AN APPLICATION TO VARY ENVIRONMENTAL PERMIT NO. RP3133PP FOR THE THORNHAUGH LANDFILL SITE OPERATED BY AUGEAN SOUTH LIMITED TO CHANGE THE RESTORATION PROFILE OF THE EXISTING PERMITTED SITE

STABILITY RISK ASSESSMENT REPORT

Report reference: AU/TH/DFR/3261/01/SRA
July 2025

Technical advisers on environmental issues

Baddesley Colliery Offices, Main Road, Baxterley, Atherstone, Warwickshire, CV9 2LE
Tel. (01827) 717891

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1. Introduction

1.1 MJCA is commissioned by Augean South Limited (Augean) to prepare a Stability Risk Assessment (SRA) to support an application (the Application) to vary Environmental Permit (EP) Number RP3133PP (the Permit) to change the current restoration levels for the Thornhaugh Landfill Site near Peterborough (the site), and to address and discharge a pre-operational condition from the Permit relating to capping. The site is operated by Augean and is consented for the deposition of non-hazardous commercial and industrial waste, stable non-reactive hazardous waste (SNRHW), asbestos and gypsum together with other high sulphate bearing wastes.

1.2 Further information on the Application is presented in the Environmental Setting and Installation Design (ESID) report reference AU/TH/LRM/5784/01/ESID dated July 2025 and the Hydrogeological Risk Assessment Review Addendum (HRAR ADD) Report reference AU/TH/JRC/20127/01 HRAR ADD dated July 2025 which accompany this variation application.

1.3 The proposed variation will change the restoration levels authorised by the Permit to allow the restoration to tie in to the restoration of the Cooks Hole Quarry site to the south of Thornhaugh Landfill Site in accordance with the Planning Consent[1] for the restoration of the two sites as explained in Section 2 of the ESID report which accompanies this variation application. The site location is shown on Figure SRA 1 and the permit boundary and the site phase boundaries are shown on Figure SRA 2. The Planning Permission 24/00210/MMFUL and Figures PS3.1 and PS3.2 showing the consented Restoration Profile and Phasing Plan for the two sites are provided in the ESID[2]. The elevation of the highest point of the restoration landform at Thornhaugh (71.5m Above Ordnance Datum) has not changed as a result of the consented changes to the restoration profile.

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1 *Planning Permission ref: 24/00210/MMFUL, granted on 26 September 2024, for: 'Continuation of landfilling operations and the importation of clean naturally occurring materials to create an integrated restoration landform with nature conservation habitats' at: Cooks Hole Quarry and Thornhaugh Landfill Site, Leicester Road, Thornhaugh, Peterborough.*

2 *'An application to vary Environmental Permit no. RP3133PP for the Thornhaugh Landfill Site operated by Augean South Limited to change the restoration profile of the existing permitted site. Environmental Setting and Installation Design (ESID) Report. Update to the 2014 ESID Report' Report reference: AU/TH/LRM/5784/01ESID, MJCA, July 2025*

1.4 In addition the proposed variation will address and discharge pre-operational condition PO5 from the Permit relating to the Capping of Phase 7A which states that:

> '*Prior to commencement of capping in Phase 7A the operator shall submit to the Environment Agency detailed written proposals to monitor or verify through other measures which may include experimentation or calculation the cap infiltration in Phase 7A and obtain the Environment Agency's written approval to them.*'

1.5 As explained in the ESID and HRAR ADD reports which accompany this permit variation application, pre-operational measure PO5 was included in the Permit to reflect changes made in a previous Permit Variation to allow a reduced basal liner system thickness formed from 0.5m of low permeability clay, a Geosynthetic Clay Liner (GCL) and a 2mm thick high density polyethylene (HDPE) geomembrane, rather than 1m of low permeability clay and a 2mm thick HDPE geomembrane. This change relied on the site being capped with a GCL and having a long term low cap infiltration rate reliant on the GCL. PO5 was added to address EA concerns in respect of the potential for deterioration of a 6mm thick GCL cap over the lifetime of Phase 7A. Subsequently the reduced basal liner thickness design was only constructed in Phase 7A and Phase 4B South, with all previous and subsequent phases employing the 1m of low permeability clay and 2mm thick HDPE geomembrane basal liner design. As explained in the HRAR ADD report, this change has allowed a 1m thick low permeability clay capping system to be used at the site, thus removing the need for the site to be capped with GCL.

1.6 This SRA has been undertaken to assess the stability of the proposed design for the landfill development and focusses on the proposed changes to capping and restoration design while also incorporating the current basal liner and side slope designs. The structure of the SRA is based on current Environment Agency (EA) guidance together with the now withdrawn template produced by the EA entitled "Stability Risk Assessment Report" Version 1 dated March 2010. The SRA shows that the stability of the proposed design is at acceptable factors of safety in the short term and in the long term.

1.7 The site is centred approximately on National Grid Reference (NGR) TF 04876 00139 approximately 2km west north west of the village of Wansford. Access to the site is from the A47 which is located adjacent to the northern boundary of the site. The location of the site is shown on Figure SRA 1.

1.8 The history of the site is described in the ESID. In summary, prior to landfilling the site was quarried for the ironstone of the Northampton Sand Formation by excavation of the overlying Lincolnshire Limestone and Grantham Formation. It is understood that the overlying materials removed during quarrying were used to backfill parts of the quarry. At a later date some of the overburden backfill was quarried and the remaining void was developed as a landfill.

1.9 The design for future landfill phases at the site is consistent generally with the designs for current landfill phases at the site the subject of the Permit which are the subject of previous SRAs in particular:

- an SRA undertaken in 2004[3] in support of the application for the Permit,
- an SRA prepared in 2007[4] that addressed the stability of a proposed separation bund between Phases 1 and 2 and Phases 4 and 7, and
- an SRA undertaken in 2014[5] prepared to support the extension of the boundary of the landfill area authorised by the Permit to include an adjacent area of land known as the Bradshaw Land and to incorporate the closed landfill area at the site comprising Phases 1 and 2.

1.10 In addition SRAs have been undertaken for the nearby Augean East Northants Resource Management Facility (ENRMF) in May 2021[6], August 2008[7] and November 2009[8]. The SRAs for ENRMF have been reviewed as part of this

[3] 'Stability Risk Assessment', Thornhaugh Landfill. Bullen Consultants, November 2004.

[4] 'Report on the stability of the northern side slope of the proposed excavations in Phase 4C and Phase 7 at Thornhaugh Landfill Site, Leicester Road, Peterborough' report reference AU/TH/SN/44460/01SA. MJCA, February 2007.

[5] An application to vary Environmental Permit No. RP3133PP for the Thornhaugh Landfill Site Operated by Augean South Limited to extend the area of the existing permitted site, Stability Risk Assessment Report', report reference: AU/TH/DFR/3181/01. MJCA, September 2014

[6] An application to vary Environmental Permit Number EPR/TP3430GW for the Hazardous Waste Landfill Site Operated by Augean South Limited at East Northants Resource Management Facility, Stability Risk Assessment Report', report reference: AU/KCW/AW/5646/01/SRA. MJCA, May 2021

[7] 'Environmental Permit (EP) Application for the Landfill Operations at the East Northants Resource Management Facility, Section D Stability Risk Assessment Report', report reference AU/KC/GRD/3141/01/SRA. MJCA, August 2008.

[8] 'A Stability Risk Assessment prepared in accordance with Improvement Action 4 of Table S1-3 to Schedule 1 to Environmental Permit reference EPR/TP34030GW for the landfill at the East Northants Resource Management Facility' report reference AU/KC/BMJ/3149/01/SRA. MJCA, November 2009

assessment as the in situ clay materials excavated at ENRMF have been and will be used to construct the low permeability clay liners and capping systems at Thornhaugh.

2. Proposed design

2.1 The proposed design for future landfill cells at Thornhaugh Landfill Site is based on the existing agreed designs with a number of modifications which have been agreed with the Environment Agency through the CQA Plan approval process. The proposed design is described in this report and includes tables and drawings which detail the proposed landfill engineering. A summary of the proposed design compared with the existing design for future landfill cells at the site is provided in Table SRA1. Plans and sections showing the proposed design of the consented future landfill phases are presented on Figures SRA3 to SRA6.

2.2 To date, landfill containment cell construction has been completed consecutively in Phase 3, Phase 6A, Phase 6B, Phase 5 North, Phase 5 South, Phase 5 Eastern Extension, Phase 7A, Phase 4B South, Phase 4B North, Phase 4C, Phase 7C and Phase 2 West. The phases still to be constructed are Phase 2 East, Phase 1 West, Phase 1 East and Phase 7B. Phase 1 and Phase 2 originally comprised unlined landfill cells which are being progressively excavated and lined to form the new Phase 2 West, Phase 2 East, Phase 1 West and Phase 1 East landfill containment cells.

Sub-grade for basal liner

2.3 Consistent with the previous design principles and SRAs the basal sub-grade will be formed by the excavation and profiling of the materials currently in situ at the site. Unsuitable materials exposed in the excavation of the basal sub-grade will be excavated and excavations will be backfilled with suitable engineering fill materials.

2.4 The surface of the basal sub-grade will range from approximately 47m above Ordnance Datum (AOD) to approximately 51m AOD. The surface of the basal subgrade is based on a minimum 1m vertical standoff from the anticipated maximum groundwater level contours as assessed in the Hydrogeological Risk Assessment (HRAR ADD)[9].

[9] 'An application to vary Environmental Permit no. RP3133PP for the Thornhaugh Landfill Site Operated by Augean South Limited to change the restoration profile of the existing permitted site. Addendum to the 2024 Review of the Hydrogeological Risk Assessment for Thornhaugh Landfill Site.' Report reference: AU/TH/JRC/20127/01 HRAR ADD, MJCA, July 2025

2.5 The basal sub-grade area will be profiled at a minimum gradient of 1v:100h rising from a low point corresponding with the location of the leachate collection and extraction sump. The proposed formation levels for future phases at the site are presented on Figure SRA3.

Sub-grade for sideslope liner

2.6 Consistent with the previous design principles and SRAs the sideslope sub-grade will be formed by excavation and profiling of the materials currently in situ at the site. Unsuitable materials exposed in the excavation of the sideslope sub-grade will be excavated and the excavations will be backfilled with suitable engineering fill materials.

2.7 The elevation of the crest of the sideslope sub-grade in future phases at the site will range between approximately 55m AOD and 60m AOD with the elevation of the toes of the slopes ranging from approximately 48m AOD to 51m AOD. The height of the sideslope sub-grade will range from 8m to 11m. The sideslope sub-grade will have a maximum slope gradient of 1v:2.5h.

2.8 Lined sideslopes will be constructed along the boundary slopes to the site. The boundaries of Phases 1 and 2 with the existing Phase 3 will be constructed as lined sideslopes against the in situ materials between Phase 3 and Phases 1 and 2. A schematic cross section showing the anticipated ground conditions at the future boundary between Phase 3 and Phases 1 and 2, based on site investigation information and the materials encountered during the excavation of Phase 2 West, is shown on Figure SRA6.

Temporary excavated slopes

2.9 Temporary excavation slopes will be formed during the excavation and construction of landfill phases. The temporary excavated slopes will have a maximum gradient of 1v:1.5h and will have a maximum vertical height of approximately 14m. Based on site investigation information presented in the 2004 SRA[3] and in the ESID[10] the sub-grade for the majority of the temporary slopes will be formed in the materials

[10] 'An application to vary Environmental Permit no. RP3133PP for the Thornhaugh Landfill Site operated by Augean South Limited to change the restoration profile of the existing permitted site. Environmental Setting and Installation Design (ESID) Report. Update to the 2014 ESID Report' Report reference: AU/TH/LRM/5784/01ESID, MJCA, July 2025

used to backfill the quarry which comprise materials from the Lincolnshire Limestone Formation and the Grantham Formation. Based on site investigation information and the excavation of Phase 2 West, in some locations in Phase 1 and in Phase 2 the temporary slopes will be excavated in ground that includes biodegradable waste materials up to 10m thick starting at depths between 0m and 5m below ground level.

Basal lining system

2.10 The basal lining system will comprise a minimum 1m thick compacted low permeability clay liner placed and compacted to achieve a maximum permeability of $1x10^{-9}$m/s and minimum shear strength of 50kPa. The clay liner will be constructed from clay materials sourced from the nearby Augean ENRMF. The clay materials will comprise Rutland Formation (formerly referred to as the Upper Estuarine series) Clay (Blue Clay) or weathered Rutland Formation and Boulder Clays (Brown Clay), which have been used successfully in the past to construct low permeability clay liners at ENRMF and Thornhaugh. The clay sources have previously both been used in a single phase but are used separately for distinct areas of the clay liner and not mixed. The clay liner will be overlain by a 2mm thick smooth high density polyethylene (HDPE) geomembrane which in turn will be overlain by a suitable geotextile protection layer or a 300mm sand protection layer.

2.11 The basal liner protection layer will be overlain by a leachate drainage blanket comprising a 300mm thick aggregate layer with HDPE leachate collection pipework. The leachate pipework will promote the drainage of leachate to a leachate collection and extraction sump positioned in the low point of each phase. Two leachate monitoring wells will be constructed in each phase. The basal liner will be constructed with a minimum gradient of 1v:100h towards the low point in each phase. The proposed levels of the top of the clay liner for future cells are presented on Figure SRA4.

2.12 Inter-cell bunds will be constructed from compacted low permeability clay directly on the basal liner. The bunds will have maximum slope gradients of 1v:2h, a minimum vertical height of 2m measured from the top of the basal clay liner and a minimum crest width of 3m. Due to the variation in basal falls between phases it may be necessary locally to increase the bund heights to a maximum vertical height of up to

3m. The bunds will be lined with 2mm thick double textured HDPE geomembrane. A geotextile protection layer will be placed over the geomembrane and the basal granular leachate drainage blanket will be extended up the full height and over the crest of the bunds.

Sideslope lining system

2.13 The sideslope lining system will comprise a minimum 1m thick compacted low permeability clay liner with a maximum hydraulic conductivity of $1x10^{-9}$m/s overlain by a 2mm thick double textured HDPE geomembrane. The protection geotextile and granular leachate drainage blanket will extend to a vertical height of 2m up the sideslopes. A protection and drainage geocomposite sufficient to provide a pathway for perched leachate and to provide protection to the underlying geomembrane will be placed over the remainder of the sideslope. Selected fine grained wastes containing clay, silt, sand and gravel up to 20mm particle size will be used as the first layer placed against the sideslope protection and drainage geocomposite. As the sideslope lining system will be constructed at the same gradient as the sideslope sub-grade it will have a maximum slope gradient of 1v:2.5h. The sideslope lining system will be constructed with typical vertical heights of between 7m and 10m.

Waste mass

2.14 Internal temporary waste slopes will be constructed at a gradient of 1v:1.5h. It is calculated that the internal temporary waste slopes have a maximum vertical height of approximately 19m based on the top of waste levels presented on Figure SRA 5.

2.15 Leachate extraction and monitoring wells comprising vertical telescopic shafts designed to accommodate axial movement, will be installed during phase construction works. The telescopic shafts will be constructed progressively so as to prevent damage caused by movement of the waste mass. Each phase will have a leachate extraction collection sump area with the extraction well located at the low point and two leachate monitoring wells. The site will continue to be operated in accordance with the approved Leachate Management Plan.

2.16 As described in the Landfill Gas Risk Assessment (LFGRA)[11] Report over 99% of the waste received by the site over the period 2014 to 2024 was recorded on the waste returns as non-biodegradable. There are no changes proposed to the types of wastes being received at the site.

2.17 As detailed in in the following capping and restoration section, and based on previous site monitoring and the nature of the waste deposited at the site, it is anticipated that the waste will undergo no significant settlement following its placement and compaction in the landfill phases.

Capping and restoration system

2.18 A 0.3m thick sub-grade will be placed on the re-profiled top of waste level to provide a smooth, firm and inert surface. The future landfill capping will comprise a 1m thick compacted low permeability clay liner with a maximum hydraulic conductivity of 1×10^{-9}m/s.

2.19 A 0.3m thick layer of sand will be placed over the rolled and smoothed upper surface of the completed low permeability cap areas. The sand drainage layer will be formed from the site derived sand of the Northampton Sand Formation or an equivalently permeable aggregate. The sand will form a drainage pathway for rainwater infiltrating through the overlying soils to the perimeter surface water collection system, sufficient to prevent the build up of perched water on the cap and to improve the stability of the restoration soils.

2.20 Over the majority of the site and along the western, northern and eastern edge of the site, a 1m to 1.5m thickness of restoration soils will be placed over the cap with thicker soil layers located in areas which will be restored to woodland. In these areas the restoration soils will be placed at the same slope gradients as the cap. As a result for these areas of the site the capping and restoration layers typically have gradients that range from approximately 1v:10h to 1v:20h with slopes lengths of between approximately 150m and approximately 300m. Steeper slopes are present locally in these areas along the edges of the site and have gradients that

[11] MJCA Report ref: AU/TH/LRM/5784/01LFGRA, dated July 2025 'An application to vary Environmental Permit No. RP3133PP for the Thornhaugh Landfill Site operated by Augean South Limited to change the restoration profile of the existing permitted site. Landfill Gas Risk Assessment.'

range from approximately 1v:3h to 1v:6h over slope lengths of between approximately 10m and 70m.

2.21 In the southern area of the site, where the site abuts the Cooks Hole Quarry site, the restoration soils will be placed to depth of up to 15m to allow the restoration between the two sites to be tied together in accordance with the consented integrated restoration scheme for the combined site. As a result for this southern area of the site the capping typically has steeper gradients that range from approximately 1v:3h to 1v:50h with slopes lengths of between approximately 10m and approximately 330m. Whereas the restoration slopes in the southern area have gradients that range from approximately 1v:12h to 1v:60 over slope lengths of between approximately 90m and 200m. This difference in capping and restoration slope gradient results in a bolstering of the steeper capped slopes providing long term stability to the underlying southern capped slopes of the site.

2.22 Given that the waste will be placed and compacted in horizontal layers and will comprise fine grained, non-biodegradable non-hazardous and stable non-reactive hazardous wastes it is considered that settlement and consolidation of the waste mass will be substantially complete prior to capping and restoration of the site. This conclusion is supported by the following:

- Settlement monitoring during annual surveys – survey monitoring undertaken at the site over the last 12 years records very little settlement: in the order of between 1% and 2%. For a waste depth of 10m this equates to a movement of approximately 100mm to 200mm over the last 12 years that the active and restored areas of the site have been monitored.

- Non-biodegradable waste – The waste deposited at the site is considered to be non-biodegradable as detailed in the Landfill Gas Risk Assessment (Appendix E to the Application report) which states: "*A review of the waste returns for the site for the last 10 years (2014-2024) shows that over 99% of the waste received by the site over this period was recorded on the waste returns as non-biodegradable and over 99% of the waste was recorded on the waste returns as coming from a non-municipal source. Although a variety of waste types were accepted during this period, the largest volume of waste types accepted were soils and treated soils, ash and construction and insulation materials containing* *asbestos. For the purpose of assessing landfill gas generation, the wastes received over the last 10 years are treated as comprising inert materials having no significant gas generating potential*."

- The consented restoration plan granted planning permission in 2024 does not include separate pre- and post-settlement restoration levels, as there is no evidence of settlement.

3. Conceptual stability site model

Introduction

3.1 The Conceptual Site Model (CSM) for the aspects of the site design relevant to the SRA is presented in this section of the report.

Basal sub-grade model

3.2 The surface of the basal sub-grade will be between approximately 47m AOD and approximately 51m AOD. The surface of the basal sub-grade will have falls of between 1v:80h and 1v:100h. The maximum groundwater level is at least 1m below the surface of the basal subgrade.

3.3 Based on previous site investigation information presented in the ESID[10] the surface of the basal sub-grade will be at an elevation that is generally above the elevation of the base of the old quarry workings so the basal sub-grade will be formed of the materials used to backfill the quarry which comprise materials from the Lincolnshire Limestone Formation and the Grantham Formation.

Sideslope sub-grade model

3.4 The sideslope sub-grade will be formed by excavation and profiling of the materials currently in situ at the site. Consistent with the 2014[5] SRA and based on information presented in the 2004[3] SRA and the ESID[10] the sideslope sub-grade will be formed of materials from the Lincolnshire Limestone Formation and the Grantham Formation which will be in situ materials or materials used to backfill the former quarry void. The backfill materials comprise mixed granular and cohesive materials derived from the Lincolnshire Limestone Formation and the Grantham Formation and based on the 2004[3] SRA are classified as granular materials with respect to their engineering properties.

3.5 Sideslopes will have a maximum vertical height of approximately 11m with a maximum slope gradient of 1v:2.5h. It is anticipated that the sideslope sub-grade is dry.

Temporary excavated slopes model

3.6 The temporary excavated slopes will have a maximum gradient of 1v:1.5h and a maximum vertical height of approximately 14m. Consistent with the 2014[5] SRA and based on information presented in the 2004[3] SRA and in the ESID[10] the majority of the temporary slopes will be formed in the materials used to backfill the quarry which comprise materials from the Lincolnshire Limestone Formation and the Grantham Formation. Based on site investigation information, in some locations in Phase 1 and in the remaining unexcavated area of Phase 2 the temporary slopes will be excavated in waste materials up to 10m thick. Therefore two separate conceptual models are used to represent the temporary slopes with one modelling slopes constructed entirely in backfill materials and the second modelling a 10m thickness of waste materials from 2.5mbgl.

Basal lining system model

3.7 The basal liner will comprise a low permeability clay liner overlain by a 2mm thick smooth HDPE geomembrane. The low permeability clay liner will be placed on the basal sub-grade and compacted to a minimum perpendicular thickness of 1m to achieve a maximum hydraulic conductivity of $1x10^{-9}$m/s and a shear strength of no less than 50kPa. The 2mm thick smooth or textured HDPE geomembrane will be placed over the prepared upper surface of the low permeability clay liner and in turn will be overlain by a suitable geotextile protection layer or a 300mm sand protection layer. The basal liner will be overlain by a leachate drainage blanket comprising a 300mm thick aggregate layer with 120mm (branch) and 160mm (main run) internal diameter HDPE leachate collection pipework. The leachate will drain to a sump in the low point of each phase. The basal liner will be constructed with the same basal gradient as the formation layer of approximately 1v:100h towards the low point in each phase.

3.8 Inter-cell bunds will be constructed from compacted low permeability clay to a maximum vertical height of 3m above the top of the basal liner with maximum slope gradients of 1v:2h. The inter-cell bunds will have a minimum crest width of 3m. The inter-cell bunds will be lined with 2mm thick double textured HDPE geomembrane. A geotextile protection layer will be placed over the geomembrane and the basal leachate drainage blanket will be extended up the sides and over the crest of the inter-cell bunds.

Sideslope lining system model

3.9 The sideslope lining system will comprise a minimum 1m thick low permeability clay liner consistent with the basal liner, overlain by a 2mm thick double textured HDPE geomembrane. The basal granular leachate drainage blanket and protection geotextile will extend to a vertical height of 2m up the sideslopes. A protection and drainage geocomposite will be placed over the remainder of the sideslope. Selected fine grained wastes containing clay, silt, sand and gravel up to 20mm particle size will be used as a first protection layer placed against the sideslope protection and drainage geocomposite.

3.10 The fine grained protection layer and waste layers will be placed progressively. The waste will be placed in horizontal layers across the full width of the landfill phases. The fine grained protection layer will be formed from non-biodegradable, fine grained materials. The waste mass will comprise non-hazardous waste and stable non-reactive hazardous waste. The fine grained protection layer and waste will be placed and compacted so as to avoid tension being mobilised in the geocomposite drainage and protection layer and underlying layers. The geocomposite layer will be inspected and monitored during waste placement.

3.11 The sideslope lining system will be constructed at the same gradient as the sideslope sub-grade. The sideslope lining system will be constructed with typical vertical heights of between 7m and 10m.

Waste mass model

3.12 Temporary waste slopes will be constructed at a gradient of 1v:1.5h. The maximum vertical height of the temporary waste slopes will be approximately 19m. The waste will be placed and compacted in horizontal layers. The waste will comprise fine grained, non-biodegradable, non-hazardous and stable non-reactive hazardous wastes. As a result it is considered that settlement and consolidation of the waste mass will be substantially complete prior to capping and restoration of the site. It is anticipated that daily cover materials will be selected from suitable excavated or imported materials.

Leachate model

3.13 During the operational phase of the landfill cells leachate levels will be maintained at a maximum of 1.5m above the top of the basal liner. Following completion of the operational phase leachate levels will continue to be maintained at a maximum of 1.5m above the top of the basal liner. However a second separate conceptual model where unmanaged leachate levels are allowed to rise to a level higher than 1.5m is considered in order to assess risks to stability should leachate levels rise to the point of maximum containment within the site.

Capping and restoration system model

3.14 A 0.3m thick sub-grade will be placed on the top of the waste prior to the placement of an engineered landfill cap. The future landfill capping will comprise a 1m thick compacted low permeability clay liner with a maximum hydraulic conductivity of $1x10^{-9}$m/s. A 0.3m thick layer of site derived sand layer will be placed over the engineered landfill cap to provide protection and drainage.

3.15 Over the majority of the site and along the western, northern and eastern flanks of the site a combined 1m to 1.5m thickness of restoration soils will be placed over the cap. In these areas the restoration soils will be placed at the same slope gradients as the cap.

3.16 In the southern area of the site, where the site abuts the Cooks Hole Quarry Site, the capping typically has steeper gradients than the southern restoration slopes. With the capping slopes tying into the perimeter lining system whereas the restoration slopes tie into the restoration of the Cooks Hole Quarry Site, bolstering the underlying capped slopes.

3.17 In order to assess the range of capping and restoration slopes identified in the design the following conceptual slope models have been developed comprising:

Western, northern and eastern flanks of the site:

- a typical worst case long slope with a gradient of 1v:10h and a length of 150m (15m high), and

- a worst case steep slope with a slope gradient of 1v:3h and a height of 6m (18m long) which represent the steepest slopes on the cap design and the maximum height over which this gradient is present in these areas of the site.

Southern area of the site:

- a worst case capped and partially restored slope, with 1m of restoration soils, with a gradient of 1v:3h and a height of 14m (42m long), and
- this 14m high slope then supported (bolstered) by a fully restored slope gradient of 1v:12h and a length of 168m.

4. Risk screening

Introduction

4.1 In this section a detailed risk screen is carried out of the conceptual model for the future excavation, construction and restoration of landfill phases at Thornhaugh Landfill Site. The risk screening is a qualitative assessment which identifies where further qualitative or quantitative assessments of the stability of the future landfill phases are necessary.

Sub-grade for basal liner screening

4.2 As the surface of the basal sub-grade has a shallow gradient of approximately 1v:100h and is anticipated to comprise competent quarry backfill materials it is considered that it is not necessary to undertake slope stability analysis or to give further consideration to settlement or instability of the basal sub-grade.

4.3 It is considered that there is no potential for basal heave. Based on information provided in the HRA the surface of the subgrade to the basal liner will be a minimum of 1m above maximum recorded groundwater levels.

Sub-grade for sideslope screening

4.4 Although the materials and proposed sideslope gradient of 1v:2.5h are consistent with and have been demonstrated to be stable in existing landfill phases at the site it is considered necessary to provide a quantitative analysis of the stability of the sideslope sub-grade to verify that a suitable factor of safety against slope failure can be calculated.

4.5 It is considered that the sideslope sub-grade at the western and northern boundaries of Phases 1 and 2 where a section of material will be left in situ between the existing contained Phase 3 and future Phase 1 and the remaining section of Phase 2 East is a situation similar to the other sideslopes at the site, therefore the assessment of the sideslope sub-grade at the western and northern boundaries of Phases 1 and 2 is addressed by the assessment of the other sideslopes at the site.

4.6 It is anticipated that the sideslope sub-grade is dry as the groundwater conditions are the same as for the basal sub-grade and it is considered that no assessment of the impact of seepage from the sideslope sub-grade is necessary.

Temporary slopes screening

4.7 Although slopes that are excavated in land adjacent to phase boundaries that are internal to the site will be temporary it is considered necessary to assess the stability of the slopes quantitatively due to their heights of up to 14m and slope gradients of up to 1v:1.5h. Stability of the temporary slopes is assessed for the slopes excavated into backfill materials and the slopes excavated into backfill and waste materials.

Basal lining system screening

4.8 As the basal lining system will be constructed over a competent sub-grade at a shallow gradient of approximately 1v:100h it is considered that it is not necessary to undertake slope stability analysis for the basal clay liner or undertake assessment of the interface stability of the geosynthetic and granular components of the basal lining system, protection layers and leachate drainage blanket.

4.9 Leachate extraction and monitoring wells will comprise vertical telescopic shafts which will be designed and installed progressively to accommodate axial movement and consolidation as the waste is placed. As a result it is considered that it is not necessary to assess the basal lining system with respect to bearing pressures from the leachate extraction and monitoring system.

4.10 As it is considered that there is no risk of basal heave of the basal liner system this will not be assessed quantitatively. Based on information provided in the HRA the base of the basal liner will be a minimum of 1m above maximum recorded groundwater levels.

4.11 It is necessary to carry out quantitative analysis of the stability of the inter-cell bunds which will be constructed with a slope gradient of 1v:2h and to a height of between 2m and 3m. The analysis is undertaken to assess the rotational stability of the clay forming the bund and the translational stability of the geomembrane, protection geotextile and granular leachate drainage blanket placed up and over the inter-cell bund slopes prior to waste placement.

Sideslope lining system screening

4.12 As the sideslope lining system will be constructed over the sideslope sub-grade the principal factor influencing stability of the sideslope lining system is the slope gradient which is 1v:2.5h. It is considered necessary to undertake a quantitative assessment of the overall slope stability for the sideslope clay liner.

4.13 It is necessary to undertake an assessment of the interface stability of the clay, geosynthetic and granular components of the sideslope lining system and leachate drainage blanket placed up the first 2m vertical height of the sideslope liner prior to waste placement.

4.14 The fine grained protection layer and waste will be placed progressively in horizontal layers to avoid tension being mobilised in the geocomposite drainage and protection layer and underlying layers. The geocomposite layer will be inspected and monitored during waste placement. As a result it is considered unnecessary to assess further the stability of the sideslope composite drainage system during or following waste placement.

Waste mass screening

4.15 As the waste mass will be placed to a maximum slope gradient of 1v:1.5h it is considered that quantitative analysis of the slope stability of the waste mass is necessary.

Capping and restoration system screening

4.16 As the slope of the capping system and restoration system is locally at a maximum gradient of up to 1v:3h it is considered necessary to provide quantitative analysis of the stability of the capping and restoration system.

4.17 As the waste will be placed and compacted in horizontal layers and will comprise fine grained, non-biodegradable, non-hazardous and stable non-reactive hazardous wastes, it is considered that settlement and consolidation of the waste mass will be substantially complete prior to capping and restoration of the site. As a result no significant settlement is anticipated to take place following future capping and restoration. As a result it is considered unnecessary to assess further the impact of long term settlement on the future capped and restored profile.

4.18 As the waste placed at the site does not generate a significant amount of landfill gas as the waste is predominantly non-biodegradable, non-hazardous and stable non-reactive hazardous wastes, it is concluded that there will be no significant gas pressure acting on the cap.

4.19 As leachate levels will be managed below the level of the underside of the cap it is considered unnecessary to assess the effect of leachate pressures acting on the underside of the cap. Nevertheless an assessment is considered appropriate where unmanaged leachate levels are allowed to rise to a level higher than 1.5m above the base in order to assess risks to stability should leachate levels rise to the point of maximum containment within the site.

5. Lifecycle phases

5.1 It is proposed that the development of the landfill and waste mass will take place in the phases as detailed on Figure SRA 5. The proposed phasing is approximate and, while the principles and order of phasing are unlikely to change, phase boundaries and haul routes may change in response to operational conditions. The boundary between future Phases 1 and 2 East and the existing Phase 3 will be constructed against and be connected to the southern boundary of Phase 3. The western boundary of Phase 2 abuts and is connected to the eastern boundary of the existing Phase 5. A complete and continuous lining system is being installed progressively across the full landfill area. Completed phases will be capped progressively as landfilling continues in newly engineered phases.

Groundwater management

5.2 Active management of groundwater will not be necessary as the maximum recorded groundwater levels are below the proposed base of the current and future landfill phases.

Leachate management

5.3 During the operational phase leachate levels will be maintained at a maximum level of 1.5m above the top of the basal liner. Leachate will collect in the leachate drainage blanket and be channelled through leachate collection pipework into a sump present in the lowest point of each phase. Hydraulic separation between the phases will be provided by the low permeability inter-cell bunds. Leachate levels will be maintained by pumping from the leachate collection sumps facilitated by a vertical extraction well in each phase.

5.4 Following completion of the operational phase the leachate levels will continue to be managed, however if unmanaged leachate levels are allowed to rise to a level higher than 1.5m is considered that the rise in leachate levels would be limited to the point of maximum containment within the site.

