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QUERCIA LIMITED

CLAYTON HALL LANDFILL

STABILITY RISK ASSESSMENT

MARCH 2025

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QUERCIA

CLAYTON HALL

STABILITY RISK ASSESSMENT

MARCH 2025

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APPENDICES

DRAWINGS	TITLE	SCALE
ST18115-050	Stability Assessment Sections	As shown
ST18115-306	Counterfort Drain Layout	1:500

1 INTRODUCTION

1.1 Background

1.1.1 Wardell Armstrong (WA) have been commissioned by Quercia to provide technical support for permitting and planning for their Clayton Hall landfill site. As part of this application, a Slope Risk Assessment (SRA) will be produced for the slope forming part of the southern face within the phase 4 boundary of Cell 4B.

1.1.2 A series of landslips occurred within Cell 4B between September and November 2024 following periods of prolonged rainfall. The landslip failure mechanisms and diagnoses are discussed in Section 3.4. As such, this SRA will feature a back analysis to verify the ground conditions at the time of failure and a remediation strategy.

1.1.3 This SRA has been prepared in accordance with the Environment Agency R & D technical Report P-385, volumes TR1 and TR2.

1.2 Site Description

1.2.1 The Site is located at Clayton Hall Landfill site, Dawson Lane, Whittle-le-Woods, Chorley, Lancashire, PR6 7DT and is operated by Quercia. The overall Clayton Hall landfill falls under permit number EPR/BV1364ID which was obtained on 04/11/2019. The permit application for Cell 4B Phase 4 for is ongoing at the time of writing this report and the proposed slope within Cell 4B Phase 4 will the focus of this SRA.

1.2.2 This SRA will discuss and analyse the southern slope of cell 4B. The topography and geology are detailed in sections 1.3 and 1.4.

1.3 Topography

1.3.1 The slope crest elevation varies between 62 and 65 m AOD (Above Ordnance Datum). The final elevation of the cell base will sit at approximately 53.5m AOD.

1.4 Geology Overview

1.4.1 British Geological Survey mapping, provided by their GeoIndex service gives a broad description of the Site's overall geology. Superficial Deposits are present at the Site and the surrounding area. Much of the Site is underlain by Glaciofluvial sand and gravel with the southernmost portions of the Site being underlain by Till and Head deposits. Bedrock geology is composed of the Sherwood Sandstone Group.

1.4.2 A site investigation conducted in 2010 included a rotary borehole, BH106A, which was drilled near the crest of Cell 4B's southern slope. The strata encountered by BH106A is summarised in Table 1 below.

Table 1.1: Generalised Geological Sequence				
Geological Unit	**Generalised Description**	**Elevation (m AOD)**	**Thickness (m)**	**Presence and location**
Topsoil	Sandy silty clay	64.03 – 63.28	0.75	Occurs in the south of the site
Till	Firm to stiff sandy silty clays with occasional gravel to fine to medium sand with clay lenses	63.28 – 37.50	17.5	Present in the south of the site. Till comprises the southern slope of Cell 4B
Sherwood Sandstone Formation	Weathered to medium strong medium grained sandstone	37.50 – Not proven	Not proven	Forms the bedrock geology for the entire Site.

2 CONCEPTUAL SITE MODEL

2.1 Overview

2.1.1 BH106A is the sole borehole within the Cell 4B boundary; therefore, the conceptual site model has been developed based solely on this borehole. Please note, the actual ground conditions may vary from those encountered within BH106A. Should the ground conditions encountered during construction vary from those assumed here, WA should be consulted, and the design be reevaluated. The conceptual site model is presented by Table 2.1.

Table 2.1: Conceptual Site Model

Geological Unit	Generalised Description	Elevation (m AOD)	Thickness (m)
Topsoil	Sandy silty CLAY with rootlets	64.03 – 63.28	~0.75
Till	Firm sandy silty CLAY.	63.28 – 60.53	~2.75
	Silty SAND with some clay lenses.	60.53 – 56.53	~4.00
	Stiff sandy silty CLAY with occasional gravel.	56.53 – -∞	∞

2.1.2

2.1.3 The following information regarding the conceptual site model can be derived from Table 2.1 and BH106A.

- Although topsoil was encountered within BH106A, it is not present in every slope stability cross section due to some of the crest levels being below the base of the topsoil layer.
- The Sherwood sandstone formation is known to form the bedrock at the Site, but it was not encountered in BH106A, and the basal sub-grade for Cell 4B is instead formed from Till.

2.2 Basal Sub-Grade

2.2.1 The basal sub-grade will be formed from the stiff sandy silty CLAY (Till) which has an upper contact at approximately 56.53m AOD. BH106A proves that the stiff sandy silty

CLAY extends to a level of 42.53m AOD and has a thickness of 14m and is therefore the only subgrade material that is considered in the modelling. The proposed cell will be cut to basal formation level, which is between 50 to 53m AOD, although there will be no requirement for significant cuts to achieve the basal formation level, as the average existing base level is between 50m AOD and 55m AOD. As such, it is anticipated that approximately 3,920m^3 of the stiff silty clay will be excavated as part of the basal cutting operation.

2.3 Side Slope Sub-Grade

2.3.1 Being a disused quarry, the existing side slope sub-grade is already present. However, a cut and fill operation will be required to achieve the desired side slope formation level and eliminate any instability risks.

2.3.2 The side slope subgrade is formed from all three Till compositions listed in Table 1.1. The elevations presented in BH106A have been used in the cut sections. In reality, given the variable nature of the Till deposit, the stratigraphy across the site may vary significantly from that within the vicinity of BH106A.

2.4 Side Slope Lining System

2.4.1 The side slope lining system will have a variable gradient that depends on the gradient of the formation. Its gradient shall vary between 1V:2.5H and 1V:4H. It shall be a combined lining system composed of the following:

0. Formation layer – Till or Engineered Clay Fill;
1. 0.5m engineered clay liner;
2. 2mm HDPE geomembrane liner;
3. Basal geotextile within 2m vertically upslope from base;
4. 0.3m drainage stone within 2m vertically upslope from base to 0.3m sand protection layer to crest; and
5. Filter geotextile over drainage stone and under first metre of sand protection layer.

2.4.2 The construction process that concerns the stability of the slope is the incremental raising of the sand protection layer that will be raised up the slope as the landfill rises. Therefore, the sand protection layer will be buttressed by the rising waste mass and will never have a slope length appreciable enough to warrant a stability analysis. As such, only the 0.5m clay liner and 0.3m drainage stone will be constructed in their entirety in a single construction phase and have to exist in a state unsupported by the waste mass.

2.5 Waste Mass

2.5.1 The landfill is to accept non-hazardous waste.

2.5.2 The incline from the formation crest will extend at a gradient of 1V:5H to intercept the maximum waste mass elevation.

2.5.3 The waste mass within cell 4B will extend to a maximum height of 26.6m above the formation level (approximately 80-85m AOD). Please note, this elevation relates to the proposed new planning level and not the superseded permitted level.

2.6 Capping System

2.6.1 The capping system for the cell 4B development shall have a 1V:5H final gradient and consist of a composite capping system, which shall comprise of the following:

0. Formation layer – waste;
1. 0.3m granular regulating layer;
2. Protection geotextile;
3. Drainage geo-composite; and
4. 1m restoration soils.

3 STABILITY RISK ASSESSMENT

3.1 Risk Screening

3.1.1 Components considered in regards to the stability of the Cell 4B area are as follows:

- Basal Sub-Grade;
- Side Slope Sub-Grade;
- Basal Lining System;
- Side Slope Lining System;
- Waste Mass;
- Capping System.

3.1.2 The stability and integrity of each of the above components have been reviewed to determine what or if further analysis is required.

Basal Sub-Grade

3.1.3 Table 3.1 outlines the stability components of the basal sub-grade which is formed of stiff sandy silty CLAY of the Till deposit.

Table 3.1: Stability Components for Basal Sub-Grade		
Excessive Deformation due to load placement or excavation	**Sub-Grade Settlement**	The basal sub-grade for the landfill is to be formed by cut and fill operations to form the required geometry. The underlying natural geology is formed of stiff CLAY of the Till deposit. These deposits are considered relatively incompressible given the deposits over consolidation history. As such, detailed strain analyses are not considered to be required.
	Basal Heave	Basal heave can occur as a result of several mechanisms, the most common of which are stress relief as a result of deep excavation and as a result of artesian water pressures. The maximum groundwater level recorded in BH106S was 58.2mAOD which is above the level of the base. However, being a disused quarry, the current basal levels are similar to the proposed formation and the cut operation will not excavate a large enough material mass to

Table 3.1: Stability Components for Basal Sub-Grade		
		create a considerable stress relief on groundwater below the base of the landfill. As such due to the low risk of basal heave resulting from excavation and groundwater, no further analysis into basal instability is required as part of this assessment.
	Slope stability	It is plausible that a deep-seated rotational slip could affect the basal region of the landfill particularly during construction and hence this will be included within the slope stability model.

Table 3.2: Stability Components for Side Slope Sub-Grade		
Excessive Deformation due to load placement or excavation	**Sub-Grade Settlement**	The side slope sub-grade for the landfill is to be formed by cut and fill operations which shall form the proposed cell profile. The underlying natural soils are not expected to pose settlement issues given the over consolidation history of the deposits. As such, detailed strain analyses are deemed unnecessary. All filling works shall be compacted as per the compaction criteria.
	Heave	Heave can occur as a result of several mechanisms, the most common of which are stress relief as a result of deep excavation and as a result of artesian water pressures. Being a disused quarry, the side slopes do not require major reworks to reach their final geometry, meaning the cuts will not induce a pressure release effect. Groundwater is within the side slope; however, this groundwater is unconfined and therefore is not under artesian pressure.
	Groundwater Seepage	Groundwater is present within the SAND layer between the approximate elevations 58.2mAOD and 59.7mAOD. It is understood this groundwater seepage was responsible for the failures which have occurred within the cell. The slope stability analysis considers the effect of this groundwater.

Table 3.2: Stability Components for Side Slope Sub-Grade		
		Lowering the level of the groundwater so it is below the face of the slope has proven an effective stabilisation measure for parts of the slope. Groundwater lowering can be achieved through the implementation of counterfort drains. These are discussed below.
Instability	**Slope Stability**	Assessment of the side slope sub-grade will be the primary focus of the slope stability analysis. For the series of failures which have occurred across the cell area. Mobilised debris shall be removed and the slopes buttressed with engineered fill.

Basal Lining System

3.1.4 Table 3.3 outlines the key stability components of the basal lining system which is to comprise a layer of engineered clay and a layer of drainage stone/sand.

Table 3.3: Stability Components for Basal Lining System		
Excessive Deformation due to load placement or excavation	**Sub-Grade Settlement**	The basal lining system will comprise compacted engineered fill and is not considered compressible.
	Basal Heave	The cut required to obtain the desired formation level mitigates the chance of basal heave following the removal of material and the reduction in overburden pressure. It is therefore unlikely that basal heave will present an issue. However, surface water control will be required during construction.
Instability	**Slope Stability**	It is plausible that a deep-seated rotational slip could affect the basal liner of the landfill particularly during construction and hence this will be included within the slope stability model.

Side Slope Lining

3.1.5 Table 3.4 outlines the key stability components of the basal lining system which is to comprise a layer of engineered clay and a layer of drainage stone/sand.

Table 3.4: Stability Components for Side Slope Liner		
Excessive Deformation due to load placement or excavation	**Liner Settlement**	The engineered fill is considered relatively incompressible and hence detailed strain analyses are not considered to be required.
	Side Slope Heave	Heave of the mineral liner is not expected. However, surface water control will be required during construction.
Instability	**Slope Stability**	It is plausible that a rotational slip could affect the side slope liner of the landfill particularly during construction. The stability of the side slope liner will be assessed as part of the limit equilibrium analysis.

Waste Mass

3.1.6 Table 3.5 outlines the key stability components of the waste mass which is to be formed from the waste material as previously discussed.

Table 3.5: Stability Components for Waste Mass		
Failure wholly in waste	**Slope Stability**	The stability of the waste body shall be analysed in the limit equilibrium analysis.
Failure involving liner system	**Slope Stability**	The placement of the waste mass may cause instability of the subgrade and lining system, which will therefore be analysed.

Capping System

3.1.7 Table 3.6 outlines the key stability components of the capping system which is to be formed from the geosynthetics/mineral capping as previously discussed.

Table 3.6: Stability Components for Capping System		
Mineral	**Slope Stability**	The stability of the capping system shall be analysed in the limit equilibrium analysis.

3.2 Lifecycle Phases

3.2.1 There will be many phases of the site development. These different phases may be more critical to the development at different stages. Therefore, it is essential that the most critical phases are analysed to ensure not only the end development is stable but also the construction phases achieve an acceptable FoS. The key lifestyle phases to be analysed are as follows:

- formation of the profile, i.e., cut to a 1V:2.5H slope angle;
- formation profile with either buttressing or counterfort drain stabilisation measures;
- construction of the lining system (basal and side slope) but no filling of waste;
- waste mass fully placed; and
- construction of the capping lining system.

3.3 Modelling Approach

3.3.1 To complete the stability risk assessment, it is essential that the design components discussed in the document are analysed. The components shall be assessed individually and as a composite system.

3.3.2 The lifecycle phases have been outlined in Section 3.2 and represent the critical scenarios to be assessed.

3.3.3 The limit equilibrium slope stability analysis has been undertaken using the Geostudio software, Slope/W (version 2024.1.0). The analysis employed utilises the methodology proposed by Morgenstern-Price to assess a series of slip surfaces in order to identify the most critical (min FoS).

3.3.4 The ‘traditional’ factor of safety (FoS) approach has been adopted for the analysis. All intermediate construction phases have been designed to exceed a FoS of 1.2. Final profile phases have been designed to exceed a FoS of 1.5. The back analysis targets a FoS just below 1.0.

3.4 Slope Failures and Back Analysis

3.4.1 Between September and November 2024, a series of landslips occurred in the existing former quarry faces that form the proposed cell. It is understood these slips occurred within the exposed slopes following periods of prolonged rainfall.

3.4.2 The WA geotechnical team have not undertaken any site-based failure diagnosis. However, a review has been undertaken of photographs, survey data and site observations recorded by the WA survey team. Based on this, we make the following assessment.

3.4.3 The failures have occurred within the silty SAND. It is suspected the failures comprised rotational slumping, driven by an increased pore pressure. Survey data reinforces that the silty SAND has shifted above the sandy silty CLAY.

3.4.4 A back analysis has been performed to verify the ground conditions leading up to the point of failure. The back analysis focuses on a section cut through the western corner of the Cell, incorporating the ground conditions specified in Table 1.1. The analysis determined an elevated groundwater level of 59.7m AOD at the time of failure. This was approximately 1.5m above the maximum recorded level in the BH106S piezometer. The geotechnical parameters determined in the back analysis are present in Section 3.5.

3.5 Geotechnical Parameters

3.5.1 The geotechnical parameters used within the analysis are outlined in this section, giving justification as to why these values have been used.

3.5.2 A summary of the geotechnical parameters used within the analysis of the development are given in Table 3.7.

Table 3.7: Geotechnical Soil Parameters

Material	**Unit Weight (kN/m^3)**	**Effective Cohesion (kPa)**	**Effective Internal Angle of Friction (°)**	**Comments**
Restoration Soil	19	0	30	Engineering judgement based on experience with similar material
Regulating Stone Layer	19	0	34	Engineering judgement based on experience with similar material
Waste Mass	12	0	25	Values given for municipal waste in CQA reports
Drainage Stone/Sand Protection Layer	19	0	34	Engineering judgement based on experience with similar material
Engineered Clay Liner	20	5	25	Clay liner is of site won material and the parameters have been based on this.

Table 3.7: Geotechnical Soil Parameters

Material	Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Effective Internal Angle of Friction (°)	Comments
Engineered Clay Fill	20	4	25	Clay fill is of site won material and the parameters have been based on this.
Engineered Stone Fill	20	0	36	Imported permeable stone.
Silty Clay (Topsoil)	18	2	20	Derived through engineering judgement based on descriptions and by back analysing the surveyed failure in Cell 4B
Firm Sandy Silty Clay	18	1	25	Derived through engineering judgement based on descriptions and by back analysing the surveyed failure in Cell 4B
Sand with Clay Lenses	18	0	32	Derived through engineering judgement based on descriptions and by back analysing the surveyed failure in Cell 4B
Stiff Sandy Silty Clay with Gravel	20	3	25	Derived through engineering judgement based on descriptions and by back analysing the surveyed failure in Cell 4B

Basal Sub Grade

3.5.3 The geotechnical soil parameters for the underlying materials have been derived from engineering judgement of the material based on the description provided in BH106A. The derivation of the soil parameters has been supported in the back analysis.

Side Slope Sub-Grade

3.5.4 The geotechnical soil parameters for the underlying materials have been derived from engineering judgement of the material based on the description provided in BH106A. The derivation of the soil parameters has been supported in the back analysis.

Basal Lining System

3.5.5 The basal lining system shall be constructed to a specific engineering specification.

3.5.6 At this stage, the specific High-Density Polyethylene (HDPE) to be used within the basal lining system has not been selected. However, it is considered that the HDPE shall be either a 2mm textured or a 2mm smooth product. The HDPE and drainage protection layers have not been included in the slope stability analyses.

3.5.7 Further analyses will be required to define the stability of the liner in-situ once the specifics are known, and interface testing is available.

Side Slope Lining System

3.5.8 The basal lining system shall be constructed to a specific engineering specification.

3.5.9 At this stage, the specific HDPE to be used within the basal lining system has not been selected. However, it is considered that the HDPE shall be either a 2mm textured or a 2mm smooth product. The HDPE and drainage protection layer have not been included in the slope stability analyses.

3.5.10 Further analyses will be required to define the stability of the liner in-situ once the specifics are known, and interface testing is available.

Waste Mass

3.5.11 The waste stream into Cell 4B shall be municipal waste. The soil parameters for this material have been provided in previous Wardell Armstrong CQA reports.

Capping System

3.5.12 The capping system shall be constructed to a specific engineering specification. The system is to comprise a combined capping system consisting of 0.3m of regulating stone underlying 1.0m of restoration soil.

3.5.13 At this stage, the specific restorations soils to be used within the capping system has not been selected. The parameters presented in Table 3.7 are considered typical of a restoration soil.

3.5.14 Further analyses will be required to define the stability of the cap in situ once the specifics are known, and source material testing is available.

Leachate and Groundwater

3.5.15 Groundwater has been back analysed to a level of 59.7m AOD. It is understood that the series of failures within the cell have been induced by this elevated groundwater level.

3.5.16 Counterfort drains shall be installed along part of the Cell following the slope reprofiling. Counterfort drain details and set out can be found in the drawings attached.

3.6 Results of the Stability Analysis Section North-South

3.6.1 Table 3.8, Table 3.9 and Table 3.11 present the results of the back and stability analyses. Table 3.10 and Table 3.12 present the results of the interlayer slip analyses, that were conducted to investigate the FoS against sliding along material contacts e.g the FoS along the engineered clay liner and drainage stone contact. Slope/W critical slip outputs are presented in Appendix 2 with Slope/W outputs from analyses calculating interlayer slips being presented in Appendix 3.

Table 3.8: Back Analysis Outputs

Section	Location	Analysis	Required FoS	FoS	Notes
Section A Back Analysis	Northwest slope	Back Analysis (July 2024)	-	0.99	Back analysis conducted to verify parameters and determine groundwater elevation at the time of failure.
		Back Analysis (November 2024)	-	0.65	

Table 3.9: Buttress Remediation Analyses

Analysis	Required FoS	Section FoS	
		Section 2	Section 3
Current Slope	1.2	0.7	0.5
Cut to formation level		0.6	0.9
Cut to formation with buttress		1.4	1.2
Full buttress		1.4	1.2
Full buttress with 0.5m clay liner		1.5	1.4
Full buttress with 0.3m drainage stone		1.6	1.4
Waste mass placed	1.5	2.3	2.3
Regulating stone placed		2.3	2.3
Restoration soils placed		2.4	2.4

Table 3.10: Buttress Remediation Analyses – Interlayer Slips			
Analysis	**Required FoS**	**Section FoS**	
		Section 2	**Section 3**
Formation – Buttress	**1.2**	2.32	1.2
Formation – Full Buttress		2.18	1.2
Full buttress – 0.5m Clay Liner		2.71	1.4
0.5m Clay Liner – 0.3m Drainage Stone		1.73	1.4
Waste Mass – Regulating Stone	**1.5**	3.4	2.3
Regulating Stone- Restoration Soil		2.96	2.4

Table 3.11: Counterfort Drain Remediation Analysis		
Analysis	**Required FoS**	**Section 5 FoS**
Current Slope	1.2	0.9
Cut to upper formation level		0.9
Cut to lower formation level		0.9
Formation level with counterfort		1.2
Formation level with 0.5m clay liner		1.3
Formation level with 0.3m drainage stone		1.3
Waste mass placed	1.5	2.3
Regulating stone placed		2.4
Restoration soils placed		2.4

Table 3.12: Counterfort Drain Remediation Analysis – Interlayer Slips		
Analysis	**Required FoS**	**Section 5 FoS**
Current Slope	1.2	0.9
Cut to upper formation level		0.9
Cut to lower formation level		0.9
Formation level with counterfort		1.2
Formation level with 0.5m clay liner		1.3
Formation level with 0.3m drainage stone		1.3
Waste mass placed	1.5	2.3
Regulating stone placed		2.4
Restoration soils placed		2.4

4 DISCUSSION AND ASSESSMENT

4.1.1 The stability risk assessment makes the following conclusions in regard to the basal and side slope sub-grades, basal and side slope lining systems, and waste mass and capping system.

4.2 Basal Sub-Grade and Side Slope Subgrade

4.2.1 The slope stability analysis indicates that a suitable FoS is not able to be reached for the temporary condition of reprofiling of the slope to the formation level. All slopes shall be reprofiled to 1V:2.5H max gradient unless landslip debris material is present, in which a steeper gradient may be adopted, and the buttress cut and replace methodology implemented (discussed below).

4.2.2 Given the site boundary limitations, primarily at the western corner, adopting a more gradual slope profile is not a feasible option. As such, a buttress must be implemented to stabilise the slope at this corner (see plan for extents). To mitigate the potential for failure during construction, a cut and replace construction methodology must be adopted. This involves the removal of mobilised landslip debris in max 3m sections and replacing it with buttress fill. The full buttress is not required initially but enough material must be placed to confine the SAND. The form of the buttress, in the context of this site, is detailed below.

- Minimum 1m basal thick drainage stone, overlain by:
- Filter fabric geomembrane, overlain by:
- Engineered clay fill of variable thickness.

4.2.3 All materials must be approved by the designer prior to placement.

4.2.4 As shown in Drawing ST18115-306, a series of counterfort drains are to be placed southeast of the buttress works. The use of counterfort drains has been proposed for cell 4B as site observations made by Wardell Armstrong engineers have confirmed that groundwater is seeping out of the face of the slope in Cell 4B, at approximately 59.7mAOD, and stability back analysis has shown that this groundwater is responsible for the slope failures that have historically occurred within Cell 4B. Counterfort drains have an ability to draw the groundwater down from the face of the slope to a groundwater depth that results in the slope having a suitable Factor of Safety against sliding. Depth and spacing of counterfort drains are the parameters influence their groundwater drawdown ability and are subsequently calculated to ensure the drains will lower groundwater to a suitable level. Using the method in Hutchinson,1977 with an iterative approach calculating different drain depths and spacings, a drain depth of 2.5m and drain spacing of 5m has been calculated (see Appendix 5 for detailed calculations). The amount of groundwater drawdown from counterfort drains with these parameters has been modelled in Geostudio Slope/W and resulted in the slope having a suitable Factory of Safety.

4.2.5 Counterfort drains shall comprise a min 1m wide trench extending down the slope. The drains shall feature a 110mm diameter perforated pipe wrapped in geotextile situated at the bottom of the trench. The trench shall be backfilled with drainage material (Class 6C of Series 600 of the Specification for Highway Works).

4.3 Basal and Side Slope Lining System

4.3.1 The limit equilibrium analysis indicates that the basal lining system is sufficiently stable and is deemed acceptable. Material parameters for the clay liner material will require validation during the works to confirm consistency through construction phases.

4.3.2 Interface shear strength analysis has been conducted for the geomembrane/clay liner and geomembrane/drainage stone interfaces, using the method provided by Jones & Dixon. The analyses reviewed four scenarios that will influence the stability of the geomembrane, and each scenario was calculated to have a Factor of Safety of at least 1.2 which is deemed suitable. Detailed interface calculations are displayed in Appendix 4. Conservative values based on experience with similar material and previous test results were used to provide the interface shear strengths to calculate Factor of Safety for the given interfaces.

4.4 Waste Mass

4.4.1 The limit equilibrium analysis indicates that the waste mass is sufficiently stable and is deemed acceptable.

4.5 Capping System

4.5.1 The limit equilibrium indicates that the proposed capping system is sufficiently stable and is deemed acceptable. These analyses are required to be revisited once specific materials have been selected and properties confirmed. Interface testing should also be available.

APPENDICES

APPENDIX 1

BH106A Borehole Log

THE ARLEY CONSULTING COMPANY LIMITED

Machine : Comacchio MC 450p **Flush :** Air **Core Dia :** 194 mm **Method :** Rotary Drilling	**Casing Diameter** 168mm cased to 38.00m	**Ground Level (mOD)** 64.03	**Site** Clayton Hall Landfill Site	**Borehole Number** 106A
	Location 356698.9 E 421790.3 N	**Dates** 15/11/2010- 17/11/2010	**Client** Quercia Limited	**Job Number** 08469
			Engineer DK	**Sheet** 1/5

Depth (m)	TCR (%)	SCR (%)	RQD (%)	FI	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water	Instr
							(0.75)	Dark brown sandy silty clay with rootlets (TOPSOIL)			
						63.28	0.75 (2.75)	Firm dark brown sandy silty CLAY			
						60.53	3.50 (4.00)	Reddish brown silty f-m SAND with some clay lenses			
						56.53	7.50	Stiff reddish brown sandy silty CLAY with occasional gravel			

Remarks
Borehole complete at 50 m

Scale (approx)	Logged By
1:50	JP

Figure No.
08469.106A

THE ARLEY CONSULTING COMPANY LIMITED			Site: Clayton Hall Landfill Site	Borehole Number: 106A
Machine : Comacchio MC 450p Flush : Air Core Dia : 194 mm Method : Rotary Drilling	Casing Diameter: 168mm cased to 38.00m	Ground Level (mOD): 64.03	Client: Quercia Limited	Job Number: 08469
	Location: 356698.9 E 421790.3 N	Dates: 15/11/2010-17/11/2010	Engineer: DK	Sheet: 2/5

Depth (m)	TCR (%)	SCR (%)	RQD (%)	FI	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water	Instr
							(14.00)				

Remarks
Borehole complete at 50 m

Scale (approx)	Logged By
1:50	JP

Figure No. 08469.106A

THE ARLEY CONSULTING COMPANY LIMITED			Site: Clayton Hall Landfill Site	Borehole Number: 106A
Machine : Comacchio MC 450p Flush : Air Core Dia : 194 mm Method : Rotary Drilling	Casing Diameter: 168mm cased to 38.00m	Ground Level (mOD): 64.03	Client: Quercia Limited	Job Number: 08469
	Location: 356698.9 E 421790.3 N	Dates: 15/11/2010-17/11/2010	Engineer: DK	Sheet: 3/5

Depth (m)	TCR (%)	SCR (%)	RQD (%)	FI	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water	Instr
						42.53	21.50 (0.50)	Grey subangular-subrounded f-c GRAVEL			
						42.03	22.00 (3.00)	Stiff reddish brown sandy silty CLAY with occasional gravel			
						39.03	25.00	Reddish brown silty f-m SAND with occasional clay lenses			

Remarks
Borehole complete at 50 m

Scale (approx)	Logged By
1:50	JP

Figure No. 08469.106A

THE ARLEY CONSULTING COMPANY LIMITED	Site: Clayton Hall Landfill Site	Borehole Number: 106A
Machine : Comacchio MC 450p Flush : Air Core Dia : 194 mm Method : Rotary Drilling	Casing Diameter: 168mm cased to 38.00m Ground Level (mOD): 64.03 Location: 356698.9 E 421790.3 N Dates: 15/11/2010-17/11/2010	Client: Quercia Limited Job Number: 08469 Engineer: DK Sheet: 4/5

Depth (m)	TCR (%)	SCR (%)	RQD (%)	FI	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water	Instr
							(12.50)				
					Water strike(1) at 37.50m.	26.53	37.50 (0.50)	Very weak/weak highly weathered SANDSTONE (recovered as gravel)		1	
						26.03	38.00	Moderately weak/moderately strong reddish brown moderately weathered medium grained SANDSTONE (Sherwood Sandstone)			

Remarks
Borehole complete at 50 m

Scale (approx)	Logged By
1:50	JP

Figure No. 08469.106A

THE ARLEY CONSULTING COMPANY LIMITED			Site: Clayton Hall Landfill Site	Borehole Number: 106A
Machine : Comacchio MC 450p Flush : Air Core Dia : 194 mm Method : Rotary Drilling	Casing Diameter: 168mm cased to 38.00m	Ground Level (mOD): 64.03	Client: Quercia Limited	Job Number: 08469
	Location: 356698.9 E 421790.3 N	Dates: 15/11/2010-17/11/2010	Engineer: DK	Sheet: 5/5

Depth (m)	TCR (%)	SCR (%)	RQD (%)	FI	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water	Instr
							(12.00)				
						14.03	50.00				

Remarks
Borehole complete at 50 m

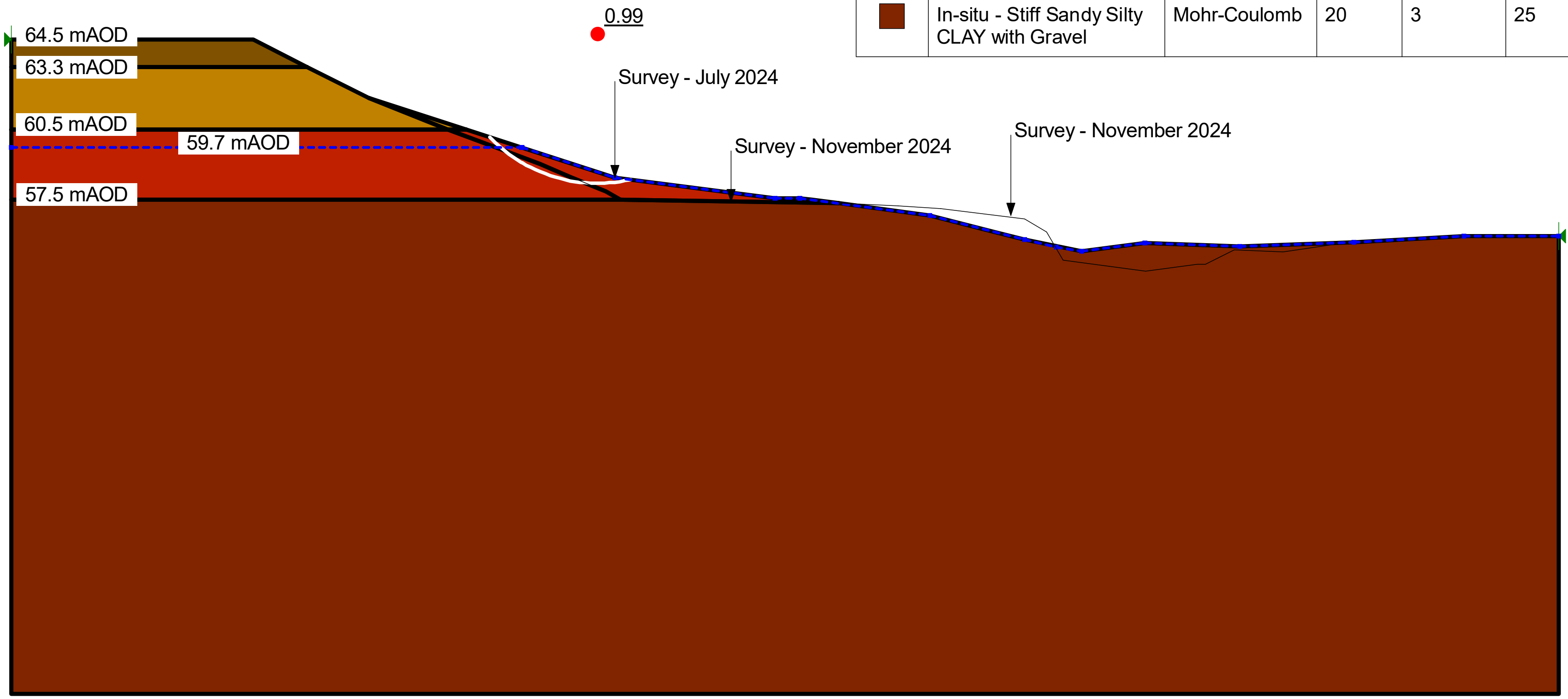
Scale (approx)	Logged By
1:50	JP

Figure No. 08469.106A

APPENDIX 2

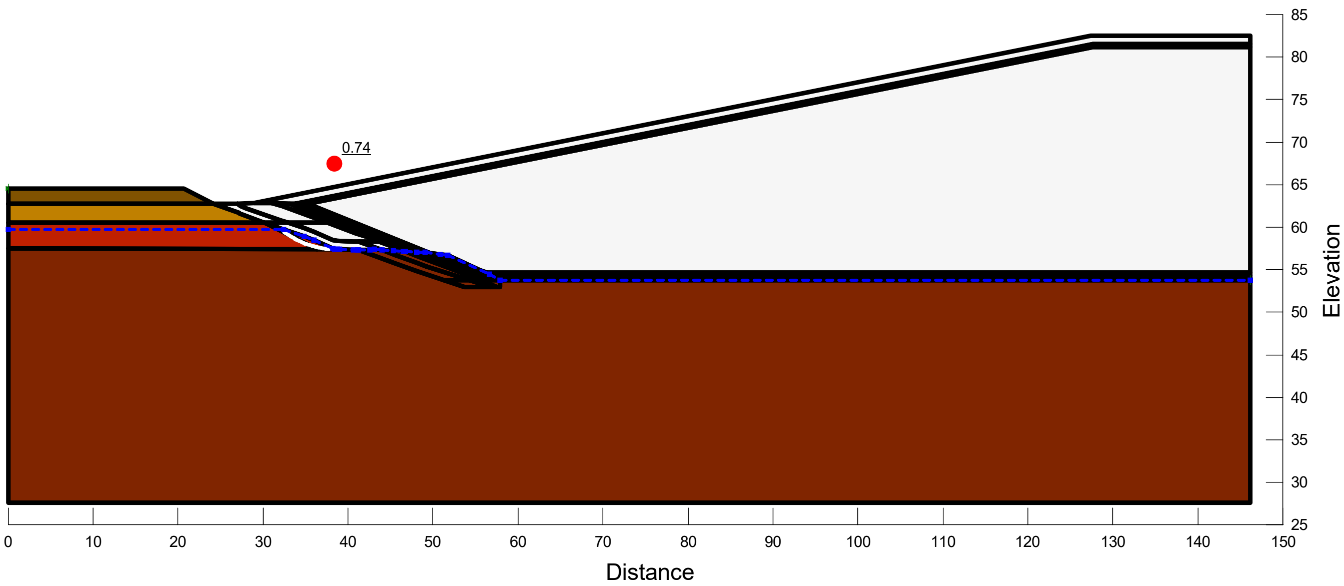
Slope Stability Critical Slip Outputs

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometri Surface
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



