NEWPORT QUARRY

Environmental Permit Variation Application

Stability Risk Assessment

Prepared for: Ingrebourne Valley Limited

Client Ref: 416.01526.00069

SLR Ref: 416.01526.00069
Version No: V1
October 2020

BASIS OF REPORT

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DOCUMENT REFERENCES

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1.0 Introduction

SLR Consulting Limited (SLR) has been instructed by Ingrebourne Valley Limited (IV) to prepare an Environmental Permit (EP) application to authorise a waste soils and aggregates recycling process and the deposit of waste for recovery in the restoration of Newport Quarry, Chalk Farm Lane, Saffron Walden, Essex, hereafter referred to as 'the site'.

The EP application seeks the use of approximately 500,000m^3 inert waste in the restoration of a chalk quarry to calcareous grassland at the site. The proposed restoration seeks to mimic the surrounding natural ground levels and will include a swale, attenuation pond and exposed areas of chalk rock face. Some areas of the quarry void have already been restored using on-site overburden materials.

As part of the permit application, SLR has undertaken a geotechnical Stability Risk Assessment (SRA). This document describes the manner in which the assessment has been carried out and presents the overall findings of the work.

Relevant background information describing the site setting (including geological, hydrological, site monitoring data and development proposals) is detailed within the site's Non-Technical Summary (NTS)[1].

The methodology adopted for this Stability Risk Assessment generally follows the principles outlined in the Environment Agency R&D Technical Report P-385, volumes TR1 and TR2[2] (from here on referred to as the guidance). Where additional analytical techniques have been used, these are described within the text.

1.1 Conceptual Stability Site Model

The conceptual stability site model has been developed from information contained in the NTS[1] and review of relevant publicly available and site specific data.

The site (centred approximately on grid reference TL 52600 33200) is an operational chalk quarry. It is approximately 10.25ha in size, of which 8.4ha is the open quarry void. The remainder has been partially restored using on-site overburden material. The quarry is located on a hill slope and the topography ranges from 97mAOD in the southeast to 62mAOD in the northwest. It is separated from the River Cam to the west by a railway line. To the east, the land rises up to 108mAOD.

In total approximately 500,000m^3 of residual and unrecyclable inert waste will be used to restore the quarry to calcareous grassland. Restoration will be undertaken in four phases over a 7 to 10-year period. Recycling operations will run in parallel with restoration operations.

A review of the British Geological Survey (BGS)[3] map, reveals that the site is underlain by bedrock of Lewes Nodular Chalk Formation and Seaford Chalk Formation (undifferentiated) – Chalk. The bedrock is a Principal Aquifer which is also designated as a Source Protection Zone 3.

No superficial deposits are recorded underlying the majority of the site. Kesgrave Catchment Subgroup – sand and gravel is recorded in the southeast of the site, with Lowestoft Formation (Diamicton) immediately east. The access track area in the west of the site is predominantly underlain by superficial Head deposits (clay, silt, sand and gravel) with Alluvium to the east.

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[1] SLR Consulting Ltd (2020). Newport Quarry Restoration Environmental Permit Application Non-Technical Summary. Prepared for Ingrebourne Valley limited. Ref: 416.01526.00069.

[2] Environment Agency R&D Technical Report P1-385/ TR1 and TR2, 'Stability of Landfill Liner Systems', March 2003.

[3] British Geological Survey – Available: mapapps.bgs.ac.uk/geologyofbritain/home.html, accessed July 2020

Five boreholes were drilled around the perimeter of the site in 2017[4]. The ground investigation intersected Made Ground ranging between 0.5m and 11m thick in the west of the site, comprising slightly sandy gravelly clay with gravel of chalk, flint and occasional bands of compacted chalk material. The Made Ground was found to be underlain by superficial deposits, up to 2m thick, comprising slightly silty sand and gravel or gravelly clay. Chalk was intersected at all exploratory locations at a minimum of 0.5m below ground level (bgl) in the north of the site and a maximum of 11.0m bgl in the west.

Groundwater is recorded approximately 5-6m below the base of the quarry. The site will be restored under dry conditions.

The following sections provide further details of the principal components of the landfill development.

1.1.1 Basal Subgrade Model

The basal subgrade to the site is formed by the base of mineral extraction of the undifferentiated Lewes Nodular Chalk Formation and Seaford Chalk Formation at approximately 60m AOD.

1.1.2 Side Slope Subgrade Model

The side slope subgrade will be formed predominantly by extraction of the in-situ chalk. Extraction currently extends up to 23m below surrounding ground levels in the central south of the site, where slopes are present at a maximum gradient of 1V:1.25H to a height of 10m. In the northeast, extraction slopes are near vertical up to 5m high, with benching.

The southwest of the site has been restored using site won overburden. The restored material will form part of the side slope subgrade in the southwest of the site. Slopes are currently present at a gradient of approximately 1V:1.8H up to a height of 9m.

An area in the northeast of the site will be restored to include an infiltration basin. The side slope subgrade will be formed of cut slopes in chalk to the north and east. Exposed geological faces will be retained where possible with chalk extracted to form the basin, excavated to 83mAOD.

1.1.3 Basal Geological Barrier Model

The basal geological barrier will be constructed using site won low permeability clay overburden and suitable, low permeability, imported inert waste material. The basal geological barrier will be constructed to a minimum thickness of 1m at a permeability no greater than $1x10^{-7}$m/s.

1.1.4 Side Slope Geological Barrier Model

The side slope geological barrier will be constructed of the same material as the basal geological barrier, comprising site won low permeability overburden and suitable, low permeability imported inert waste material. The side slope geological barrier will be constructed to a minimum thickness of 1m at a permeability no greater than $1x10^{-7}$m/s.

1.1.5 Waste Mass Model

The site will be restored in lifts using indigenous overburden material and residual unrecyclable inert waste material to achieve the restoration profile, minus the upper calcareous soil layers. Strict waste acceptance procedures will be in place at the site to ensure that non-inert waste is not accepted at the site.

[4] ESI Limited (2017). Chalk Farm Quarry, Newport, Essex: CQA Validation (Report ref: 65917R4). Prepared for Ingrebourne Valley Ltd.

1.1.6 Capping System Model

The site will be restored as close as possible to the site's natural contours prior to chalk extraction. Two soil layers will be laid over the Waste Mass; a lower soil layer of indigenous chalk fines at a thickness of approximately 0.3-0.5m and an upper calcareous soil layer at a thickness of 0.25-0.3m. There is no requirement for an engineered cap.

2.0 STABILITY RISK ASSESSMENT

Each of the six principal components of the conceptual stability site model has been considered and the various elements of that component have been assessed with regard to stability.

The principal components considered are:

- The basal subgrade.
- The side slope subgrade.
- The basal geological barrier.
- The side slope geological barrier.
- The waste.
- The capping system.

2.1 Risk Screening

Issues relating to stability and integrity for each principal component of the proposed development have been subject to a preliminary review to determine the need to undertake further detailed geotechnical analyses. The following sections present the results of this screening exercise.

2.1.1 Basal Subgrade Screening

The base of the site will be formed by in-situ chalk. Each aspect of the stability and deformability of the basal subgrade identified in the Guidance is discussed in Table 2-1 below.

Table 2-1 Stability Components for Basal Subgrade

Excessive Deformation	Compressible subgrade	The basal subgrade will be formed by in-situ chalk of the Lewes Nodular Chalk Formation and Seaford Chalk Formation (undifferentiated). The chalk is considered effectively incompressible under the limited weight imparted by the waste mass. This component does not require further consideration.
	Basal heave	Groundwater is recorded approximately 5-6m below the base of the excavation. The site will be restored dry. Therefore, basal heave will not occur. This component does not require further consideration.
	Cavities in subgrade	No cavities have been recorded during extraction of chalk. However, natural cavities have been recorded in the in the surrounding area. Visual inspection of the basal subgrade is required prior to placement of the basal geological barrier to assess the presence of cavities. Based on SLR's experience in similar geology, underlying cavities will not impact the integrity of the basal geological barrier.
Filling on Waste	Compressible waste	Not applicable.
	Cavities in waste	Not applicable.

Given the foregoing, it is considered that the basal subgrade system does not require further assessment.

2.1.2 Side Slope Subgrade Screening

The controlling factors that will affect the stability and deformability of the side slope subgrade are detailed in Table 2-2, below.

Table 2-2 Stability/Integrity Components of Side Slope Subgrade

<table>
<tr><td rowspan="13">Cut slope</td><td rowspan="3">Rock</td><td>Stability</td><td>The current side slopes were excavated during chalk extraction. Geotechnical Assessments will have been carried out at the site under the requirements of the Quarries Regulations 1999. These assessments would identify any issue with the stability of the side slopes.
The side slope subgrade will be inspected prior to restoration.
This component does not require further consideration.</td></tr>
<tr><td>Cavities in subgrade</td><td>No cavities have been recorded on site; however, natural cavities have been recorded in the Upper Chalk Formation in the surrounding area.
Visual inspection of the side slope subgrade is required prior to placement of the side slope geological barrier. Cavities will be filled with indigenous material or with geological barrier material.
This component does not require further consideration.</td></tr>
<tr><td>Deformability</td><td>The side slope subgrade will be formed by in-situ chalk. The chalk is considered effectively incompressible under the limited weight imparted by the waste mass.
This component does not require further consideration.</td></tr>
<tr><td rowspan="4">Cohesive soils</td><td>Stability</td><td>Not applicable.</td></tr>
<tr><td>Deformability</td><td>Not applicable.</td></tr>
<tr><td>Time dependent stability</td><td>Not applicable.</td></tr>
<tr><td>Groundwater</td><td>Not applicable.</td></tr>
<tr><td rowspan="3">Granular soils</td><td>Stability</td><td>The infiltration basin in the northeast of the site will be constructed by extraction of in-situ chalk to 83mAOD. The north and western boundaries will be formed by cut slopes up to 5m high. This component requires further consideration.</td></tr>
<tr><td>Deformability</td><td>Not applicable.</td></tr>
<tr><td>Groundwater</td><td>Not applicable.</td></tr>
<tr><td rowspan="6">Fill Slope</td><td rowspan="3">Cohesive soils</td><td>Stability</td><td>The southwest of the site has been restored using site won overburden. Slopes are currently present at a gradient of 1V:1.8H up to 9m above the base of the quarry.
Visual inspection has confirmed that the slopes are currently vegetated and are stable at this gradient. This component does not require further consideration.</td></tr>
<tr><td>Time dependent stability</td><td>Not applicable.</td></tr>
<tr><td>Groundwater</td><td>Groundwater is present approximately 5-6m below the base of the quarry. The quarry will be restored dry. This component does not require further consideration.</td></tr>
<tr><td rowspan="3">Granular soils</td><td>Stability</td><td>Not applicable.</td></tr>
<tr><td>Deformability</td><td>Not applicable.</td></tr>
<tr><td>Groundwater</td><td>Not applicable.</td></tr>
</table>

Given the foregoing, it is considered that the side slope subgrade requires further assessment.

2.1.3 Basal Geological Barrier System Screening

The controlling factors that influence the stability and integrity of the basal geological barrier system are given in Table 2-3, below.