Landfill gas management

5.5 As detailed in the LFGRA report, based on the low organic content of wastes accepted currently and proposed to be accepted at the site in the future and the associated low potential for the generation of landfill gas there are no proposals to collect landfill gas from future phases of the site. As a result no infrastructure for the control or extraction of landfill gas is included in the proposed design. In order to confirm that the waste deposited in future phases has a negligible potential to generate landfill gas leachate wells in each of the phases will be monitored for landfill gas.

Daily cover characteristics

5.6 Following placement waste will be covered daily consistent with practice at the current operational landfill. Where asbestos waste is deposited the upper surface of the asbestos waste will be covered with a minimum 1m thickness of suitable daily cover material consistent with previous practice. Temporary slopes excavated between phases which comprise waste materials will be covered with cover materials at the end of each day.

6. Data summary

6.1 The geotechnical parameters used in the SRA are derived from the SRAs undertaken as part of the 2014 SRA[5] for the existing landfill area and where relevant the SRAs undertaken for ENRMF. Data from the 2004 SRA[3] and from the 2007 SRA[4] that focused on the stability of a proposed separation bund between Phases 1 and 2 and Phases 4 and 7 have been reviewed. In addition SRAs that were undertaken for the nearby Augean ENRMF in August 2008[7], November 2009[8] and May 2021[6] have been reviewed as part of this assessment as the site derived clay liner material used at ENRMF has been and will be used to construct the low permeability clay liners at Thornhaugh and the overburden materials from ENRMF will be used in the restoration of Thornhaugh.

6.2 Geotechnical parameters for the geosynthetic materials used in the design are based on values presented in Jones and Dixon "Stability of Landfill Lining Systems" Environment Agency R&D Technical Report PI-385 TR1[12]. Data have been sourced from other Environment Agency Guidance such as LFE5 – Using Geomembranes in Landfill Engineering[13] and manufacturers' data sheets for products used previously or anticipated to be used in construction works at the site.

6.3 A summary of the values for the geotechnical parameters used in the assessment is presented in Table SRA2 and the justifications for their use are presented in Section 8 of this report.

6.4 Values for the parameters relating to groundwater levels, leachate levels, phasing and the lifecycle of the site are consistent with the HRA and ESID sections of the application to vary the existing permit.

[12] R&D Technical Report PI-385. 'The stability of landfill lining systems'. Environment Agency, 2000.
[13] LFE 5 – Using geomembranes in landfill engineering. Environment Agency.

7. Justification for modelling approach and software

7.1 In this section of the report a description is provided of the general approach that is taken to the modelling followed by a description of the approach that is taken for each component of the CSM identified as needing further assessment based on the risk screening.

7.2 The SRA analyses are undertaken in general accordance with conventional British Standard methodologies using global factors of safety rather than incorporating partial factors into the individual parameters describing the slopes, strengths and forces. This is to maintain consistency with the previous SRAs undertaken at the site and Environment Agency guidance[12] which references the use of both global and partial factors.

Computer software used in the analysis

7.3 Analysis of stability against rotational failure is undertaken using the two dimensional limit equilibrium programme Rocscience Inc. Slide2. Slopes are analysed using the Spencer method. The Spencer method has been selected as it is one of the more mathematically robust limit equilibrium methods and considers both shear and normal inter-slice forces together with moment and force equilibrium[14]. It is considered that this method is more appropriate than simpler methods such as Bishop's Simplified Method or Janbu's Simplified Method.

7.4 Analysis of stability against translational sliding failures at the interfaces of the geosynthetic materials and soils are assessed using spreadsheets developed using the approach recommended by Jones and Dixon (1998) as provided in R&D Technical Report PI-385[12]. The spreadsheets include calculation of tensile forces developed within the geosynthetic materials.

Sideslope sub-grade modelling approach

7.5 Analysis of the stability of the sideslope sub-grade against rotational failure under long term drained (effective stress) conditions is undertaken for the conceptualised worst case slope and materials with respect to stability. As the materials from

[14] Stability Modelling with Slide2 Modeler Version 9.034 64bit. 2D Limit Equilibrium Analysis for Slopes. (dated: April 2024). Rocscience Inc.

which the sideslope sub-grade is formed comprise quarry backfill, which based on the 2004 SRA[3] are classified as granular materials with respect to their engineering properties, the stability of the sideslope sub-grade is not modelled under undrained (total stress) conditions. For the purpose of modelling it is assumed conservatively that all of the sideslope sub-grade comprises backfilled materials rather than in situ materials as the backfilled materials are assessed to have lower strength parameters than the in situ materials. As the slope gradient of 1v:2.5h is consistent for all areas of the sideslope sub-grade and the materials from which the sub-grade is constructed are assumed conservatively to be backfill, the worst case with respect to the stability of the sideslope sub-grade is considered to comprises the location where it is at its maximum height. The maximum height of the sideslope sub-grade is approximately 11m and this height is used in the model with a 1v:2.5h slope gradient which comprises the maximum slope gradient at which the sideslope sub-grade will be cut. The groundwater level is modelled at 1m below the surface of the basal subgrade.

Temporary slopes modelling approach

7.6 Analysis of the stability of the temporary slopes against rotational failure is undertaken for the conceptualised worst cases with respect to stability. Separate analysis is undertaken for temporary slopes that will be excavated in backfilled materials and for temporary slopes that will be excavated in waste materials due to the different geotechnical properties of these materials. The maximum height of the temporary slopes will be approximately 14m and this height is used in the model together with the maximum slope gradient to which the temporary slopes will be constructed of 1v:1.5h. A thickness of 10m of waste below a depth of 2.5m below ground level is used for the temporary slopes that are excavated in the waste based on the anticipated greatest thickness of waste that will be present in the temporary slopes. The waste materials and backfill are modelled under long term drained conditions. The groundwater level is modelled at 1m below the surface of the basal subgrade.

Basal liner modelling approach

7.7 Analysis of the stability against rotational failure of the inter-cell bunds together with the interface stability of the geosynthetic components of the lining system and the granular leachate drainage blanket over the inter-cell bunds is undertaken.

7.8 The analysis is undertaken for the bunds in both undrained (short term, total stress) and drained (long term, effective stress) conditions as they will be constructed from cohesive materials which will be left unsupported prior to waste placement. The inter-cell bunds will be modelled as being 3m high with a crest width of 3m and sideslope gradients of 1v:2h. These dimensions are used in the models as they represent the maximum heights and slope gradients for the bunds hence comprise the worst case conceptualisation with respect to rotational stability.

7.9 The translational interface stability of the geosynthetic components of the lining system and granular drainage blanket on the slopes of the inter-cell bund are assessed prior to the placement of supporting waste to assess the stability of the placed granular leachate drainage blanket to the full height of the bund and the tensile forces which may be mobilised within the geosynthetic materials. The stability of the geosynthetic components of the lining system and granular leachate blanket on the slopes of the inter-cell bund have been assessed using short term total stress (drained) and long term effective stress (undrained) shear strength parameters. Following placement of waste in horizontal layers against the drainage gravel the risk posed by failure of the gravel leachate drainage blanket will be reduced due to the buttressing effects of the waste.

Sideslope liner modelling approach

7.10 Analysis of the stability against rotational failure under short term undrained conditions and long term drained conditions is undertaken for the clay component of the sideslope liner as it will be constructed from cohesive materials which will be left unsupported prior to waste placement. The dimensions for the sideslope liner assessed in the modelling are based on the conceptualised worst case dimensions for the sideslope sub-grade over which it will be constructed. As a result the dimensions of the sideslope liner assessed comprise a height of 10m and slope gradient of 1v:2.5h. The sideslope lining system will be constructed above the 1m thick basal liner and extend up the remaining height of the sub-grade slope and will comprise a minimum 1m thick compacted low permeability clay liner.

7.11 A 2mm thick double textured HDPE geomembrane will be placed over the low permeability clay liner constructed on the sideslope. A protection geotextile and granular leachate drainage blanket will extend from the basal lining system to a vertical height of 2m up the sideslope liner. Above this a protection and drainage geocomposite will be placed to the full height of the sideslope. The translational stability of the unsupported granular leachate drainage blanket and interface stability of the underlying geosynthetic components of the side slope lining system prior to placement of the waste is considered using short term total stress (undrained) and long term effective stress (drained) shear strength parameters.

Waste mass modelling approach

7.12 Analysis of stability against rotational failure is undertaken for the temporary slopes that are formed in the waste mass. The waste mass model includes support at the toe of the waste slopes provided by the inter-cell bunds under drained and undrained conditions. The maximum slope gradient proposed for the temporary slopes in the waste mass of 1v:1.5h and the maximum waste slope height of 19m is used in the assessment in order to model the conceptualised worst case with respect to the stability of the slopes.

Capping system modelling approach

7.13 In order to assess the stability against rotational failure for the range of capping and restoration slopes the following conceptualised worst cases slopes are modelled:

Western, northern and eastern flanks of the site:

- a typical long slope with a gradient of 1v:10h and a length of 150m (15m high), and
- a conceptualised worst case steep slope with a slope gradient of 1v:3h and a height of 6m (18m long) which represents the steepest slopes on the cap design and the maximum height over which this gradient will be present in these areas of the site.

Southern area of the site:

- a worst case capped and partially restored slope, with 1m of restoration soils, with a gradient of 1v:3h and a height of 14m (42m long), and
- this 14m high slope is then supported (bolstered) by a fully restoration slope gradient of 1v:12h and a length of 168m.

7.14 The components analysed against rotational stability are the underlying waste mass, cap sub-grade layer, 1m clay capping layer where present, and the 1m thick and the 1.5m thick restoration soils. The models have been assessed using short term (undrained) and long term effective stress (drained) shear strength parameters where relevant.

7.15 Each rotational stability model has been assessed with leachate levels representative of the managed and unmanaged lifecycle phases. During the operational phase leachate levels are assessed at 1.5m above the top of the basal liner. During the post-operational phase it is expected that maximum leachate levels will remain at a level 1.5m above the top of the basal lining system. However for the purposes of this assessment leachate levels have been analysed at higher levels which correspond to a maximum containment level (i.e. at the crest of the sideslope liner). As leachate levels at maximum containment level are representative of the post-operational phase these models are assessed under long term drained conditions only.

8. Justification for the geotechnical parameters used in the analyses

8.1 The values for the geotechnical parameters selected for use in the analyses are discussed and references are provided of their sources below and in Table SRA2.

Geotechnical parameters selected for the basal and sideslope sub-grade

8.2 The values for the geotechnical parameters used in the model for the backfill which forms the sub-grade are those used in the 2014 SRA[5] and are based on those used for backfill in the sub-grade analyses from the 2004 SRA[3]. In the 2014 SRA the backfill was assigned a friction angle of 30° and an apparent cohesion of 5kPa and these values have been selected for the backfill which forms the basal and sideslope sub-grade. In the 2014 SRA[5] the backfill was assigned a bulk unit weight of 18.5kN/m^3 and these values have been selected for the backfill which forms the basal and sideslope sub-grade.

Geotechnical parameters selected for the landfill liner and leachate drainage blanket

8.3 The values for the geotechnical parameters for the low permeability clay component of the lining system are those used in the 2014 SRA[5] and are presented in Table SRA2. Based on MJCA's experience of the design and construction quality assurance of low permeability liners constructed from the Blue Upper Estuarine Clay (now known as the Rutland Formation) and the Brown Boulder Clay a single set of values for geotechnical parameters has been selected to represent both types of clay for the purpose of this SRA. The clay liner materials will be sourced from ENRMF. The values for the geotechnical parameters for the clay liner used in this assessment are consistent with those parameters presented in the previous SRAs for Thornhaugh and ENRMF and include an apparent cohesion under long term drained conditions of 2kPa. This apparent cohesion is to promote the analysis of deeper higher hazard rotational failures in the models rather than small and shallow translational slip surfaces and to reflect observations of the long term stability of slopes constructed from the two types of clay used at Thornhaugh Landfill Site and at ENRMF. This is consistent with the 2021 SRA[6] submitted for ENRMF as part of the western landfill area permit variation application.

8.4 The values for the parameters used for the assessment of the interface stability of the components of the lining system and granular leachate drainage blanket are presented in Table SRA2 and are those used in the 2014 SRA[5]. The interface shear strength values are taken from Jones and Dixon “Stability of Landfill Lining Systems” Environment Agency R&D Technical Report PI-385 TR1[12]. The tensile strength properties of the geomembrane component of the lining system are based on values presented in Environment Agency Guidance LFE5 – Using Geomembranes in Landfills[13]. The tensile strength properties of the geotextile component of the lining system are based on values presented on Geofabrics datasheets (Appendix SRA3 of the 2014 SRA[4]) for Geofabrics HPS7 product which is likely to be equivalent to the lowest strength of geotextile specified in the works based on the depth of waste and size of drainage stone. The values for the geotechnical parameters for the bulk unit weight, friction angle and apparent cohesion of the gravel used in the leachate drainage blanket are taken from the values used in the 2014 SRA[5] for Thornhaugh.

8.5 It is anticipated that it will be necessary to obtain representative interface shear strength values, tensile strength values and cylinder test results for the materials proposed for use in the construction works to demonstrate that they can achieve the same stability criteria and level of protection assumed in this assessment. Further assessments may be necessary prior to incorporation of geosynthetic materials into the lining system.

Geotechnical parameters selected for the waste mass

8.6 The values for the geotechnical parameters used in the analyses of the waste mass are presented in Table SRA2 and are those used in the 2014 SRA[5]. The values for the geotechnical parameters selected for the waste mass are those presented in Jones and Dixon “Stability of Landfill Lining Systems” Environment Agency R&D Technical Report PI-385 TR1 (Reference 9).

Geotechnical parameters selected for the capping system

8.7 The values for the geotechnical parameters used for the assessment of the stability of the components of the capping system are presented in Table SRA2.

8.8 The values for the geotechnical parameters for the low permeability clay cap component of the capping system are those used for the clay liner (paragraph 8.3). The values used for the sand drainage and protection layer are consistent with those used for the quarry backfill (paragraph 8.2) however the apparent cohesion has been reduced from 5kPa to 0kPa to reflect that the material is no longer in situ and has been worked and behaves as a granular sand. In addition the saturated unit weight has been used to reflect the potential for the sand to contain water when used as a drainage layer.

8.9 It is anticipated that the restoration soils which will be placed over the cap will be imported materials comprising the excavated in situ materials from ENRMF. The values of the geotechnical parameters for the bulk unit weight, friction angle and apparent cohesion of the restoration soils are the same as those used for the site derived excavated materials used in the restoration of ENRMF as presented in in the 2021 SRA[6] for ENRMF.

8.10 It is anticipated that the materials used to form the sub-grade to the capping layer will comprise the same materials placed and compacted in the same manner as those used in the clay liner and cap and will have the same geotechnical parameters as those used for the clay liner and cap.

9. Selection of appropriate factors of safety

9.1 In the following paragraphs the factors of safety (FOS) selected for the assessment of each component of the future landfill phases identified in the risk screening as needing further assessment are presented. The general principle is that a minimum global FOS of 1.3 has been set where a slope or structure is not buried and can be monitored and if necessary repaired should it show signs of instability. The FOS could be reduced to 1.2 or 1.1 if the slope is a temporary slope which if it were to show signs of failure would not have a detrimental effect on existing engineering structures at the site such as unsupported inter-cell bunds, internal temporary waste slopes or stockpiles. A higher factor of safety approaching 1.4 or 1.5 may be more appropriate where slopes or structures are buried or no longer monitored. Where the integrity of geosynthetic components of the lining system are analysed no tension should be mobilised and forces should be transferred to the underlying layers.

9.2 It is considered that the selected factors of safety are consistent with those recommended in the Environment Agency guidance[12] and with global factors of safety based on combined partial factors recommended in Eurocode 7. The factors of safety used for each element assessed in the SRA are summarised in Table SRA3 and are consistent with the factors of safety (FOS) selected in the 2014 SRA.

Factor of safety for the sideslope sub-grade

9.3 The target FOS for the sideslope sub-grade is 1.3 which will apply prior to the construction of the lining system and placement of waste against the completed sideslopes when it will be possible to observe and monitor their stability. The consequence of failure of the sideslope sub-grade prior to construction of the liner and prior to placement of the waste is limited as there is no landfill containment, leachate or gas control infrastructure or structures which could be affected by a slope failure. This FOS is therefore relevant to the short term total stress (undrained) state and to the long term effective stress (drained) state stability analyses of the sideslope sub-grade prior to construction of the lining system or placement of waste. The long term effective stress (drained) stability of the buried sideslope sub-grade is considered as part of the sideslope liner and waste mass stability assessments.

Factor of safety for temporary excavated slopes

9.4 The target FOS for the temporary excavated slopes is 1.1 as the consequence of failure of the slopes is limited as it is unlikely that landfill containment, leachate or gas control infrastructure will be affected by a slope failure. In addition the slopes are temporary and will be left open so can be monitored and remediated as necessary.

Factor of safety for the basal liner

9.5 The target FOS for the rotational stability of the inter-cell bund and the interface stability of the composite lining system and leachate drainage blanket on the slopes of the inter-cell bunds is 1.2. As the composite lining system and leachate drainage blanket on the slopes of the inter-cell bunds can be monitored prior to waste placement and remediated if necessary the consequences of failure are limited. No tension should be mobilised in the geosynthetic components of the bund prior to waste placement and during waste placement procedures will be such that no tension is mobilised. Following waste placement the composite lining system and leachate drainage blanket on the slopes of the inter-cell bunds will be supported and buttressed eliminating the risk of long term failure.

Factor of safety for the sideslope liner

9.6 The target FOS for the sideslope liner is 1.3 for the construction phase of the lining system and prior to the placement of waste against the completed slopes during which it will be possible to observe and monitor the stability. This FOS is therefore relevant to the short term total stress (undrained) and to the long term effective stress (drained) stability analyses of the sideslope liner prior to waste placement.

9.7 The long term effective stress (drained) stability of the buried sideslope liner following placement of waste is considered as part of the waste mass stability assessment.

9.8 The target FOS for the translational and interface stability of the geosynthetic and granular components of the lining system for the first 2m of vertical height up the side slopes is 1.3. The target will be for no tension to be mobilised in the geosynthetic components prior to waste placement and during waste placement procedures will be such that no tension is mobilised.

Factor of safety for the waste mass

9.9 The effects of waste mass failure would be confined to the landfill site and there will be no effect on structures outside the landfill. A stability failure of the waste mass could result in damage to the lining system. It is considered that a target FOS of 1.3 is appropriate for large full height waste slopes, however internal temporary waste slopes which are unlikely to damage the lining system if they fail may have a reduced FOS of 1.1. It is considered that a target FOS of 1.2 against rotational failure of the inter-cell bund is appropriate as identified previously. These FOS are relevant to the short term total stress (undrained) and to the long term effective stress (drained) stability analyses of the waste mass, bunds and liner.

Factor of safety for the capping system

9.10 It is unlikely that a failure of the capping system and restoration soils will affect structures external to the landfill but could result in odour nuisance and an increase in the volume of water infiltrating the waste mass and as a result an increase in the generation of leachate. Following completion of the landfill the frequency at which slopes will be monitored will be reduced and it is considered that a FOS of 1.4 is appropriate to both the short term total stress (undrained) and to the long term effective stress (drained) stability analyses of the capping system and restoration soils.

10. Analyses

10.1 The results of the stability analyses are detailed in the following section and are summarised in Table SRA4. The results of the analysis of rotational failure are presented in Appendix SRA1 and the results of the analysis for translational failure are presented in Appendix SRA2.

Basal sub-grade analysis

10.2 No analysis has been undertaken for the basal sub-grade. See the basal sub-grade risk screening paragraphs 4.2 and 4.3.

Sideslope sub-grade analysis

10.3 Analysis has been carried out of the long term effective stress (drained) stability of the sideslope sub-grade for the maximum slope height of 11m and maximum gradient of 1v:2.5h that will be constructed at the site. The calculated FOS against rotational failure of the sideslope sub-grade is 1.921. The Slide2 plot for the analysis is presented as Plot 1 in Appendix SRA1.

Temporary slopes analysis

10.4 Analysis has been carried out of the long term effective stress (drained) stability of the temporary sideslopes that will be formed in the backfill materials for the maximum slope height of 14m and maximum gradient of 1v:1.5h that will be constructed at the site. The calculated FOS against rotational failure of the temporary slope in the backfilled materials is 1.218. The Slide2 plot for the analysis is presented as Plot 2 in Appendix SRA1.

10.5 Analysis has been carried out of the long term effective stress (drained) stability of the temporary sideslopes that will be formed in the backfill and waste materials for the maximum slope height of 14m and maximum gradient of 1v:1.5h that will be constructed at the site. The calculated FOS against rotational failure of the temporary slope in the backfill and waste materials under drained (long term) conditions is 1.143. The Slide2 plot for the analysis is presented as Plot 3 in Appendix SRA1.

Basal lining system analysis

10.6 The stability of the inter-cell bund against rotational failure has been analysed quantitatively by modelling in Slide2. Analyses have been carried out to determine the short term total stress (undrained) and long term effective stress (drained) stability of the inter-cell bund for the maximum anticipated 3m high bund at the maximum slope gradient of 1v:2h and crest width of 3m. The calculated FOS against rotational failure of the inter-cell bund is 4.460 for the undrained (short term) conditions and 1.209 for the drained (long term) conditions. The Slide2 plots for the analyses are presented as Plots 4 and 5 in Appendix SRA1.

10.7 Analyses have been carried out of the short term stability of the geosynthetic lining and granular leachate drainage blanket up the slopes of the inter-cell bunds. The calculated FOS against translational failure of the granular leachate drainage blanket is 1.53 when the underlying clay bund is in short term undrained conditions and 1.53 when the underlying bund is in long term drained conditions. No tension is mobilised in the geomembrane or protection geotextile components of the inter-cell bund lining system as the forces are transferred to underlying layers. The calculations for the assessments are presented as Spreadsheets 1 to 4 at Appendix SRA2. The results are the same for the undrained clay (long term) and for the drained clay (short term) conditions as the critical failure interface is not the clay/geomembrane interface.

Sideslope lining system analysis

10.8 Analyses have been carried out of the short term total stress (undrained) and long term effective stress (drained) stability of the sideslope clay liner for the maximum height of the sideslope of 10m and the maximum gradient of 1v:2.5h that will be constructed at the site. The calculated FOS against failure of the sideslope liner is 2.125 for the undrained (short term) conditions and 1.319 for the drained (long term) conditions. The Slide2 plots for the analyses are presented as Plots 6 and 7 in Appendix SRA1.

10.9 Analyses have been carried out of the stability of the extension of the basal granular leachate drainage blanket to a vertical height of 2m up the sideslopes prior to deposition of waste. The calculated FOS against translational failure of the granular leachate drainage blanket for a maximum height of 2m at a gradient of 1v:2.5h is 1.96 for both drained and undrained clay conditions. No tension is mobilised in the geomembrane or protection geotextile components of the sideslope lining system with the forces transferred to underlying layers. The calculations for the assessments are presented as Spreadsheets 5 to 8 at Appendix SRA2. The results are also presented in Table SRA4 and are the same for the drained clay (short term) and for the undrained clay (long term) assessments as the critical failure interface is not the clay/geomembrane interface.

Waste mass analysis

10.10 Analysis of the stability of the temporary waste slope with respect to rotational failure has been undertaken for long term effective stress (drained) conditions of the waste with support provided by the inter-cell bund and liner under drained and undrained conditions at the toe of the waste slope.

10.11 The maximum waste slope height of 19m and gradient of 1v:1.5h that are present at the site were assessed. The calculated FOS against failure of the 1v:1.5h temporary waste slope only is 1.135. The calculated FOS of the 1v:1.5h temporary slope for failure through the inter-cell bund at the toe of the waste slope is 1.495 for undrained conditions and 1.124 when the inter-cell bund is drained. When the inter-cell bund is drained the lowest FOS against failure occurs in the inter-cell bund rather than in the waste mass at a FOS below the target FOS of 1.2. The Slide2 plots for the analyses are presented as Plots 8 and 9 in Appendix SRA1.

10.12 As a result of the low FOS for the failure through the inter-cell bund at the toe of the waste slope for undrained conditions an assessment of the maximum waste slope height of 19m with a slackened gradient 1v:2h was also undertaken. The calculated FOS against failure of the 1v:2h temporary waste slope through the inter-cell bund at the toe of the waste slope is 1.391 for undrained conditions and 1.209 when the inter-cell bund is drained. The calculated FOS against failure of the 1v:2h temporary waste slope through the liner below the waste slope is 1.369 for drained conditions. The Slide2 plots for the analyses are presented as Plots 10 and 11 in Appendix SRA1.

Capping system analysis

Northern area: Western, northern and eastern flanks of the site

10.13 The stability of the northern area capping system, consisting of a 0.3m clay subgrade, 1m engineered clay cap and 0.3m sand drainage and protection layer, has been analysed against rotational failure. The analysis has been undertaken quantitatively by modelling in Slide2 at a number of conceptual sections through the restoration profile for 1m and for 1.5m of restoration soils. The stability of a long section at a gradient of 1v:10h for a slope length of 150m (15m high) and a steep section at a gradient of 1v:3h at a height of 6m (18m long) have been considered. These slopes have been assessed under short term total stress (undrained) and long term effective stress (drained) conditions together with managed and unmanaged leachate. Managed leachate levels have been analysed at a maximum level of 1.5m above the top of the basal liner. Unmanaged leachate levels have been modelled at maximum containment levels which have been taken as the crest of the sideslope liner.

10.14 The calculated FOS against rotational failure of the capping system and 1m thickness of restoration soils for the long section with managed leachate levels is 4.837 for short term total stress (undrained) conditions and 4.616 for long term effective stress (drained) conditions. The calculated FOS against rotational failure of the capping system and 1m thickness of restoration soils for the steep section with managed leachate levels is 2.157 for the short term total stress (undrained) and 1.486 for the long term effective stress (drained) conditions and managed leachate. The Slide2 plots for the assessment are presented as Plots 12 to 15 in Appendix SRA1 and the results are presented in Table SRA4.

10.15 The calculated FOS against rotational failure of the capping system and 1m thickness of restoration soils for the long section with unmanaged leachate at maximum containment levels is 4.619 for long term effective stress (drained) conditions. The calculated FOS of the capping system and 1m restoration soils for the steep section with unmanaged leachate at maximum containment levels is 1.486 for long term effective stress (drained) conditions. The Slide2 plots for the assessment are presented as Plots 16 and 17 in Appendix SRA1. The results are presented in Table SRA4.

10.16 The calculated FOS against rotational failure of the capping system and 1.5m thickness of restoration soils for the long section with managed leachate levels is 4.774 for short term total stress (undrained) conditions and 4.610 for long term effective stress (drained) conditions. The calculated FOS against rotational failure of the capping system and 1.5m thickness of restoration soils for the steep section with managed leachate levels is 2.091 for the short term total stress (undrained) and 1.544 for the long term effective stress (drained) conditions and managed leachate. The Slide2 plots for the assessment are presented as Plots 18 to 21 in Appendix SRA1 and the results presented in Table SRA4.

10.17 The calculated FOS against rotational failure of the capping system and 1.5m thickness of restoration soils for the long section with unmanaged leachate at maximum containment levels is 4.614 for long term effective stress (drained) conditions. The calculated FOS of the capping system and 1.5m restoration soils for the steep section with unmanaged leachate at maximum containment levels is 1.544 for long term effective stress (drained) conditions. The Slide2 plots for the assessment are presented as Plots 22 and 23 in Appendix SRA1. The results are presented in Table SRA4.

Southern area of the site

10.18 The stability of the southern area capping system, consisting of a 0.3m clay subgrade, 1m engineered clay cap and 0.3m sand drainage and protection layer, has been analysed against rotational failure. The analysis has been undertaken quantitatively by modelling in Slide2 at two conceptual sections through the restoration profile consisting of:

- a worst case capped but only partially restored slope, with 1m of restoration soils, at a gradient of 1v:3h for a slope height of 14m (42m long), and
- this 14m high slope then supported (bolstered) by a fully restored slope gradient of 1v:12h and a length of 16m.

10.19 These slopes have been assessed under short term total stress (undrained) and long term effective stress (drained) conditions together with managed and unmanaged leachate. Managed leachate levels have been analysed at a maximum level of 1.5m above the top of the basal liner. Unmanaged leachate levels have been modelled at maximum containment levels which have been taken as the crest of the sideslope liner.

10.20 The calculated FOS against rotational failure of the partially restored capping system with 1m thickness of restoration soils with managed leachate levels is 2.119 for short term total stress (undrained) conditions and 1.409 for long term effective stress (drained) conditions. The calculated FOS against rotational failure of the fully restored and supported (bolstered) capping system with managed leachate levels is 5.818 for the short term total stress (undrained) and 5.939 for the long term effective stress (drained) conditions and managed leachate. The Slide2 plots for the assessment are presented as Plots 24 to 27 in Appendix SRA1 and the results are presented in Table SRA4.

10.21 The calculated FOS against rotational failure of the partially restored capping system with 1m thickness of restoration soils with unmanaged leachate at maximum containment levels is 1.409 for long term effective stress (drained) conditions. The calculated FOS of the fully restored and supported (bolstered) capping system with unmanaged leachate at maximum containment levels is 5.939 for long term effective stress (drained) conditions. The Slide2 plots for the assessment are presented as Plots 28 and 29 in Appendix SRA1. The results are presented in Table SRA4.

11. Assessment

Basal sub-grade assessment

11.1 Based on the qualitative and risk screening assessments undertaken it is considered that the basal sub-grade is stable.

Sideslope sub-grade assessment

11.2 The results of the analysis for stability of the sideslope sub-grade against rotational failure for the maximum anticipated slope height of 11m at a maximum gradient of 1v:2.5h show that the sideslope sub-grade has factors of safety above the target FOS of 1.3.

Temporary slopes assessment

11.3 The results of the analysis for stability of the temporary slopes formed in the backfill and in the waste materials against rotational failure for the maximum anticipated slope height of 14m at a maximum gradient of 1v:1.5h show that the temporary slopes have factors of safety above the target FOS of 1.1.

Basal lining system assessment

11.4 Based on the qualitative and risk screening assessments undertaken it is considered that the basal lining system is stable.

11.5 The results of the rotational stability analyses for the inter-cell bund for the maximum slope height of 3m at a gradient of 1v:2h and crest width of 3m show that the inter-cell bunds have FOS above the target FOS of 1.2 in the short term total stress (undrained) and in the long term effective stress (drained) conditions.

11.6 The spreadsheet analysis of the interface and translational stability for the geosynthetic lining system and leachate drainage blanket on the slopes of the inter-cell bund shows that for a slope height of 3m at a gradient of 1v:2h the FOS for translational stability of the leachate drainage blanket is above the target FOS of 1.2 and no tension is mobilised in the protection geotextile or in the geomembrane.

Sideslope lining system assessment

11.7 The results of the rotational stability analyses for the sideslope lining system modelled for the maximum anticipated slope height of 10m at a gradient of 1v:2.5h show that the sub-grade and clay liner have factors of safety above the target FOS of 1.3 in the short term total stress (undrained) and in the long term effective stress (drained) conditions.

11.8 The spreadsheet analysis of the extension of the granular leachate drainage blanket to a vertical height of 2m up the sideslope at a gradient of 1v:2.5h shows that the granular leachate drainage blanket has a FOS against translational failure above the target of 1.3. No tension is mobilised in the geosynthetic components of the lining system which underlie the granular drainage blanket and forces are transferred to underlying layers.

11.9 Based on the results of the qualitative and risk screening assessment it is concluded that it is not necessary to undertake analysis of the stability of the interfaces of the geomembrane or protection and drainage geocomposite layers overlying the sideslope clay liner during or following waste placement. The waste will be placed progressively in horizontal layers across the full width of the landfill phase to avoid tension being mobilised in the geosynthetic layers. Selected fine grained wastes containing clay, silt, sand and gravel up to 20mm particle size will be used as the first layer placed against the sideslope protection and drainage geocomposites.

Waste mass assessment

11.10 The results of the rotational stability analyses for the 17m high internal temporary waste slopes only at gradients of 1v:1.5h show that the FOS is greater than the target FOS of 1.1. However, the calculated FOS of the 1v:1.5h temporary slope for failure through the inter-cell bund at the toe of the waste slope when the inter-cell bund is drained is below the target FOS of 1.2. As a result further assessment was undertaken with a slackened waste slope gradient 1v:2h. The calculated FOS against failure of the slackened 1v:2h temporary waste slope through the inter-cell bund at the toe of the waste slope is greater than the target FOS of 1.2. In addition the calculated FOS against failure of the 1v:2h temporary waste slope through the liner below the waste slope for drained conditions is greater than the target FOS of 1.3.

Capping system assessment

11.11 The rotational stability of the northern area capping system, 1m and 1.5m of restoration soils and underlying waste mass has been analysed under conditions with leachate levels controlled to 1.5m above the top of the basal liner and following the cessation of leachate management with leachate at the maximum containment levels. The analyses calculate factors of safety greater than the target FOS of 1.4 in the short term total stress (undrained) and in the long term effective stress (drained) analyses and under managed and unmanaged leachate conditions.

