Augean
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LANDFILL ENVIRONMENTAL PERMIT APPLICATION
STABILITY RISK ASSESSMENT (SRA) REPORT

FOR THE DEVELOPMENT CONSENT ORDER APPLICATION FOR THE ALTERATION AND CONSTRUCTION OF HAZARDOUS WASTE AND LOW LEVEL RADIOACTIVE WASTE FACILITIES AT THE EAST NORTHANTS RESOURCE MANAGEMENT FACILITY, STAMFORD ROAD, NORTHAMPTONSHIRE

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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
May 2021

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1. Introduction

1.1. MJCA is commissioned by Augean South Limited (Augean) to prepare a Stability Risk Assessment (SRA) report to support an application to vary Environmental Permit reference EPR/TP3430GW (the landfill EP) to extend the hazardous waste landfill at East Northants Resource Management Facility (the site).

1.2. The structure of this SRA is based on a template produced by the Environment Agency entitled "Stability Risk Assessment Report" Version 1 dated March 2010 (Reference 1).

1.3. The proposals are for a western extension to the current hazardous waste landfill site and incorporate changes to the restoration profile of the existing landfill site in order to integrate the western extension area. The proposed engineering design for the western extension area is based on the currently approved design for the existing landfill area with a number of modifications as detailed in Table SRA1. Where applicable, the stability assessment undertaken for the western extension area is based on the methodologies and parameters employed in stability risk assessments for the existing landfill area undertaken as part of the 2014 permit variation application for the existing landfill EP or submitted subsequently in support or changes to the site design agreed through Construction Quality Assurance Plans as provided previously to and accepted by the Environment Agency in the following documents:

i. "Stability Risk Assessment (SRA)" document reference AU/KCE/AW/5469/01 dated September 2014 (Appendix A of Permit Variation Application) was prepared by MJCA in support of the 2014 permit variation application for the existing landfill EP (Reference 2)

ii. "Capping Stability Risk Assessment" Report No. 3649-R01 SRA, Issue 01 dated 30 November 2016 was prepared by TerraConsult Ltd in order to accompany a CQA Plan for the site capping allowing the replacement of the 1mm thick HPDE membrane cap with 1m of site derived engineered clay (Reference 3).

1.4. ENRMF is centred approximately on National Grid Reference (NGR) TF 008 000 approximately 1.7km east south east of Duddington and approximately 2.6km north of the village of Kings Cliffe. The site location is presented on Figure SRA1. To the south west, west, north east and north of ENRMF is woodland. A small number of residential properties and a group of agricultural and commercial buildings are located to the east of the site. The land to the north west and south of the site is primarily agricultural. Historically the existing site has been subject to clay extraction. The western extension area is currently agricultural land. A topographical survey of the western extension area and the existing ENRMF landfill site is presented as Figure SRA2.

1.5. The current hazardous waste landfill is located in the eastern part of the site area and comprises landfilling in Phases 1 to 11 with a number of phases subdivided into two or more sub-phases A, B or C. Landfill operations are complete in Phases 1, 2, 3 and 4, 5 and 6A and 6B. The current operational phases are Phase 6C and Phase 10 which are almost complete. A new Phase 7 was being constructed at the time of reporting. The current operational phases are located in the central and northern part of the existing landfill area with Phase 7 being located in the south western part of the existing landfill. A waste treatment and recovery facility with a waste treatment pad and dredging waste temporary storage area are located in the north western part of the existing landfill area together with the landfill gas flare and surface water management area. The waste reception area, weighbridge, site offices and mess facilities are located to the east and south east of the existing landfill area.

1.6. The proposed western extension area lies to the west, south west and north west of the existing landfill area. The western extension area is intercepted by a number of natural and man-made linear features which splits the site into four areas. A hydrological and hydrogeological area of doline features associated with west to east drainage pathways towards a swallow hole, crosses the western extension area to the north west of the current landfill area, separating the northern area of the site from the rest of the site. As detailed in the ESID and HRA it is intended to leave a minimum 20m wide route through this area to maintain a surface water flow path from west to east. In addition, as detailed in the ESID and HRA, it is proposed that no landfilling will take place in a 150m wide zone across this area until further investigation is undertaken to verify the ground conditions and the nature and extent of solution features which may be present and require treatment prior to landfill development. Two water pipelines and a gas pipeline cross the southern area of the site separating the remaining western extension area into a further three areas.

1.7. The proposed western extension area has been designed based on principles similar to those applied to the existing landfill area. The proposed design of the western extension area is presented in Section 2 and summarised in Table SRA1. Ten operational phases are proposed comprising Phases 12 to 21 as shown on Figure SRA3.

1.8. Further background information on the permit variation application, of which this SRA forms a part, is presented in the Environmental Setting and Installation Design (ESID) Report reference AU/KCW/AW/5646/01/ESID and the Hydrogeological Risk Assessment (HRA) Report reference AU/KCW/AW/5646/01/HRA.

2. Proposed design of the western extension area

2.1. Introduction

2.1.1. The proposed design of the western extension area at ENRMF has been prepared by MJCA for Augean. The proposed design is based on the design of the existing landfill area with a number of modifications. The proposed design of the western extension area is described in this report including tables and drawings which detail the proposed landfill engineering. A summary of the proposed design for the western extension area together with a comparison between the proposed design and the design of the existing landfill area is provided in Table SRA1. Plans and sections showing the proposed western extension area design are presented as Figures SRA3, SRA4, SRA5, SRA6 and SRA7.

2.2. Basal formation area

2.2.1. The basal formation area of the western extension area will be profiled at a minimum gradient of 1v:100h falling from a high point in each phase to a low point corresponding to the future location of a leachate collection and extraction sump. The proposed formation levels are presented on Figure SRA3.

2.2.2. The basal formation level will be formed by excavation and profiling of the in situ glacial clays and Rutland Formation to the formation levels presented on Figure SRA3. Consistent with the current site design a minimum thickness of 2m of the glacial clays or/and Rutland Formation material will be left in situ above the top of the Lincolnshire Limestone. Details of how the formation levels have been derived and agreed with the Environment Agency are presented in the ESID and HRA.

2.2.3. Details of the investigation and assessment to determine the levels, falls and contours of the surface of the Lincolnshire Limestone are provided in the HRA and ESID. The falls of the surface of the Lincolnshire Limestone vary in direction and gradient across the site area. In the northern area to the north of the area of dolines (Phases 12 to 14) the surface of the limestone falls towards a low point on the eastern boundary of the northern area at gradients of between 1v:100h to 1v:25h. In the southern area (Phases 15 to 17) to the south of gas pipeline the surface of the limestone falls towards the north east at gradients of between 1v:100h to 1v:25h. In the triangular area between the gas pipeline and the water pipelines (Phase 18) the surface of the limestone falls towards the south west at a gradient of approximately 1v:40h. In the central area between the water pipelines and the area of dolines (Phases 19, 20 and 21) the surface of the limestone falls towards the south east at gradients of between 1v:200h and 1v:100h. As a result the basal falls of the individual phases have been adjusted to accommodate the topography of the underlying geology and in places steepened to create basal slopes of no shallower than 1v:100h and up to maximum of approximately 1v:25h.

2.3. Sideslope formation and perimeter bund

2.3.1. All excavated sideslopes in the western extension area will be cut at a maximum gradient of 1v:2.5h in the sub-grade. In places to the north and south of the area of dolines the Rutland Formation is relatively shallow resulting in only shallow excavation above the retained 2m thickness which results in side slope of less than 5m high. In order to provide a sideslope sub-grade round the full perimeter of the western extension area with a height of no less than 5m, a free standing perimeter bund will be constructed to form the upper portion of the 5m side slope sub grade. The minimum 5m side slope sub-grade depth has been selected as it is generally consistent with the minimum side slope sub-grade depth for the engineered cells in the current landfill area and once lined with 1m of engineering clay will provide a minimum 4m of containment depth for leachate within the landfill phases. The crest width of the perimeter bund will be a minimum of 3m. The internal slope gradients of the perimeter bund will be a maximum of 1v:2.5h. The external slopes gradients of the perimeter bund will be at the same gradient as the restoration slopes and will be 1m below the proposed final restoration profile to allow the placement of restoration soils. The perimeter bunds will be constructed from engineered site derived fill placed and compacted in accordance with the requirements of the Specification for Highway Works (Reference 4).

2.3.2. The sideslopes for the western extension area will typically have vertical heights of between approximately 5m and 16.5m. The base of the excavation is typically at elevations between 72m Above Ordnance Datum (AOD) and 79m AOD. Original ground levels round the site typically range from 80m AOD to 90m AOD.

2.3.3. The sideslopes forming the landfill phases over which the landfill liner will be constructed will be excavated in the overlying in situ glacial clay and brown clay deposits and the underlying clays and siltstones of the Rutland Formation. Unsuitable materials exposed in the excavation of the sideslope formation which could act as a failure plane or provide a significant conduit for the movement of water will be excavated and backfilled with suitable engineering fill materials.

2.4. Basal lining system

2.4.1. The basal lining system will comprise a minimum 1m thick compacted low permeability clay liner with a maximum hydraulic conductivity of 1×10^{-9}m/s and a 2mm thick smooth high density polyethylene (HDPE) geomembrane. The basal liner will be overlain by either a geotextile protection layer or a 300mm thick sand protection layer and geotextile separator. The protection layer will be overlain by a minimum 300mm thick granular leachate drainage blanket or a tyre bale leachate drainage blanket with gravel pipe runs and leachate well areas. The leachate drainage system for each phase will incorporate 180mm external diameter leachate collection pipework radiating from a leachate collection sump and two remote leachate monitoring wells.

2.4.2. Inter-cell bunds will be constructed from compacted low permeability clay and will form part of 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, to accommodate the topography of the underlying geology it will be necessary to increase the inter-cell bund heights locally to a maximum vertical height of 3m. The bunds will be lined with 2mm thick double textured HDPE geomembrane. A geotextile protection layer will be placed over the geomembrane and a minimum 300mm thick granular leachate drainage blanket will be extended up the full height and over the crest of the bunds to form a continuous leachate drainage blanket between phases.

2.5. Sideslope lining system

2.5.1. The sideslope lining system will comprise a minimum 1m thick compacted low permeability clay liner with a maximum hydraulic conductivity of 1×10^{-9}m/s overlain by a 2mm thick double textured HDPE geomembrane. A protection geotextile and minimum 300mm thick granular leachate drainage blanket will be installed 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 in diameter will be used as the first layer placed against the sideslope protection and drainage geocomposite. The sideslope lining system will be constructed at the same gradient as the sideslope sub-grade and therefore will have a maximum slope gradient of 1v:2.5h. The sideslope lining system will be constructed with typical vertical heights of between 4m and 15.5m.

2.6. Waste mass

2.6.1. Internal temporary waste slopes in the western extension area will be constructed at a gradient of 1v:3h. These waste slopes are calculated to have a maximum vertical height of approximately 20m based on the top of waste levels. The toe of the temporary waste slopes may be supported by inter-cell bunds as described in Section 2.4 which would reduce the maximum vertical waste slope height to 18m.

2.6.2. Leachate extraction and monitoring wells will be installed during cell construction works and will comprise vertical telescopic shafts which will be designed to accommodate axial movement. The telescopic shafts will be constructed progressively so as to prevent damage caused by differential settlement of the waste mass. Each phase will have a leachate collection sump area with an extraction well located at the low point and two remote leachate monitoring wells. A reinforced concrete target pad will be constructed in the vicinity of the leachate collection sump to facilitate retrospective drilling of a leachate extraction well, should this be needed. From the results of the landfill gas risk assessment it is concluded that gas management infrastructure will not be necessary in the western extension area. Gas monitoring in the waste will be carried out at the leachate monitoring wells which will be designed and constructed to facilitate gas monitoring.

2.7. Capping and restoration system

2.7.1. A 0.3m thick regulating layer will be placed over the completed top of waste level to provide a smooth, firm and inert sub-grade surface on which to construct the capping system. The cap will comprise either a 1mm thick HDPE or linear low density polyethylene (LLDPE) geomembrane, or a minimum 1m thick compacted low permeability clay capping layer with a maximum hydraulic conductivity of $1x10^{-9}$m/s.

2.7.2. A suitable drainage geocomposite will be placed over the cap to act as a drainage pathway from the overlying restoration materials to the perimeter surface water collection system. The drainage geocomposite material selected will be sufficient to prevent the build up of perched water on the cap, and in the case of the geomembrane to improve stability of the restoration materials and to act as a separation and protection layer with the overlying restoration materials.

2.7.3. A 1m to 1.5m thickness of restoration materials will be placed over the cap. The thicker layers will be located in areas which will be restored to woodland. The restoration materials will be placed at the same slope gradients as the cap. The capping and restoration layers typically have average gradients of approximately 1v:6h with slope lengths of up to 150m. The capping and restoration layers have maximum gradients of approximately 1v:4h for lower slopes with heights of approximately 12m.

3. Conceptual site stability model

3.1. Introduction

3.1.1. The principles of the proposed western extension design are summarised in Section 2 and in Table SRA1. In this section the conceptual models of the engineered containment system for the western extension area are described in detail. A number of the conceptual models assessed represent worst case scenarios with combined worst case dimensions for height, gradient, leachate levels and water levels. The combination of worst case height and gradients may not exist in reality but are considered in order to provide a conservative analysis of the western extension area design. In accordance with the Environment Agency SRA Template (Reference 1) there are six major components of the conceptual stability site model:

- The basal sub-grade
- The sideslope sub-grade and perimeter bund
- The basal lining system
- The sideslope lining system
- The waste mass
- The capping system.

3.1.2. Qualitative or quantitative assessments are undertaken for each design element as identified by risk screening of the conceptual models presented in Section 4. Where applicable, the assessments are based on the methodologies, parameters and results of the stability risk assessments undertaken in support of the previous Environmental Permit Variation application for the existing site as detailed in Section 1.3.

Basal sub-grade model

3.1.3. The top of the excavated formation level of the basal sub-grade will be between approximately 72m AOD and 79m AOD, as shown on Figure SRA3, with the base of the landfill excavation formed in the glacial clays and Rutland Formation strata which typically comprise firm to hard clays with occasional silt or siltstone bands. A description of the sub-grade anticipated to be encountered in the base of the excavation is provided in the ESID and HRA and is based on a site investigation undertaken by MJCA in the western extension area between November 2019 and March 2020 (Reference 5). The base of the excavation will have basal falls of between 1v:25h and 1v:100h.

3.1.4. The proposed base of the western extension area is above the groundwater level within the underlying Lincolnshire Limestone. A minimum of 2m of in situ glacial clays and/or Rutland Formation material will be left in place above the top of the Lincolnshire Limestone. In parts if the northern area of the site the thickness of in situ glacial clays and/or Rutland Formation material left in place above the top of the Lincolnshire Limestone may need to be increased so that the base of excavation is above the maximum groundwater levels recorded in the Lincolnshire Limestone and the determination of the final design of the basal level will be based on the results of ongoing groundwater monitoring.

3.1.5. From a review of the site investigation and resistivity imaging surveys undertaken of the western extension area it is concluded in the ESID and HRA that with the exception of the 150m standoff zone centred on the doline area (as detailed in 1.6) there was no evidence of voids or significant discontinuities in the surface or body of the Lincolnshire Limestone underlying the site. This is consistent with inspections of the surface of the exposed limestone together with resistivity surveys of the limestone prior to liner construction presented in the Construction Quality Assurance (CQA) verification reports for phases of the existing landfill site.

3.1.6. As identified in the ESID the geology is generally consistent between the existing landfill and the proposed western extension area outside the 150m standoff across the doline area. As a result, outside the 150m standoff, the western extension area will be excavated and engineered consistent with the methods employed in the current site. As the in situ glacial clays and/or Rutland Formation is retained above the Lincolnshire Limestone it is not possible to inspect visually the surface of the limestone although, subject the CQA requirements for each landfill phase, resistivity imaging surveys and verification boreholes will be employed during the construction of the western extension area phases.

3.1.7. The doline area is associated with west to east drainage pathways towards the swallow hole area and crosses the western extension area to the north west of the current landfill area, separating the northern area of the site from the rest of the site. As detailed in the ESID and HRA it is intended to leave a minimum 20m wide route through this area to maintain a surface water flow path from west to east. In addition it is proposed that no landfilling of waste will take place in a 150m wide standoff across this area until further investigation is undertaken to verify the ground conditions and the nature and extent of solution features which may be present and require treatment prior to landfill development.

3.1.8. The details of the investigation and subsequent landfill engineering of the 150m wide standoff across the potential doline area will be subject to agreement with the Environment Agency. It is anticipated that this could consist of the following two stages, the first once this part of the site has been cleared of vegetation and the second following excavation:

(1) Undertake an investigation and resistivity survey at current ground levels to investigate the presence of potential anomalies followed by treatment of voids by grouting, or amendment of the 20m drainage route to avoid landfilling waste in the area of potential voids.

(2) Undertake further resistivity surveys and investigation of anomalies once the area has been excavated to formation levels with all anomalies grouted and treated consistent with the rest of site.

3.2. Sideslope sub-grade and perimeter bund model

3.2.1. The sideslopes will be excavated in a sub-grade comprising overlying glacial clays and brown clays where present and the underlying clays and siltstone bands of the Rutland Formation. Unsuitable shallow soils and made ground materials if present overlying the natural in situ materials will be removed and will not form part of the sub-grade to the sideslopes. The crests of the sideslopes will typically be at 80m AOD to 90m AOD with the toes of the slopes at approximately 72m AOD to 79m AOD. Sideslopes will typically have a maximum vertical height of approximately 16.5m with a maximum slope gradient of 1v:2.5h.

3.2.2. The groundwater conditions for the sideslope sub-grade are the same as for the basal sub-grade as described in Section 0. No perched water bodies have been identified in the Rutland Formation or overlying clays.

3.2.3. Where the side slope subgrade is less than 5m high a perimeter bund will be constructed to extend the side slope subgrade so that it is a minimum of 5m high. Perimeter bunds will be free standing at the crest of the excavated side slope and will be constructed from compacted site derived engineering fill materials in accordance with the requirements of the Specification for Highways (Reference 4). The perimeter bunds will be constructed to a maximum vertical height of 5m with maximum internal slope gradients of 1v:2.5h and external slope gradients consistent with the restoration profile and no greater than 1v:4h. The perimeter bunds will have a crest width of 3m.

3.3. Basal lining system model

3.3.1. 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 as described in Section 0 and compacted to a minimum perpendicular thickness of 1m to achieve a maximum hydraulic conductivity of no more than 1×10^{-9}m/s and a shear strength of no less than 50kPa. The 2mm thick HDPE geomembrane will be placed over the prepared upper surface of the low permeability clay liner followed by either a suitable geotextile protection layer or a minimum 300mm thick sand protection layer and separation geotextile. The basal liner will be overlain by a leachate drainage blanket which will comprise either a minimum 300mm thick aggregate layer or a tyre bale layer with gravel filled drainage runs. The leachate drainage blanket will have 180mm external diameter HDPE leachate collection pipework. The leachate pipework will drain to a sump in the low points of each phase. The basal liner will be constructed with the same basal gradients as the formation layer of between 1v:25h and 1v:100h towards the low point in each phase.

3.3.2. 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 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 a minimum

300mm thick aggregate layer leachate drainage blanket will be extended up the sides and over the crest of the inter-cell bunds.

3.4. Sideslope lining system model

3.4.1. 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. A minimum 300mm thick aggregate layer 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 in diameter will be used as the first layer placed against the sideslope protection and drainage geocomposite.

3.4.2. Waste will be placed progressively in horizontal layers across the full width of the landfill phases. The waste mass will be hazardous waste which will comprise treatment residues, contaminated materials including soils and materials containing asbestos. These materials will be predominantly non-biodegradable, fine grained materials which when placed in the existing landfill compact readily and provide a stable working surface. The 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.

3.4.3. The sideslope lining system will be constructed at the same gradient as the sideslope sub-grade and perimeter bund. The sideslope lining system will be constructed with typical vertical heights of between 4m and 15.5m.

3.5. Waste mass model

3.5.1. Temporary waste slopes for the western extension area will be constructed at a gradient of 1v:3h. The maximum vertical height of the temporary waste slopes will be approximately 20m. The wastes to be deposited in the western extension area will be hazardous wastes similar to those deposited in the existing landfill area. It is anticipated that daily cover materials for the western extension area will be selected from suitable excavated or imported materials. Support to the toe of the waste slope will be provided by the inter-cell bunds which form part of the basal lining system as described in Sections 2.4 and 3.3 which reduce the maximum vertical waste slope height to 18m.

3.5.2. During the operational phase of the western extension area leachate levels will be maintained at a maximum of 1m above the top of the basal liner. Following completion of the operational phase in the western extension area leachate levels will continue to be maintained at a maximum of 1m above the top of the basal liner.

3.6. Capping and restoration system model

3.6.1. A 0.3m thick sub-grade will be placed on the re-profiled top of waste level prior to either the placement of a 1mm thick HDPE geomembrane or linear low density polyethylene (LLDPE) geomembrane, or the placement of a minimum 1m thick compacted low permeability clay capping layer. A suitable drainage geocomposite will be placed over the capping layer. A combined 1m to 1.5m thickness of restoration materials will be placed over the cap. The restoration materials will be placed at the same slope gradients as the cap and extend to the base of the capped slopes including the base of any perimeter bund.

3.6.2. In order to assess the full range of capping and restoration slopes identified in Section 2.7 a number of conceptual slope models have been developed comprising a long slope with a gradient of 1v:6h and 150m long and a steep slope which represents the lower slopes and which have slope gradients of up to 1v:4h with slope heights of approximately 12m.

3.6.3. Given that the waste will be placed and compacted in horizontal layers and will comprise fine grained, non-biodegradable 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.

4. Risk screening

4.1. Introduction to risk screening

4.1.1. This section presents a detailed risk screening of the conceptual models for the proposed western extension area which are described in Section 3. The risk screening is a qualitative assessment which identifies where further quantitative assessments of the stability of the western extension area are necessary.

4.2. Basal sub-grade screening

4.2.1. As the basal sub-grade comprises competent Lincolnshire Limestone and in situ Rutland Formation excavated to a shallow gradient of between approximately 1v:25h and 1v:100h it is considered that it is not necessary to undertake a slope stability analysis.

4.2.2. Based on site investigation and groundwater monitoring data information provided in the HRA the groundwater at the site is within the underlying Lincolnshire Limestone. The excavation to form the basal subgrade will leave in place a minimum of 2m of in situ glacial clays and/or Rutland Formation material above the top of the Lincolnshire Limestone. The maximum groundwater level recorded in the Lincolnshire Limestone over the vast majority of the western extension area is more than 3m below the base of the excavation. The exception is the most northern Phase 12 and 13 area where maximum groundwater levels in the Lincolnshire Limestone have been recorded close to proposed excavation levels. The basal subgrade excavation levels may be raised locally in the northern area of the site so that they are above the maximum groundwater levels recorded in the Lincolnshire Limestone should higher groundwater levels be recorded prior to the proposed excavation period to prevent basal heave. Nevertheless, it is considered necessary to provide a quantitative analysis of the risk of basal heave occurring in the northern area of the site.

4.2.3. Based on site investigation and resistivity imaging surveys undertaken of the western extension area it is concluded in the ESID and HRA that with the exception of the 150m standoff centred on the doline area (as detailed in 1.6) there was no evidence of voids or significant discontinuities in the surface or body of the Lincolnshire Limestone underlying the site. As the geology is consistent between the existing landfill and the proposed western extension area it is considered that there is no need for quantitative assessment of the basal subgrade outside the 150m standoff across the doline area. As the in situ Rutland Formation is retained above the Lincolnshire Limestone it is not possible to inspect visually the surface of the limestone although confirmatory resistivity imaging surveys and verification boreholes will be employed during the construction of the western extension area phases.

4.2.4. As detailed in the ESID and HRA no landfilling will take place in a 150m wide standoff across the doline area until further investigation is undertaken to verify the ground conditions and the nature and extent of solution features which may be present and require treatment prior to landfill development. Subject to this further investigation it may be necessary to undertake quantitative assessment of the ground conditions within the 150m wide zone across the doline area. However this is not possible until further investigation is undertaken and for the purpose of this SRA it is assumed that further investigation in the 150m standoff across the doline area finds no evidence of voids or significant discontinuities in the surface or body of the Lincolnshire Limestone underlying the site or that any voids found are treated and grouted as agreed at the time with the Environment Agency. As detailed in the ESID and HRA, and irrespective of the outcome of further investigation and assessment, it is currently intended to leave a minimum 20m wide route through the doline area to maintain a surface water flow path from west to east.

4.2.5. Based on the Envirocheck report for the western extension area there is no evidence of underground mining in the vicinity of the site. Accordingly it is not necessary to carry out further assessment of the basal sub-grade. This is consistent with the conclusions of the stability assessments undertaken for the existing landfill area.

4.3. Sideslope sub-grade and perimeter bund screening

4.3.1. As the sideslopes will be excavated to a gradient of 1v:2.5h it is considered necessary to provide a quantitative analysis of the stability of the sideslope sub-grade for the western extension area.

4.3.2. As the perimeter bunds will be up to 5m high with maximum internal slope gradients of 1v:2.5h it is considered necessary to carry out quantitative analysis of the stability of the perimeter bunds where they are to be constructed at the crest of sideslope subgrade slopes.

4.3.3. Given that groundwater is in the strata underlying the site and not in perched water bodies below the base of excavation it is considered that there is no additional need to assess the potential for heave of the sideslope sub-grade beyond that identified to be assessed for the basal sub-grade in Section 4.2.