Table 2-3 Stability/Integrity Components of Basal Geological Barrier System

Mineral only	Stability and Integrity	The basal geological barrier system will comprise engineered low permeability clay. In terms of potential for movements along the basal geological barrier, the development of the landfill will result in the generation of temporary waste slopes. The presence of temporary slopes may result in instability within the waste and the along basal geological barrier system. Since this issue is largely dependent upon the geometry of the waste mass, this aspect of the stability review is covered under Section 2.1.5, Waste Mass Stability.
	Compressible subgrade	The basal subgrade will comprise engineered low permeability clay which is considered to be effectively incompressible under the stresses imposed by the waste height proposed. This component does not require further consideration.
	Cavities	No cavities have been recorded during extraction of chalk. However, natural cavities have been recorded in the in the surrounding area. Visual inspection of the basal subgrade is required prior to placement of the basal geological barrier to assess the presence of cavities. Based on SLR's experience in similar geology underlying cavities will not impact the integrity of the basal geological barrier.
	Basal heave	Groundwater is recorded between 5m and 6m below the base of the excavation. The site will be restored dry. This component does not require further consideration.
Geosynthetic / clay geological barrier	Stability and Integrity	Not applicable.
	Compressible subgrade	Not applicable.
	Cavities	Not applicable.
	Basal heave	Not applicable.

Given the foregoing, it is considered that the basal geological barrier does not require further assessment apart from where influenced by stability of the waste mass. This is considered in Section 2.1.5.

2.1.4 Side Slope Geological Barrier System Screening

The controlling factors that influence the stability and integrity of the side slope geological barrier system are given in Table 2-4 below.

Table 2-4 Stability/Integrity Components of Side Slope Geological Barrier System

Unconfined	Mineral only	Stability	The geological barrier will be constructed in lifts of selected imported material in line with the waste mass. The geological barrier will be a minimum of 1.0m thick. Further assessment is required to determine the stability of the geological barrier during construction.
		Integrity	The integrity of the side slope geological barrier will not be compromised in the unconfined condition providing the stability assessment returns a sufficiently high factor of safety. This aspect of the assessment does not require further consideration.
	Geosynthetic / mineral	Stability	Not applicable.
		Integrity	Not applicable.
Confined	Mineral only	Stability	If the stability in the unconfined condition is satisfactory, it is clear that the stability of the side slope geological barrier system in the confined condition will be greater due to the buttressing effect of the waste and will therefore be satisfactory. This issue is considered as being separate from the Waste Mass Analysis, which examines the influence of the confined side slope geological barrier system on the overall stability of the waste mass. The issue of confined side slope geological barrier system stability is therefore considered as part of the Waste Mass Analysis.
		Integrity	If the integrity in the unconfined condition is satisfactory (which may be concluded from a simple consideration of the factor of safety), it is clear that the integrity of the side slope geological barrier system in the confined condition will be greater due to the buttressing effect of the waste and will therefore be satisfactory.
	Geosynthetic / mineral	Stability	Not applicable
		Integrity	Not applicable

Given the foregoing, it is considered that the side slope geological barrier system requires further assessment.

2.1.5 Waste Mass Screening

The controlling factors that influence the stability of the waste mass are presented in Table 2-5 below.

Table 2-5 Stability Components of Waste Slopes

Failure wholly in waste	Stability		Inert waste will be placed in phases within the void. Temporary waste slopes will be generated through progressive filling. Temporary waste slopes will require further assessment. The infiltration pond in the northeast of the site will be formed by extracted chalk overlain by restored waste to the south. This component will require further assessment.
Failure involving geological barrier and waste	Mineral only	Stability	The development of the void by progressive infilling will result in the generation of a single temporary waste slope in the short term. The proposed method of working is likely to generate a temporary waste slope adjacent to the side slope geological barrier that has the potential to shear through the side or basal geological barriers. This element requires further assessment.
		Integrity	Not applicable
	Geosynthetic / Mineral	Stability	Not applicable
		Integrity	Not applicable

Given the foregoing, it is considered that the waste mass requires further assessment.

Leachate Collection System

Due to the nature of the inert waste to be deposited at Newport Quarry, potentially polluting leachate will not be generated. Consequently, a specific leachate collection system is not required and will not be installed.

Gas Collection System

Due to the nature of the waste to be deposited at Newport Farm Quarry, a significant volume of landfill gas will not be generated. Therefore, a gas extraction system is not warranted and will not be installed. The waste will be subject to waste acceptance criteria and waste acceptance procedures to ensure imported waste is not likely to generate landfill gas.

2.1.6 Capping System Screening

No formal capping is proposed at Newport Quarry; therefore, analysis of the capping system is not considered necessary.

2.2 Lifecycle Phases

This aspect of the assessment identifies the critical phases during the development of the landfill.

The void will be progressively restored in phases following mineral extraction. Placement will result in development of temporary waste slopes in each phase. Following placement some slopes will be re-graded to form the proposed restoration profile.

To ensure the SRA has fully addressed the key issues throughout the life of the landfill, the side slope subgrade surrounding the infiltration basin, the side slope geological barrier and waste mass slope stability will be considered as part of the SRA.

2.3 Data Summary

The following data are required as input for the analyses undertaken for this Stability Risk Assessment

- Material unit weight; and,
- Drained and undrained shear strength of soils and waste.

It should be noted that there is no laboratory test data relating to the shear strength of the materials available on the site or those proposed for import to site.

There is limited available information on appropriate effective stress shear strength parameters for the in-situ materials. Boreholes have been conducted around the perimeter of the site and these provide qualitative descriptions of the materials present.

Where no direct measurement of a particular property is available, reference has been made to the borehole logs and relevant experience from within SLR in the same or similar materials.

The geotechnical parameter values adopted are discussed in more detail in Section 2.6.

2.4 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 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 by limit equilibrium slope stability analyses, which are the only type of analyses required for the current study.

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
- Property - relating to site infrastructure, third party property
- Human beings (i.e. direct risk)
- Ecological receptors

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

2.4.1 Factor of Safety for Basal Subgrade

This element has been screened out in Section 2.1.1; therefore, the selection of an appropriate factor of safety is not required.

2.4.2 Factor of Safety for Side Slope Subgrade

A factor of safety is of 1.3 is considered appropriate when using conservative shear strength parameters.

2.4.3 Factor of Safety for Basal Geological Barrier

This element has been screened out in Section 2.1.3; therefore, the selection of an appropriate factor of safety is not required.

2.4.4 Factor of Safety for Side Slope Geological Barrier

A factor of safety of 1.3 is considered appropriate when using conservative peak shear strength parameters. Where reduced shear strength parameters are adopted (for example, for very long-term conditions, involving the 'fully-softened' or residual shear strength of the side slope geological barrier), it is considered that the factor of safety could be reduced to a value greater than unity, in accordance with the advice given in the Guidance.

2.4.5 Factor of Safety for Waste Mass

There are no inert waste shear strength parameters available in the Guidance, therefore effective stress shear strength parameters have been used, based on the likely materials accepted at the site. In this case it is considered appropriate to adopt a factor of safety of 1.3.

2.4.6 Factor of Safety for Capping System

An assessment is not required on this component as it has been screened out in Section 2.1.6.

2.5 Justification for Modelling Approach and Software

In order to perform a comprehensive Stability Risk Assessment, the components of the recovery operation, as previously described in Section 1.2 of this document, have to be considered not only individually but also in conjunction with one another where relevant. Any analytical techniques adopted for such an assessment should adequately represent all of the considered scenarios, i.e. the different modelled phases of the lifecycle, for both confined and unconfined conditions (where appropriate). The methodology and the software should also achieve the desired output parameters for the assessment, e.g. determination of limit equilibrium factor of safety or calculation of strains within geological barrier components.

The analytical methods used in the original Stability Risk Assessment include:

- Limit equilibrium stability analyses for the derivation of factors of safety for the side slope subgrade, side slope geological barrier and temporary waste slopes.

The limit equilibrium analyses have been undertaken using the package Slope/W 2018, version 9.1 (Geo-Slope International). The Morgenstern-Price[5] non-circular method of analysis has been used.

2.6 Justification of Geotechnical Parameters Selected for Analysis

The following sections present a justification for the various parameters used in the stability analyses based on the following criteria:

- An assessment of the suitability of non-site-specific data, where used.
- Methods for the derivation of the parameters adopted.

A summary of the geotechnical parameters used in the design and analysis of the development are presented in tabular form for each component of the landfill in Table 2-6.

The parameters used in the analysis have been:

- Adapted from similar work undertaken by SLR.
- Inferred from site specific data or other relevant published data.

It should be noted that the geotechnical parameters for limit equilibrium analysis include the shear strength and unit weight of each material within the model, plus pore water or gas pressure assumptions. Shear strength has been defined using total or undrained (s_u), and effective shear strength parameters of cohesion, (c′), and the angle of shearing resistance, (ø′).

[5] Morgenstern, N.R and Price, V.E. (1965), 'The analysis of stability of general slip surfaces' Geotechnique.

2.6.1 Parameters Selected for Basal Subgrade Analysis

Analysis of the basal subgrade is not necessary as it has been screened out in Section 2.1.1.

2.6.2 Parameters Selected for Side Slopes Subgrade Analysis

The parameters required for the side slope subgrade analysis are the angle of shearing resistance and cohesion for the in-situ superficial deposits and the in-situ Lewes Nodular Chalk Formation and Seaford Chalk Formation (undifferentiated) chalk. In-situ material parameters have been selected based on back analysis of existing slopes, site observations and CIRIA guidance[6]. The adopted parameters are presented in Table 2-6.

2.6.3 Parameters Selected for Basal Geological Barrier Analysis

The parameters required for the basal geological barrier system analysis (undertaken as part of the Waste Mass Analysis) are the typical angle of shearing resistance and cohesion of low permeability engineered clay. The adopted parameters are presented in Table 2-6.

2.6.4 Parameters Selected for Side Slope Geological Barrier Analyses

It should be noted here that the unconfined and confined side slope geological barrier analyses are distinct and dealt with in separate sections of this report. The former is analysed and assessed in Section 2.7.4, while the latter is undertaken as part of the Waste Mass Analysis (Section 2.7.5**Error! Reference source not found.**) since the side slope geological barrier integrity depends fundamentally upon the behaviour of the waste.

The parameters required for the side slope geological barrier system analysis (undertaken as part of the Waste Mass Analysis) are the angle of shearing resistance and cohesion of the geological barrier. This has been assigned drained parameters and includes both peak and post peak values for the stability analysis. The parameters selected, based on SLR's recent experience, are presented in Table 2-6. below.

2.6.5 Parameters Selected for Waste Analyses

In terms of the waste strength, SLR has adopted conservative values of effective shear strength parameters, with the values are presented in Table 2-6. These have been adopted based on assumptions made from SLR's recent experience.

2.6.6 Parameters Selected for Capping Analyses

Analysis of the capping is not necessary as it has been screened out in Section 2.1.6

[6] CIRIA C574. Part 6 – Cuttings, retaining structures and anchorages.