11.12 The rotational stability of the southern area capping system and underlying waste mass with partial, 1m of restoration soils, and then fully restored and supported has been analysed under conditions with leachate levels controlled to 1.5m above the top of the basal liner and following the cessation of leachate management with leachate at the maximum containment levels. The analyses calculate factors of safety greater than the target FOS of 1.4 in the short term total stress (undrained) and in the long term effective stress (drained) analyses and under managed and unmanaged leachate conditions.

12. Risk based monitoring scheme

12.1 From the results of the SRA it is calculated that the target factors of safety can be achieved at all stages of the development of the future landfill phases provided that the materials used in the construction of the landfill achieve the values for the geotechnical parameters used in the assessment.

12.2 Topographical surveys will be carried out annually to identify areas of settlement or instability with regular routine visual inspection of the exposed basal and sideslope sub-grade, basal and sideslope lining system, waste mass, capping and restoration system. Following completion of the restoration of the site a visual inspection for signs of settlement or instability will be undertaken during the annual topographical survey visits. The results of the topographical surveys will be forwarded to the Environment Agency in accordance with the reporting requirements of the Permit. Should an area of concern be identified from the regular routine visual inspections or during subsequent inspections the Environment Agency will be notified as soon as practicable. Proposals to monitor, investigate and remediate instability as necessary will be included in the notification to the Environment Agency.

12.3 As part of the CQA procedures for the construction works it will be necessary to obtain representative internal and interface shear strength values, tensile, flow and protection properties for the geosynthetic materials proposed to be used in the construction works to demonstrate that they can achieve the same stability criteria assumed in this assessment and fulfil the design requirements. Where necessary further assessments may be needed prior to the incorporation of geosynthetic materials into the lining system.

12.4 The waste placed at the site will comprising fine grained, non-biodegradable, non-hazardous and stable non-reactive hazardous wastes, and will be placed and compacted in horizontal lifts across the full width of the operational phase. This is to prevent tension and instability of the geosynthetics used in the composite sideslope lining systems and to ensure that settlement and consolidation of the waste mass will be substantially complete prior to capping and restoration of the site. Selected fine grained wastes containing clay, silt and sand and gravel up to 20mm particle size will be used as the first layer placed against the sideslope protection and drainage geocomposite. The sideslope geocomposite will be monitored during waste placement to verify that there is no evidence of tension being mobilised in the geocomposite or damage to the geocomposite and underlying geomembrane liner.

12.5 Temporary waste slopes placed at gradients of 1v:1.5h will be monitored to verify that there is no evidence of instability and supported in the medium to long term by the placement of waste in adjacent phases. Temporary waste slopes which are to be left unsupported beyond the short term shall be placed at gradient of no greater than 1v:2h to improve the medium to longer term stability of the supporting and containing intercell bunds at the toe of the waste slopes.

12.6 Temporary excavated slopes will be monitored to verify that there is no evidence of instability. Should evidence of instability be identified then the slope gradients and heights will be reduced as necessary. Temporary waste slopes will be monitored throughout the life of the site to verify that there is no evidence of instability. Should evidence of instability be identified then the slope gradients of the temporary waste slopes will be reduced as necessary.

12.7 The 0.3m sand drainage layer placed over the capping system shall be formed from site derived sand. It may be necessary to review the shear stress parameters for the engineering clay liner, cap and restoration materials should the nature of the materials used change from those assessed which are assumed to be in situ site derived materials sourced from Augean's nearby ENRMF.

TABLES

Table SRA1

Summary of the proposed design compared with the existing design for future landfill cells at Thornhaugh Landfill

Element	Current design[1]	Proposed design for the future cells at the site
Basal sub-grade		
Strata	Quarry backfill materials comprising mixed granular and cohesive materials derived from the Lincolnshire Limestone Formation and Grantham Formation together with in situ ground comprising rocks from the Lincolnshire Limestone Formation and Grantham Formation.	Quarry backfill materials comprising mixed granular and cohesive materials derived from the Lincolnshire Limestone Formation and Grantham Formation together with in situ ground comprising rocks from the Lincolnshire Limestone Formation and Grantham Formation.
Gradient	A minimum gradient of 1v:100h towards a sump in each landfill phase.	A minimum gradient of 1v:100h towards a sump in each landfill phase.
Formation level	Levels range from approximately 46.5mAOD to 51mAOD and are based on a 1m vertical standoff from groundwater.	Levels range from approximately 48mAOD to 51mAOD as shown on Figure SRA3 and are based on a 1m vertical standoff from groundwater.
Sideslope sub-grade		
Strata	Quarry backfill materials comprising mixed granular and cohesive materials derived from the Lincolnshire Limestone Formation and Grantham Formation together with in situ ground comprising rocks from the Lincolnshire Limestone Formation and Grantham Formation.	Quarry backfill materials comprising mixed granular and cohesive materials derived from the Lincolnshire Limestone Formation and Grantham Formation together with in situ ground comprising rocks from the Lincolnshire Limestone Formation and Grantham Formation.
Gradient	Sideslope sub-grade to be excavated to a maximum gradient of 1v:2.5h.	Sideslope sub-grade to be excavated to a maximum gradient of 1v:2.5h.
Heights	Approximately 8m to 10m high slopes.	Approximately 8m to 11m high slopes.
Temporary slopes		
Strata	Quarry backfill materials comprising mixed granular and cohesive materials derived from the Lincolnshire Limestone Formation and Grantham Formation, waste materials up to 10m thick and in situ ground comprising rocks from the Lincolnshire Limestone Formation and Grantham Formation.	Quarry backfill materials comprising mixed granular and cohesive materials derived from the Lincolnshire Limestone Formation and Grantham Formation, waste materials up to 10m thick and in situ ground comprising rocks from the Lincolnshire Limestone Formation and Grantham Formation.
Gradients	Temporary slopes to be excavated to a maximum gradient of 1v:1.5h.	Temporary slopes to be excavated to a maximum gradient of 1v:1.5h.
Heights/base	Up to approximately 14m high slopes.	Up to approximately 14m high slopes.
Basal lining system		
Mineral barrier	The basal mineral barrier agreed in the previous Permit Variation consisted of: • a minimum 0.5m thickness of clay compacted to achieve a maximum permeability of 1x10^{-9} m/s and a minimum shear strength of 50kPa. • Overlain by a Geosynthetic Clay Liner (GCL) After the construction of Phase 7A and 4B South it was agreed through the CQA approval process to revert to the previous basal mineral barrier site design consisting of: • a minimum 1m thickness of clay compacted to achieve a maximum permeability of 1x10^{-9} m/s and a minimum shear strength of 50kPa. The clay source will be Boulder or Rutland Formation clays sourced from ENRMF. If more than one type of clay is used the different clay sources will be used separately to form distinct areas of the clay liner and will not be mixed.	A minimum 1m thickness of clay compacted to achieve a maximum permeability of 1x10^{-9} m/s and a minimum shear strength of 50kPa. The clay source will be Boulder or Rutland Formation clays sourced from ENRMF. If more than one type of clay is used the different clay sources will be used separately to form distinct areas of the clay liner and will not be mixed.
Geomembrane	2mm thick smooth HDPE geomembrane.	2mm thick smooth HDPE geomembrane.
Geomembrane protector	Geotextile protection layer	A geotextile protection layer, with an option for a 300mm sand protection layer on the basal area with a geotextile protection layer on the bunds.
Leachate drainage blanket	The leachate drainage blanket agreed in the previous Permit Variation consisted of: • a 300mm of granular drainage stone with leachate collection pipework installed in the drainage blanket. The granular drainage blanket will be underlain by a protection geotextile. Each phase will have an extraction sump, two monitoring wells and target pads. It was agreed through the CQA approval process that alternative leachate drainage blanket component designs could be used at the site consisting of: • a 150mm of 10mm stone overlain by a 250mm layer of 20/40mm stone as this specification allowed a reduction in the protection geotextile specification. • a layer of tyre bale underlain by either protection geotextile or a sand protection layer. • an option to use a sand protection layer under the gravel drainage layers provided a separation geotextile was installed above the sand protection layer.	300mm of 20/40mm granular drainage stone with leachate collection pipework installed in the drainage blanket. The granular drainage blanket will be underlain by a protection geotextile layer, with an option for a 300mm sand protection layer on the basal area with the geotextile protection layer on the bunds. Each phase will have an extraction sump, two monitoring wells and target pads. Alternative leachate drainage blanket component designs, not assessed as part of this SRA, may also be employed through the CQA approvals process, such as those listed below which have previously been agreed at the site: • a 150mm layer of 10mm stone overlain by a 250mm layer of 20/40mm stone with associated change in the protection geotextile specification. • a layer of tyre bale underlain by either protection geotextile or a sand protection layer. • an option to use a sand protection layer under the gravel drainage layers provided a separation geotextile was installed above the sand protection layer.
Leachate levels	Maximum 1.5m.	Maximum 1.5m.

Element	Current design[1]	Proposed design for the future cells at the site
Sideslope lining system		
Mineral barrier	The basal mineral barrier agreed in the previous Permit Variation consisted of: • a minimum 0.5m thickness of clay compacted to achieve a maximum permeability of 1x10^{-9} m/s and a minimum shear strength of 50kPa. • Overlain by a Geosynthetic Clay Liner (GCL) After the construction of Phase 7A and 4B South it was agreed through CQA to revert to the previous basal mineral barrier site design consisting of: • a minimum 1m thickness of clay compacted to achieve a maximum permeability of 1x10^{-9} m/s and a minimum shear strength of 50kPa. The clay source will be in situ Boulder or Rutland Formation clays sourced from ENRMF. If more than one type of clay is used the different clay sources will be used separately to form distinct areas of the clay liner and will not be mixed.	A minimum 1m thickness of clay compacted to achieve a maximum permeability of 1x10^{-9} m/s and a minimum shear strength of 50kPa. The clay source will be Boulder or Rutland Formation clays sourced from ENRMF. If more than one type of clay is used the different clay sources will be used separately to form distinct areas of the clay liner and will not be mixed.
Geomembrane	2mm thick double textured HDPE geomembrane.	2mm thick double textured HDPE geomembrane.
Leachate drainage blanket	The basal granular drainage blanket will be extended 2m vertically up the sideslopes and will be underlain by a protection geotextile. Over the remainder of the sideslopes a geocomposite drainage layer will be installed to drain perched leachate to the basal leachate drainage blanket and to act as a geomembrane protection geotextile. Selected fine grained wastes containing clay, silt and sand and gravel no greater than 20mm particle size will be used as a first protection layer placed against the drainage geocomposite.	The basal granular drainage blanket will be extended 2m vertically up the sideslopes and will be underlain by a protection geotextile. Over the remainder of the sideslopes a geocomposite drainage layer will be installed to drain perched leachate to the basal leachate drainage blanket and to act as a geomembrane protection geotextile. Selected fine grained wastes containing clay, silt and sand and gravel no greater than 20mm particle size will be used as a first protection layer placed against the drainage geocomposite.
Inter-cell bunds		
Gradient	Sideslopes of bunds to have a maximum gradient of 1v:2h.	Sideslopes of bunds to have a maximum gradient of 1v:2h.
Height	Minimum of 2m up to a maximum of 3m.	Minimum of 2m up to a maximum of 3m.
Crest width	Minimum 3m.	Minimum 3m.
Waste mass and temporary waste slopes		
Waste	Waste materials consistent with those placed previously at the site comprising non-hazardous and stable non-reactive hazardous waste.	Waste materials consistent with those placed previously at the site comprising non-hazardous and stable non-reactive hazardous waste.
Settlement/ Surcharge	15%	None, as evidence from waste inputs, survey monitoring and gas data has concluded that settlement is not taking place within the waste mass other than initial self-weight settlement occurring during waste placement.
Waste slope gradient	Temporary waste slopes to be constructed to a maximum gradient of 1v:2h.	Temporary waste slopes to be constructed to a maximum gradient of 1v:1.5h. If temporary waste slopes are to be left open beyond the short term then they should be constructed to a gradient of no greater than 1v:2h.
Waste slope height	Maximum waste slope height of approximately 17m.	Maximum waste slope height of approximately 19m.
Capping and restoration system[2]		
Components	The capping system assessed in the previous SRA in support of the Permit Variation consists of: • A 0.3m thick sub-grade overlain by a 1mm thick HDPE or LLDPE geomembrane cap which is protected by a drainage geocomposite. However this was changed during the permit determination period to consist of: • A 0.3m thick sub-grade overlain by a Geosynthetic Clay Liner (GCL) which is overlain and protected by a 300mm thick sand drainage layer formed from the site derived sand of the Northampton Sand Formation. 1m of soils or 1.5m of soils in areas where trees are to be planted.	A 0.3m thick sub-grade overlain by a 1m thick low permeability clay cap which is overlain and protected by a 300mm thick granular drainage layer. Minimum of 1m of soils or 1.5m of soils in areas where trees are to be planted.
Height and gradient	Pre-settlement capping and restoration slopes are typically approximately 10m high with slope gradients of approximately 1v:20h. The steepest slopes will be at a maximum gradient of 1v:3h and the maximum height over which this gradient is present is approximately 6m.	Capping and restoration slopes are typically approximately 10m to 20m high with slope gradients of approximately 1v:10 to 1v:20h. The steepest restored slopes will be at a maximum gradient of 1v:3h and the maximum height over which this gradient is present is approximately 6m. The steepest unrestored or partially restored slopes along the southern boundary between Thornhaugh and Cooks Hole will be at a maximum gradient of 1v:3h and 14m high and once restored will be at a maximum gradient of 1v:12h.

[1] In accordance with the current site permit requirements or as agreed through the CQA Plans in accordance with the current site permit requirements.
[2] A number of the current design elements differ from those assessed in SRA prepared for the previous permit variation as they either changed through correspondence during the permit determination stage, as referenced in Table S1.2 Operating techniques of the permit, or have been changed through agreement with local EA technical officers of engineering designs and CQA Plans.

Table SRA2

Values for the geotechnical parameters used in the stability analyses

Material and intended use	Unit weight	Undrained parameters (short term)	Drained parameters (long term)
Quarry backfill (sub-grade and temporary slopes) [a]	γ = 18.5 kN/m^3	c' = 5 kPa Ø' = 30°	
Remoulded clay (basal and sideslope liner, clay cap and clay cap subgrade) [b]	γ = 20 kN/m^3	c = 50 kPa Ø = 0°	c' = 2 kPa Ø' = 20°
Leachate drainage gravel [b]	γ_d = 18 kN/m^3 γ_{sat} = 20 kN/m^3	c' = 0 kPa Ø' = 35°	
Waste (waste mass and a component of some of the temporary slopes) [c]	γ_d = 10 kN/m^3 γ_{sat} = 12 kN/m^3	c' = 5 kPa Ø' = 25°	
Sand drainage and protection layer material [d]	γ_d = 18.5kN/m^3 γ_{sat} = 20kN/m^3	c' = 0 kPa Ø' = 30°	
Restoration soils imported from ENRMF [e]	γ_d = 18 kN/m^3 γ_{sat} = 20 kN/m^3	c' = 5 kPa Ø' = 25°	
Geosynthetic interface shear strength values	**Peak [c]**		**Residual [c]**
Geomembrane (liner) Textured HDPE/clay undrained Textured HDPE/clay drained Textured HDPE or LLDPE/non-woven geotextile	α = 36 kPa δ = 4.4° α = 26.7 kPa δ = 10.7° α = 6.9 kPa δ = 25.8°		α = 34 kPa δ = 3.1° α = 26.7 kPa δ = 10.7° α = 4 kPa δ = 13°
Non-woven geotextile (side slope protection and sideslope drainage) Non-woven geotextile/gravel	α = 0 kPa δ = 35°		α = 0 kPa δ = 35°
Geosynthetic tensile properties			
Geomembrane [f] 2mm thick double textured HDPE geomembrane	29 kN/m		
Non-woven geotextile [g] Basal protection geotextile Geotextile component of drainage geocomposite	40 kN/m 30 kN/m		

Notes
(a) Used in the 2014 SRA[5] and based on values presented in the 2004 SRA[3] for Thornhaugh
(b) Used in the 2014 SRA[5] and based on values presented in the 2008[7] and 2009[8] SRAs for ENRMF
(c) Based on values presented in Jones and Dixon "Stability of Landfill Lining Systems" Environment Agency R&D Technical Report PI-385 TR1[12].
(d) Based on values presented in the 2004 SRA[3] for Thornhaugh for the backfilled quarry material with the apparent cohesion reduced from 5kPa to 0kPa to reflect that the material is no longer in situ and has been worked and behaves as a granular sand.
(e) Based on values used in the 2021 SRA[6] for ENRMF and data presented in previous stability risk assessments undertaken for ENRMF.
(f) Based on values presented in Environment Agency Guidance LFE5 – Using Geomembranes in Landfill Engineering[13]
(g) Based on tensile strength values presented on Geofabrics datasheets for Geofabrics HPS7 and GPT5 products which are likely to be equivalent to the lowest strength of geotextile and drainage geocomposite respectively specified in the works based on the maximum depth of waste of 20m and the 10mm size of drainage stone used in the lower layer of the gravel leachate drainage blanket.

Table SRA3

Selected Factors of Safety

Component	Factor of Safety	
	Short term	Long term
Rotational stability of sideslope sub-grade	1.3	
Rotational stability of temporary slopes	1.1	
Rotational stability of basal lining system (inter-cell bund)	1.2	1.2
Translational and interface stability of granular leachate drainage blanket on inter-cell bund	1.2 No tension	
Rotational stability of sideslope lining system	1.3	1.3
Translational and interface stability of granular leachate drainage blanket on first vertical 2m of sideslopes	1.3 No tension	
Rotational stability of internal temporary waste mass slopes	1.1	1.1
Rotational stability of waste mass slopes, failure of which could damage the lining system: - basal liner - intercell bund	 1.3 1.2	 1.3 1.2
Rotational stability of capping system	1.4	1.4
Translational and interface stability of capping system	1.4 (peak interface strength values) 1.1 (residual interface strength values) No tension	

Table SRA4

Results of the stability analyses

<table>
<tr><th rowspan="2">Model component</th><th rowspan="2">Analysis</th><th rowspan="2">Calculations</th><th colspan="3">Factor of safety</th><th rowspan="2">Comment</th></tr>
<tr><th>Short term</th><th>Long term</th><th>Target</th></tr>
<tr><td>Basal sub-grade</td><td>Basal heave</td><td>N/A</td><td colspan="4">Qualitative assessment demonstrates stability against basal heave</td></tr>
<tr><td rowspan="2">Sideslope sub-grade</td><td>Stability against heave of the sideslope</td><td>N/A</td><td colspan="4">Qualitative assessment demonstrates stability against heave of the sideslope</td></tr>
<tr><td>Stability against rotational failure of the 1v:2.5h 11m high sideslope sub-grade</td><td>Appendix SRA1 Plot 1</td><td colspan="2">1.921</td><td>1.3</td><td>Factor of safety greater than target</td></tr>
<tr><td rowspan="2">Temporary slopes</td><td>Stability against rotational failure of the 1v:1.5h 14m high temporary slope cut into backfill materials</td><td>Appendix SRA1 Plot 2</td><td colspan="2">1.218</td><td>1.1</td><td>Factor of safety greater than target</td></tr>
<tr><td>Stability against rotational failure of the 1v:1.5h 14m high temporary slope cut into backfill and waste materials</td><td>Appendix SRA1 Plot 3</td><td colspan="2">1.143</td><td>1.1</td><td>Factor of safety greater than target</td></tr>
<tr><td rowspan="3">Basal lining system</td><td>Basal heave of the basal sub-grade affecting the basal liner</td><td>N/A</td><td colspan="4">Qualitative assessment demonstrates stability against basal heave</td></tr>
<tr><td>Stability against rotational failure of the 1v:2h 3m high inter-cell bund with a minimum crest width of 3m</td><td>Appendix SRA1 Plots 4 & 5</td><td>4.460</td><td>1.209</td><td>1.2</td><td>Factors of safety greater than target</td></tr>
<tr><td>Translational and interface stability of granular leachate drainage blanket up 1v:2h 3m high slope of inter-cell bund</td><td>Appendix SRA2 Spreadsheets 1 to 4</td><td>1.53
No tension</td><td>1.53
No tension</td><td>1.2
No tension</td><td>Factors of safety greater than target. Forces transferred to underlying layers</td></tr>
<tr><td rowspan="5">Sideslope lining system</td><td>Heave of the sideslope sub-grade affecting the sideslope liner</td><td>N/A</td><td colspan="4">Qualitative assessment demonstrates stability against heave of the sideslope</td></tr>
<tr><td>Stability against rotational failure of 1m thick clay liner with slope of 1v:2.5h at 10m high</td><td>Appendix SRA1 Plots 6 & 7</td><td>2.125</td><td>1.319</td><td>1.3</td><td>Factors of safety greater than target</td></tr>
<tr><td>Translational and interface stability of granular leachate drainage blanket extended to a 2m vertical height up the 1v:2.5h sideslope</td><td>Appendix SRA2 Spreadsheets 5 to 8</td><td>1.96
No tension</td><td>1.96
No tension</td><td>1.3
No tension</td><td>Factors of safety greater than target. Forces transferred to underlying layers</td></tr>
<tr><td>Interface stability of geomembrane for full height of the sideslope lining system</td><td>N/A</td><td colspan="3">Not required – see risk screening section 4.14</td><td rowspan="2">Waste placement procedures will be such as to prevent tension being mobilised in the geosynthetic elements of the sideslope liner</td></tr>
<tr><td>Interface stability of drainage geocomposite for full height of the sideslope lining system</td><td>N/A</td><td colspan="3">Not required – see risk screening section 4.14</td></tr>
<tr><td rowspan="2">Waste mass</td><td>Rotational stability of 1v:1.5h temporary 19m high waste slopes with toe support from inter-cell bund and 1.5m of leachate</td><td>Appendix SRA1 Plots 8 & 9</td><td>1.135 for waste slope

1.495 for intercell bund and liner</td><td>1.124 for waste, inter-cell bund and liner</td><td>1.1 for waste slope

1.2 for inter-cell bund

1.3 for liner</td><td>Factors of safety greater than target for short term. In medium term analyses the factor of safety for the bund and containment may fall below the target.</td></tr>
<tr><td>Rotational stability of 1v:2h longer term temporary 19m high waste slopes with toe support from inter-cell bund and 1.5m of leachate</td><td>Appendix SRA1 Plots 10 & 11</td><td>1.391</td><td>1.209 for bund and 1.369 for waste and liner</td><td>1.1 for waste slope

1.2 for inter-cell bund

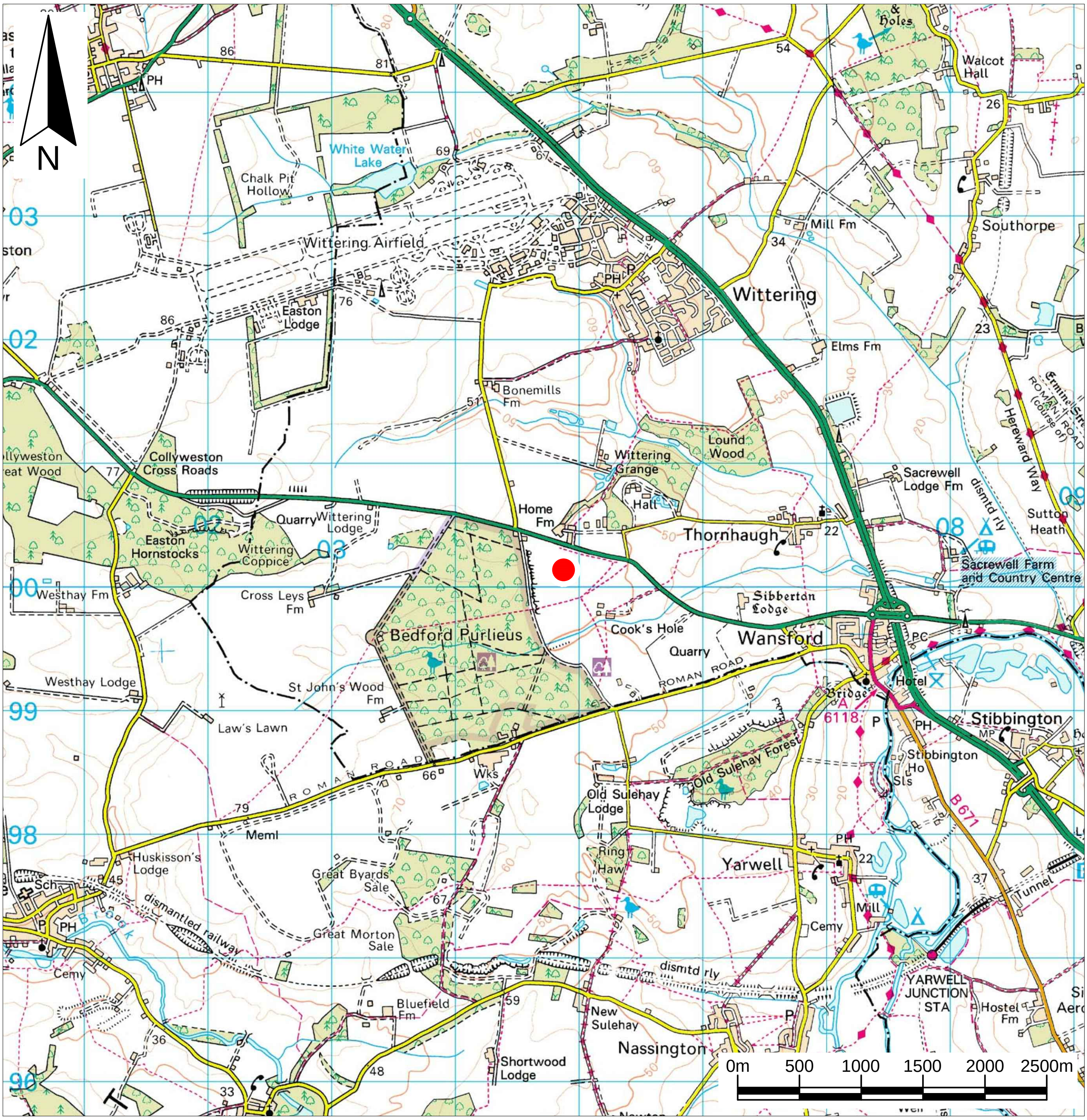
1.3 for liner</td><td>Factors of safety greater than target. In long term analyses the lowest factor of safety occurs in the inter-cell bund</td></tr>
<tr><td rowspan="3">Capping system Northern Area (western, northern and eastern flanks of the site)</td><td>Northern area: Rotational stability of waste, cap and restoration for a 1v:10h 15m high slope with managed 1.5m of leachate and 1m thick restoration soils</td><td>Appendix SRA1 Plots 12 & 13</td><td>4.837</td><td>4.616</td><td>1.4</td><td>Factors of safety greater than target</td></tr>
<tr><td>Northern area: Rotational stability of waste, cap and restoration for 1v:3h 6m high slope with managed 1.5m of leachate and 1m thick restoration soils</td><td>Appendix SRA1 Plots 14 & 15</td><td>2.157</td><td>1.486</td><td>1.4</td><td>Factors of safety greater than target</td></tr>
<tr><td>Northern area: Rotational stability of waste, cap and restoration for a 1v:10h 15m high slope with unmanaged leachate and 1m thick</td><td>Appendix SRA1 Plot 16</td><td>N/A</td><td>4.619</td><td>1.4</td><td>Factors of safety greater than target. Short term conditions not assessed as unmanaged leachate is a long term</td></tr>
</table>

Table SRA4

Results of the stability analyses

Model component	Analysis	Calculations	Factor of safety			Comment
			Short term	Long term	Target	
	restoration soils					scenario
	Northern area: Rotational stability of waste, cap and restoration for a 1v:3h 6m high slope with unmanaged leachate and 1m thick restoration soils	Appendix SRA1 Plot 17	N/A	1.486	1.4	Factors of safety greater than target. Short term conditions not assessed as unmanaged leachate is a long term scenario
	Northern area: Rotational stability of waste, cap and restoration for a 1v:10h 15m high slope with managed 1.5m of leachate and 1.5m thick restoration soils	Appendix SRA1 Plots 18 & 19	4.774	4.610	1.4	Factors of safety greater than target
	Northern area: Rotational stability of waste, cap and restoration for a 1v:3h 6m high slope with managed 1.5m of leachate and 1.5m thick restoration soils	Appendix SRA1 Plots 20 & 21	2.091	1.544	1.4	Factors of safety greater than target
	Northern area: Rotational stability of waste, cap and restoration for a 1v:10h 15m high slope with unmanaged leachate and 1.5m thick restoration soils	Appendix SRA1 Plot 22	N/A	4.614	1.4	Factors of safety greater than target. Short term conditions not assessed as unmanaged leachate is a long term scenario
	Northern area: Rotational stability of waste, cap and restoration for a 1v:3h 6m high slope with unmanaged leachate and 1.5m thick restoration soils	Appendix SRA1 Plot 23	N/A	1.544	1.4	Factors of safety greater than target. Short term conditions not assessed as unmanaged leachate is a long term scenario
Capping system Southern Area (boundary between Thornhaugh and Cooks Hole)	Southern area: Rotational stability of waste, cap and partial restoration for a 1v:3h 14m high slope with managed 1.5m leachate and 1m of restoration soils	Appendix SRA1 Plots 24 & 25	2.119	1.409	1.4	Factors of safety greater than target.
	Southern area: Rotational stability of buried 1v:3h 14m high waste and cap slope with a 1v:12h fully restored slope, with managed 1.5m leachate	Appendix SRA1 Plots 26 & 27	5.818	5.939	1.4	Factors of safety greater than target.
	Southern area: Rotational stability of waste and cap for a 1v:3h 14m high slope with unmanaged leachate	Appendix SRA1 Plot 28	N/A	1.409	1.4	Factors of safety greater than target.
	Southern area: Rotational stability of buried 1v:3h 14m high waste and cap slope with a 1v:12h fully restored slope, with unmanaged leachate	Appendix SRA1 Plot 29	N/A	5.939	1.4	Factors of safety greater than target.

FIGURES



Key / Notes

● Site location

Rev	Status	Drn	App	Chk	Date
	Final	HL	HL	DFR	11/07/25

Site
Thornhaugh Landfill Site

Client
Augean

Title
The site location

Figure SRA 1

Scale
1:50,000@A4

Drawing Ref
AU/TH/06-25/25020

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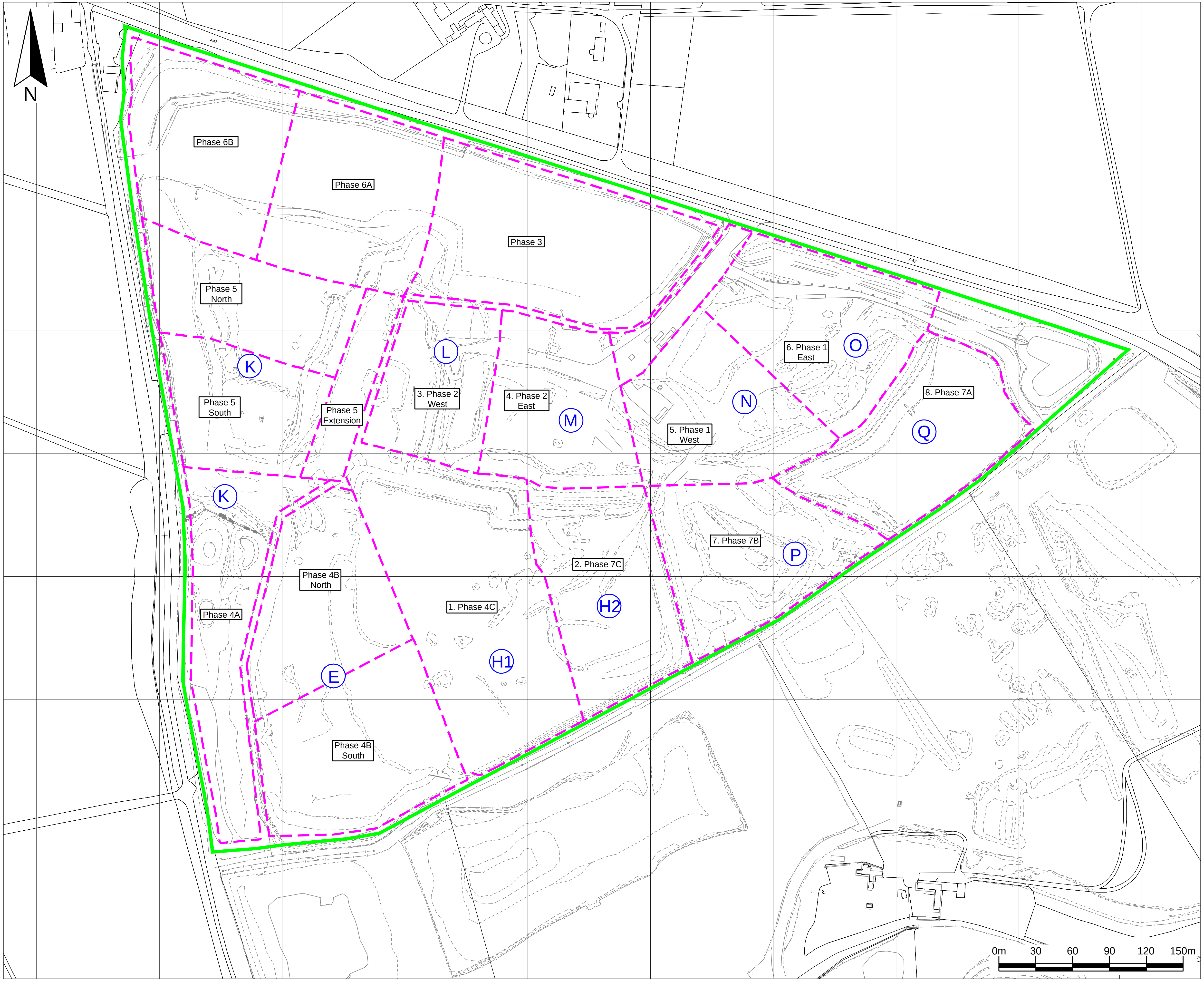
Technical advisers on environmental issues

Baddesley Colliery Offices,
Main Road, Baxterley, Atherstone,
Warwickshire, CV9 2LE.
Telephone : 01827 717891
Fax : 01827 718507



Key / Notes

Current Environmental Permit boundary (reference RP3133PP)

Approximate existing phase boundaries

D — Proposed order of phasing for remaining phases in Cooks Hole Quarry and Thornhaugh Landfill Site. Labels for the Phases in Cooks Hole Quarry are not shown on this drawing but are shown on Figure ESID7

Phase 5 North — Original name of phase area

4. Phase 2 East — Original name of phase area with proposed order of phasing for remaining phases in Thornhaugh Landfill Site

Notes:
The proposed phasing shown is approximate and, while the principles and order of phasing are unlikely to change, phase boundaries and haul routes may change in response to operational conditions.