Back Analysis (July 2024)
Cell 4B_20241129 - Section A (western failure back analysis)_v1.gsz
13/12/2024 1:300

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

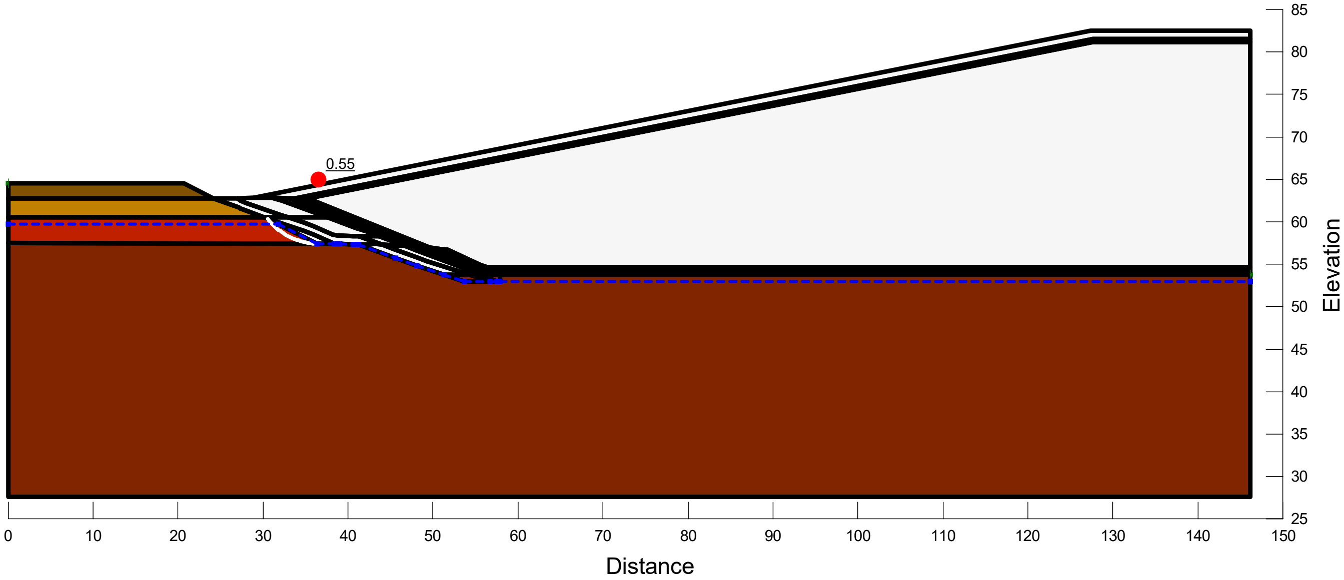


CURRENT

Cell 4B_20241208 - Section 2.gsz

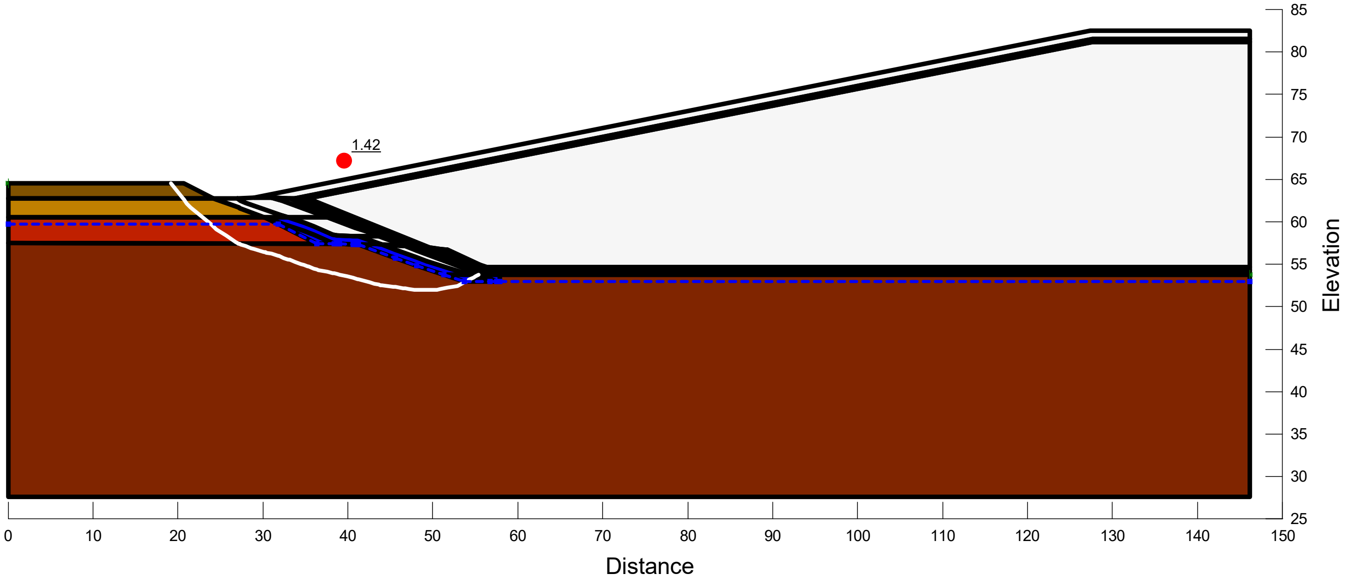
16/12/2024 1:890

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



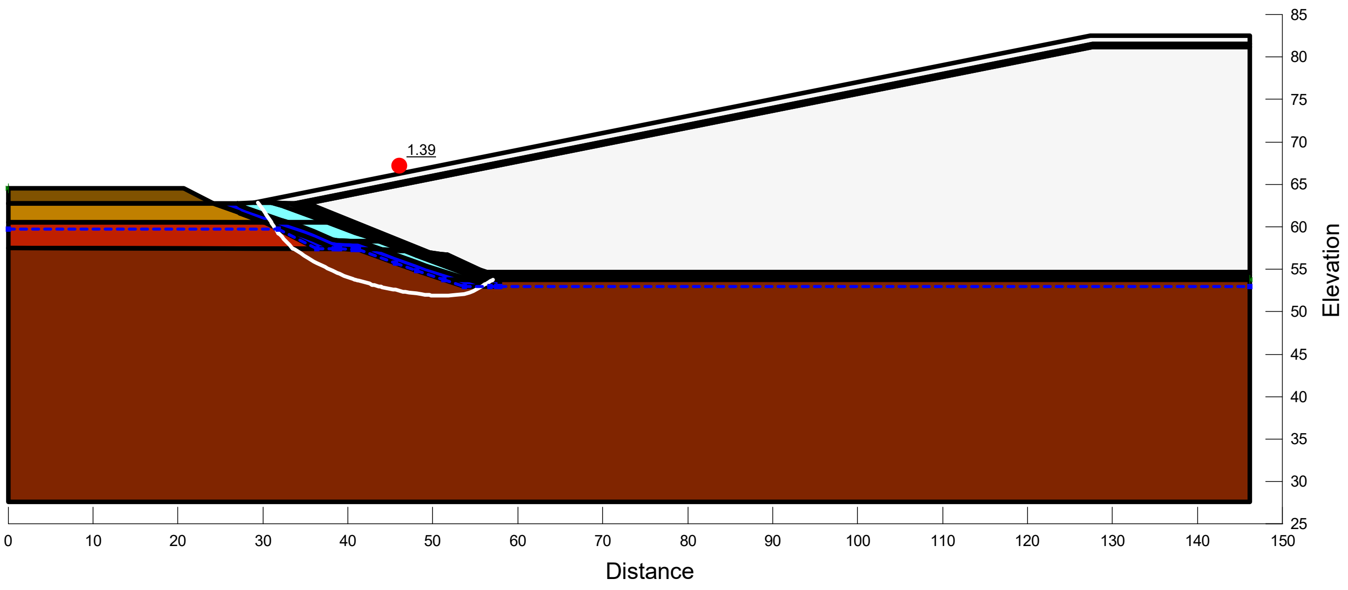
CUT TO FORMATION LEVEL	
Cell 4B_20241208 - Section 2.gsz	
16/12/2024	1:890

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



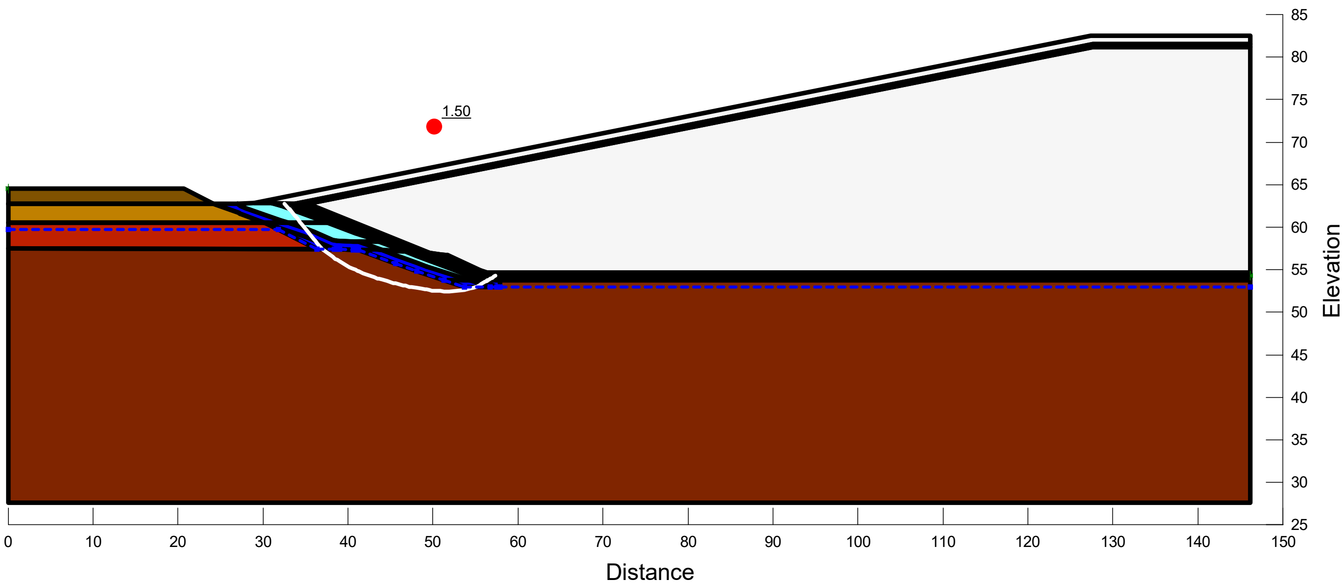
CUT TO FORMATION LEVEL WITH BUTTRESS	
Cell 4B_20241208 - Section 2.gsz	
16/12/2024	1:890

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Engineered Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



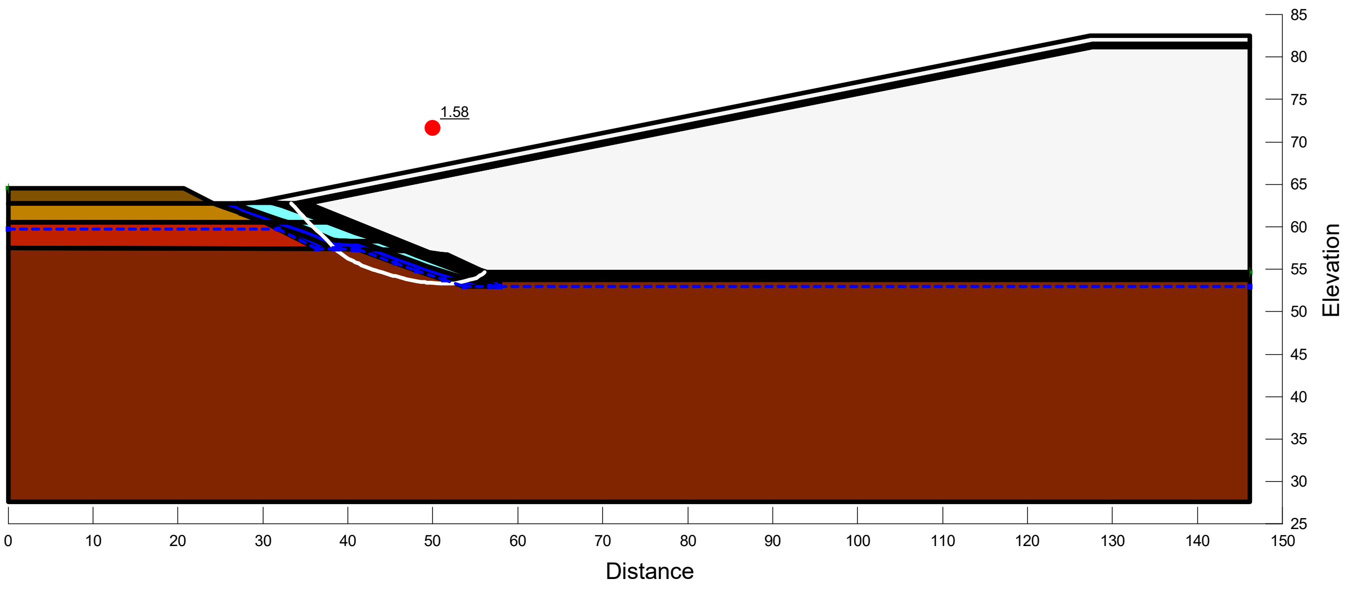
FULL BUTTRESS	
Cell 4B_20241208 - Section 2.gsz	
16/12/2024	1:890

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Engineered Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



FULL BUTTRESS WITH 0.5m CLAY LINER	
Cell 4B_20241208 - Section 2.gsz	
16/12/2024	1:890

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

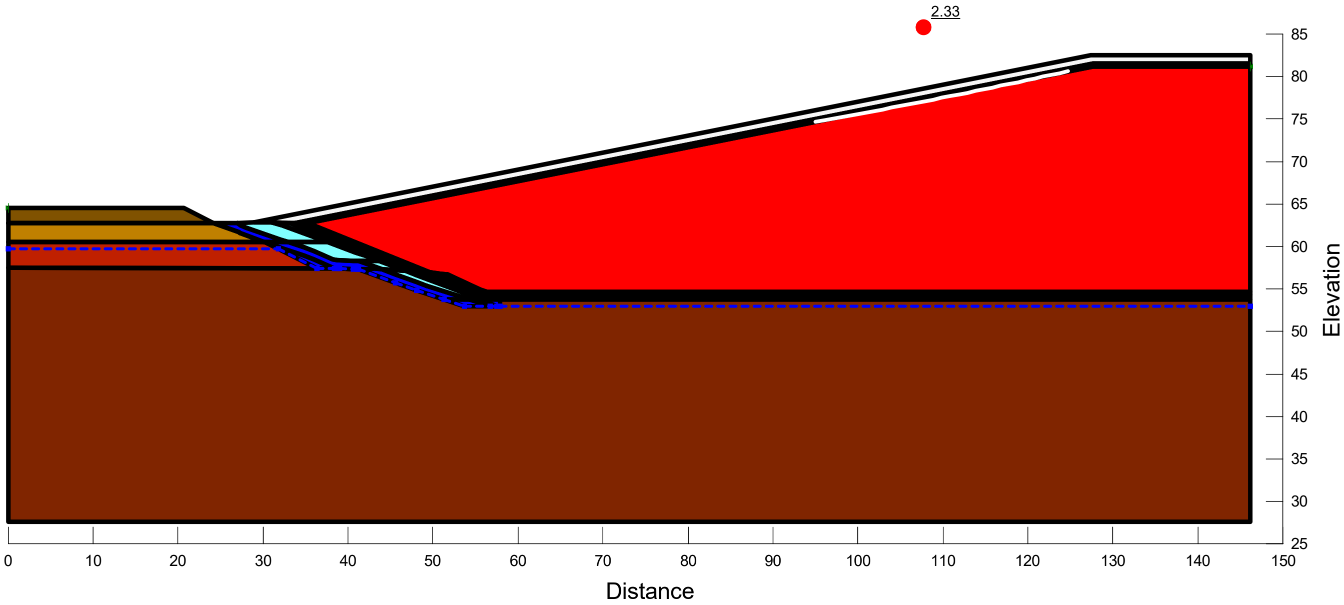


FULL BUTTRESS WITH 0.3m DRAINAGE STONE

Cell 4B_20241208 - Section 2.gsz

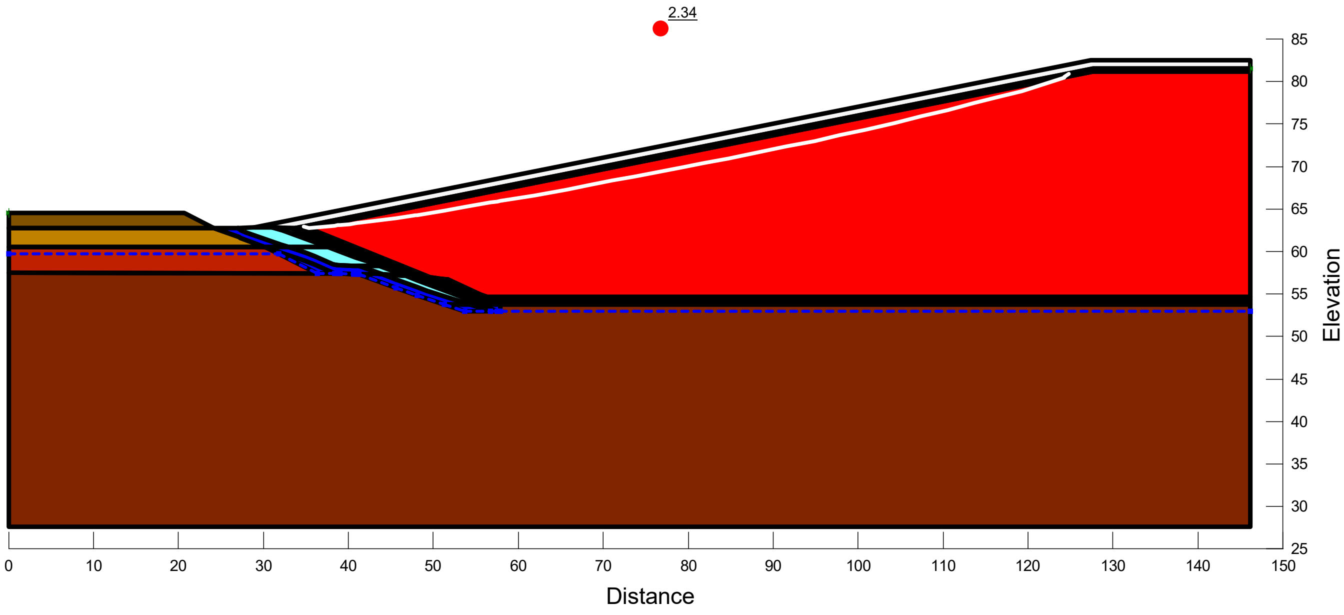
16/12/2024 1:890

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	Imported - Waste Mass	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



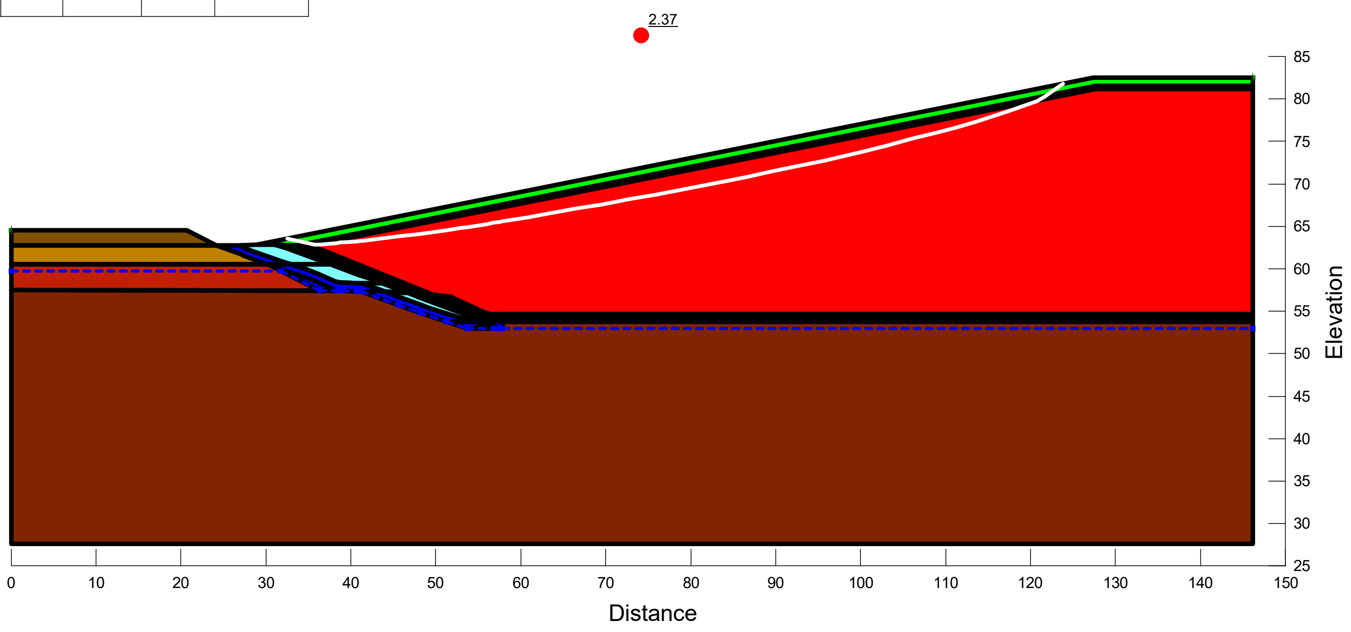
WASTE MASS PLACED	
Cell 4B_20241208 - Section 2.gsz	
16/12/2024	1:890

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	Imported - Regulating Stone Layer	Mohr-Coulomb	19	0	34	1
	Imported - Waste Mass	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



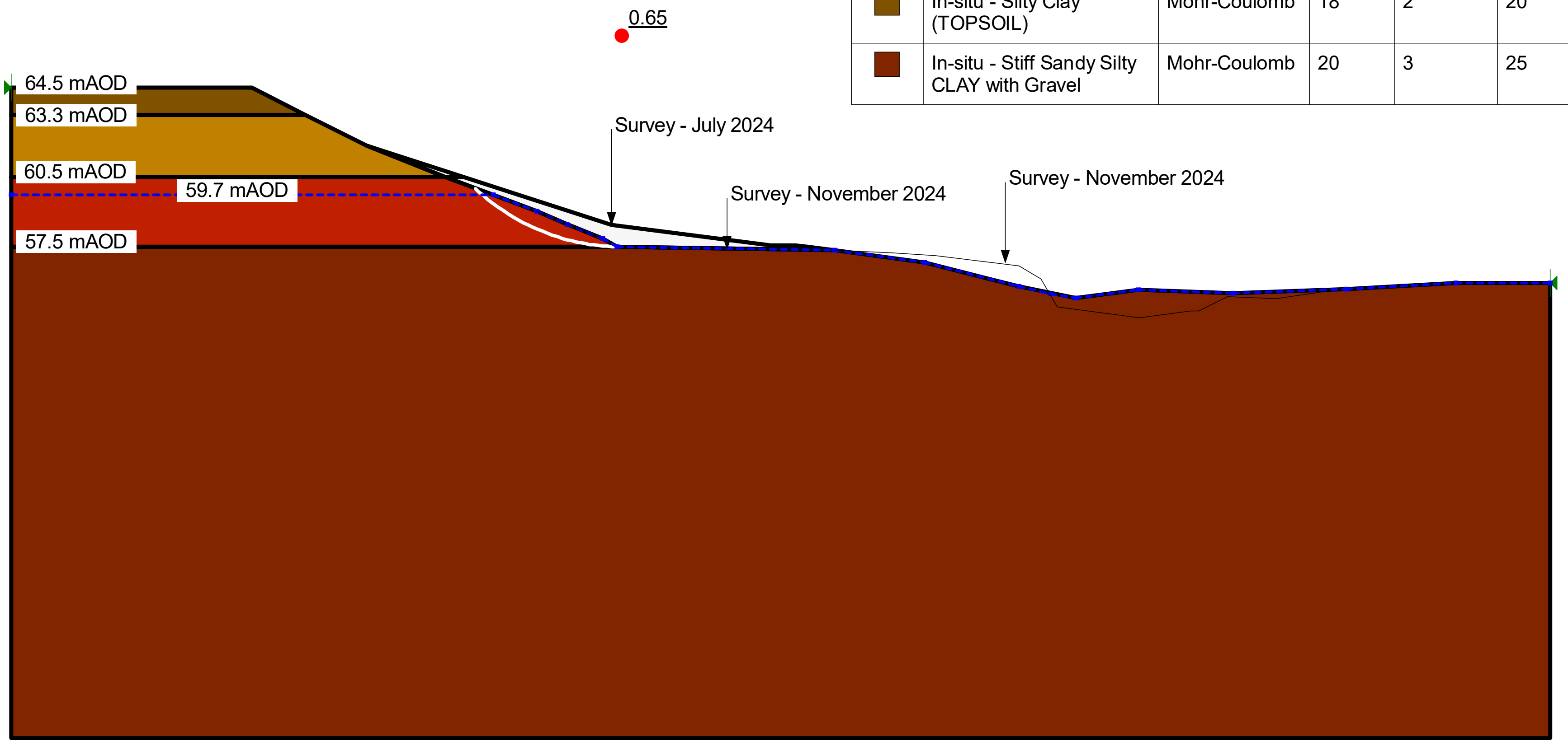
REGULATING STONE PLACED	
Cell 4B_20241208 - Section 2.gsz	
16/12/2024	1:890

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	Imported - Regulating Stone Layer	Mohr-Coulomb	19	0	34	1
	Imported - Restoration Soil	Mohr-Coulomb	19	0	30	1
	Imported - Waste Mass	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



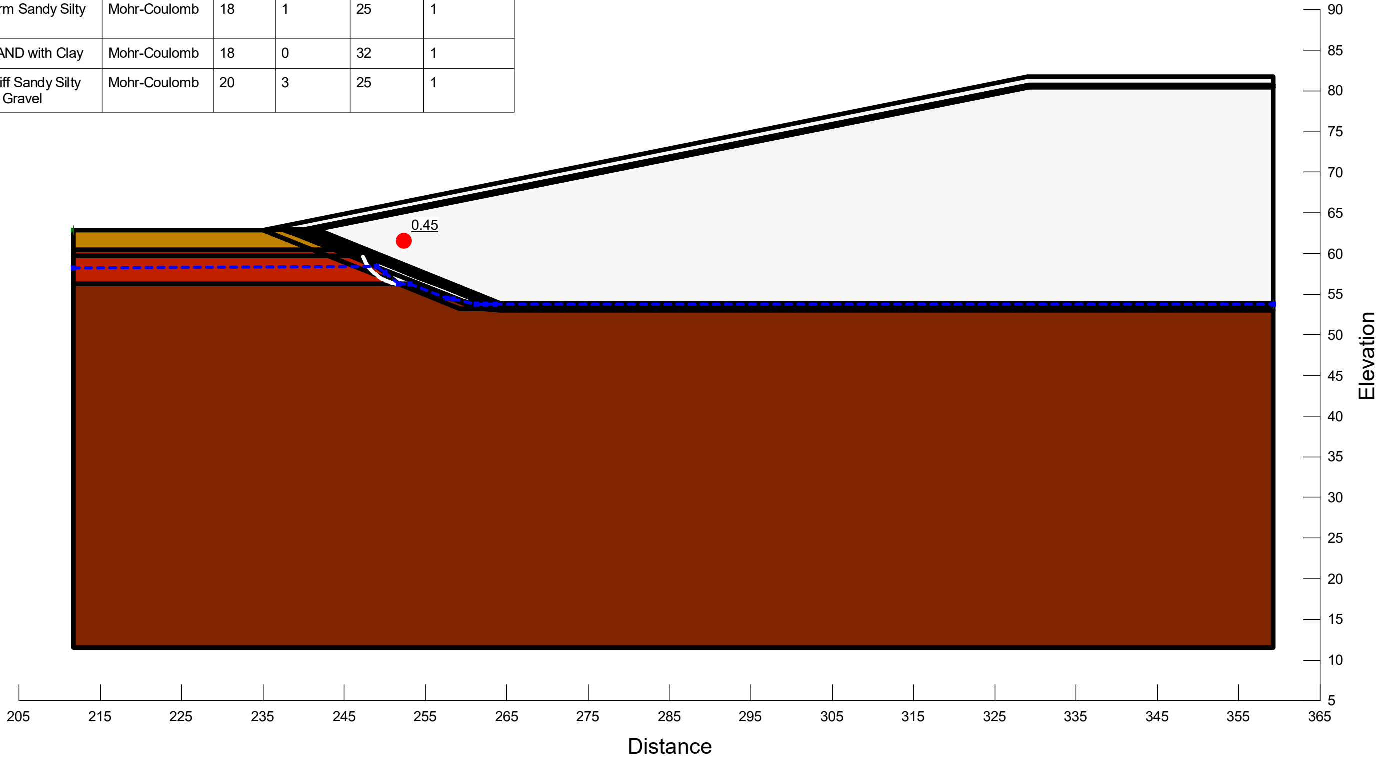
RESTORATION SOILS PLACED	
Cell 4B_20241208 - Section 2.gsz	
16/12/2024	1:890

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometri Surface
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