4.4. Basal lining system screening

4.4.1. Subject to the basal heave assessment identified in Section 4.1 and the satisfactory further investigation of the 150m standoff from the doline area it is concluded that the basal sub-grade over which the basal lining system will be engineered is stable and that investigation by resistivity imaging surveys is undertaken during cell construction works to verify that no voids are present in the underlying strata. As a result it is considered that it is not necessary to analyse the stability of the basal liner. Leachate extraction and monitoring wells will comprise vertical telescopic shafts which will be designed and installed progressively to accommodate axial movement and settlement. 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.

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

4.5. Sideslope lining system screening

4.5.1. As the sideslope lining system will be constructed over the sideslope sub-grade and perimeter bunds where present the principal factor influencing stability of the sideslope lining system is the slope gradient. It is concluded in Section 4.3 that it is necessary to carry out further assessment of the sideslope sub-grade and perimeter bunds so it is considered necessary to provide a quantitative analysis of the rotational stability of the 1m thick low permeability sideslope lining system.

4.5.2. With respect to the interface stability of the geomembrane, protection geotextile and granular leachate drainage blanket it is considered that as with the inter-cell bunds an analysis will be undertaken to assess the integrity and stability of the geosynthetics and drainage gravel placed up the first 2m of the side slopes prior to waste placement.

4.5.3. As described in paragraph 3.4.2 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 geocomposite drainage system during or following waste placement.

4.6. Waste mass screening

4.6.1. As internal temporary waste mass slopes will be placed to gradients of up to 1v:3h it is considered that quantitative analysis of the stability of the waste mass is necessary.

4.7. Capping and restoration system screening

4.7.1. As the slope of the capping system and restoration system is at gradients of up 1v:4h it is considered necessary to provide quantitative analysis of the stability of the capping and restoration for the western extension area. It is necessary to assess both the geosynthetic and the clay capping systems. In addition to the rotational stability of the capping and restoration system it is considered that analysis of the translational stability of the interfaces of the layers making up the capping and restoration systems is necessary.

4.7.2. It is considered that settlement and consolidation of the waste will have completed predominantly prior to capping and restoration of the site given that it will be placed and compacted in layers and given the nature of the hazardous wastes to be deposited at the site which will comprise predominantly fine grained, non-biodegradable materials.

4.7.3. Due to the waste types it is considered that there will be a negligible potential for the generation of gas and therefore it is considered unnecessary to assess the effect of gas acting on the underside of the cap.

4.7.4. 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.

5. Lifecycle phases

5.1. It is proposed that the development of the landfill and waste mass for the western extension area will take place in ten phases numbered Phases 12 to 21 as presented on Figure SRA3. The waste mass in successive phases will generally abut the waste mass of previous phases. Phases 12, 13 and 14 will be progressively constructed southwards in the northern area with the final standoff from the doline area being determined and agreed prior to the construction of Phase 14. Phases 15, 16 and 17 will be progressively constructed from south to north in the area to south of the gas pipeline. Phase 18 will be constructed in the triangular area to the west of the water pipelines. Phases 19, 20 and 21 will be constructed progressively from south to north in the remaining area abutting the current site Phases 7, 8, 9 and 10. The engineered landfill liner will be connected between the existing landfill and western extension area where they abut to provide a continuous landfill containment system between the two areas of the site. Completed phases will be capped and restored 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 western extension area.

Leachate management

5.3. Leachate levels during the operational phase in the western extension area will be maintained at a maximum level of 1m above the top of the basal liner. Leachate will be collected by the leachate drainage blanket and channelled by 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. Leachate will be used as a source of liquid for the on-site waste treatment facility or removed from the site by tanker for treatment and disposal.

Landfill gas management

5.4. As described in the ESID the waste types that will be deposited in the western extension area have a negligible potential for biodegradation or the generation of landfill gas. As a result no infrastructure for the control or extraction of landfill gas is included in the proposed design for the western extension area. Landfill gas will be monitored in the leachate monitoring boreholes during the operational lifetime of each phase and following completion of capping.

Daily cover characteristics

5.5. Waste placement and covering where necessary in the western extension area will be consistent with practices at the current operational landfill.

6. Stability assessments for the western extension area

6.1. Introduction

6.1.1. In the risk screening it is concluded that the majority of the conceptual models for the western extension area need further assessment to confirm that any potential effects resulting from amendments to the landfill design or changes in dimensions are considered.

6.2. Data summary

6.2.1. The proposed design for the western extension area has been prepared by MJCA and is based on an updated version of the existing site design as discussed in detail in Sections 2 and 3 of this report. The proposed design of the western extension area is summarised in Table SRA1 and on Figures SRA3, SRA4, SRA5, SRA6 and SRA7.

6.2.2. The values for the geotechnical parameters used in the following analyses are derived predominantly from the stability risk assessments undertaken for the existing landfill area at ENRMF. Where values for the parameters have been updated this is identified. A summary of the geotechnical parameters and values is presented in Table SRA2 and in this section with details of the sources of parameter values and justifications for use.

6.2.3. 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.

6.3. Justification for modelling approach

6.3.1. The stability risk assessment analyses have been undertaken in general accordance with conventional British Standards methodologies rather than Eurocodes. As a result, global factors of safety have been assessed rather than incorporating partial factors into the individual parameters describing the slopes, strengths and forces. This is to maintain consistency and allow comparison with the previous stability risk assessments undertaken in support of the application for the EP and consistent with Environment Agency Guidance (Reference 6).

6.3.2. The dimensions, slope gradients, elevations, groundwater levels and leachate levels used in the analyses have been discussed in detail in Sections 2 and 3 of this report and are presented in Table SRA1. The values for geotechnical parameters selected for use in the assessment are discussed and justified in Section 6.5 and presented in Table SRA2. Target factors of safety used in the assessment are discussed in Section 6.6 and presented in Table SRA3.

6.3.3. A summary follows of the assessment and analyses necessary as identified in the risk screening (Section 4).

Basal sub-grade modelling approach

6.3.4. As identified in risk screening for the basal sub-grade in Section 4.2 the potential for basal heave in the northern area where the maximum groundwater levels are close to the top of the basal subgrade level needs further analysis as part of this SRA.

6.3.5. The excavation to form the basal subgrade will leave in place a minimum of 2m of in situ glacial clays and/or Rutland Formation material above the top of the Lincolnshire Limestone. Where this would result in maximum groundwater levels at the time of excavation being above the basal subgrade level the thickness of in situ glacial clays and/or Rutland Formation material left in place above the top of the Lincolnshire Limestone will be increased so that the basal subgrade level is above the maximum groundwater levels recorded in the Lincolnshire Limestone. To assess this it is considered necessary to provide a quantitative analysis of the risk of basal heave occurring in the northern area of the site.

6.3.6. The risk of basal heave has been assessed by comparing the upward pressure from the confined groundwater within the Lincolnshire Limestone on the base of the in situ glacial clays and/or Rutland Formation material left in place with the vertical downward stress exerted by the retained in situ glacial clays and/or Rutland Formation material.

Sideslope sub-grade and perimeter bund modelling approach

6.3.7. As identified in risk screening for the sideslope sub-grade and perimeter bund in Section 4.3 the sideslope sub-grade needs further quantitative assessment as part of this SRA.

6.3.8. The sideslopes will be excavated in the sub-grade of the in situ glacial clays and Rutland Formation to form slopes with maximum gradients of 1v:2.5h. The assessment considers the anticipated maximum sub-grade sideslope with a vertical slope height of 16.5m. Maximum groundwater levels will be below the base of the basal subgrade excavation.

6.3.9. Perimeter bunds will be constructed at the crest of the excavated side slope where the side slope subgrade is less than 5m high so that the side slope is a minimum of 5m high. The perimeter bund will be constructed from compacted site derived engineering fill materials and have a maximum vertical height of 5m with maximum internal slope gradients of 1v:2.5h and external slope gradients consistent with the restoration profile and no greater than 1v:4h. The perimeter bund will have a crest width of 3m.

6.3.10. The stability of the sideslope sub-grade and the perimeter bund has been analysed using short term total stress (undrained) and long term effective stress (drained) shear strength parameters.

Basal lining system

6.3.11. As identified in risk screening for the basal lining system in Section 4.4 the aspects of the basal lining system which need further assessment are the stability of the inter-cell bunds and the interface stability of the geosynthetic lining system and the granular leachate drainage blanket placed on the sideslopes and over the inter-cell bunds.

6.3.12. The inter-cell bunds will be constructed from low permeability engineered clay and have a maximum vertical height of 3m above the top of the basal clay liner with a maximum slope gradient of 1v:2h and crest width of 3m. The stability of the inter-cell bunds has been analysed using short term total stress (undrained) and long term effective stress (drained) shear strength parameters.

6.3.13. The interface stability of the geosynthetic lining system and granular leachate drainage blanket on the slopes of the inter-cell bund are assessed prior to supporting waste being placed 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 layers. The stability of the geosynthetic lining system and of the granular leachate blanket on the slopes of the inter-cell bund has 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 lining system

6.3.14. As identified in risk screening for the sideslope lining system in Section 4.5 it is considered necessary to undertake quantitative analysis of the stability of the sideslope liner and the interface stability of the geosynthetic lining system and granular leachate drainage blanket placed on the sideslopes to a vertical height of 2m.

6.3.15. The assessment considers the anticipated maximum sub-grade sideslope vertical height of 16.5m. The assessment considers the anticipated maximum sideslope liner vertical slope height of 15.5m allowing for the 1m basal liner. The maximum groundwater level will be below the base of the basal subgrade excavation. The assessment also considers the sideslope liner constructed against a maximum 5m high perimeter bund which allowing for the 1m basal liner assesses a maximum perimeter bund sideslope liner vertical slope height of 4m.

6.3.16. The sideslope lining system will extend up the full height of the sub-grade and perimeter bund slope at a maximum gradient of 1v:2.5h and will comprise a minimum 1m thick compacted low permeability clay liner. The low permeability clay liner will be constructed from site-derived clays from the excavation of the landfill to formation levels. The clays will be placed and re-compacted in layers to achieve the required hydraulic conductivity and shear strength criteria.

6.3.17. The sideslope sub-grade, perimeter bund and sideslope liner stability for the maximum vertical slope heights have been assessed using short term total stress (undrained) and long term effective stress (drained) shear strength parameters.

6.3.18. 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 be placed 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 lining system prior to placement of the waste have been assessed using short term total stress (undrained) and long term effective stress (drained) shear strength parameters.

6.3.19. Waste will be placed progressively in horizontal layers across the full width of the landfill cell to avoid the mobilisation of tension in the geosynthetic components of the sideslope lining system. Selected fine grained wastes containing clay, silt, sand and gravel up to a grain size of 20mm in diameter will be used as the first layer placed against the sideslope protection and drainage geocomposite. It is considered that as a result there is no need for further assessment of the geosynthetic components of the sideslope liner during and following waste placement.

Waste mass

6.3.20. As identified in risk screening for the waste mass in Section 4.6 it is necessary to undertake quantitative analysis of the stability of the temporary waste slopes.

6.3.21. The stability of the temporary waste slopes is assessed for a waste slope constructed to the maximum void height and for the full width of the phase with the waste toe against the inter-cell bund. The temporary waste slope has been assessed to a maximum height of 20m. The temporary waste slope is analysed with leachate at a level of 1m above the top of the basal lining system which is the maximum level at which the leachate will be maintained during the operational phase of the landfill.

Capping system

6.3.22. As identified in the risk screening in Section 4.7 it is necessary to undertake quantitative analysis of the stability of both the geosynthetic and the clay capping systems in relation to the slope and interface stability of the restoration profile and underlying waste mass.

6.3.23. In order to assess the stability against rotational failure for the full range of capping and restoration slopes a number of conceptual models are considered as described in Section 3.6. The analysis considers the stability of a long slope with a gradient of 1v:6h at 150m long and a steep slope which represents the lower slopes with a gradient of 1v:4h and a slope height of 12m. The components analysed are the underlying waste mass, regulating sub-grade layer, with or without a 1m clay cap and both 1m and 1.5m thicknesses of the restoration materials. The models have been assessed using short term (undrained) and long term effective stress (drained) shear strength parameters where relevant.

6.3.24. Each of the models has been assessed with leachate levels representative of the managed and unmanaged lifecycle phases. During the operational phase leachate levels are assessed at 1m above the top of the basal liner. During the post-operational phase it is expected that maximum leachate levels will continue to be controlled at a level 1m above the top of the basal lining system. However at some point it is anticipated that leachate levels will be allowed to rise and therefore leachate levels have also been analysed at higher levels which correspond to the assumed maximum contained leachate level within the site.

6.3.25. An assessment is also made of the interface stability of the interfaces between the sub-grade, the geomembrane cap, drainage geocomposite and overlying restoration materials or between the clay cap, drainage geocomposite and overlying restoration materials. The assessment also considers the stability against translational sliding of the overlying restoration materials with and without water present in the drainage geocomposite and overlying restoration materials. The spreadsheet analyses consider the stability of a long slope with a gradient of 1v:6h at 150m long and a shorter steep slope with a gradient of 1v:4h at 12m high. Interface parameters used in the assessment of the capping system are for peak values and residual values to reflect the risks associated with vehicle movements during the placement of subsequent restoration layers. Separate spreadsheet analyses have been completed for restoration material thicknesses of 1m and 1.5m.

6.3.26. The effects of excess landfill gas pressures and excess pore water pressures from leachate in the waste acting on the underside of the cap is not assessed. As detailed in Section 4.7 it is considered that the wastes which will be deposited in the western extension area have negligible potential for the generation of landfill gas. It is therefore considered unnecessary to assess the risk that excess landfill gas pressures will develop on the underside of the cap. Section 4.7 also details the maximum leachate levels for the operational and post operational phases of the landfill which will be maintained at a level of 1m above the top of the basal liner. It is unlikely that significant leachate pore pressures will develop on the underside of the cap. For the purposes of this assessment maximum leachate levels have also been analysed at levels which correspond to the assumed maximum contained leachate level within the site.

6.4. Computer software used in the analysis

6.4.1. Analysis of stability against rotational failure has been undertaken using the two dimensional limit equilibrium programme SLOPE/W. 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 (Reference 7). It is considered that this method is more appropriate than simpler methods such as Bishop's Simplified Method or Janbu's Simplified Method.

6.4.2. Analysis of stability against translational sliding failures at the interfaces of the regulating subgrade or clay, geosynthetics 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 (Reference 6). The spreadsheets include calculation of tensile forces developed within the geosynthetics.

6.5. Justification of the geotechnical parameters selected for the analyses

Geotechnical parameters selected for the basal and sideslope sub-grade and the perimeter bund

6.5.1. The geotechnical parameters and the values used in the analyses of the basal and sideslope sub-grade and the perimeter bund are presented in Table SRA2. Consistent with the approach taken in the stability assessments for the existing landfill area, for the purpose of modelling, the Lincolnshire Limestone is considered to act as an impenetrable bedrock layer. The values for the geotechnical parameters selected for the in situ clay are the same as those used in the stability assessments for the existing landfill area (Reference 2).

6.5.2. The values for the geotechnical parameters selected for the re-moulded clay for the perimeter bund are the same as those used in the stability assessments for the existing landfill area (Reference 2) for the basal and side slope liners and the intercell bunds. Consistent with the assessment of the existing landfill area the values for the long term effective stress state (drained) parameters selected for the remoulded clay forming the perimeter bund have an effective cohesion of 2kPa rather than 0kPa. This is to promote the analysis of deeper higher hazard rotational failures in the models rather than shallow translational failures and to reflect observations of the long term stability of constructed slopes in the current landfill.

Geotechnical parameters selected for the basal lining system

6.5.3. The values for the geotechnical parameters used in the analysis of the inter-cell bunds of the basal lining system and Rutland Formation sub-grade are presented in Table SRA2. The values for the geotechnical parameters selected for the in situ clay of the sub-grade are the parameters described previously for the basal and sideslope sub-grade and for the re-moulded clay of the perimeter bund. As for the perimeter bund the values for the geotechnical parameters selected for the re-moulded clay for the sideslope liner are the same as those used in the stability assessments for the existing landfill area (Reference 2). Consistent with the assessment of the existing landfill area the values for the long term effective stress state (drained) parameters selected for the remoulded clay forming the inter-cell bunds have an effective cohesion of 2kPa to promote the analysis of deeper higher hazard rotational failures in the models rather than shallow translational failures and to reflect observations of the long term stability of constructed slopes in the current landfill.

6.5.4. For the assessment of the interface stability of the geosynthetic lining system and granular leachate drainage blanket on the slopes of the inter-cell bunds the parameters used are presented in Table SRA2. The interface shear strength values are taken from the stability risk assessments undertaken for the existing landfill area and Environment Agency guidance (Reference 6). The properties of the granular leachate drainage blanket are obtained from the stability assessments for the existing landfill area (Reference 2).

6.5.5. The selected conservative tensile strength for the geomembrane is based on guidance produced by the Environment Agency (Reference 9). An extract of the guidance is provided in Appendix SRA1. The value selected is consistent with, or more conservative than, tensile strengths achieved in laboratory testing by geomembranes used during the construction of the existing landfill area phases.

6.5.6. The selected conservative tensile strength for the protection geotextile is based on the properties of HPS7 geotextile manufactured by Geofabrics, which based on their guidelines for landfill protection layers may be the minimum specification suitable for up to 17m of waste and a drainage stone of 10mm provided in Appendix SRA1. The value selected is consistent with tensile strength values achieved in laboratory testing by materials used in the construction of previous landfill phases in the existing landfill area.

6.5.7. 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, strength 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 sideslope lining system

6.5.8. The geotechnical parameters used in the analysis of the sideslope lining system and sub-grade are presented in Table SRA2. The values for the geotechnical parameters selected for the in situ clay of the sub-grade, the re-moulded clay for the sideslope liner and geosynthetics used in the geosynthetic lining system are the values described previously for the basal and sideslope sub-grade and basal lining system.

Geotechnical parameters selected for the waste mass

6.5.9. The geotechnical parameters selected for analysis of the waste mass and inter-cell bunds are presented in Table SRA2. The values for the parameters selected for the waste mass are taken from stability assessments for the existing landfill area (Reference 2).

6.5.10. The values for the geotechnical parameters selected for the inter-cell bunds are the values used for the re-moulded in situ clay assessed in the sideslope lining system analyses and as presented in Table SRA2.

Geotechnical parameters selected for the capping system

6.5.11. The geotechnical parameters selected for the capping system are presented in Table SRA2. The values for the geotechnical parameters selected for the Lincolnshire Limestone, in situ glacial and Rutland Formation clays, re-compacted clay and waste are the values described in the basal and sideslope sub-grade, sideslope lining and waste mass assessments. Parameters are presented for both a clay capping system and a geomembrane capping system.

6.5.12. It is anticipated that the sub-grade to the capping system and for the clay capping system where it is used will comprise suitable site-derived engineering materials, which are likely to have similar properties to those used to construct the low permeability clay liner. Therefore the values for the geotechnical parameters selected for the sub-grade and the clay capping system will be the same as the values selected for the re-moulded in situ clay as described in the basal and sideslope lining assessments.

6.5.13. It is anticipated that the restoration materials which will be placed over the cap will comprise site-derived overburden materials. The values for the geotechnical parameters selected for the restoration soils are taken from the stability assessments undertaken for the existing landfill area.

6.5.14. Consistent with stability assessments for the existing landfill area (Reference 2), the interface shear strength values used to assess the geotextile component of the drainage geocomposite placed over either the clay cap or the 1mm thick HDPE geomembrane or linear low density polyethylene (LLDPE) geomembrane cap and below the restoration materials are taken from Environment Agency guidance (Reference 6). The tensile strength for the drainage geocomposite is based on the properties of the geotextile element of Pozidrain 7S10 geocomposite manufactured by ABG which it is a typical protection and drainage geocomposite employed in capping system of the existing landfill area. A manufacturer’s data sheet for Pozidrain 7S10 is presented in Appendix SRA1.

6.5.15. The interface shear strength values used to assess the geomembrane component of a geomembrane cap are taken from Environment Agency guidance (Reference 6) and are consistent with values used in stability assessments for the existing landfill area (Reference 2). Both peak and residual values have been used in the assessment of the capping system. The selected conservative tensile strength for the geomembrane component of the cap is based on guidance produced by the Environment Agency (Reference 9).

6.5.16. It is anticipated that it will be necessary to obtain representative interface shear strength values, tensile strength values, flow properties 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 capping system.

6.6. Selection of appropriate factors of safety

6.6.1. The following section presents the target factors of safety (FOS) selected for assessment of the conceptual models as required by risk screening. 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 they 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 fail 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 or capping system are analysed no tension should be mobilised and forces transferred to the underlying layers. It is considered that this is consistent with Environment Agency guidance (Reference 6) and with factors of safety attained in stability risk assessments undertaken for the existing landfill area (Reference 2). This approach is generally consistent with the combined partial factors recommended in Eurocode 7. The target FOS are summarised in Table SRA3.

Factor of safety for the basal sub-grade

6.6.2. Consistent with the stability assessments undertaken for the existing landfill area at ENRMF, analysis of the rotation stability of the basal sub-grade is not necessary as discussed in Section 4.2. A target factor of safety of 1.5 has been selected for the basal heave assessment consistent with Environment Agency guidance (Reference 6) as basal heave may not be possible to easily observe or retrospectively remediate.

Factor of safety for the sideslope sub-grade

6.6.3. Prior to the construction of the lining system and placement of waste against the completed sideslopes during which time it will be possible to observe and monitor their stability, the target FOS for the sideslope sub-grade is 1.3. The consequence of failure of the sideslope sub-grade 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 the perimeter bund

6.6.4. Prior to the construction of the lining system and placement of waste against the completed perimeter bund, during which time it will be possible to observe and monitor their stability, the target FOS for both the internal and external slopes of the perimeter bund is 1.2. The consequence of failure of the perimeter bund slopes prior to lining and 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 internal perimeter bund slopes prior to construction of the lining system or placement of waste. The long term effective stress (drained) stability of the buried internal slope of the perimeter bund is considered as part of the sideslope liner and waste mass stability assessments.

6.6.5. Following landfilling, capping and restoring the landfill the frequency at which the external slopes of the perimeter bund will be monitored will be reduced and it is considered that a FOS of 1.4 is appropriate for the long term rotational stability of the external permitter bund slopes.

Factor of safety for the basal lining system

6.6.6. A FOS of 1.2 has been selected for analysis of the stability of the inter-cell bunds and the lining system extending up the slopes of the inter-cell bunds prior to waste placement. The composite lining systems and leachate drainage blanket on the slopes of the inter-cell bunds can be monitored prior to waste placement and remediated if necessary and therefore it is considered that the consequences of failure are limited. 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. No tension should be mobilised in the geosynthetic components of the lining system.

Factor of safety for the sideslope lining system

6.6.7. The target FOS for the sideslope liner is 1.3 for the construction phase of the lining system and prior to placement of waste against the completed slopes during which it will be possible to observe and monitor their stability. This FOS is therefore relevant to the short term total stress state (undrained) and to the long term effective stress state (drained) stability analyses of the sideslope liner prior to waste placement. 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. No tension should be mobilised in the geosynthetic components of the lining system.

Factor of safety for the waste mass

6.6.8. The effects of the waste mass failure will 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 smaller internal waste slopes which are unlikely to damage the lining system if they fail may have a reduced FOS of 1.2. It is considered that a target FOS of 1.2 against rotational failure of the inter-cell bund is appropriate as identified previously.

Factor of safety for the capping system

6.6.9. A failure of the capping system and restoration soils is unlikely to have an effect on 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 for the rotational stability assessment and the assessment of interface stability based on peak values. Given the conservatism of residual values and the likelihood that these would be localised and not present throughout the whole of the analysed slope it is considered that a FOS of 1.1 is appropriate for the interface stability based on residual values. No tension should be mobilised in the geosynthetic components of the capping system.

6.7. Analyses

Basal sub-grade analysis

6.7.1. The stability against heave due to groundwater of the basal subgrade layer has been analysed quantitively in a spreadsheet. The spreadsheet analyses have been undertaken to determine the FOS against heave of the basal subgrade by comparing the upward pressure from confined groundwater with the vertical downward stress exerted by the overlying material. The results of the spreadsheet analyses are presented at Appendix SRA2. The calculated factor of safety against heave of the basal subgrade is 2.0.

Sideslope sub-grade and internal slope of the perimeter bund analysis

6.7.2. The stability of the sideslope sub-grade and the internal slope of the perimeter bund against rotational failure has been analysed quantitatively by modelling in SLOPE/W.

6.7.3. Analyses have been carried out to determine the short term total stress (undrained) and long term effective stress (drained) stability of the sideslope sub-grade for the maximum anticipated 16.5m high sub-grade sideslopes at the maximum gradient of 1v:2.5h as described in paragraph 6.3.8. The calculated factors of safety against rotational failure of the 16.5m high sideslope sub-grade are 1.400 for the undrained (short term) conditions and 1.330 for the drained (long term) conditions.

6.7.4. Analyses have been carried out to determine the short term total stress (undrained) and long term effective stress (drained) stability of the internal slope of the perimeter bund for its maximum anticipated height of 5m at the maximum gradient of 1v:2.5h as described in paragraph 6.3.9. The calculated factors of safety against rotational failure of the 5m high perimeter bund internal slope are 3.650 for the undrained (short term) conditions and 1.269 for the drained (long term) conditions.

6.7.5. The SLOPE/W plots for the sideslope sub-grade and perimeter bund are presented as Plots 1a, 1b, 1c and 1d in Appendix SRA3. The results are presented in Table SRA4.

Basal lining system analysis

6.7.6. The stability of the inter-cell bund against rotational failure has been analysed quantitatively by modelling in SLOPE/W. 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 as described in paragraph 6.3.12. The calculated factors of safety against rotational failure of the inter-cell bund are 3.572 for the undrained (short term) conditions and 1.227 for the drained (long term) conditions. The SLOPE/W plots for the sideslope sub-grade are presented as Plots 2a and 2b in Appendix SRA3. The results are presented in Table SRA4.