Table 2-6
Geotechnical Design Parameters

Material	Unit Weight, γ (kN/m³)	Effective cohesion, c′ (kPa)	Angle of Shearing Resistance, ø' (°)	Undrained Shear Strength (kPa)	Typical Description
Overburden	18	1	30	-	In-situ superficial deposits.
In-situ Unstructured Chalk	18	0	33	-	Weathered chalk of Lewes Nodular Chalk Formation and Seaford Chalk Formation (Undifferentiated) CIRIA unstructured chalk[6].
In-situ Chalk	18	1	39	-	Lewes Nodular Chalk Formation and Seaford Chalk Formation (Undifferentiated). Back analysis.
Geological Barrier	18	0 (0)*	24.5 (18)	50	Engineered low permeability clay
Inert Waste	16	0.5	26	-	Inert waste

* Values in parentheses are fully softened (residual) values

2.7 Analyses

Details of the various Stability Risk Assessment analyses undertaken for the site are presented in the following sections.

2.7.1 Basal Subgrade Analysis

Analysis of the basal subgrade is not necessary, as it has been screened out in Section 2.1.1.

2.7.2 Side Slope Subgrade Analysis

Analysis of the side slope subgrade has been undertaken to consider side slopes surrounding the proposed infiltration basin in the northeast of the site. Back analysis for the existing side slope subgrade has been undertaken to determine material parameters for in-situ structured chalk. In the absence of site-specific material parameters CIRIA guidance has been used to determine the worst credible chalk properties for weathered chalk.

The north and east slopes will be formed of cut slopes comprising weathered chalk, currently exposed by the limit of extraction, and the underlying chalk; likely to be structured. Initial analysis has been carried out for the proposed 1V:1H cut slope up to 6m high. A piezometric line has been applied to represent water within the infiltration basin. The analysis returns an unacceptable factor of safety of less than 1.3. Analysis of the slope at a gradient of 1V:2H returns an acceptable factor of safety, in excess of 1.3. The results are summarised in Table 2-7 with analyses presented in Appendix SRA-1. Based on this, it will be necessary to cut the north and east slopes to a maximum gradient of 1V:2H.

The slope to the south of the infiltration basin will be constructed of imported inert waste to a maximum of 90mAOD. The base of the slope, beyond the current extraction limits, will be formed by extraction of chalk to 83mAOD. This slope is considered in more detail as part of waste mass analysis in Section 2.7.5.

Table 2-7
Summary of Stability Analysis for Unconfined Side Slope Geological Barrier

Figure	File	Method	Factor of Safety	Comments
SRA1-1	SRA1	Drained Circular	0.679	Cut slope 6m high at a gradient of 1V:1H. Unstructured chalk over structured chalk. Unacceptable (FOS<1.3)
SRA1-2	SRA1	Drained Circular	1.323	Cut slope 6m high at a gradient of 1V:2H. Unstructured chalk over structured chalk. Acceptable (FOS>1.3)

2.7.3 Basal Geological Barrier

Analysis of the basal geological barrier is not necessary, as it has been screened out in Section 2.1.3.

2.7.4 Side Slope Geological Barrier Analysis

Unconfined Geological Barrier Stability

The unconfined side slope geological barrier will comprise low permeability clay. In order to provide an effective barrier this will be placed onto the existing in-situ side slope subgrade at a minimum thickness of 1.0m.

An initial analysis has been carried out to demonstrate, in principle, the geological barrier could be placed to the full height of the side slope and remain stable under short term conditions. Figure SRA2-1 in Appendix SRA2 demonstrates a factor of safety of 1.365 is achieved in this condition.

Due to the steep gradient of base of the side slope subgrade, the side slope geological barrier will be placed as buttress, in line with the waste mass. A maximum of 3m vertical height of geological barrier will remain unconfined at any time. A minimum 4m wide bench at the crest of the side slope geological barrier will be required to ensure an adequate safe working platform for construction plant. A final check has been carried out to consider the stability of subsequent lifts of the geological barrier, placed partially over the waste mass.

The analysis considers the geological barrier to be in a drained condition as a worst case; however, undrained conditions are likely to exist in the short term, prior to buttressing with waste. The results are presented in

Table 2-8.

Table 2-8
Summary of Stability Analysis for Unconfined Side Slope Geological Barrier

Figure	File	Method	Factor of Safety	Geological Barrier Shear Strength			Comments
				s_u (kPa)	c' (kPa)	ϕ' (°)	
SRA2-1	SRA2	Undrained Circular	1.365	50	-	-	Side slope 23m high with gradient up to 1V:1.25H barrier across entire side slope subgrade. Undrained shear strength. Acceptable (FOS>1.3)
SRA2-2	SRA2	Drained Circular	1.469	-	0.5	26	1V:2.5H gradient. Drained shear strength. 3m high lift. Acceptable (FOS>1.3)
SRA2-3	SRA2	Drained Circular	1.469	-	0.5	26	1V:2.5H gradient. Drained shear strength. Second 3m high lift. Acceptable (FOS>1.3)

As presented in Appendix SRA2, analysis returns a factor of safety of 1.469 for a single 3m lift in drained conditions. This is considered acceptable.

It is not anticipated that post peak softened shear strength conditions will develop in the unconfined condition, as progressive tipping of the waste will ensure buttressing of the landfill side slopes.

Confined Liner Stability

Analysis of the confined side slope geological barrier stability has been undertaken as part of the waste mass analysis, as described in Section 2.7.5. This is because both stability of the geological barrier and the waste mass are inter-related.

2.7.5 Waste Analysis

In considering the stability of the waste mass, the stability and integrity of the geological barrier system would normally be considered as they are intrinsically linked. The three potential modes of failure considered are:

- Mode 1 - Critical Slip Surfaces passing solely through the waste.
- Mode 2 - Critical Slip Surfaces passing through the waste and the basal geological barrier.
- Mode 3 - Critical Slip Surfaces passing down through the side slope geological barrier and along the basal geological barrier.

Analyses have been dealt with in terms of circular and non-circular 2-D limit equilibrium using the computer program Slope/W. Stability analysis outputs are presented in Appendix SRA3.

In order to provide a conservative representation of the stability of the waste mass, analyses consider inert waste composed of predominantly clay.

Groundwater is recorded below the base of the excavation; however, it is likely that pore fluid pressures may exist within the waste mass. Pore fluid pressure is the combined effect of water and gas pressures. The distribution of pore fluid pressure varies within the waste mass due to a number of factors, including the nature and variability of the waste and the presence of perched water tables.

In order to model the pore fluid pressures in the waste mass a pore water pressure ratio (r_u) of 0.1 will be applied to the waste mass to represent a worst-case condition.

Mode 1 Waste Mass Stability

Mode 1 analysis has been carried out on the anticipated maximum 22m high inert waste slope (the full depth of the excavation at its deepest point) with a 1m thick basal geological barrier, at a gradient of 1V:3H.

The results of the Mode 1 analyses are summarised Table 2-9 below. Mode 1B considers pore water pressure within the entire waste mass.

Table 2-9
Summary of Waste Stability Analysis for Mode 1

Figure	File	Method	Factor of Safety	r_u	Comments
SRA3-1	SRA3	Drained Circular	1.535	0	22m high slope at 1V:3H gradient. Failure solely within waste mass. Acceptable (FOS >1.3)
SRA3-2	SRA3	Drained Circular	1.370	0.1	22m high slope at 1V:3H gradient. Failure solely within waste mass. Acceptable (FOS >1.3)

Figures SRA3-1 and SRA3-2 demonstrate a factor of safety in excess of 1.3, which is considered to be acceptable.

Mode 2 Waste Mass Stability

Mode 2 considers a potential failure mechanism that passes through the waste and into the basal interface. Short term conditions are modelled in the geological barrier with peak material parameters. The long-term conditions consider post peak or residual (softened) shear strength conditions.

The 22m high waste mass has been analysed with a slope gradient of 1V:3.5H. A pore water pressure ratio of 0.1 has been applied to the waste mass in analyses Mode 2B and 2D.

Output drawings from Slope/W, detailing the slope profiles and the critical slip planes for each scenario analysed for Mode 2, are presented in Appendix SRA3.

The factors of safety reported for peak and residual shear strengths of the geological barrier are summarised in Table 2-10.

Table 2-10
Summary of Waste Stability Analysis for Mode 2

Figure	File	Method	FoS	Geological Barrier		r_u	Comments
				ø' (°)	c' (kPa)		
SRA3-3	SRA3	Drained Non-circular	1.527	24.5	0	0	Mode 2A: Peak shear strength in basal geological barrier Acceptable (FOS >1.3)
SRA3-4	SRA3	Drained Non-circular	1.362	24.5	0	0.1	Mode 2B: Peak shear strength in basal geological barrier Acceptable (FOS >1.3)
SRA3-5	SRA3	Drained Non-circular	1.378	18	0	0	Mode 2C: Residual shear strength in basal geological barrier Acceptable (FOS > 1.0)
SRA3-6	SRA3	Drained Non-circular	1.274	18	0	0.1	Mode 2D: Residual shear strength in basal geological barrier Acceptable (FOS > 1.0)

Figure SRA3-5 and SRA3-6 assume the angle of shearing resistance in the basal interface at the base of the waste mass is in a long term softened condition, with a value of ø'=18° and c'=0kPa. Since softened shear strength values have been assumed, the allowable factor of safety has been reduced to greater than 1.0, in line with the recommendations in the Guidance. All analyses return acceptable factors of safety.

Mode 3 Waste Mass Stability

Mode 3 considered a potential, non-circular slip surface passing down through the side slope geological barrier system and along the basal geological barrier system.

The analysis considers the following scenarios:

- Peak shear strength conditions in the basal geological barrier with softened shear strength conditions in the side slope geological barrier; and,
- Softened shear strength conditions in both the basal and side slope geological barriers.

The results are presented in Table 2-11 below and the analysis sections are presented in Appendix SRA3.

Table 2-11
Summary of Waste Stability Analysis for Mode 3

Figure	File	Method	FoS	Side Slope Geological Barrier		Basal Geological Barrier		Comments
				ø′ (°)	c′ (kPa)	ø′ (°)	c′ (kPa)	
SRA3-7	SRA3	Drained Non-circular	1.986	18	0	24	0.5	Peak shear strength for basal geological barrier. Acceptable (FOS >1.3)
SRA3-8	SRA3	Drained Non-circular	1.209	18	0	18	0	Softened shear strength for basal geological barrier. Acceptable (FOS >1.0)

Both scenarios return an acceptable factor of safety as shown in Figures SRA3-7 and SRA3-8.

Infiltration Pond Restoration Slope Analysis

Additional analysis has been carried out to consider the maximum gradient for the proposed restoration slope south of the infiltration pond. A cross-section has been developed to represent a worst-case scenario with extracted chalk at the base of the basin at 83mAOD to 86mAOD, overlain by imported inert waste up to 90mAOD. A r_u of 0.1 has been applied to represent pore water pressure within the waste mass. A piezometric line has been applied to represent water within the basin.

The results are presented in and the analysis section is present in Appendix SRA3. Waste placed at a maximum gradient of 1V:3H returns an acceptable factor of safety.

Table 2-12
Summary of Infiltration Pond Stability Analysis

Figure	File	Method	Factor of Safety	r_u	Comments
SRA3-9	SRA3	Drained Circular	1.398	0.1	4m high waste slope 1V:3H gradient (including basal geological barrier). Acceptable (FOS >1.3)

2.7.6 Capping Stability Analysis

An assessment is not required on this component as it has been screened out in Section 2.1.6.