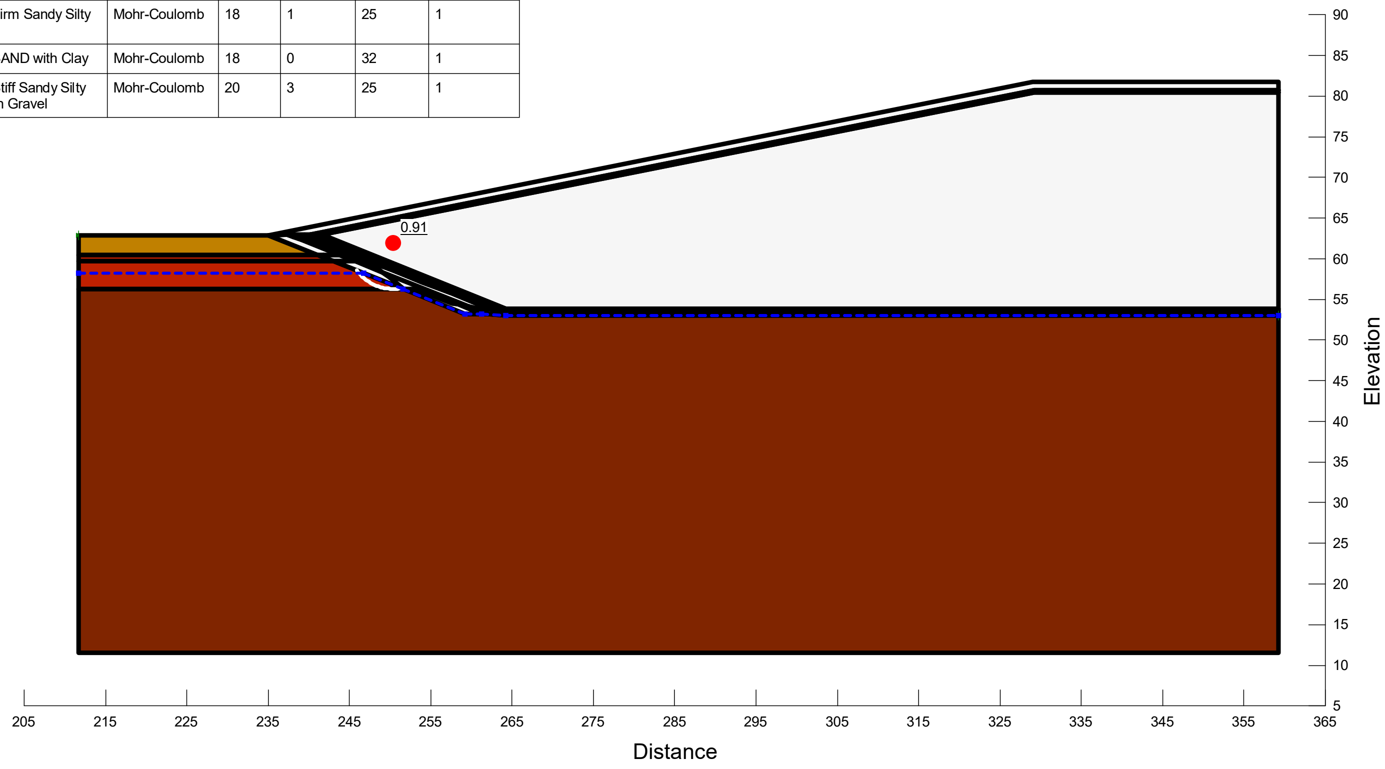
Back Analysis (November 2024)	
Cell 4B_20241129 - Section A (western failure back analysis)_v1.gsz	
13/12/2024	1:300

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



CURRENT	
Cell 4B_20241208 - Section 3_v1.gsz	
17/12/2024	1:930

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

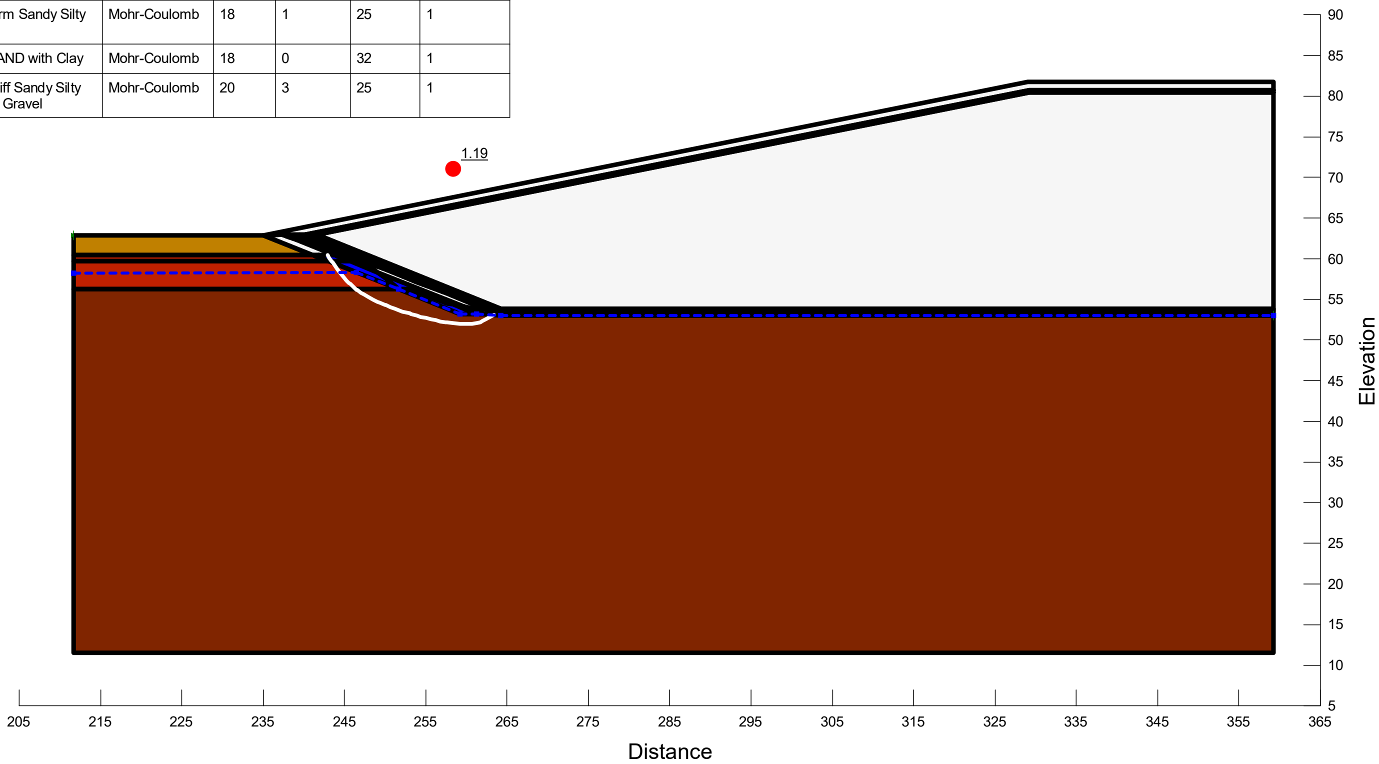


CUT TO FORMATION LEVEL

Cell 4B_20241208 - Section 3_v1.gsz

17/12/2024 1:930

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

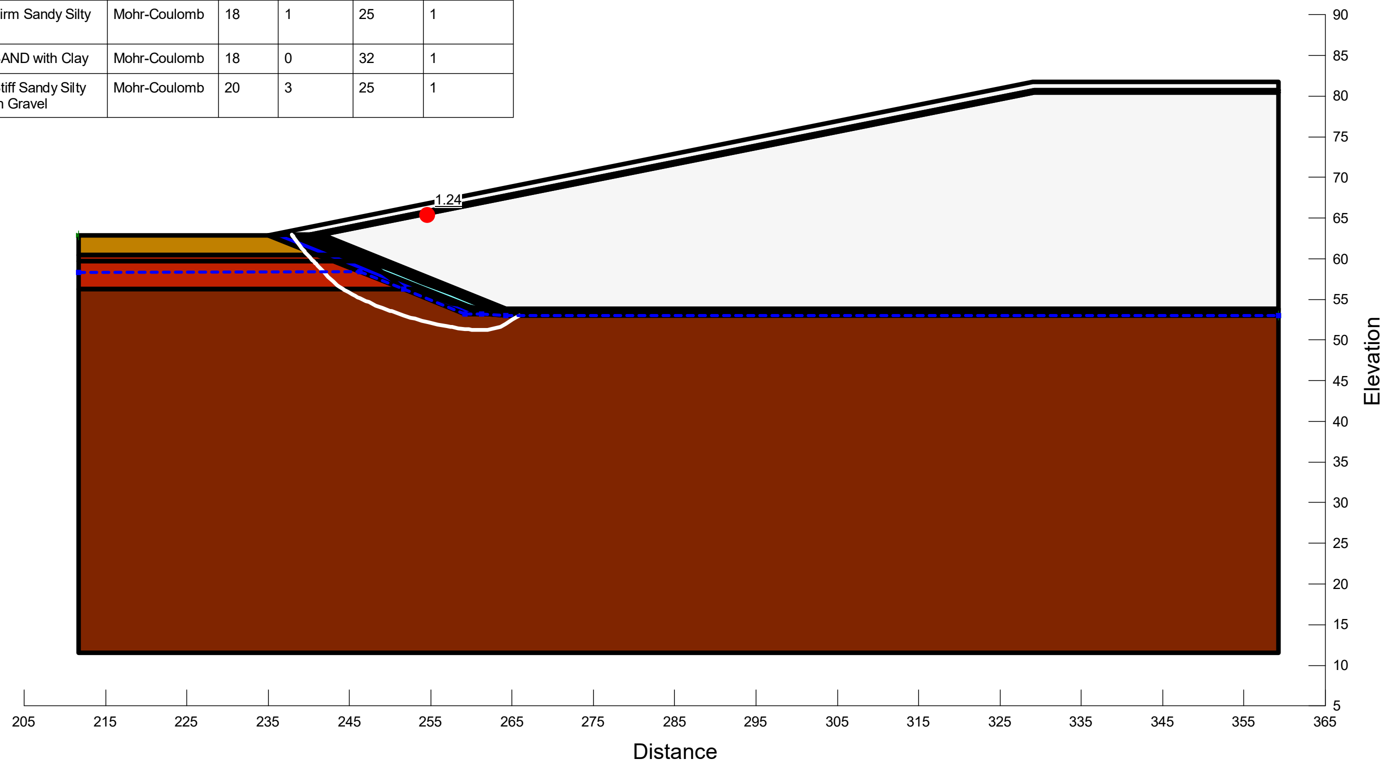


CUT TO FORMATION LEVEL WITH BUTTRESS

Cell 4B_20241208 - Section 3_v1.gsz

17/12/2024 1:930

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

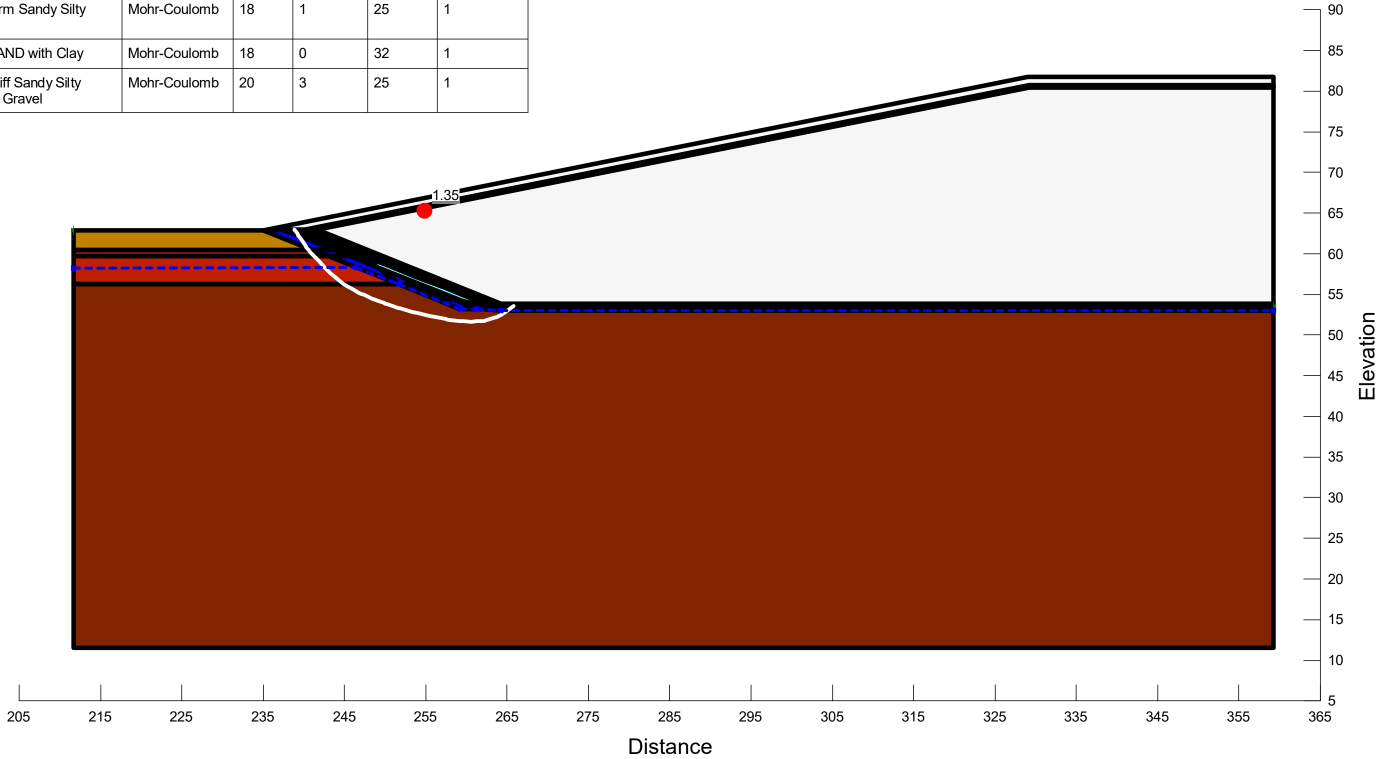


FULL BUTTRESS

Cell 4B_20241208 - Section 3_v1.gsz

17/12/2024 1:930

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

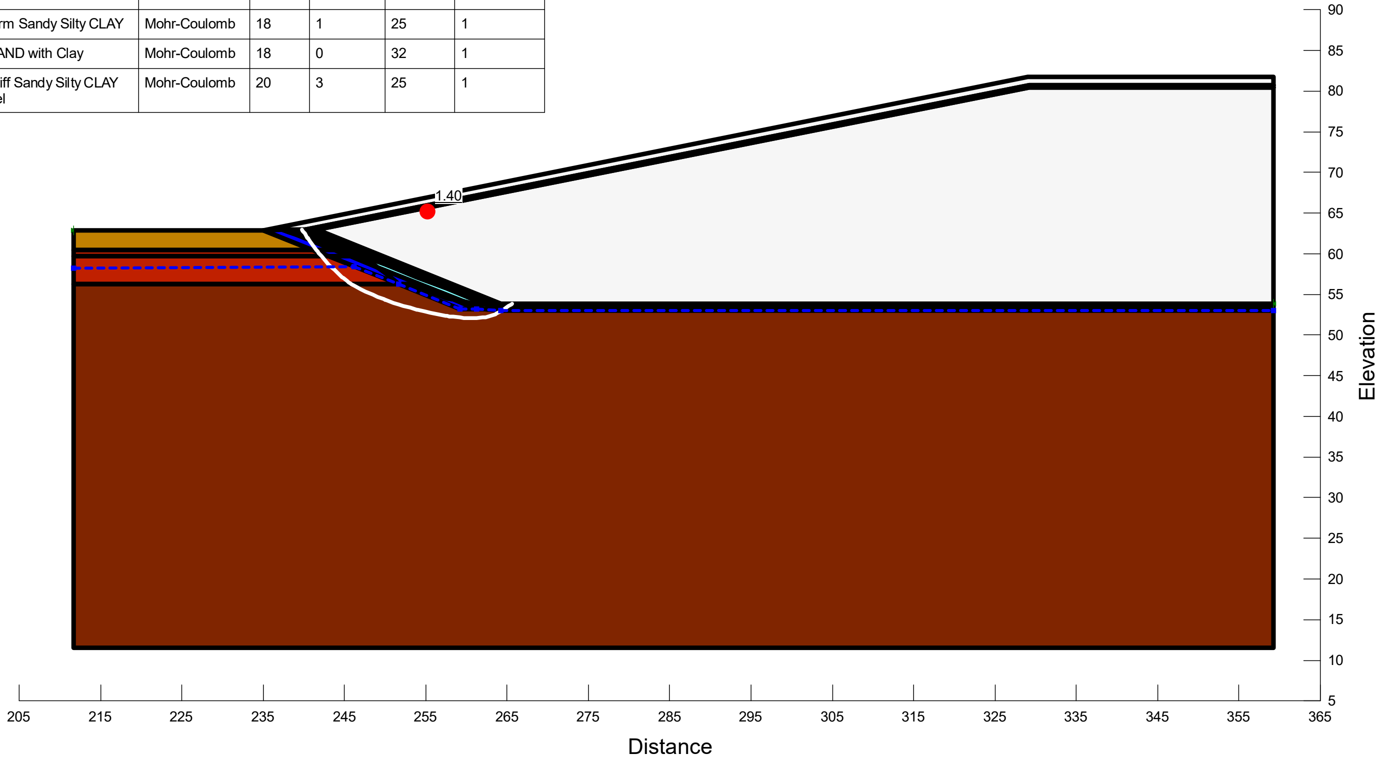


FULL BUTTRESS WITH 0.5m CLAY LINER

Cell 4B_20241208 - Section 3_v1.gsz

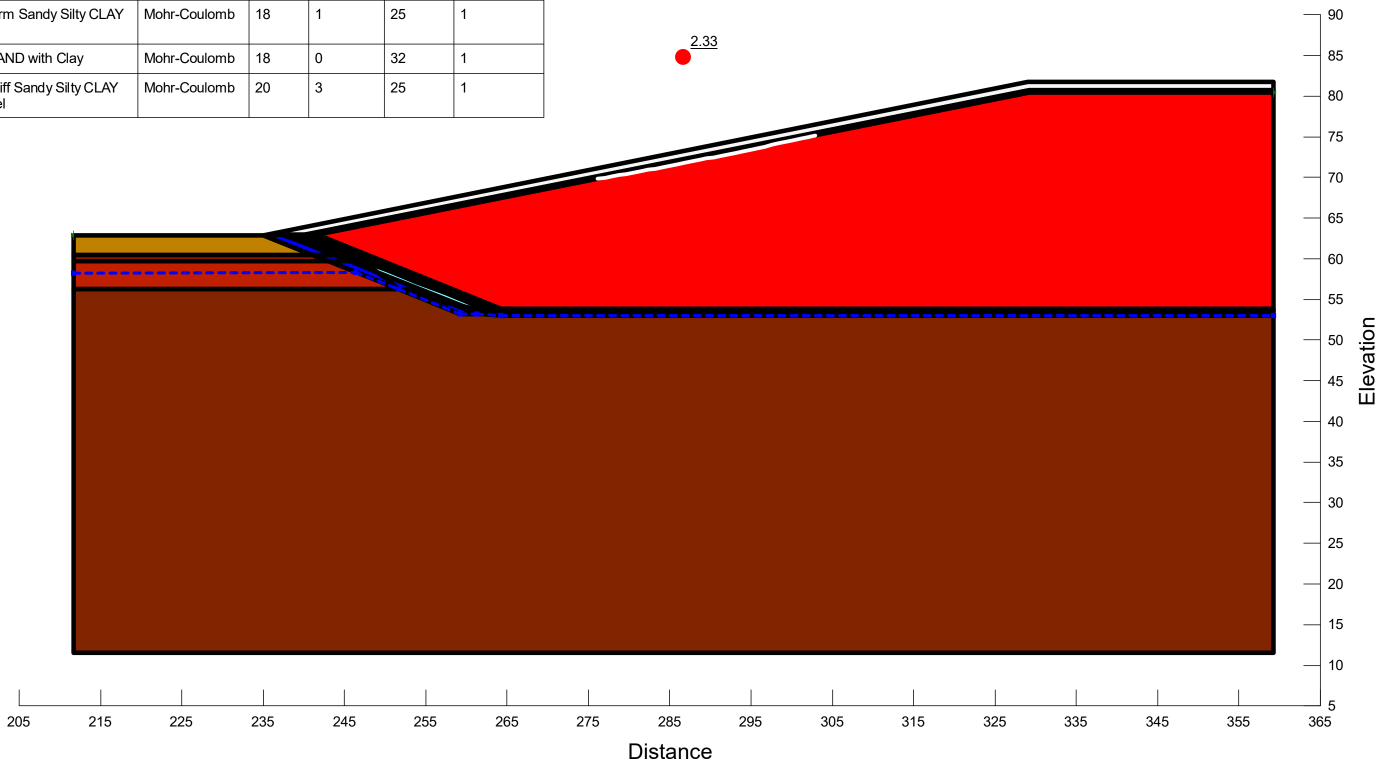
17/12/2024 1:930

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



FULL BUTTRESS WITH 0.3m DRAINAGE STONE	
Cell 4B_20241208 - Section 3_v1.gsz	
17/12/2024	1:930

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	Imported - Waste Mass	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

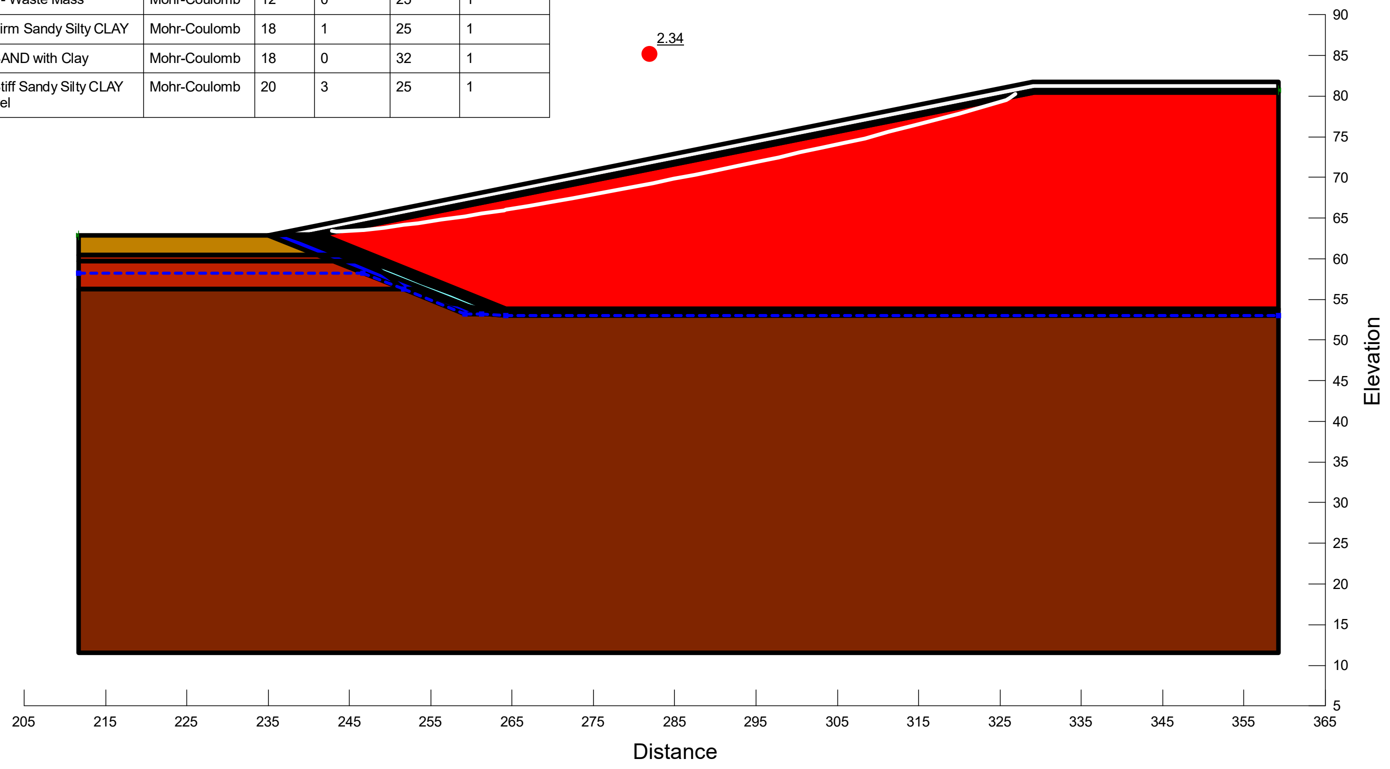


WASTE MASS PLACED

Cell 4B_20241208 - Section 3_v1.gsz

17/12/2024 1:930

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	Imported - Regulating Stone Layer	Mohr-Coulomb	19	0	34	1
	Imported - Waste Mass	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

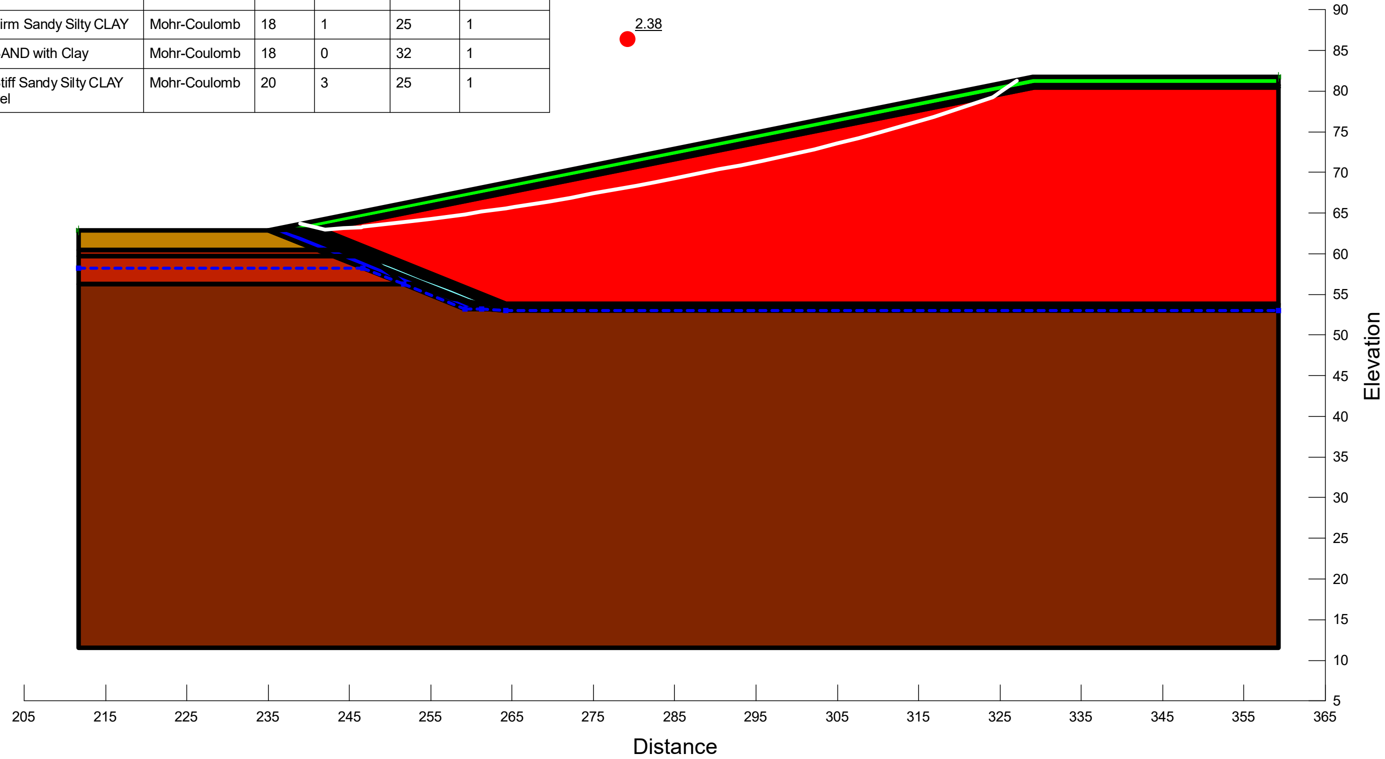


REGULATING STONE PLACED

Cell 4B_20241208 - Section 3_v1.gsz

17/12/2024 1:930

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	Imported - Regulating Stone Layer	Mohr-Coulomb	19	0	34	1
	Imported - Restoration Soils	Mohr-Coulomb	19	0	30	1
	Imported - Waste Mass	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

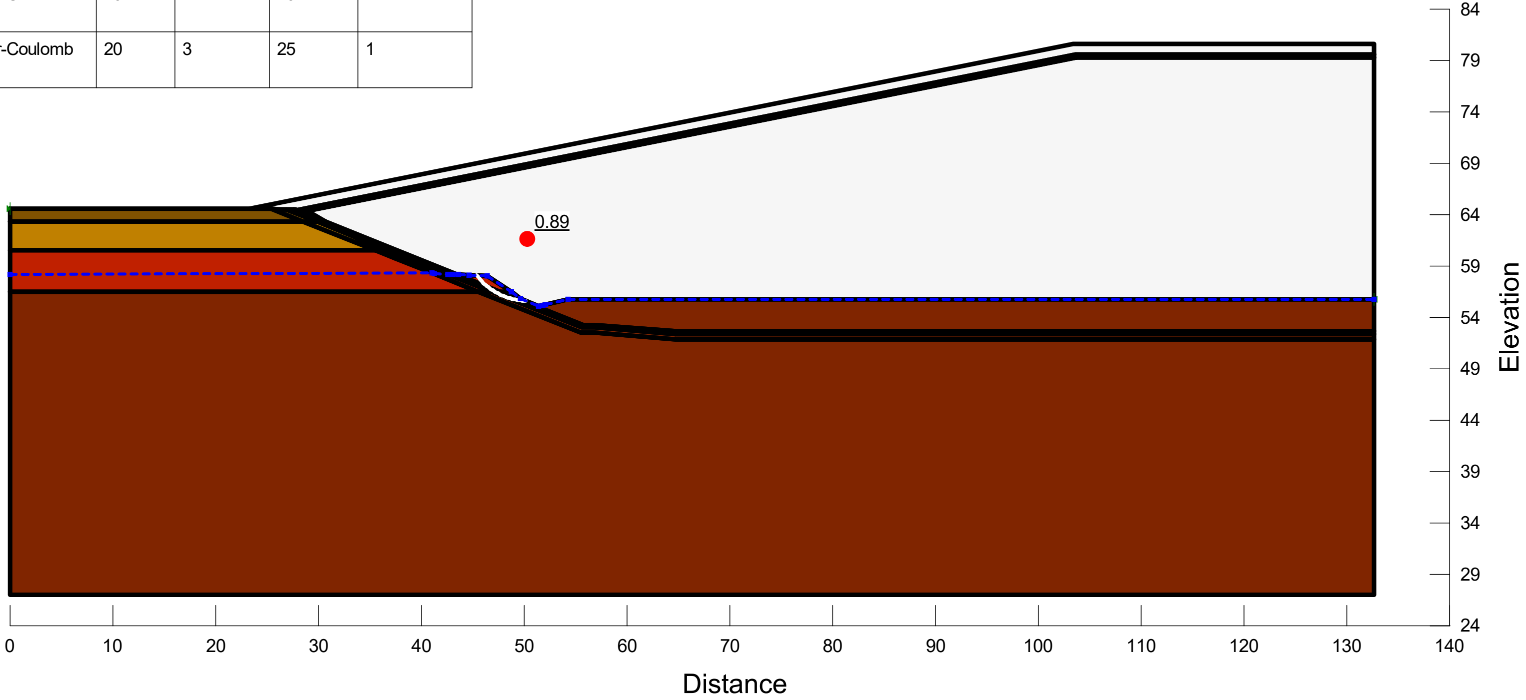


RESTORATION SOILS

Cell 4B_20241208 - Section 3_v1.gsz

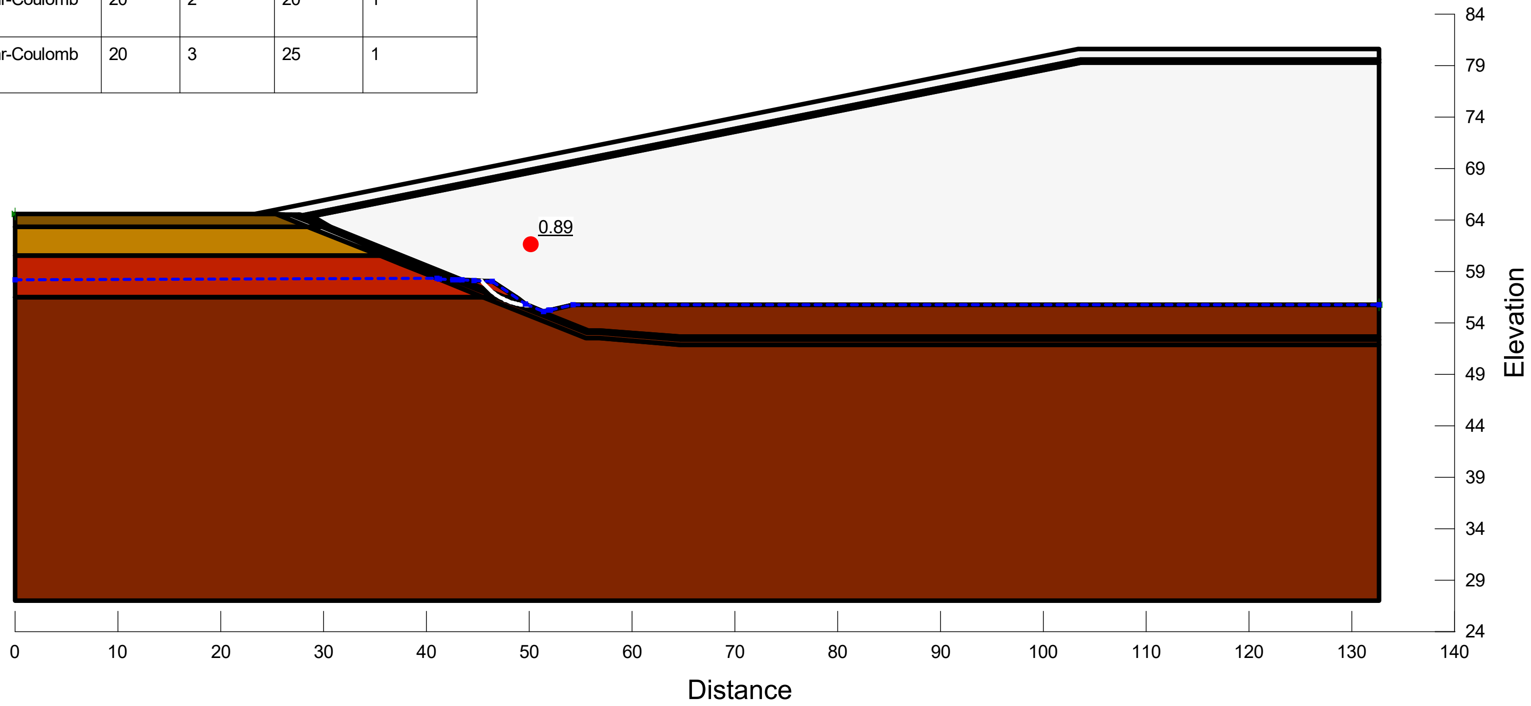
17/12/2024 1:930

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



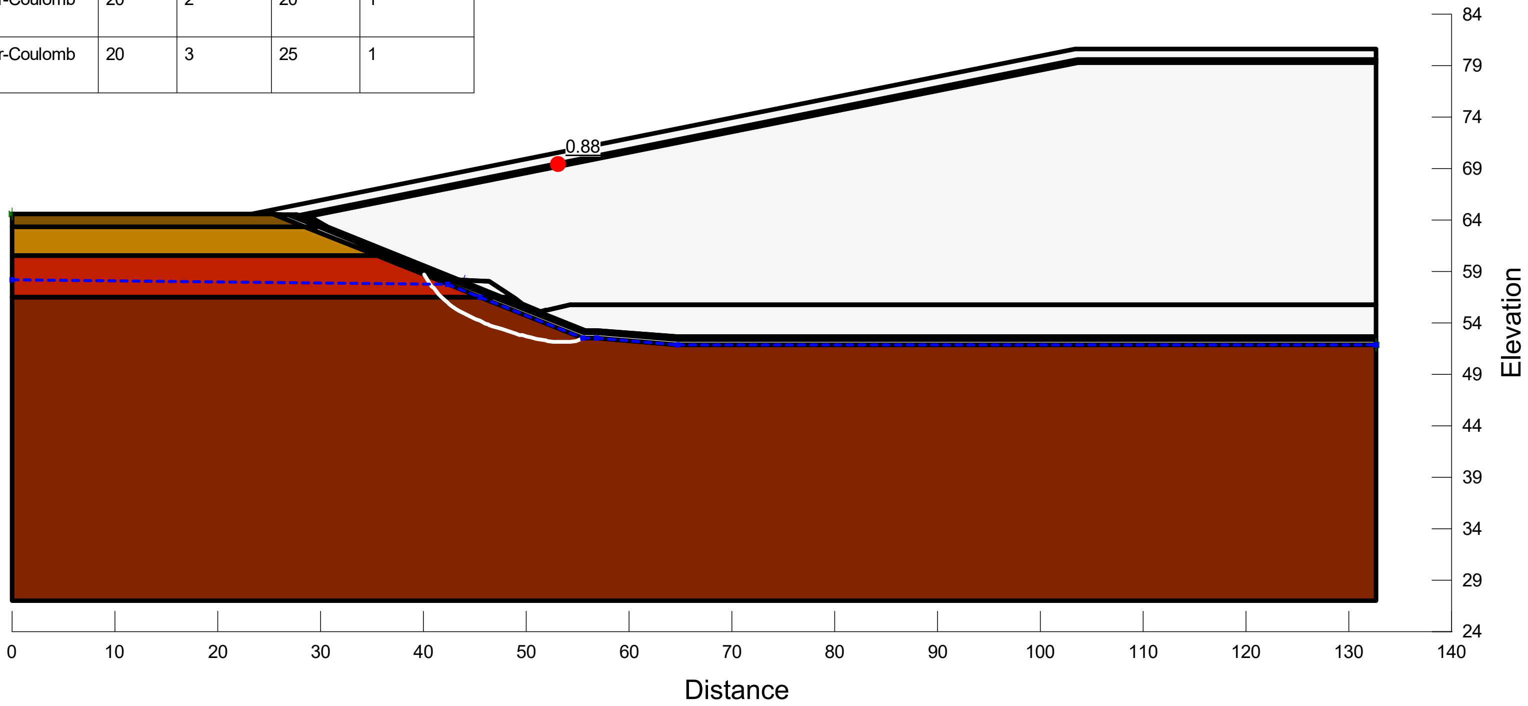
CURRENT	
Cell 4B_20241208 - Section 5_v4.gsz	
16/12/2024	1:735