6.7.7. Analyses have been carried out to assess the stability of the extension of the geosynthetic components of the lining system and granular leachate drainage blanket up the slopes of the inter-cell bunds, prior to the deposition of waste. The calculated FOS against translational failure of the granular leachate drainage blanket for a maximum bund height of 3m at a gradient of 1v:2h is 1.53. No tension is mobilised in the geomembrane or protection geotextile components of the inter-cell bund lining system with the forces transferred to underlying layers. The calculations for the assessments are presented as Spreadsheets 1 to 4 at Appendix SRA4. The results are 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.

Sideslope and perimeter bund lining system analysis

6.7.8. The stability of the sideslope clay lining system against rotational failure has been analysed quantitatively by modelling in SLOPE/W. Analyses have been carried out for the stability of the sideslope liner clay for the maximum anticipated 15.5m vertical height under short term total stress (undrained) and long term effective stress (drained) conditions. The stability of the underlying sideslope sub-grade under drained conditions for each case is also considered in the assessment. The calculated FOS against failure of the 15.5m high sideslope liner are 1.447 for the undrained (short term) conditions and 1.320 for the drained (long term) conditions. The SLOPE/W plots of the assessments are presented as Plots 3a and 3b in Appendix SRA3. The results are presented in Table SRA4.

6.7.9. The stability of the perimeter bund clay sideslope lining system against rotational failure has been analysed quantitatively by modelling in SLOPE/W. Analyses have been carried out for the stability of the perimeter bund sideslope liner clay for the maximum anticipated 4m vertical height under short term total stress (undrained) and long term effective stress (drained) conditions. The stability of the underlying perimeter bund under drained conditions for each case is also considered in the assessment. The calculated FOS against failure of the 4m high perimeter bund clay sideslope liner are 2.067 for the undrained (short term) conditions and 1.352 for the drained (long term) conditions. The SLOPE/W plots of the assessments are presented as Plots 3c and 3d in Appendix SRA3. The results are presented in Table SRA4.

6.7.10. Analyses have been carried out of the stability of the extension of the granular leachate drainage blanket to a vertical height of 2m up the sideslopes prior to the 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. 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 SRA4. The results are 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

6.7.11. The stability of the temporary waste slope against rotational failure has been analysed quantitatively by modelling in SLOPE/W. Analysis has been undertaken for waste with toe support provided by an inter-cell bund. The calculated FOS against failure of the temporary waste slope with a maximum vertical height of 20m is 1.638. The SLOPE/W plot of the assessment is presented as Plot 4 in Appendix SRA3. The results are presented in Table SRA4.

Capping system analysis

6.7.12. The stability of both the geosynthetic and the clay capping systems against rotational failure have been analysed quantitatively by modelling in SLOPE/W at a number of conceptual sections through the restoration profile for both 1m and 1.5m of restoration soils. The stability of a long section at a gradient of 1v:6h for a slope length of 150m and a steep slope which represents the lower slopes with a gradient of 1v:4h and a slope height of 12m have been considered under short term total stress (undrained) and long term effective stress (drained) conditions and with managed and unmanaged leachate. Managed leachate levels have been analysed at a maximum level of 1m 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 in each case.

Geosynthetic capping system analysis

6.7.13. The calculated factors of safety against rotational failure of the geosynthetic capping system and 1m thickness of restoration soils for the 150m long section with managed leachate levels are 2.971 for short term total stress (undrained) conditions and 2.950 for long term effective stress (drained) conditions. The calculated factors of safety against rotational failure of the geosynthetic capping system and 1m thickness of restoration soils for the 12m high steep section with managed leachate levels are 2.278 for the short term total stress (undrained) and 2.263 for the long term effective stress (drained) conditions and managed leachate. The SLOPE/W plots for the assessment are presented as Plots 5a, 5b, 5c and 5d in Appendix SRA3 and the results are presented in Table SRA4.

6.7.14. The calculated factor of safety against rotational failure of the geosynthetic capping system and 1m thickness of restoration materials for the long section with unmanaged leachate at maximum containment levels is 2.880 for long term effective stress (drained) conditions. The calculated factor of safety of the geosynthetic capping system and 1m restoration materials for the steep section with unmanaged leachate at breakout levels is 2.206 for long term effective stress (drained) conditions. The SLOPE/W plots for the assessment are presented as Plots 6a and 6b in Appendix SRA2. The results are presented in Table SRA4.

6.7.15. The calculated factors of safety against rotational failure of the capping system and 1.5m thickness of restoration materials for the long section with managed leachate levels are 2.974 for short term total stress (undrained) conditions and 2.956 for long term effective stress (drained) conditions. The calculated factors of safety against rotational failure of the geosynthetic capping system and 1.5m thickness of restoration materials for the steep section with managed leachate levels are 2.308 for the short term total stress (undrained) and 2.293 for the long term effective stress (drained) conditions and managed leachate. The SLOPE/W plots for the assessment are presented as Plots 7a, 7b, 7c and 7d in Appendix SRA3 and the results presented in Table SRA4.

6.7.16. The calculated factor of safety against rotational failure of the geosynthetic capping system and 1.5m thickness of restoration materials for the long section with unmanaged leachate at maximum containment levels is 2.890 for long term effective stress (drained) conditions. The calculated factor of safety of the geosynthetic capping system and 1.5m restoration materials for the steep section with unmanaged leachate at breakout levels is 2.243 for long term effective stress (drained) conditions. The SLOPE/W plots for the assessment are presented as Plots 8a and 8b in Appendix SRA3. The results are presented in Table SRA4.

6.7.17. The stability of the interfaces of the geosynthetic capping system between the underlying 1mm thick HDPE geomembrane or linear low density polyethylene (LLDPE) geomembrane, drainage geocomposite and overlying restoration materials and the stability against sliding of the overlying restoration materials has been assessed quantitatively in a series of spreadsheet analyses. The spreadsheet analyses have been undertaken to determine the FOS against translational sliding of the 1m thick and 1.5m thick restoration materials and to assess whether tension would be mobilised in the geotextile layer of the drainage geocomposite or the geomembrane. The analyses consider both the short term and the long term conditions prior to and following build up of water flow in the drainage geocomposite and restoration materials. The analysis also considers peak and residual interface strengths for the interfaces between the geomembrane and the overlying geocomposite together with the geocomposite and the overlying restoration materials. The results of the spreadsheet analyses are presented at Appendix SRA4.

6.7.18. Spreadsheets 9 to 12 analyse the long slope capping system with 1m thick restoration materials at a maximum gradient of 1v:6h and a slope length of 150m using peak interface shear strength values. Spreadsheets 13 to 16 analyse the same slope using residual interface shear strength values. The calculated factor of safety against translational failure using peak interface shear strength values is 3.58 in the short term and 2.56 in the long term conditions. The calculated factor of safety against translational failure using residual interface shear strength values is 6.07 in the short term and 5.05 in the long term conditions. No tension is mobilised in the geosynthetic components of the capping system with forces transferred to underlying layers.

6.7.19. Spreadsheets 17 to 20 analyse the long slope capping system with 1.5m thick restoration materials at a maximum gradient of 1v:6h and a slope length of 150m using peak interface shear strength values. Spreadsheets 21 to 24 analyse the same slope using residual interface shear strength values. The calculated factor of safety against translational failure using peak interface shear strength values is 3.76 in the short term and 2.72 in the long term conditions. The calculated factor of safety against translational failure using residual interface shear strength values is 5.24 in the short term and 4.25 in the long term conditions. No tension is mobilised in the geosynthetic components of the capping system with forces transferred to the underlying layers.

6.7.20. Spreadsheets 25 to 28 analyse the steep slope capping system with 1m thick restoration materials at a maximum gradient of 1v:4h and a height of 12m using peak interface shear strength values. Spreadsheets 29 to 32 analyse the same slope using residual interface shear strength values. The calculated factor of safety against translational failure using peak interface shear strength values is 2.49 in the short term and 1.79 in the long term conditions. The calculated factor of safety against translational failure using residual interface shear strength values is 4.23 in the short term and 3.52 in the long term conditions. No tension is mobilised in the geosynthetic components of the capping system with forces transferred to underlying layers.

6.7.21. Spreadsheets 33 to 36 analyse the capping system and 1.5m thick restoration materials at a maximum gradient of 1v:4h and for a height of 12m using peak interface shear strength values. Spreadsheets 37 to 40 analyse the same slope using residual interface shear strength values. The calculated factor of safety against translational failure using peak interface shear strength values is 2.64 in the short term and 1.92 in the long term conditions. The calculated factor of safety against translational failure using residual interface shear strength values is 3.70 in the short term and 3.00 in the long term conditions. No tension is mobilised in the geosynthetic components of the capping system with forces transferred to the underlying layers.

6.8. *Clay capping system analysis*

6.8.1. The calculated factors of safety against rotational failure of the clay capping system and 1m thickness of restoration soils for the 150m long section with managed leachate levels are 2.954 for short term total stress (undrained) conditions and 2.260 for long term effective stress (drained) conditions. The calculated factors of safety against rotational failure of the clay capping system and 1m thickness of restoration soils for the 12m high steep section with managed leachate levels are 2.312 for the short term total stress (undrained) and 1.905 for the long term effective stress (drained) conditions and managed leachate. The SLOPE/W plots for the assessment are presented as Plots 9a, 9b, 9c and 9d in Appendix SRA3 and the results are presented in Table SRA4.

6.8.2. The calculated factor of safety against rotational failure of the clay capping system and 1m thickness of restoration materials for the long section with unmanaged leachate at maximum containment levels is 2.260 for long term effective stress (drained) conditions. The calculated factor of safety of the clay capping system and 1m restoration materials for the steep section with unmanaged leachate at breakout levels is 1.905 for long term effective stress (drained) conditions. The SLOPE/W plots for the assessment are presented as Plots 10a and 10b in Appendix SRA3. The results are presented in Table SRA4.

6.8.3. The calculated factors of safety against rotational failure of the clay capping system and 1.5m thickness of restoration materials for the long section with managed leachate levels are 2.954 for short term total stress (undrained) conditions and 2.368 for long term effective stress (drained) conditions. The calculated factors of safety against rotational failure of the geosynthetic capping system and 1.5m thickness of restoration materials for the steep section with managed leachate levels are 2.323 for the short term total stress (undrained) and 1.907 for the long term effective stress (drained) conditions and managed leachate. The SLOPE/W plots for the assessment are presented as Plots 11a, 11b, 11c and 11d in Appendix SRA3 and the results presented in Table SRA4.

6.8.4. The calculated factor of safety against rotational failure of the clay capping system and 1.5m thickness of restoration materials for the long section with unmanaged leachate at maximum containment levels is 2.368 for long term effective stress (drained) conditions. The calculated factor of safety of the clay capping system and 1.5m restoration materials for the steep section with unmanaged leachate at breakout levels is 1.907 for long term effective stress (drained) conditions. The SLOPE/W plots for the assessment are presented as Plots 12a and 12b in Appendix SRA3. The results are presented in Table SRA4.

6.8.5. The stability of the interfaces in the clay capping system between the clay, drainage geocomposite and overlying restoration materials and the stability against sliding of the overlying restoration materials has been assessed quantitatively in a series of spreadsheet analyses. The spreadsheet analyses have been undertaken to determine the FOS against translational sliding of the 1m thick and 1.5m thick restoration materials and to assess whether tension would be mobilised in the geotextile layer of the drainage geocomposite. The analyses consider both the short term and the long term conditions prior to and following build up of water flow in the drainage geocomposite and restoration materials. The analysis also considers peak and residual interface strengths for the interfaces between the clay and the overlying geocomposite together with the geocomposite and the overlying restoration materials. The results of the spreadsheet analyses are presented at Appendix SRA4.

6.8.6. Spreadsheets 41 to 44 analyse the long slope clay capping system with 1m thick restoration materials at a maximum gradient of 1v:6h and a slope length of 150m using peak interface shear strength values. Spreadsheets 45 to 48 analyse the same slope using residual interface shear strength values. The calculated factor of safety against translational failure using peak interface shear strength values is 3.58 in the short term and 2.56 in the long term conditions. The calculated factor of safety against translational failure using residual interface shear strength values is 6.07 in the short term and 5.05 in the long term conditions. No tension is mobilised in the geosynthetic components of the clay capping system with forces transferred to underlying layers.

6.8.7. Spreadsheets 49 to 52 analyse the long slope clay capping system with 1.5m thick restoration materials at a maximum gradient of 1v:6h and a slope length of 150m using peak interface shear strength values. Spreadsheets 53 to 56 analyse the same slope using residual interface shear strength values. The calculated factor of safety against translational failure using peak interface shear strength values is 3.76 in the short term and 2.72 in the long term conditions. The calculated factor of safety against translational failure using residual interface shear strength values is 5.24 in the short term and 4.25 in the long term conditions. No tension is mobilised in the geosynthetic components of the clay capping system with forces transferred to the underlying layers.

6.8.8. Spreadsheets 57 to 60 analyse the steep slope clay capping system with 1m thick restoration materials at a maximum gradient of 1v:4h and a height of 12m using peak interface shear strength values. Spreadsheets 61 to 64 analyse the same slope using residual interface shear strength values. The calculated factor of safety against translational failure using peak interface shear strength values is 2.49 in the short term and 1.79 in the long term conditions. The calculated factor of safety against translational failure using residual interface shear strength values is 4.23 in the short term and 3.52 in the long term conditions. No tension is mobilised in the geosynthetic components of the clay capping system with forces transferred to underlying layers.

6.8.9. Spreadsheets 65 to 68 analyse the clay capping system and 1.5m thick restoration materials at a maximum gradient of 1v:4h and for a height of 12m using peak interface shear strength values. Spreadsheets 69 to 72 analyse the same slope using residual interface shear strength values. The calculated factor of safety against translational failure using peak interface shear strength values is 2.64 in the short term and 1.92 in the long term conditions. The calculated factor of safety against translational failure using residual interface shear strength values is 3.70 in the short term and 3.00 in the long term conditions. No tension is mobilised in the geosynthetic components of the clay capping system with forces transferred to the underlying layers.

6.9. Assessment

Basal sub-grade assessment

6.9.1. The results of the analysis of heave due to groundwater pressures acting on the basal subgrade show that provided the base of excavation in the Rutland formation is above the groundwater levels recorded in the underlying Lincolnshire Limestone the basal sub-grade has factors of safety above the target FOS of 1.5.

6.9.2. During the construction of the western extension area phases, outside the 150m standoff across the doline area, resistivity imaging surveys will be employed subject to CQA requirements and if necessary verification boreholes will be drilled consistent with practice at the existing landfill area.

6.9.3. No landfilling will take place in the 150m wide standoff across the doline area until further investigation is undertaken to verify the ground conditions and the nature and extent of solution features which may be present and require treatment prior to landfill development. Subject to this further investigation it may be necessary to undertake quantitative assessment of the ground conditions within the 150m wide standoff across the doline area. Irrespective of the outcome of further investigation and assessment a minimum 20m wide route will be left through the doline area to maintain a surface water flow path from west to east.

Sideslope sub-grade and perimeter bund assessment

6.9.4. The results of the analysis for stability of the sideslope sub-grade against rotational failure for the maximum anticipated slope height of 16.5m 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 in the short term total stress (undrained) and in the long term effective stress (drained) analyses.

6.9.5. The results of the analysis for stability of the perimeter bund against rotational failure for the maximum anticipated perimeter bund height of 5m at a maximum internal slope gradient of 1v:2.5h show that the perimeter bund has factors of safety above the target FOS of 1.2 in the short term total stress (undrained) and in the long term effective stress (drained) analyses.

Basal lining system assessment

6.9.6. It is considered that based on this assessment and with reference to previous stability assessments undertaken for the existing landfill area that the basal lining system for the western extension area is stable.

6.9.7. 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.

6.9.8. 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 show 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

6.9.9. The results of the rotational stability analyses for the sideslope lining system modelled for the maximum anticipated slope height of 15.5m 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.

6.9.10. The spreadsheet analyses which consider the extension of the granular leachate drainage blanket to a vertical height of 2m up the sideslope at a gradient of 1v:2.5h show 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.

6.9.11. Based on the results of the 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 as the waste will be placed progressively in horizontal layers across the full width of the landfill cell to avoid tension being mobilised in the geosynthetic layers. Selected fine grained wastes containing clay, silt, sand and gravel up to 20mm in diameter will be used as the first layer placed against the sideslope protection and drainage geocomposite.

Waste mass assessment

6.9.12. The results of the rotational stability analyses for the 20m high temporary waste slopes at gradients of 1v:3h show that the FOS is greater than the target FOS of 1.3.

Capping system assessment

6.9.13. The rotational stability of the geomembrane and clay capping systems, 1m and 1.5m of restoration materials and underlying waste mass has been analysed under conditions with leachate levels controlled to 1m 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 both the short term total stress (undrained) and long term effective stress (drained) analyses and under managed and unmanaged leachate conditions.

6.9.14. The spreadsheet analysis for the stability of the 1m and 1.5m thick restoration materials against translational sliding calculates FOS above the target of 1.4 for peak interface shear strength parameters and calculates FOS above the target of 1.1 for residual interface shear strength parameters. No tension is mobilised in the geosynthetic components of either the geomembrane or clay capping systems and forces are transferred to underlying layers.

7. Risk based monitoring scheme

7.1. From the results of the stability risk assessment it is calculated that the target factors of safety can be achieved at all stages of the development of the western extension area provided that the materials used in construction of the landfill achieve the geotechnical parameters used in the analyses. It is considered appropriate to undertake an annual topographic survey 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 and capping system. Following completion of restoration of the site a visual inspection for signs of settlement or instability will be undertaken during the annual topographical survey visits.

7.2. The results of the annual topographical surveys will be forwarded to the Environment Agency. 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.

7.3. No landfilling will take place in the 150m wide zone across the doline area until further investigation is undertaken to verify the ground conditions and the nature and extent of solution feature which may be present and require treatment prior to landfill development. Subject to this further investigation it may be necessary to undertake quantitative assessment of the ground conditions within the 150m wide zone across the doline area. Irrespective of the outcome of further investigation and assessment a minimum 20m wide standoff route will be left through the doline area to maintain a surface water flow path from west to east.

7.4. Subject to agreed CQA procedures for each landfill phase outside the 150m zone across the doline area, resistivity imaging surveys and verification boreholes will be undertaken to verify that there are no anomalies or significant voids within the basal sub-grade underlying the western extension area phases.

7.5. As part of the CQA procedures for the engineering 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 or capping systems.

7.6. Waste will be placed in horizontal lifts across the full width of the operational phase to prevent tension and instability of the geosynthetics used in the sideslope lining system. Selected fine grained wastes containing clay, silt and sand and gravel up to 20mm in diameter will be placed as the first layer against the sideslope protection and drainage geocomposite. The sideslope protection and drainage geocomposite will be monitored during waste placement to verify that there is no evidence of tension being mobilised within the geocomposite or damage to the geocomposite and underlying geomembrane liner.

References

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2. "Stability Risk Assessment (SRA)" document reference AU/KCE/AW/5469/01 dated September 2014, Appendix A of Permit Variation Application prepared by MJCA.

3. "Capping Stability Risk Assessment" Report No. 3649-R01 SRA, Issue 01 dated 30 November 2016, TerraConsult Ltd.

4. Volume 1 of the Manual of Contract Documents for Highway Works, "Specification for Highway Works, Series 600, Earthworks" (March 2020 Amendment) published by the Highways Agency.

5. 'Factual report of a site investigation in a potential extension to East Northants Resource Management Facility and Construction Quality Assurance Verification Report for the boreholes installation of groundwater and landfill gas monitoring boreholes drilled during the site investigation.' Report reference AU/KCW/JRC/2936/01. MJCA, June 2020.

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8. '4. Properties of clay materials, soils and mudrocks' Geological Society, London. Engineering Geology Special Publications. 2006, v.21, p94.

9. 'LFE5 – Using geomembranes in landfill engineering' Environment Agency.

TABLES

Table SRA1

Summary of the proposed design for the western extension area and comparison with the design of the existing landfill area at ENRMF

Element	Current design of the existing landfill area[1]	Proposed design for the western extension area
Excavated slopes		
Strata	The sideslope will be excavated in glacial clays, brown clays and clays of the Rutland Formation to a formation level 2m above the top of the Lincolnshire Limestone.	The sideslope will be excavated in glacial clays, brown clays and clays of the Rutland Formation to a formation level 2m above the top of the Lincolnshire Limestone.
Gradient	Sideslope gradients: maximum 1v:2.5h. Basal gradients: typically up to 1v:50h, minimum 1v:100h	Sideslope gradients: maximum 1v:2.5h. Basal gradients: typically up to 1v:25h, minimum 1v:100h
Height	Typically 5m to 12m. Maximum of approximately 16.5m located along a 10m length of the eastern boundary of Phases 6 and 10 which reflects stockpiled materials and made ground which was removed prior to construction.	Excavated slopes range from approximately 1.5m to 16.5m. Where the excavated slopes are less than 5m the excavation boundary shall be adjusted and a perimeter bund constructed to maintain a minimum equivalent excavated perimeter side slope depth of 5m. Maximum anticipated slope height of approximately 16.5m.
Perimeter bunds		
Gradient	Not in current design	Maximum 1v:2.5h internal face and 1v4h external face.
Height	Not in current design	Up to a maximum of 5m to provide a minimum equivalent excavated perimeter side slope of 5m.
Crest width	Not in current design	Minimum 3m.
Basal lining system		
Mineral barrier	Minimum 1m thick engineered clay liner with a hydraulic conductivity of no more than 1x10^{-9}m/s. Intercell bunds with a maximum vertical height of 3m, side slopes of 1v:2h and crest width of 3m.	Minimum 1m thick engineered clay liner with a hydraulic conductivity of no more than 1x10^{-9}m/s. Intercell bunds with a maximum vertical height of 3m, side slopes of 1v:2h and crest width of 3m.
Geomembrane	2mm thick smooth HDPE geomembrane with either a protection geotextile or a 300mm sand protection layer.	2mm thick smooth HDPE geomembrane with either a protection geotextile or a 300mm sand protection layer.
Leachate drainage blanket	Either a 300mm thick granular a tyre bale leachate drainage blanket layer on the base with a 300mm thick granular layer installed up and over the inter-cell bunds and up the first 2m vertical height of the sideslopes. Containing 180mm external diameter HDPE leachate collection pipework draining to a sump in the low point of each phase.	Either a 300mm thick granular or a tyre bale leachate drainage blanket layer on the base with a 300mm thick granular layer installed up and over the inter-cell bunds and up the first 2m vertical height of the sideslopes. Containing 180mm external diameter HDPE leachate collection pipework draining to a sump in the low point of each phase.
Sideslope lining system		
Mineral barrier	Minimum 1m thick engineered clay liner with a hydraulic conductivity of no more than 1x10^{-9}m/s.	Minimum 1m thick engineered clay liner with a hydraulic conductivity of no more than 1x10^{-9}m/s.
Geomembrane	2mm thick double textured HDPE geomembrane.	2mm thick double textured HDPE geomembrane.
Leachate drainage blanket	Suitable drainage geocomposite to act as a pathway for perched leachate to drain to the basal leachate drainage blanket and provide protection to the underlying geomembrane.	Suitable drainage geocomposite to act as a pathway for perched leachate to drain to the basal leachate drainage blanket and provide protection to the underlying geomembrane.
Inter-cell bunds		
Gradient	1v:2h.	1v:2h.
Height	Minimum 2m.	Minimum 2m but up to a maximum of 3m to accommodate basal level differences between phases.
Crest width	Minimum 3m.	Minimum 3m.
Waste mass		
Gradient	1v:3h.	1v:3h
Depth of waste	Approximately 17m depth of waste. 15m maximum temporary waste slope.	Up to approximately 20m depth of waste. 18m maximum temporary waste slope.
Waste placement	Waste placed progressively in horizontal layers across the full width of the landfill cell. Selected fine grained wastes containing clay, silt, sand and gravel up to a grain size of 20mm in diameter will be used as the first layer placed against the sideslopes.	Waste placed progressively in horizontal layers across the full width of the landfill cell. Selected fine grained wastes containing clay, silt, sand and gravel up to a grain size of 20mm in diameter will be used as the first layer placed against the sideslopes.
Capping and restoration system		
Components	A 0.3m thick sub-grade layer placed over the completed and profiled waste surface. 1mm thick HDPE geomembrane or linear low density polyethylene (LLDPE) geomembrane with a suitable protection and drainage geocomposite. Subsequently amended through a CQA Plan and stability risk assessment to 1m thick low permeability engineered clay layer with a suitable protection and drainage geocomposite 1m to 1.5m thickness of restoration materials. The thicker layers are located in the areas which will be restored to woodland .	A 0.3m thick sub-grade layer placed over the completed and profiled waste surface. Either: 1mm thick HDPE geomembrane or linear low density polyethylene (LLDPE) geomembrane with a suitable protection and drainage geocomposite. Or: 1m thick low permeability engineered clay layer with a suitable protection and drainage geocomposite. And: 1m to 1.5m thickness of restoration materials. The thicker layers are located in the areas which will be restored to woodland.
Gradient	Typical gradients of between approximately 1v:10h and 1v:20h with slope lengths of between 150m at 1v:10h and greater than approximately 200m at 1v:20h. Steeper slopes are present along the northern boundary with the steepest at a gradient of 1v:3h over 10m in the eastern section of the northern boundary.	Typical maximum average gradient of 1v:6h for slope lengths of up to 150m. Maximum gradient of approximately 1v:4h for lower slopes with heights of approximately 12m.
Height	Maximum of approximately 14m.	Maximum of approximately 18m.