Drawing based on models reference AU-US-17845.LSS

Rev	Status	Drn	App	Chk	Date
	Final	KR	HL	DFR	11/07/25

Site: Thornhaugh Landfill Site

Client: Augean

Title: Current site layout

Figure SRA 2 — Scale: 1:3,000@A3

Drawing Ref: AU/TH/06-25/25007

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Technical advisers on environmental issues
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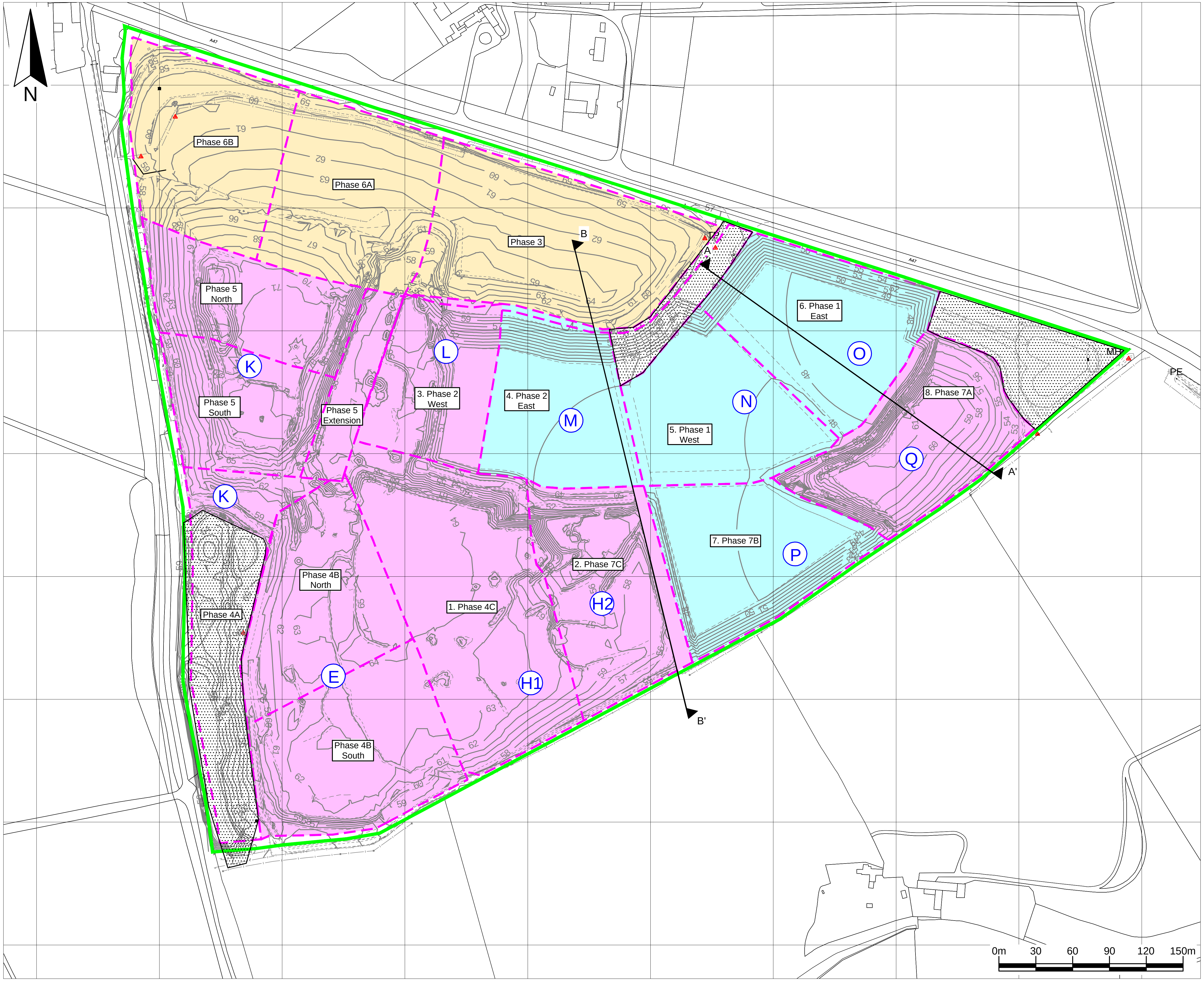
Fax : 01827 718507



Key / Notes

- Current Environmental Permit boundary (reference RP3133PP)
- Approximate existing phase boundaries
- (D) Proposed order of phasing for remaining phases in Cooks Hole Quarry and Thornhaugh Landfill Site. Labels for the Phases in Cooks Hole Quarry are not shown on this drawing but are shown on Figure ESID7
- (Phase 5 North) Original name of phase area
- (4. Phase 2 East) Original name of phase area with proposed order of phasing for remaining phases in Thornhaugh Landfill Site
- (A ▲ ▲ A') Location of cross sections. Conceptual cross sections shown on Figure SRA6
- Completed and restored area
- Partially filled area
- New landfill area not yet constructed
- County wildlife site (Phase 4A), and areas that will not be landfilled
- (—50—) Contours (mAOD)

Notes:

The proposed phasing shown is approximate and, while the principles and order of phasing are unlikely to change, phase boundaries and haul routes may change in response to operational conditions.

Drawing based on model reference AU-TH-17913.LSS

	Final	KR	HL	DFR	11/07/25
Rev	Status	Drn	App	Chk	Date

Site
Thornhaugh Landfill Site

Client
Augean

Title
Plan showing the basal subgrade levels for future phases of landfilling

Figure SRA 3

Scale
1:3,000@A3

Drawing Ref
AU/TH/06-25/25008

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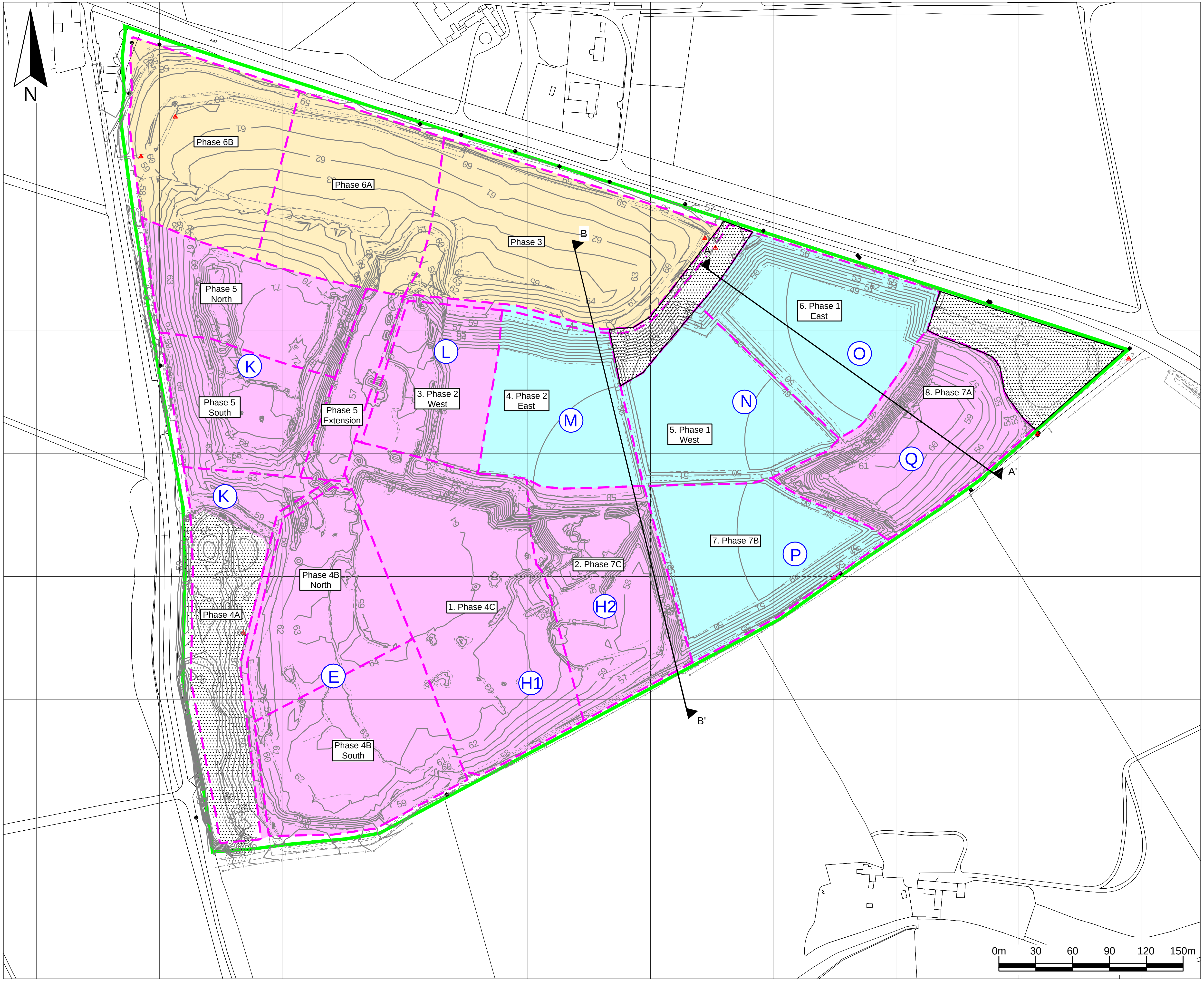
Fax : 01827 718507



Key / Notes

- Current Environmental Permit boundary (reference RP3133PP)
- Approximate existing phase boundaries
- D — Proposed order of phasing for remaining phases in Cooks Hole Quarry and Thornhaugh Landfill Site. Labels for the Phases in Cooks Hole Quarry are not shown on this drawing but are shown on Figure ESID7
- Phase 5 North — Original name of phase area
- 4. Phase 2 East — Original name of phase area with proposed order of phasing for remaining phases in Thornhaugh Landfill Site
- A A' — Location of cross sections. Conceptual cross sections shown on Figure SRA6
- Completed and restored area
- Partially filled area
- New landfill area not yet constructed
- County wildlife site (Phase 4A), and areas that will not be landfilled
- 50 — Contours (mAOD)

Notes:
The proposed phasing shown is approximate and, while the principles and order of phasing are unlikely to change, phase boundaries and haul routes may change in response to operational conditions.

Drawing based on model reference AU-TH-17914.LSS

Rev	Status	Drn	App	Chk	Date
	Final	KR	HL	DFR	11/07/25

Site
Thornhaugh Landfill Site

Client
Augean

Title
Plan showing the top of the clay liner

Figure SRA 4

Scale
1:3,000@A3

Drawing Ref
AU/TH/06-25/25009

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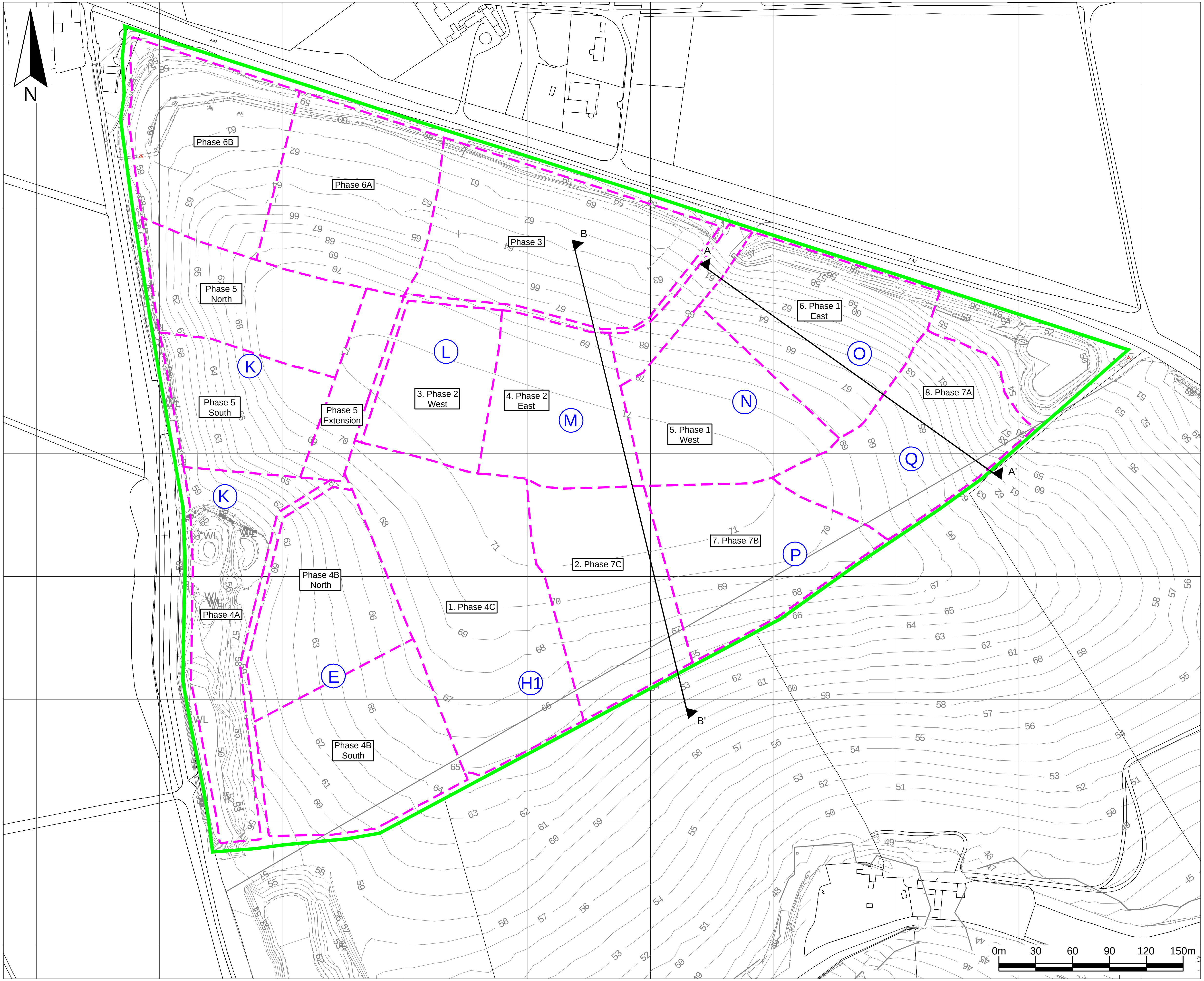
Telephone : 01827 717891
Fax : 01827 718507



Key / Notes

Current Environmental Permit boundary (reference RP3133PP)

Approximate existing phase boundaries

Proposed order of phasing for remaining phases in Cooks Hole Quarry and Thornhaugh Landfill Site. Labels for the Phases in Cooks Hole Quarry are not shown on this drawing but are shown on Figure ESID7

Phase 5 North — Original name of phase area

4. Phase 2 East — Original name of phase area with proposed order of phasing for remaining phases in Thornhaugh Landfill Site

A A' — Location of cross sections. Conceptual cross sections shown on Figure SRA6

50 — Contours (mAOD)

Notes:
The proposed phasing shown is approximate and, while the principles and order of phasing are unlikely to change, phase boundaries and haul routes may change in response to operational conditions.

Drawing based on model reference AU-CH-17143.LSS

Rev	Status	Drn	App	Chk	Date
	Final	KR	HL	DFR	11/07/25

Site
Thornhaugh Landfill Site

Client
Augean

Title
Plan showing the restoration levels

Figure SRA 5

Scale
1:3,000@A3

Drawing Ref
AU/TH/06-25/25010

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Technical advisers on environmental issues
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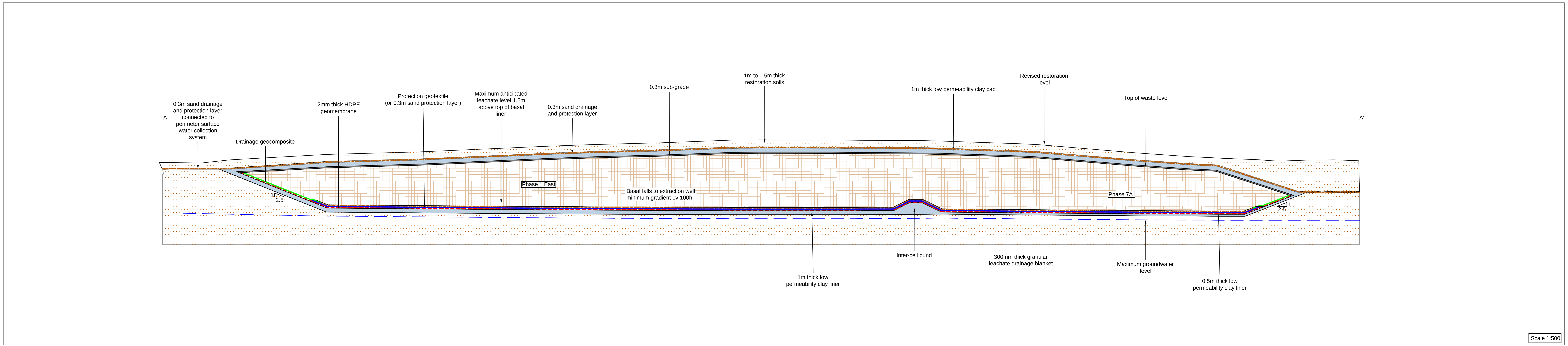
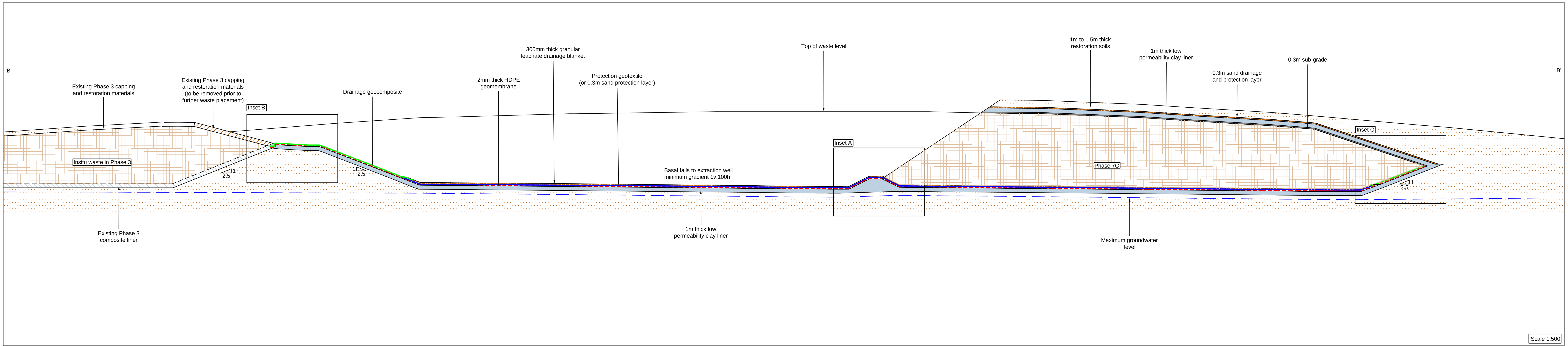
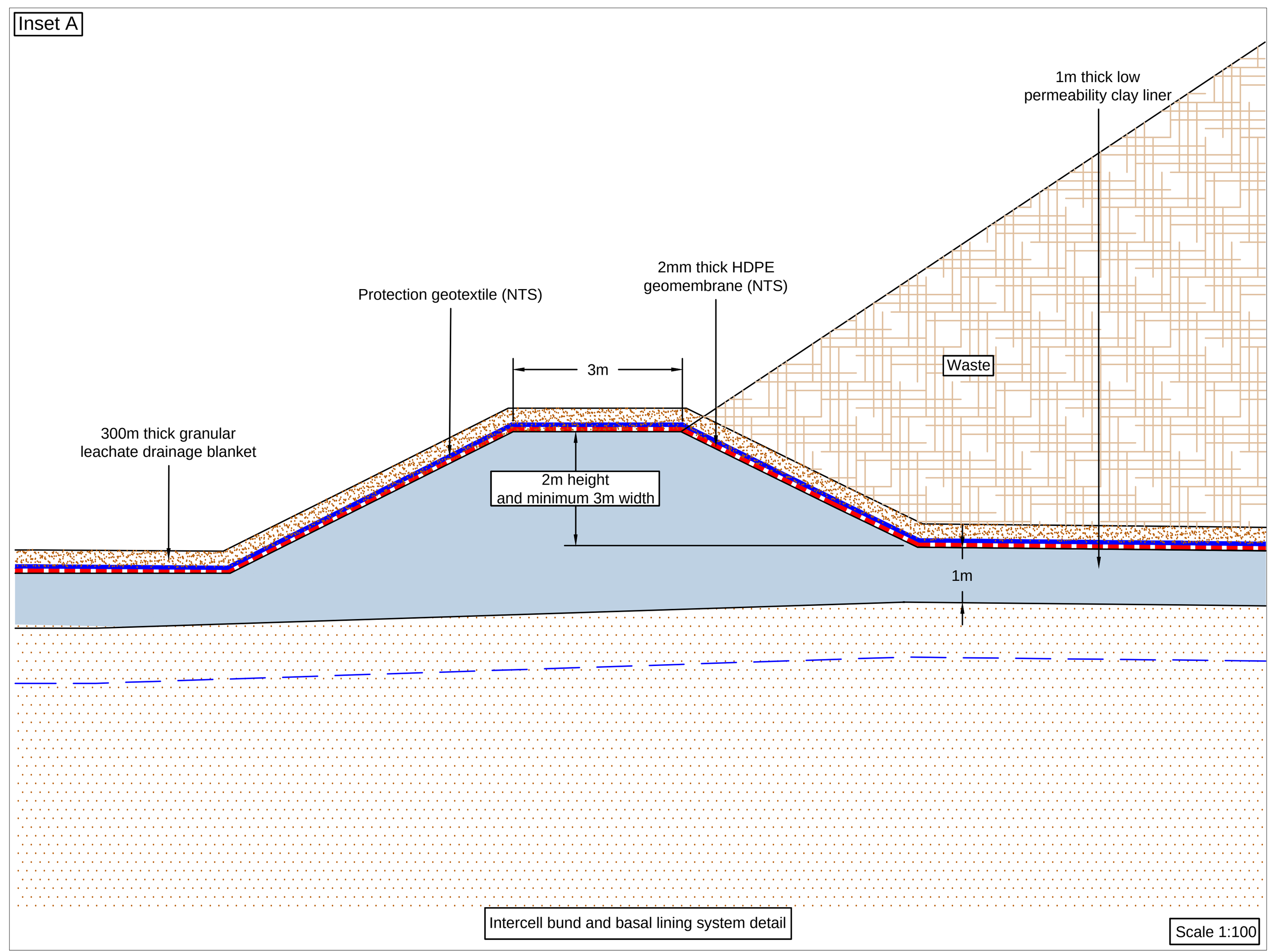
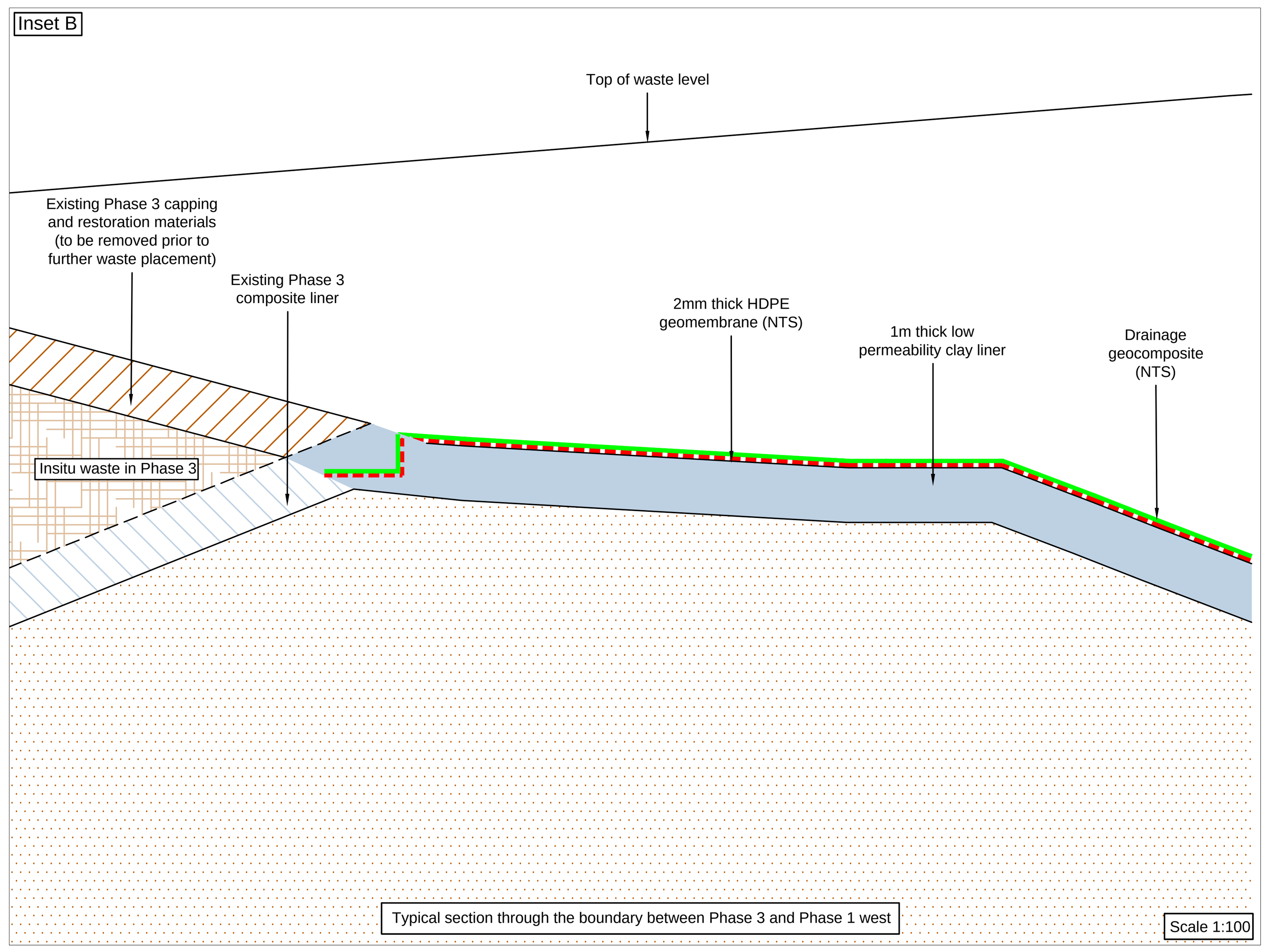
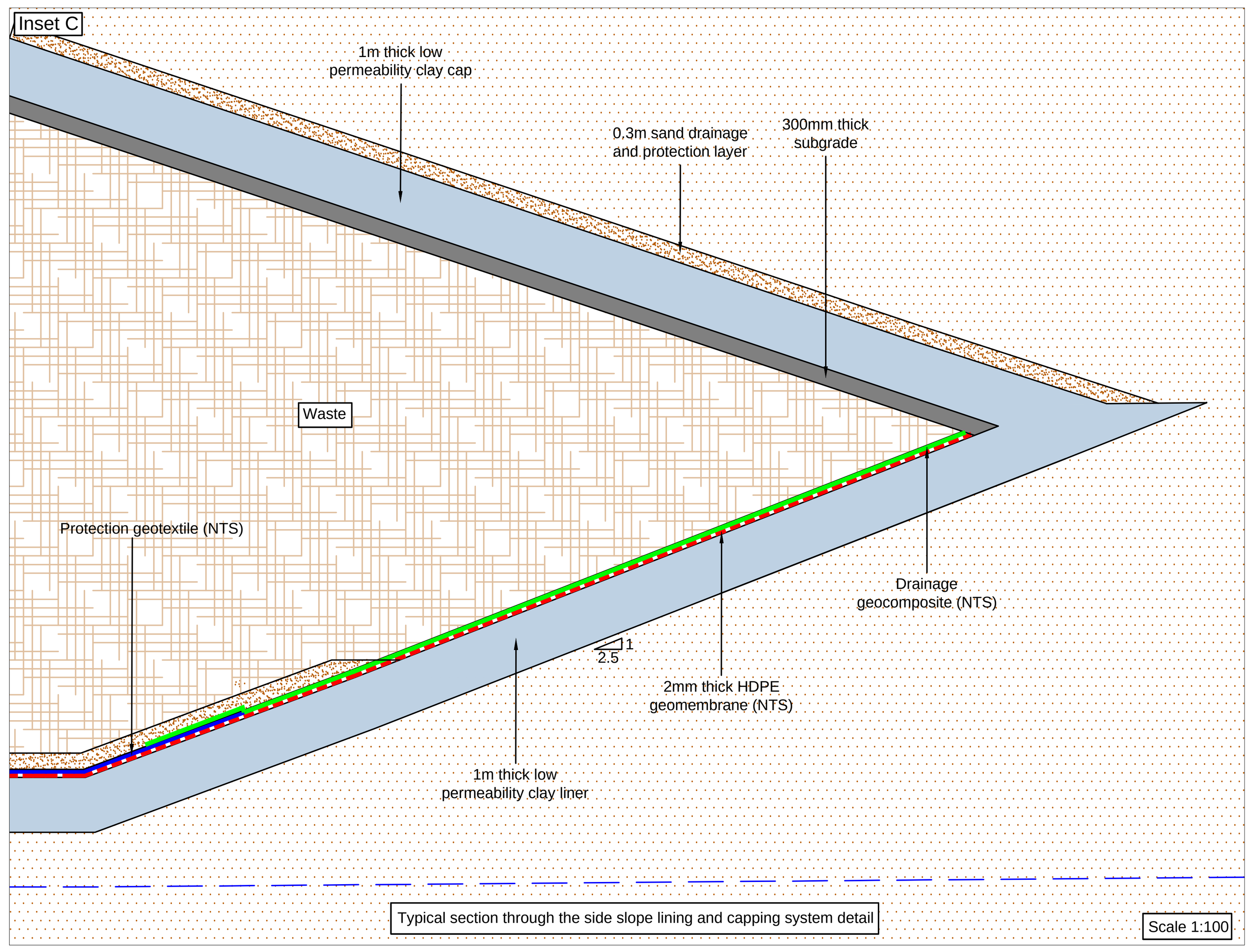
Main Road, Baxterley, Atherstone,
Warwickshire, CV9 2LE.
Telephone : 01827 717891
Fax : 01827 718507











Key / Notes

NTS - Not to scale

Notes:
Based on models references AU-CH-17020.LSS, AU-CH-17021.LSS and AU-CH-17143.LSS.

Section location lines shown on drawing references AU/TH/06-25/20008 and AU/TH/06-25/20008.