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



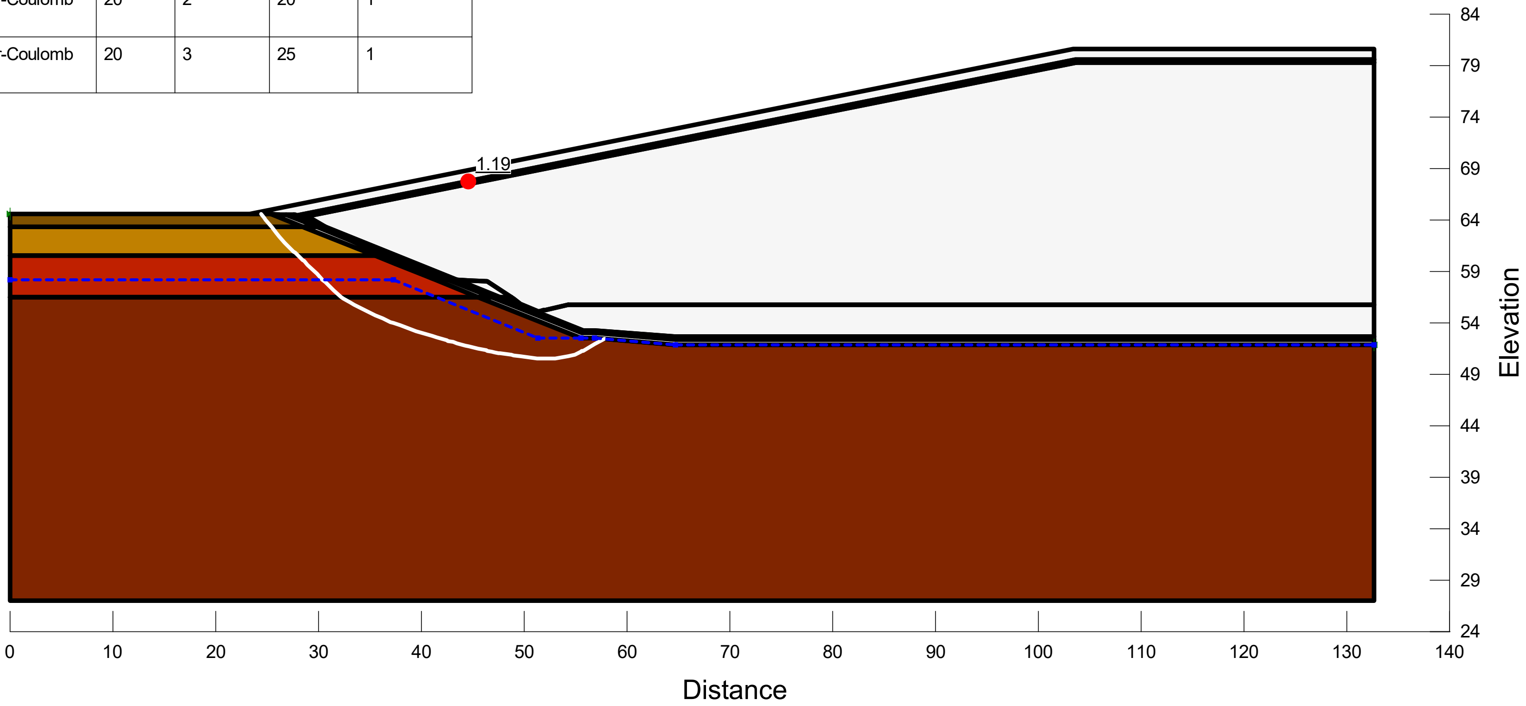
CUT TO UPPER FORMATION LEVEL	
Cell 4B_20241208 - Section 5_v4.gsz	
16/12/2024	1:735

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



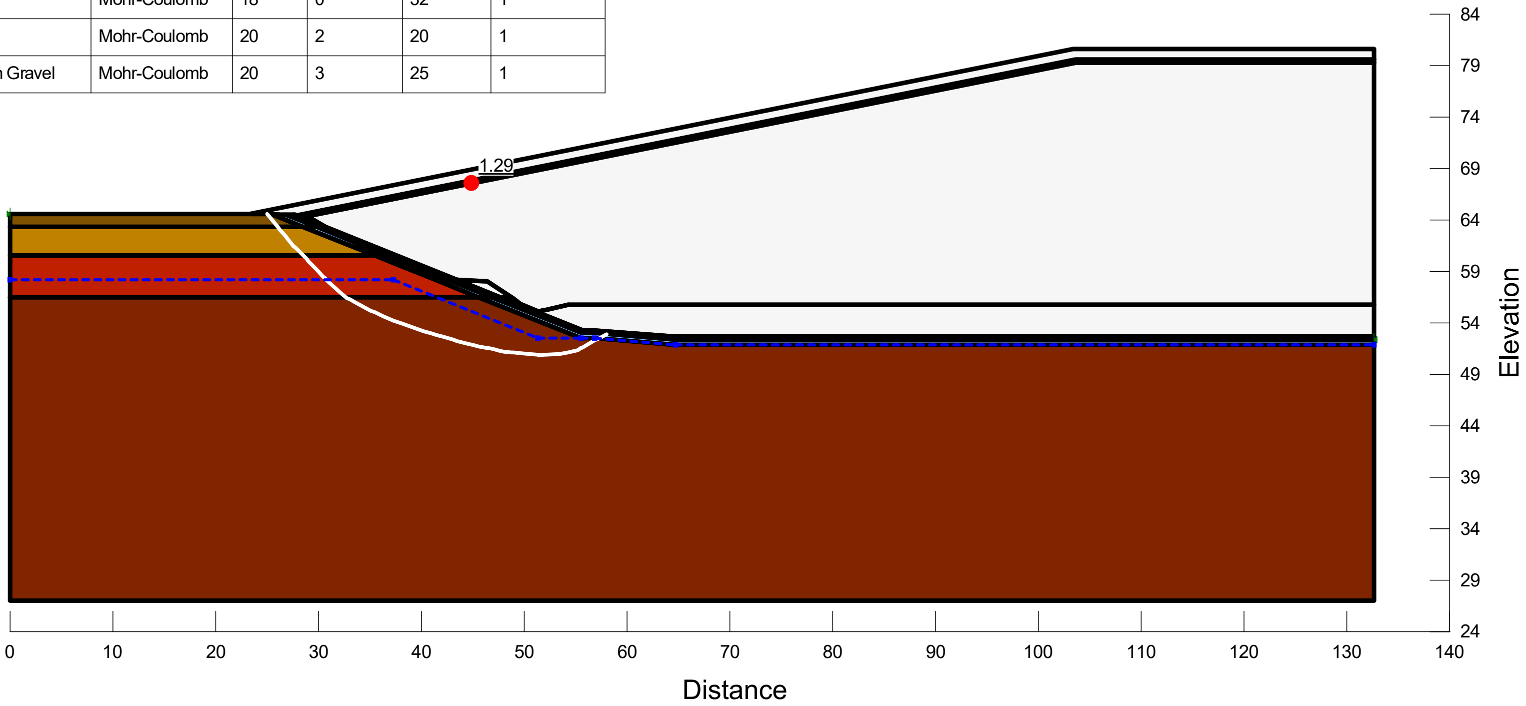
CUT TO LOWER FORMATION LEVEL	
Cell 4B_20241208 - Section 5_v4.gsz	
16/12/2024	1:735

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



CUT TO FORMATION LEVEL WITH COUNTERFORT	
Cell 4B_20241208 - Section 5_v4.gsz	
16/12/2024	1:735

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

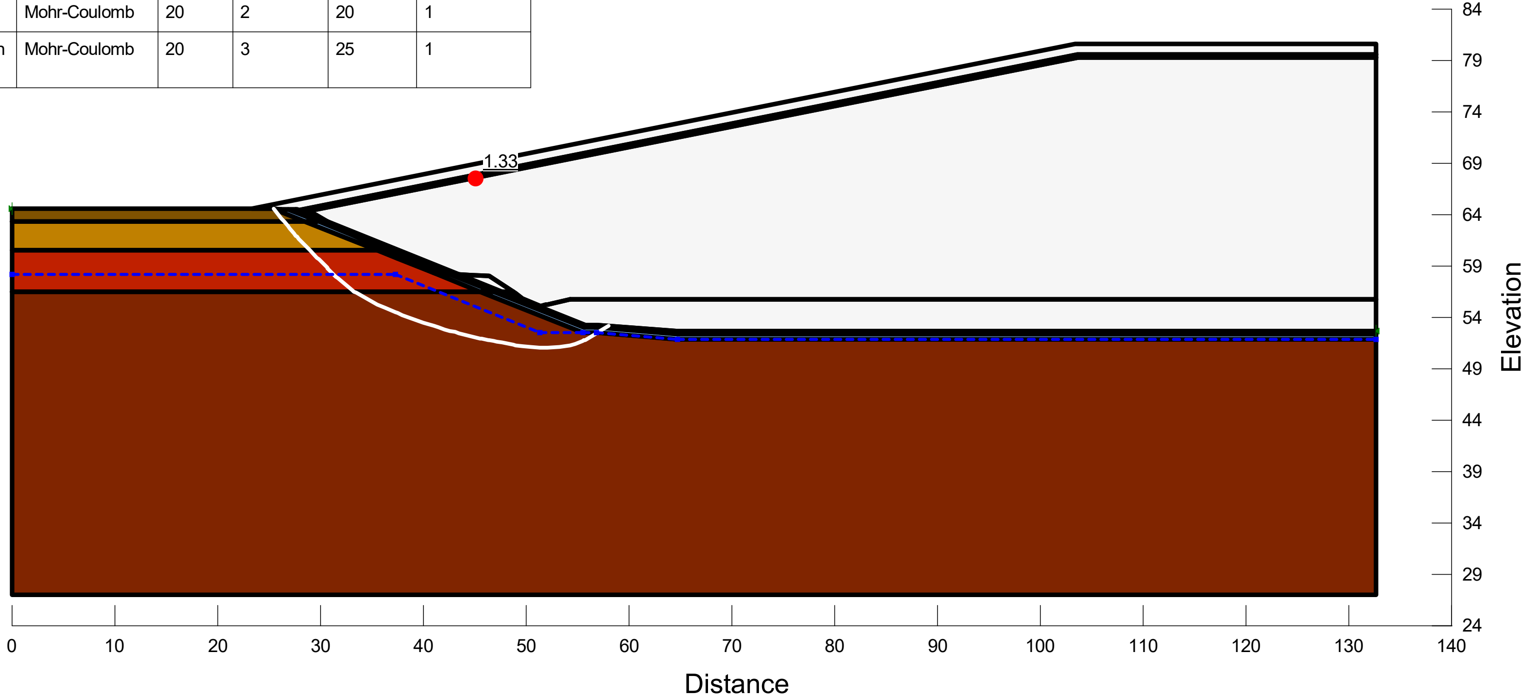


CUT WITH 0.5m CLAY LINER

Cell 4B_20241208 - Section 5_v4.gsz

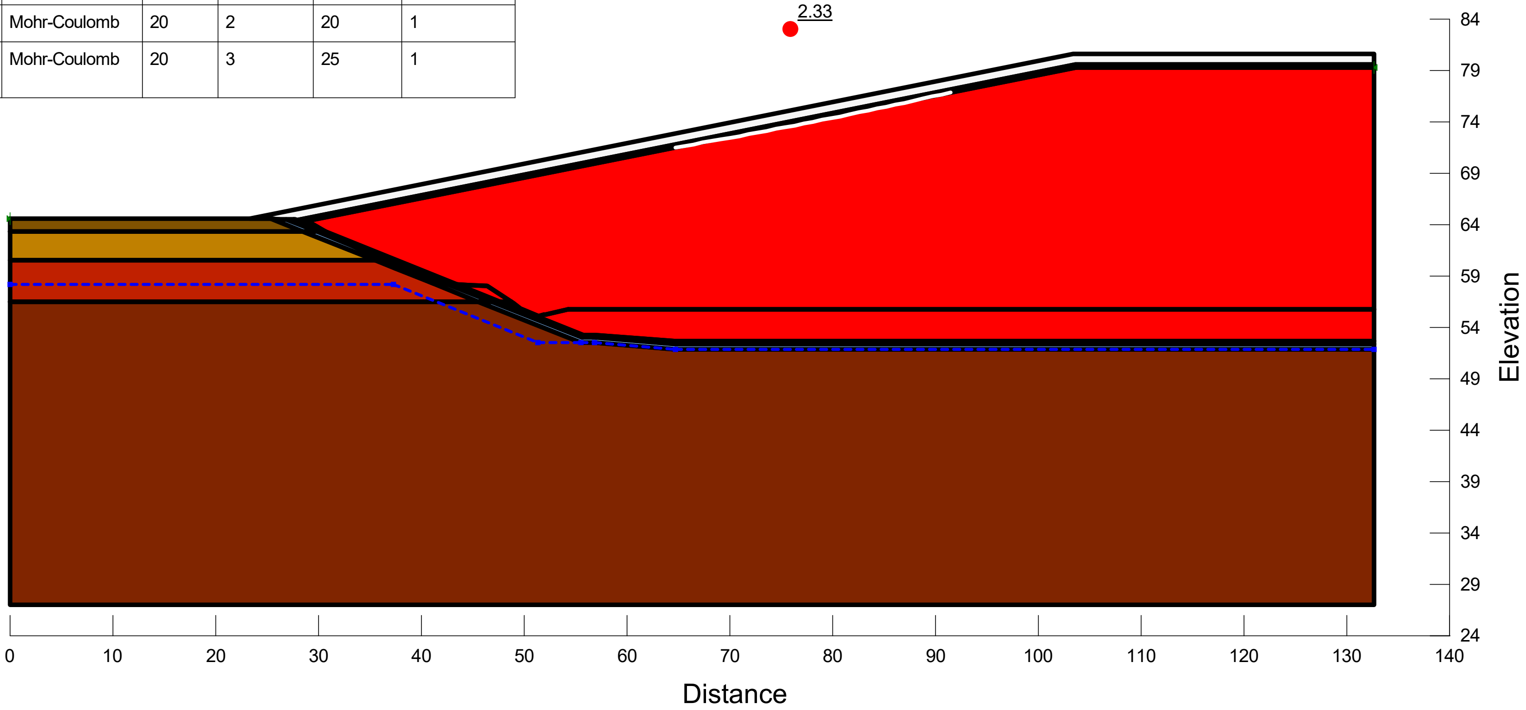
16/12/2024 1:735

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



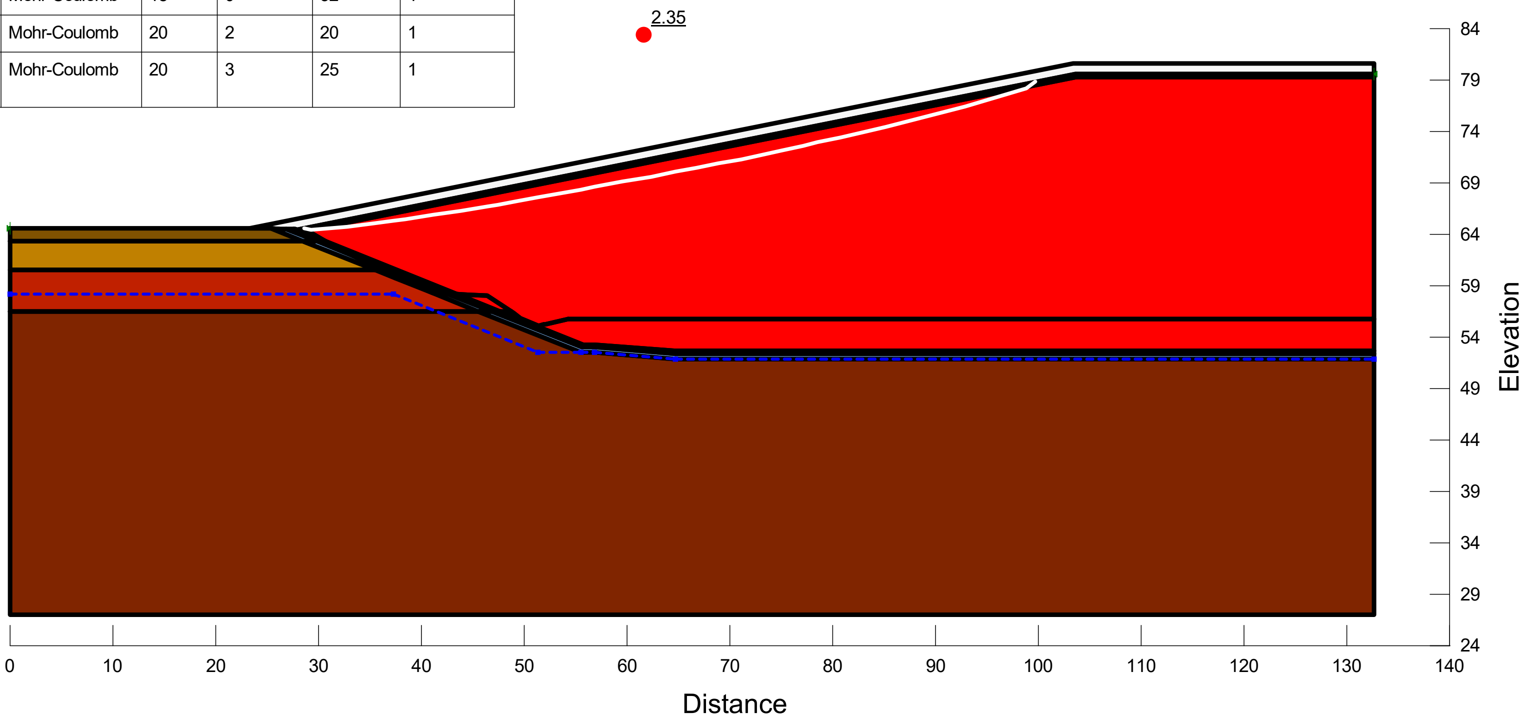
CUT WITH 0.3 DRAINAGE STONE	
Cell 4B_20241208 - Section 5_v4.gsz	
16/12/2024	1:735

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Waste	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



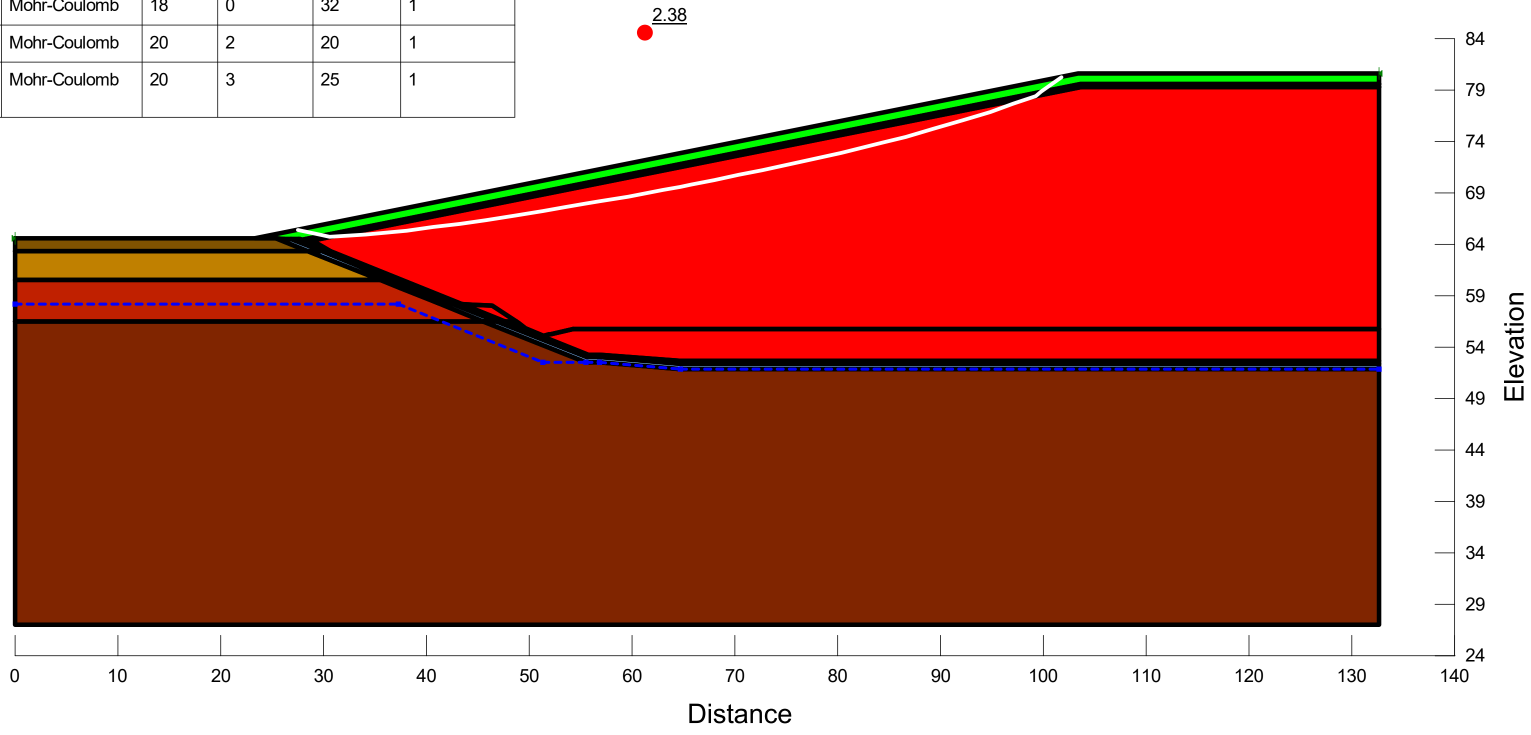
WASTE MASS PLACED	
Cell 4B_20241208 - Section 5_v4.gsz	
16/12/2024	1:735

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Regulating Layer	Mohr-Coulomb	19	0	34	1
	Imported - Waste	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



REGULATING STONE PLACED	
Cell 4B_20241208 - Section 5_v4.gsz	
16/12/2024	1:735

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Regulating Layer	Mohr-Coulomb	19	0	34	1
	Imported - Restoration Soils	Mohr-Coulomb	19	0	30	1
	Imported - Waste	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

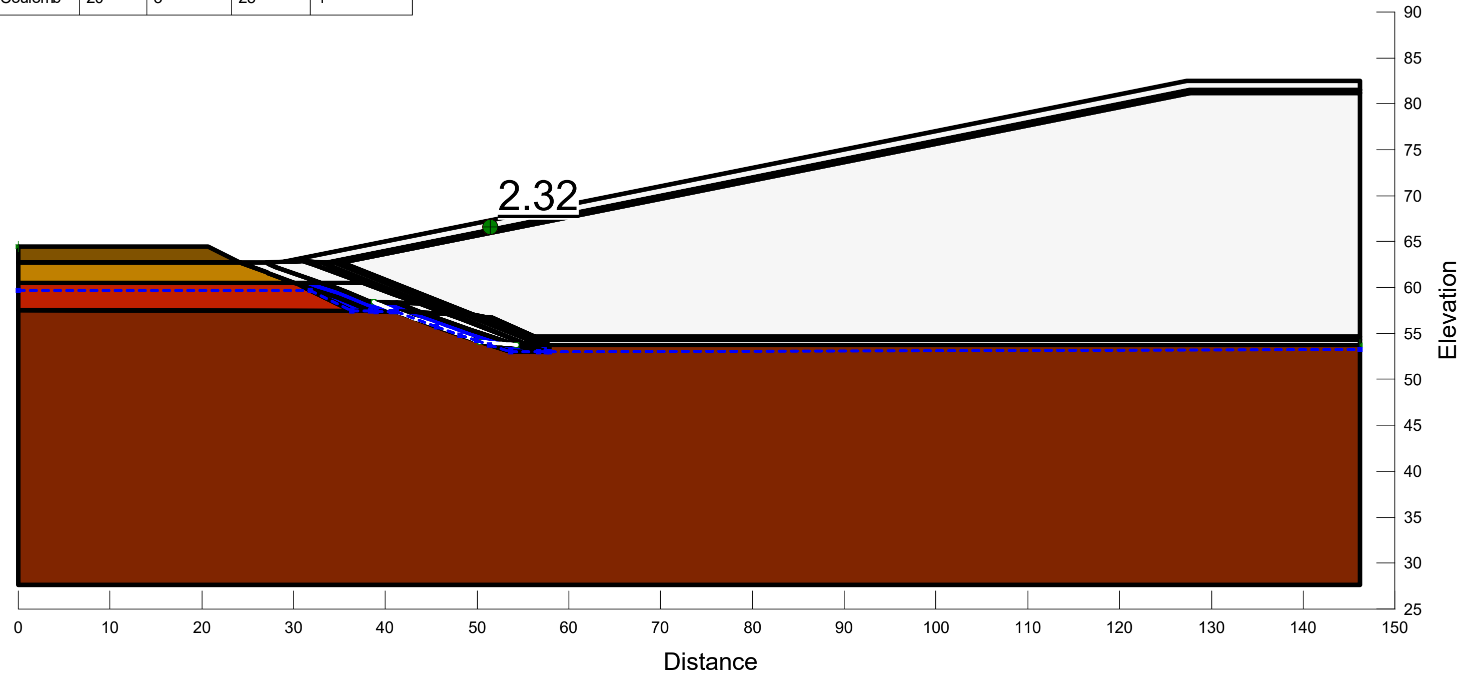


RESTORATION SOILS PLACED
Cell 4B_20241208 - Section 5_v4.gsz
16/12/2024 1:735

APPENDIX 3

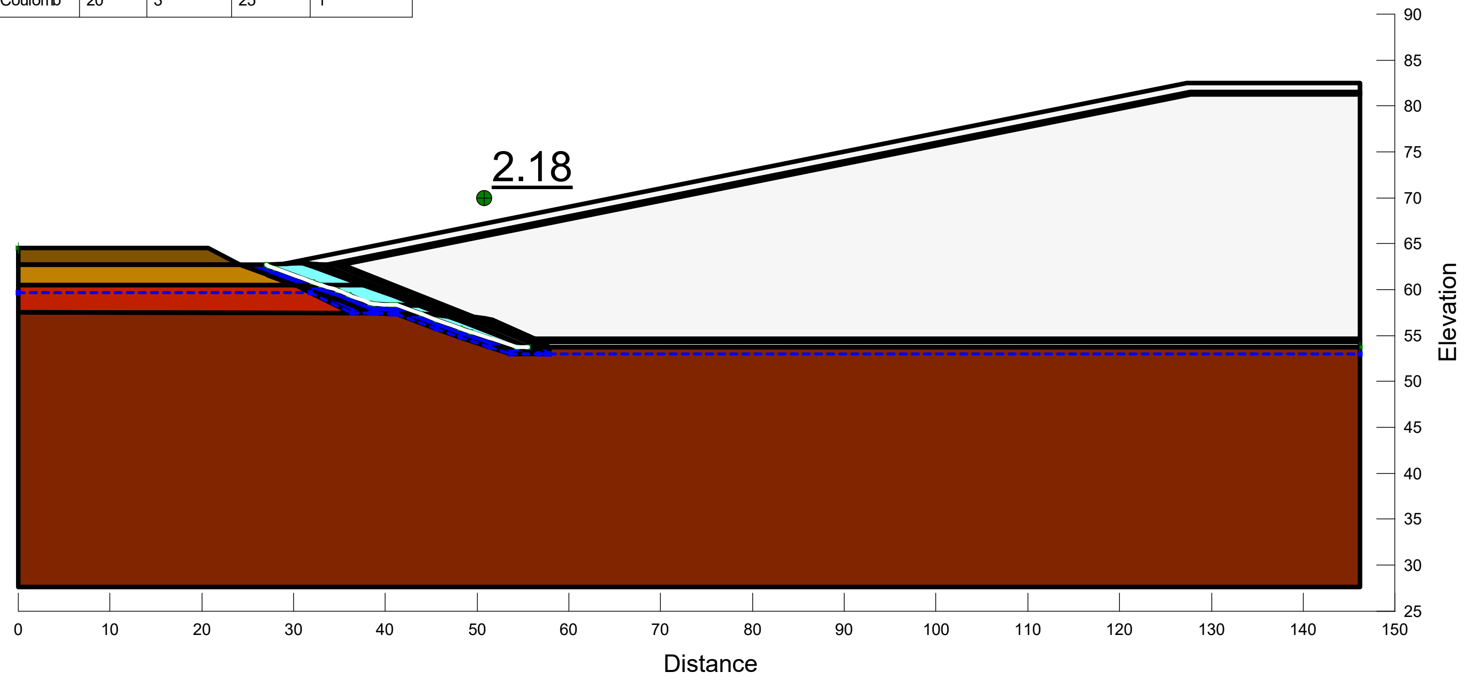
Slope Stability Interlayer Slip Outputs

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



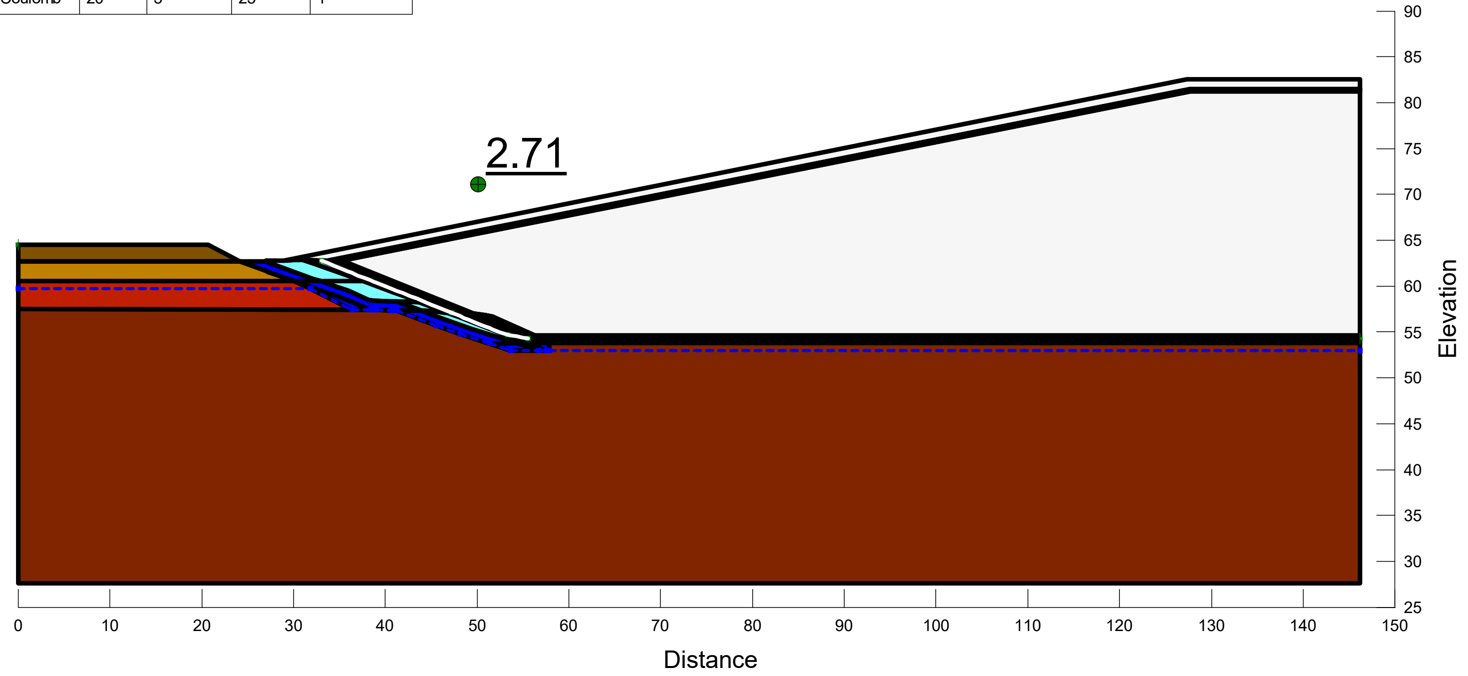
FORMATION - BUTTRESS CONTACT SLIP	
Interlayer Slips Section 2.gsz	
03/03/2025	1:824