[1] In accordance with the current site permit requirements or as agreed through the CQA Plans in accordance with the current site permit requirements

Table SRA2

Geotechnical parameters used in the stability analyses for the western extension area

Material and intended use	**Unit weight**	**Undrained parameters (short term)**	**Drained parameters (long term)**
In situ glacial clays and Rutland Formation (basal and sideslope sub-grade)[2,3]	$\gamma = 20\ kN/m^3$	c = 55 kPa Ø = 0°	c' = 5 kPa Ø' = 22.5°
Engineered clay (basal and sideslope liner, perimeter and intercell bunds and clay capping and regulating layer)[2,3]	$\gamma = 20\ kN/m^3$	c = 50 kPa Ø = 0°	c' = 2 kPa Ø' = 20°
Waste (waste mass)[2]	$\gamma = 15\ kN/m^3$	c' = 5 kPa Ø' = 25°	
Restoration soils[2]	$\gamma_{dry} = 18\ kN/m^3$ $\gamma_{sat} = 20\ kN/m^3$	c' = 5 kPa Ø' = 25°	
Leachate drainage gravel[2]	$\gamma_{dry} = 18\ kN/m^3$ $\gamma_{sat} = 20\ kN/m^3$	c' = 0 kPa Ø' = 35°	
Geosynthetic interface values		**Peak**	**Residual**
<u>Geomembrane (liner)</u> Textured HDPE/non-woven geotextile[4] Textured HDPE/clay undrained[4] Textured HDPE/clay drained[4]		α = 7 kPa δ = 26° α = 36 kPa δ = 4.4° α = 26.7 kPa δ = 10.7°	α = 4 kPa δ = 13° α = 34 kPa δ = 3.1°
<u>Non-woven geotextile (basal protection, and sideslope and capping drainage)</u> Non-woven geotextile/gravel[4] Non-woven geotextile/restoration soils[4] Non-woven geotextile/clay - undrained[4] Non-woven geotextile/clay - drained[4]		α = 0 kPa δ = 35° α = -1.3 kPa δ = 33.1° α = 5.3 kPa δ = 25.3° α = 4.4 kPa δ = 32.5°	α = 0 kPa δ = 35° α = 7.7 kPa δ = 28.7° α = 55.6 kPa δ = 17.7°
<u>Geomembrane (capping system)</u> Textured HDPE or LLDPE/non-woven geotextile[4]		α = 7 kPa δ = 26°	α = 4 kPa δ = 13°
Geosynthetic tensile properties		**Tensile strength**	
<u>Geomembrane</u> 2mm thick double textured geomembrane[5] 1mm thick double textured geomembrane[5]		29 kN/m 15 kN/m	
<u>Non-woven geotextile</u> Basal protection geotextile[6] Geotextile of side slope drainage geocomposite[6] Geotextile of capping drainage geocomposite[6]		40 kN/m (HPS 7 - 20m height, 10mm stone) 35 kN/m (HPS 6 - 15m height, 10mm stone) 19 kN/m (Pozidrain 7S10)	

Key to symbols:

γ – unit weight; c – cohesion; c' – effective cohesion; Ø – friction angle; Ø' – effective friction angle; α - interface cohesion; δ - interface friction angle

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[2] Values based on data presented in previous stability risk assessments undertaken for the existing landfill area at ENRMF (Reference 2).
[3] Values for long term apparent cohesion for in situ clays and remoulded clays to reflect site investigation data and long term stability of excavated and constructed slopes in the current landfill area.
[4] Values based on conservative estimates taken from Tables 7.3 and 7.4 of Jones and Dixon "Stability of Landfill Lining Systems" Environment Agency R&D Technical Report PI-385 TR1 (Reference 6).
[5] Tensile properties of geomembranes based on "LFE5 – Using geomembranes in landfill engineering" Environment Agency (Reference 13). An extract is presented at Appendix SRA1. Values for the 2mm thick double textured geomembrane similar to those used in construction of sideslope liner for Phase 5A and Phase 5B in the existing landfill area.
[6] Values obtained from manufacturer's data sheets presented in Appendix SRA1. Values are based on the minimum lowest strength geotextile likely to be specified for each engineering component.

Table SRA3

Selected Factors of Safety

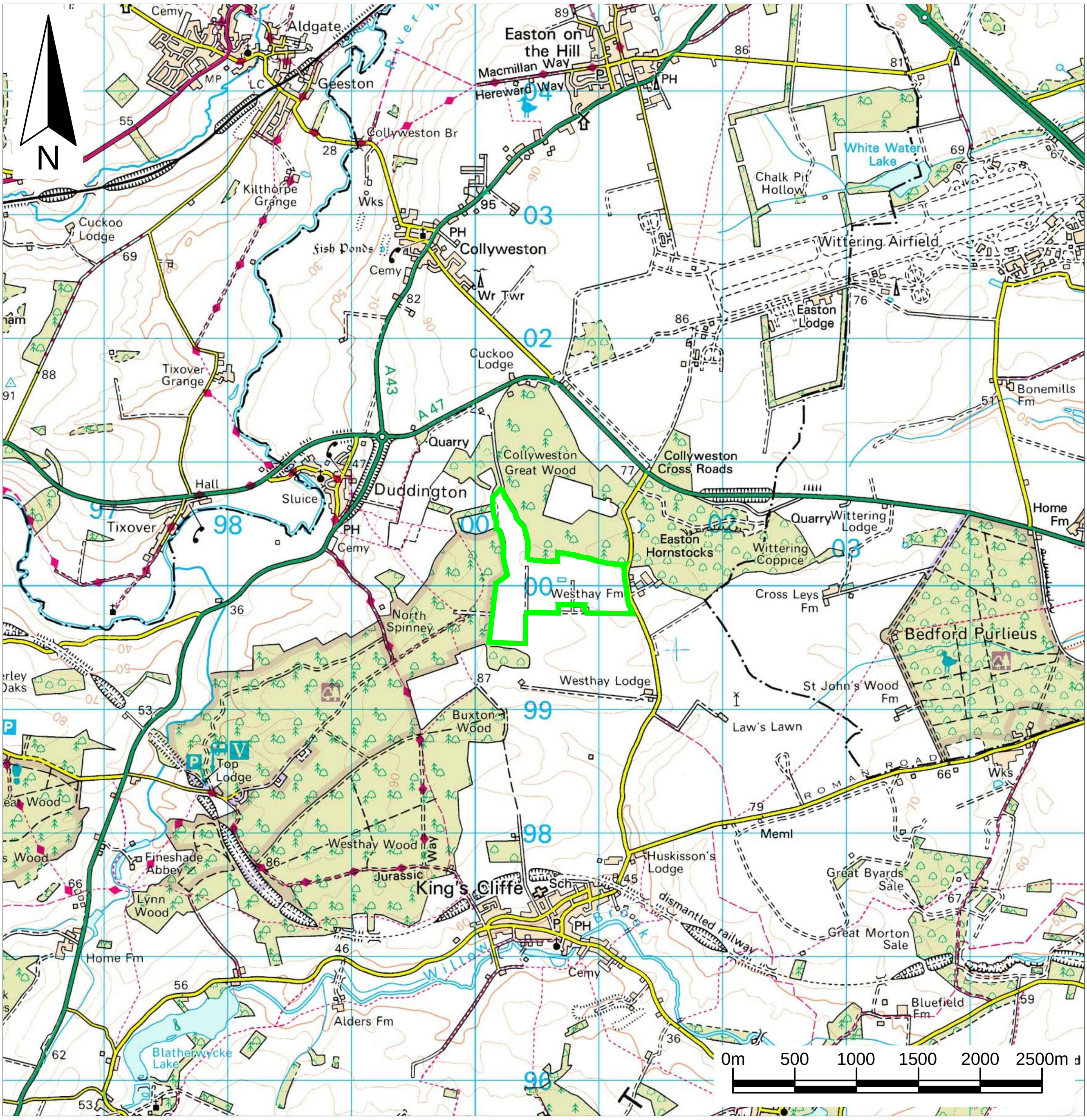
Component	Factor of safety: Short term	Factor of safety: Long term	Integrity of geosynthetic components
Basal sub-grade heave	1.5	N/A	N/A
Sideslope sub-grade and perimeter bund internal slope	1.2	1.2	N/A
Perimeter bund external slope	1.3	1.4	N/A
Basal lining system (inter-cell bund)	1.2	1.2	No tension to be mobilised
Sideslope lining system	1.3	1.3	No tension to be mobilised
Waste mass	1.3	1.3	N/A
Capping system	1.4 (peak values) 1.1 (residual values)	1.4 (peak values) 1.1 (residual values)	No tension to be mobilised

Table SRA4 Results of the stability analyses

Model component	Analysis	Calculations	Factor of safety			Comment
			Short term	Long term	Target	
Basal sub-grade	Basal heave	Appendix SRA2	2.0	N/A	1.5	Factors of safety greater than target. Retained depth of in situ material above the limestone is equal to or greater than the maximum groundwater level above the top of the limestone .
	Dissolution void related instability	N/A	Qualitative assessment demonstrates that void related instability will not affect the basal sub-grade outside the 150m doline area .			Conclusion consistent with previous stability assessments undertaken for the existing landfill area. 150m doline area will be subject to further investigation before landfilling.
	Mining related instability	N/A	Qualitative assessment demonstrates that mining related instability will not affect the basal sub-grade.			Conclusion consistent with previous stability assessments undertaken for the existing landfill area.
Sideslope sub-grade and perimeter bund	Stability against heave of the sideslope sub-grade	N/A	Qualitative assessment demonstrates stability against heave of the sideslope sub-grade with reference to basal sub-grade.			Conclusion consistent with previous stability assessments undertaken for the existing landfill area and the basal heave analysis for the basal subgrade.
	Stability against rotational failure of the 1v:2.5h 16.5m high sideslope sub-grade	Appendix SRA3 Plots 1a and 1b	1.400	1.330	1.3	Factors of safety greater than target
	Stability against rotational failure of the 1v:2.5h 5m high perimeter bund	Appendix SRA3 Plots 1c and 1d	3.650	1.269	1.2	Factors of safety greater than target
Basal lining system	Basal heave of the basal sub-grade affecting the basal liner	N/A	Qualitative assessment demonstrates stability against basal heave based on the results of the basal subgrade analysis.			Consistent with conclusions of previous stability assessments undertaken for the existing landfill area and the basal heave analysis for the basal subgrade.
	Stability against rotational failure of the 1v:2h 3m high inter-cell bund	Appendix SRA3 Plots 2a and 2b	3.572	1.227	1.2	Factors of safety greater than target.
	Translational and interface stability of granular leachate drainage blanket up 1v:2h 3m high slope of inter-cell bund.	Appendix SRA4 Spreadsheets 1 to 4	1.53 No tension	1.53 No tension	1.2 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
Sideslope lining system	Stability against rotational failure of 1m thick clay liner with slope of 1v:2.5h at 15.5m high	Appendix SRA3 Plots 3a and 3b	1.447	1.320	1.3	Factors of safety greater than target.
	Stability against rotational failure of 1m thick clay liner with slope of 1v:2.5h at 4m high against the perimeter bund	Appendix SRA3 Plots 3c and 3d	2.067	1.352	1.3	Factors of safety greater than target.
	Translational and interface stability of granular leachate drainage blanket extended to a 2m vertical height up the 1v:2.5h sideslope	Appendix SRA4 Spreadsheets 5 to 8	1.96 No tension	1.96 No tension	1.3 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Interface stability of geomembrane for full height of the sideslope lining system.	Not required – see risk screening Section 4.5.3				Waste placement procedures will be such as to prevent tension being mobilised in the geosynthetic elements of the sideslope liner.
	Interface stability of drainage geocomposite for full height of the sideslope lining system.	Not required – see risk screening Section 4.5.3				
Waste mass	Rotational stability 1v:3h 20m high temporary waste slopes with toe support	Appendix SRA3 Plot 4	N/A	1.638	1.3	Factor of safety greater than target.
Geosynthetic Capping system	Rotational stability of waste, geosynthetic cap and 1m of restoration for 1v:6h 150m long slope with managed leachate	Appendix SRA3 Plots 5a and 5b	2.971	2.950	1.4	Factor of safety greater than target.
	Rotational stability of waste, geosynthetic cap and 1m of restoration for 1v:4h 12m high slope with managed leachate	Appendix SRA3 Plots 5c and 5d	2.278	2.263	1.4	Factor of safety greater than target.
	Rotational stability of waste, geosynthetic cap and 1m of restoration for 1v:6h 150m long slope with unmanaged leachate	Appendix SRA3 Plot 6a	N/A	2.880	1.4	Factor of safety greater than target.
	Rotational stability of waste, geosynthetic cap and 1m of restoration for 1v:4h 12m high slope with unmanaged leachate	Appendix SRA3 Plot 6b	N/A	2.206	1.4	Factor of safety greater than target.
	Rotational stability of waste, geosynthetic cap and 1.5m of restoration for 1v:6h 150m long slope with managed leachate	Appendix SRA3 Plots 7a and 7b	2.974	2.956	1.4	Factor of safety greater than target.
	Rotational stability of waste, geosynthetic cap and 1.5m of restoration for 1v:4h 12m high slope with managed leachate	Appendix SRA3 Plots 7c and 7d	2.308	2.293	1.4	Factor of safety greater than target.
	Rotational stability of waste, geosynthetic cap and 1.5m of restoration for 1v:6h 150m long slope with unmanaged leachate	Appendix SRA3 Plot 8a	N/A	2.890	1.4	Factor of safety greater than target.
	Rotational stability of waste, geosynthetic cap and 1.5m of restoration for 1v:4h 12m high slope with unmanaged leachate	Appendix SRA3 Plot 8b	N/A	2.243	1.4	Factors of safety greater than target.
	Translational and interface stability of geosynthetic cap with 1m of restoration for 1v:6h 150m long slope and peak interface values	Appendix SRA4 Spreadsheets 9 to 12	3.58 No tension	2.56 No tension	1.4 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of geosynthetic cap with 1m of restoration for 1v:6h 150m long slope and residual interface values	Appendix SRA4 Spreadsheets 13 to 16	6.07 No tension	5.05 No tension	1.1 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of geosynthetic cap with 1.5m of restoration for 1v:6h 150m long slope and peak interface values	Appendix SRA4 Spreadsheets 17 to 20	3.76 No tension	2.72 No tension	1.4 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of geosynthetic cap with 1.5m of restoration for 1v:6h 150m long slope and residual interface values	Appendix SRA4 Spreadsheets 21 to 24	5.24 No tension	4.25 No tension	1.1 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of geosynthetic cap with 1m of restoration for 1v:4h 12m high slope and peak interface values	Appendix SRA4 Spreadsheets 25 to 28	2.49 No tension	1.79 No tension	1.4 No tension	Factors of safety greater than target. Forces transferred to underlying layers.

Model component	Analysis	Calculations	Factor of safety			Comment
			Short term	Long term	Target	
	Translational and interface stability of geosynthetic cap with 1m of restoration for 1v:4h 12m high slope and residual interface values	Appendix SRA4 Spreadsheets 29 to 32	4.23 No tension	3.52 No tension	1.1 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of geosynthetic cap with 1.5m of restoration for 1v:4h 12m high slope and peak interface values	Appendix SRA4 Spreadsheets 33 to 36	2.64 No tension	1.92 No tension	1.4 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of geosynthetic cap with 1.5m of restoration for 1v:4h 12m high slope and residual interface values	Appendix SRA4 Spreadsheets 37 to 40	3.70 No tension	3.00 No tension	1.1 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
Clay Capping system	Rotational stability of waste, clay cap and 1m of restoration for 1v:6h 150m long slope with managed leachate	Appendix SRA3 Plots 9a and 9b	2.954	2.260	1.4	Factor of safety greater than target.
	Rotational stability of waste, clay cap and 1m of restoration for 1v:4h 12m high slope with managed leachate	Appendix SRA3 Plots 9c and 9d	2.312	1.905	1.4	Factor of safety greater than target.
	Rotational stability of waste, clay cap and 1m of restoration for 1v:6h 150m long slope with unmanaged leachate	Appendix SRA3 Plots 10a	N/A	2.260	1.4	Factor of safety greater than target.
	Rotational stability of waste, clay cap and 1m of restoration for 1v:4h 12m high slope with unmanaged leachate	Appendix SRA3 Plots 10b	N/A	1.905	1.4	Factor of safety greater than target.
	Rotational stability of waste, clay cap and 1.5m of restoration for 1v:6h 150m long slope with managed leachate	Appendix SRA3 Plots 11a and 11b	2.954	2.368	1.4	Factor of safety greater than target.
	Rotational stability of waste, clay cap and 1.5m of restoration for 1v:4h 12m high slope with managed leachate	Appendix SRA3 Plots 11c and 11d	2.323	1.907	1.4	Factor of safety greater than target.
	Rotational stability of waste, clay cap and 1.5m of restoration for 1v:6h 150m long slope with unmanaged leachate	Appendix SRA3 Plots 12a	N/A	2.368	1.4	Factor of safety greater than target.
	Rotational stability of waste, clay cap and 1.5m of restoration for 1v:4h 12m high slope with unmanaged leachate	Appendix SRA3 Plots 12b	N/A	1.907	1.4	Factors of safety greater than target.
	Translational and interface stability of clay cap with 1m of restoration for 1v:6h 150m long slope and peak interface values	Appendix SRA4 Spreadsheets 41 to 44	3.58 No tension	2.56 No tension	1.4 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of clay cap with 1m of restoration for 1v:6h 150m long slope and residual interface values	Appendix SRA4 Spreadsheets 45 to 48	6.07 No tension	5.05 No tension	1.1 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of clay cap with 1.5m of restoration for 1v:6h 150m long slope and peak interface values	Appendix SRA4 Spreadsheets 49 to 52	3.76 No tension	2.72 No tension	1.4 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of clay cap with 1.5m of restoration for 1v:6h 150m long slope and residual interface values	Appendix SRA4 Spreadsheets 53 to 56	5.24 No tension	4.25 No tension	1.1 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of clay cap with 1.5m of restoration for 1v:4h 12m high slope and peak interface values	Appendix SRA4 Spreadsheets 57 to 60	2.49 No tension	1.79 No tension	1.4 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of clay cap with 1.5m of restoration for 1v:4h 12m high slope and residual interface values	Appendix SRA4 Spreadsheets 61 to 64	4.23 No tension	3.52 No tension	1.1 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of clay cap with 1m of restoration for 1v:4h 12m high slope and peak interface values	Appendix SRA4 Spreadsheets 65 to 68	2.64 No tension	1.92 No tension	1.4 No tension	Factors of safety greater than target. Forces transferred to underlying layers.
	Translational and interface stability of clay cap with 1m of restoration for 1v:4h 12m high slope and residual interface values	Appendix SRA4 Spreadsheets 69 to 72	3.70 No tension	3.00 No tension	1.1 No tension	Factors of safety greater than target. Forces transferred to underlying layers.

FIGURES



Key / Notes

Approximate proposed boundary for the variation to Environmental Permit number EPR/TP3430GW

Rev	Status	Drn	App	Chk	Date
	Final	SRW	HL	DFR	30/04/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean
SOUTH LTD

Title
The site location

Figure SRA1

Scale
1:50,000@A4

Drawing Ref
AU/KCW/12-20/22126

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Key / Notes

	Water area
	Woodland area
	Overgrown area
	Approximate phase boundary
	Proposed western extension to the ENRMF hazardous waste landfill Environmental Permit
	Approximate phase boundary in the Western Fields Extension
	Approximate location of a gas well
	Approximate location of a leachate well
	Approximate location of a borehole
	Approximate location of a dust monitoring point
	Approximate location of a survey peg
	Approximate location of a groundwater monitoring borehole
	Approximate location of a survey station
	Feature shown on LSS model reference "FULL SITE SURVEY UPDATE 24.05.2005.lss

This drawing may not include all of the features listed in the above key

Notes:
Drawing based on LSS model reference 'AU-US-15845.LSS' and 'FULL SITE SURVEY UPDATE 24.05.2005.lss' provided by Egniol in 2005

The survey data is based on the ENRMF site control 'KINGSCONTROL' created using the co-ordinates of 6 survey points supplied by Augean PLC. The co-ordinate system was established and transformed via a OneStep transformation using a Leica GPS system in February 2007.

Rev	Status	Drn	App	Chk	Date
	Final	SRW	HL	DFR	30/04/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
The current topography at the site based on the topographical survey undertaken in January 2021 and the proposed phase boundaries

Figure SRA2 | Scale 1:2,500@A1

Drawing Ref
AU/KCW/12-20/22127

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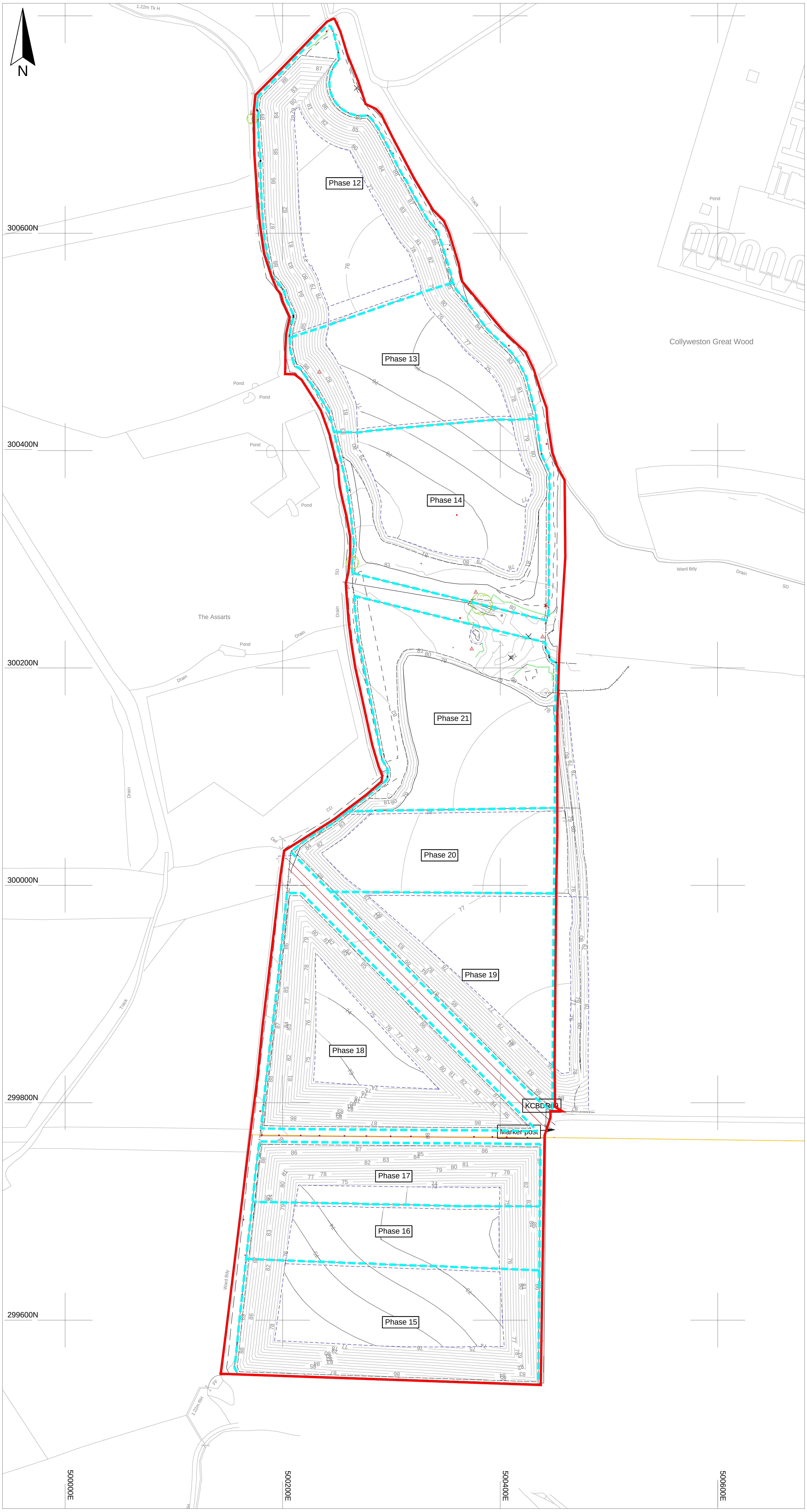

Key / Notes

- Building
- Bottom of Bank
- Bottom of Ditch
- Edge of Road
- Change of Surface
- Fence
- Gate
- Hedge
- Pipe
- Plant/structure
- Kerbline
- Top of Bank
- Top of Ditch
- Track
- Verge
- Wall
- Edge of Water
- Overhead power line
- Contours (mAOD)
- Proposed western extension to the ENRMF hazardous waste landfill Environmental Permit
- Approximate phase boundary in the Western Extension
- Approximate location of a survey station
- Feature shown on LSS model reference "FULL SITE SURVEY UPDATE 24.05.2005.lss

This drawing may not include all of the features listed in the above key

Notes:
Drawing based on LSS model reference AU-KCW-15870.LSS

Rev	Status	Drn	App	Chk	Date
	Final	KR	HL	DFR	30/04/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
Formation model for the Western Extension to East Northants Resource Management Facility