Rev	Status	Drn	App	Chk	Date
	Final	KR	HL	DFR	11/07/25

Site
Thornhaugh Landfill Site

Client
Augean

Title
Conceptual cross sections

Figure SRA 6

Scale
As shown@A1

Drawing Ref
AU/TH/06-25/25011

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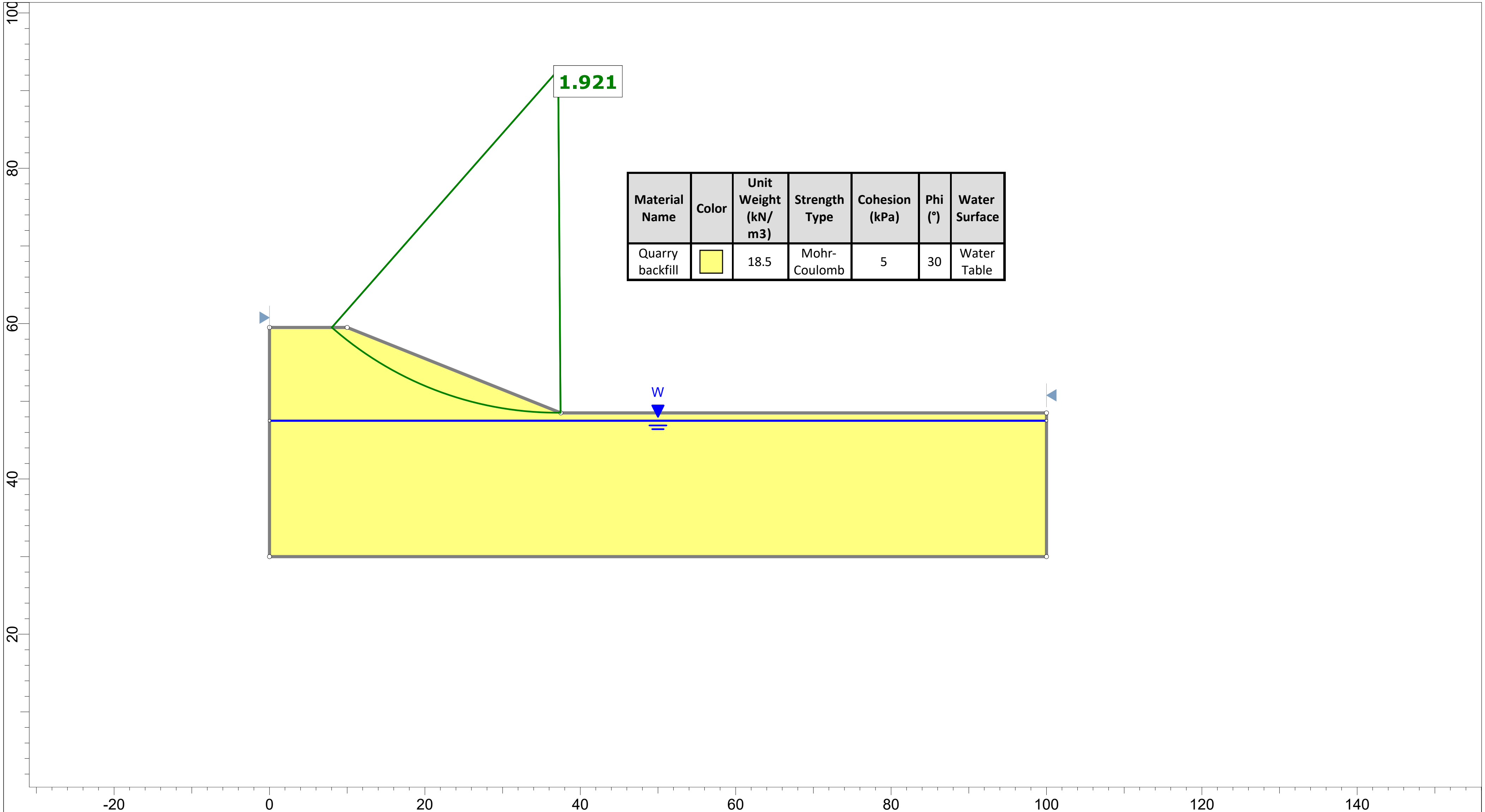
Technical advisers on environmental issues
Baddesley Colliery Offices,
Main Road, Baxterley, Atherstone,
Warwickshire, CV9 2LE.
Telephone : 01827 717891
Fax : 01827 718507

APPENDICES

APPENDIX SRA1

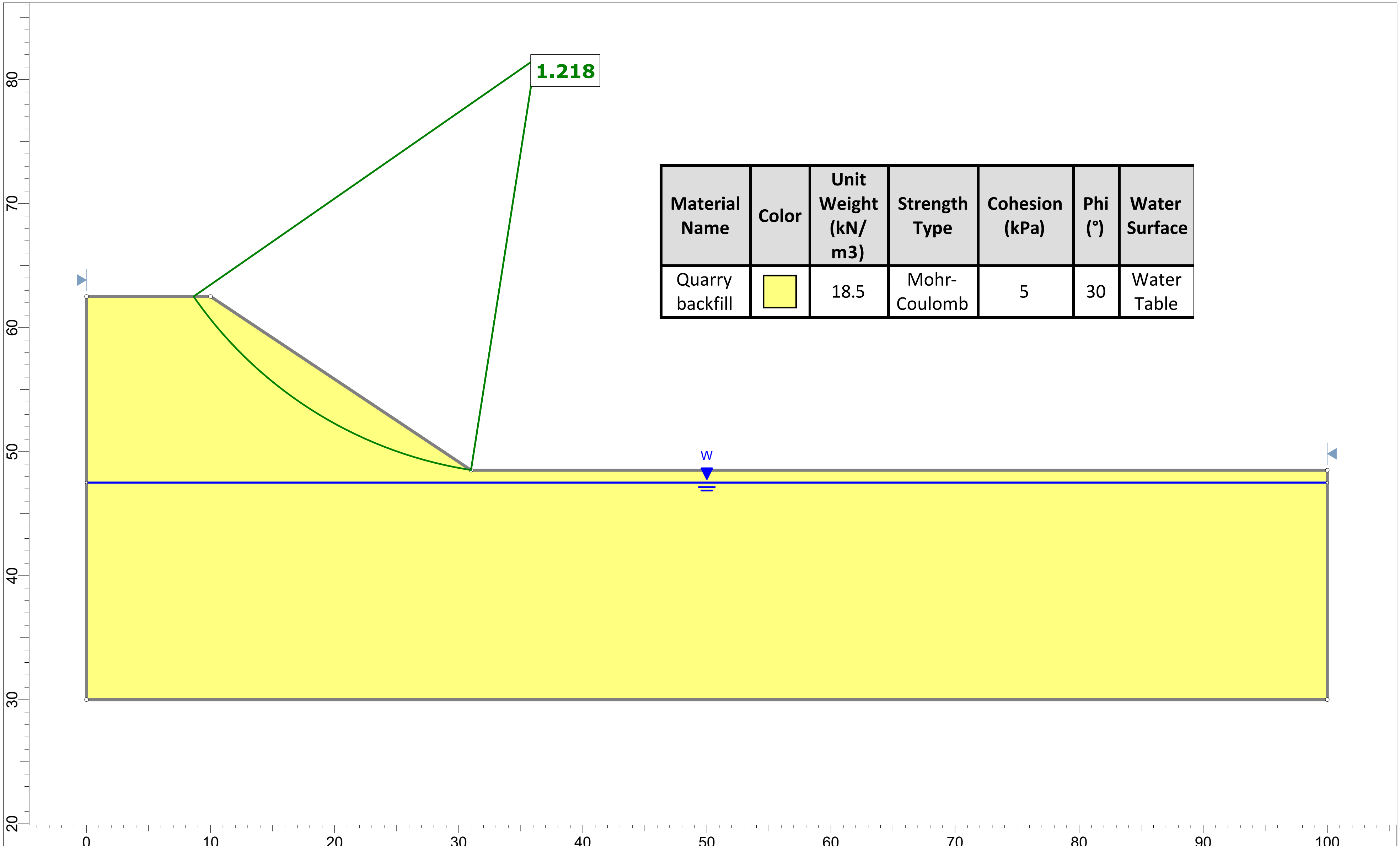
RESULTS OF THE ANALYSES OF ROTATIONAL FAILURE



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Quarry backfill		18.5	Mohr-Coulomb	5	30	Water Table

MJCA
Technical advisers on environmental issues

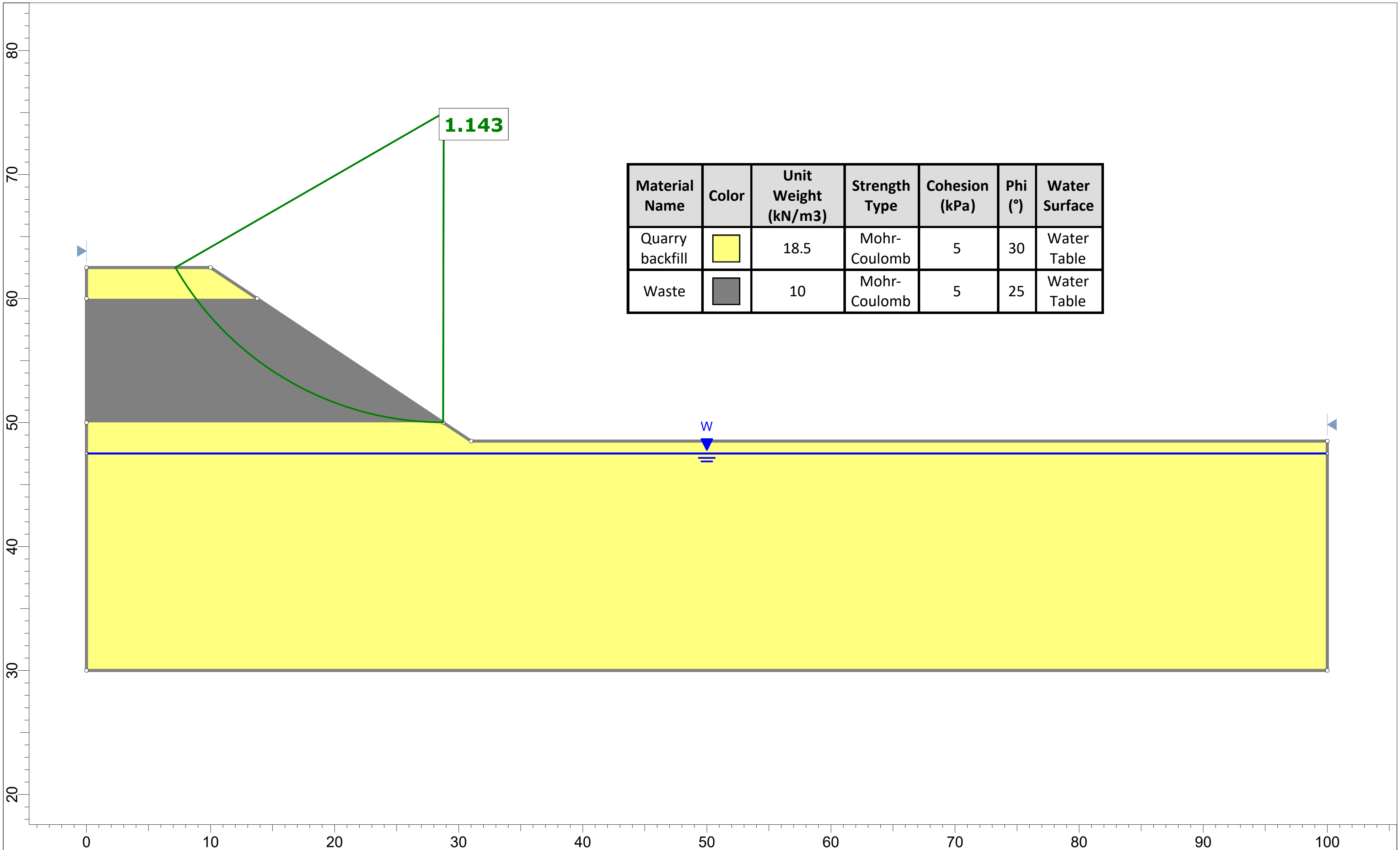
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	01_Sideslope sub-grade - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	26/06/2025 09:19:28	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Quarry backfill		18.5	Mohr-Coulomb	5	30	Water Table

MJCA
Technical advisers on environmental issues

Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	02_Temporary slopes - backfill - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	26/06/2025 09:23:07	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Quarry backfill		18.5	Mohr-Coulomb	5	30	Water Table
Waste		10	Mohr-Coulomb	5	25	Water Table

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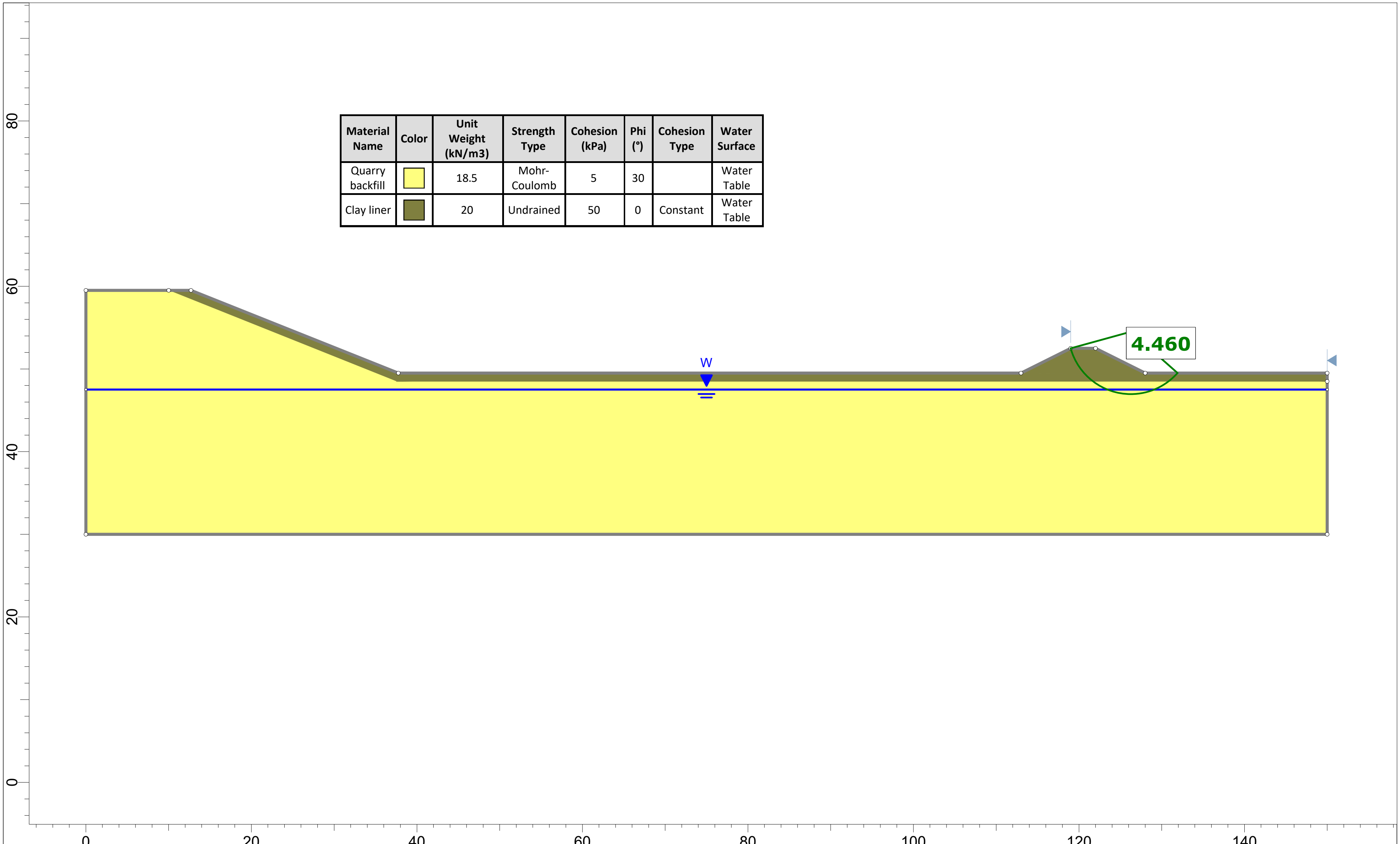
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	03_Temporary slopes - waste - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	26/06/2025 09:26:13	*Reference*	AU/TH/DFR/3361/01SRA

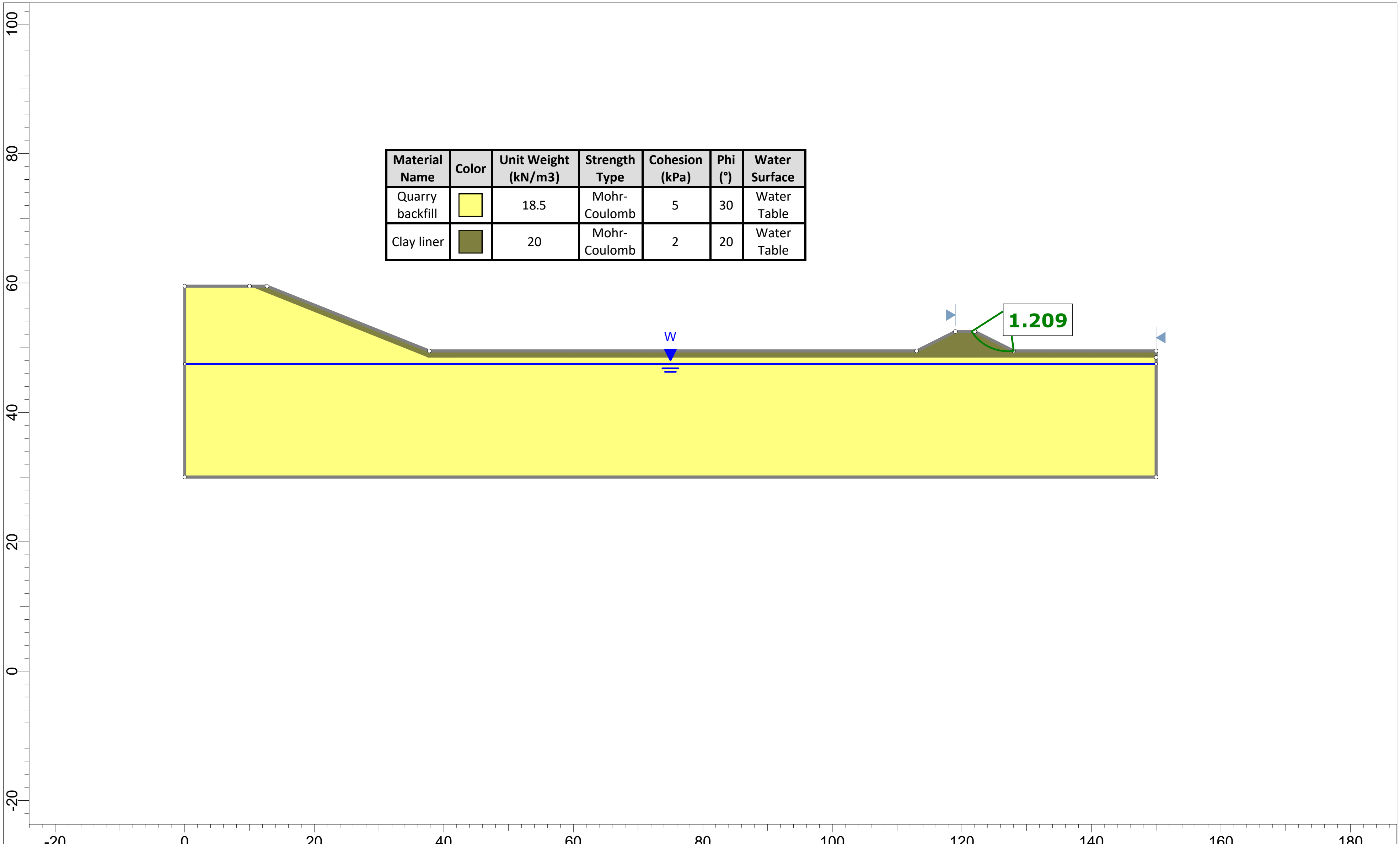
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Water Surface
Quarry backfill		18.5	Mohr-Coulomb	5	30		Water Table
Clay liner		20	Undrained	50	0	Constant	Water Table



Technical advisers on environmental issues

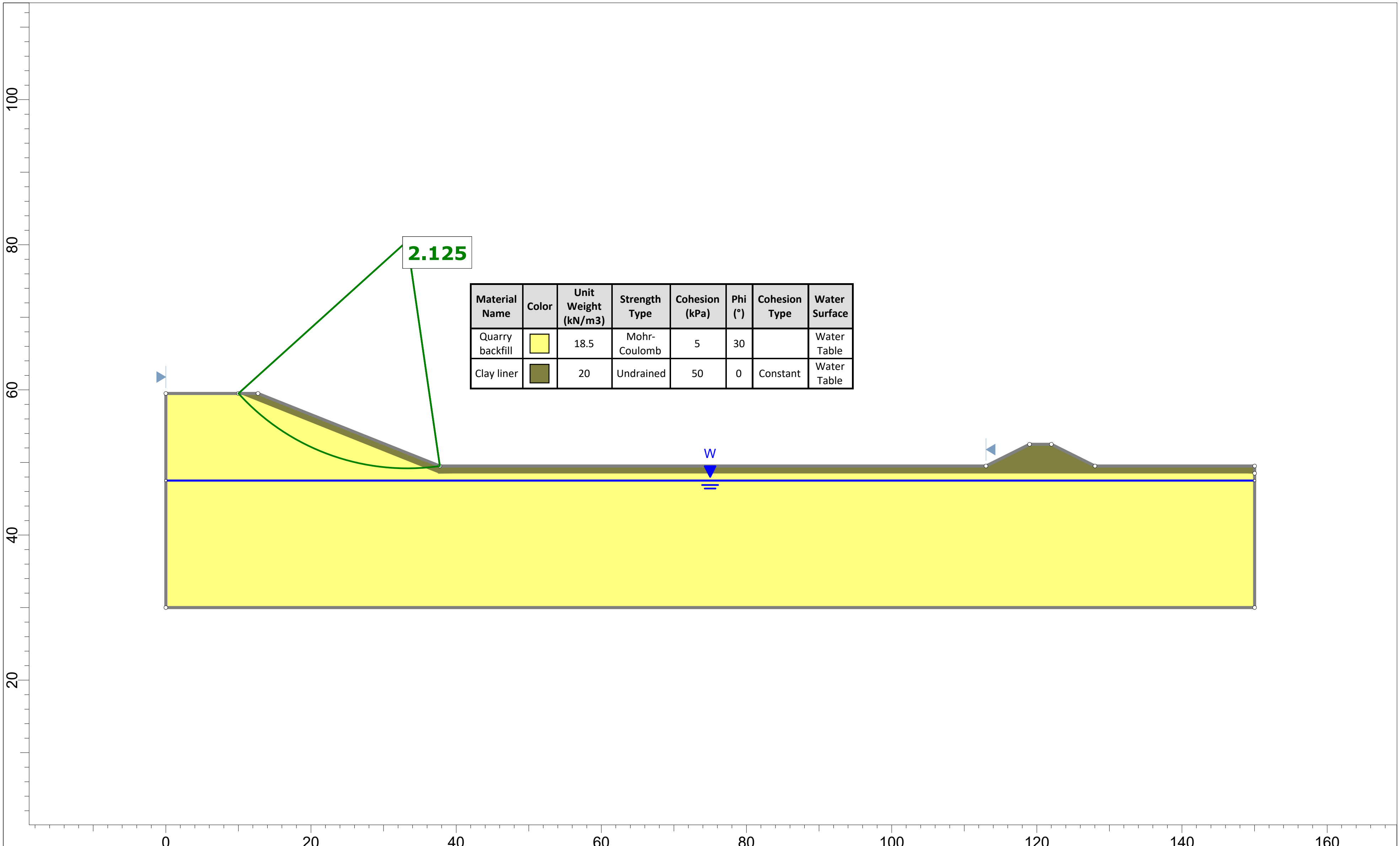
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	04_Intercell bunds - undrained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	26/06/2025 09:50:31	*Reference*	AU/TH/DFR/3361/01SRA

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Quarry backfill		18.5	Mohr-Coulomb	5	30	Water Table
Clay liner		20	Mohr-Coulomb	2	20	Water Table



Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	05_Intercell bunds - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	26/06/2025 09:57:37	*Reference*	AU/TH/DFR/3361/01SRA

Technical advisers on environmental issues



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Water Surface
Quarry backfill		18.5	Mohr-Coulomb	5	30		Water Table
Clay liner		20	Undrained	50	0	Constant	Water Table

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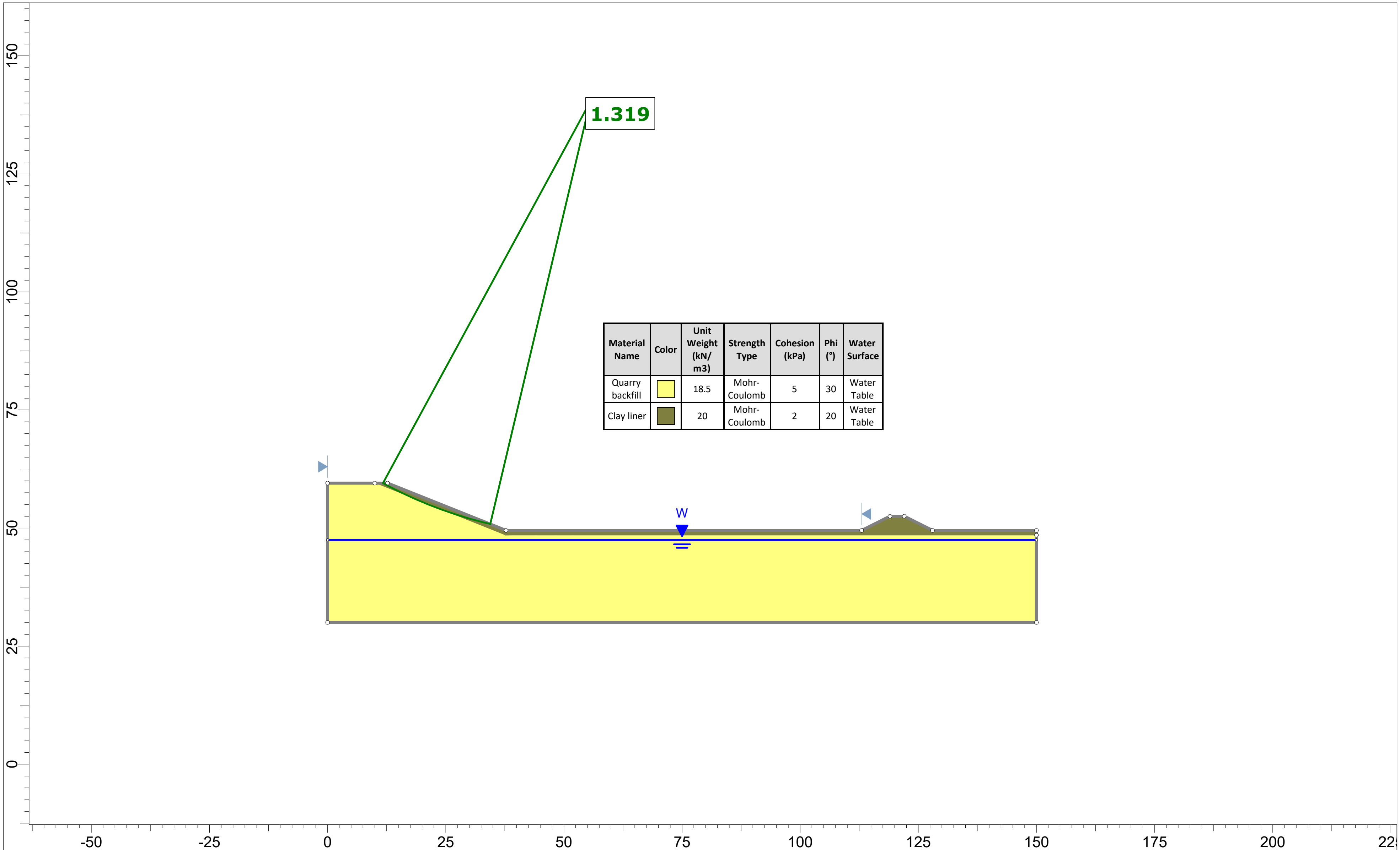
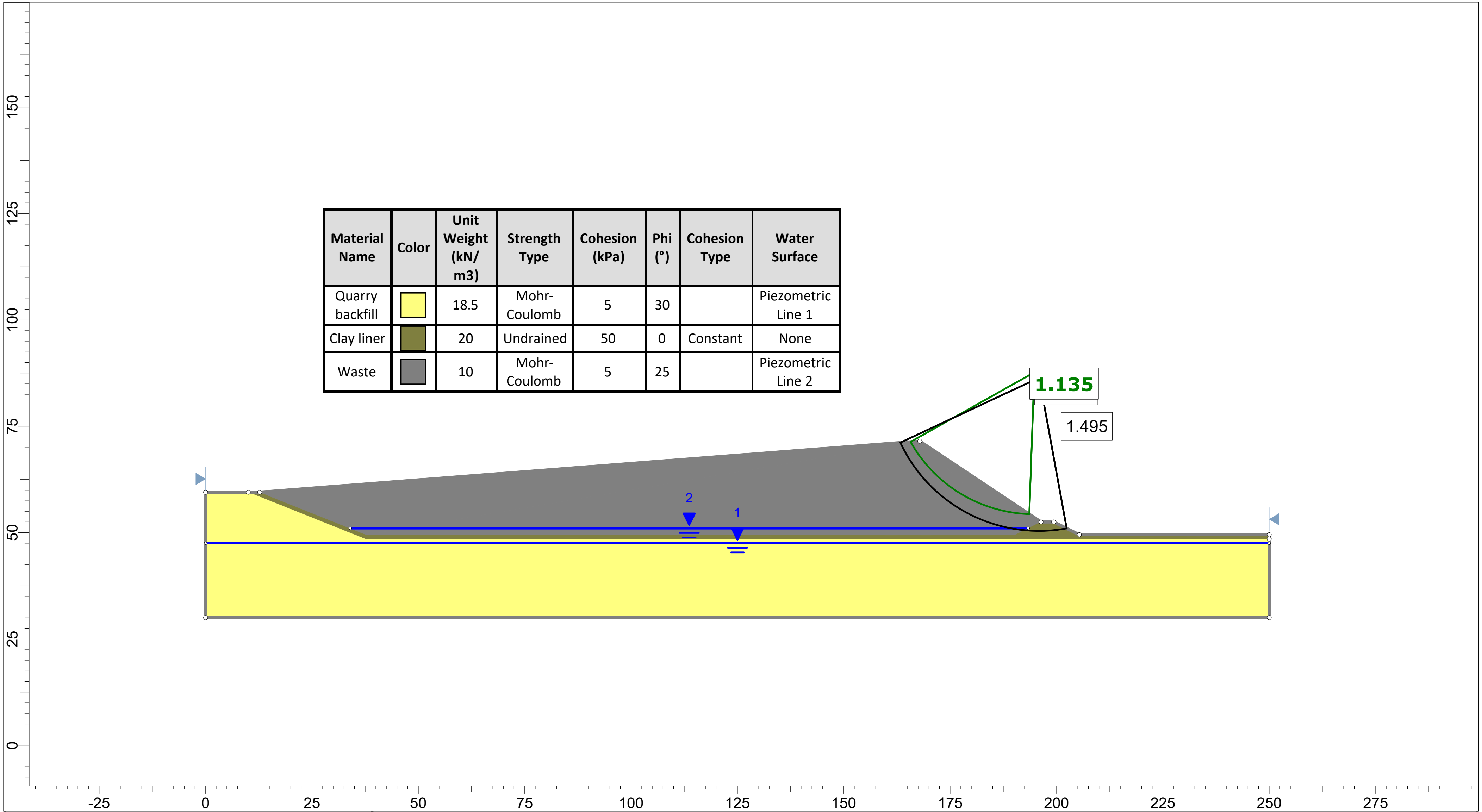
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	06_Sideslope liner - undrained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	26/06/2025 10:27:28	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Quarry backfill		18.5	Mohr-Coulomb	5	30	Water Table
Clay liner		20	Mohr-Coulomb	2	20	Water Table