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Engineered Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



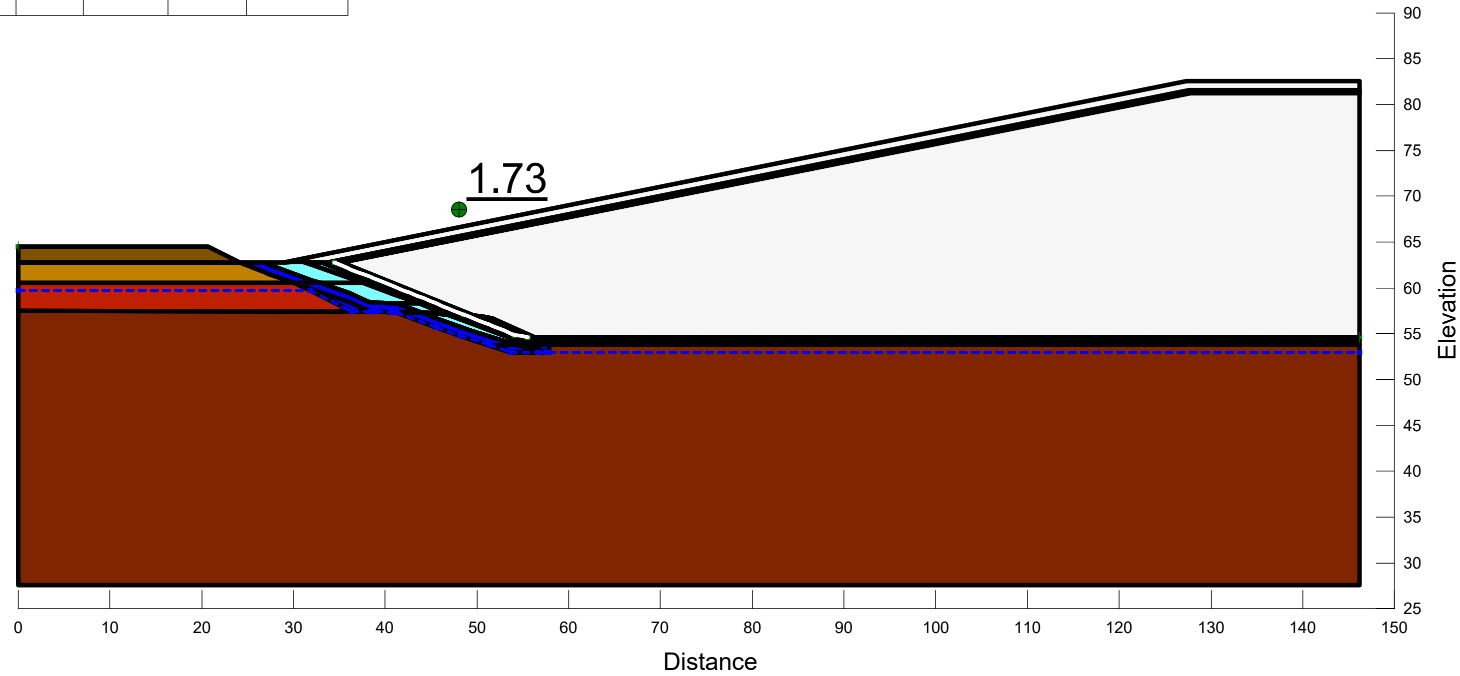
FORMATION - FULL BUTTRESS CONTACT SLIP	
Interlayer Slips Section 2.gsz	
03/03/2025	1:824

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Engineered Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy SIlty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



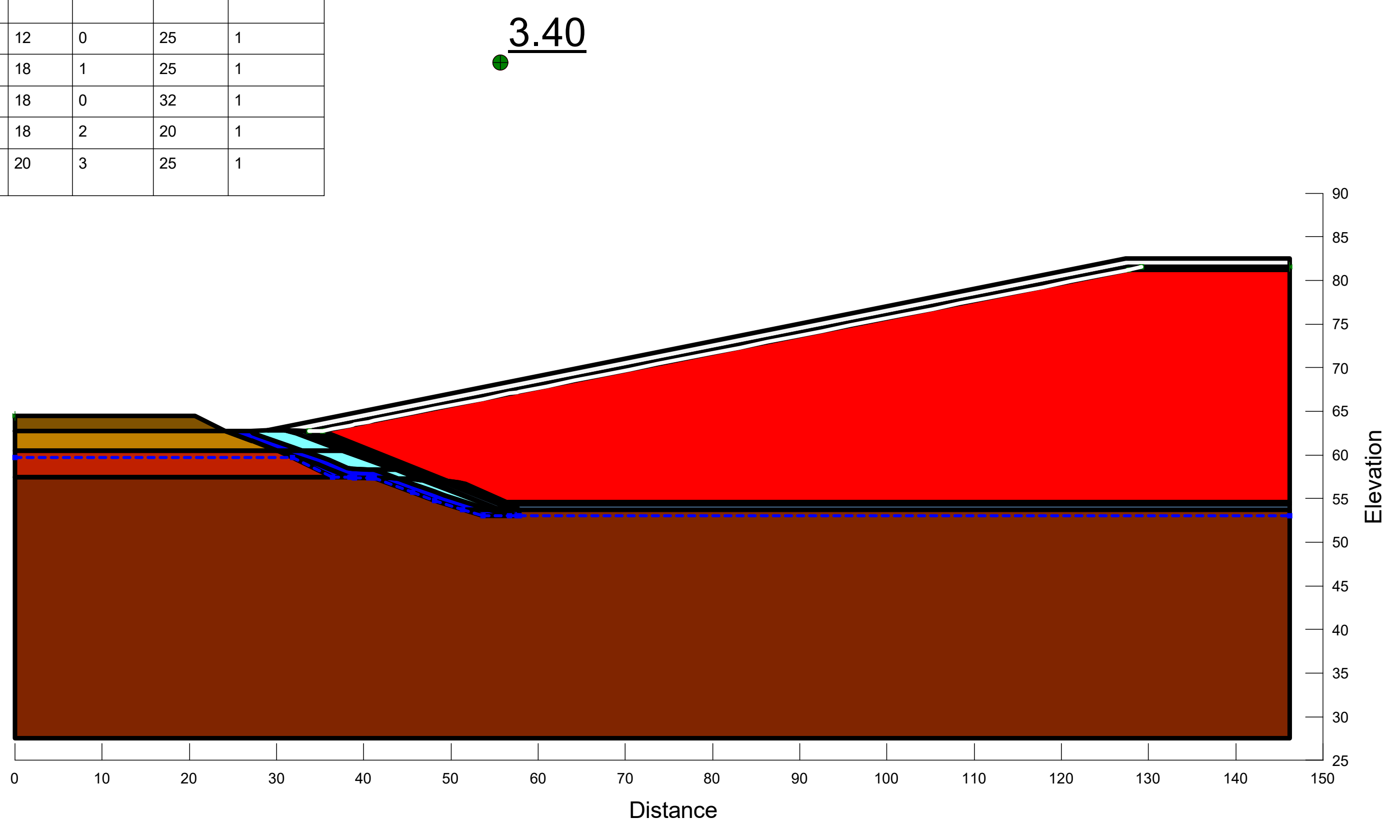
FULL BUTTRESS - 0.5m CLAY LINER SLIP	
Interlayer Slips Section 2.gsz	
03/03/2025	1:824

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



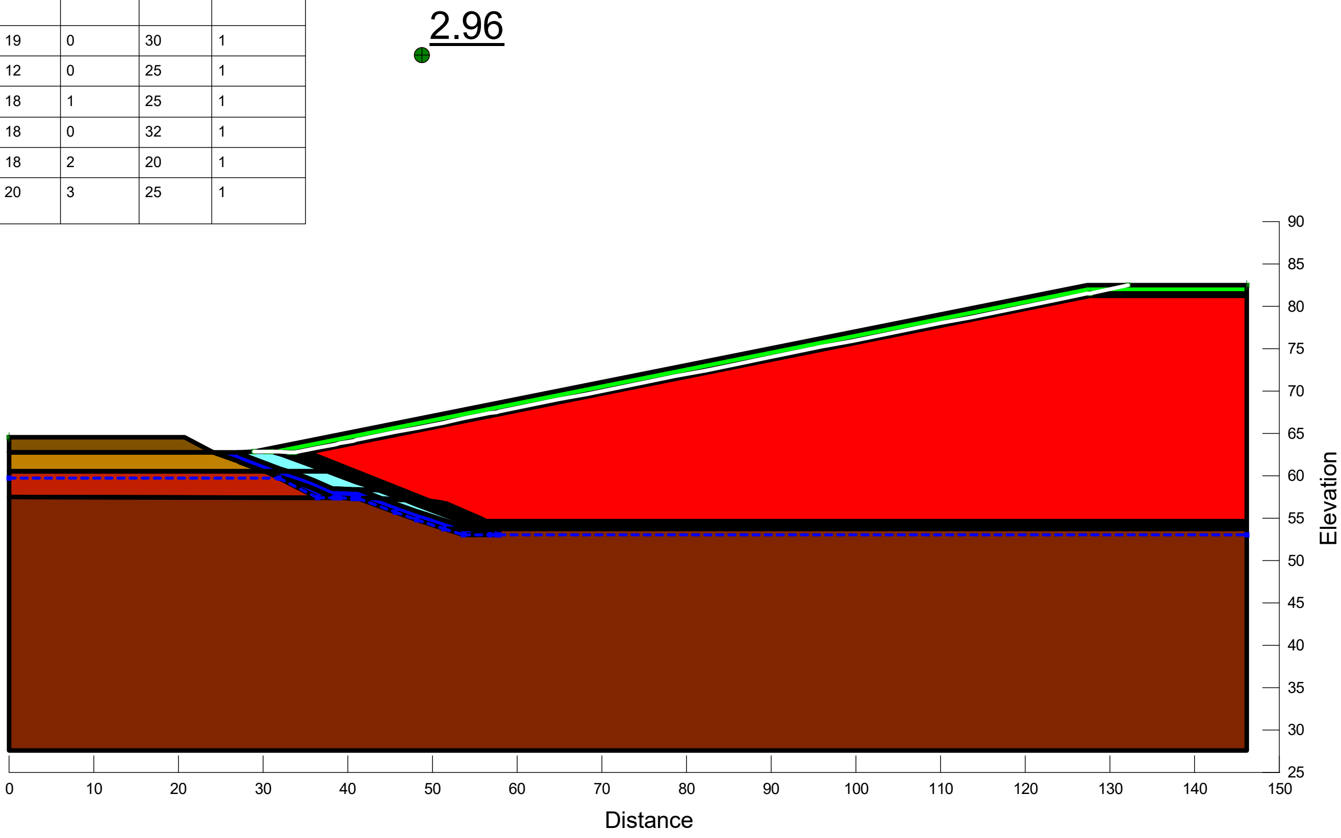
0.5m CLAY LINER - 0.3m DRAINAGE STONE SLIP	
Interlayer Slips Section 2.gsz	
03/03/2025	1:824

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	Imported - Regulating Stone Layer	Mohr-Coulomb	19	0	34	1
	Imported - Waste Mass	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



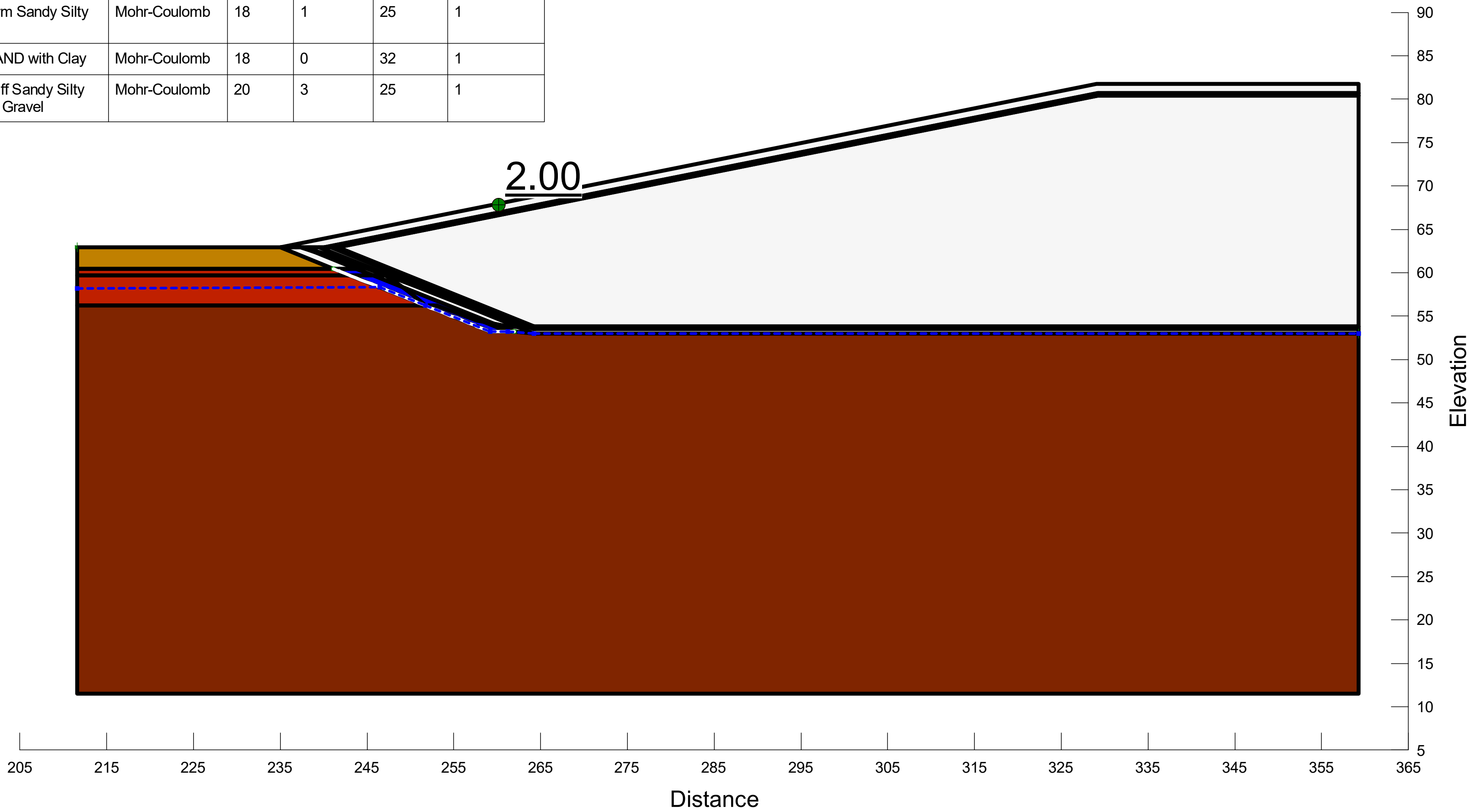
WASTE MASS - REGULATING STONE SLIP	
Interlayer Slips Section 2.gsz	
03/03/2025	1:867

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Granular Fill	Mohr-Coulomb	20	0	36	1
	Imported - Regulating Stone Layer	Mohr-Coulomb	19	0	34	1
	Imported - Restoration Soil	Mohr-Coulomb	19	0	30	1
	Imported - Waste Mass	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	18	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



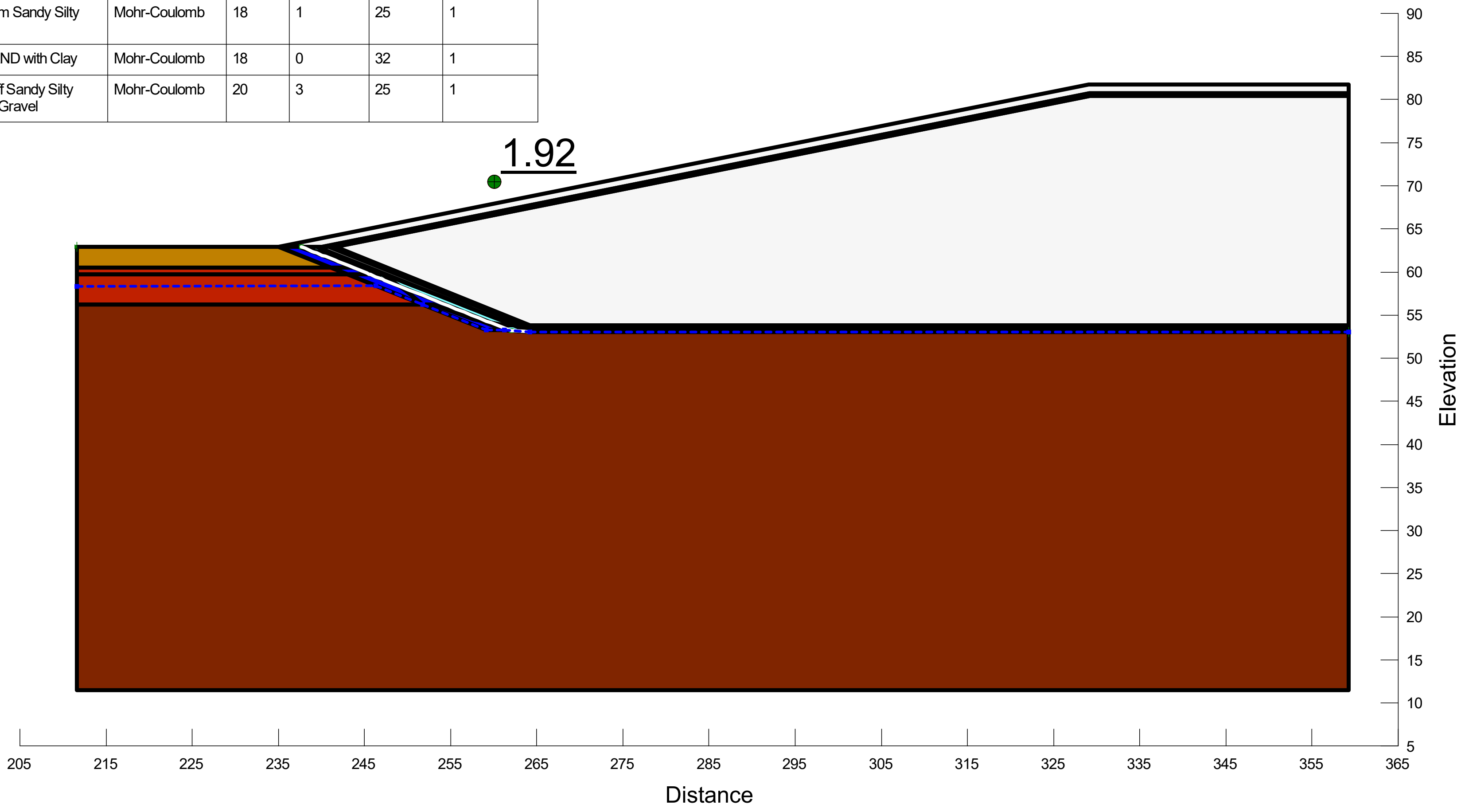
REGULATING STONE - RESTORATION SOILS SLIP	
Interlayer Slips Section 2.gsz	
03/03/2025	1:893

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



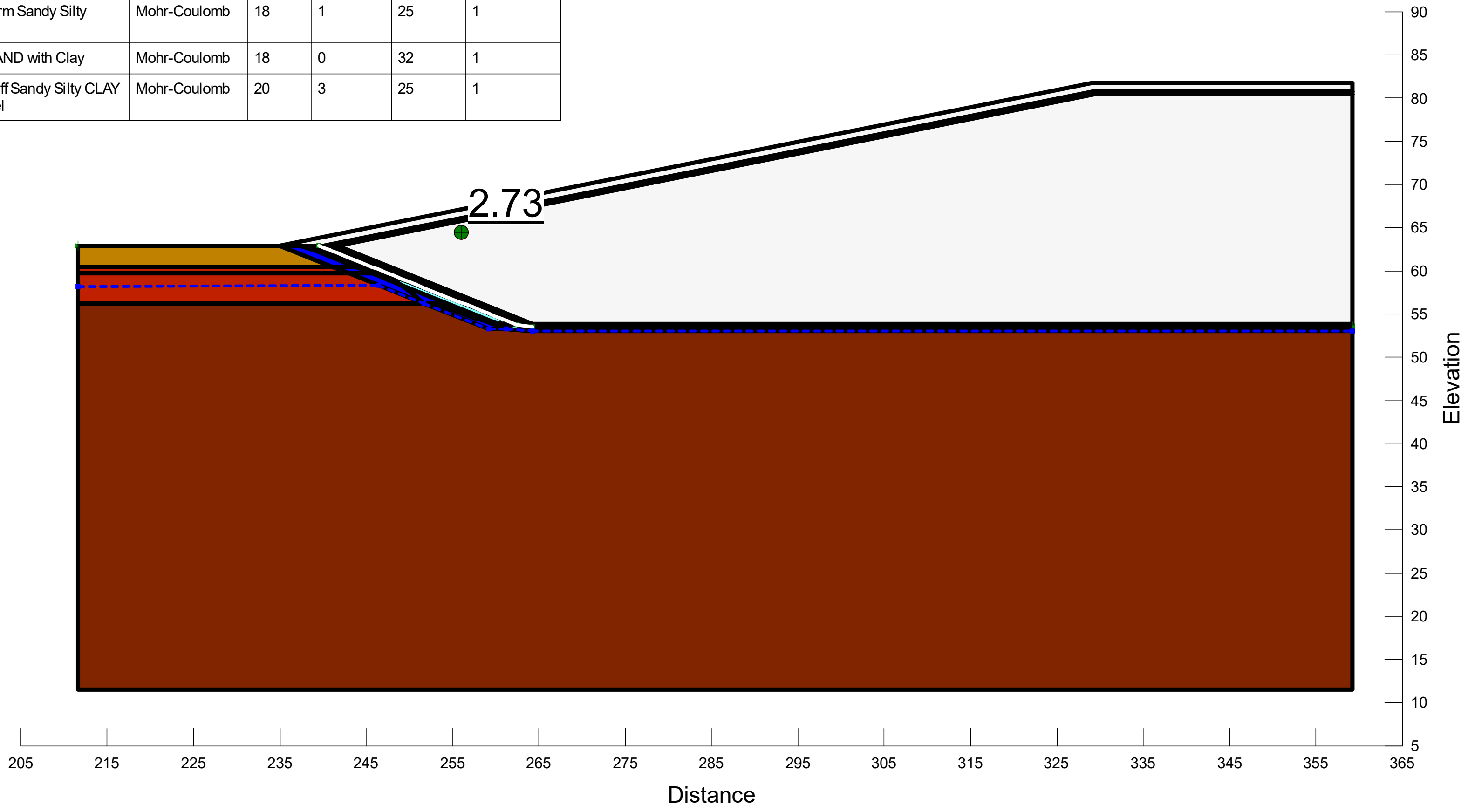
FORMATION - BUTTRESS SLIP	
Interlayer Slips Section 3.gsz	
28/02/2025	1:753

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



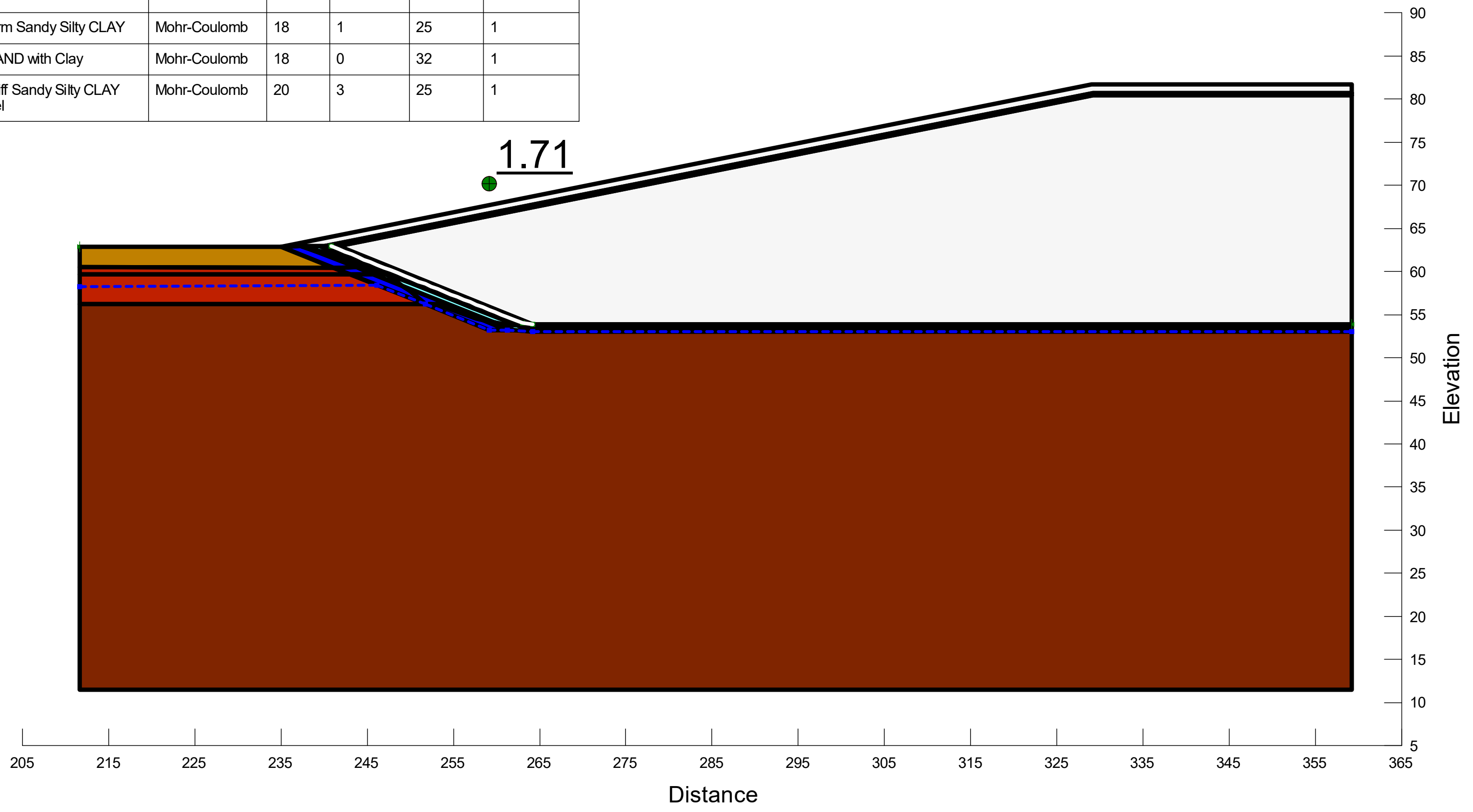
FORMATION - FULL BUTTRESS SLIP	
Interlayer Slips Section 3.gsz	
28/02/2025	1:778

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



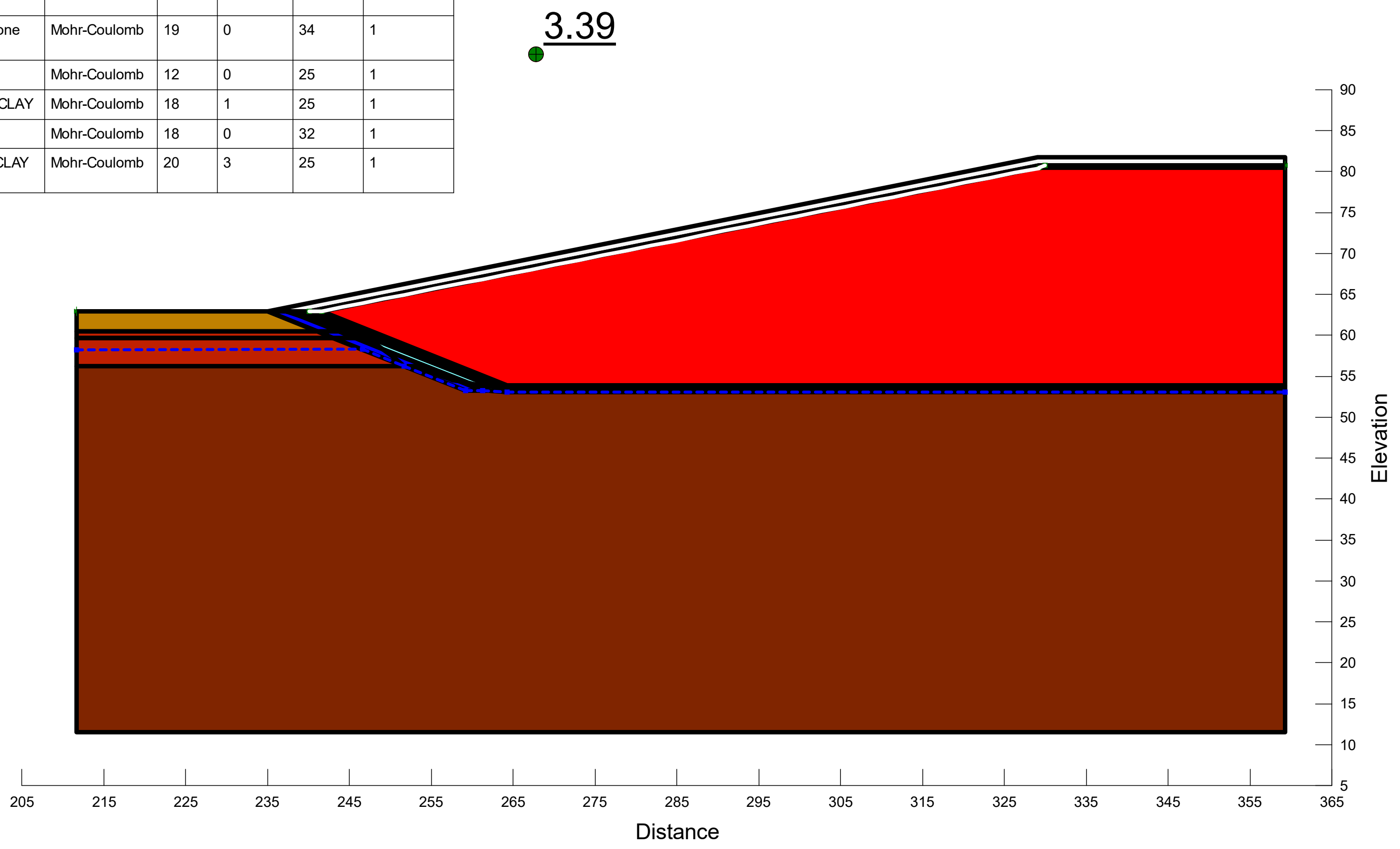
FULL BUTTRESS - 0.5m CLAY LINER SLIP	
Interlayer Slips Section 3.gsz	
28/02/2025	1:816