2.8 Assessment

2.8.1 Basal Subgrade Assessment

Assessment of the basal subgrade is not required since it has been eliminated from consideration by the screening process within Section 2.1.1.

2.8.2 Side Slope Subgrade Assessment

Assessment of the side slope subgrade considers slopes surrounding the proposed infiltration basin in the northeast of the site. Slopes constructed at a gradient of 1V:2H by cut in in-situ chalk return an acceptable factor of safety.

2.8.3 Basal Geological Barrier Assessment

Assessment of the basal geological barrier is not required since it has been eliminated from consideration by the screening process within Section 2.1.3.

2.8.4 Side Slope Geological Barrier Assessment

The assessment considers the stability of the geological barrier installed on a 23m high slope. It resulted in an acceptable factor of safety in undrained conditions.

Assessment also considered the medium to long term stability of the geological barrier constructed in lifts. The lifts will be buttressed by the placement of waste. Based on phases of filling the side slope geological barrier critical slopes will remain in unconfined conditions for a relatively short time period.

Assessment of the confined side slope geological barrier is addressed in Section 2.8.5 below.

2.8.5 Waste Assessment

Waste Mass Stability

This Stability Risk Assessment incorporates analyses of the geological barrier stability, since this component plays a role in waste mass stability. The assessment considers the worst-case scenario which is a slope from the base of the void to surrounding ground level.

Stability analysis considered three potential modes of failure:

- Mode 1 - Critical Slip Surfaces passing solely through the waste
- Mode 2 - Critical Slip Surfaces passing through the waste and the basal interface.
- Mode 3 - Critical Slip Surfaces passing down through the side slope geological barrier and along the basal geological barrier.

Where appropriate, each assessment considers a worst-case scenario with elevated pore pressure within the waste mass. Additionally, Mode 2 and Mode 3 analyses consider both peak and residual (softened) strength parameters within the geological barrier.

The stability assessment demonstrated that temporary inert waste slopes at a gradient of 1V:3H up to 22m high (excluding the basal geological barrier) return an adequate factor of safety in all modelled conditions. As shown in Section 2.7.5 the factor of safety is acceptable under both short (peak) and long-term conditions.

2.8.6 Capping Assessment

Assessment of this component is not required as it was eliminated from consideration by the screening process (Section 2.1.6).

3.0 MONITORING

3.1 The Risk Based Monitoring Scheme

Based upon the foregoing Stability Risk Assessment, a simple risk-based monitoring scheme is considered appropriate for the future development of the landfill. The monitoring is limited to ensuring compliance with the tipping rules and monitoring of groundwater levels.

3.2 Basal Subgrade Monitoring

Monitoring during construction will comprise inspection of the side slope subgrade following mineral excavation.

No additional instrumentation is deemed as being required post closure.

3.3 Side Slope Subgrade Monitoring

Monitoring during construction will comprise inspection of the side slope subgrade following mineral excavation.

No additional instrumentation is deemed as being required during construction or post closure.

3.4 Basal Geological Barrier System Monitoring

Monitoring during construction will comprise construction quality assurance to ensure compliance with the construction specification.

No additional instrumentation is deemed as being required during construction or post closure.

3.5 Side Slope Geological Barrier System Monitoring

Monitoring during construction will comprise construction quality assurance to ensure compliance with the construction specification.

No additional instrumentation is deemed as being required during construction or post closure.

3.6 Waste Mass Monitoring

Tip faces and surrounding areas should be inspected daily for signs of failure. In order to ensure an acceptable factor of safety is maintained the inert waste should be placed in horizontal layers as far as reasonably practicable with consideration to the type of material being imported.

No other specific monitoring is required for the waste other than to record waste elevations across the site. Once placement is completed the majority of the waste mass will be confined within surrounding ground levels, so post completion waste mass monitoring is not required.

3.7 Capping Monitoring

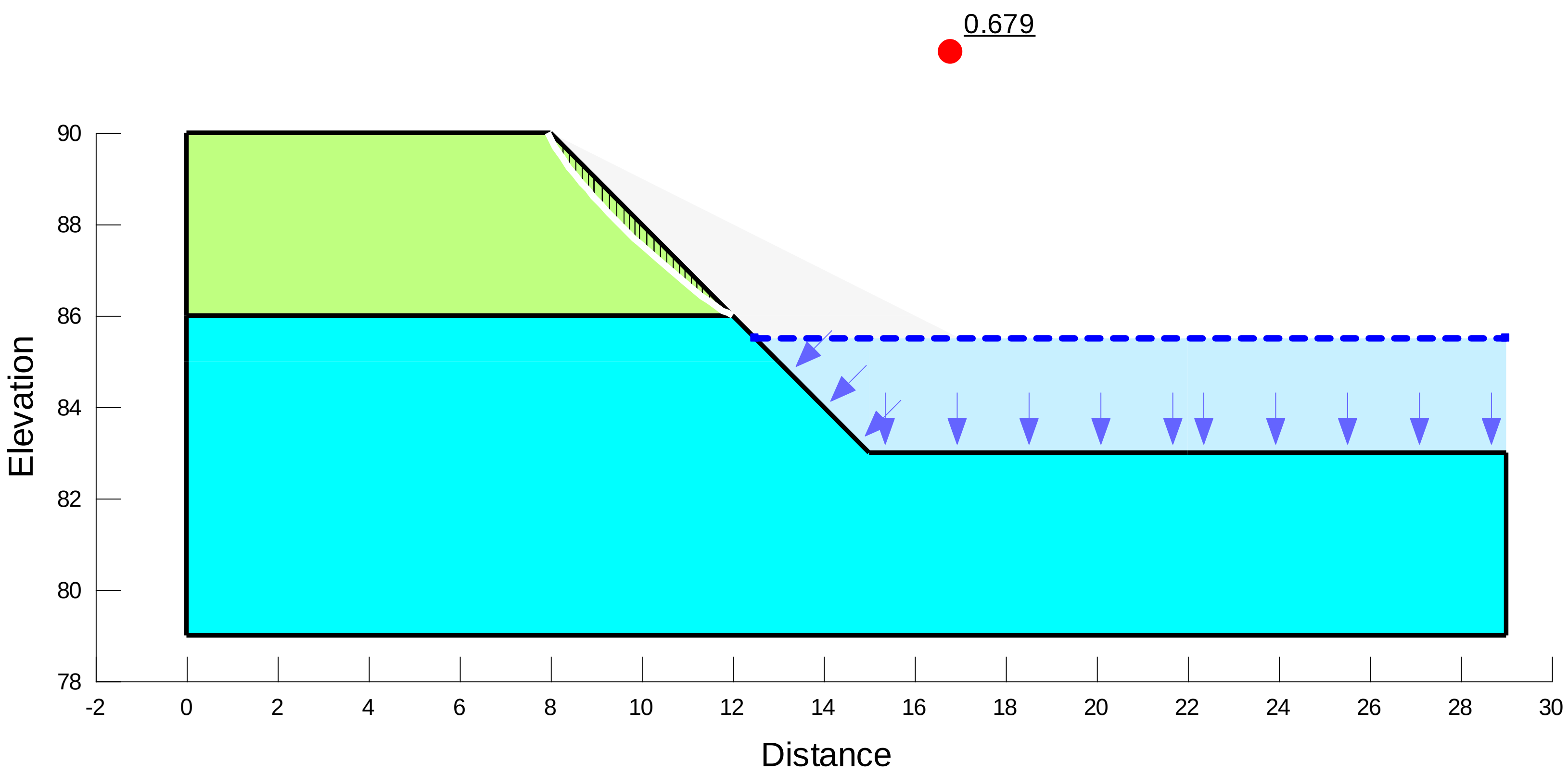
No capping is proposed.

APPENDIX SRA1

Side Slope Subgrade Analysis Results

File Name: 200929 416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry Restoration
Name: Chalk Slope - 1V:1H
Method: Morgenstern-Price
Factor of Safety: 0.679

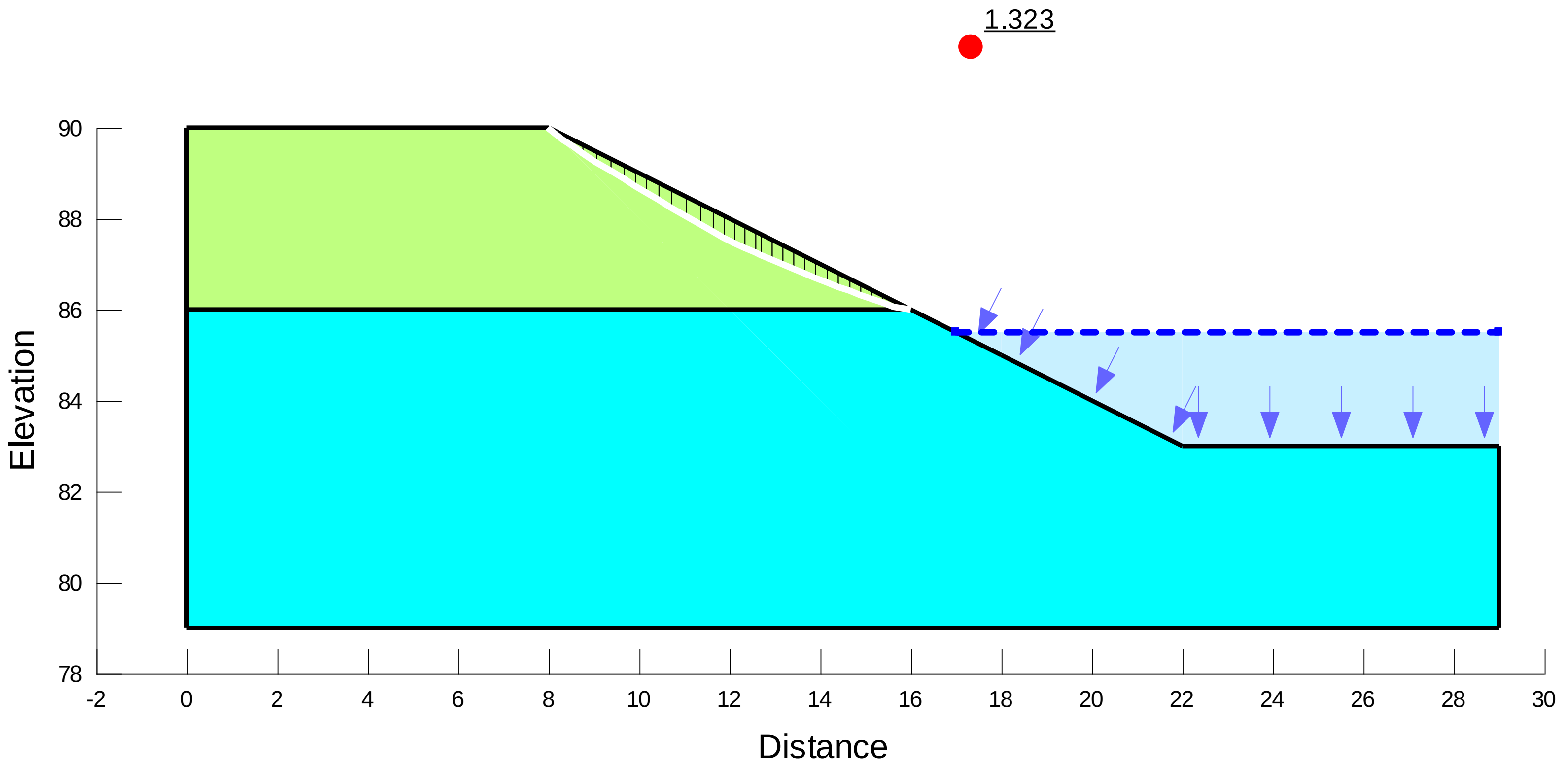
Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Grade Dc (Unstructured) Chalk	18	0	33	0	1
	Structured Chalk	18	1	39	0	1