Figure SRA3

Scale
1:2,500@A1

Drawing Ref
AU/KCW/12-20/22128

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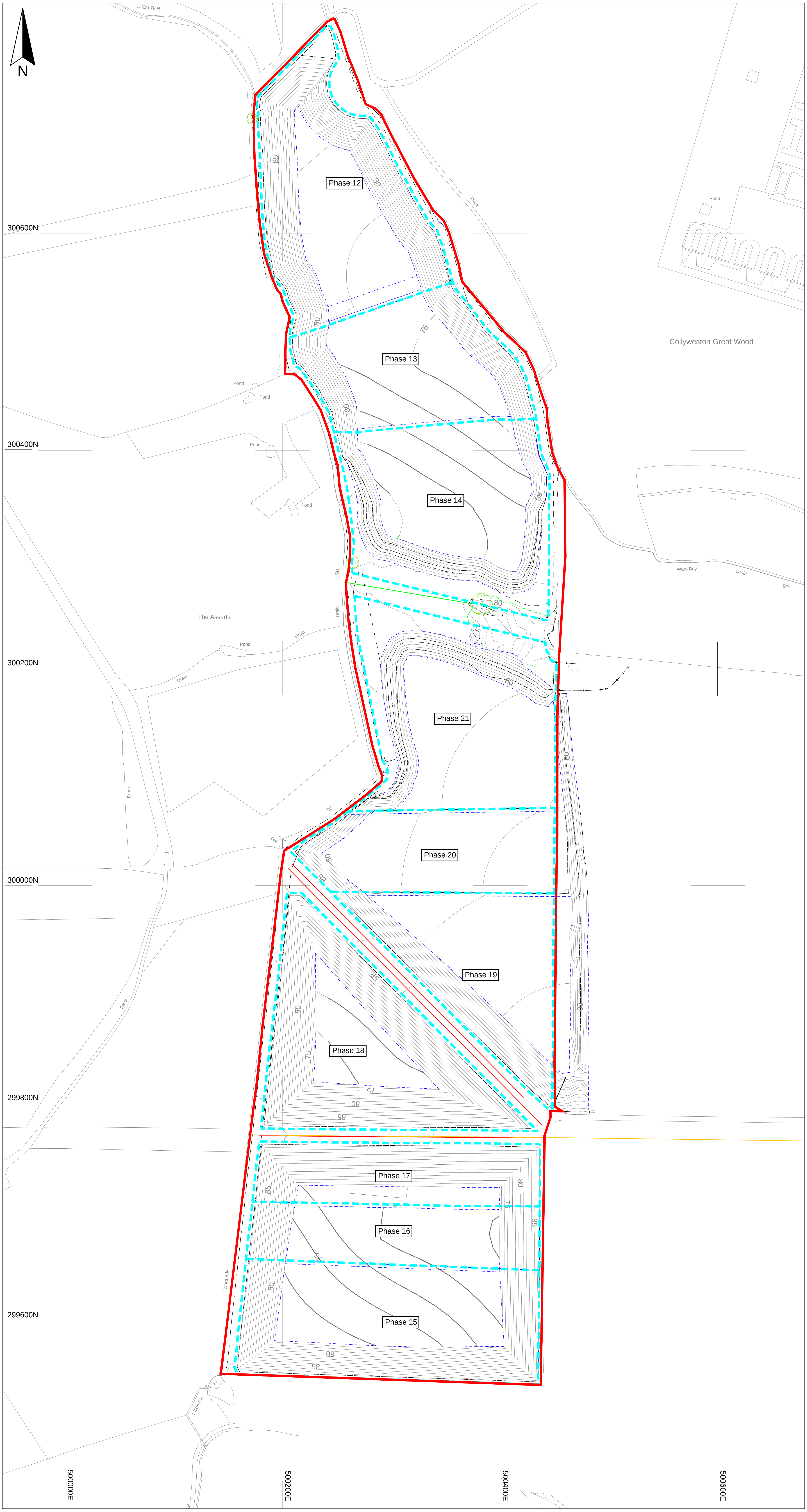

Key / Notes

- Building
- Bottom of Bank
- Bottom of Ditch
- Edge of Road
- Change of Surface
- Fence
- Gate
- Hedge
- Pipe
- Plant/structure
- Kerbline
- Top of Bank
- Top of Ditch
- Track
- Verge
- Wall
- Edge of Water
- Overhead power line
- Contours (mAOD)
- Proposed western extension to the ENRMF hazardous waste landfill Environmental Permit
- Approximate phase boundary in the Western Extension
- Approximate location of a survey station
- Feature shown on LSS model reference "FULL SITE SURVEY UPDATE 24.05.2005.lss

This drawing may not include all of the features listed in the above key

Notes:
Drawing based on LSS model reference AU-KCW-15871.LSS

Rev	Status	Drn	App	Chk	Date
	Final	KR	HL	DFR	30/04/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
Formation model including the constructed bunds for Phases 14 and 21 for the Western Extension to East Northants Resource Management Facility

Figure SRA4
Scale 1:2,500@A1

Drawing Ref
AU/KCW/12-20/22172

MJCA Technical advisers on environmental issues

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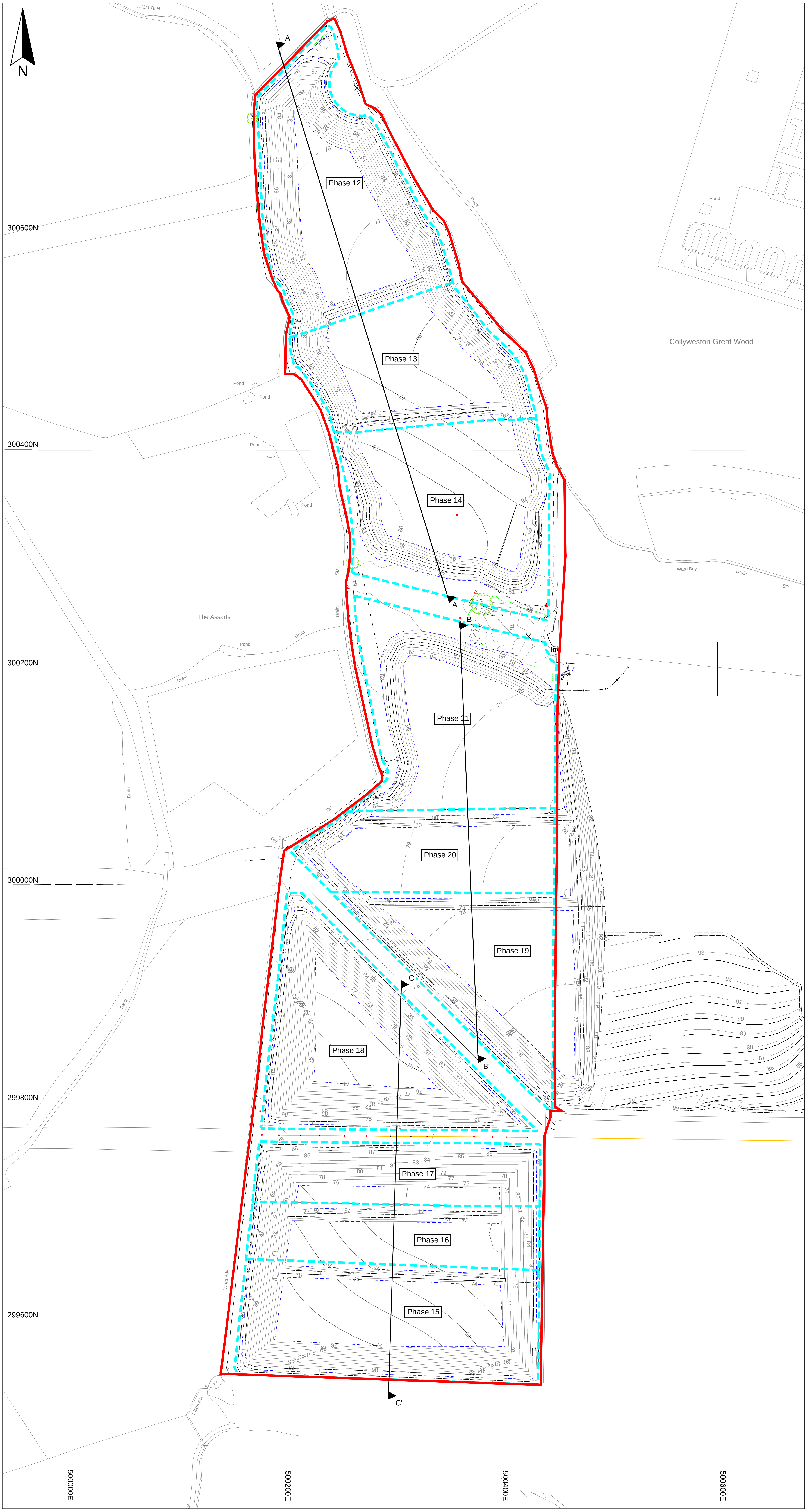

Key / Notes

- Building
- Bottom of Bank
- Bottom of Ditch
- Edge of Road
- Change of Surface
- Fence
- Gate
- Hedge
- Pipe
- Plant/structure
- Kerbline
- Top of Bank
- Top of Ditch
- Track
- Verge
- Wall
- Edge of Water
- Overhead power line
- Contours (mAOD)
- Proposed western extension to the ENRMF hazardous waste landfill Environmental Permit
- Approximate phase boundary in the Western Extension
- Approximate location of a survey station
- Feature shown on LSS model reference "FULL SITE SURVEY UPDATE 24.05.2005.lss
- Cross sections locations (shown on drawing reference AU/KCW/12-20/22130)

This drawing may not include all of the features listed in the above key

Notes:
Drawing based on LSS model reference AU-KCW-15872.LSS

Rev	Status	Drn	App	Chk	Date
	Final	KR	HL	DFR	30/04/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
Top of clay liner for the Western Extension to East Northants Resource Management Facility

Figure SRA5

Scale 1:2,500@A1

Drawing Ref
AU/KCW/12-20/22129

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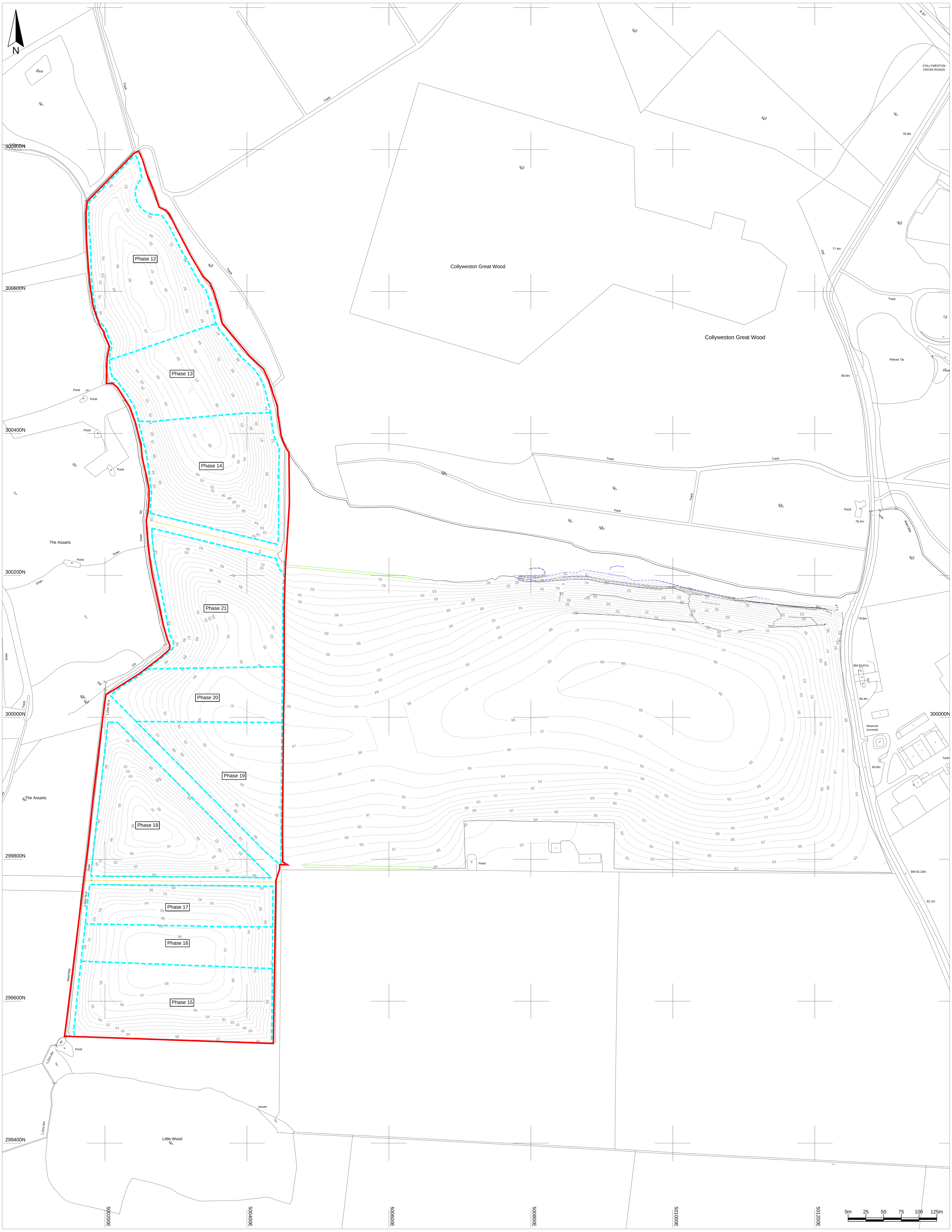

Key / Notes

(red outline)	Proposed western extension to the ENRMF hazardous waste landfill Environmental Permit
(cyan dashed)	Approximate phase boundary in the Western Extension
90	Contours (mAOD)
	Bottom of bank
	Top of bank
	Change of surface
	Fenceline
	Hedge
	Pipeline

Note:
Based on LSS model Reference 'JULY20_ENRMF_WATER PIPE RETAINED_SCENARIO 1B_V2.lss' provided by DB Landscape Consultancy on 10 July 2020

Rev	Status	Drn	App	Chk	Date
	Final	KR	HL	DFR	30/04/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
The restoration contours for the site

Figure SRA6 | Scale 1:2,500@A1

Drawing Ref
AU/KCW/12-20/22130

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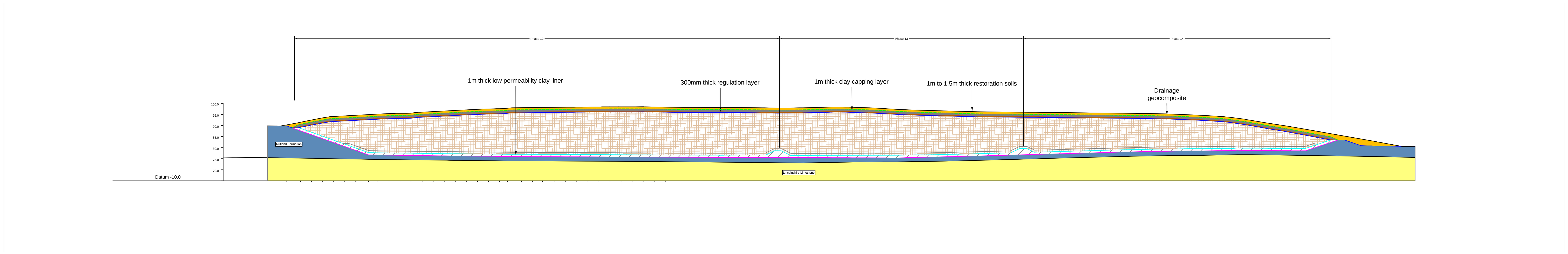

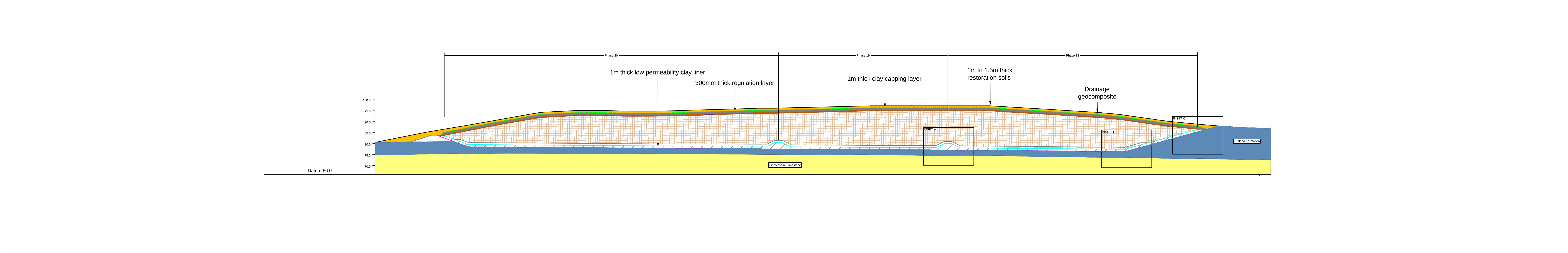

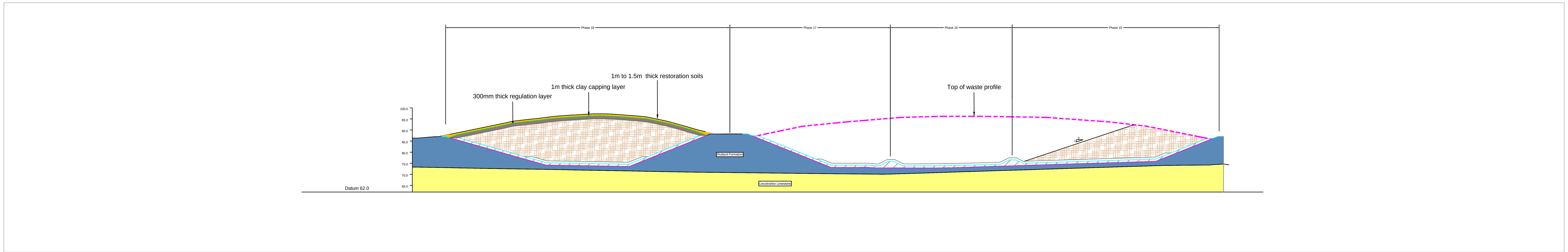

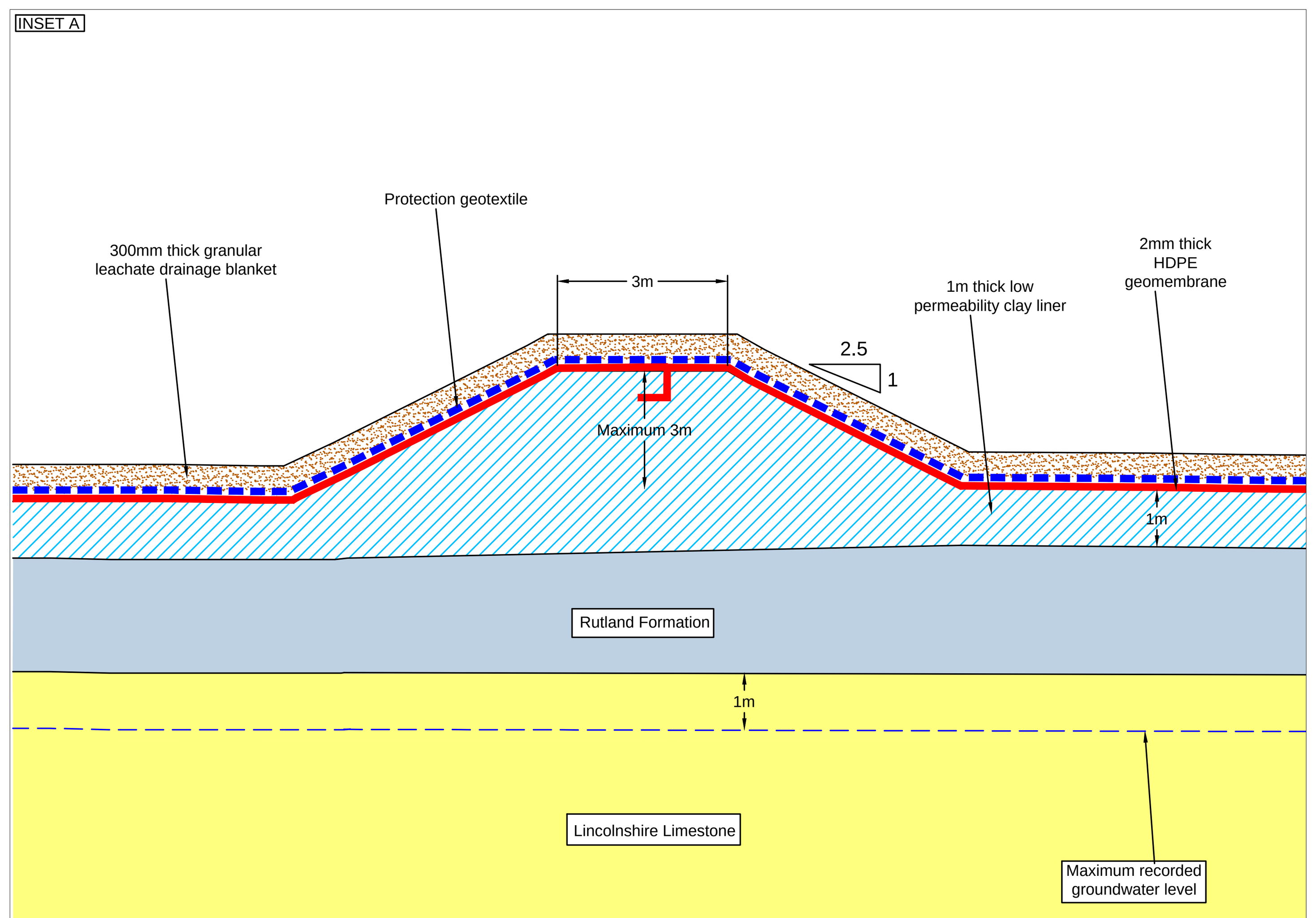

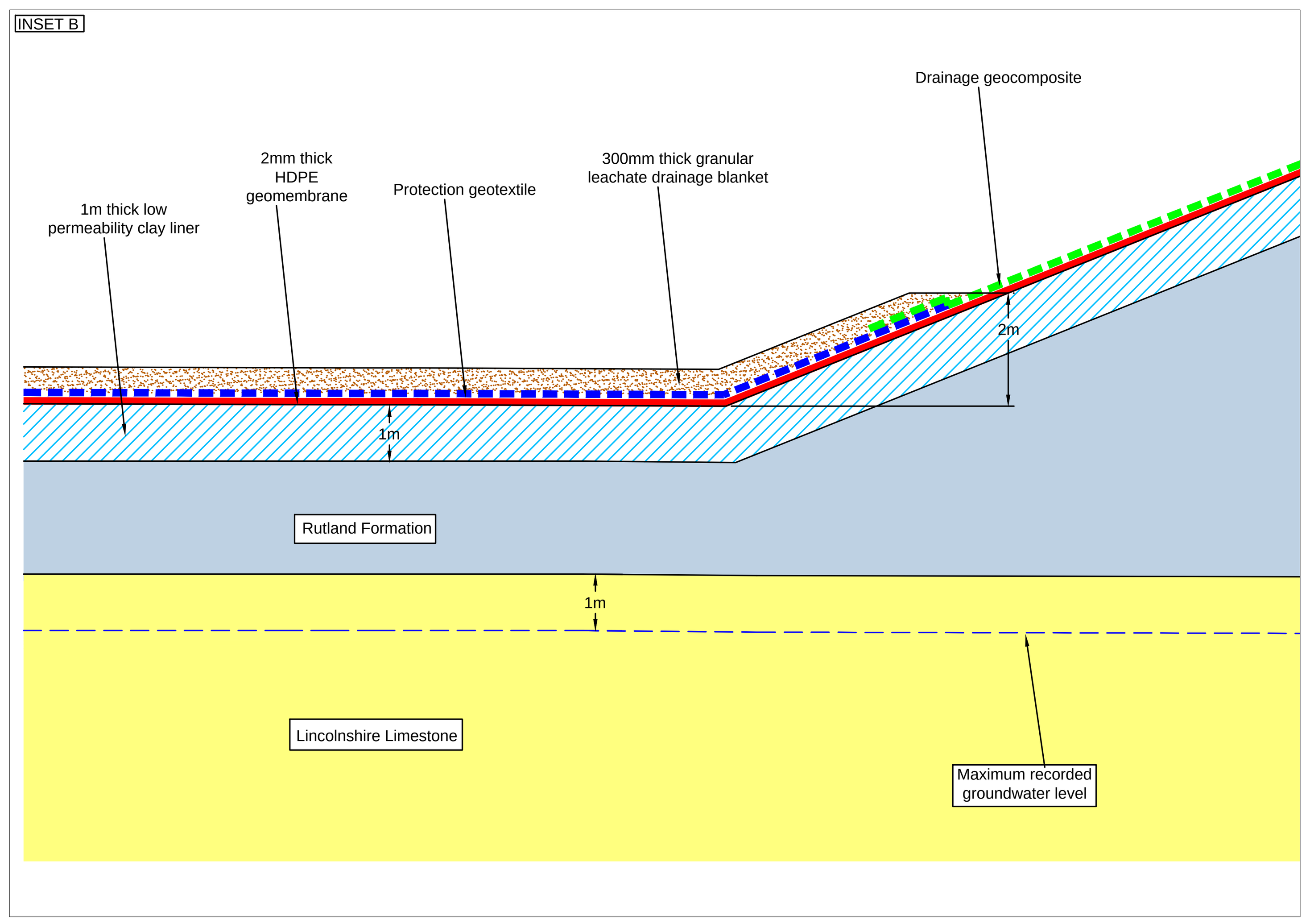

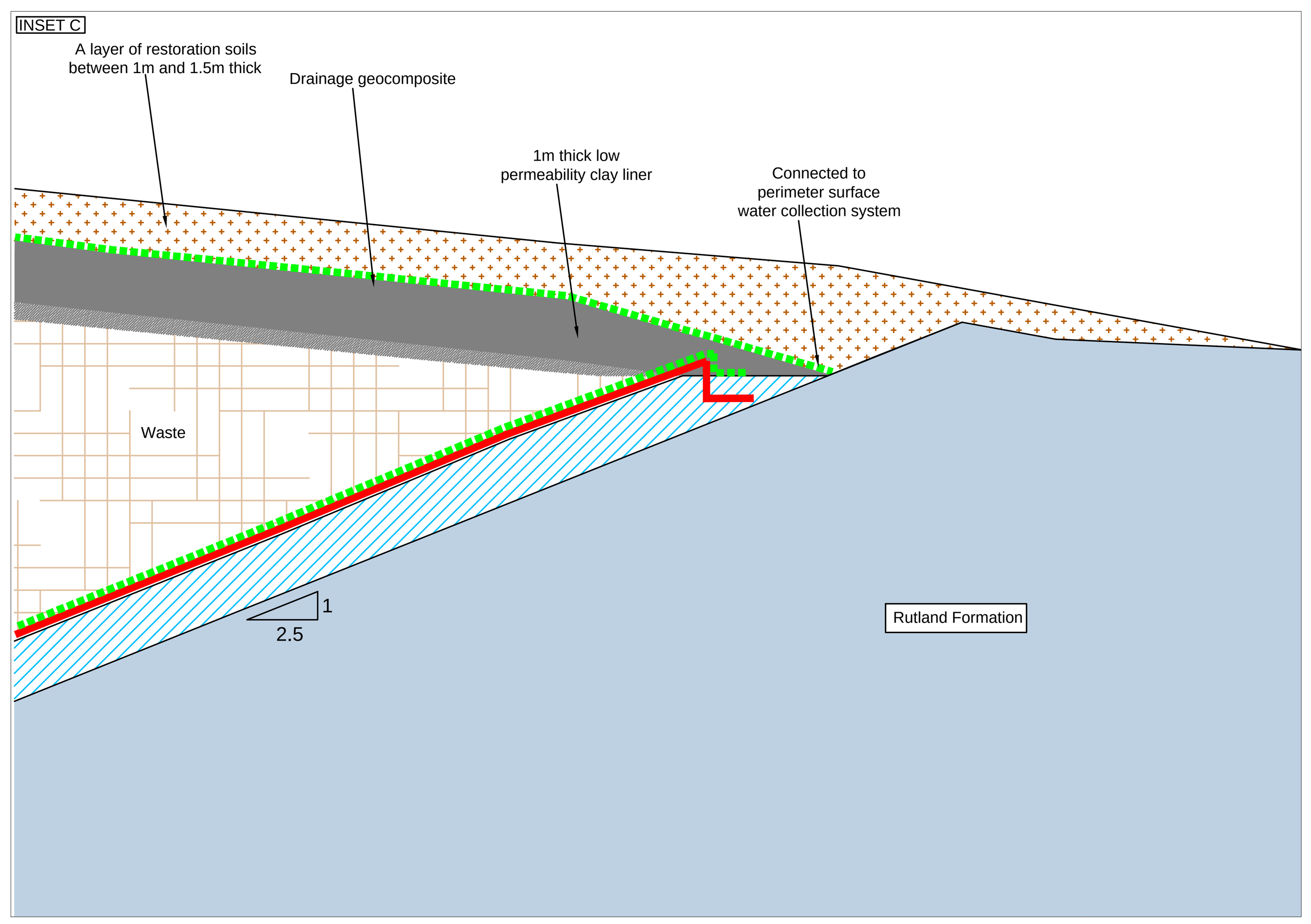

Key / Notes

- 300mm thick regulation layer
- 1m thick clay capping layer
- 1m thick restoration soils
- 1m thick low permeability clay liner
- Drainage geocomposite