Technical advisers on environmental issues

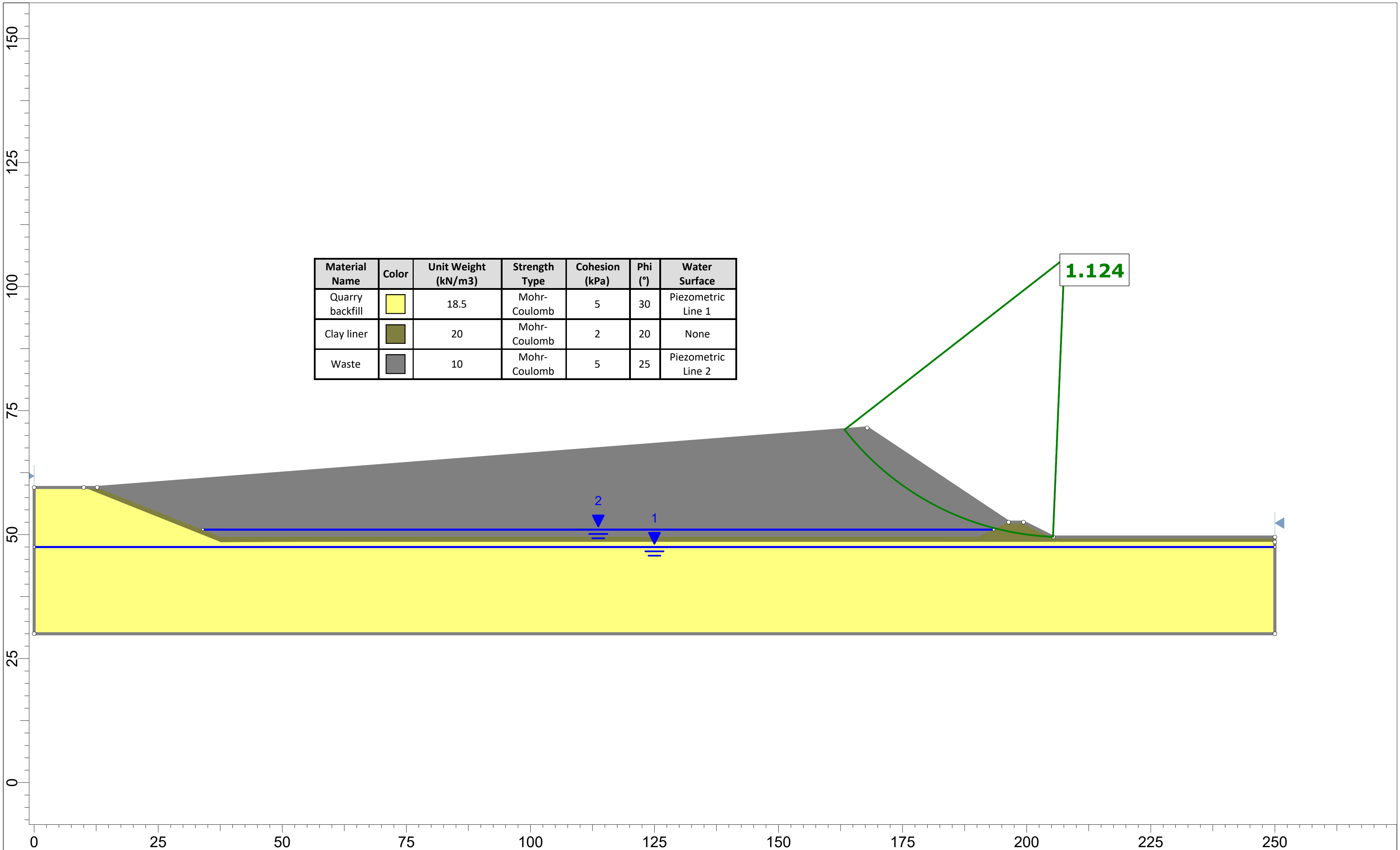
Project	Thornhaugh Landfill Site
Client	Augean South Limited
Filename/scenario	07_Sideslope liner - drained.slim
Drawn By / Checked By	DFR / LCH
Analysis Method	Spencer
Date	26/06/2025 10:33:17
Reference	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Water Surface
Quarry backfill		18.5	Mohr-Coulomb	5	30		Piezometric Line 1
Clay liner		20	Undrained	50	0	Constant	None
Waste		10	Mohr-Coulomb	5	25		Piezometric Line 2

MJCA
Technical advisers on environmental issues

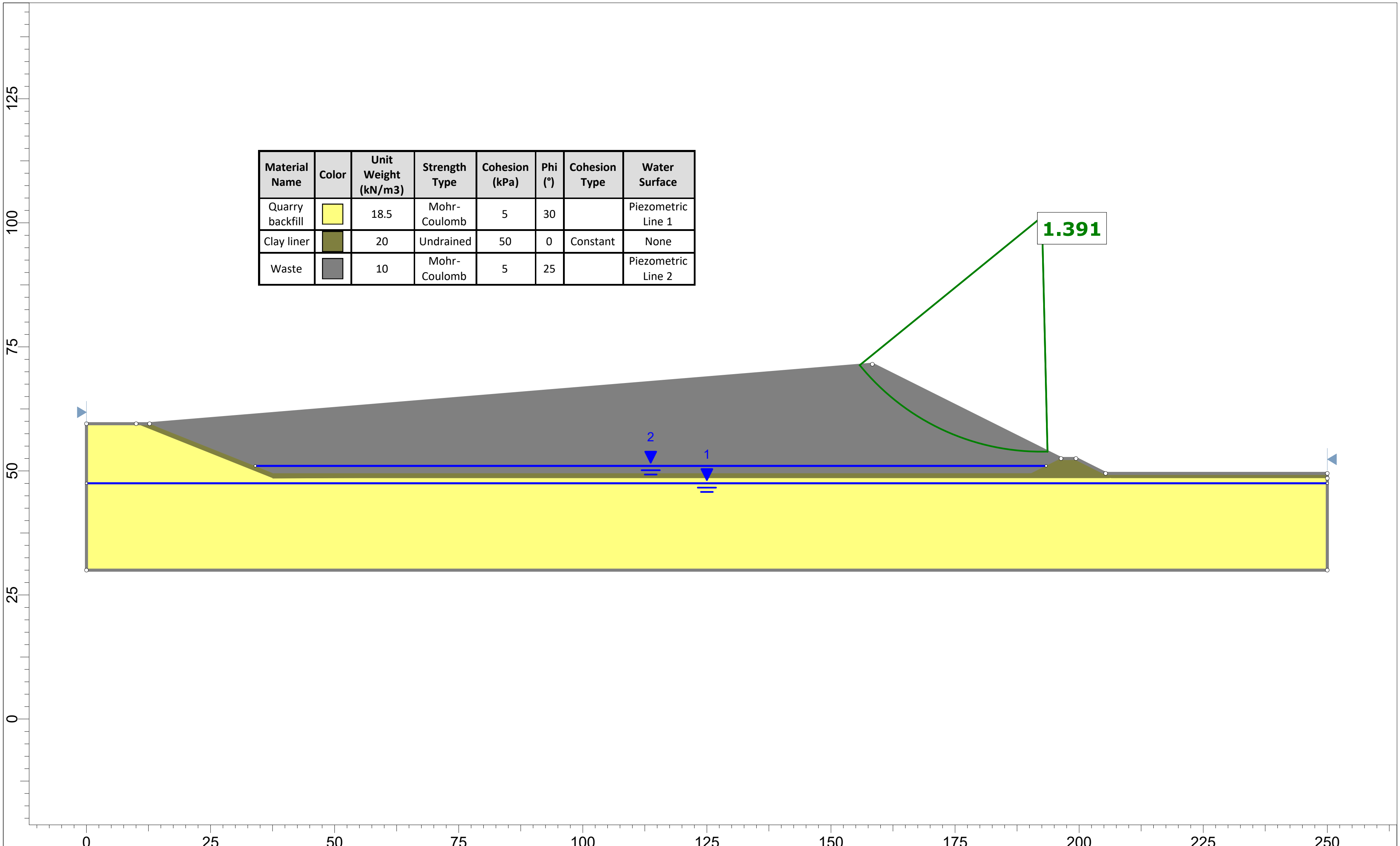
Project	Thornhaugh Landfill Site
Client	Augean South Limited
Filename/scenario	08_Waste mass - undrained intercell bund.slim
Drawn By / Checked By	DFR / LCH
Analysis Method	Spencer
Date	26/06/2025 12:40:01
Reference	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1
Clay liner		20	Mohr-Coulomb	2	20	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2

MJCA
Technical advisers on environmental issues

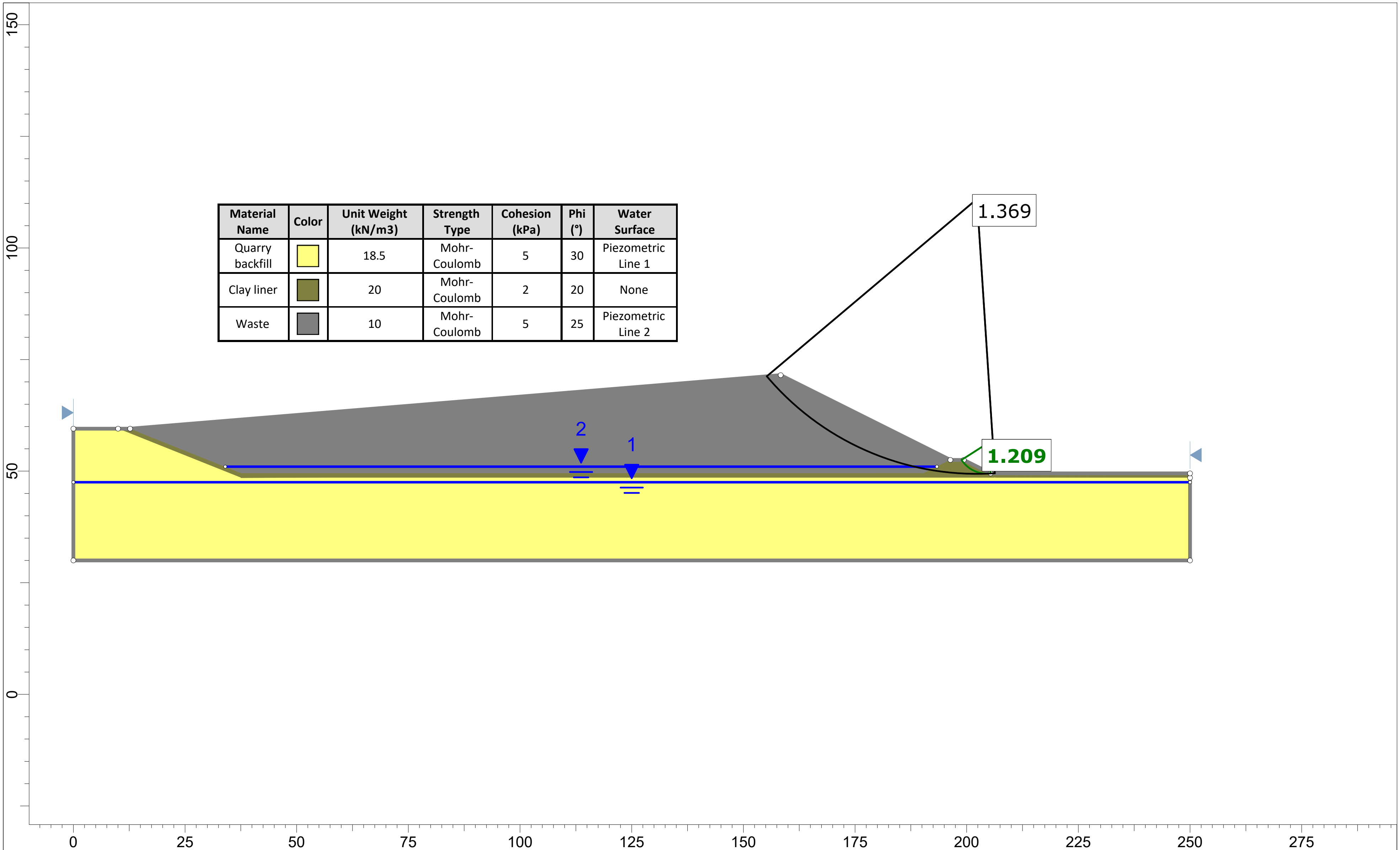
Project	Thornhaugh Landfill Site
Client	Augean South Limited
Filename/scenario	09_Waste mass - drained intercell bund.slim
Drawn By / Checked By	DFR / LCH
Analysis Method	Spencer
Date	26/06/2025 12:50:02
Reference	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Water Surface
Quarry backfill		18.5	Mohr-Coulomb	5	30		Piezometric Line 1
Clay liner		20	Undrained	50	0	Constant	None
Waste		10	Mohr-Coulomb	5	25		Piezometric Line 2

MJCA
Technical advisers on environmental issues

Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	10_Waste mass 1v2h - undrained intercell bund.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	26/06/2025 12:53:21	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1
Clay liner		20	Mohr-Coulomb	2	20	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2

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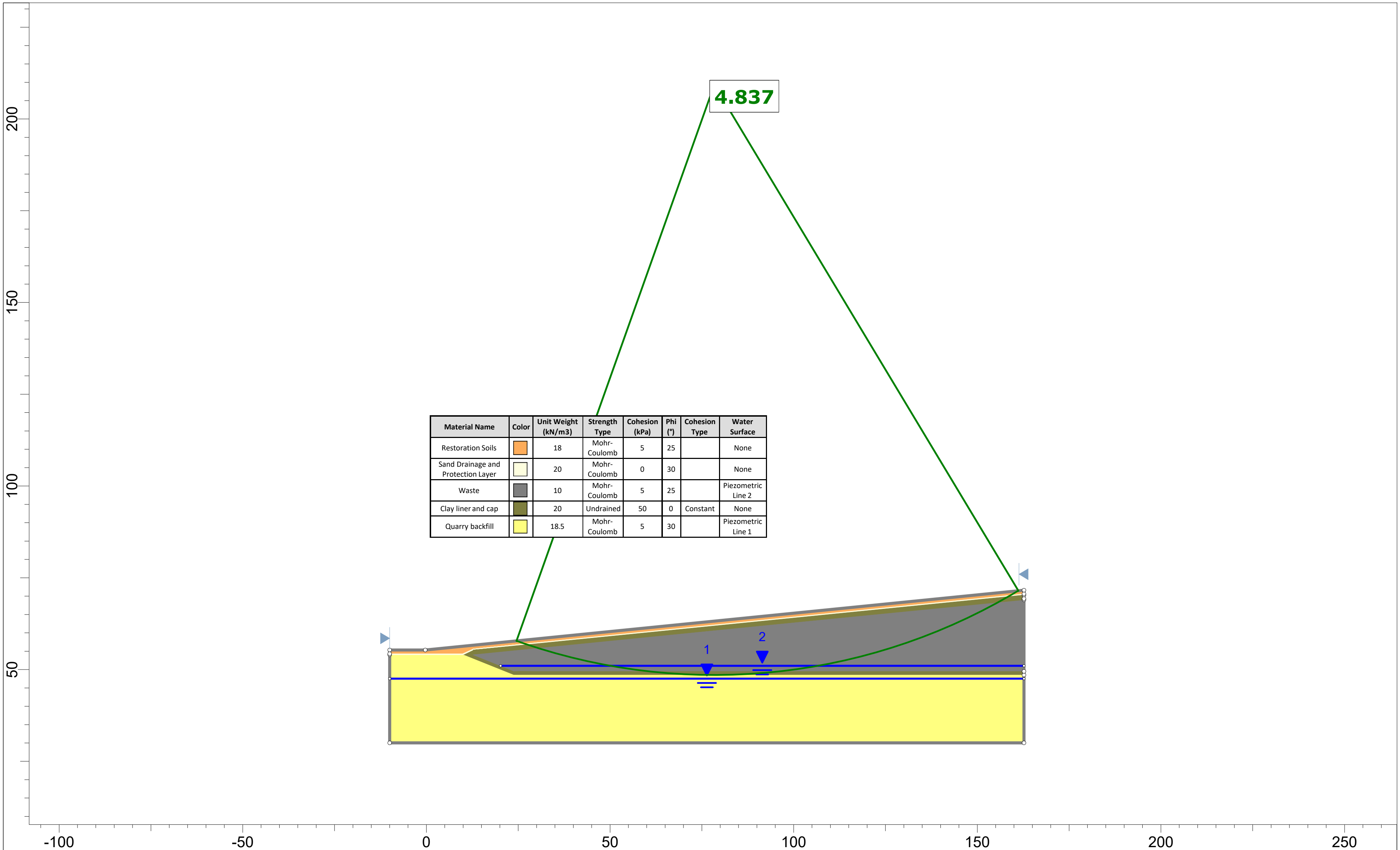
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	11_Waste mass 1v2h - drained intercell bund.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	26/06/2025 13:00:38	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25		None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30		None
Waste		10	Mohr-Coulomb	5	25		Piezometric Line 2
Clay liner and cap		20	Undrained	50	0	Constant	None
Quarry backfill		18.5	Mohr-Coulomb	5	30		Piezometric Line 1

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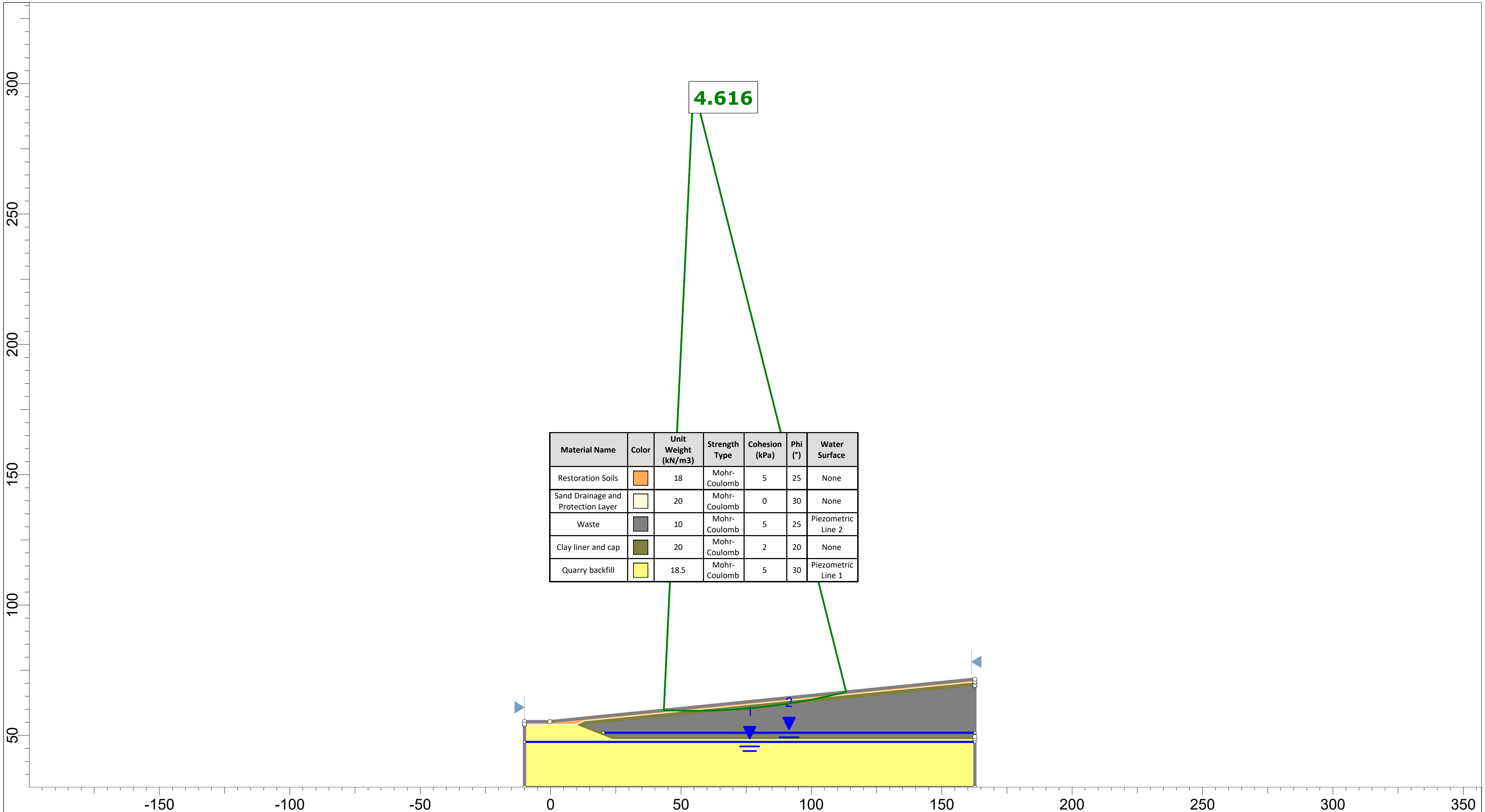
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	12_Cap - long N slope - 1m rest - 1.5m leachate - undrained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	27/06/2025 16:18:41	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25	None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2
Clay liner and cap		20	Mohr-Coulomb	2	20	None
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1

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Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	13_Cap - long N slope - 1m rest - 1.5m leachate - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
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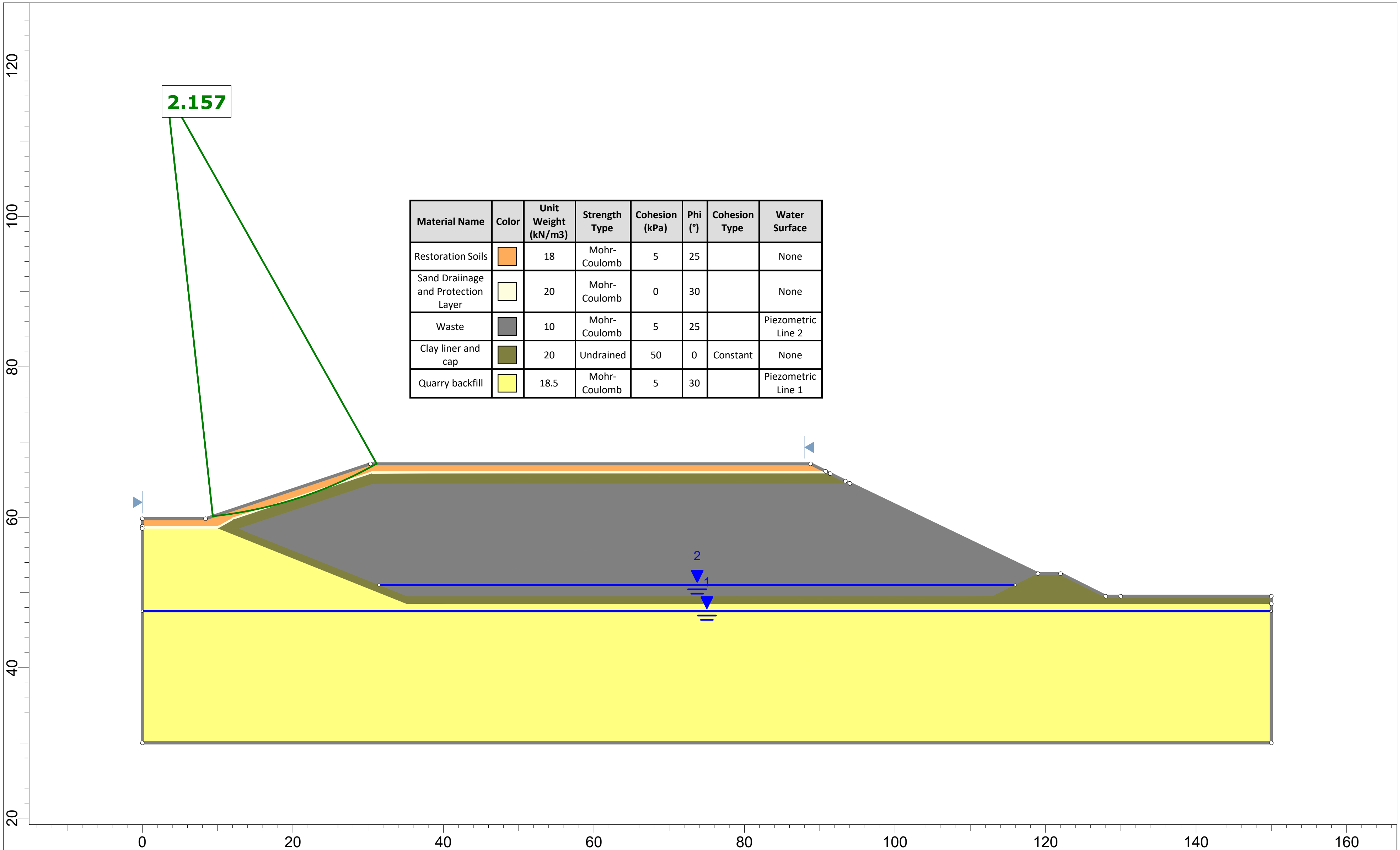

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25		None
Sand Draiinage and Protection Layer		20	Mohr-Coulomb	0	30		None
Waste		10	Mohr-Coulomb	5	25		Piezometric Line 2
Clay liner and cap		20	Undrained	50	0	Constant	None
Quarry backfill		18.5	Mohr-Coulomb	5	30		Piezometric Line 1

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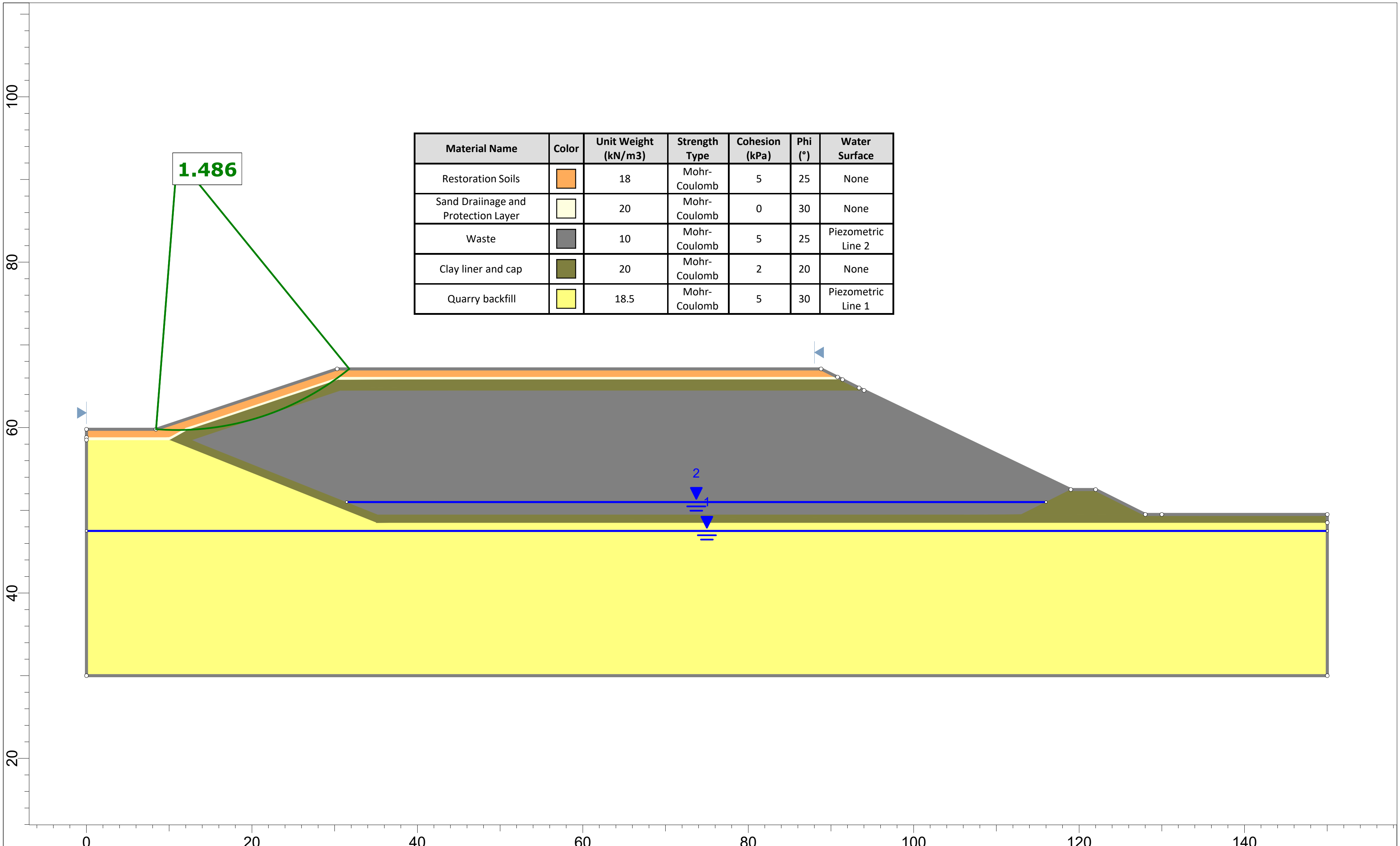
Project	Thornhaugh Landfill Site
Client	Augean South Limited
Filename/scenario	14_Cap - steep slope - 1m rest - 1.5m leachate - undrained.slim
Drawn By / Checked By	DFR / LCH
Analysis Method	Spencer
Date	27/06/2025 15:36:40
Reference	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25	None
Sand Draiinage and Protection Layer		20	Mohr-Coulomb	0	30	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2
Clay liner and cap		20	Mohr-Coulomb	2	20	None
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1

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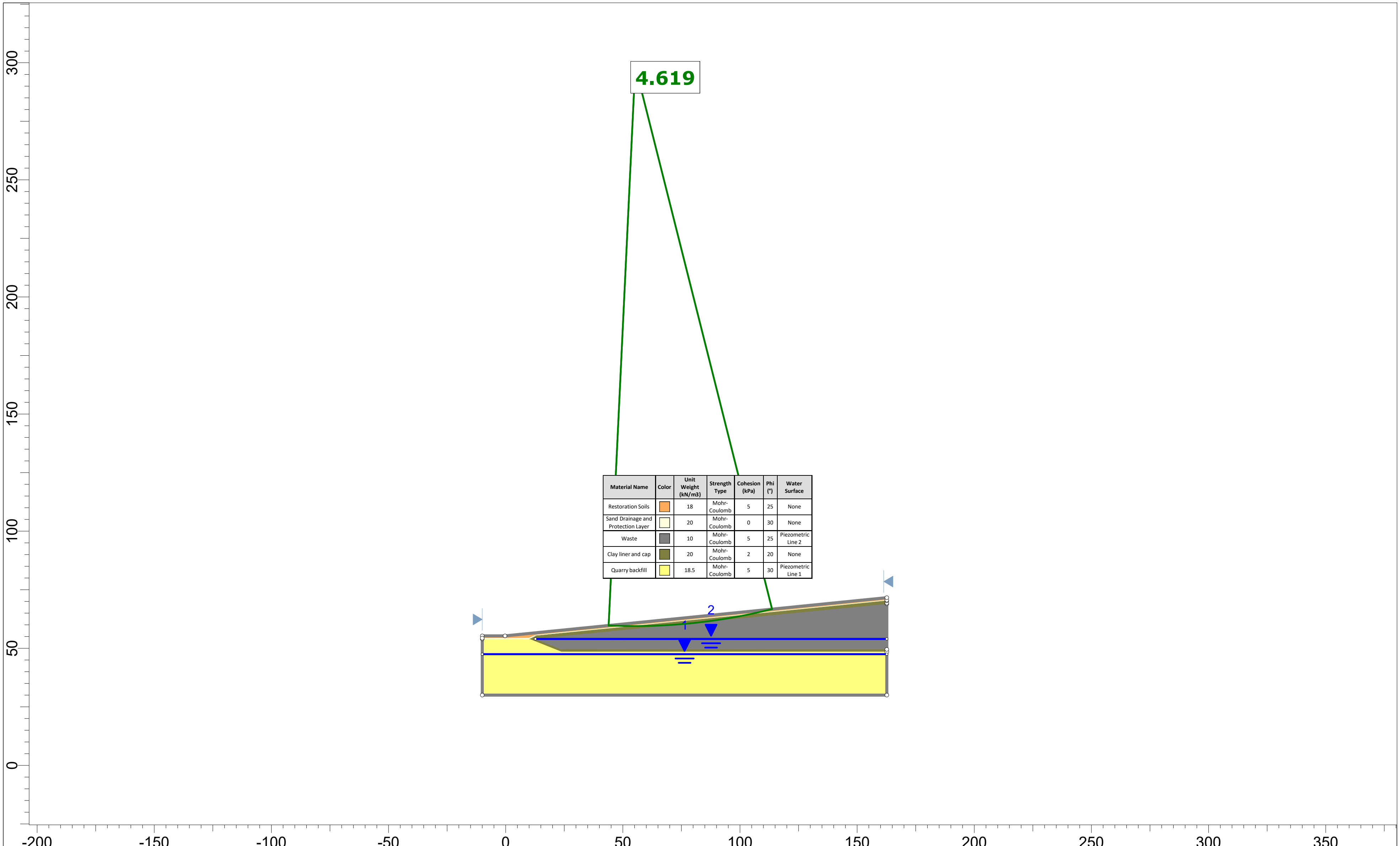
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	15_Cap - steep slope - 1m rest - 1.5m leachate - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	27/06/2025 15:38:19	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25	None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2
Clay liner and cap		20	Mohr-Coulomb	2	20	None
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1