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



0.5m CLAY LINER - 0.3m DRAINAGE STONE SLIP	
Interlayer Slips Section 3.gsz	
03/03/2025	1:841

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	Imported - Regulating Stone Layer	Mohr-Coulomb	19	0	34	1
	Imported - Waste Mass	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

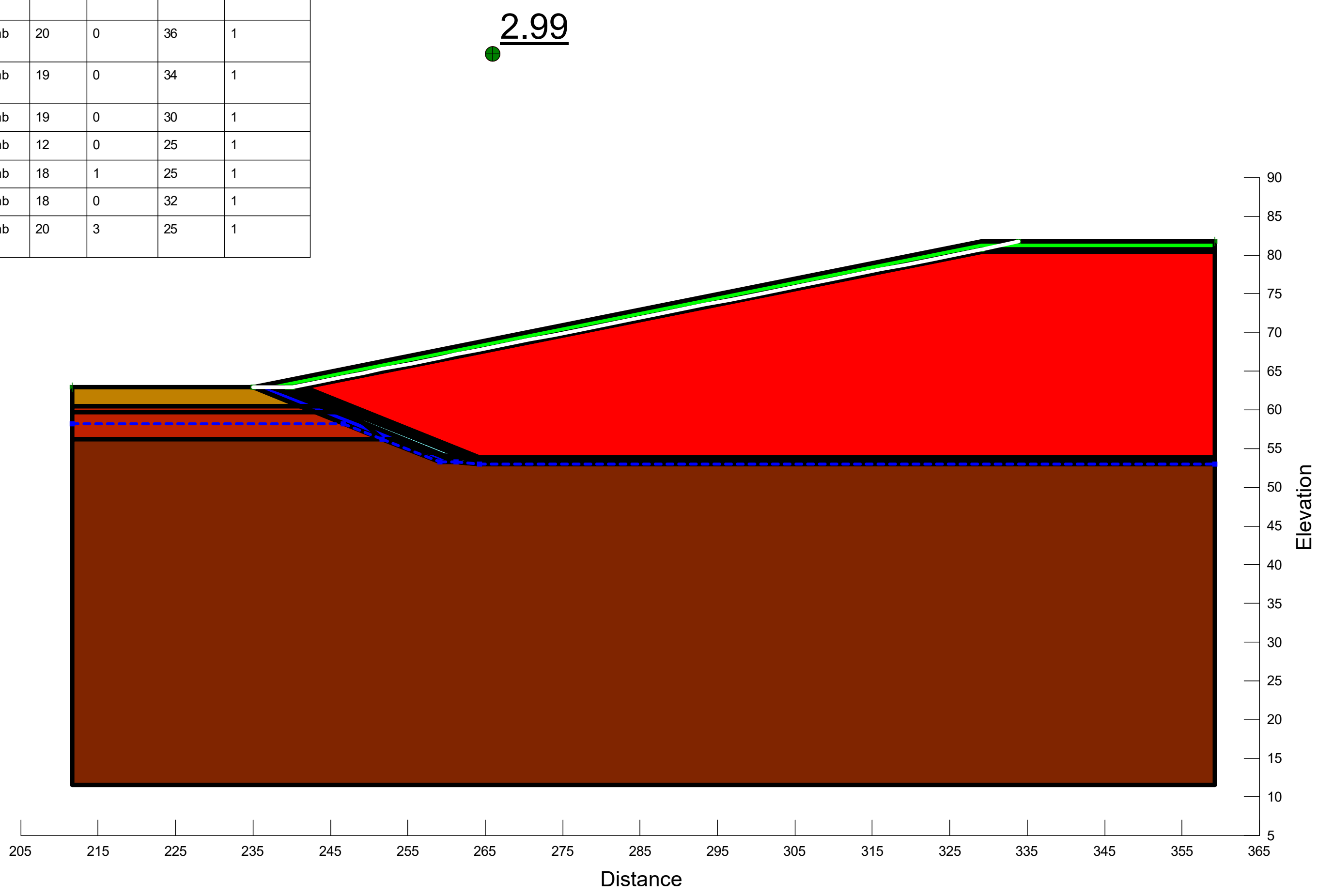


WASTE - REGULATING STONE SLIP

Interlayer Slips Section 3.gsz

28/02/2025 1:905

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Clay Fill	Mohr-Coulomb	20	4	25	1
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Engineered Stone Fill	Mohr-Coulomb	20	0	36	1
	Imported - Regulating Stone Layer	Mohr-Coulomb	19	0	34	1
	Imported - Restoration Soils	Mohr-Coulomb	19	0	30	1
	Imported - Waste Mass	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1

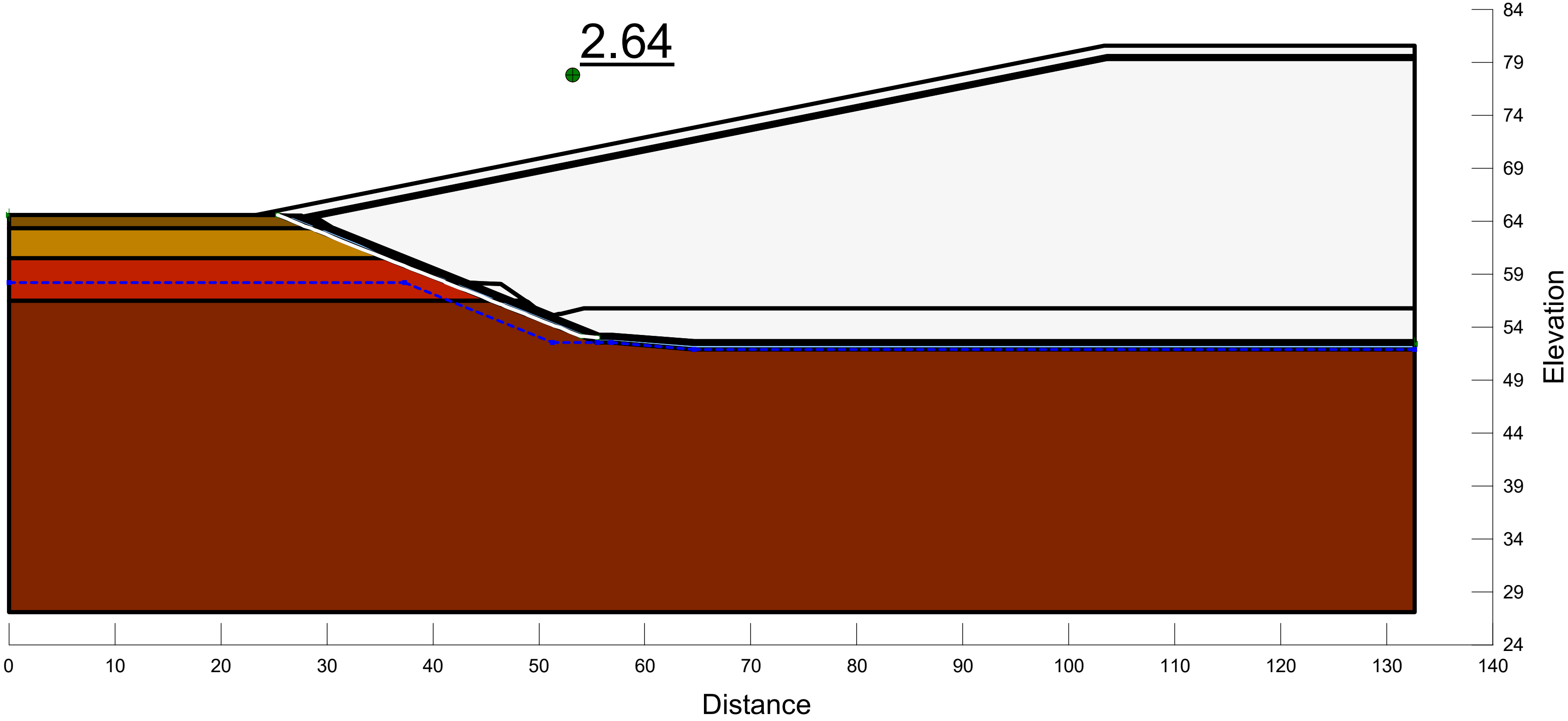


REGULATING STONE - RESTORATION SOILS SLIP

Interlayer Slips Section 3.gsz

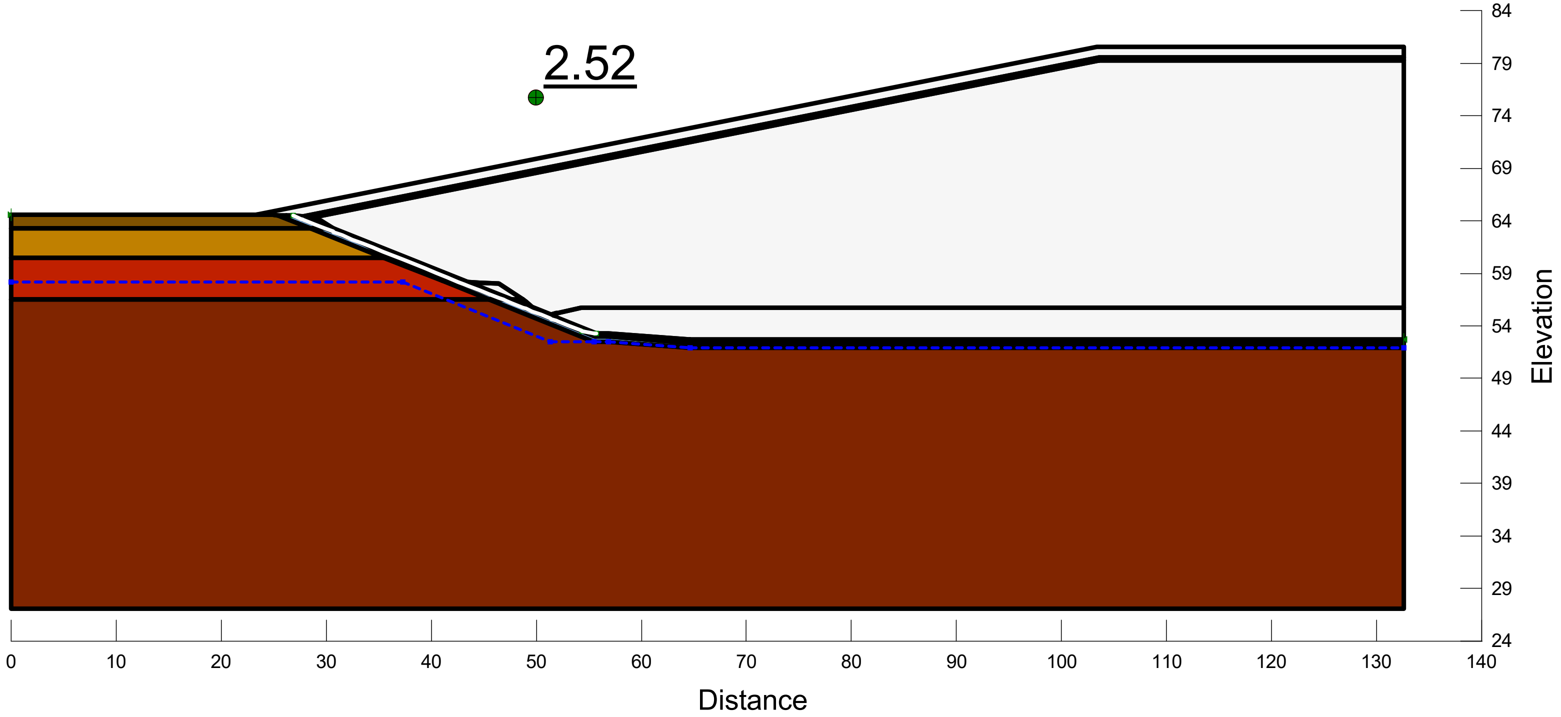
28/02/2025 1:946

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



FORMATION WITH COUNTERFORT - 0.5m CLAY LINER SLIP	
Interlayer Slips Section 5.gsz	
28/02/2025	1:658

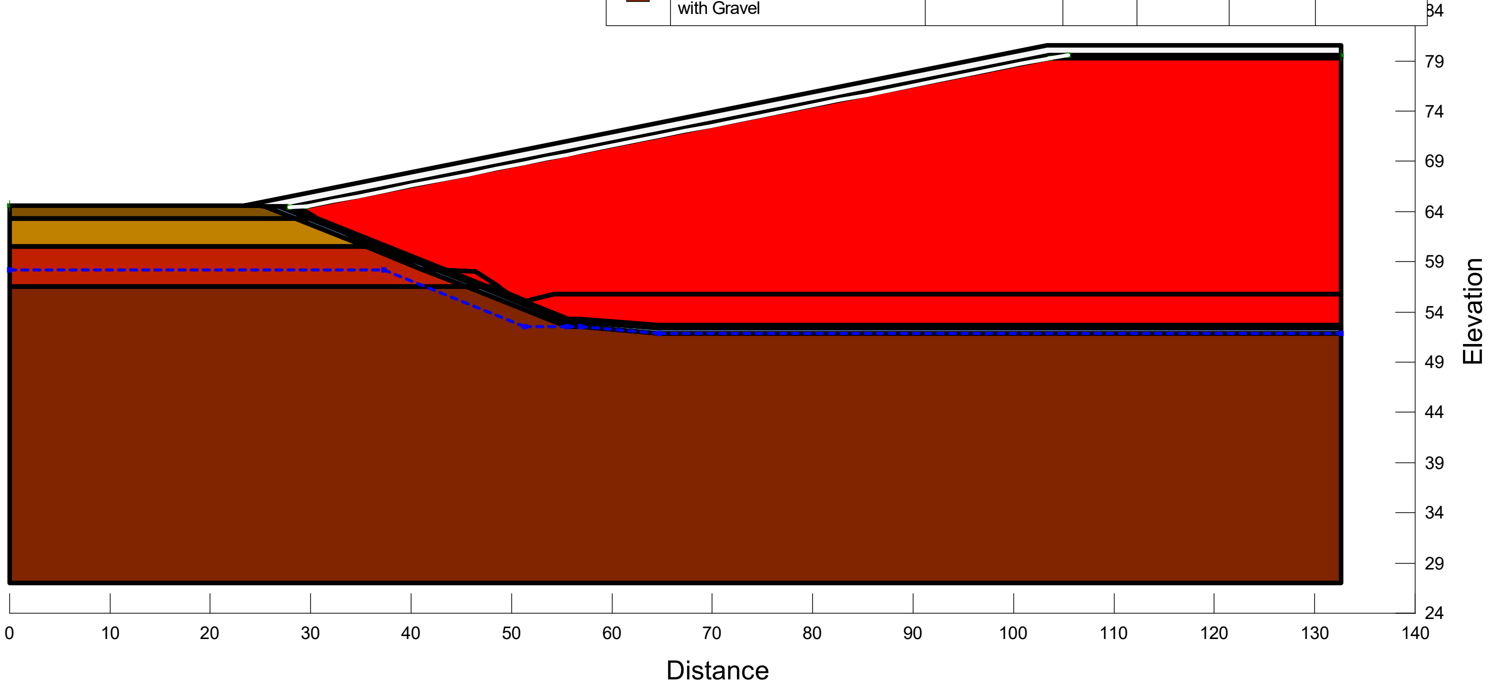
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



0.5m CLAY LINER - 0.3m DRAINAGE STONE SLIP	
Interlayer Slips Section 5.gsz	
28/02/2025	1:720

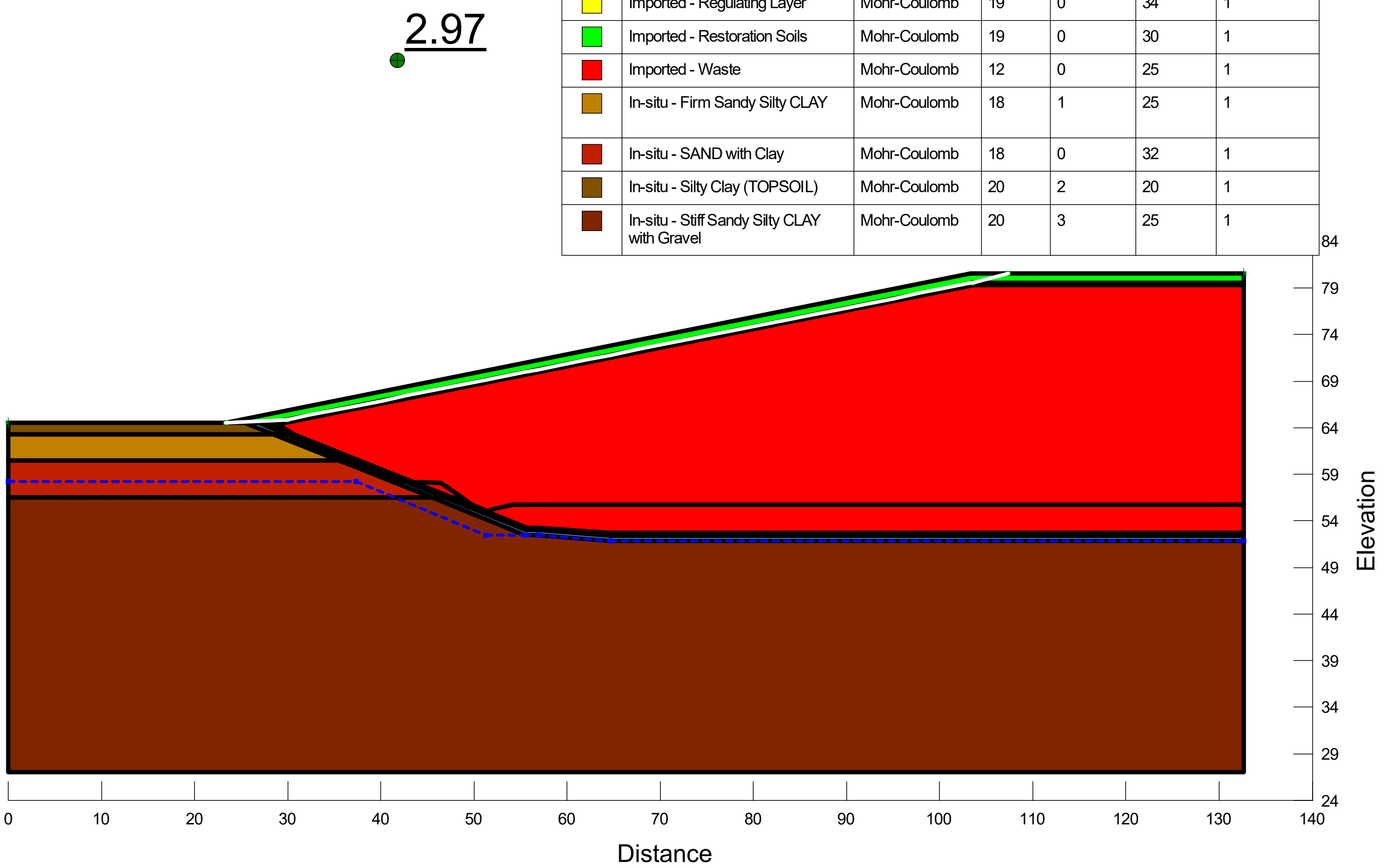
3.42

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Regulating Layer	Mohr-Coulomb	19	0	34	1
	Imported - Waste	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



WASTE - REGULATING STONE SLIP	
Interlayer Slips Section 5.gsz	
28/02/2025	1:753

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	Imported - Drainage Stone/Sand Protection Layer	Mohr-Coulomb	19	0	34	1
	Imported - Engineered Clay Liner	Mohr-Coulomb	20	5	25	1
	Imported - Regulating Layer	Mohr-Coulomb	19	0	34	1
	Imported - Restoration Soils	Mohr-Coulomb	19	0	30	1
	Imported - Waste	Mohr-Coulomb	12	0	25	1
	In-situ - Firm Sandy Silty CLAY	Mohr-Coulomb	18	1	25	1
	In-situ - SAND with Clay	Mohr-Coulomb	18	0	32	1
	In-situ - Silty Clay (TOPSOIL)	Mohr-Coulomb	20	2	20	1
	In-situ - Stiff Sandy Silty CLAY with Gravel	Mohr-Coulomb	20	3	25	1



REGULATING STONE - RESTORATION SOIL SLIP	
Interlayer Slips Section 5.gsz	
28/02/2025	1:778

APPENDIX 4

Geomembrane Interface Calculation

wardell armstrong	Client:	Quercia
	Project:	Clayton Hall Landfill Cell 4B
	Job No.:	ST18115

Calculation:	Calc. by: (name & signature)	Checked by: (name & signature)	Approved by: (name & signature)
Stability Calculation for a Landfill Capping System (Inc Construction Plant Moving downslope)	Gareth Temple-Smith G Temple Smith	Allan Sim Allan S	Allan Sim Allan S
	Date: 03/03/2025	Date: 03/03/2025	Date: 03/03/2025

Reference: Method after Jones and Dixon (also Koerner) — Provenance

Bulldozer	Value		Provenance
Weight of machine	196.59	kN	Based on Caterpillar D6
Track width	0.61	m	Based on Caterpillar D6
Track length	3.27	m	Based on Caterpillar D6
Max Speed (forward) Vf	3.14	m/s	
Max Speed (reverse) Vr	4.00	m/s	
Time taken to reach max speed	4.00	s	
Pressure on tracks	49.28	kN/m2	
Influence factor	0.95		
Equivalent Force per Unit Width at the Geomembrane interface (WE)	153.08	kN/m	
Normal Effective Force at the Geomembrane Interface (NE)	142.43	kN/m2	
Dynamic Force per unit Width Parallel to the Slope at the Geomembrane Interface (FE)	15.62	kN/m2	

Input Parameters:

	Value	Unit		Provenance
Capping Protection Layer Unit Weight	19	kN/m3		Conservative value based on experience with similar material
Capping Protection Layer Cohesion	0	kN/m2	tan	Conservative value based on experience with similar material
Capping Protection Layer Friction	34	Deg		Conservative value based on experience with similar material
Capping Protection Layer Thickness	0.3	m		Design value. 0.3m of drainage stone
Slope Height	12	m	(maximum)	Design value
Slope angle	21.5	Deg		Designed 1 in 2.5 slope. Worst case gradient
Geosynthetic Interface Shear Strengths				
Upper Protection (Drainage Stone)/HDPE Friction	32	Deg	tan	Conservative value based on experience with similar material
Upper Protection (Drainage Stone)/HDPE Cohesion	0	kN/m2		Conservative value based on experience with similar material

	29	
Derived Parameters	2	
	28	
Sin B	0.00	
Cos B	0.93	
Tan B	0.39	
Length of slope	32.74	m
Weight of Active Wedge (WA)	181.77	kN
Effective Normal Force along Failure Plane (NA)	169.12	kN/m2
Weight of Passive Wedge (WP)	2.51	kN
Adhesive Force between Cover Soil and Liner for Active Wedge (CA)	0.00	kN/m2
Cohesive Force along the Failure Plane of the Passive Wedge ©	0.00	kN/m2

Determination of Factor of Safety

Parameter a	128.72
Parameter b	-213.16
Parameter c	48.13

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

Factor of Safety = **1.39**

Conclusions

The capping displays an adequate Factor of Safety to be stable on the maximum design slope of 1 in 2.5, including plant movement, for the short term.

APPENDIX 5

Counterfort Drain Design Summary

Counterfort Drain Depth (m)	Permeability (m/s)	Height of GW between Drains (m)	Average Height of GW between Drains (m)	GW Drawdown Depth BGL (m)	Spacing (m)
3.5	1.00E-07	-	-	Invalid	5
4	1.00E-07	4	2	2	5
4.5	1.00E-07	4.4	2.2	2.45	5
5	1.00E-07	4.8	2.4	2.8	5
2	1.00E-06	1.62	0.81	1.19	5
2.5	1.00E-06	1.9	0.95	1.55	5
3	1.00E-06	2.22	1.11	1.89	5
2	1.00E-05	0.76	0.38	1.62	5
2.5	1.00E-05	1.1	0.55	1.95	5

Counterfort Drain Drawdown Estimate

	user input value
	output value

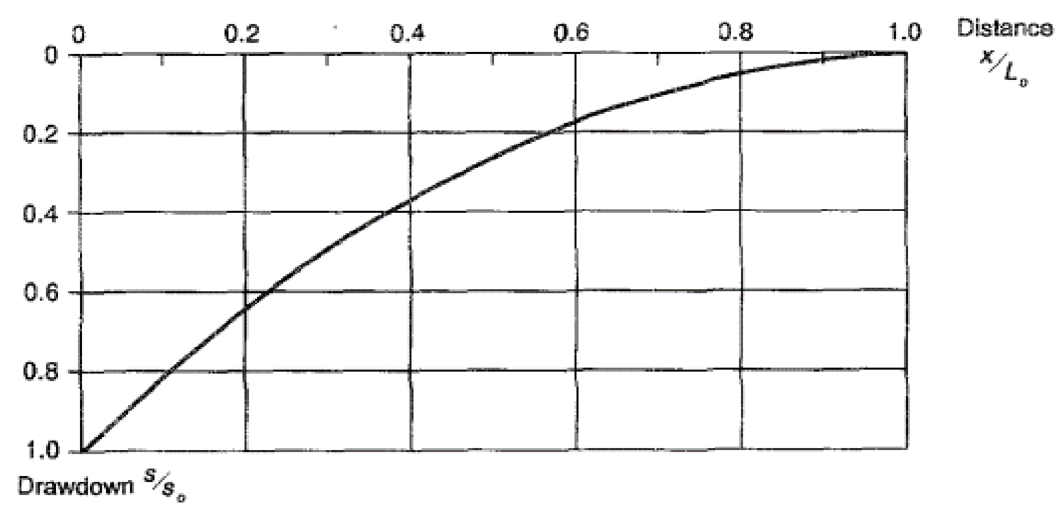
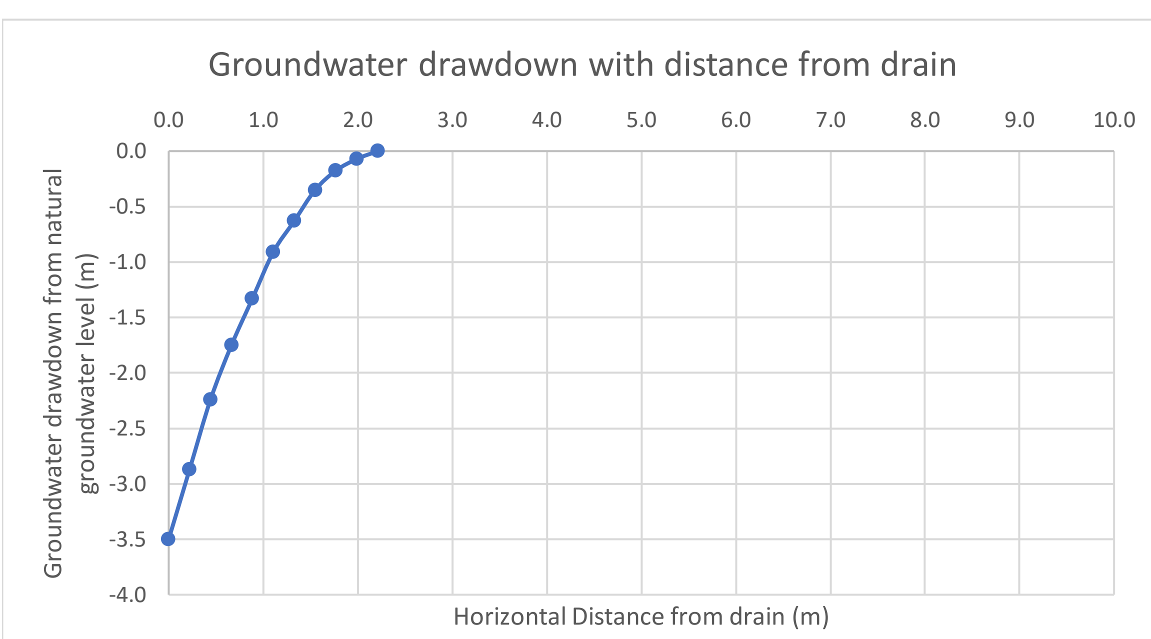


Figure 6.16 *Dimensionless drawdown curve for horizontal plane flow to a line of wells acting as a pumped slot in a low permeability soil*

Parameter	Value	Unit	Description
C	2000	-	coefficient (1500 - 2000 for line flow to trenches and 3000 for radial flow from a pump well)
h	3.5	m	total height of groundwater drawdown expected at drain location (ie. what is the height between the drain and the natural groundwater level)
k	1.00E-07	m/s	soil permeability
ds	5	m	proposed drain spacing
x	2.50	m	proposed half of the drain spacing
L_o	2.21	m	horizontal infleunce distance of drains
x/L_o ratio	1.13	-	
s/s_o ratio	-	-	estimate from Figure 6.16 based on x/Lo ratio
s	-	m	groundwater drawdown at center spacing of drains (assuming influence from 2 drains and direct super position)
b	-	m	water rise between drain locations
b/2	-	m	average water rise above counterforts for slope stability modelling

GROUNDWATER DRAWDOWN ASSUMING PLANAR FLOW

Horizontal Distance ratio	Horizontal Distance from drain(m)	s/so ratio	Groundwater drawdown (m)
0	0.00	1	-3.50
0.1	0.22	0.82	-2.87
0.2	0.44	0.64	-2.24
0.3	0.66	0.5	-1.75
0.4	0.89	0.38	-1.33
0.5	1.11	0.26	-0.91
0.6	1.33	0.18	-0.63
0.7	1.55	0.1	-0.35
0.8	1.77	0.05	-0.18
0.9	1.99	0.02	-0.07
1	2.21	0	0.00



Counterfort Drain Drawdown Estimate

	user input value
	output value

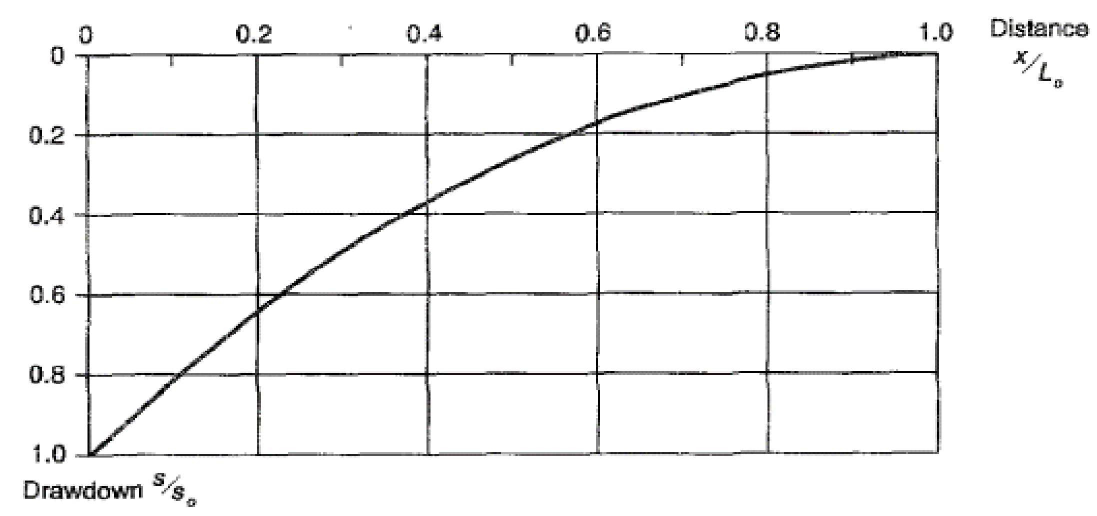
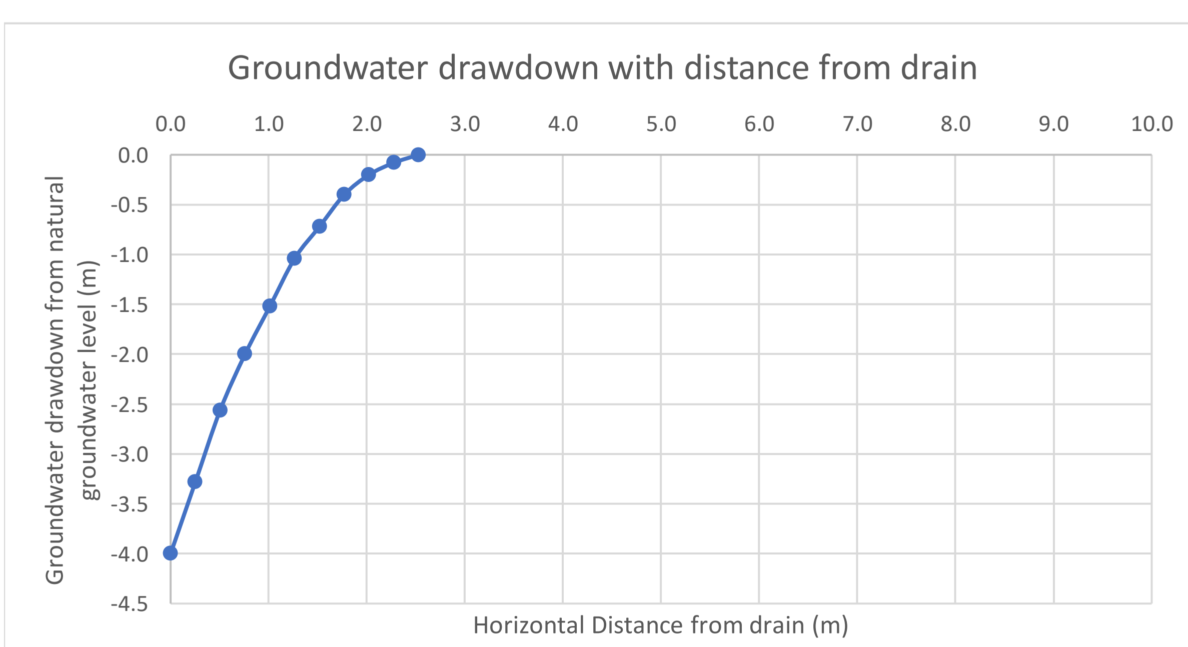