Side Slope Subgrade – Cut Slope 1V:1H			Newport Quarry SRA
	SLR	Project:	Stability Risk Assessment
		Date:	October 2020 — Scale: NTS
	Rev. 0 - 200807 416.01526.00069 Newport Quarry SRA App	Drawing:	**Drawing SRA1-1** — Appendix. **SRA1**

File Name: 200929 416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry Restoration
Name: Chalk Slope - 1V:2H
Method: Morgenstern-Price
Factor of Safety: 1.323

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Grade Dc (Unstructured) Chalk	18	0	33	0	1
	Structured Chalk	18	1	39	0	1



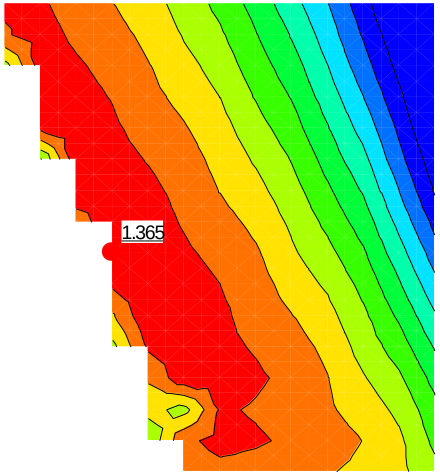
Side Slope Subgrade Cut Slope 1V:2H		SLR	Project:	NEWPORT QUARRY SRA	
				STABILITY RISK ASSESSMENT	
			Date:	OCTOBER 2020	SCALE: NTS
		Rev. 0 - 200807 416.01526.00069 Newport Quarry SRA App	Drawing:	**DRAWING SRA1-2**	Appendix. **SRA1**

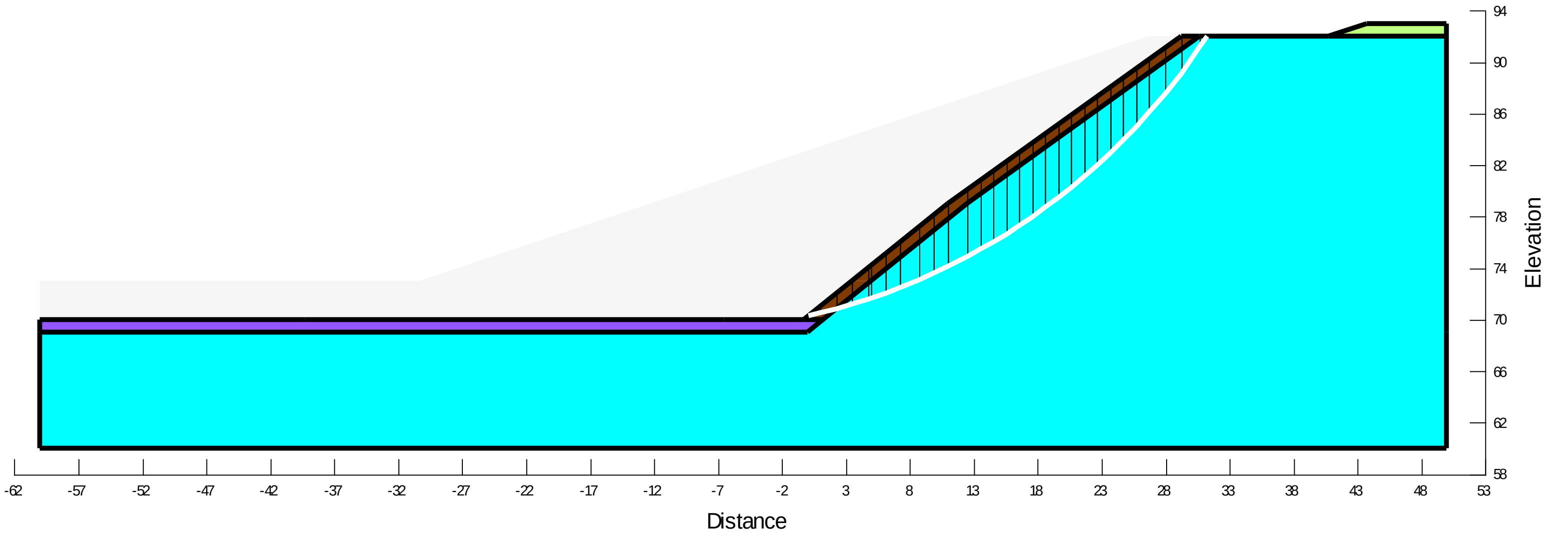
APPENDIX SRA2

Side Slope Geological Barrier Analysis Results

File Name: 200722_416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry
Name: SRA2-1 Undrained Geological Barrier
Method: Morgenstern-Price
Factor of Safety: 1.365

Color	Name	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
	Geological Barrier Peak Strength	16		0.5	26	0
	Geological Barrier Undrained Conditions	16	50			
	In-situ Chalk	18		1	39	0
	Overburden	18		1	30	0





Side Slope Geological Barrier - Undrained

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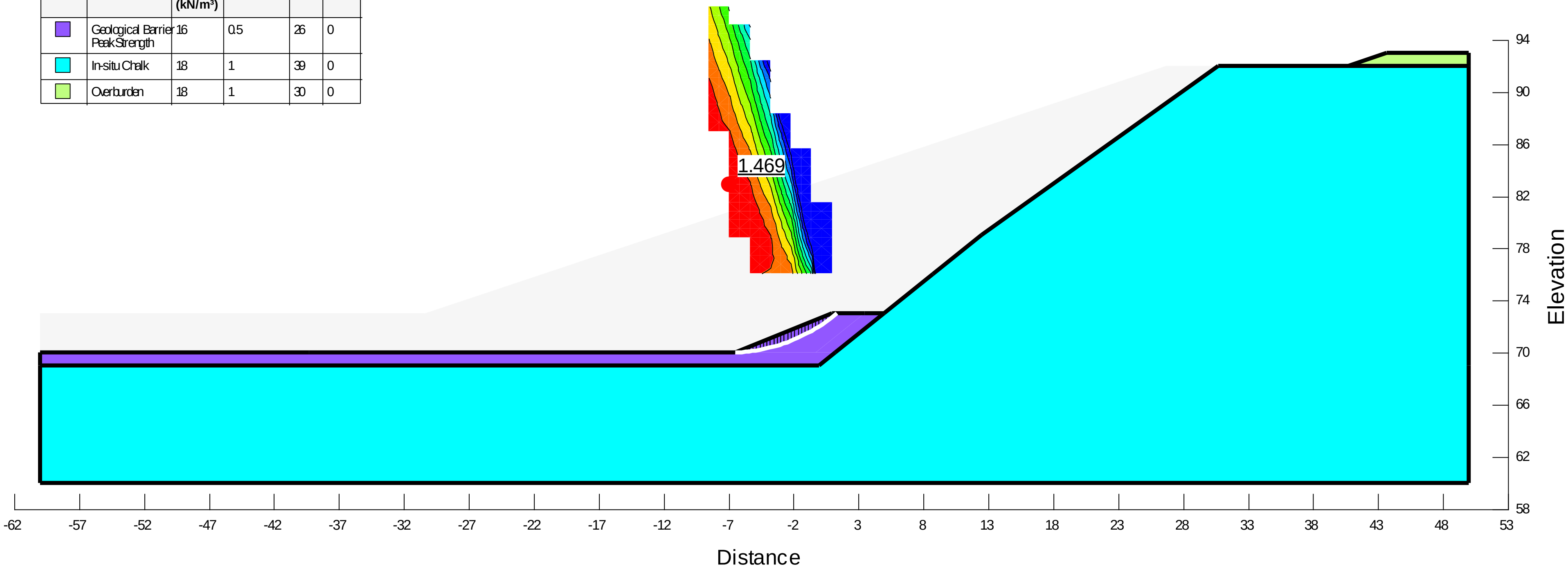
Drawing: **DRAWING SRA2-1**

Appendix. **SRA2**

File Name: 200722_416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry
Name: SRA2-2 Geological Barrier
Method: Morgenstern-Price
Factor of Safety: 1.469

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
	Geological Barrier Peak Strength	16	0.5	26	0
	In-situ Chalk	18	1	39	0
	Overburden	18	1	30	0



Side Slope Geological Barrier

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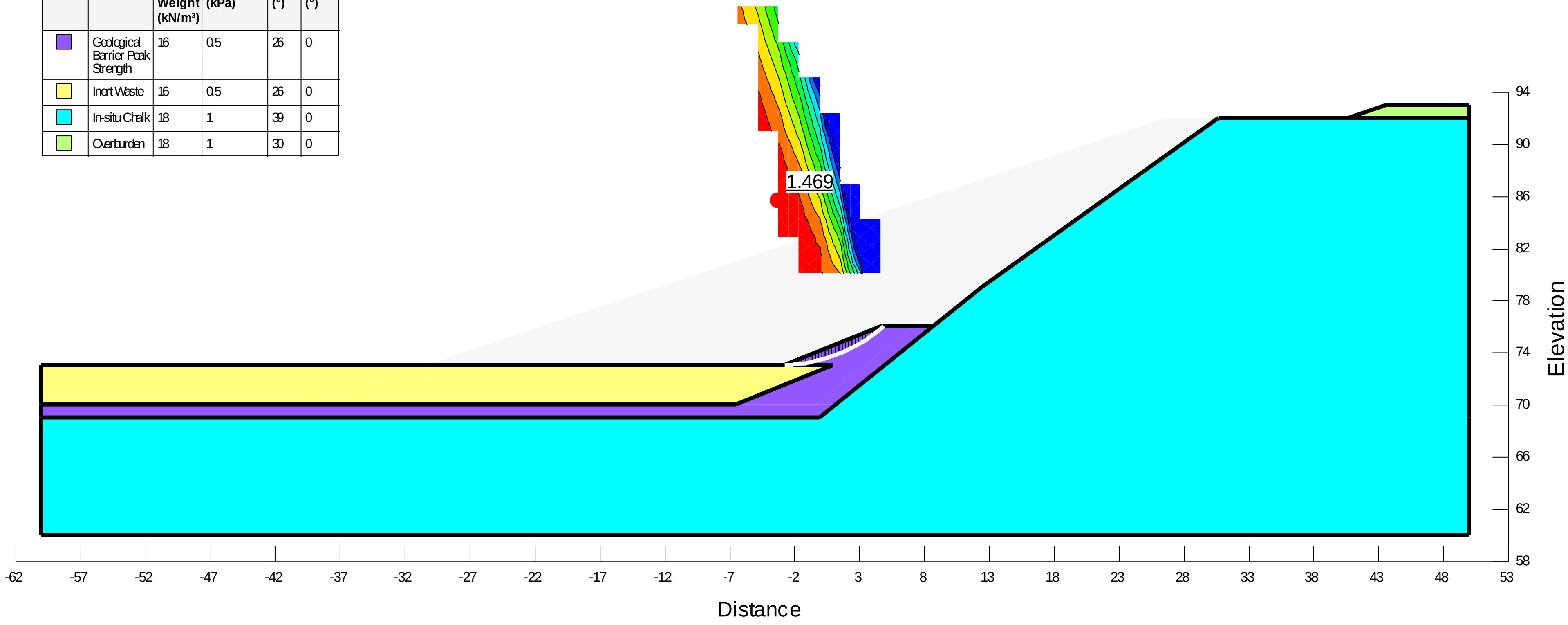
Date:	OCTOBER 2020
Scale:	NTS
Drawing:	DRAWING SRA2-2
Appendix.	SRA2