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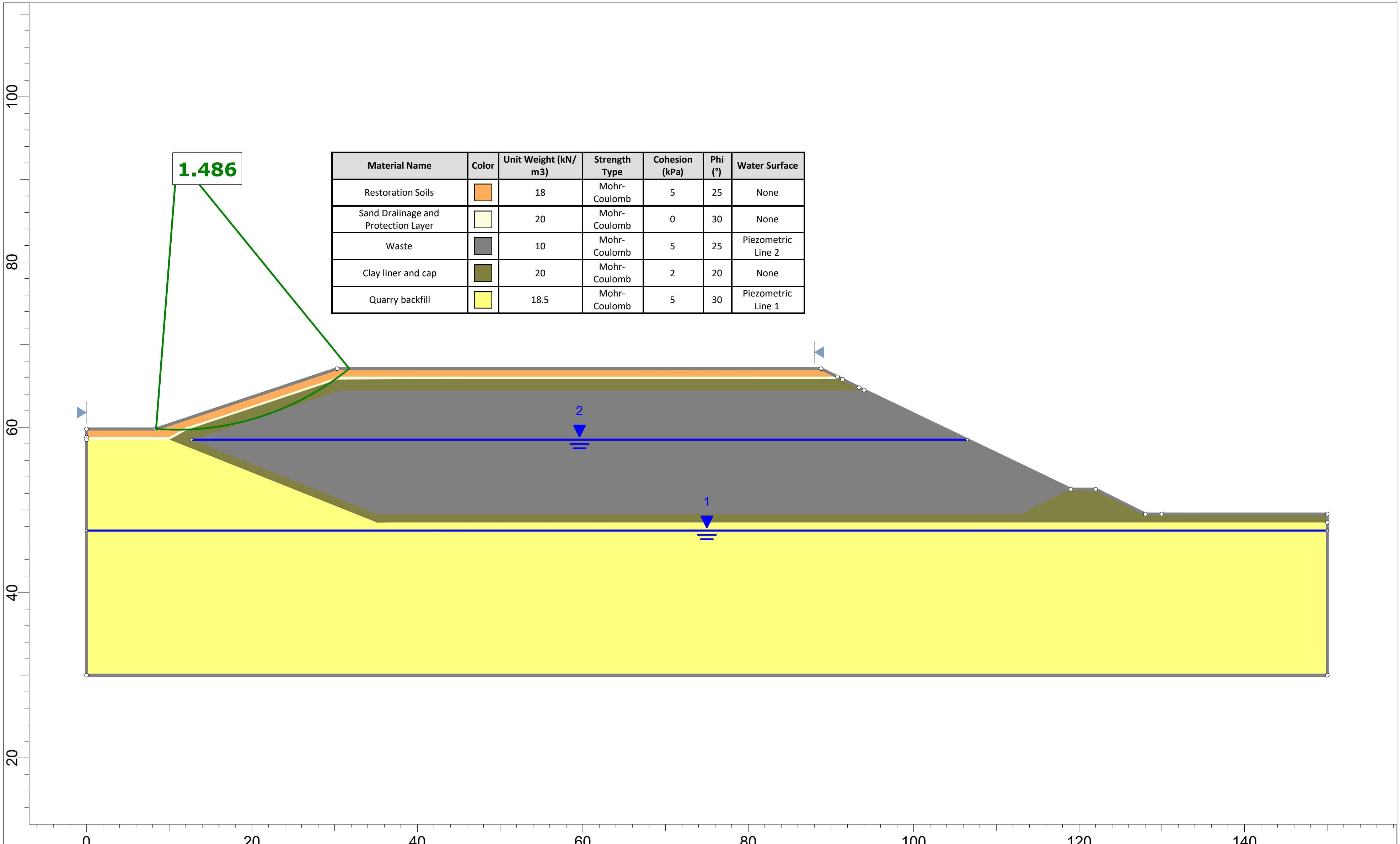
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	16_Cap - long N slope - 1m rest - uncontrolled leachate - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	10/07/2025 13:57:28	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25	None
Sand Draiinage and Protection Layer		20	Mohr-Coulomb	0	30	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2
Clay liner and cap		20	Mohr-Coulomb	2	20	None
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1

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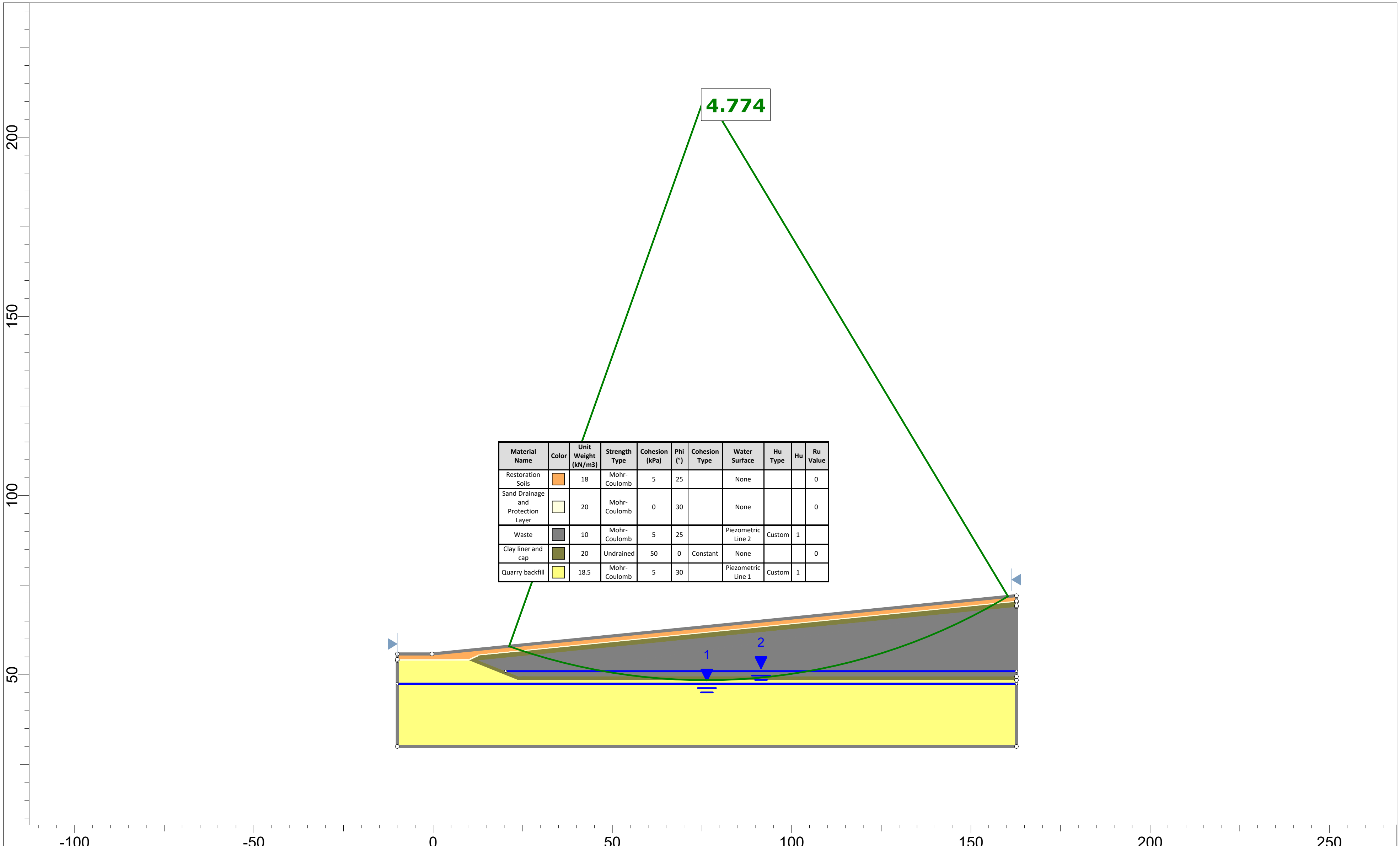
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	17_Cap - steep slope - 1m rest - uncontrolled leachate - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	27/06/2025 16:36:24	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Water Surface	Hu Type	Hu	Ru Value
Restoration Soils		18	Mohr-Coulomb	5	25		None			0
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30		None			0
Waste		10	Mohr-Coulomb	5	25		Piezometric Line 2	Custom	1	
Clay liner and cap		20	Undrained	50	0	Constant	None			0
Quarry backfill		18.5	Mohr-Coulomb	5	30		Piezometric Line 1	Custom	1	

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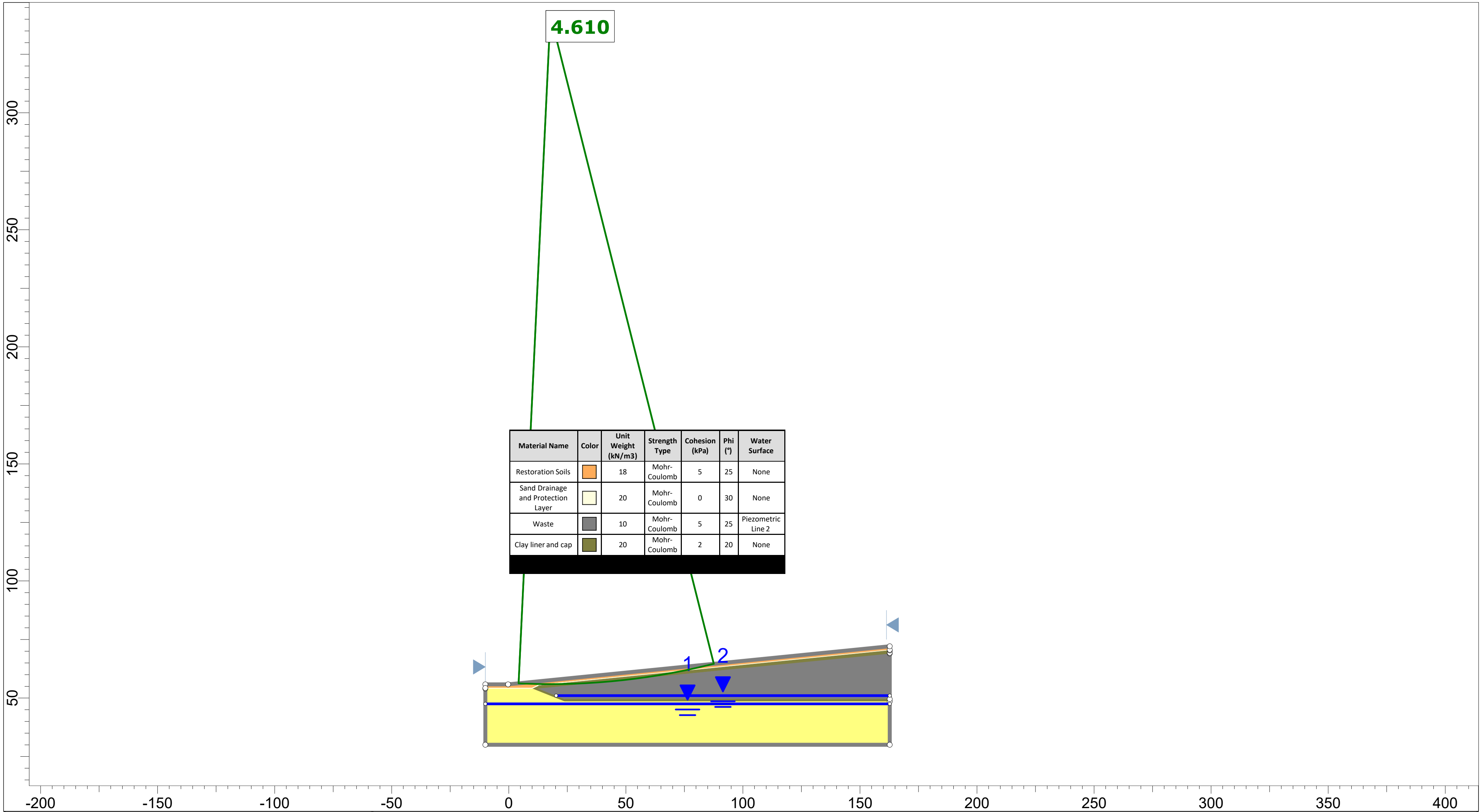
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	18_Cap - long N slope - 1.5m rest - 1.5m leachate - undrained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	27/06/2025 16:39:41	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25	None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2
Clay liner and cap		20	Mohr-Coulomb	2	20	None

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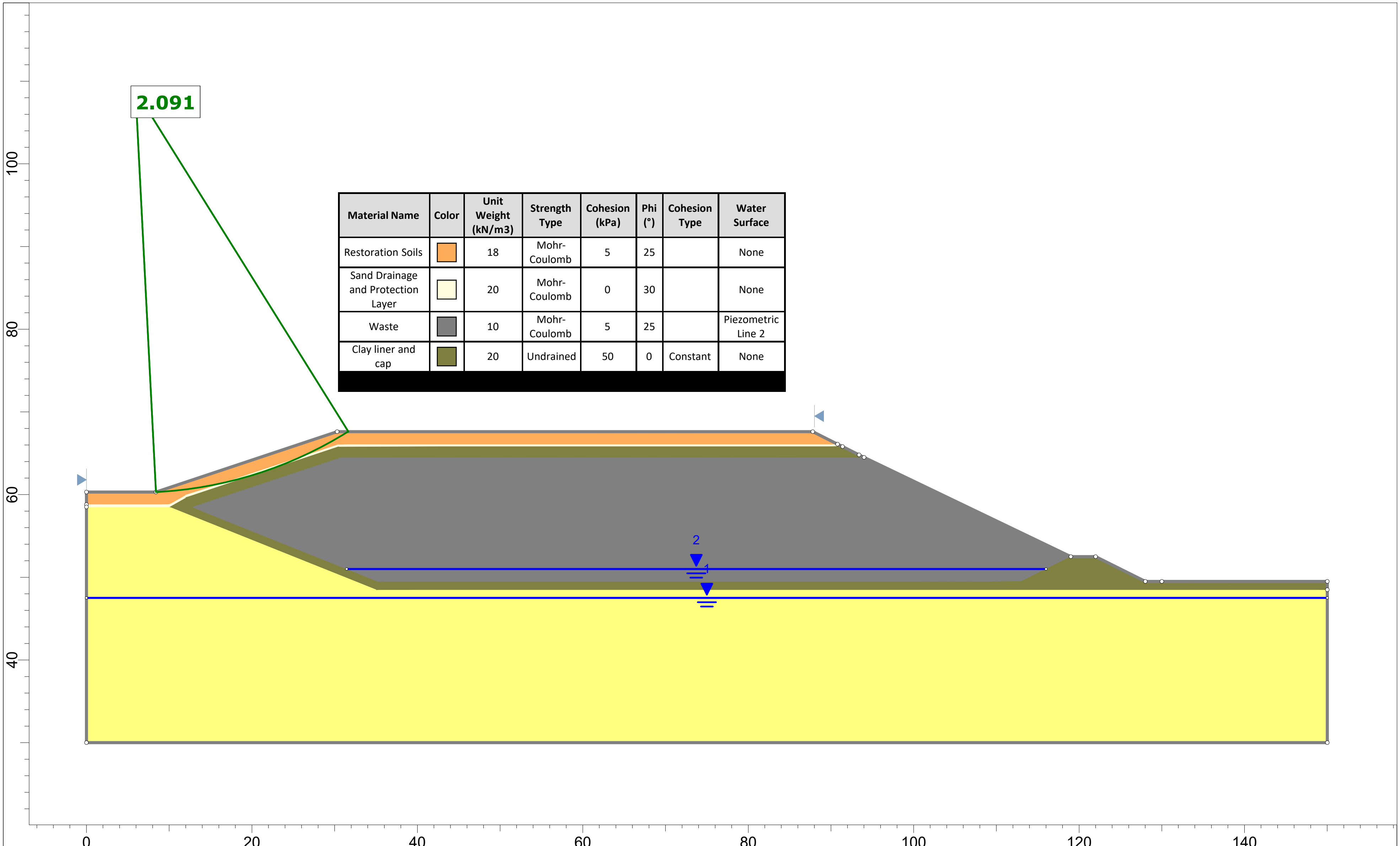
Project	Thornhaugh Landfill Site
Client	Augean South Limited
Filename/scenario	19_Cap - long N slope - 1.5m rest - 1.5m leachate - drained.slim
Drawn By / Checked By	DFR / LCH
Analysis Method	Spencer
Date	27/06/2025 17:06:36
Reference	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25		None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30		None
Waste		10	Mohr-Coulomb	5	25		Piezometric Line 2
Clay liner and cap		20	Undrained	50	0	Constant	None

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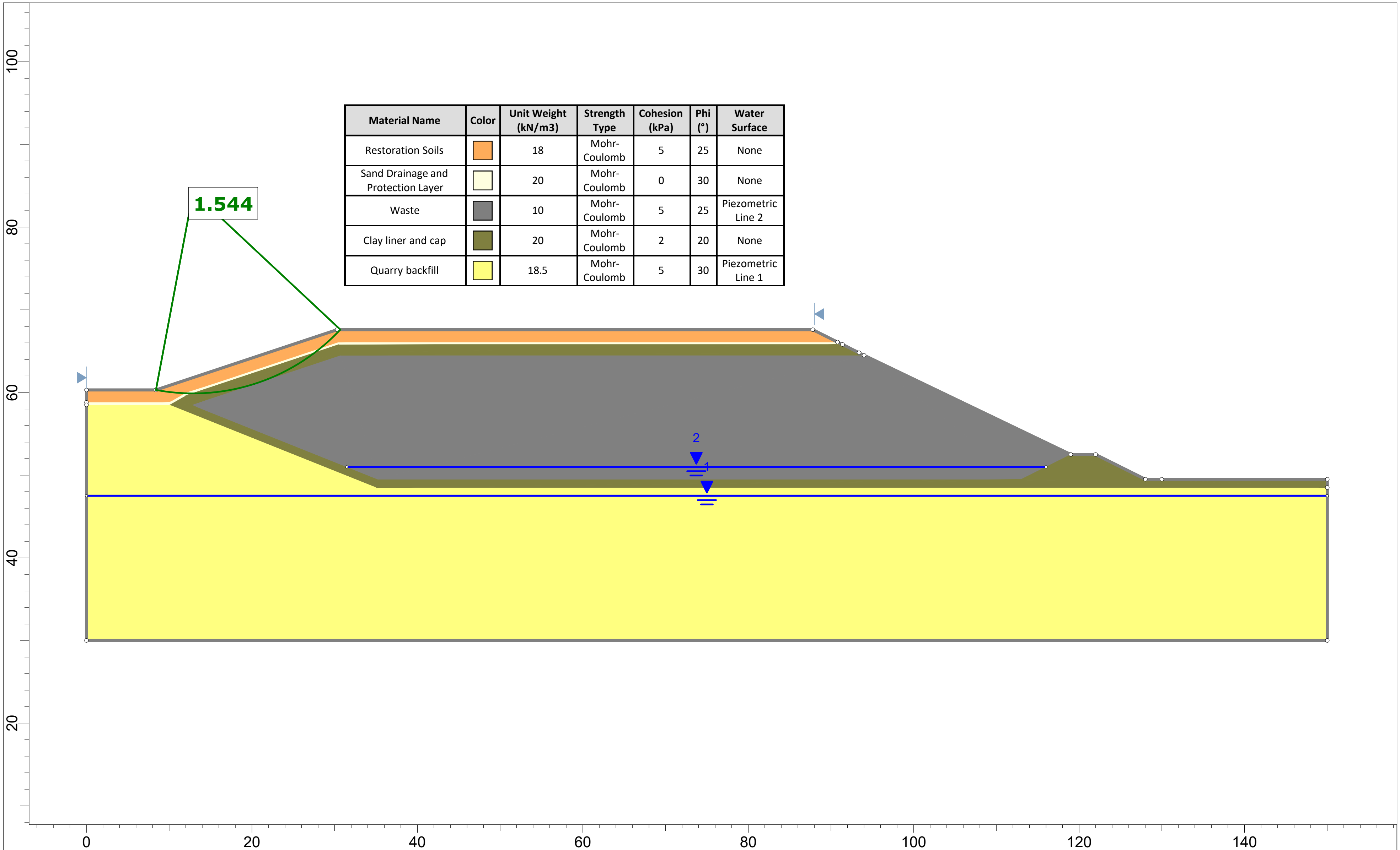
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	20_Cap - steep slope - 1.5m rest - 1.5m leachate - undrained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	10/07/2025 14:01:34	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25	None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2
Clay liner and cap		20	Mohr-Coulomb	2	20	None
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1

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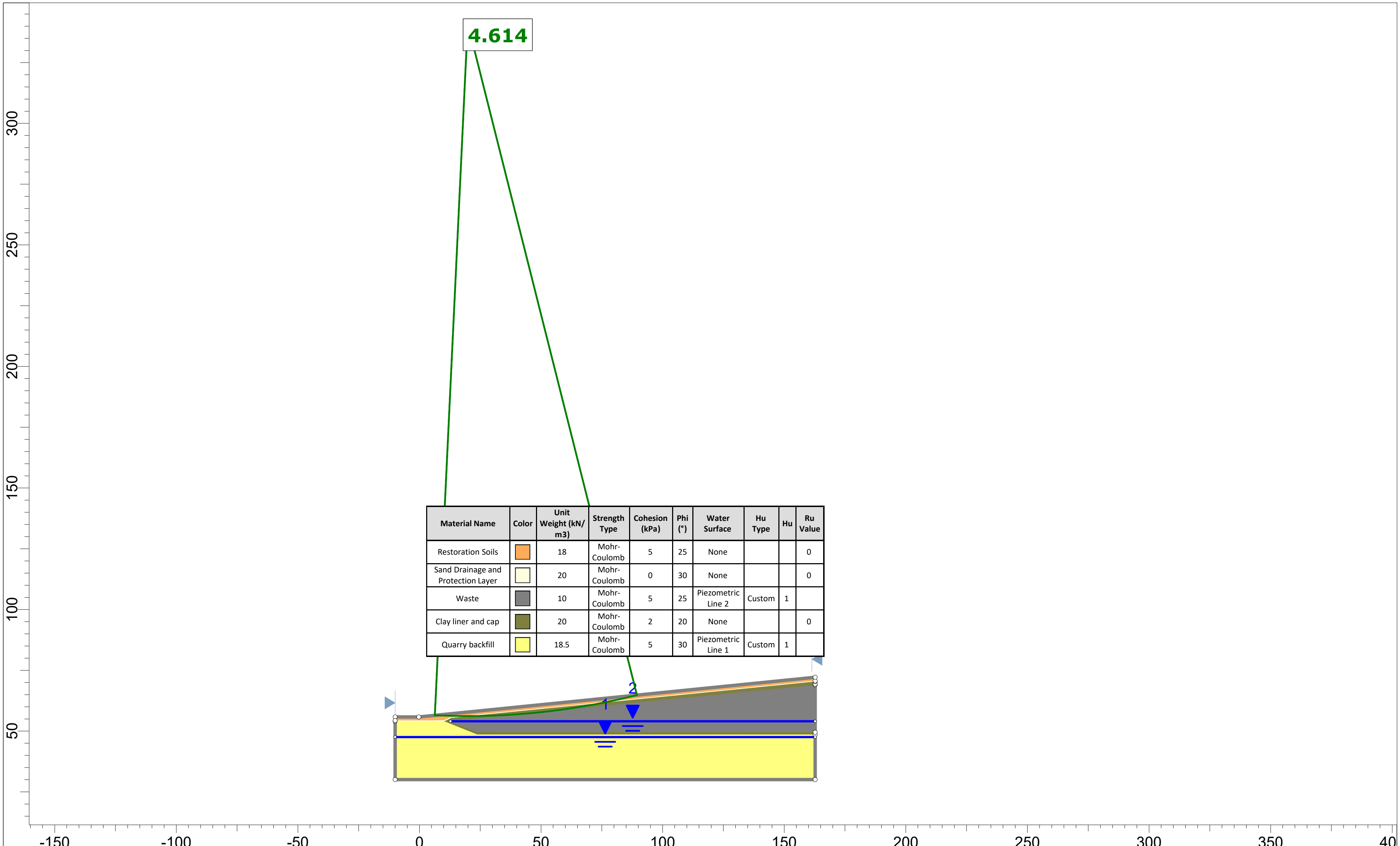
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	21_Cap - steep slope - 1.5m rest - 1.5m leachate - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	10/07/2025 14:03:46	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Hu Type	Hu	Ru Value
Restoration Soils		18	Mohr-Coulomb	5	25	None			0
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30	None			0
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2	Custom	1	
Clay liner and cap		20	Mohr-Coulomb	2	20	None			0
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1	Custom	1	

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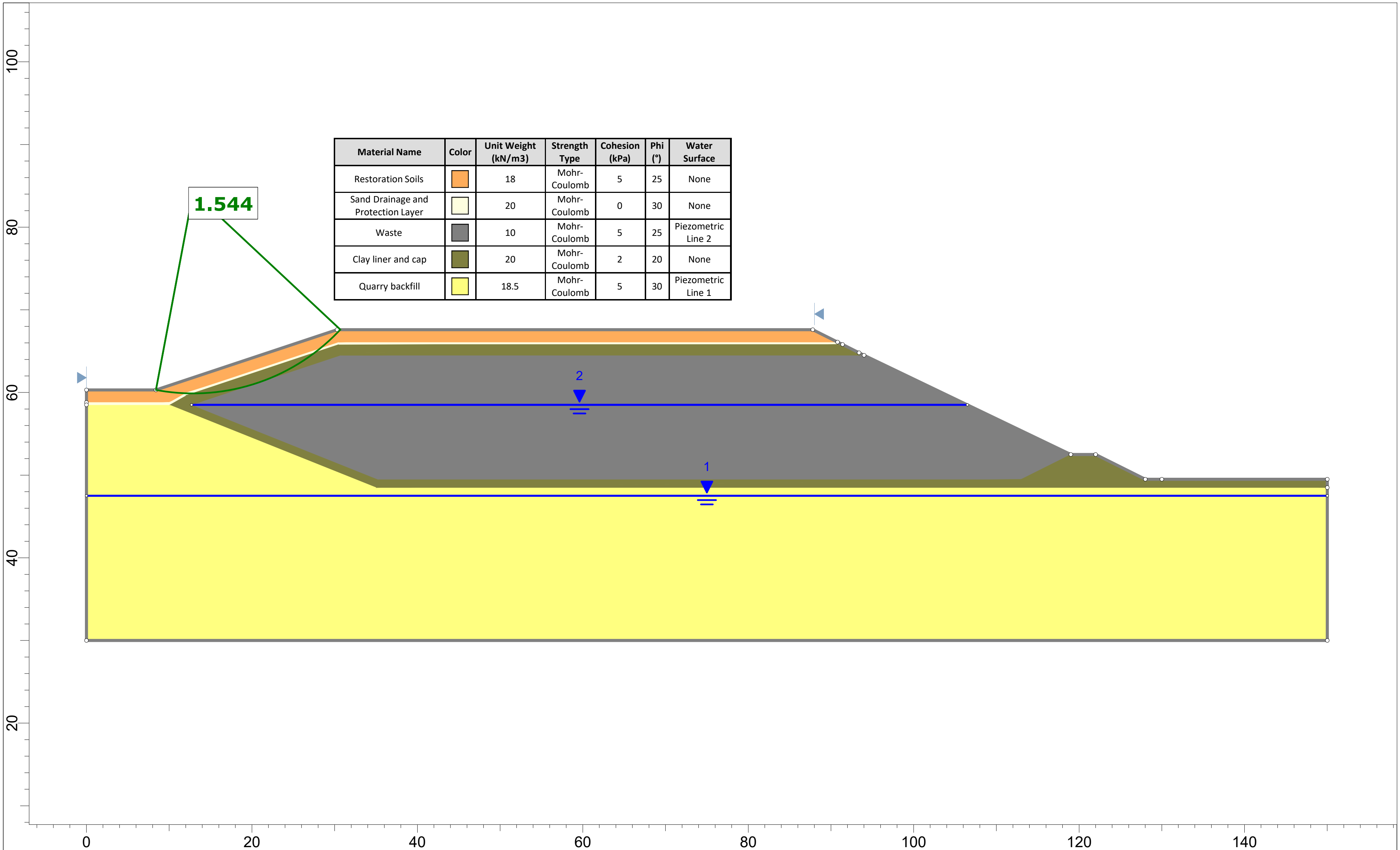
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	22_Cap - long N slope - 1.5m rest - uncontrolled leachate - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	27/06/2025 17:22:57	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25	None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2
Clay liner and cap		20	Mohr-Coulomb	2	20	None
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1

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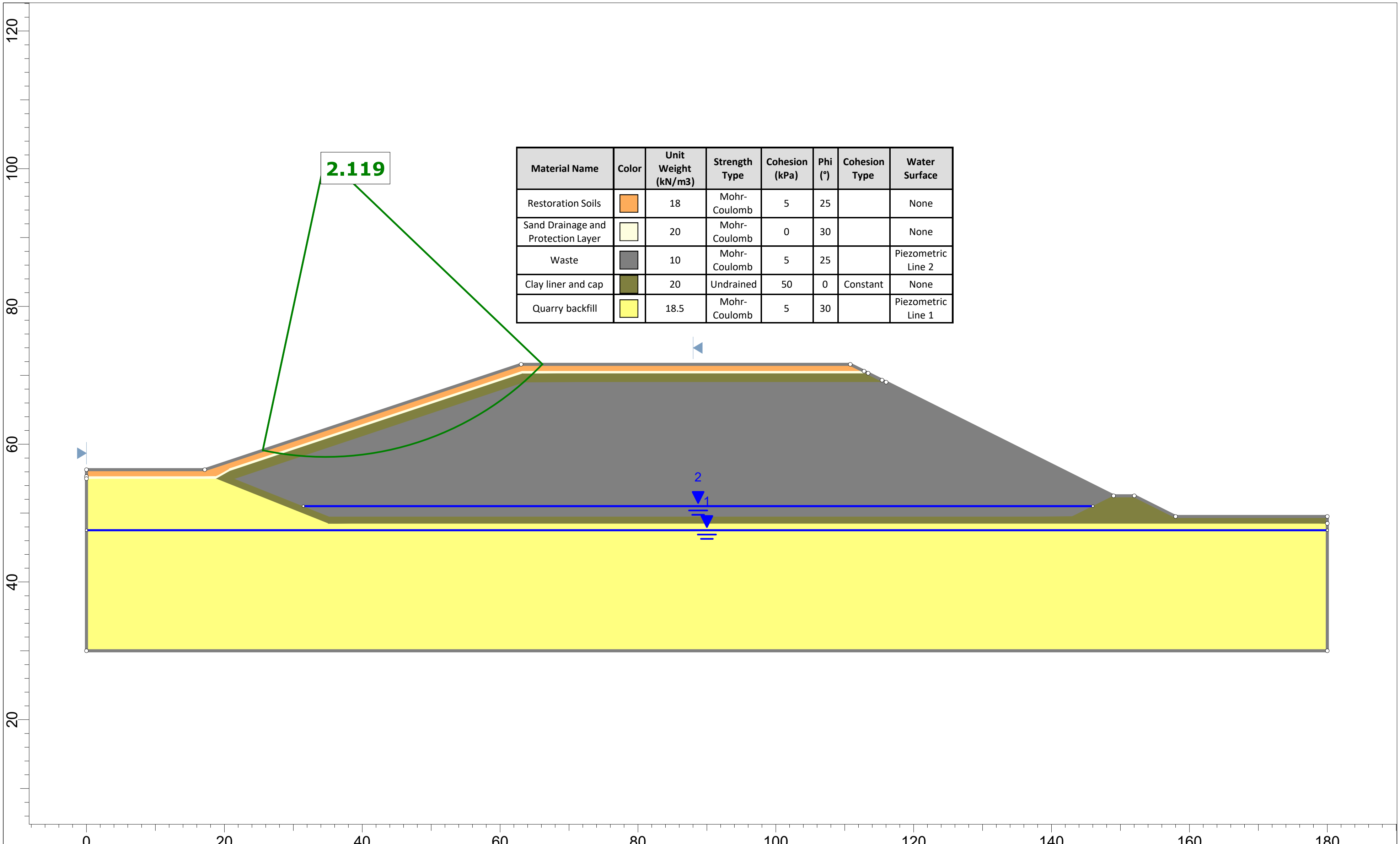
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	23_Cap - steep slope - 1.5m rest - uncontrolled leachate - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	10/07/2025 14:05:55	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25		None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30		None
Waste		10	Mohr-Coulomb	5	25		Piezometric Line 2
Clay liner and cap		20	Undrained	50	0	Constant	None
Quarry backfill		18.5	Mohr-Coulomb	5	30		Piezometric Line 1