Figure 6.16 *Dimensionless drawdown curve for horizontal plane flow to a line of wells acting as a pumped slot in a low permeability soil*

Parameter	Value	Unit	Description
C	2000	-	coefficient (1500 - 2000 for line flow to trenches and 3000 for radial flow from a pump well)
h	4	m	total height of groundwater drawdown expected at drain location (ie. what is the height between the drain and the natural groundwater level)
k	1.00E-07	m/s	soil permeability
ds	5	m	proposed drain spacing
x	2.50	m	proposed half of the drain spacing
L_o	2.53	m	horizontal infleunce distance of drains
x/L_o ratio	0.99	-	
s/s_o ratio	0	-	estimate from Figure 6.16 based on x/Lo ratio
s	0.00	m	groundwater drawdown at center spacing of drains (assuming influence from 2 drains and direct super position)
b	4	m	water rise between drain locations
b/2	2	m	average water rise above counterforts for slope stability modelling

GROUNDWATER DRAWDOWN ASSUMING PLANAR FLOW

Horizontal Distance ratio	Horizontal Distance from drain(m)	s/so ratio	Groundwater drawdown (m)
0	0.00	1	-4.00
0.1	0.25	0.82	-3.28
0.2	0.51	0.64	-2.56
0.3	0.76	0.5	-2.00
0.4	1.01	0.38	-1.52
0.5	1.26	0.26	-1.04
0.6	1.52	0.18	-0.72
0.7	1.77	0.1	-0.40
0.8	2.02	0.05	-0.20
0.9	2.28	0.02	-0.08
1	2.53	0	0.00



Counterfort Drain Drawdown Estimate

(blue)	user input value
(green)	output value

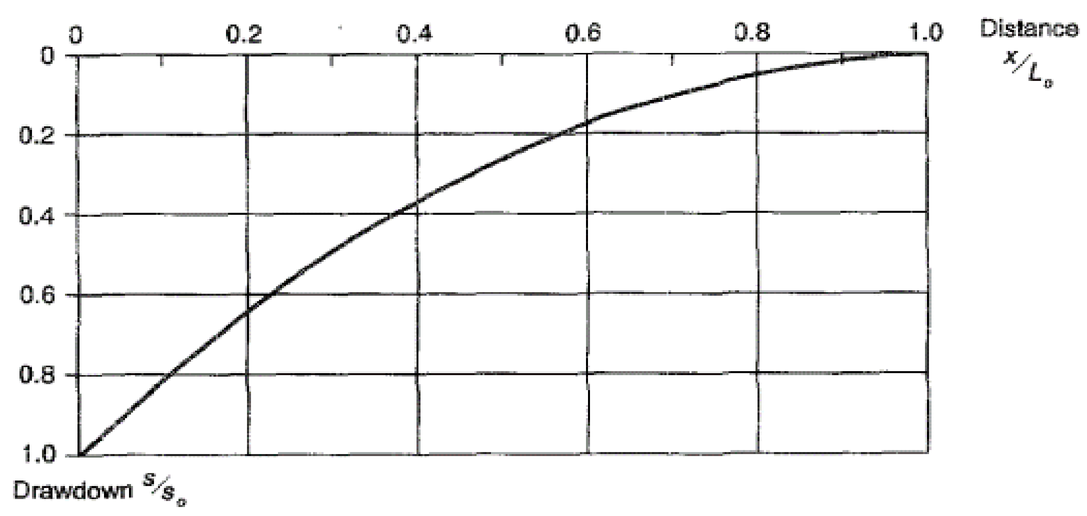
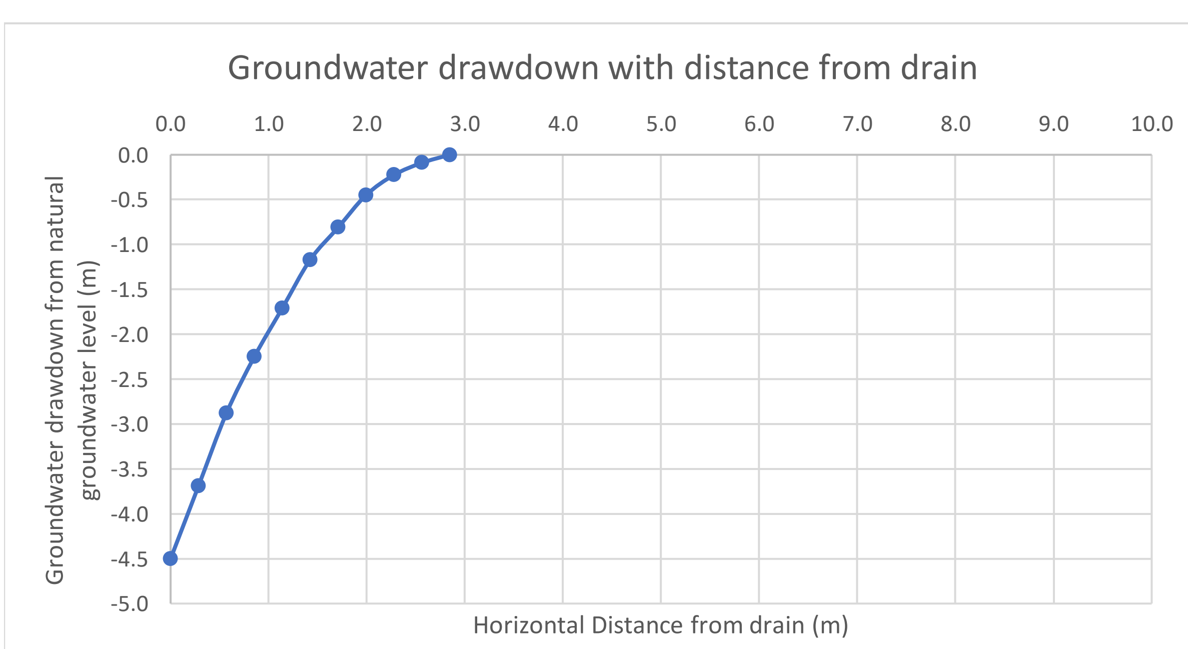


Figure 6.16 *Dimensionless drawdown curve for horizontal plane flow to a line of wells acting as a pumped slot in a low permeability soil*

Parameter	Value	Unit	Description
C	2000	-	coefficient (1500 - 2000 for line flow to trenches and 3000 for radial flow from a pump well)
h	4.5	m	total height of groundwater drawdown expected at drain location (ie. what is the height between the drain and the natural groundwater level)
k	1.00E-07	m/s	soil permeability
ds	5	m	proposed drain spacing
x	2.50	m	proposed half of the drain spacing
L_o	2.85	m	horizontal infleunce distance of drains
x/L_o ratio	0.88	-	
s/s_o ratio	0.05	-	estimate from Figure 6.16 based on x/Lo ratio
s	0.10	m	groundwater drawdown at center spacing of drains (assuming influence from 2 drains and direct super position)
b	4.4	m	water rise between drain locations
b/2	2.2	m	average water rise above counterforts for slope stability modelling

GROUNDWATER DRAWDOWN ASSUMING PLANAR FLOW

Horizontal Distance ratio	Horizontal Distance from drain(m)	s/so ratio	Groundwater drawdown (m)
0	0.00	1	-4.50
0.1	0.28	0.82	-3.69
0.2	0.57	0.64	-2.88
0.3	0.85	0.5	-2.25
0.4	1.14	0.38	-1.71
0.5	1.42	0.26	-1.17
0.6	1.71	0.18	-0.81
0.7	1.99	0.1	-0.45
0.8	2.28	0.05	-0.23
0.9	2.56	0.02	-0.09
1	2.85	0	0.00



Counterfort Drain Drawdown Estimate

	user input value
	output value

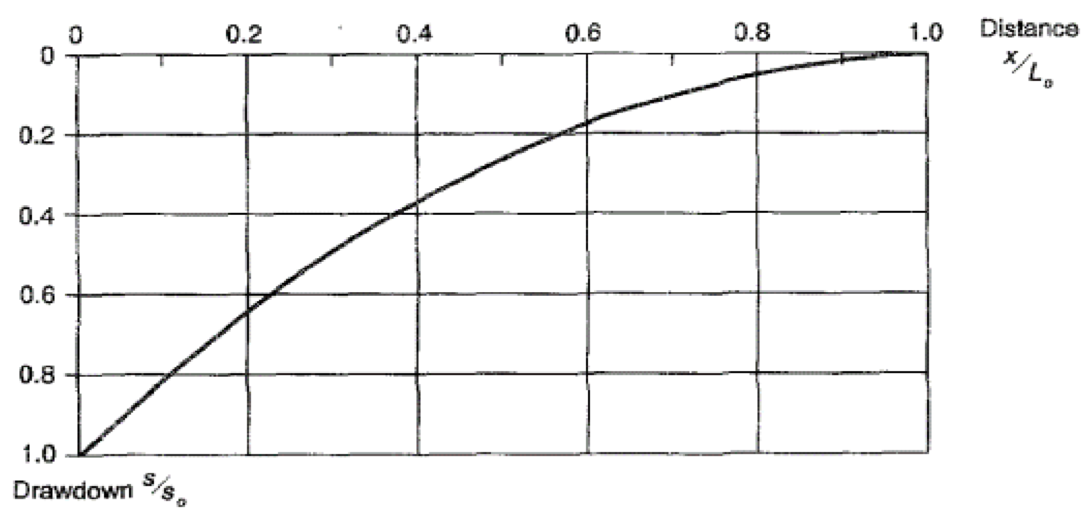
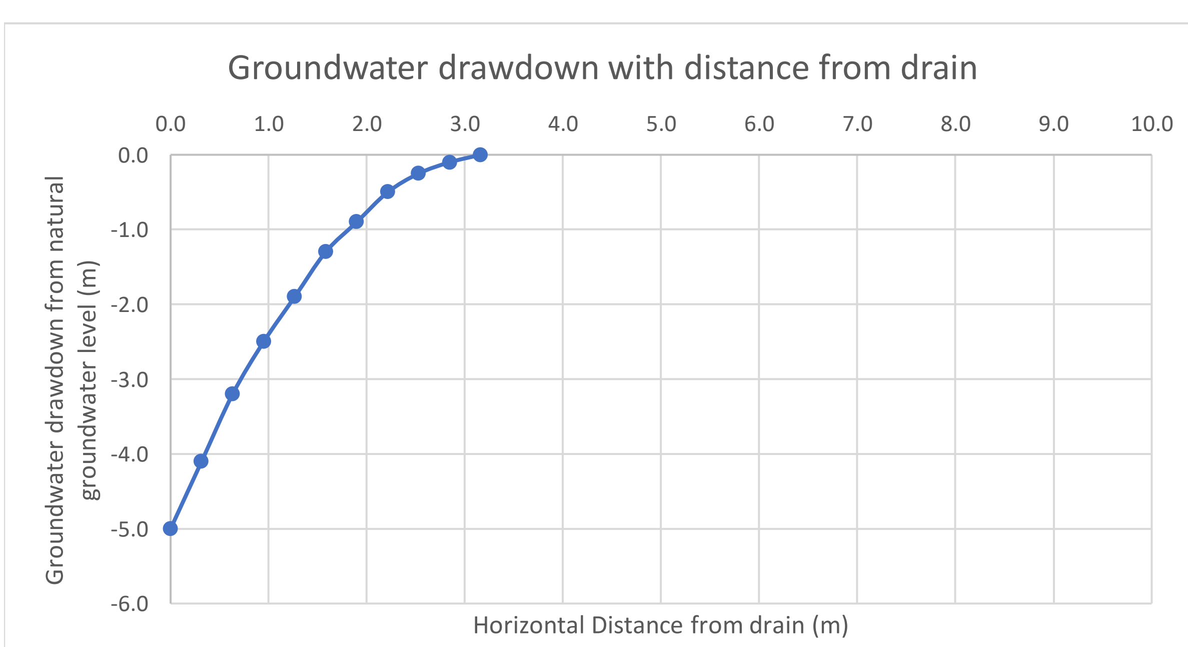


Figure 6.16 *Dimensionless drawdown curve for horizontal plane flow to a line of wells acting as a pumped slot in a low permeability soil*

Parameter	Value	Unit	Description
C	2000	-	coefficient (1500 - 2000 for line flow to trenches and 3000 for radial flow from a pump well)
h	5	m	total height of groundwater drawdown expected at drain location (ie. what is the height between the drain and the natural groundwater level)
k	1.00E-07	m/s	soil permeability
ds	5	m	proposed drain spacing
x	2.50	m	proposed half of the drain spacing
L_o	3.16	m	horizontal infleunce distance of drains
x/L_o ratio	0.79	-	
s/s_o ratio	0.1	-	estimate from Figure 6.16 based on x/Lo ratio
s	0.20	m	groundwater drawdown at center spacing of drains (assuming influence from 2 drains and direct super position)
b	4.80	m	water rise between drain locations
b/2	2.40	m	average water rise above counterforts for slope stability modelling

GROUNDWATER DRAWDOWN ASSUMING PLANAR FLOW

Horizontal Distance ratio	Horizontal Distance from drain(m)	s/so ratio	Groundwater drawdown (m)
0	0.00	1	-5.00
0.1	0.32	0.82	-4.10
0.2	0.63	0.64	-3.20
0.3	0.95	0.5	-2.50
0.4	1.26	0.38	-1.90
0.5	1.58	0.26	-1.30
0.6	1.90	0.18	-0.90
0.7	2.21	0.1	-0.50
0.8	2.53	0.05	-0.25
0.9	2.85	0.02	-0.10
1	3.16	0	0.00



Counterfort Drain Drawdown Estimate

	user input value
	output value

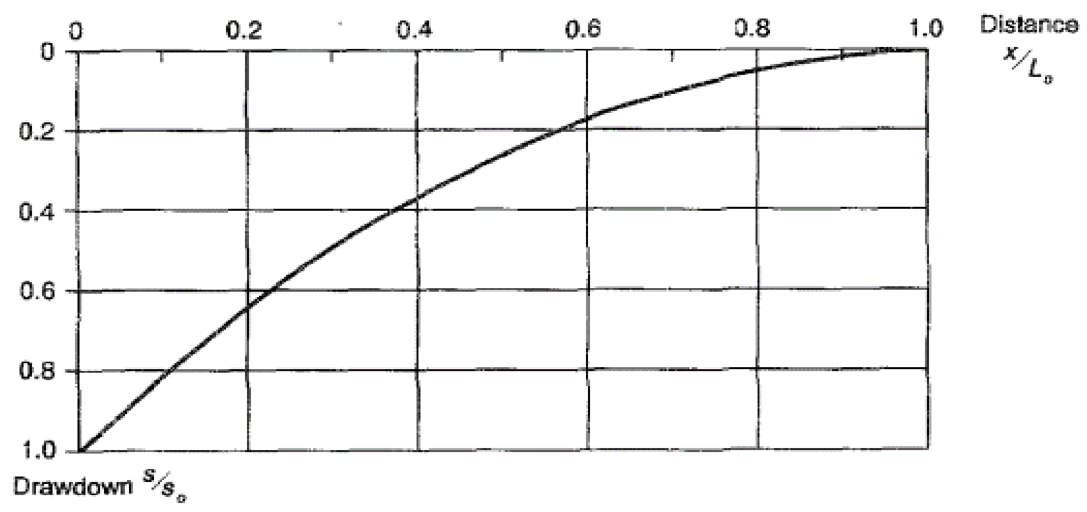
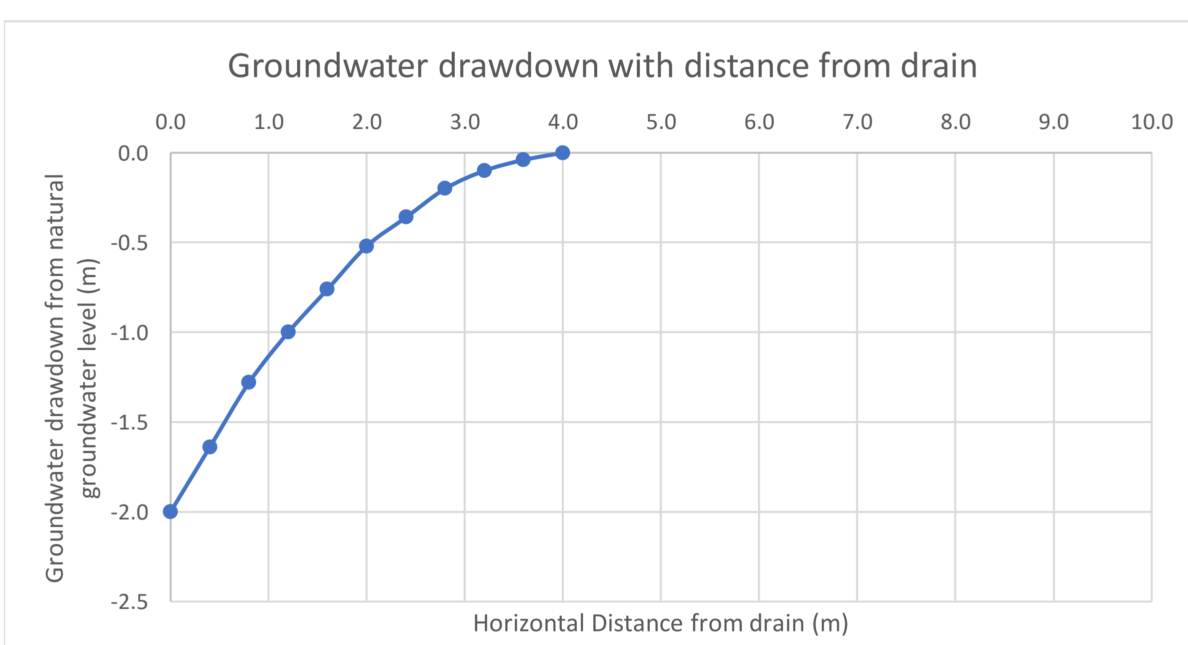


Figure 6.16 *Dimensionless drawdown curve for horizontal plane flow to a line of wells acting as a pumped slot in a low permeability soil*

Parameter	Value	Unit	Description
C	2000	-	coefficient (1500 - 2000 for line flow to trenches and 3000 for radial flow from a pump well)
h	2	m	total height of groundwater drawdown expected at drain location (ie. what is the height between the drain and the natural groundwater level)
k	1.00E-06	m/s	soil permeability
ds	5	m	proposed drain spacing
x	2.50	m	proposed half of the drain spacing
L_o	4.00	m	horizontal infleunce distance of drains
x/L_o ratio	0.63	-	
s/s_o ratio	0.19	-	estimate from Figure 6.16 based on x/Lo ratio
s	0.38	m	groundwater drawdown at center spacing of drains (assuming influence from 2 drains and direct super position)
b	1.62	m	water rise between drain locations
b/2	0.81	m	average water rise above counterforts for slope stability modelling

GROUNDWATER DRAWDOWN ASSUMING PLANAR FLOW

Horizontal Distance ratio	Horizontal Distance from drain(m)	s/so ratio	Groundwater drawdown (m)
0	0.00	1	-2.00
0.1	0.40	0.82	-1.64
0.2	0.80	0.64	-1.28
0.3	1.20	0.5	-1.00
0.4	1.60	0.38	-0.76
0.5	2.00	0.26	-0.52
0.6	2.40	0.18	-0.36
0.7	2.80	0.1	-0.20
0.8	3.20	0.05	-0.10
0.9	3.60	0.02	-0.04
1	4.00	0	0.00



Counterfort Drain Drawdown Estimate

	user input value
	output value

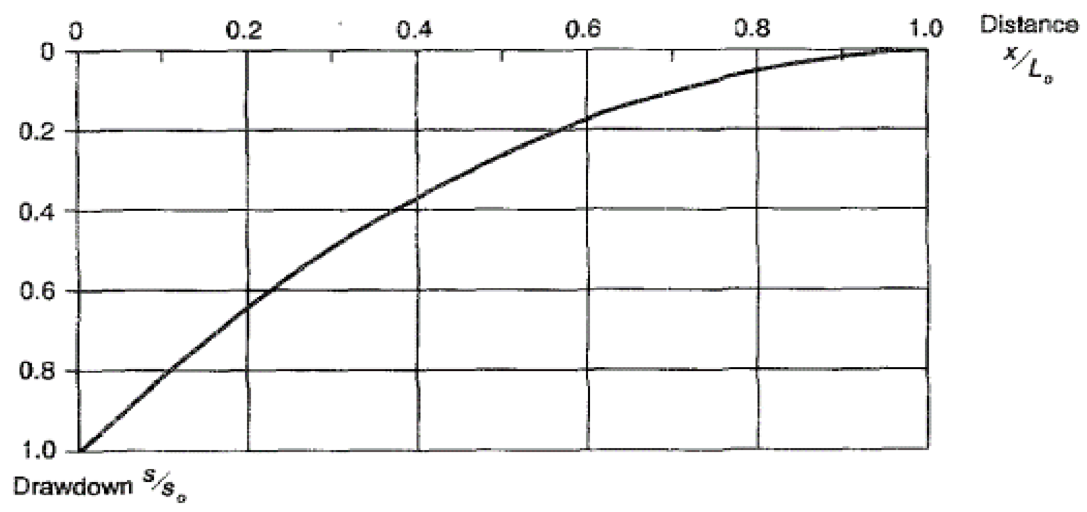
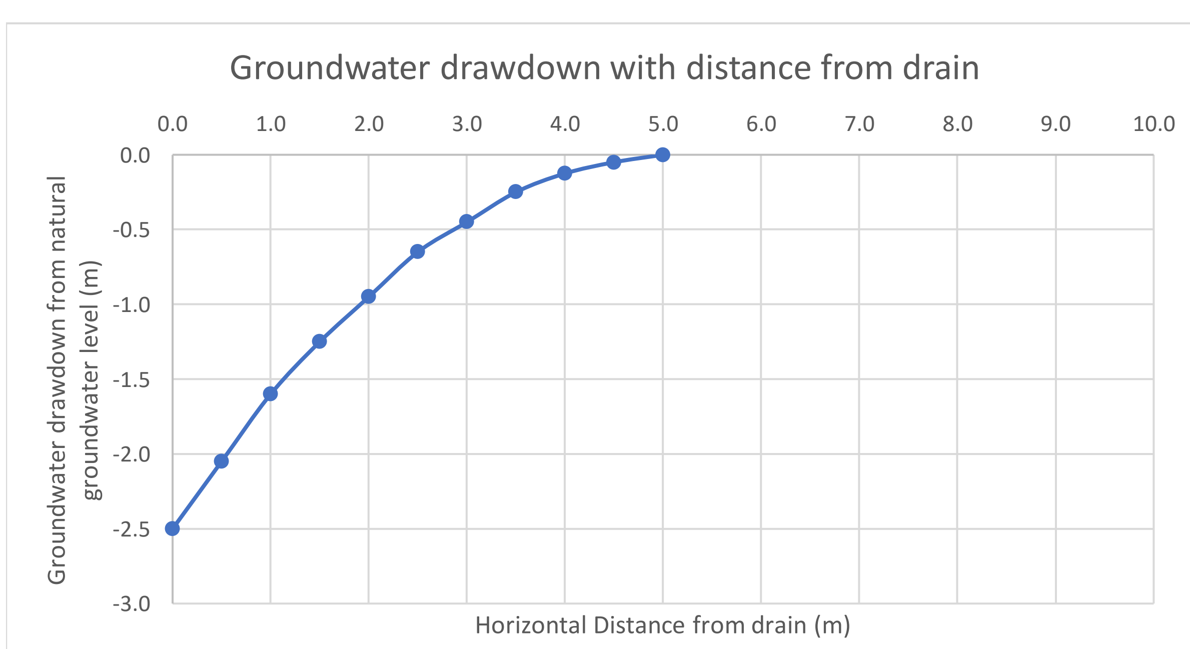


Figure 6.16 *Dimensionless drawdown curve for horizontal plane flow to a line of wells acting as a pumped slot in a low permeability soil*

Parameter	Value	Unit	Description
C	2000	-	coefficient (1500 - 2000 for line flow to trenches and 3000 for radial flow from a pump well)
h	2.5	m	total height of groundwater drawdown expected at drain location (ie. what is the height between the drain and the natural groundwater level)
k	1.00E-06	m/s	soil permeability
ds	5	m	proposed drain spacing
x	2.50	m	proposed half of the drain spacing
L_o	5.00	m	horizontal infleunce distance of drains
x/L_o ratio	0.50	-	
s/s_o ratio	0.3	-	estimate from Figure 6.16 based on x/Lo ratio
s	0.60	m	groundwater drawdown at center spacing of drains (assuming influence from 2 drains and direct super position)
b	1.90	m	water rise between drain locations
b/2	0.95	m	average water rise above counterforts for slope stability modelling

GROUNDWATER DRAWDOWN ASSUMING PLANAR FLOW

Horizontal Distance ratio	Horizontal Distance from drain(m)	s/so ratio	Groundwater drawdown (m)
0	0.00	1	-2.50
0.1	0.50	0.82	-2.05
0.2	1.00	0.64	-1.60
0.3	1.50	0.5	-1.25
0.4	2.00	0.38	-0.95
0.5	2.50	0.26	-0.65
0.6	3.00	0.18	-0.45
0.7	3.50	0.1	-0.25
0.8	4.00	0.05	-0.13
0.9	4.50	0.02	-0.05
1	5.00	0	0.00



Counterfort Drain Drawdown Estimate

	user input value
	output value

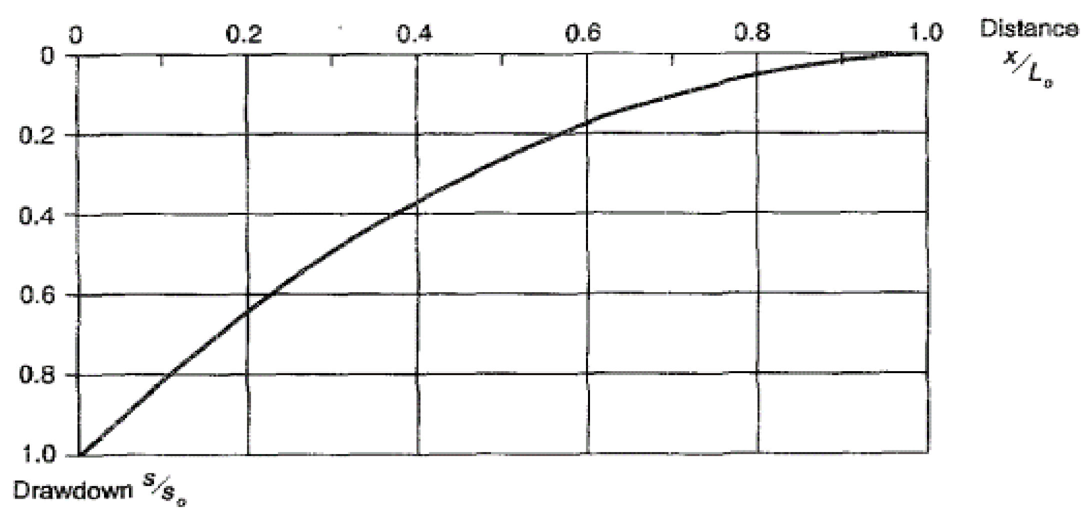
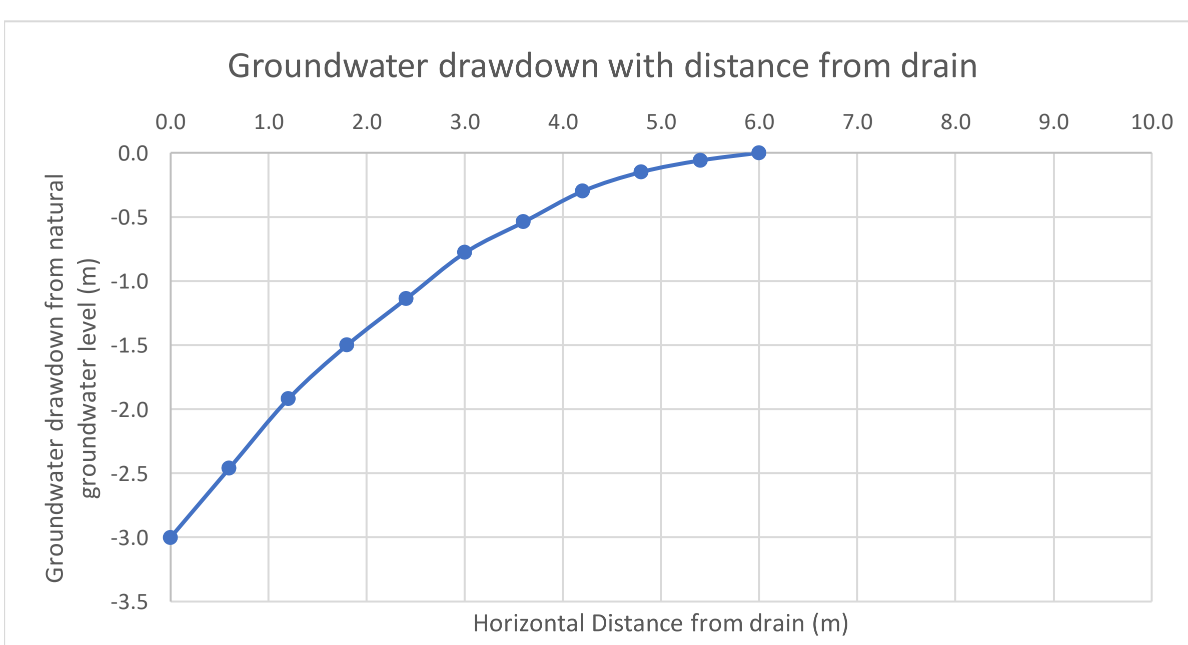


Figure 6.16 *Dimensionless drawdown curve for horizontal plane flow to a line of wells acting as a pumped slot in a low permeability soil*

Parameter	Value	Unit	Description
C	2000	-	coefficient (1500 - 2000 for line flow to trenches and 3000 for radial flow from a pump well)
h	3	m	total height of groundwater drawdown expected at drain location (ie. what is the height between the drain and the natural groundwater level)
k	1.00E-06	m/s	soil permeability
ds	5	m	proposed drain spacing
x	2.50	m	proposed half of the drain spacing
L_o	6.00	m	horizontal infleunce distance of drains
x/L_o ratio	0.42	-	
s/s_o ratio	0.39	-	estimate from Figure 6.16 based on x/Lo ratio
s	0.78	m	groundwater drawdown at center spacing of drains (assuming influence from 2 drains and direct super position)
b	2.22	m	water rise between drain locations
b/2	1.11	m	average water rise above counterforts for slope stability modelling

GROUNDWATER DRAWDOWN ASSUMING PLANAR FLOW

Horizontal Distance ratio	Horizontal Distance from drain(m)	s/so ratio	Groundwater drawdown (m)
0	0.00	1	-3.00
0.1	0.60	0.82	-2.46
0.2	1.20	0.64	-1.92
0.3	1.80	0.5	-1.50
0.4	2.40	0.38	-1.14
0.5	3.00	0.26	-0.78
0.6	3.60	0.18	-0.54
0.7	4.20	0.1	-0.30
0.8	4.80	0.05	-0.15
0.9	5.40	0.02	-0.06
1	6.00	0	0.00