Sections lines shown on Figures SRA5 drawing reference AU/KCW/12-20/22129

Rev	Status	Drn	App	Chk	Date
	Final	KR	HL	DFR	30/04/21

Site: EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client: Augean SOUTH LTD

Title: Conceptual cross sections

Figure SRA 7

Scale: 1:1,000@A1

Drawing Ref: AU/KCW/12-20/22131

MJCA
Technical advisers on environmental issues
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APPENDIX SRA1

GEOSYNTHETIC MATERIAL MANUFACTURERS' DATA SHEETS AND EXTRACTS FROM ENVIRONMENT AGENCY GUIDANCE LFE 5

Typical stone gradings

Typical test pressures (kPa)[1]	Waste depth (m)	10	20	20	20	30	30	32	40	Maximum stone size (mm
		5-10	5-20	10-20	20	10-30	20-30	16-32	20-40	Stone grading (mm)
245	10	HPS5	HPS6	HPS6	HPS7	HPS9	HPS11	HPS9	HPS35	
370	15	HPS6	HPS7	HPS7	HPS11	HPS11	HPS12	HPS11	HPS35	
490	20	HPS7	HPS9	HPS9	HPS14	HPS12	HPS14	HPS12	HPS40	
615	25	HPS8	HPS9	HPS11	HPS17	HPS14	HPS17	HPS14	HPS40	
735	30	HPS9	HPS11	HPS14	HPS17	HPS17	HPS19/22	HPS19/22	HPS40	Geotextile grade
860	35	HPS11	HPS14	HPS17	HPS17	HPS17	HPS22/25	HPS22/25	HPS40	
980	40	HPS11	HPS17	HPS17	HPS19	HPS19/22	HPS30/35	HPS30/35	x	
1105	45	HPS14	HPS17	HPS19	HPS22	HPS25/30	HPS35/40	HPS35/40	x	
1225	50	HPS17	HPS17	HPS22	HPS30	HPS35/40	HPS35/40	HPS35/40	x	

Notes:
1. Typical test pressures are based on a waste density of 1000kg/m^3 using The Environmental Agency standard calculation for accelerated testing: Depth of waste x Density x Acceleration due to gravity (9.81 x 10^{-3}m/sec^2) x Safety factor (2.5)
2. Assumes sub-rounded stone & waste density of 1t/m^3.
3. Two grades are shown where the loading conditions are more severe and the angularity of the stone is more critical. The lower grade is predicted for well-rounded stone and the higher grade for angular stone.
4. x denotes that no solution is possible with a single layer of geotextile within the limiting strain of 0.25% required by The Environment Agency. Please contact GEOfabrics Limited for an alternative protection solution.
5. The data contained in this table is for guidance only. The geotextile grade should be confirmed by cylinder testing with a sample of the stone to be used & at a load that simulates the waste depth.
6. Please contact GEOfabrics to arrange a complementary UKAS accredited cylinder test to either Environment Agency Methodology for cylinder testing of protectors for geomembranes (UK) or Determination of the long-term protection efficiency of geotextiles in contact with geosynthetic barriers EN 13719.

16/6/09

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Leeds LS10 1RZ, United Kingdom
Tel: [redacted] [redacted] Fax: [redacted]

HPS (High Performance Square) non-woven needlepunched geotextiles - 08/08/12

Optimised for maximum mechanical performance - not weight. Sufficient mass of fibre will be included to achieve these performance values.
All GEOfabrics' HPS products are tested, in an independently-audited, ISO 17025, UKAS-acredited laboratory, for all mechanical-performance properties at a minimum of one set every 6000m^2

	Test		HPS2	HPS2.5	HPS3	HPS4	HPS5	HPS6	HPS7	HPS8	HPS9	HPS11	HPS12	HPS14	HPS17	HPS19	HPS22	HPS25	HPS30	HPS35	HPS40
Polymer			Prime-quality, virgin polypropylene containing 1% carbon black UV inhibitor.																		
Fibre type			A blend of high-tenacity, staple fibres with diameters selected for optimum performance.																		
Static puncture strength [CBR] (kN)	BS EN ISO 12236		2	2.5	3	4	5	6	7	8	9	11	12	14	17	19	22	25	30	35	40
Push-through displacement (mm)			75	75	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
Tensile strength (kN/m)	BS EN ISO 10319	md	10	15	20	25	30	35	40	45	50	60	65	75	90	100	115	130	160	180	210
		cmd	10	15	20	25	30	35	40	45	50	60	65	75	90	100	115	130	160	180	210
Tensile elongation %	BS EN ISO 10319	md	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
		cmd	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Cone drop (mm)	BS EN 13433		13	10	6	5	5	4	3	2	2	1	1	0	0	0	0	0	0	0	0
Thickness @ 2kPa (mm)	BS EN ISO 9863-1		3.5	3.5	3.9	4.4	4.9	5.2	5.5	5.8	6	6.7	7	7.8	8.8	9.5	10.5	14	15	16.5	17
Apparent pore size 90% finer (μm)	EN ISO 12956		150	150	130	100	80	80	80	70	70	<69	<69	<69	<69	<69	<69	<69	<69	<69	<69
Waterflow (l/s/m^2)	BS EN ISO 11058		100	100	85	75	65	55	50	45	40	35	30	25	15	10	9	8	8	5	5
Coefficient of permeability (m/s)		$x10^{-3}$	7.0	7.0	6.6	6.6	6.4	5.7	5.5	5.2	4.8	4.7	4.2	3.9	2.6	1.9	1.9	2.2	2.4	1.7	1.7
Protector Efficiency (kN/m^2)	EN ISO 13719	$x 10^3$	N/A	N/A	N/A	N/A	14	20	25	30	33	39	42	48	56	60		100	139	175	210
Resistance to weathering (UV) @ 50MJ/m^2 radiant exposure (1-4 months depending on location/season)	EN12224		Retained strength = >90%																		
Resistance to oxidation (150 years)	EN13438		Retained strength after 84 days = >90%																		
Microbiological resistance	EN12225		Retained strength = 100%																		
Resistance to liquids (pH 1.5 to 12.1)	EN14030		Retained strength = >90%																		
Needle detection			The full width of each product is electronically inspected during the production process																		
Standard roll length (m)			200	200	175	150	150	150	125	125	100	75	75	75	50	50	50	50	50	50	50
Standard roll width (m) #			6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5.9	5.9	5.9	5.9
Approximate roll weight (kg) *			298	372	378	396	460	532	513	610	570	496	537	627	525	584	690	850	973	1120	1298

Roll widths of 5.9m are supplied for container shipments. * Roll weight for handling guidance only.

Values are *Typical*, with the exception of Thickness, which is *Nominal*. *Typical* indicates the mean value derived from the samples taken for any one test as defined in the BS EN ISO standard - usually the mean of five samples. Nominal is a guide value.

0338

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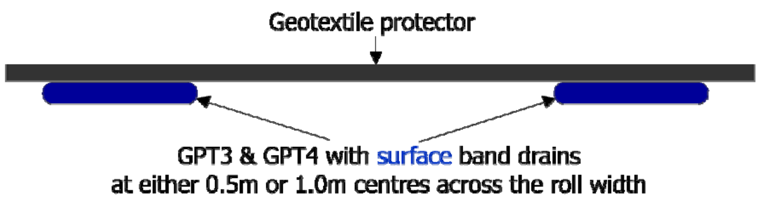
Tel: [redacted]
www.geofabrics.com e-mail: [redacted]

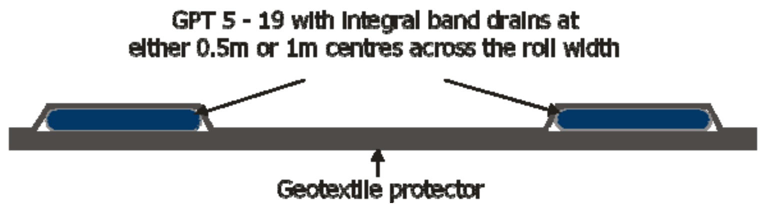
protexia™ GPT group data sheet

GEOfabrics™

10/3/11

Configuration: Non-woven, needlepunched geotextile with integral longitudinal band drains at regular centres.





	Method	Units	GPT3	GPT4	GPT5	GPT6	GPT7	GPT8	GPT9	GPT11	GPT12	GPT14	GPT17	GPT19
Drain			extruded profile											
Polymer			polypropylene											
Width		mm	100											
Geotextile			needlepunched non-woven											
Polymer			virgin polypropylene with 1% carbon black											
CBR puncture resistance	BS EN ISO 12236	kN	3	4	5	6	7	8	9	11	12	14	17	19
Tensile strength (MD & CMD)	BS EN ISO 10319	kN/m	20	25	30	35	40	45	50	60	65	75	90	100
Tensile elongation (MD & CMD)		%	80										90	
Water flow	BS EN ISO 11058	l/m²/s	50	45	40	40	35	30	30	24	16	16	10	10
Cone drop	BS EN ISO 13433	mm	6	5	5	4	3	2	2	1	1	0.1	0	0
Composite														
In-plane flow capacity (i=1)	EN ISO 12958	l/s/m width	With band drains @1.0m centres [@0.5m centres]											
@20kPa			0.2 [0.4]											
@100kPa			0.2 [0.4]											
@200kPa			0.17 [0.34]											
Thickness (excl. drain)	BS EN ISO 9863-1	mm	3.8	4.5	4.9	5.5	5.8	5.8	6.0	6.7	7	7.8	8.2	9.5
Standard roll length		m	75						50					
Standard roll width		m	5.9											
Approximate roll weight		kg	200	230	275	325	350	430	300	360	400	450	550	630

Values are Typical, with the exception of Thickness, which is Nominal. Typical indicates the mean value derived from the samples taken for any one test as defined in the BS EN ISO standard - usually the mean of five samples. Nominal is a guide value.
No warranty is given or implied for the use of this information for design and installation as these are beyond our control. Roll weights are provided for site-handling guidance only.
GEOfabrics Limited reserves the right to change specifications without notice.

igs

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Skelton Grange Rd, Stourton
Leeds LS10 1RZ
United Kingdom

[redacted]

enhancing... improving... cleaning... restoring...
changing... tackling... protecting... reducing...
create a better place... influencing... inspiring...
advising... managing... adapting...

LFE5 - Using geomembranes in landfill engineering

GEHO0409BPNH-E-E

High density polyethylene (HDPE) geomembrane – textured

Properties	Test method	Test value							Testing frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness – mils (min.ave.) ● Lowest individual for 8 out of 10 values ● Lowest individual for any of the 10 values	D 5994	nom. (-5%) - 10% - 15%	nom. (-5%) - 10% - 15%	nom. (-5%) - 10% - 15%	nom. (-5%) - 10% - 15%	nom. (-5%) - 10% - 15%	nom. (-5%) - 10% - 15%	nom. (-5%) - 10% - 15%	Per roll
Asperity Height mils (min, avg.) (1)	GM 12	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	90,000 kg
Density (min.ave.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	Every2nd roll (2)
Tensile Properties (min, avg.) (3) • Yield strength • Break strength • Yield elongation • Break elongation	D 6693 Type IV	 11 kN/m 8 kN/m 12% 100%	 15 kN/m 10 kN/m 12% 100%	 18 kN/m 13 kN/m 12% 100%	 22 kN/m 16 kN/m 12% 100%	 29 kN/m 21 kN/m 12% 100%	 37kN/m 26 kN/m 12% 100%	 44 kN/m 32 kN/m 12% 100%	9,000 kg
Tear Resistance (min.ave.)	D 1004	93 N	125 N	156 N	187 N	249 N	311 N	374 N	20,000 kg
Puncture Resistance (min.ave.)	D 4833	200 N	267 N	333 N	400 N	534 N	667 N	800 N	20,000 kg
Stress Crack Resistance (4)	D 5397 (App.)	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	Per GRI GM 10
Carbon Black Content (range)	D 1603 (5)	2.0 – 3.0%	2.0 – 3.0%	2.0 – 3.0%	2.0 – 3.0%	2.0 – 3.0%	2.0 – 3.0%	2.0 – 3.0%	9,000 kg
Carbon Black Dispersion	D5596	Note (6)	Note (4)	Note (4)	Note (4)	Note (4)	Note (4)	Note (4)	20, 000 kg
Oxidative Induction Time (OIT) (min, avg.) (7) (a) Standard OIT - or – (b) High Pressure OIT	 D 3895 D 5885	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	90,000 kg
Oven Aging at 85°C (7), (8) (a) Standard OIT (min, avg) - % retained after 90 days - or – (b) High Pressure OIT (min, avg) - % retained after 90 days	D 5721 D 3895 D 5885	 55 % 80 %	 55 % 80 %	 5 % 80 %	 55 % 80 %	 55 % 80 %	 55 % 80 %	 55 % 80 %	Per each formulation
UV Resistance (9) (a) Standard OIT (min, avg) - or – (b) High pressure OIT (min, avg) - % retained after 1600hrs (11)	GM11 D 3895 D 5885	 N. R. (10) 50 %	 N. R. (8) 50 %	 N. R. (8) 50 %	 N. R. (8) 50 %	 N. R. (8) 50 %	 N. R. (8) 50 %	 N. R. (8) 50 %	Per each formulation

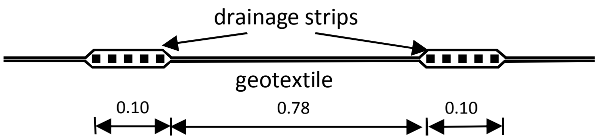
(1) Of 10 readings; 8 out of 10 must be ≥ 0.18 mm, and lowest individual reading must be ≥ 0.13mm
(2) Alternate the measurement side for double sided textured sheet
(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 33mm
Break elongation is calculated using a gage length of 50mm
(4) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets the same formulation as being used for the textured sheet materials. The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value Via MQC testing.
(5) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established)
(6) Carbon black dispersion (only near spherical agglomerates) 10 different views:
9 in categories 1 or 2 and 1 in category 3
(7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(8) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(9) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C
(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(11) UV resistance is based on percent retained value regardless of the original HP-OIT value

Pozidrain STRIP 10

creative geosynthetic engineering

Data Sheet

POZIDRAIN STRIP 10 is a geocomposite drainage and protection layer comprising cuspated HDPE drainage strips embedded at regular intervals between two layers of medium weight non-woven filter/protection geotextile. The composite provides strength, protection and a drainage capacity tailored to the application. The major application of Pozidrain Strip 10 is for sub-surface drainage and gas venting on the slopes of landfill caps.



Geocomposite Properties		**4S10**	**6S10**	**7S10**		
Thickness at 2kPa max / min	(mm)	5.8 / 2.4	7.3 / 2.4	8.8 / 2.4	±10%	EN ISO 9863-1
Mass per unit area	(g/m²)	340	350	370	approx	EN ISO 9864
Tensile strength MD / CMD	(kN/m)	19 / 19	19 / 19	19 / 19	-15%	EN ISO 10319
Elongation at peak MD / CMD	(%)	45 / 45	45 / 45	45 / 45	nominal	EN ISO 10319
CBR puncture resistance (2)	(N)	3 200	3 200	3 200	-20%	EN ISO 12236
Dynamic perforation cone drop (2)	(mm)	16	16	16	+20%	EN ISO 13433
In-plane water flow (3)	HG 1.0					Hydraulic gradient
at 20kPa confining pressure	(l/m·s)	0.10	0.18	0.24	±20%	EN ISO 12958
at 100kPa confining pressure	(l/m·s)	0.08	0.15	0.20	±20%	EN ISO 12958
at 200kPa confining pressure	(l/m·s)	0.07	0.12	0.15	±20%	EN ISO 12958
In-plane water flow (3)	HG 0.1					Hydraulic gradient
at 20kPa confining pressure	(l/m·s)	0.03	0.05	0.07	±20%	EN ISO 12958
at 100kPa confining pressure	(l/m·s)	0.02	0.04	0.05	±20%	EN ISO 12958
at 200kPa confining pressure	(l/m·s)	0.017	0.03	0.04	±20%	EN ISO 12958
with **soft foam** contact surfaces to simulate textile intrusion into the core due to soil pressure						
Resistance to weathering		To be covered in 28 days				EN 12224
Resistance to chemicals		Excellent				EN 14030
Design life		120 years (manufacturer's declaration)				
Geotextile Properties						
Pore size O_{90}	(µm)	120	120	120	±30%	EN ISO 12956
Water flow at 50mm head (4)	(l/m²·s)	103	103	103	±30%	EN ISO 11058
Breakthrough head	(mm)	0	0	0	nominal	
Type and material	Non-woven needle-punched and heat-treated staple fibre polypropylene					
Product Dimensions						
Standard roll dimensions	(m)	4.55 x 100	4.55 x 90	4.55 x 75		

Notes

1. The values given are indicative and correspond to nominal results obtained in our laboratories and testing institutes. In line with our policy of continuous improvement the right is reserved to make changes without notice at any time.
2. CBR and cone drop values are for textile only; the contribution of the core is ignored.
3. Stated in-plane flow is the wide width average. Flow is concentrated in drainage strips and results should be corrected to wide width averages.
4. Values for perpendicular water flow are given for the area of the drainage strip. Due to the increased thickness of textile and its bonding, perpendicular flow between drainage strips will be less than half of the above values.
5. The tolerance on roll length is ±1.5% and on roll width is ±1.0%; in multi-core products this may manifest itself between core elements.
6. Guidance on interface shear strength, creep and certain other parameters is available. Site specific tests are strongly recommended.
7. Final determination of the suitability of any information is the sole responsibility of the user. ABG will be pleased to discuss the use of this or any other product but responsibility for selection of a material and its application in any specific project remains with the user.

CE

0799-CPR-30

abg ltd. [redacted]

APPENDIX SRA2

RESULTS OF THE BASAL HEAVE ASSESSMENTS

Job No:	AU/KCW/AW/5646/01		
Date:	Apr 2021	Engineer:	DFR
Sheet	1	Checked:	SK
of	1	**Project reference**	

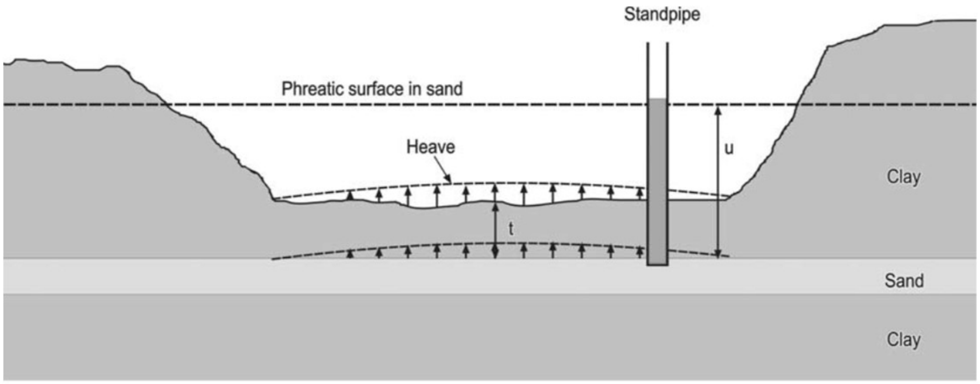
Technical advisers on environmental issues
Baddesley Colliery Offices, Main Road, Baxterley
Atherstone Warwickshire CV9 2LE
Tel: [redacted]

Western Exension Area ENRMF
Stability Risk Assessment

Basal heave - northern landfill area

Aim: To assess the stability against heave of the basal subgrade by comparing the upward pressure from confined groundwater with the vertical downward stress exerted by the overlying material.

Approach: Jones & Dixon (2003).



Factor of safety for basal heave = $\dfrac{\gamma_{soil} \times t}{\gamma_{water} \times u}$

(where $\gamma_{soil} \cong 20\ kN/m^3$ and $\gamma_{water} \cong 10\ kN/m^3$)

Notes on figure:

1 Figure source is Figure 9.6 "Ground conditions that can lead to basal heave" from Environment Agency Technical Report "Stability of Landfill Lining Systems: Report No. 1 Literature Review, R&D Technical Report P1-385/TR1, D R V Jones and N Dixon, 2003.

2 For ENRMF the sand represents the Lincolnshire Limestone and clay represents the overlying glacial clays and Rutland Formation material.

Input parameters:

In situ glacial clays and Rutland Formation material unit weight (bulk)	γ_{soil}	20	kN/m^3
Groundwater unit weight	γ_{water}	10	kN/m^3
Maximum groundwater level above Lincolnshire Limestone	u	2	m
Minimum thickness of retained in situ material above limestone	t	2	m

Factor of safety for basal heave: 2.0

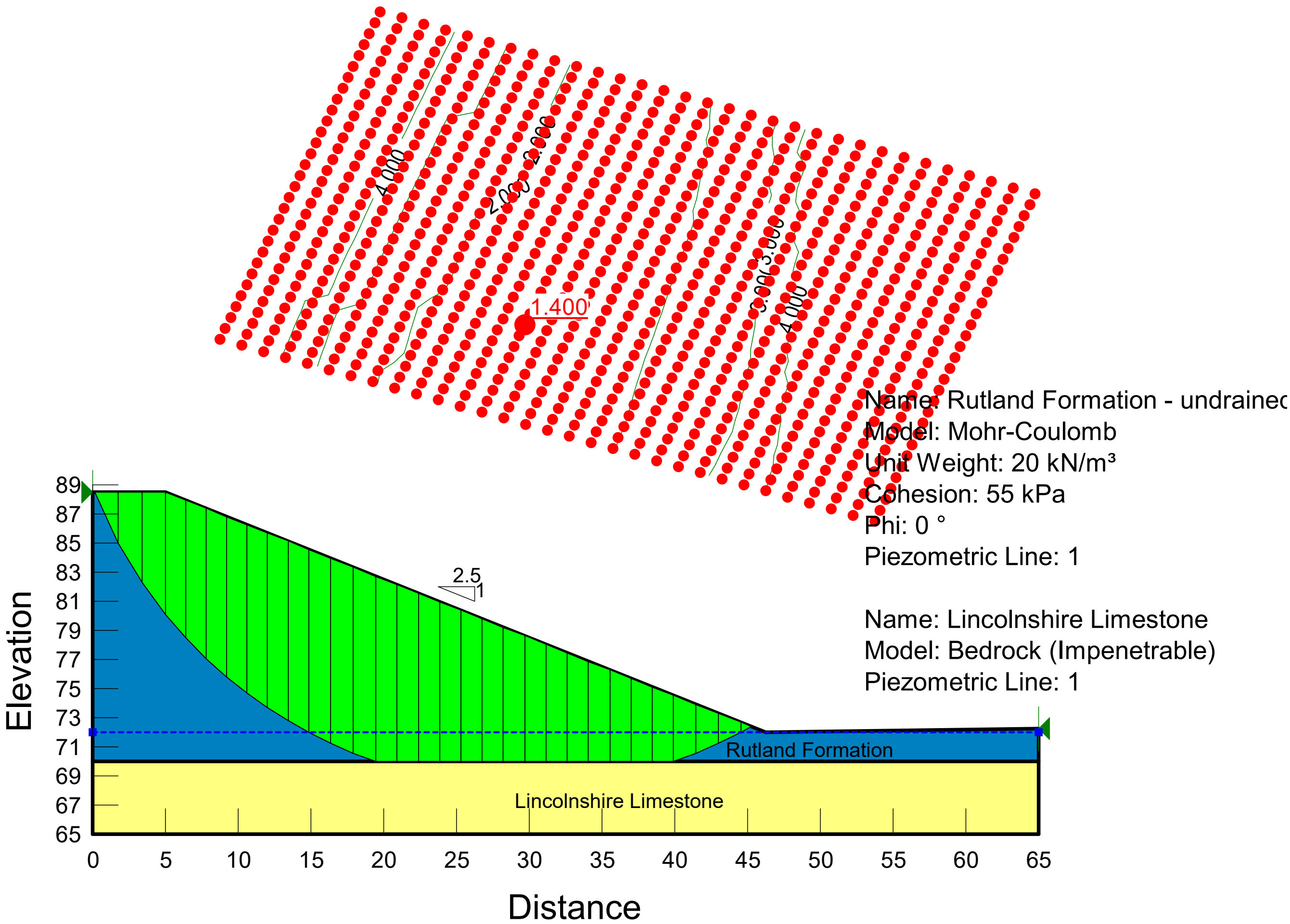
Conclusion:

The retained in situ glacial clays and Rutland Formation provide sufficient weight to prevent basal heave of the subgrade provided the minimum thickness of the retained in situ material above the limestone is equal to or greater than the maximum groundwater level above the top of the limestone.