File Name: 200722_416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry
Name: SRA2-3 Geological Barrier
Method: Morgenstern-Price
Factor of Safety: 1.469

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
	Geological Barrier Peak Strength	16	0.5	26	0
	Inert Waste	16	0.5	26	0
	In-situ Chalk	18	1	39	0
	Overburden	18	1	30	0



Side Slope Geological Barrier - Lift

SLR

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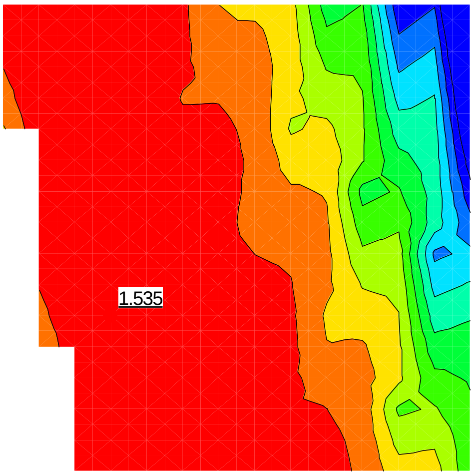
Project:	NEWPORT QUARRY SRA STABILITY RISK ASSESSMENT
Date:	OCTOBER 2020 — SCALE: NTS
Drawing:	DRAWING SRA2-3 — Appendix. SRA2

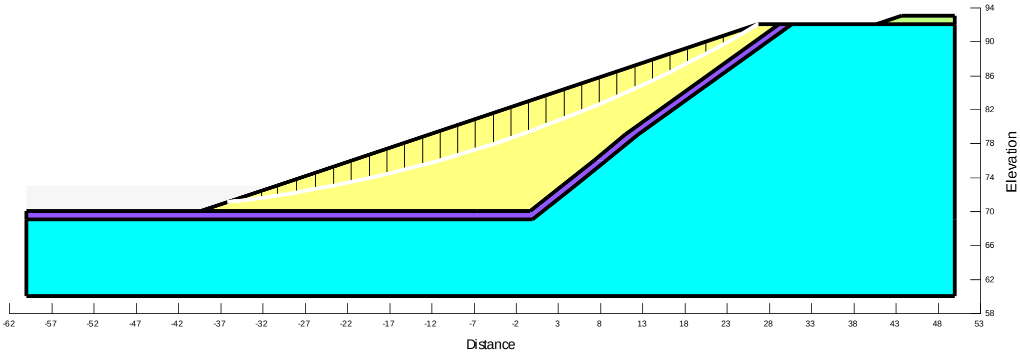
APPENDIX SRA3

Waste Mass Analysis Results

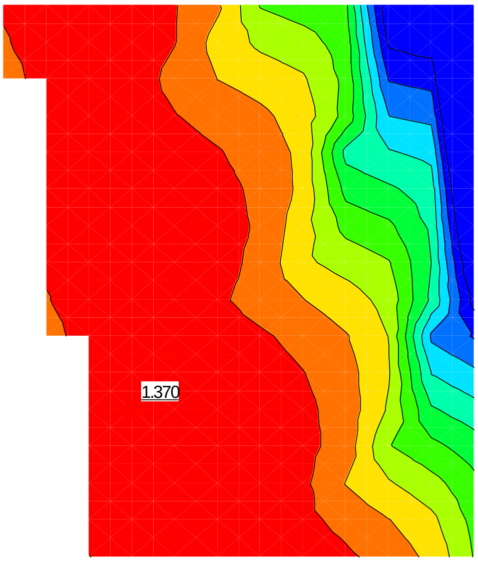


File Name: 200722_416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry
Name: SRA3-1 Waste Mass Mode 1A
Method: Morgenstern-Price
Factor of Safety: 1.535

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
Purple	Geological Barrier Peak Strength	16	0.5	26	0
Yellow	Inert Waste	16	0.5	26	0
Cyan	In-situ Chalk	18	1	39	0
Light green	Overburden	18	1	30	0

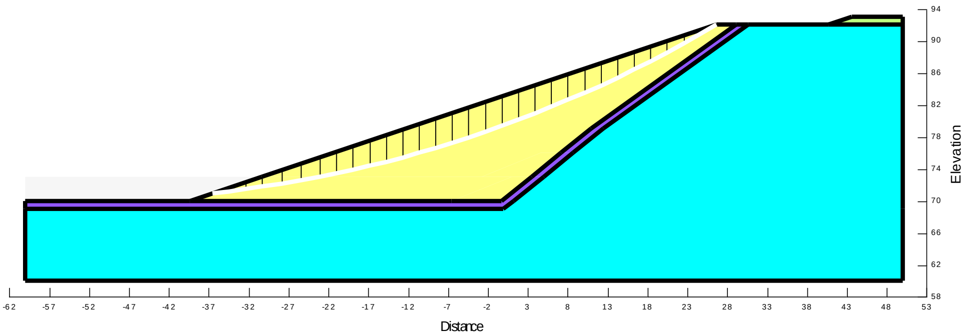


Waste Mass Mode 1A		Rev. 0 - 200807 416.01526.00069 Newport Quarry SRA App	Project:	NEWPORT QUARRY SRA
				STABILITY RISK ASSESSMENT
			Date:	OCTOBER 2020 — SCALE: NTS
			Drawing:	DRAWING SRA3-1 — Appendix. SRA3



File Name: 200722_416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry
Name: SRA3-2 Waste Mass Mode 1B
Method: Morgenstern-Price
Factor of Safety: 1.370

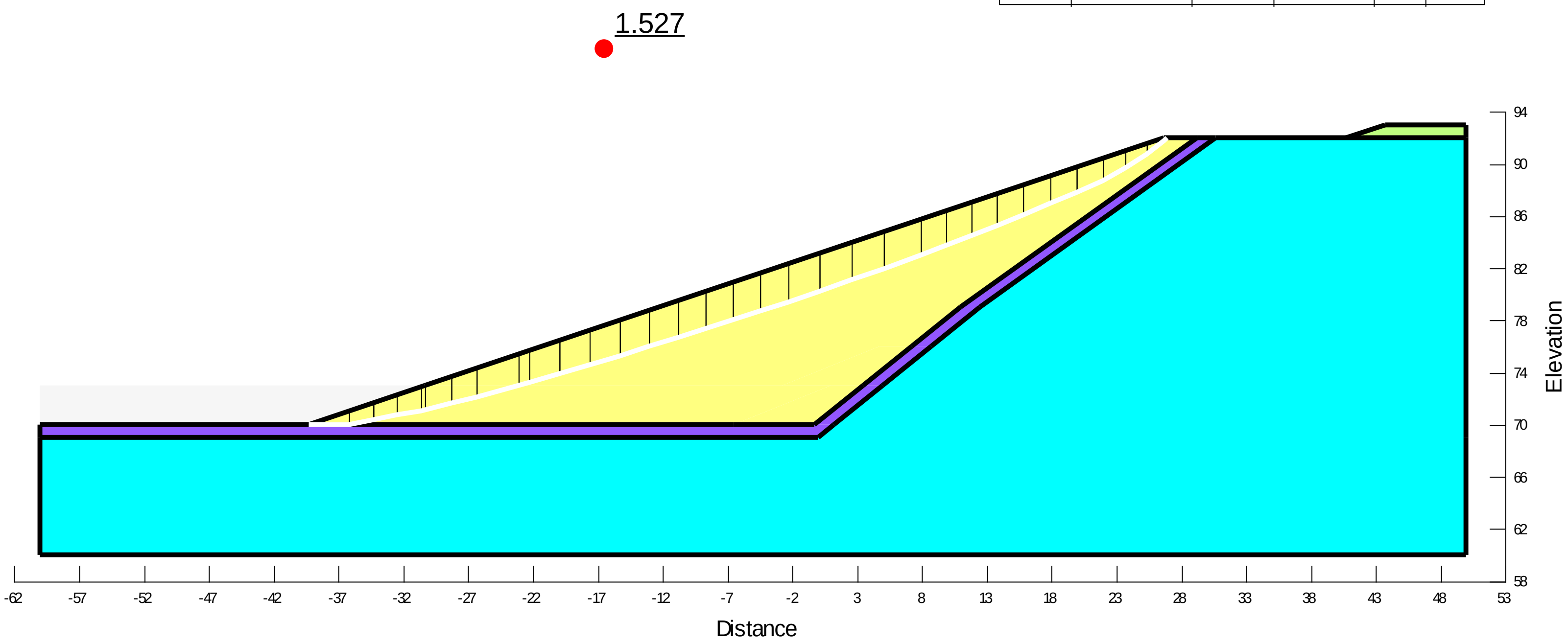
Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Ru
	Geological Barrier Peak Strength	16	0.5	26	0	0
	Inert Waste	16	0.5	26	0	0.1
	In-situ Chalk	18	1	39	0	0
	Overburden	18	1	30	0	0



Waste Mass Mode 1B		SLR	Project:	NEWPORT QUARRY SRA STABILITY RISK ASSESSMENT
			Date:	OCTOBER 2020 — SCALE: NTS
		Rev. 0 - 200807 416.01526.00069 Newport Quarry SRA App	Drawing:	DRAWING SRA3-2 — Appendix. SRA3

File Name: 200722_416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry
Name: SRA3-3 Waste Mass Mode 2A
Method: Morgenstern-Price
Factor of Safety: 1.527

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
	Geological Barrier Peak Strength	16	0.5	26	0
	Inert Waste	16	0.5	26	0
	In-situ Chalk	18	1	39	0
	Overburden	18	1	30	0