Counterfort Drain Drawdown Estimate

user input value
output value

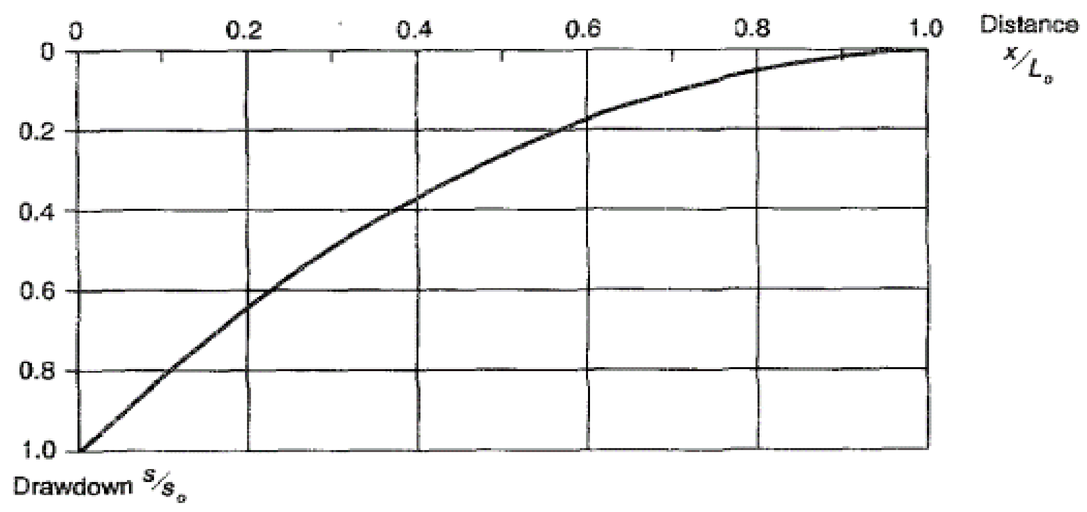
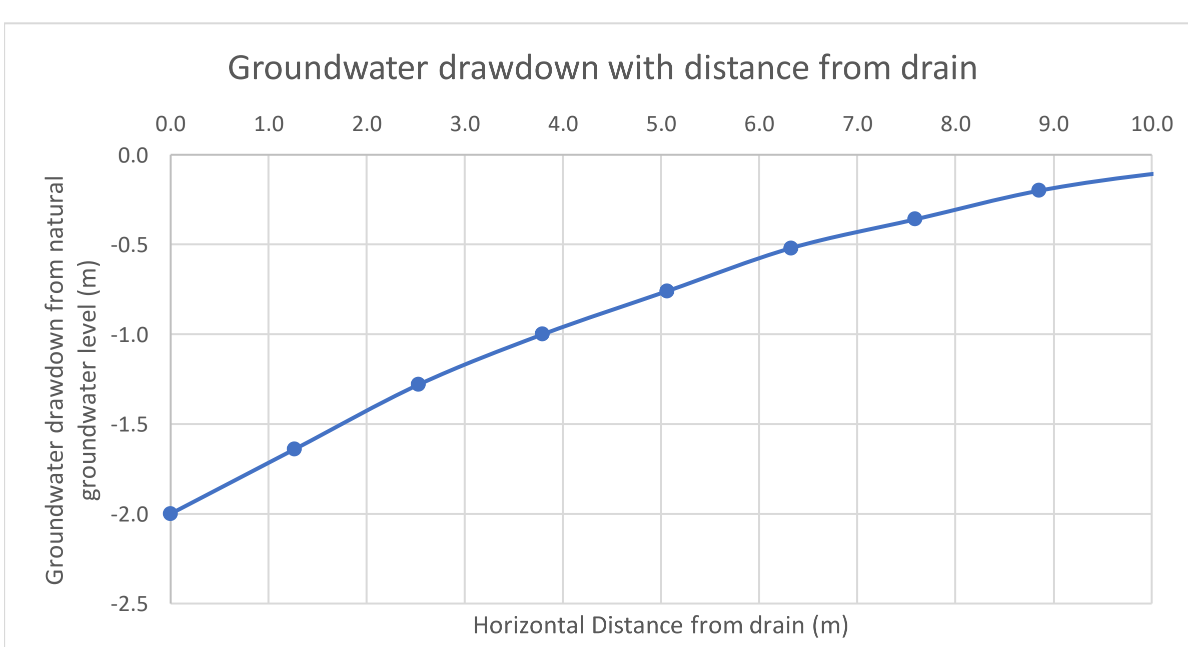


Figure 6.16 *Dimensionless drawdown curve for horizontal plane flow to a line of wells acting as a pumped slot in a low permeability soil*

Parameter	Value	Unit	Description
C	2000	-	coefficient (1500 - 2000 for line flow to trenches and 3000 for radial flow from a pump well)
h	2	m	total height of groundwater drawdown expected at drain location (ie. what is the height between the drain and the natural groundwater level)
k	1.00E-05	m/s	soil permeability
ds	5	m	proposed drain spacing
x	2.50	m	proposed half of the drain spacing
L_o	12.65	m	horizontal infleunce distance of drains
x/L_o ratio	0.20	-	
s/s_o ratio	0.62	-	estimate from Figure 6.16 based on x/Lo ratio
s	1.24	m	groundwater drawdown at center spacing of drains (assuming influence from 2 drains and direct super position)
b	0.76	m	water rise between drain locations
b/2	0.38	m	average water rise above counterforts for slope stability modelling

GROUNDWATER DRAWDOWN ASSUMING PLANAR FLOW

Horizontal Distance ratio	Horizontal Distance from drain(m)	s/so ratio	Groundwater drawdown (m)
0	0.00	1	-2.00
0.1	1.26	0.82	-1.64
0.2	2.53	0.64	-1.28
0.3	3.79	0.5	-1.00
0.4	5.06	0.38	-0.76
0.5	6.32	0.26	-0.52
0.6	7.59	0.18	-0.36
0.7	8.85	0.1	-0.20
0.8	10.12	0.05	-0.10
0.9	11.38	0.02	-0.04
1	12.65	0	0.00



Counterfort Drain Drawdown Estimate

	user input value
	output value

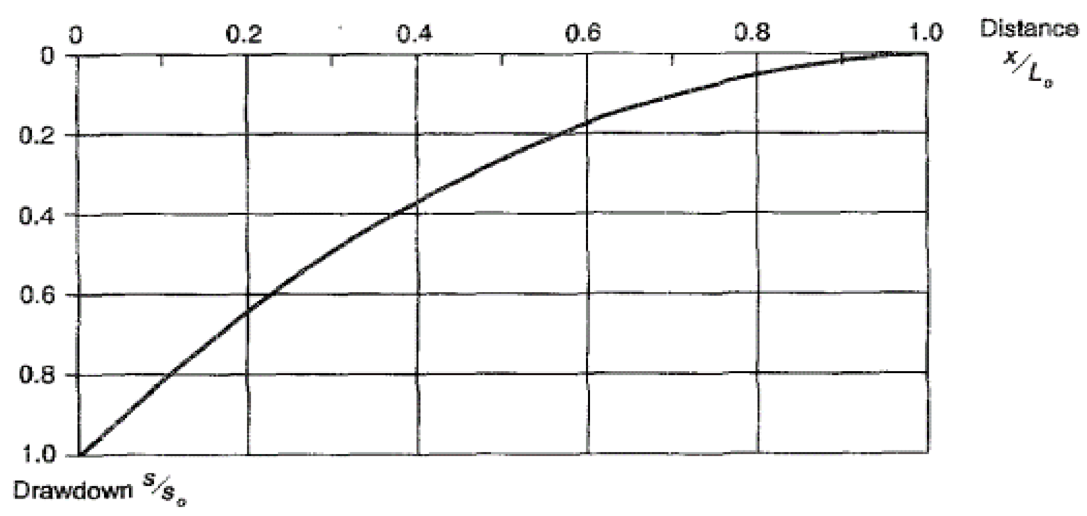
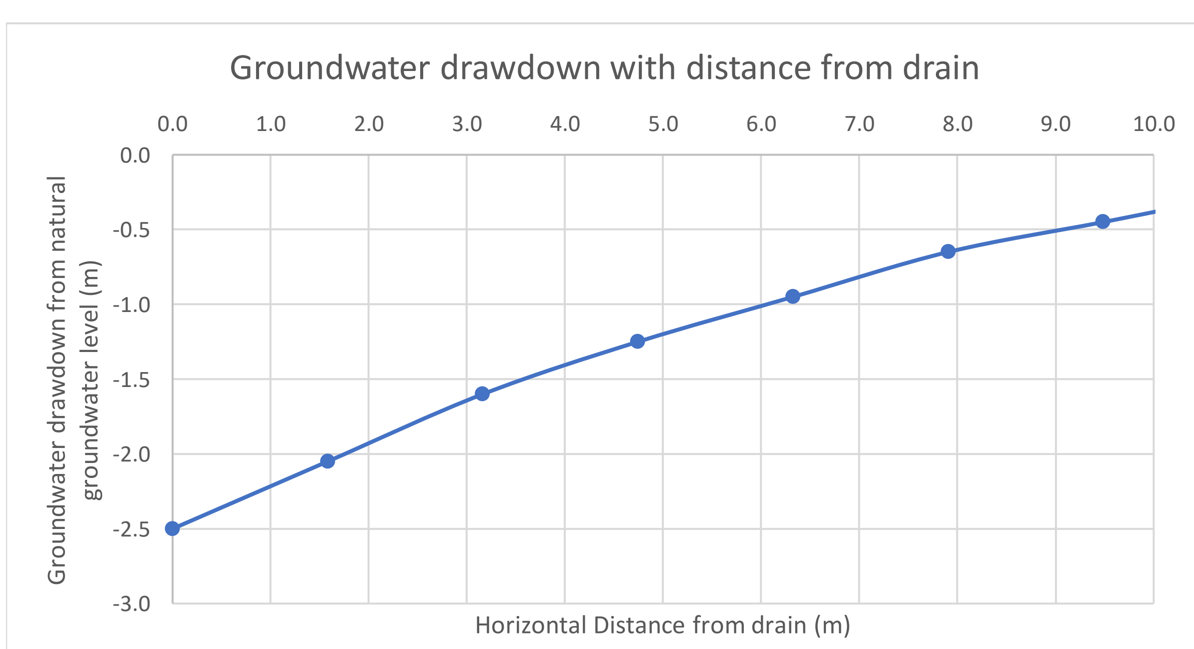


Figure 6.16 *Dimensionless drawdown curve for horizontal plane flow to a line of wells acting as a pumped slot in a low permeability soil*

Parameter	Value	Unit	Description
C	2000	-	coefficient (1500 - 2000 for line flow to trenches and 3000 for radial flow from a pump well)
h	2.5	m	total height of groundwater drawdown expected at drain location (ie. what is the height between the drain and the natural groundwater level)
k	1.00E-05	m/s	soil permeability
ds	5	m	proposed drain spacing
x	2.50	m	proposed half of the drain spacing
L_o	15.81	m	horizontal infleunce distance of drains
x/L_o ratio	0.16	-	
s/s_o ratio	0.7	-	estimate from Figure 6.16 based on x/Lo ratio
s	1.40	m	groundwater drawdown at center spacing of drains (assuming influence from 2 drains and direct super position)
b	1.10	m	water rise between drain locations
b/2	0.55	m	average water rise above counterforts for slope stability modelling

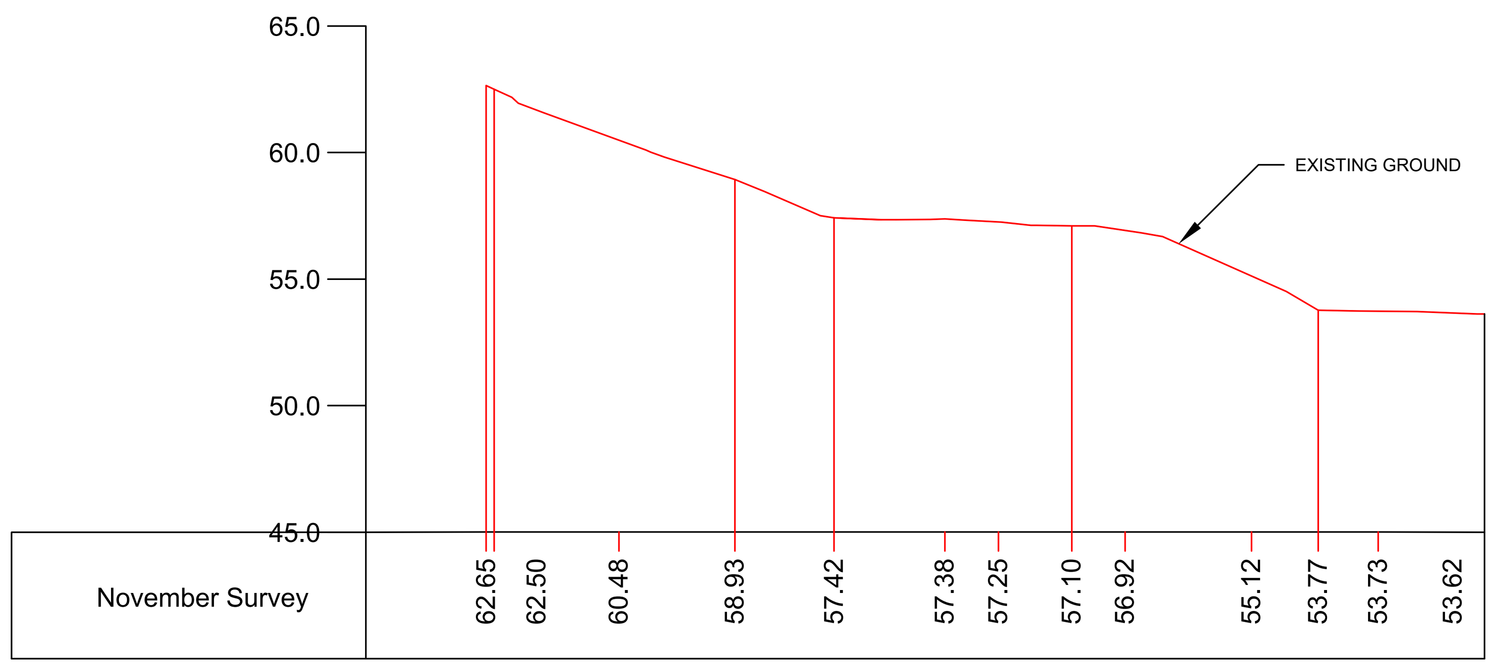
GROUNDWATER DRAWDOWN ASSUMING PLANAR FLOW

Horizontal Distance ratio	Horizontal Distance from drain(m)	s/so ratio	Groundwater drawdown (m)
0	0.00	1	-2.50
0.1	1.58	0.82	-2.05
0.2	3.16	0.64	-1.60
0.3	4.74	0.5	-1.25
0.4	6.32	0.38	-0.95
0.5	7.91	0.26	-0.65
0.6	9.49	0.18	-0.45
0.7	11.07	0.1	-0.25
0.8	12.65	0.05	-0.13
0.9	14.23	0.02	-0.05
1	15.81	0	0.00

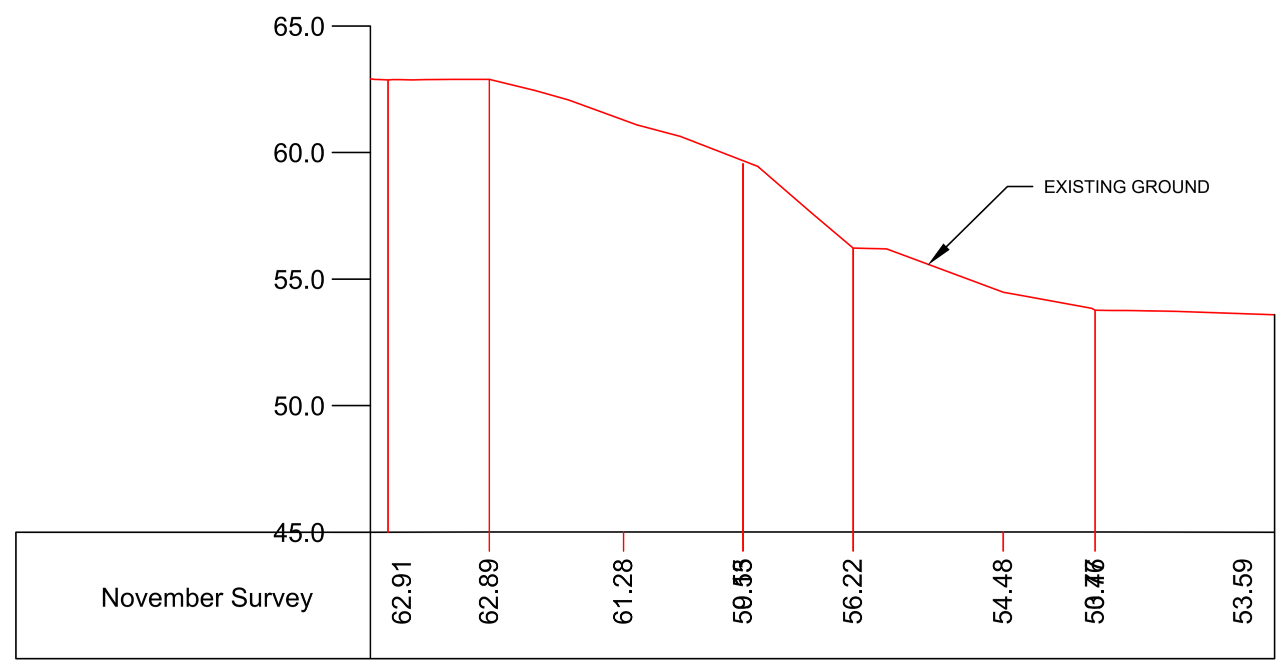


DRAWINGS

DO NOT SCALE FROM THIS DRAWING



SECTION 2
SCALE 1:250



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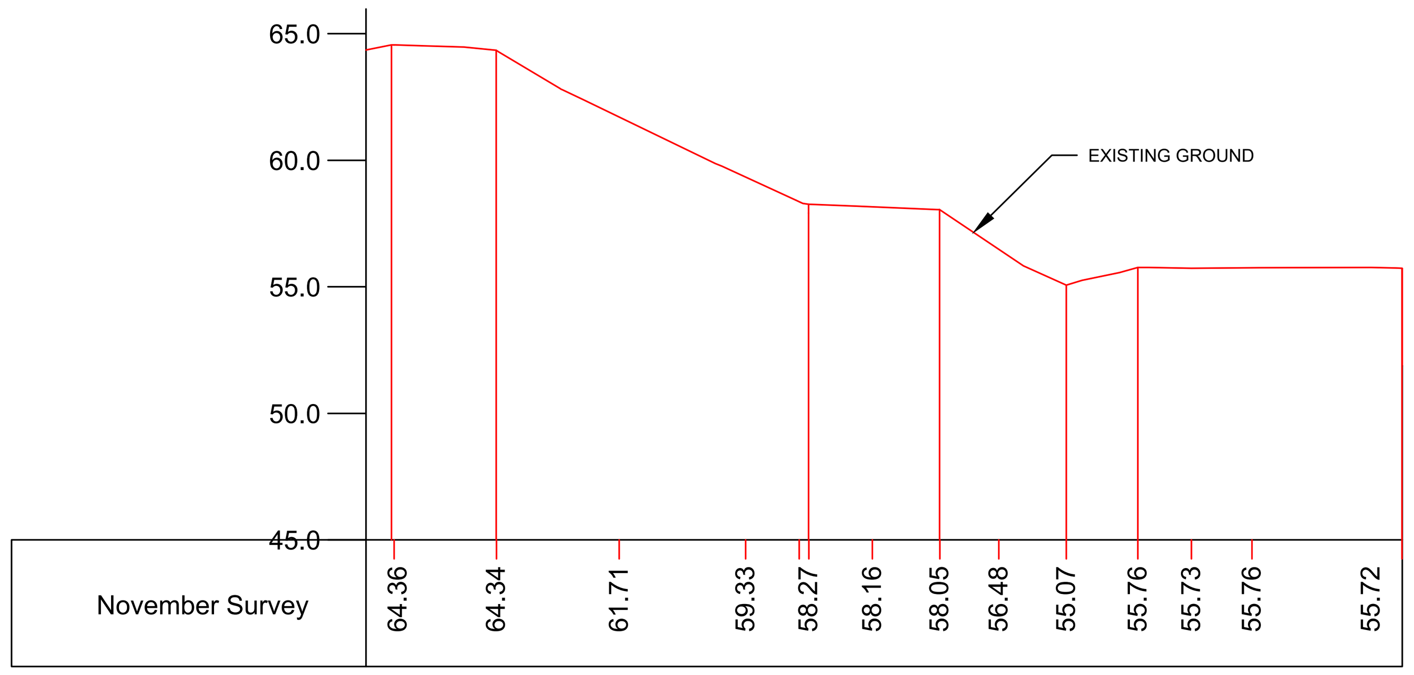

SECTION 5
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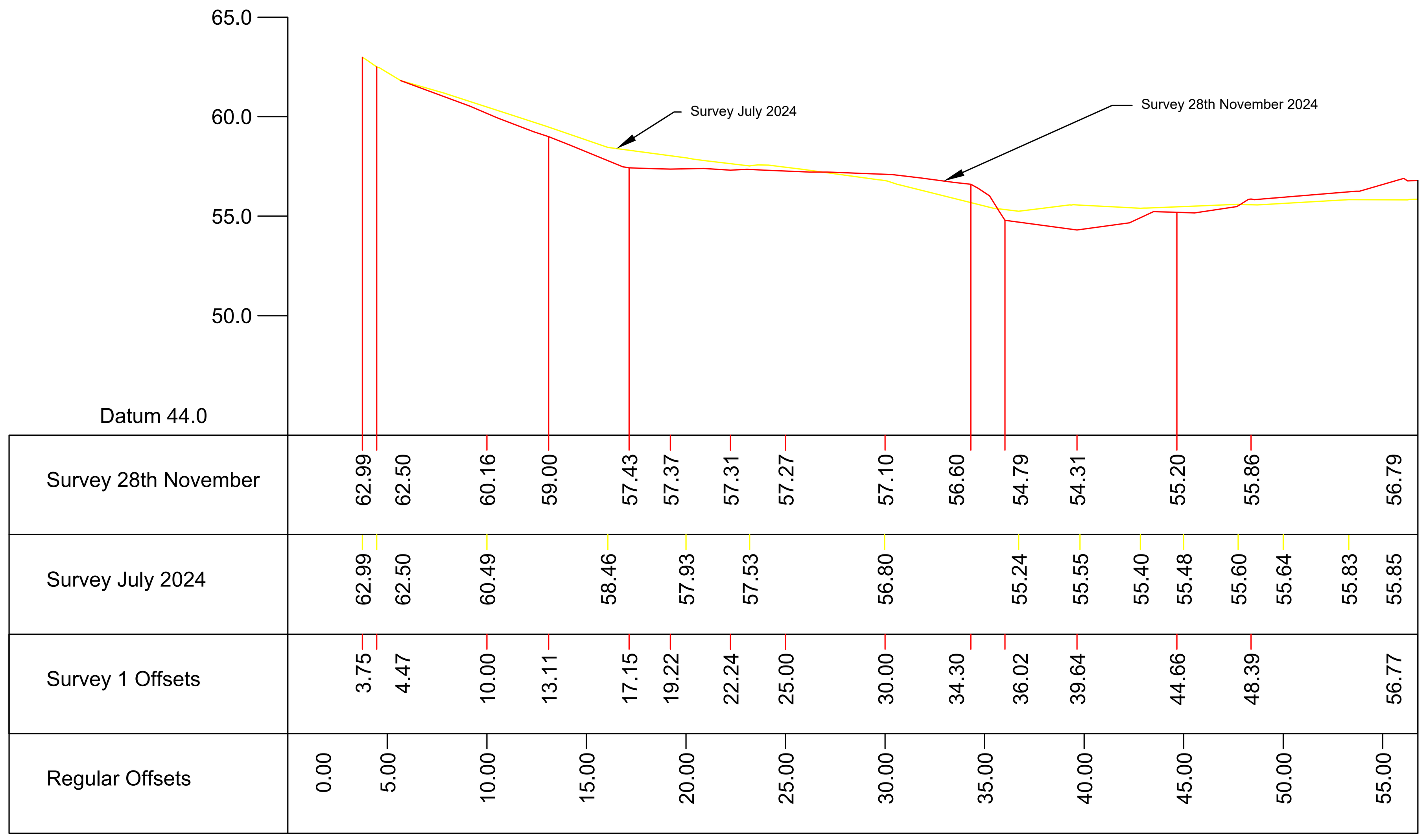
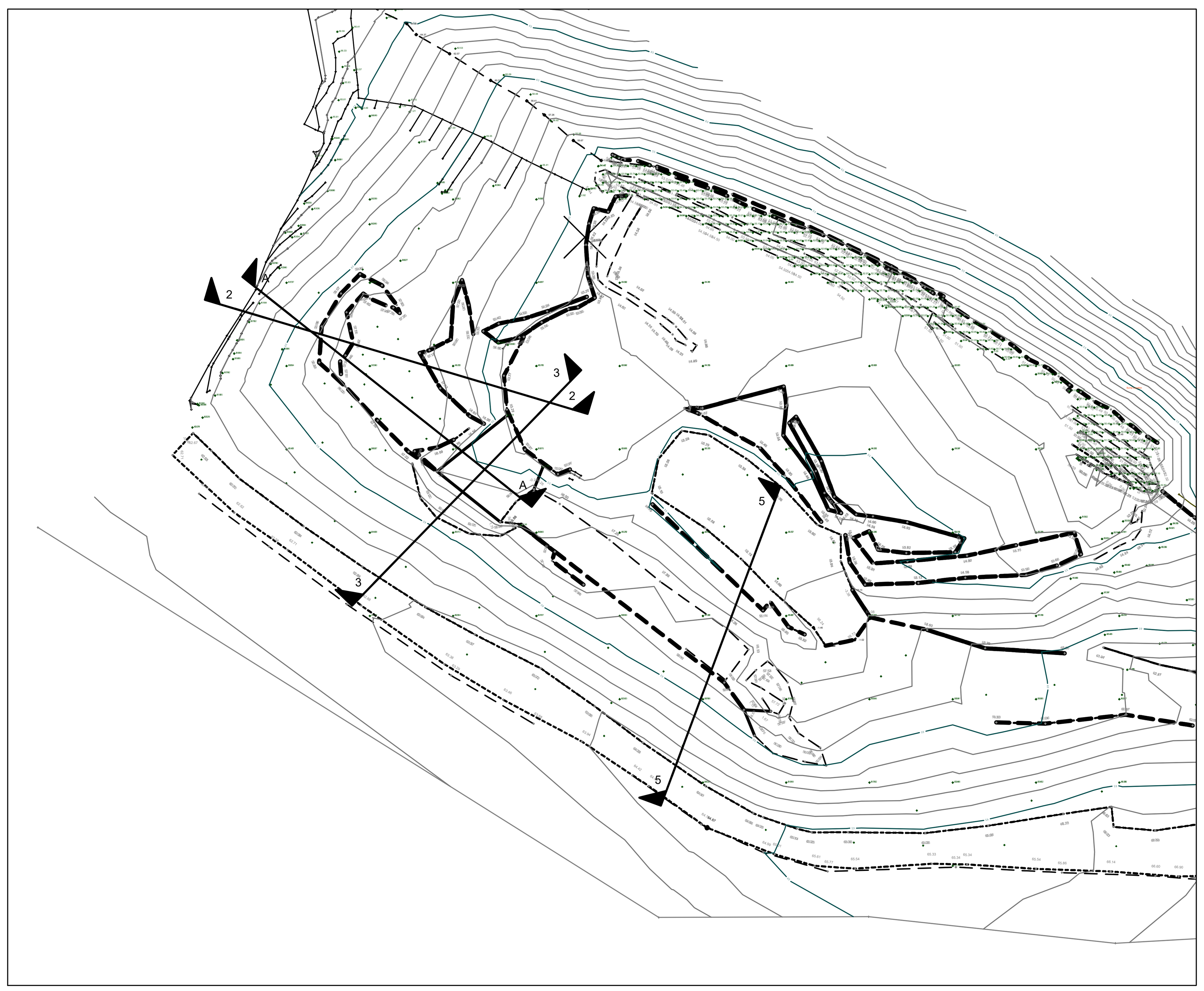


SECTION A
SCALE 1:250



SECTION LOCATIONS
SCALE 1:500

REVISION	DETAILS	DATE	DRAWN	CHK'D	APP'D
A	FIRST ISSUE	18/12/24	SRB	BS	AS

CLIENT
NEALES WASTE MANAGEMENT

PROJECT
CLAYTON HALL LANDFILL SITE
CELL 4B

DRAWING TITLE
STABILITY ASSESSMENT SECTIONS

DRG No.	REV	SUIT. CODE
ST18115-050	A	

DRG SIZE	SCALE	DATE
A1	AS SHOWN	DEC 24

DRAWN BY	CHECKED BY	APPROVED BY
SRB	BS	AS

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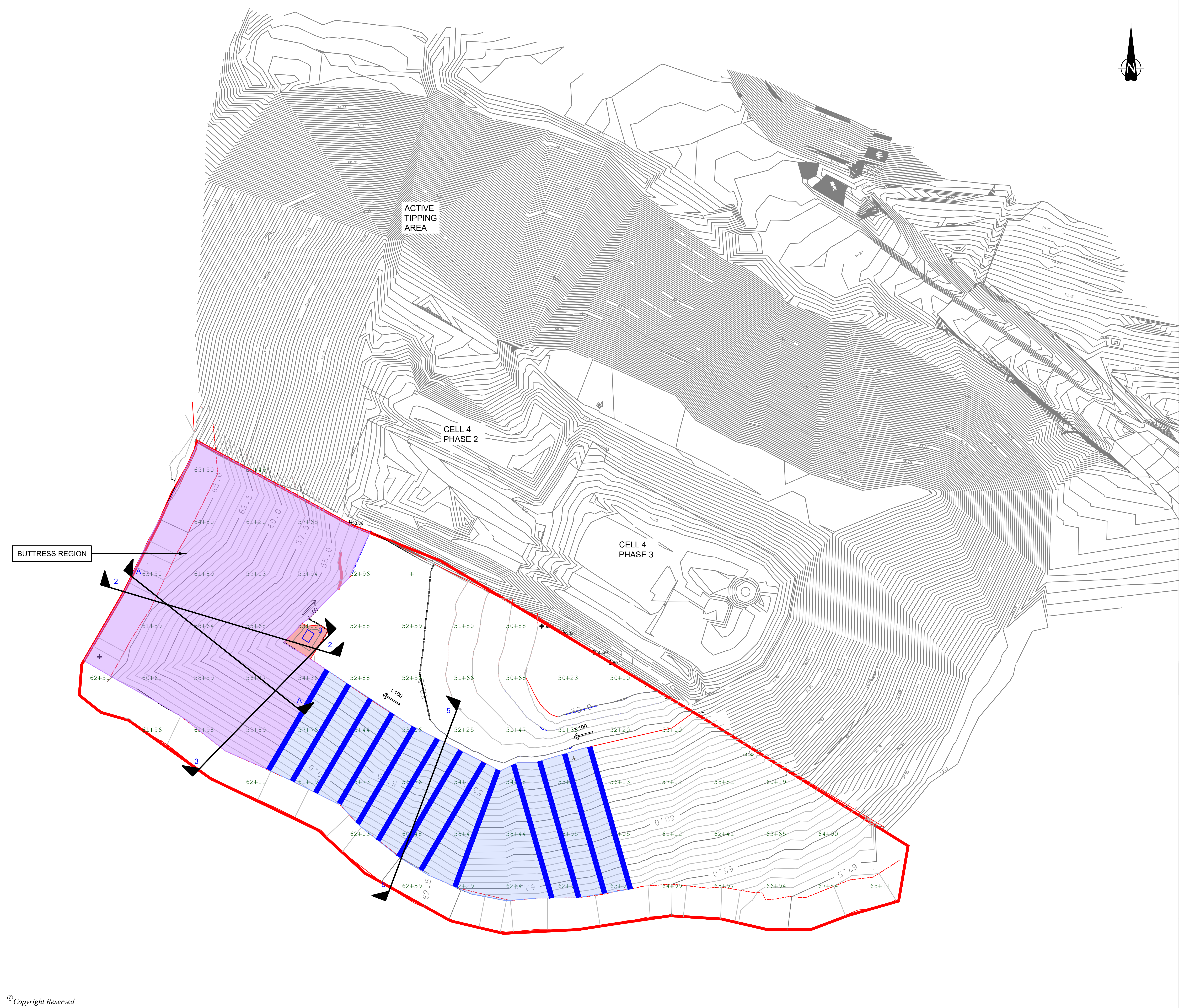

DO NOT SCALE FROM THIS DRAWING

KEY:

PROPOSED CELL 4 PHASE 4 BOUNDARY

51 66 PROPOSED TOP OF FORMATION LEVELS

PROPOSED LOCATION OF SIDE WALL RISER SUMP

INDICATIVE LOCATION OF COUNTERFORT DRAIN

BUTTRESS REGION

A A SECTION LINE

NOTES

REFER TO DRAWING ST18115-050 FOR CROSS SECTIONAL DETAILS

TOPOGRAPHY IS BASED ON PROPOSED TOP OF FORMATION LEVELS

REVISION	DETAILS	DATE	DRAWN	CHK'D	APP'D
A	APPROVED ISSUE	03-03-25	DG	GTS	AS

CLIENT
NEALES WASTE MANAGEMENT

PROJECT
CLAYTON HALL LANDFILL SITE
CELL 4 PHASE 4

DRAWING TITLE
COUNTERFORT DRAIN LAYOUT

DRG No.	REV	SUIT. CODE
ST18115-306	A	

DRG SIZE	SCALE	DATE
A2	1:500	18-02-25

DRAWN BY	CHECKED BY	APPROVED BY
DR	GTS	AS

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N:\ST\ST18115 - CLAYTON HALL LANDFILL\03 - DESIGN\AUTOCAD\ST18115-306-A COUNTERFORT DRAIN LAYOUT.DWG

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