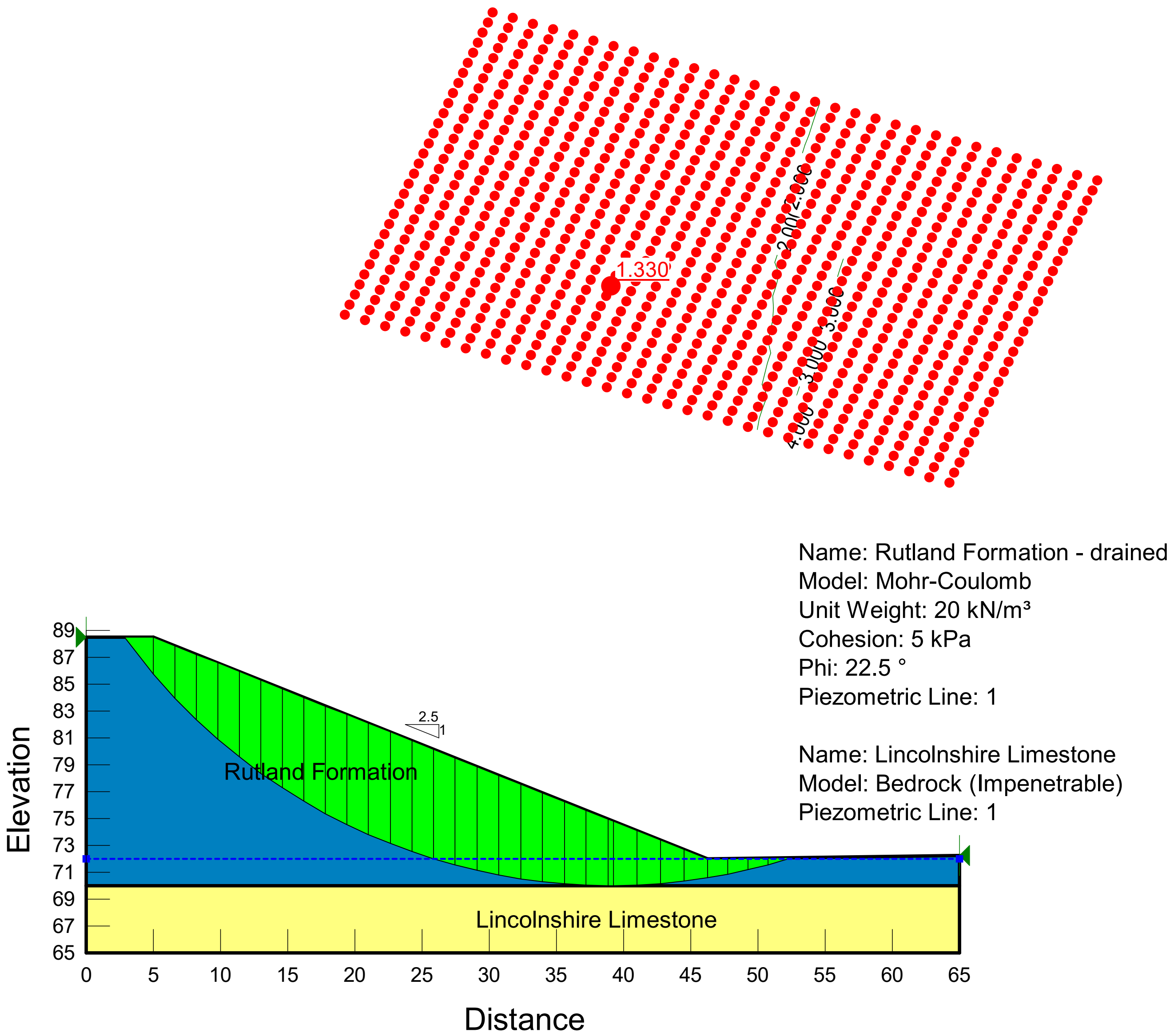
APPENDIX SRA3

RESULTS OF THE ROTATIONAL FAILURE ASSESSMENTS

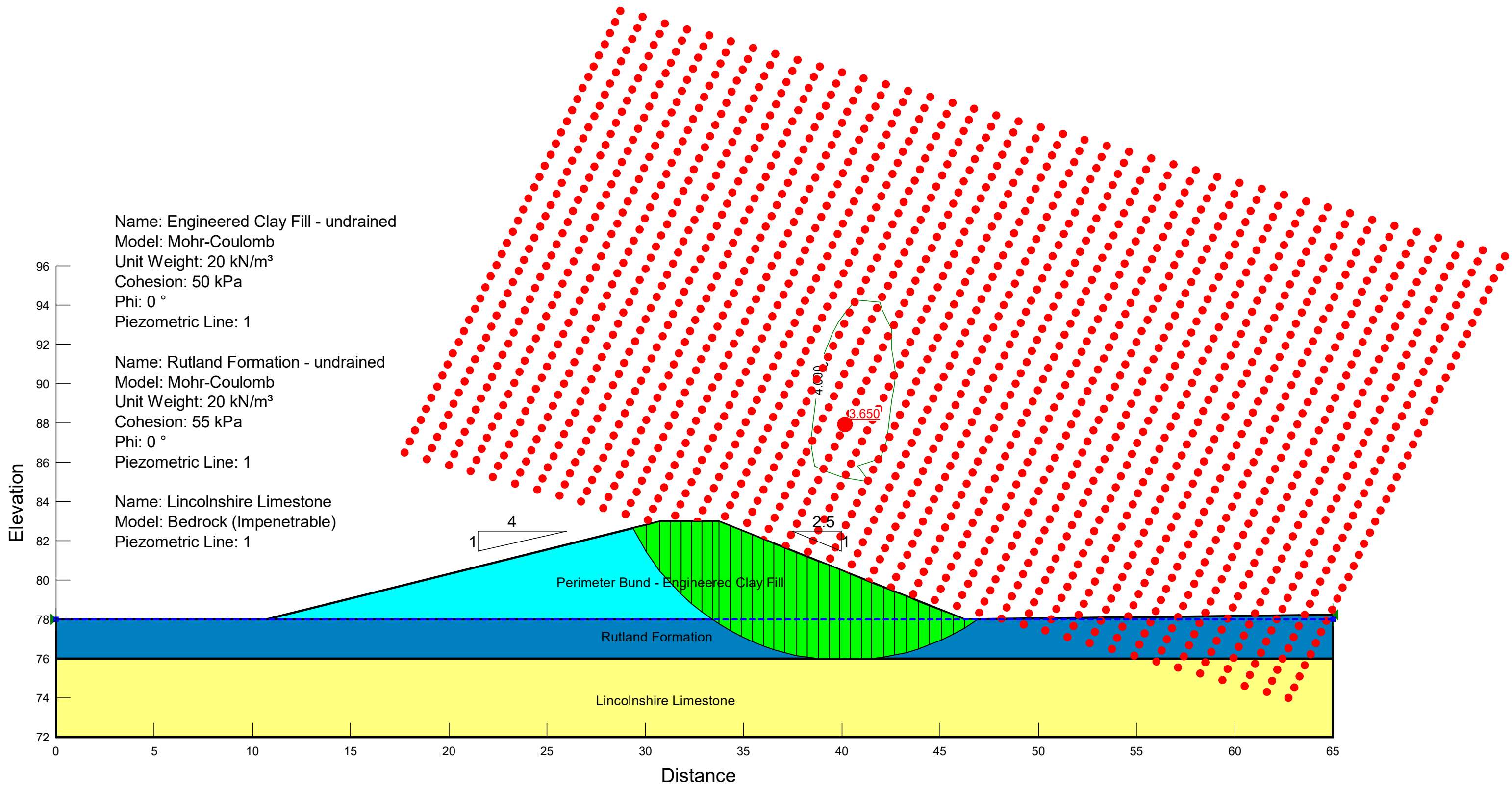
Plot 1a
ENRMF western extension area
File Name: 01a_Sideslope sub-grade - 16.5m slope - undrained FOS 1.400.gsz
Method: Spencer
FOS: 1.400



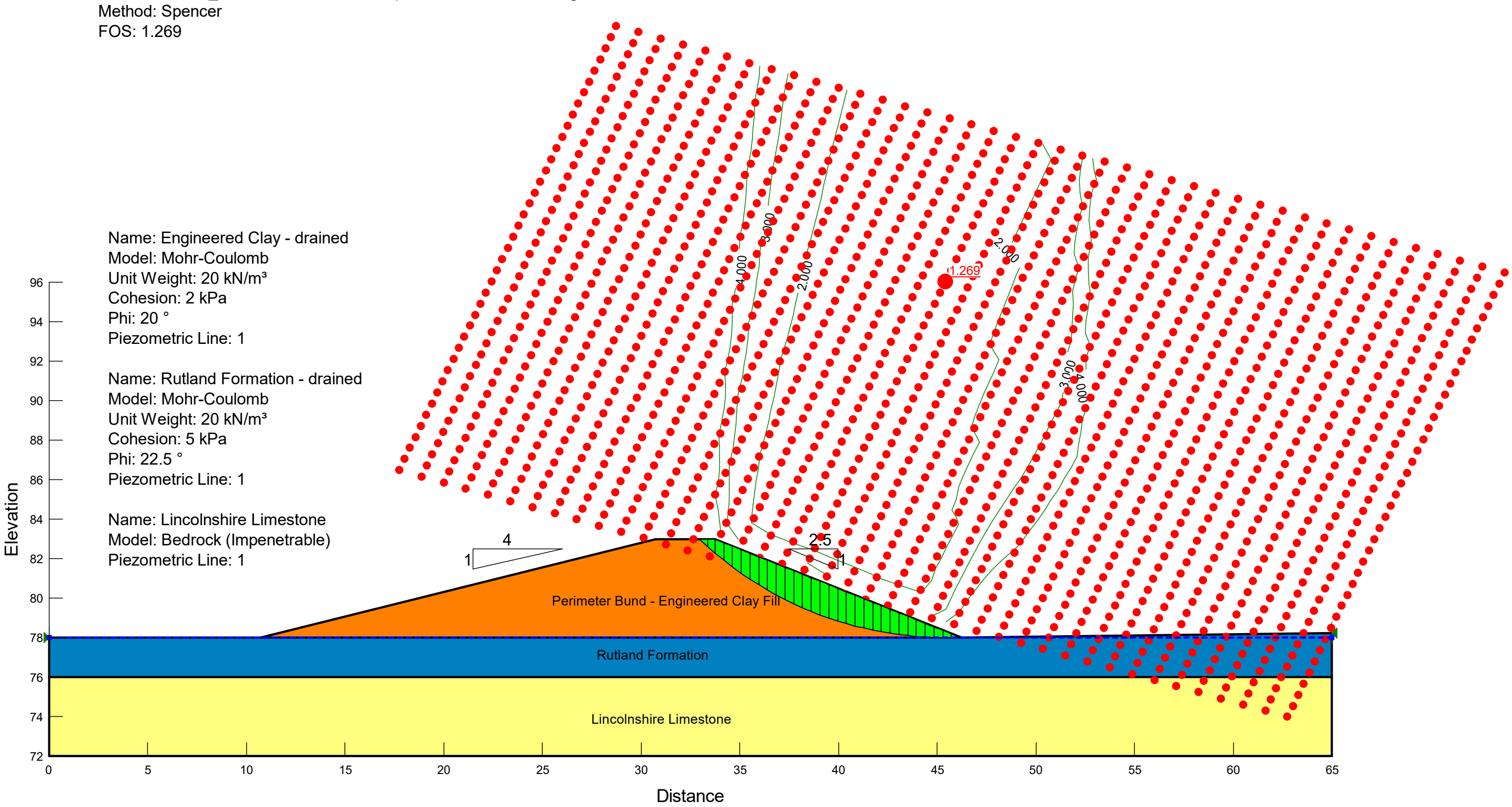
Plot 1b
ENRMF western extension area
File Name: 01b_Sideslope sub-grade - 16.5m slope - drained FOS 1.330.gsz
Method: Spencer
FOS: 1.330



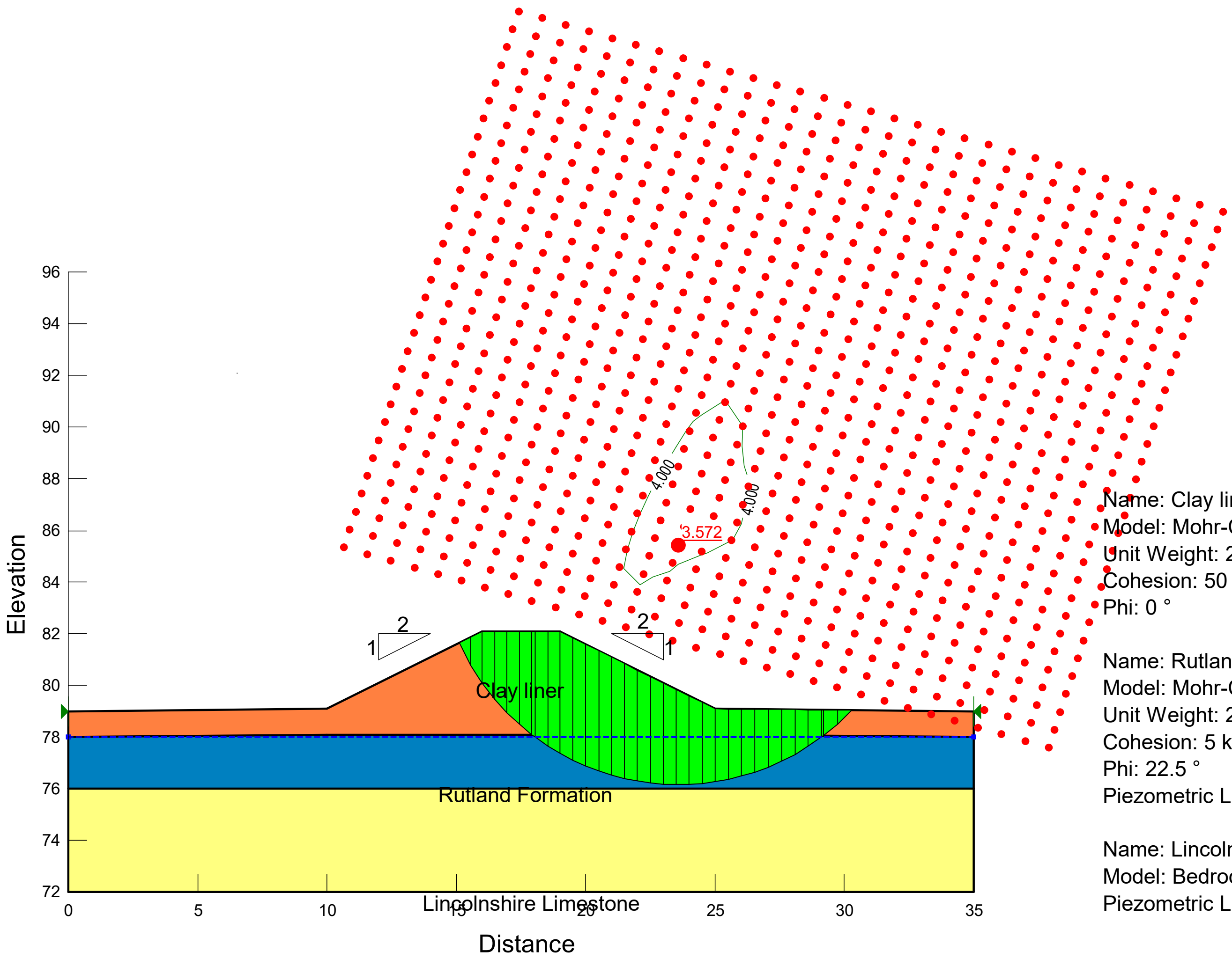
Plot 1c
ENRMF western extension area
File Name: 01c_Perimeter bund - 5m slope - undrained FOS 3.650.gsz
Method: Spencer
FOS: 3.650



Plot 1d
ENRMF western extension area
File Name: 01d_Perimeter bund - 5m slope - drained FOS 1.269.gsz
Method: Spencer
FOS: 1.269



Plot 2a
ENRMF western extension area
File Name: 02a_Basal liner - intercell bund - undrained FOS 3.572.gsz
Method: Spencer
FOS: 3.572



Name: Clay liner - undrained
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 50 kPa
Phi: 0 °

Name: Rutland Formation - drained
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °
Piezometric Line: 1

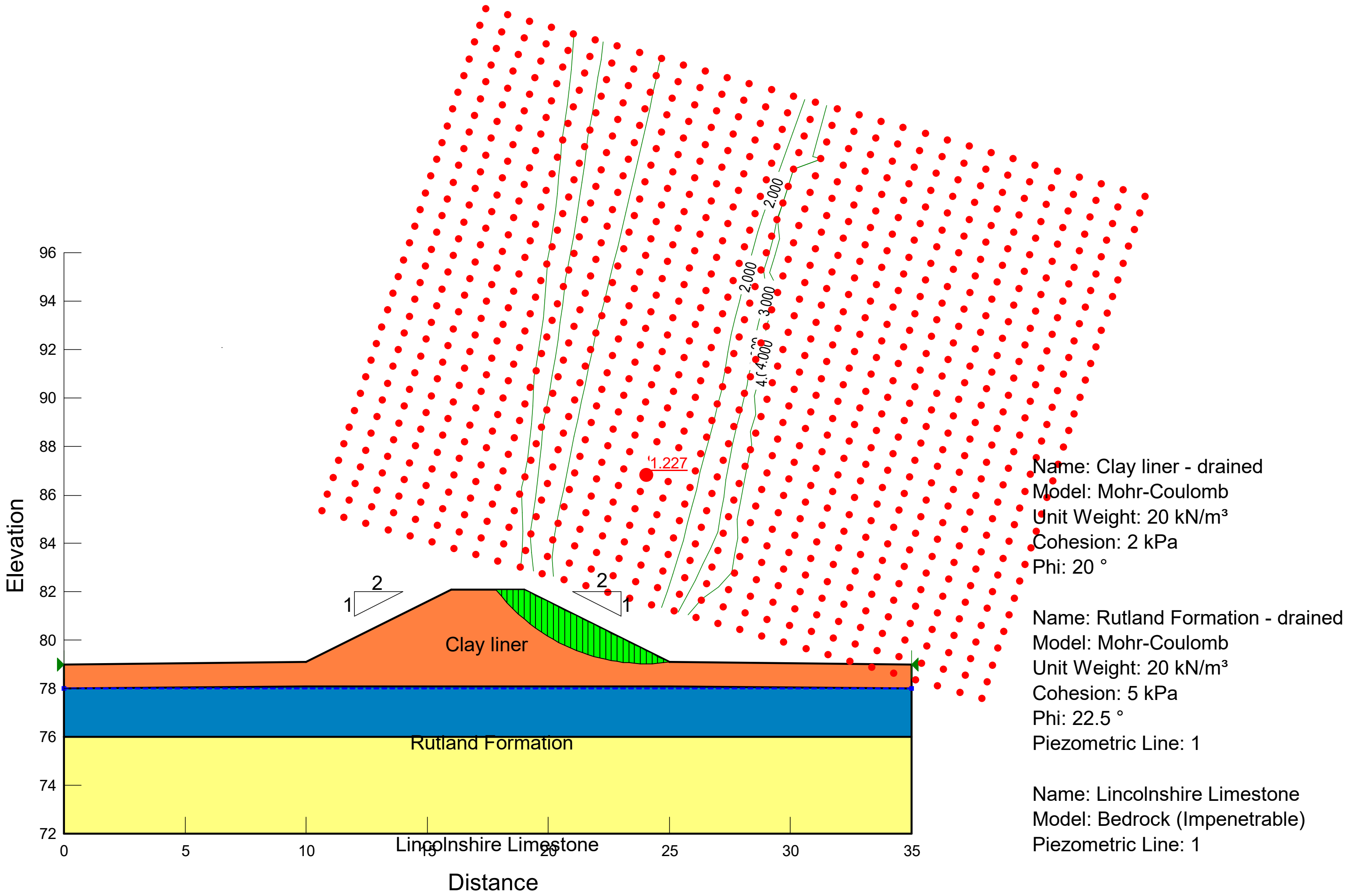
Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)
Piezometric Line: 1