Waste Mass Mode 2A

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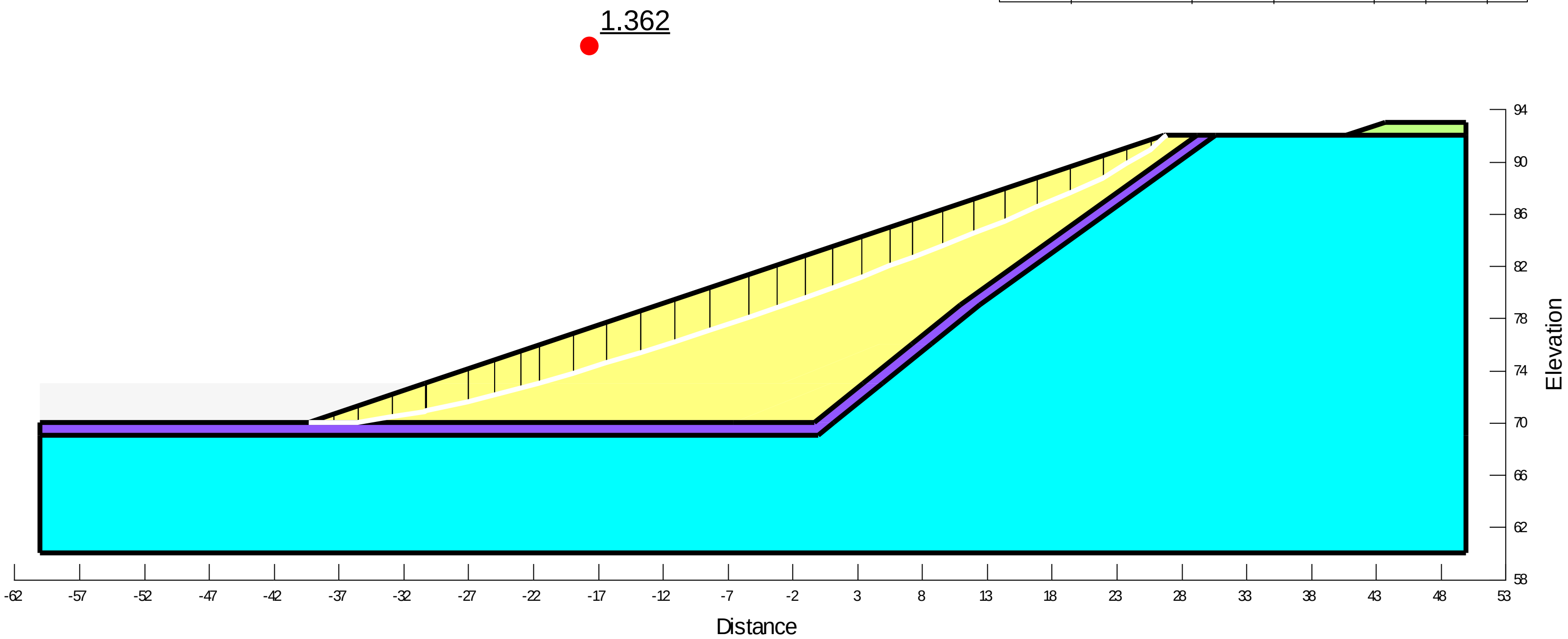
SCALE: NTS

Drawing: DRAWING SRA3-3

Appendix. SRA3

File Name: 200722_416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry
Name: SRA3-4 Waste Mass Mode 2B
Method: Morgenstern-Price
Factor of Safety: 1.362

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Ru
(purple)	Geological Barrier Peak Strength	16	0.5	26	0	0
(yellow)	Inert Waste	16	0.5	26	0	0.1
(cyan)	In-situ Chalk	18	1	39	0	0
(green)	Overburden	18	1	30	0	0



Waste Mass Mode 2B

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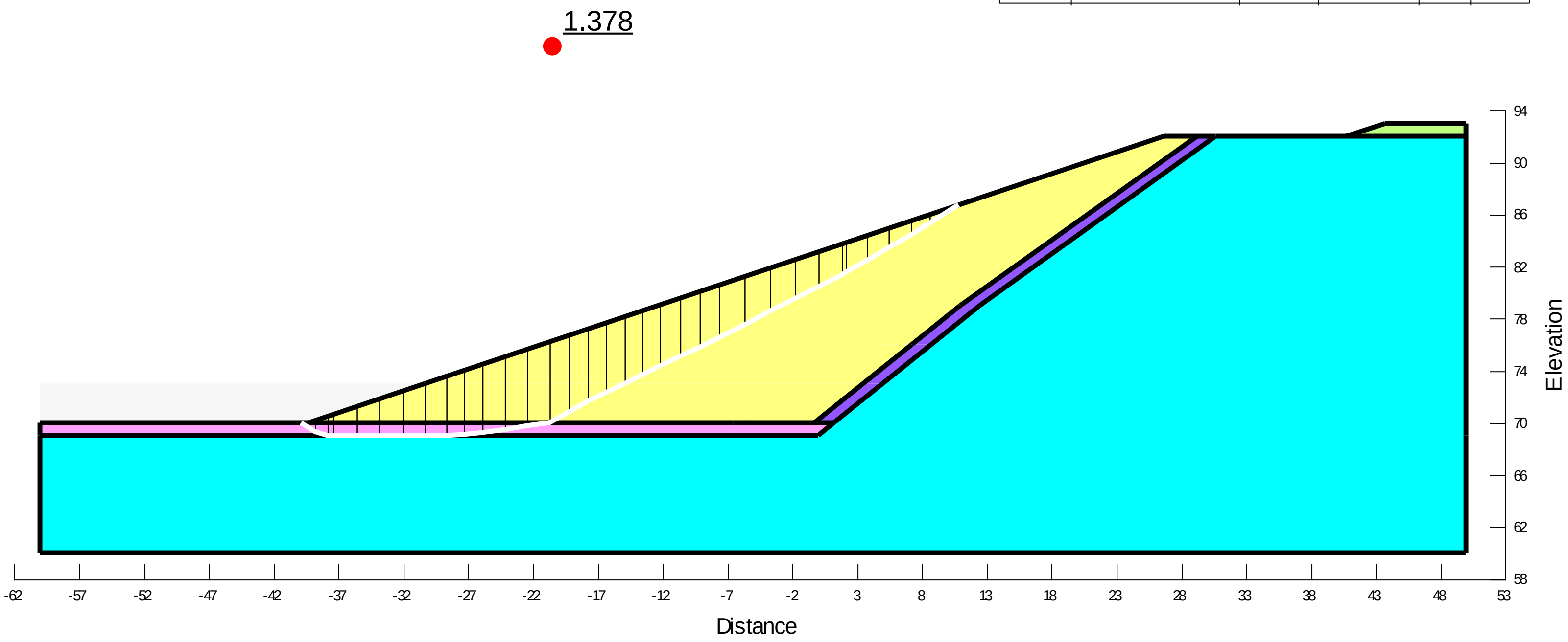
Project:	NEWPORT QUARRY SRA STABILITY RISK ASSESSMENT
Date:	OCTOBER 2020 — SCALE: NTS
Drawing:	DRAWING SRA3-4 — Appendix. SRA3

File Name: 200722_416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry
Name: SRA3-5 Waste Mass Mode 2C
Method: Morgenstern-Price
Factor of Safety: 1.378

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
	Geological Barrier Peak Strength	16	0.5	26	0
	Geological Barrier Residual Strength	16	0	18	0
	Inert Waste	16	0.5	26	0
	In-situ Chalk	18	1	39	0
	Overburden	18	1	30	0



Waste Mass Mode 2C

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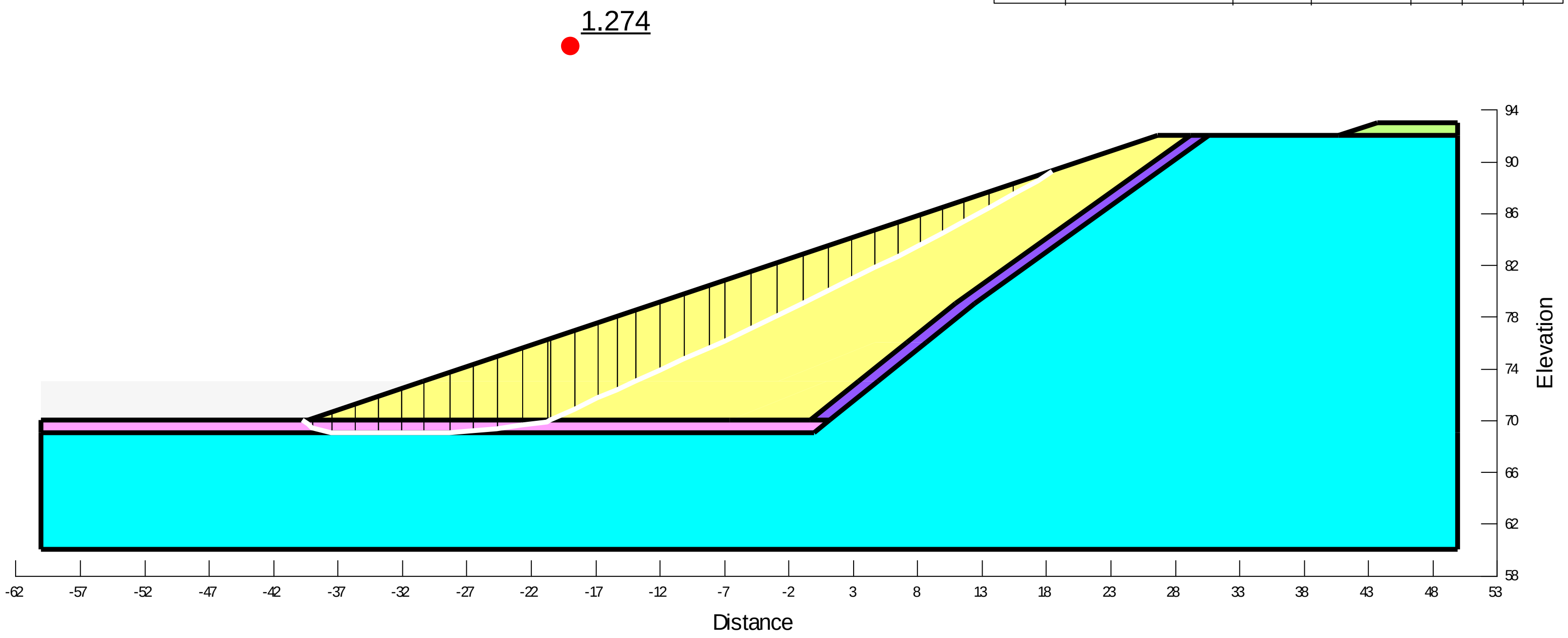
Project:	NEWPORT QUARRY SRA
	STABILITY RISK ASSESSMENT
Date:	OCTOBER 2020 — SCALE: NTS
Drawing:	DRAWING SRA3-5 — Appendix. SRA3

File Name: 200722_416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry
Name: SRA3-6 Waste Mass Mode 2D
Method: Morgenstern-Price
Factor of Safety: 1.274

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Ru
	Geological Barrier Peak Strength	16	0.5	26	0	0
	Geological Barrier Residual Strength	16	0	18	0	0
	Inert Waste	16	0.5	26	0	0.1
	In-situ Chalk	18	1	39	0	0
	Overburden	18	1	30	0	0