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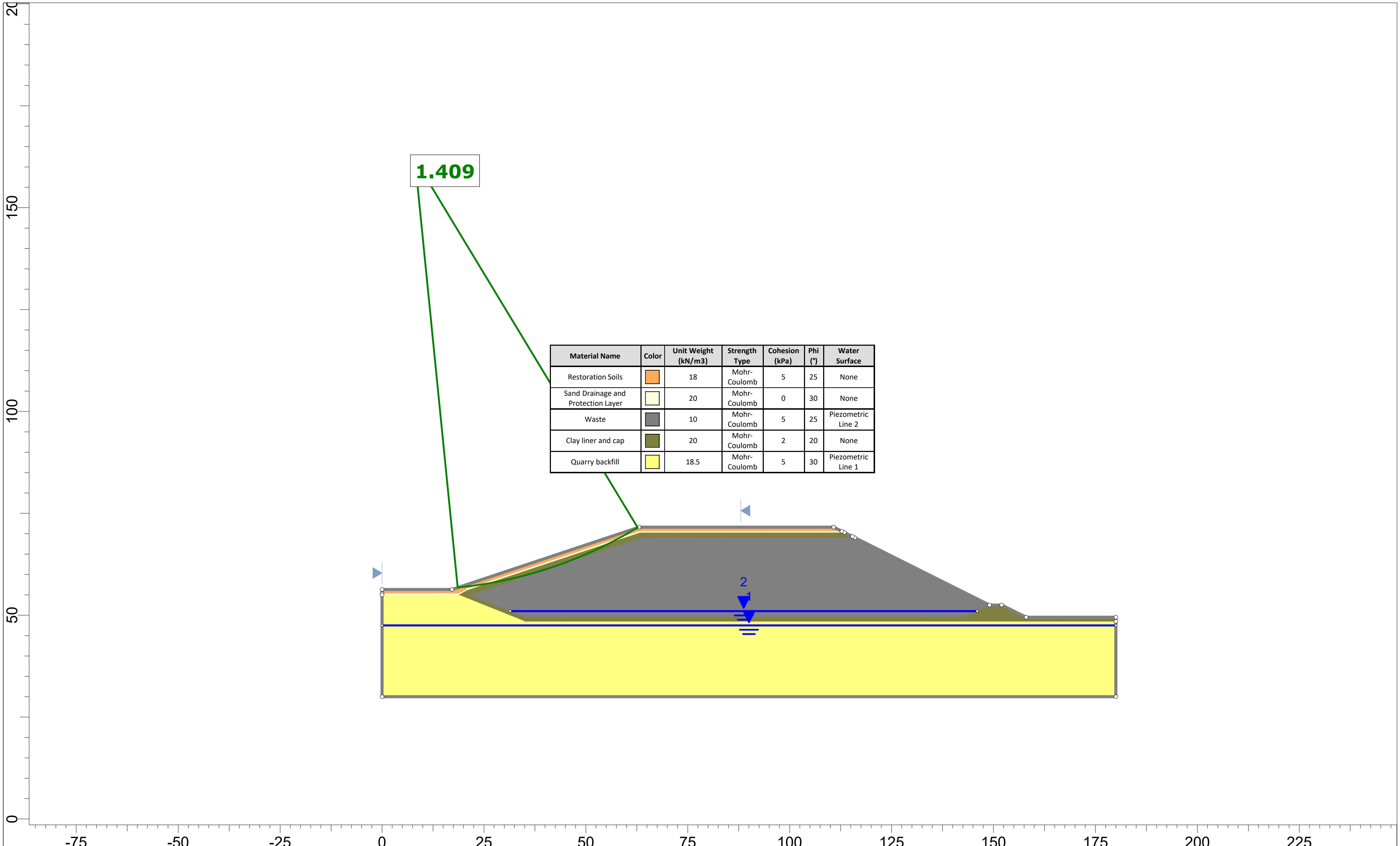
Project	Thornhaugh Landfill Site
Client	Augean South Limited
Filename/scenario	24_Cap - southern slope - unrestored - 1.5m leachate - undrained.slim
Drawn By / Checked By	DFR / LCH
Analysis Method	Spencer
Date	10/07/2025 14:38:45
Reference	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25	None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2
Clay liner and cap		20	Mohr-Coulomb	2	20	None
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1

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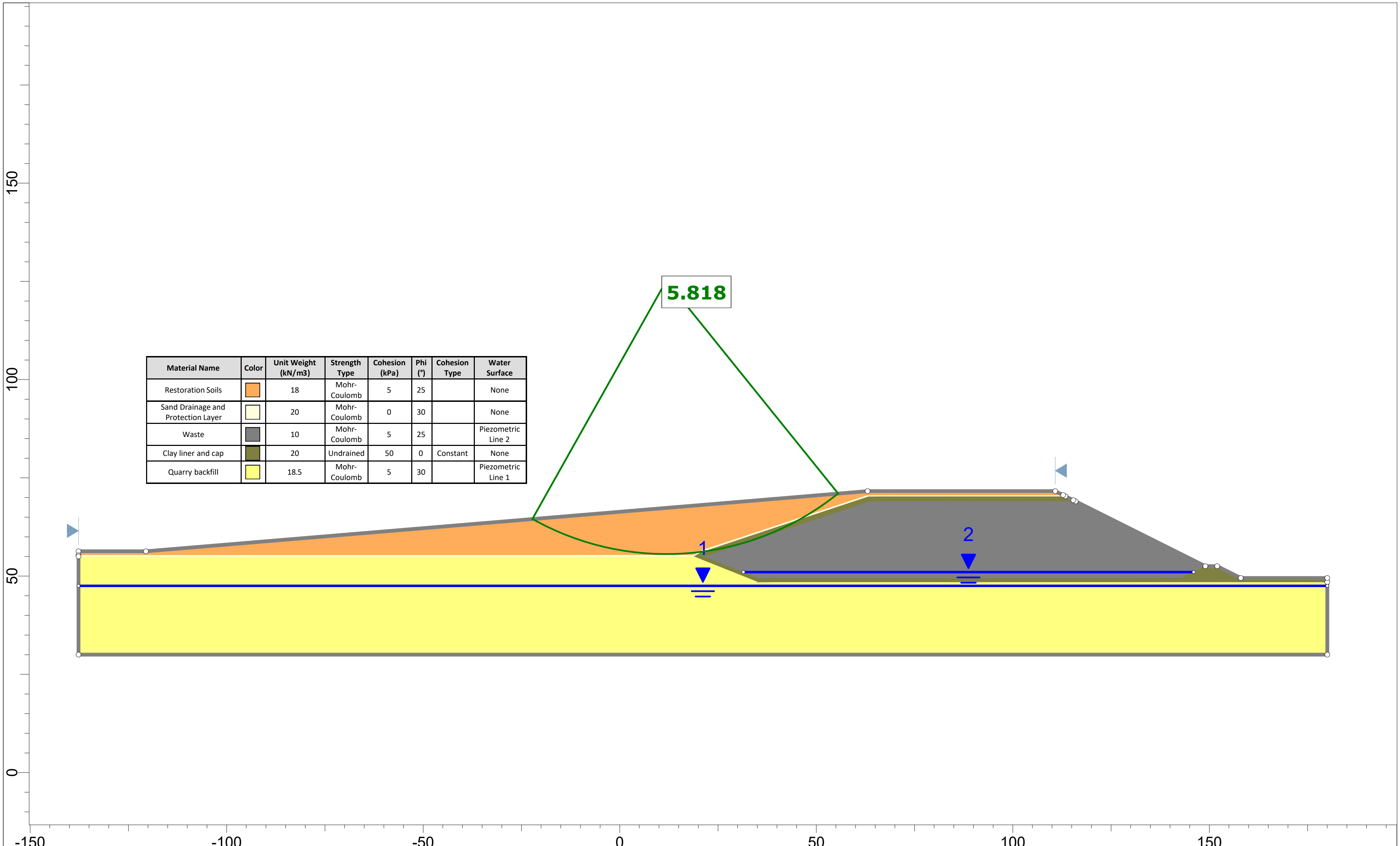
Project	Thornhaugh Landfill Site
Client	Augean South Limited
Filename/scenario	25_Cap - southern slope - unrestored - 1.5m leachate - drained.slim
Drawn By / Checked By	DFR / LCH
Analysis Method	Spencer
Date	10/07/2025 14:41:02
Reference	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25		None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30		None
Waste		10	Mohr-Coulomb	5	25		Piezometric Line 2
Clay liner and cap		20	Undrained	50	0	Constant	None
Quarry backfill		18.5	Mohr-Coulomb	5	30		Piezometric Line 1

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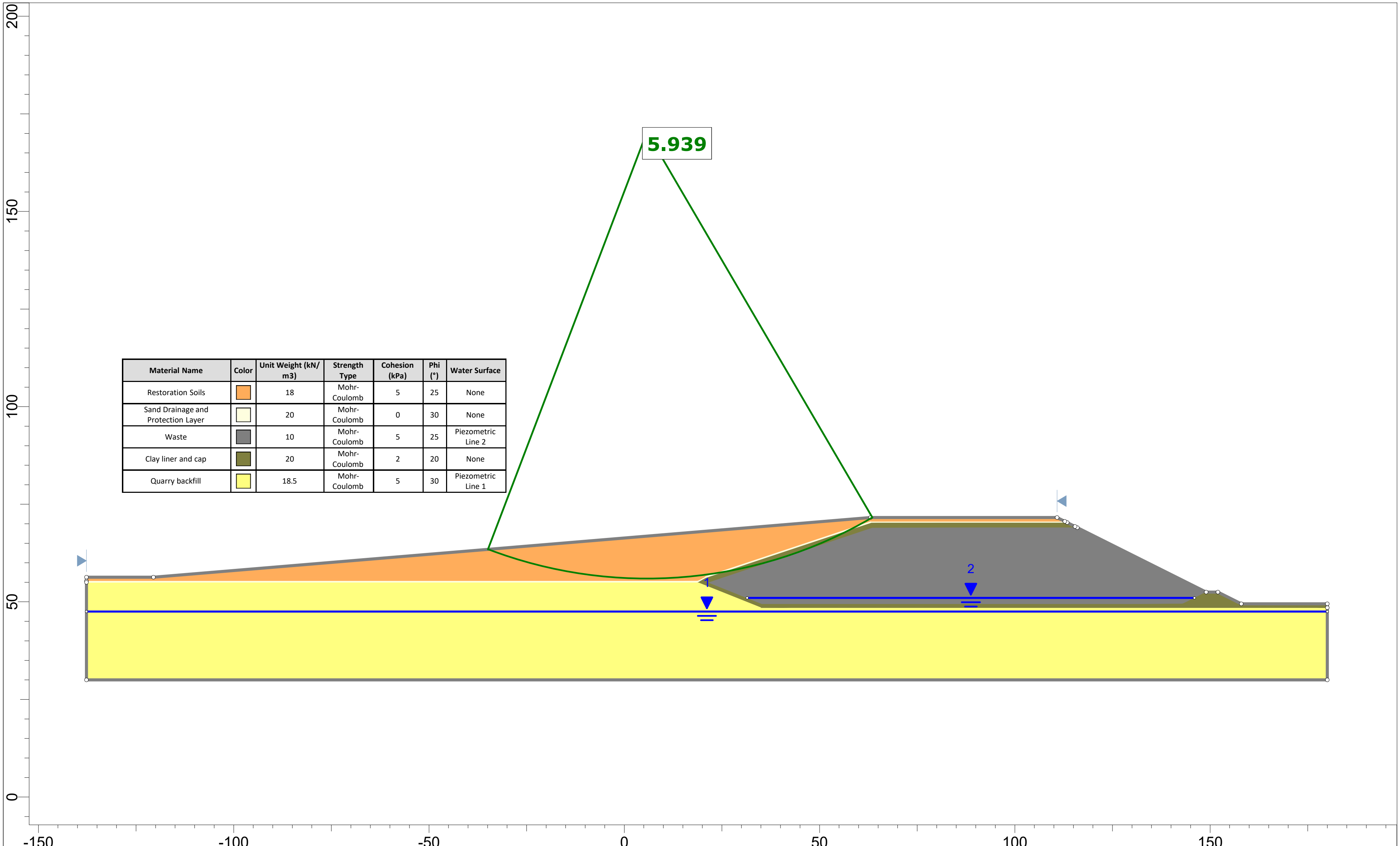
Project Thornhaugh Landfill Site	
Client Augean South Limited	*Filename/scenario* 26_Cap - southern slope - restored - 1.5m leachate - undrained.slim
Drawn By / Checked By DFR / LCH	*Analysis Method* Spencer
Date 10/07/2025 14:44:56	*Reference* AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25	None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2
Clay liner and cap		20	Mohr-Coulomb	2	20	None
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1

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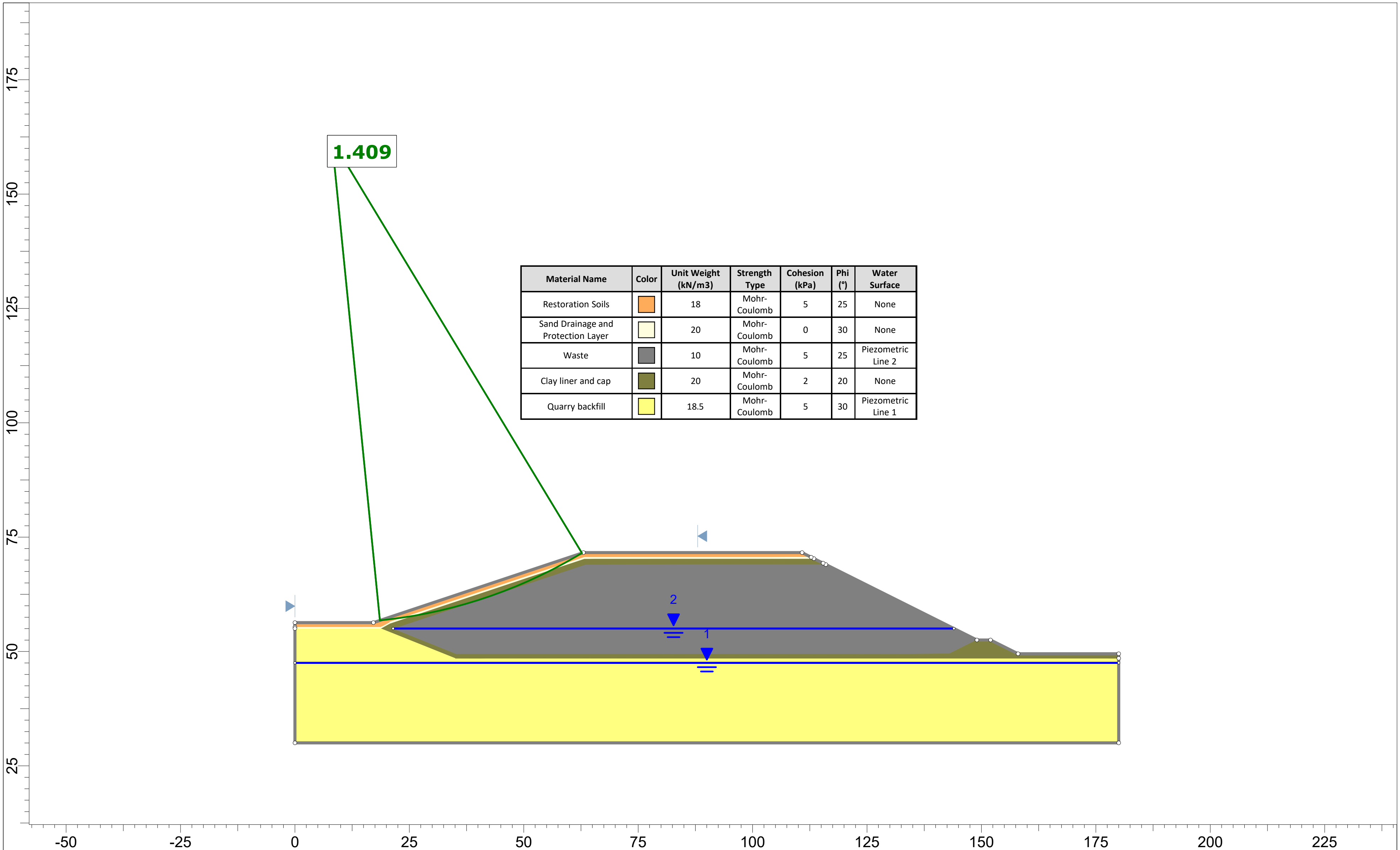
Project Thornhaugh Landfill Site	
Client Augean South Limited	*Filename/scenario* 27_Cap - southern slope - restored - 1.5m leachate - drained.slim
Drawn By / Checked By DFR / LCH	*Analysis Method* Spencer
Date 10/07/2025 14:48:21	*Reference* AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25	None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2
Clay liner and cap		20	Mohr-Coulomb	2	20	None
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1

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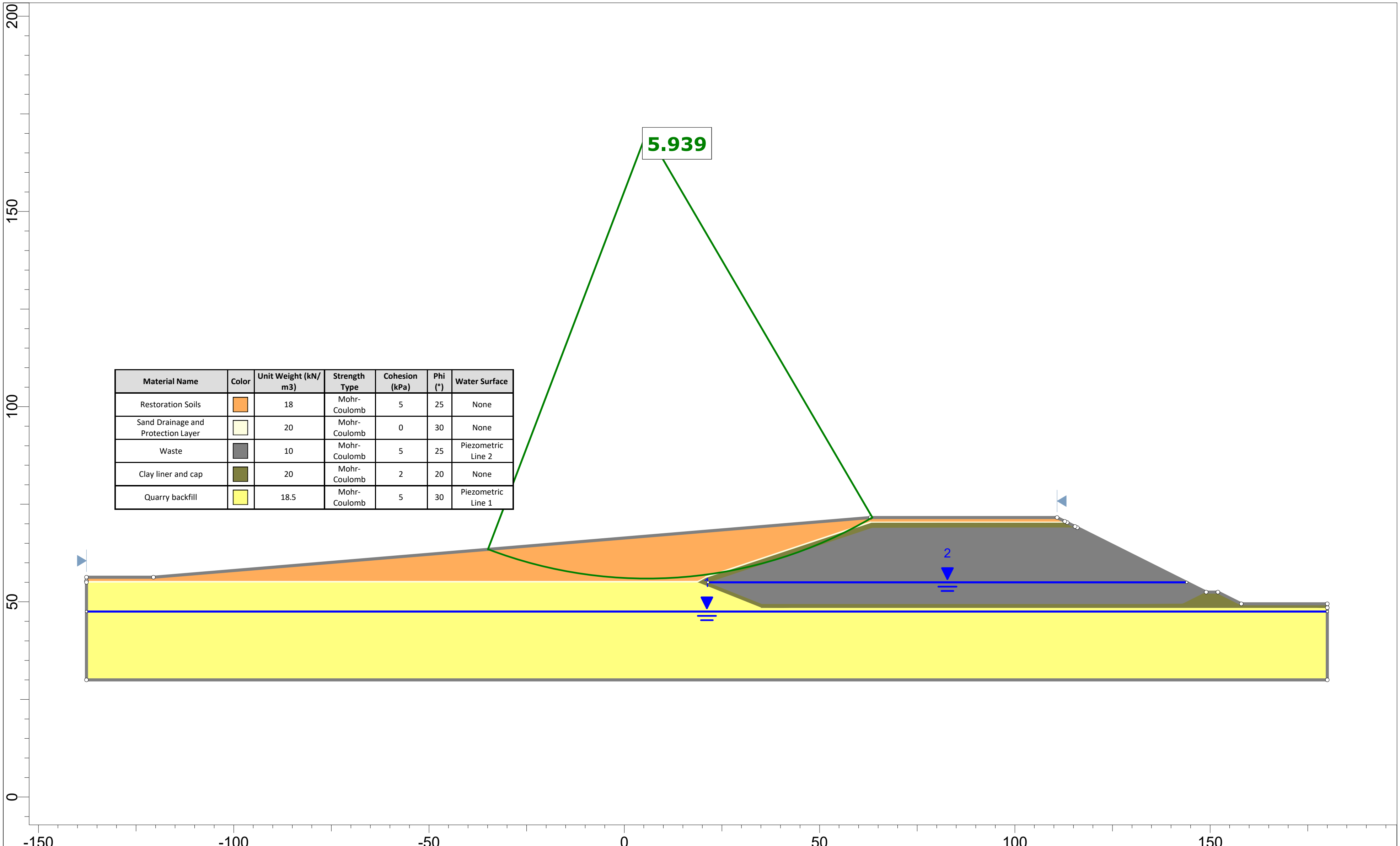
Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	28_Cap - southern slope - unrestored - uncontrolled leachate - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	10/07/2025 14:51:53	*Reference*	AU/TH/DFR/3361/01SRA



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface
Restoration Soils		18	Mohr-Coulomb	5	25	None
Sand Drainage and Protection Layer		20	Mohr-Coulomb	0	30	None
Waste		10	Mohr-Coulomb	5	25	Piezometric Line 2
Clay liner and cap		20	Mohr-Coulomb	2	20	None
Quarry backfill		18.5	Mohr-Coulomb	5	30	Piezometric Line 1

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Project	Thornhaugh Landfill Site		
Client	Augean South Limited	*Filename/scenario*	29_Cap - southern slope - restored - uncontrolled leachate - drained.slim
Drawn By / Checked By	DFR / LCH	*Analysis Method*	Spencer
Date	10/07/2025 14:54:17	*Reference*	AU/TH/DFR/3361/01SRA

APPENDIX SRA2

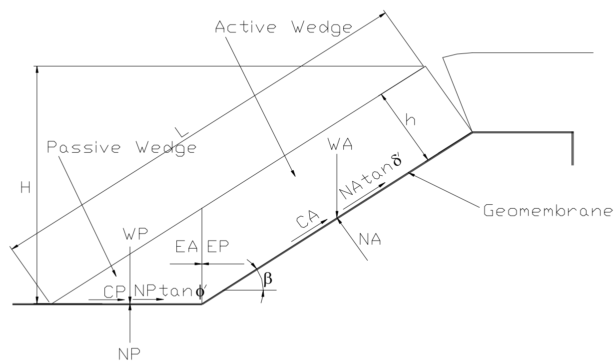
RESULTS OF THE ANALYSES OF TRANSLATIONAL FAILURE

MJCA Technical advisers on environmental issues	**Job No:**	AU/TH/DFR/3261/01		
	Date:	July 2025	**Engineer:**	LCH
	Sheet	1	**Checked:**	DFR
	of	8	**Project reference**	
Baddesley Colliery Offices, Main Road, Baxterley Atherstone Warwickshire CV9 2LE Tel: 01827 717891 Fax: 01827 718507	Thornhaugh Landfill Site Stability Risk Assessment			

Integrity of geosynthetic lining system on inter-cell bund (undrained clay)

Aim: To assess the integrity of the geosynthetic lining system on the inter-cell bund following placement of the leachate drainage blanket and prior to placement of waste.

Approach: Jones & Dixon (1998).



Input parameters:

					radians
Leachate drainage gravel unit weight (bulk)	γ_b		18	kN/m³	
Leachate drainage gravel unit weight (saturated)	γ_{sat}		20	kN/m³	
Leachate drainage gravel effective friction	ϕ'		35	°	0.61
Leachate drainage gravel cohesion	c'		0	kN/m²	
Thickness of leachate drainage gravel	h		0.3	m	
Height of slope	H		3	m	
Slope angle	β		26.57	°	0.46

Geosynthetics interface shear strengths:

Leachate drainage gravel / geotextile friction angle	δ_1	35	°	0.61
Leachate drainage gravel / geotextile cohesion intercept	α_1	0	kN/m²	
Geotextile / geomembrane friction angle	δ_2	25.8	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	6.9	kN/m²	
Geomembrane / undrained clay liner friction angle	δ_3	4.4	°	0.08
Geomembrane / undrained clay liner cohesion intercept	α_3	36	kN/m²	
Parallel submergence ratio, PSR		0		

Geosynthetic tensile strengths:

Geotextile	40	kN/m
Geomembrane	29	kN/m

Stability of leachate drainage blanket

Calculated Parameters:

Length of slope, L	6.71	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	34.20	kN
Weight and Effective Weight of Passive Wedge, W_P	2.03	kN
Pore pressure perp to slope, Un	0.00	kN
Pore pressure in interwedge surface, Uh	0.000	kN
Force Normal to Active Wedge, N_A	30.59	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 13.68
b -25.4
c 6.71

$aF^2+bF+c=0$ *0.32* *1.53*

Factor of Safety against leachate drainage blanket sliding **1.53**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-47.17	kN
Tension developed in geomembrane, T	-203.62	kN

Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the inter-cell bund lining system when the leachate drainage blanket is placed up the slope of the inter-cell bund to an unsupported vertical height of 3m. No tension is mobilised in the geotextile or geomembrane based on this height of leachate drainage blanket.

MJCA Technical advisers on environmental issues	Job No:	AU/TH/DFR/3261/01		
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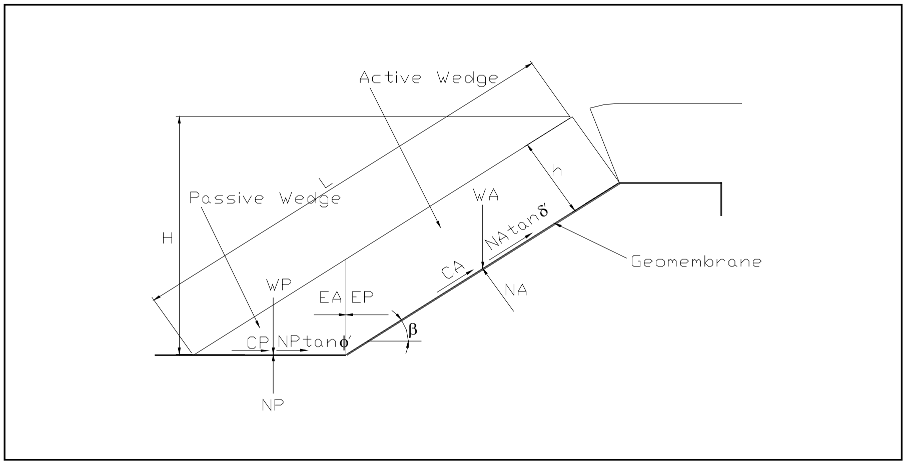
Integrity of geosynthetic lining system on inter-cell bund (drained clay)

Aim: To assess the integrity of the geosynthetic lining system on the inter-cell bund following placement of the leachate drainage blanket and prior to placement of waste.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Leachate drainage gravel unit weight (bulk)	γ_b	18	kN/m³	
Leachate drainage gravel unit weight (saturated)	γ_{sat}	20	kN/m³	
Leachate drainage gravel effective friction	ϕ'	35	°	0.61
Leachate drainage gravel cohesion	c'	0	kN/m²	
Thickness of leachate drainage gravel	h	0.3	m	
Height of slope	H	3	m	
Slope angle	β	26.57	°	0.46
Geosynthetics interface shear strengths:				
Leachate drainage gravel / geotextile friction angle	δ_1	35	°	0.61
Leachate drainage gravel / geotextile cohesion intercept	α_1	0	kN/m²	
Geotextile / geomembrane friction angle	δ_2	25.8	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	6.9	kN/m²	
Geomembrane / drained clay liner friction angle	δ_3	10.7	°	0.19
Geomembrane / drained clay liner cohesion intercept	α_3	26.7	kN/m²	
Parallel submergence ratio, PSR		0		
Geosynthetic tensile strengths:				
Geotextile		40	kN/m	
Geomembrane		29	kN/m	

Stability of leachate drainage blanket

Calculated Parameters:

Length of slope, L	6.71	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	34.20	kN
Weight and Effective Weight of Passive Wedge, W_P	2.03	kN
Pore pressure perp to slope, Un	0.00	kN
Pore pressure in interwedge surface, Uh	0.000	kN
Force Normal to Active Wedge, N_A	30.59	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 13.68
b -25.36
c 6.71

$aF^2+bF+c=0$ *0.32* *1.53*

Factor of Safety against leachate drainage blanket sliding **1.53**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-47.17	kN
Tension developed in geomembrane, T	-144.87	kN

Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the inter-cell bund lining system when the leachate drainage blanket is placed up the slope of the inter-cell bund to an unsupported vertical height of 3m. No tension is mobilised in the geotextile or geomembrane based on this height of leachate drainage blanket.

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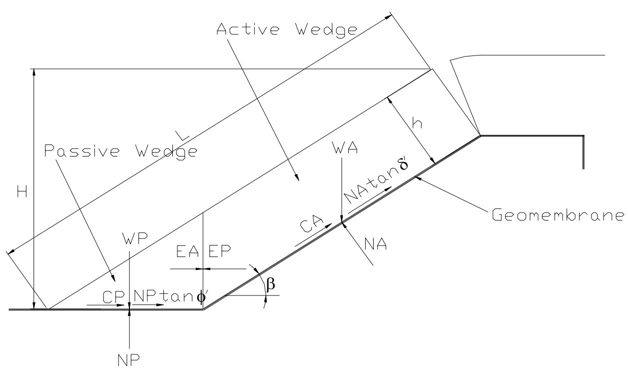
Integrity of geosynthetic lining system on sideslope (undrained clay)

Aim:
To assess the integrity of the geosynthetic lining system on the sideslope following placement of the leachate drainage blanket and prior to placement of waste.

Approach: Jones & Dixon (1998).



Input parameters:

				radians
Leachate drainage gravel unit weight (bulk)	γ_b	18	kN/m³	
Leachate drainage gravel unit weight (saturated)	γ_{sat}	20	kN/m³	
Leachate drainage gravel effective friction	ϕ'	35	°	0.61
Leachate drainage gravel cohesion	c'	0	kN/m²	
Thickness of leachate drainage gravel	h	0.3	m	
Height of slope	H	2	m	
Slope angle	β	21.8	°	0.38

Geosynthetics interface shear strengths:

Leachate drainage gravel / geotextile friction angle	δ_1	35	°	0.61
Leachate drainage gravel / geotextile cohesion intercept	α_1	0	kN/m²	
Geotextile / geomembrane friction angle	δ_2	25.8	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	6.9	kN/m²	
Geomembrane / undrained clay liner friction angle	δ_3	4.4	°	0.08
Geomembrane / undrained clay liner cohesion intercept	α_3	36	kN/m²	
Parallel submergence ratio, PSR		0		

Geosynthetic tensile strengths:

Geotextile	40	kN/m
Geomembrane	29	kN/m

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Stability of leachate drainage blanket

Calculated Parameters:

Length of slope, L	5.39	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	26.73	kN
Weight and Effective Weight of Passive Wedge, W_P	2.35	kN
Pore pressure perp to slope, Un	0.00	kN
Pore pressure in interwedge surface, Uh	0.000	kN
Force Normal to Active Wedge, N_A	24.82	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 9.22
b -20.4
c 4.52

$aF^2+bF+c=0$ *0.25* *1.96*

Factor of Safety against leachate drainage blanket sliding **1.96**

PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-40.56	kN
Tension developed in geomembrane, T	-170.32	kN

Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the sideslope lining system when the leachate drainage blanket is placed up the slope of the inter-cell bund to an unsupported vertical height of 2m. No tension is mobilised in the geotextile or geomembrane based on this height of leachate drainage blanket.

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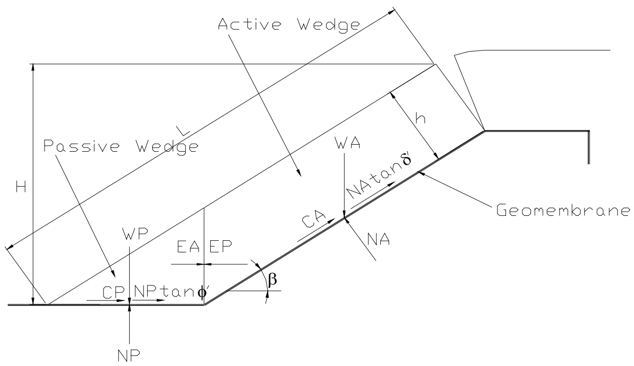
Integrity of geosynthetic lining system on sideslope (drained clay)

Aim:

To assess the integrity of the geosynthetic lining system on the sideslope following placement of the leachate drainage blanket and prior to placement of waste.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Leachate drainage gravel unit weight (bulk)	γ_b	18	kN/m³	
Leachate drainage gravel unit weight (saturated)	γ_{sat}	20	kN/m³	
Leachate drainage gravel effective friction	ϕ'	35	°	0.61
Leachate drainage gravel cohesion	c'	0	kN/m²	
Thickness of leachate drainage gravel	h	0.3	m	
Height of slope	H	2	m	
Slope angle	β	21.8	°	0.38
Geosynthetics interface shear strengths:				
Leachate drainage gravel / geotextile friction angle	δ_1	35	°	0.61
Leachate drainage gravel / geotextile cohesion intercept	α_1	0	kN/m²	
Geotextile / geomembrane friction angle	δ_2	25.8	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	6.9	kN/m²	
Geomembrane / drained clay liner friction angle	δ_3	10.7	°	0.19
Geomembrane / drained clay liner cohesion intercept	α_3	26.7	kN/m²	
Parallel submergence ratio, PSR		0		
Geosynthetic tensile strengths:				
Geotextile		40	kN/m	
Geomembrane		29	kN/m	

Stability of leachate drainage blanket

Calculated Parameters:

Length of slope, L	5.39	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	26.73	kN
Weight and Effective Weight of Passive Wedge, W_P	2.35	kN
Pore pressure perp to slope, Un	0.00	kN
Pore pressure in interwedge surface, Uh	0.000	kN
Force Normal to Active Wedge, N_A	24.82	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 9.22
b -20.36
c 4.52

$aF^2+bF+c=0$ *0.25* *1.96*

Factor of Safety against leachate drainage blanket sliding **1.96**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-40.56	kN
Tension developed in geomembrane, T	-123.26	kN

Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the sideslope lining system when the leachate drainage blanket is placed up the slope of the inter-cell bund to an unsupported vertical height of 2m. No tension is mobilised in the geotextile or geomembrane based on this height of leachate drainage blanket.