions and information provided in this report are on the basis of WYG using due skill and care in the preparation of the report.

This report refers, within the limitations stated, to the environment of the site in the context of the surrounding area at the time of the inspections. Environmental conditions can vary and no warranty is given as to the possibility of changes in the environment of the site and surrounding area at differing times.

This report is limited to those aspects reported on, within the scope and limits agreed with the client under our appointment. It is necessarily restricted and no liability is accepted for any other aspect. It is based on the information sources indicated in the report. Some of the opinions are based on unconfirmed data and information and are presented as the best obtained within the scope for this report.

Reliance has been placed on the documents and information supplied to WYG by others but no independent verification of these has been made and no warranty is given on them. No liability is accepted or warranty given in relation to the performance, reliability, standing etc of any products, services, organisations or companies referred to in this report.

Whilst skill and care have been used, no investigative method can eliminate the possibility of obtaining partially imprecise, incomplete or not fully representative information. Any monitoring or survey work undertaken as part of the commission will have been subject to limitations, including for example timescale, seasonal and weather related conditions.

Although care is taken to select monitoring and survey periods that are typical of the environmental conditions being measured, within the overall reporting programme constraints, measured conditions may not be fully representative of the actual conditions. Any predictive or modelling work, undertaken as part of the commission will be subject to limitations including the representativeness of data used by the model and the assumptions inherent within the approach used. Actual environmental conditions are typically more complex and variable than the investigative, predictive and modelling approaches indicate in practice, and the output of such approaches cannot be relied upon as a comprehensive or accurate indicator of future conditions.

The potential influence of our assessment and report on other aspects of any development or future planning requires evaluation by other involved parties.

The performance of environmental protection measures and of buildings and other structures in relation to acoustics, vibration, noise mitigation and other environmental issues is influenced to a large extent by the degree to which the relevant environmental considerations are incorporated into the final design and specifications and the quality of workmanship and compliance with the specifications on site during construction. WYG accept no liability for issues with performance arising from such factors.