Waste Mass Mode 2D

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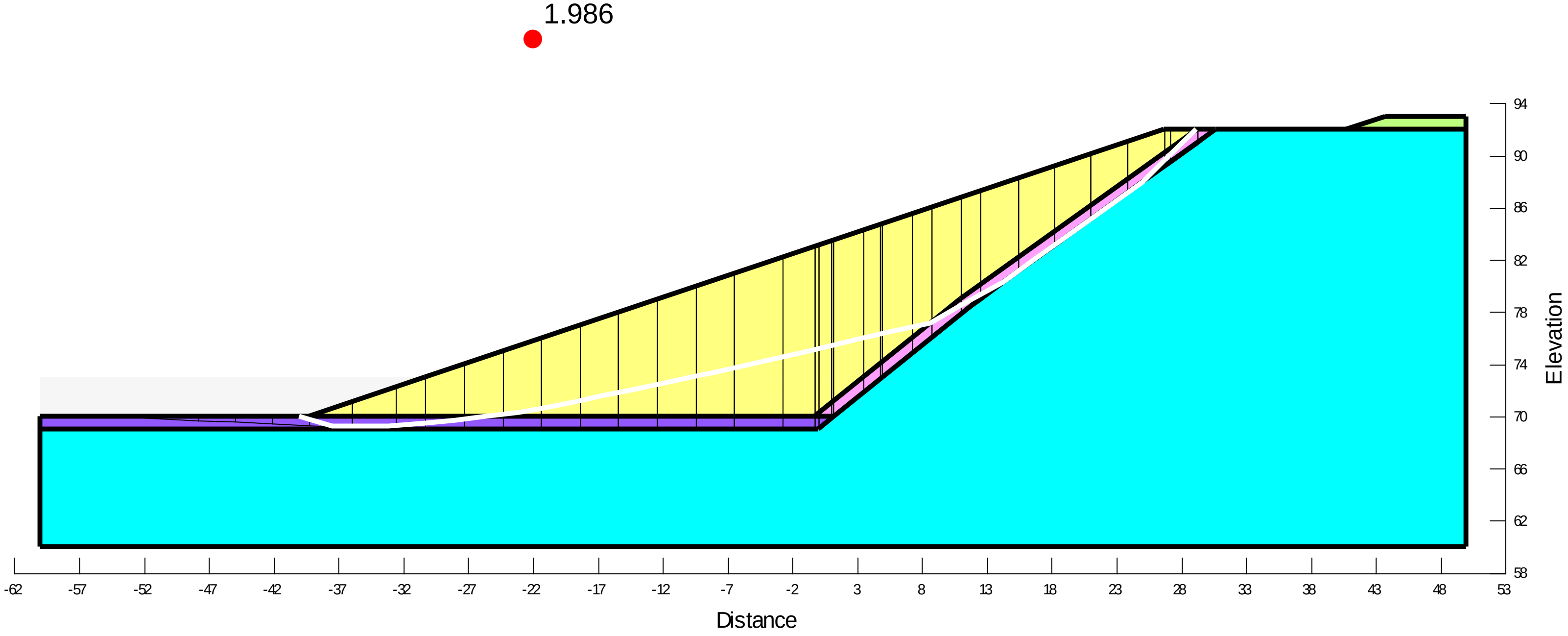
Project:	NEWPORT QUARRY SRA
	STABILITY RISK ASSESSMENT
Date:	OCTOBER 2020 — SCALE: NTS
Drawing:	**DRAWING SRA3-6**
Appendix.	**SRA3**

File Name: 200722_416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry
Name: SRA3-7 Waste Mass Mode 3A
Method: Morgenstern-Price
Factor of Safety: 1.986

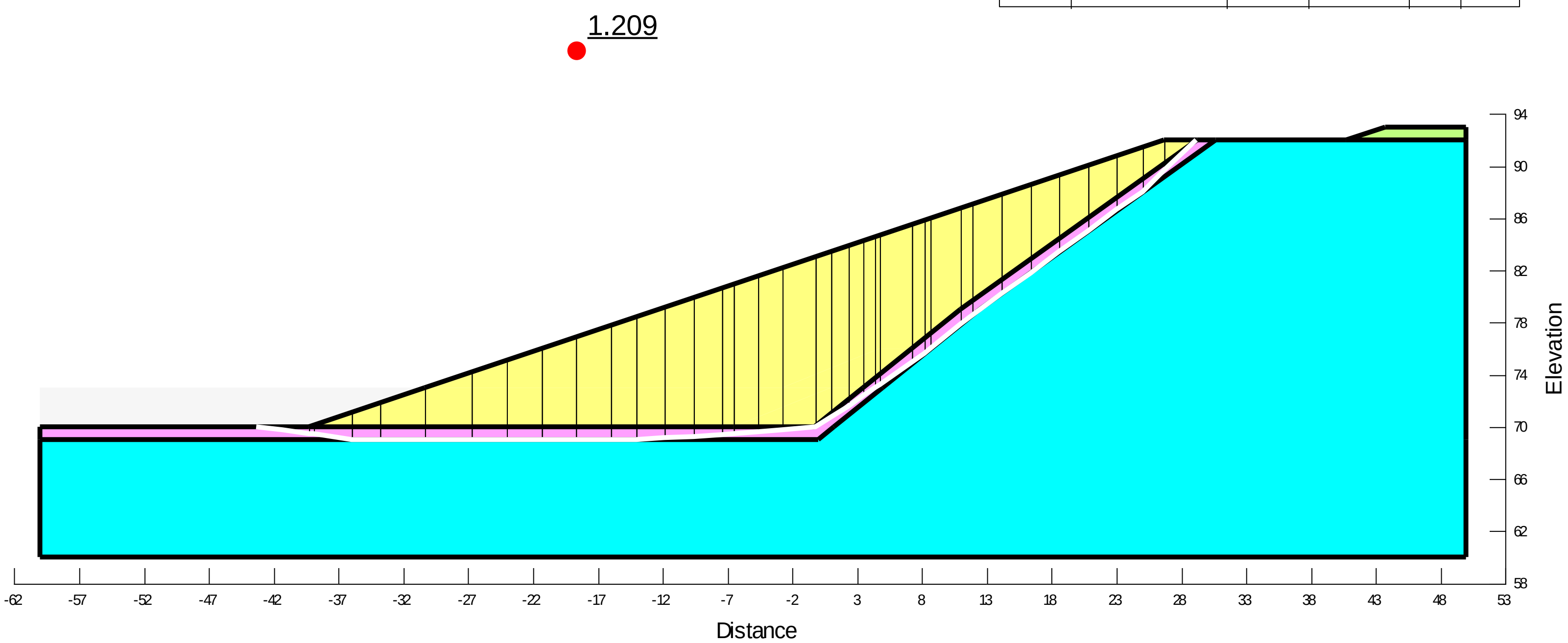
Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
Purple	Geological Barrier Peak Strength	16	0.5	26	0
Pink	Geological Barrier Residual Strength	16	0	18	0
Yellow	Inert Waste	16	0.5	26	0
Cyan	In-situ Chalk	18	1	39	0
Light green	Overburden	18	1	30	0



Waste Mass Mode 3A		SLR	Project:	NEWPORT QUARRY SRA
				STABILITY RISK ASSESSMENT
			Date:	OCTOBER 2020 — SCALE: NTS
		Rev. 0 - 200807 416.01526.00069 Newport Quarry SRA App	Drawing:	DRAWING SRA3-7 — Appendix. SRA3

File Name: 200722_416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry
Name: SRA3-8 Waste Mass Mode 3B
Method: Morgenstern-Price
Factor of Safety: 1.209

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)
	Geological Barrier Residual Strength	16	0	18	0
	Inert Waste	16	0.5	26	0
	In-situ Chalk	18	1	39	0
	Overburden	18	1	30	0



Waste Mass Mode 3B

SLR

Rev. 0 - 200807 416.01526.00069 Newport Quarry SRA App

Project: NEWPORT QUARRY SRA

STABILITY RISK ASSESSMENT

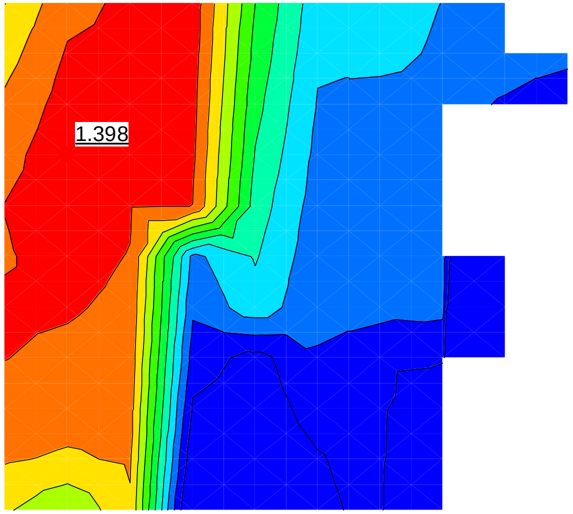
Date: OCTOBER 2020

SCALE: NTS

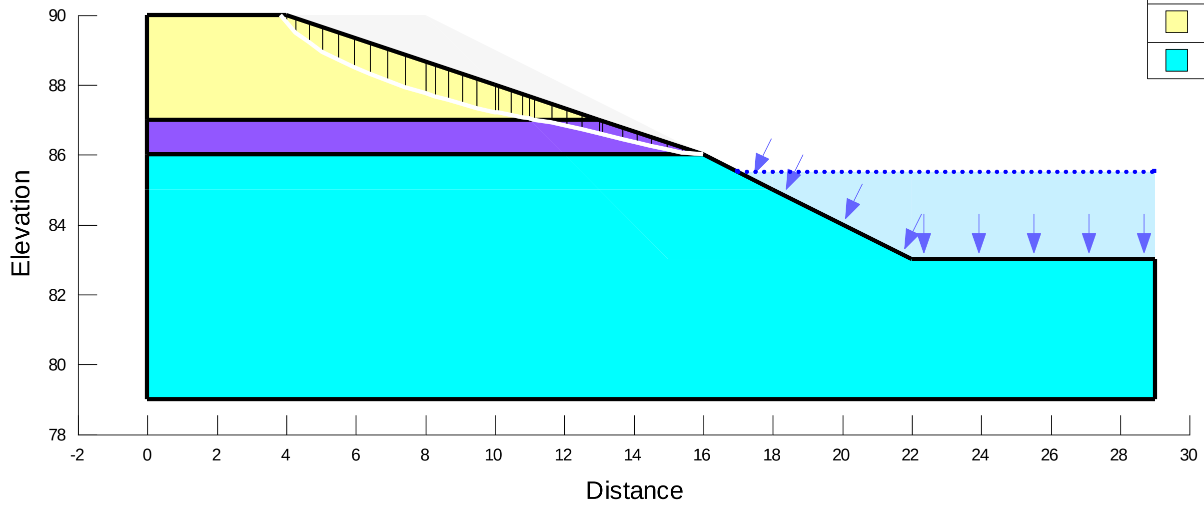
Drawing: **DRAWING SRA3-8**

Appendix. **SRA3**

File Name: 201021416.01526.00069 Newport Quarry.gsz
Title: Newport Quarry Restoration
Name: Chalk Waste Slope
Method: Morgenstern-Price
Factor of Safety: 1.398



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line	Ru	Include Ru in PWP
	Basal Geological Barrier	18	0	24.5	0	1		No
	Inert Waste	16	0.5	24	0	1	0.1	Yes
	Structured Chalk	18	1	39	0	1		No



Infiltration Basin Waste Mass Slope – 1V:3H

SLR

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Project: NEWPORT QUARRY SRA

STABILITY RISK ASSESSMENT

Date: OCTOBER 2020

SCALE: NTS

Drawing: DRAWING SRA3-9

Appendix. SRA3

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