Plot 2b

ENRMF western extension area

File Name: 02b_Basal liner - intercell bund - drained FOS 1.227.gsz

Method: Spencer
FOS: 1.227

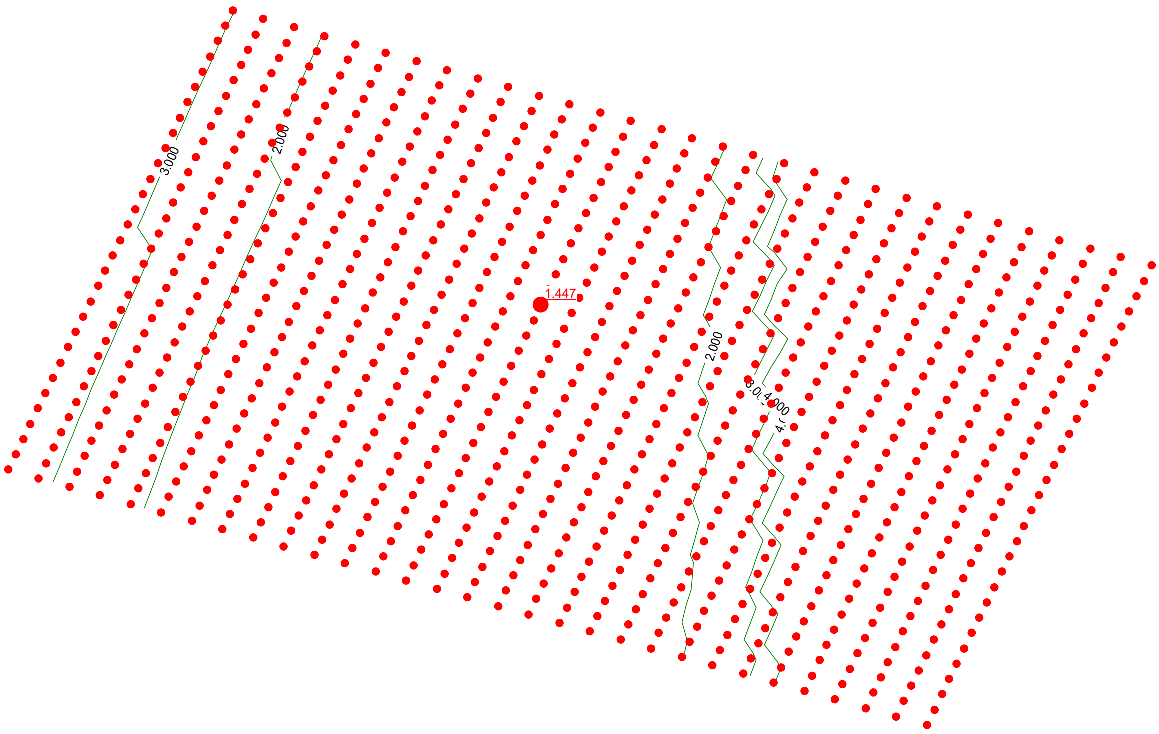


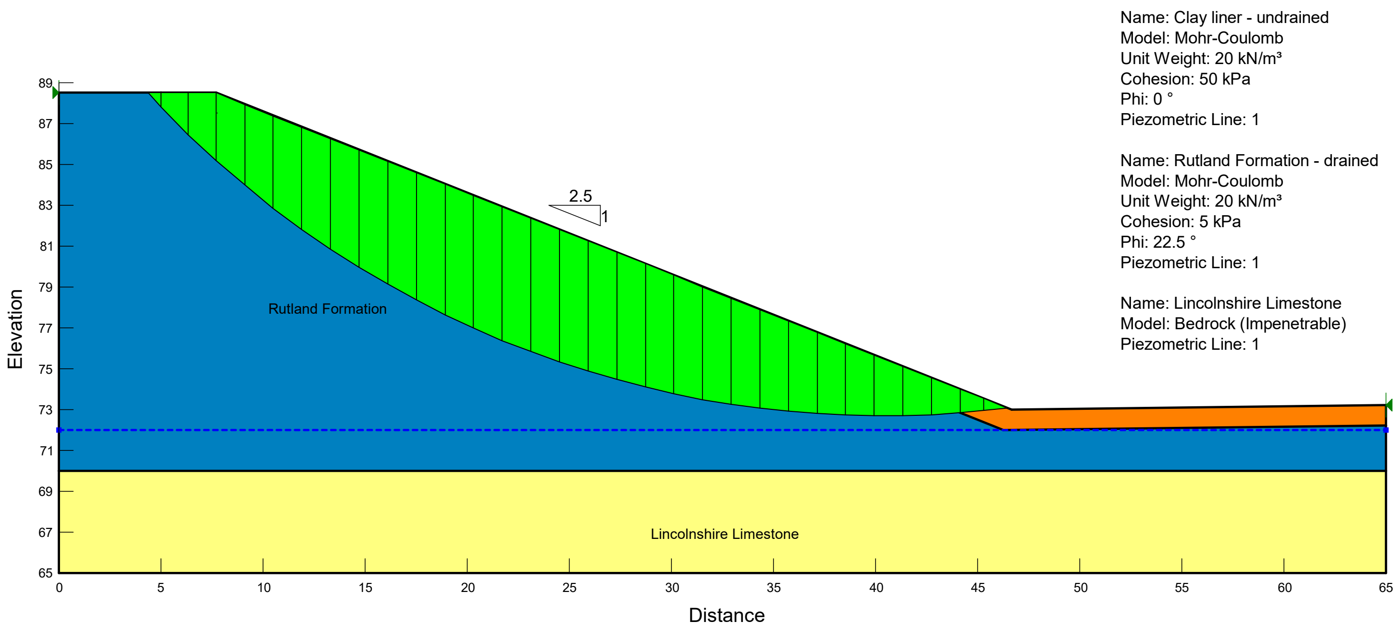
Plot 3a

ENRMF western extension area

File Name: 03a_Sideslope liner - 15.5m slope - undrained FOS 1.447.gsz

Method: Spencer
FOS: 1.447



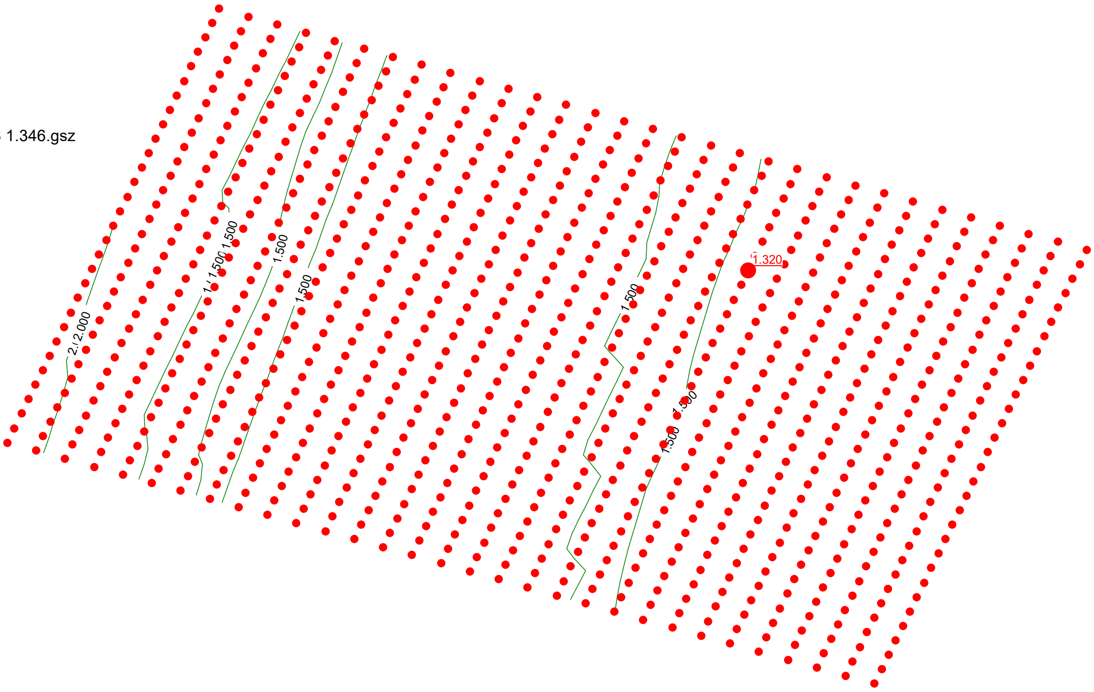


Plot 3b

ENRMF western extension area

File Name: 03b_Sideslope liner - 15.5m slope - drained FOS 1.346.gsz

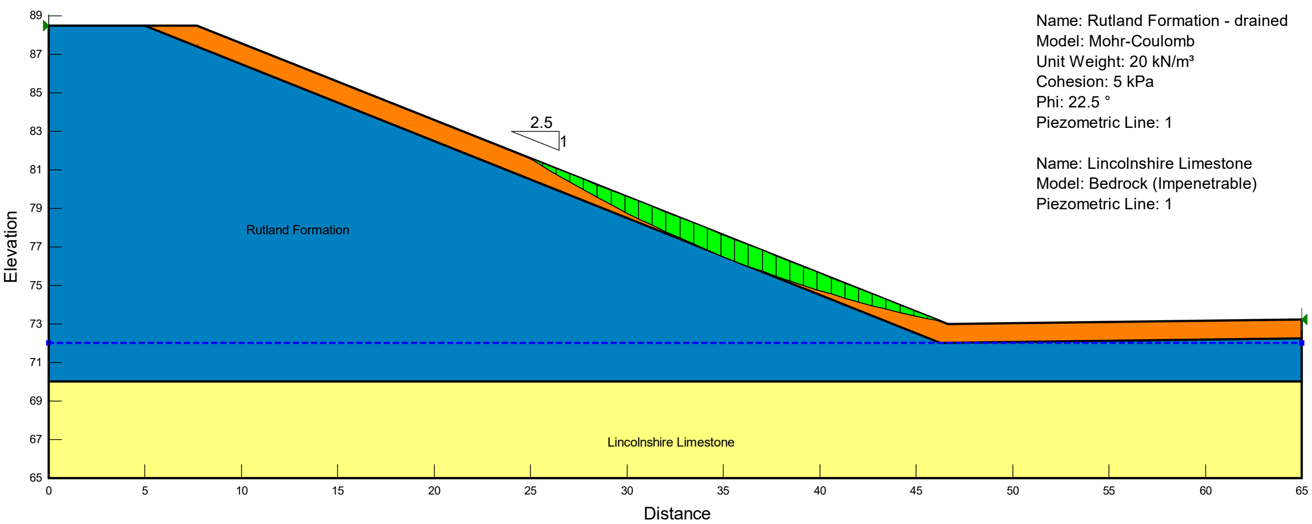
Method: Spencer
FOS: 1.320

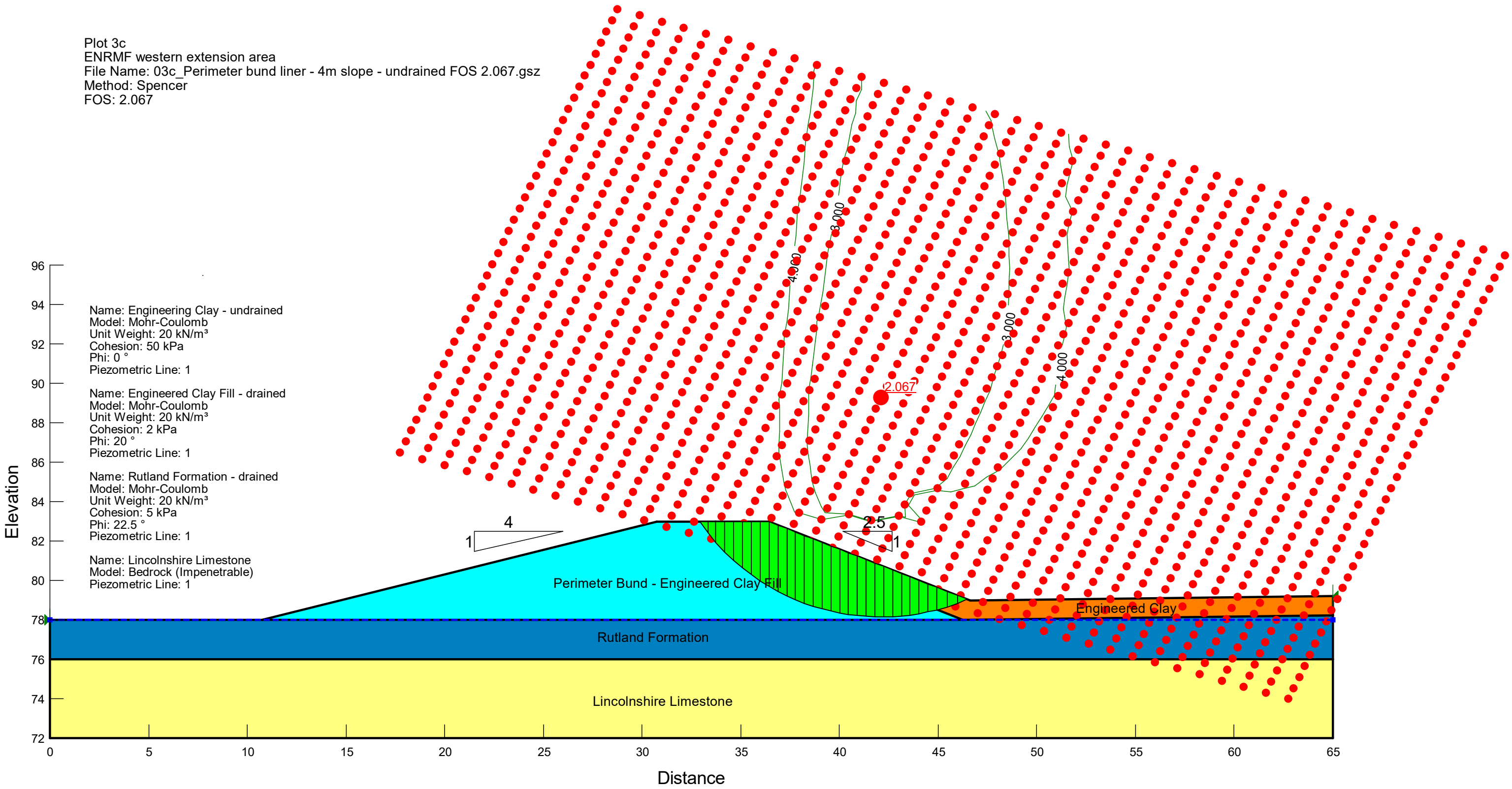


Name: Clay liner - drained
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °
Piezometric Line: 1

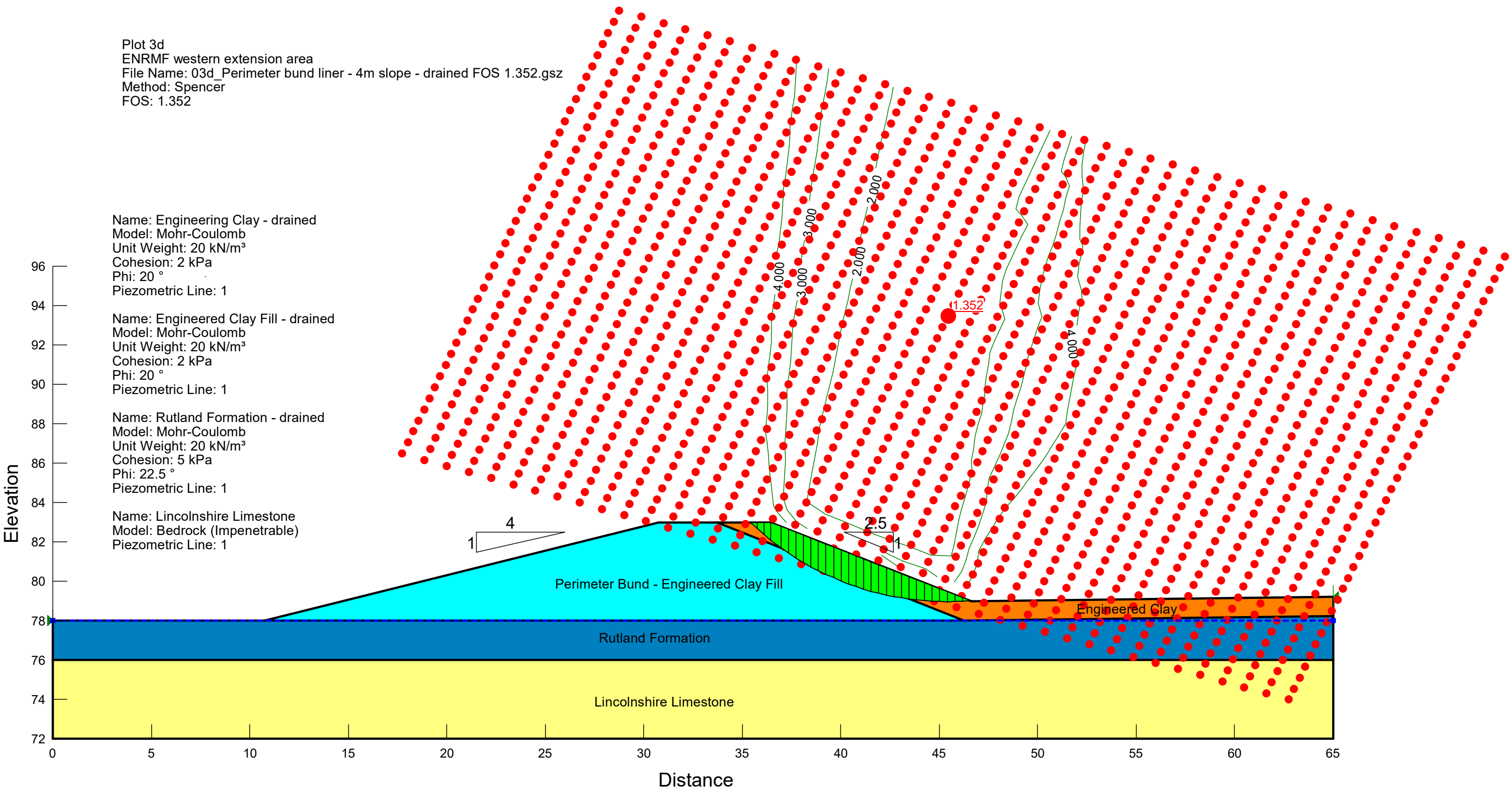
Name: Rutland Formation - drained
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °
Piezometric Line: 1

Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)
Piezometric Line: 1





Plot 3c
ENRMF western extension area
File Name: 03c_Perimeter bund liner - 4m slope - undrained FOS 2.067.gsz
Method: Spencer
FOS: 2.067
Name: Engineering Clay - undrained
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 50 kPa
Phi: 0 °
Piezometric Line: 1
Name: Engineered Clay Fill - drained
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °
Piezometric Line: 1
Name: Rutland Formation - drained
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °
Piezometric Line: 1
Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)
Piezometric Line: 1
2.067
3.000
4.000
3.000
4.000
4
1
2.5
1
Perimeter Bund - Engineered Clay Fill
Engineered Clay
Rutland Formation
Lincolnshire Limestone
Elevation
Distance
96
94
92
90
88
86
84
82
80
78
76
74
72
0
5
10
15
20
25
30
35
40
45
50
55
60
65



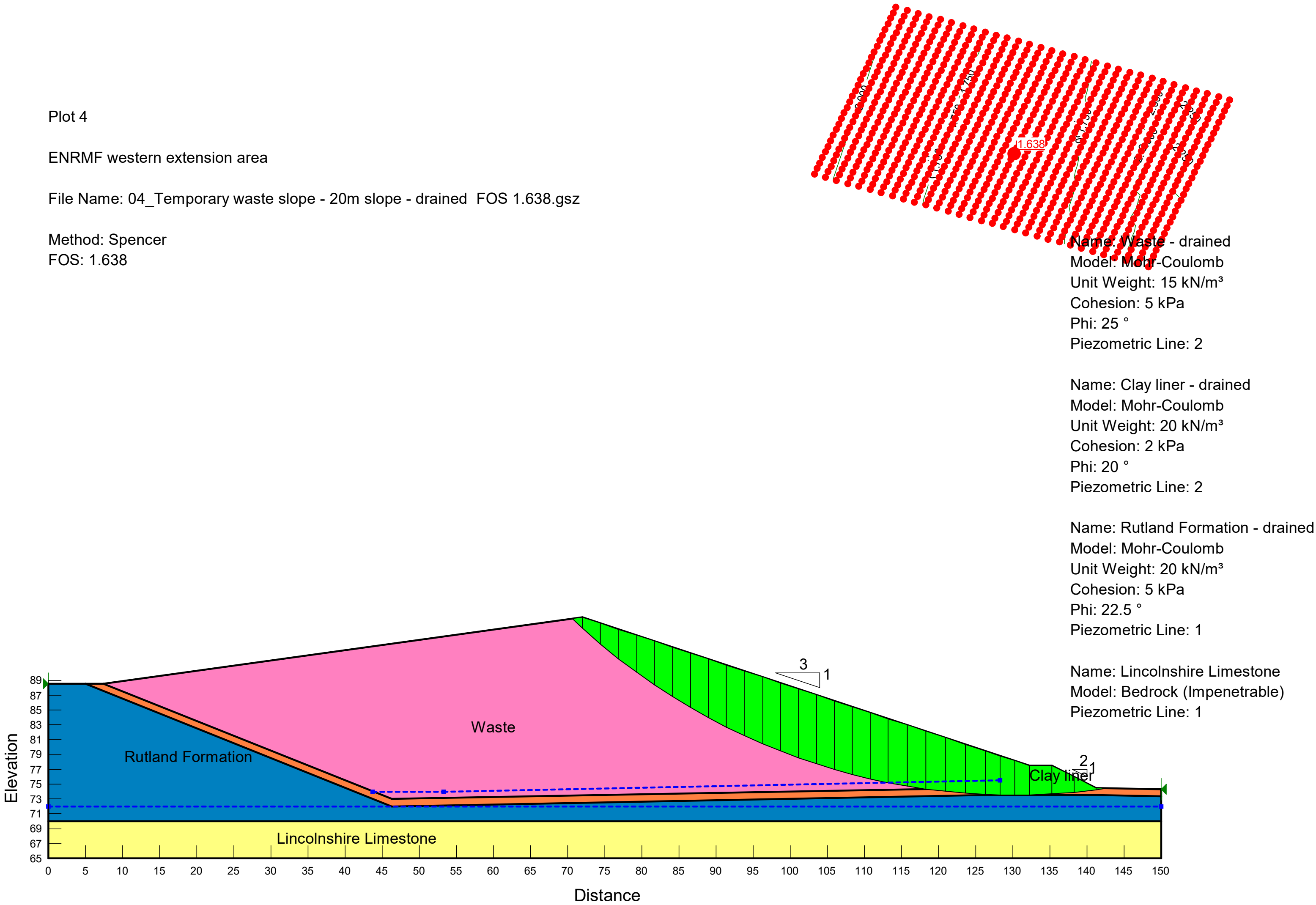
Plot 3d
ENRMF western extension area
File Name: 03d_Perimeter bund liner - 4m slope - drained FOS 1.352.gsz
Method: Spencer
FOS: 1.352
Name: Engineering Clay - drained
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °
Piezometric Line: 1
Name: Engineered Clay Fill - drained
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °
Piezometric Line: 1
Name: Rutland Formation - drained
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °
Piezometric Line: 1
Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)
Piezometric Line: 1
1.352
4.000
3.000
2.000
4
1
2.5
1
Perimeter Bund - Engineered Clay Fill
Engineered Clay
Rutland Formation
Lincolnshire Limestone
Elevation
Distance
96
94
92
90
88
86
84
82
80
78
76
74
72
0
5
10
15
20
25
30
35
40
45
50
55
60
65

Plot 4

ENRMF western extension area

File Name: 04_Temporary waste slope - 20m slope - drained FOS 1.638.gsz

Method: Spencer
FOS: 1.638

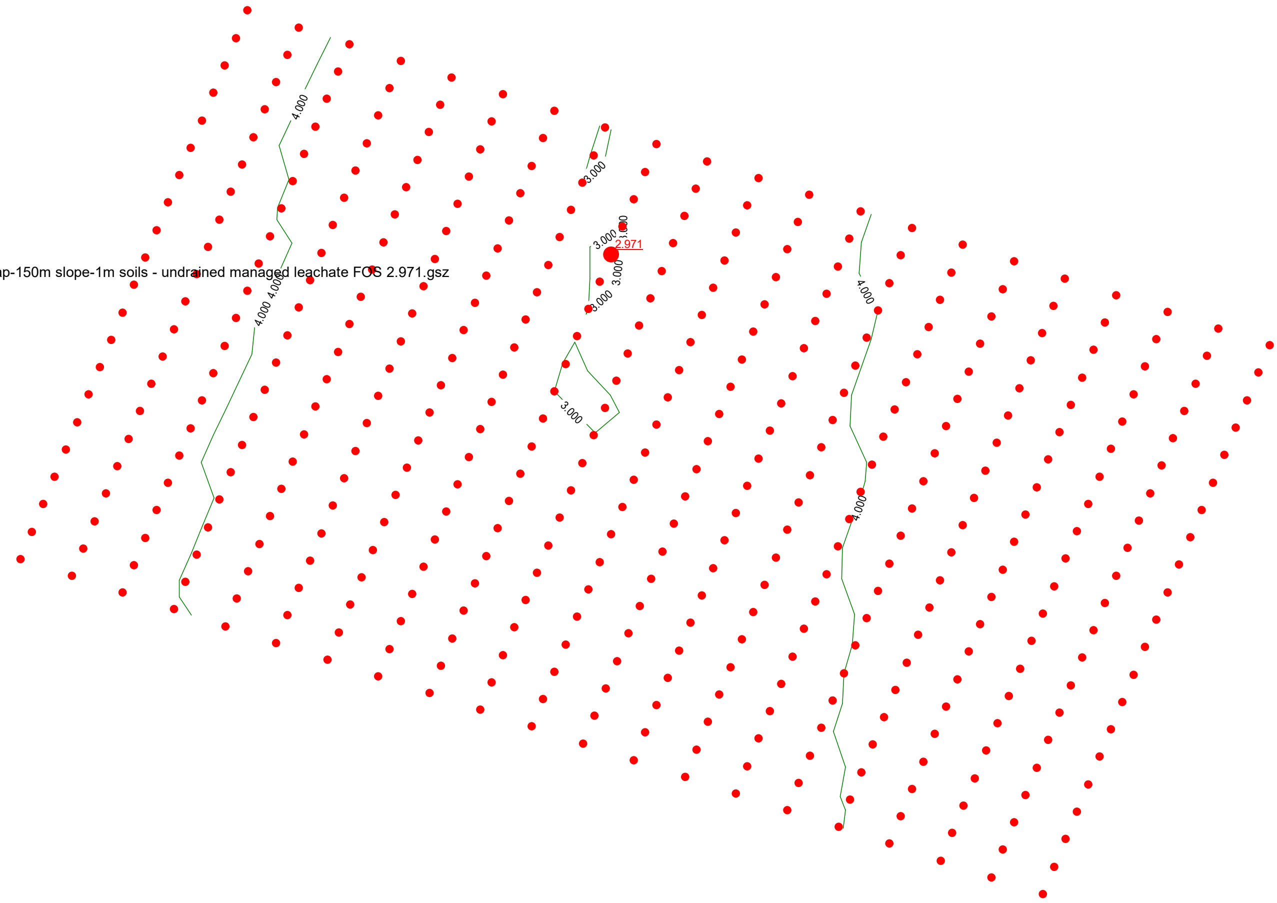


Plot 5a

ENRMF western extension area

File Name: 05a_Geosynthetic Cap-150m slope-1m soils - undrained managed leachate FOS 2.971.gsz

Method: Spencer
FOS: 2.971



Name: Restoration materials - drained
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

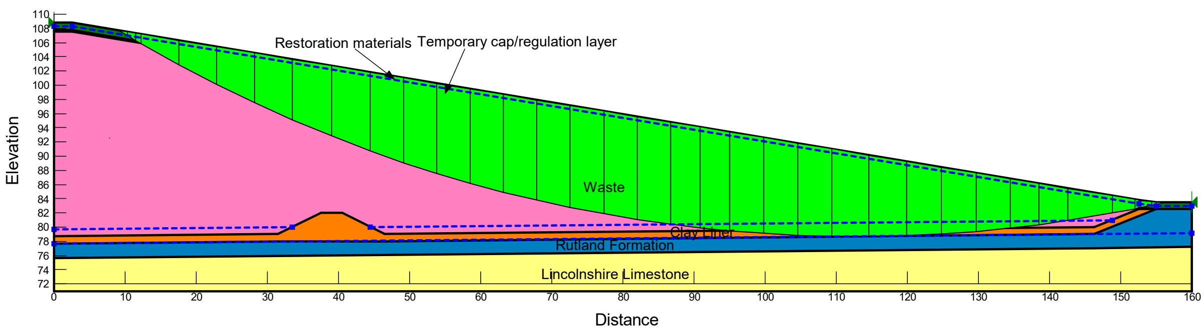
Name: Temporary cap/regulation layer - undrained
Unit Weight: 20 kN/m³
Cohesion: 50 kPa
Phi: 0 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)

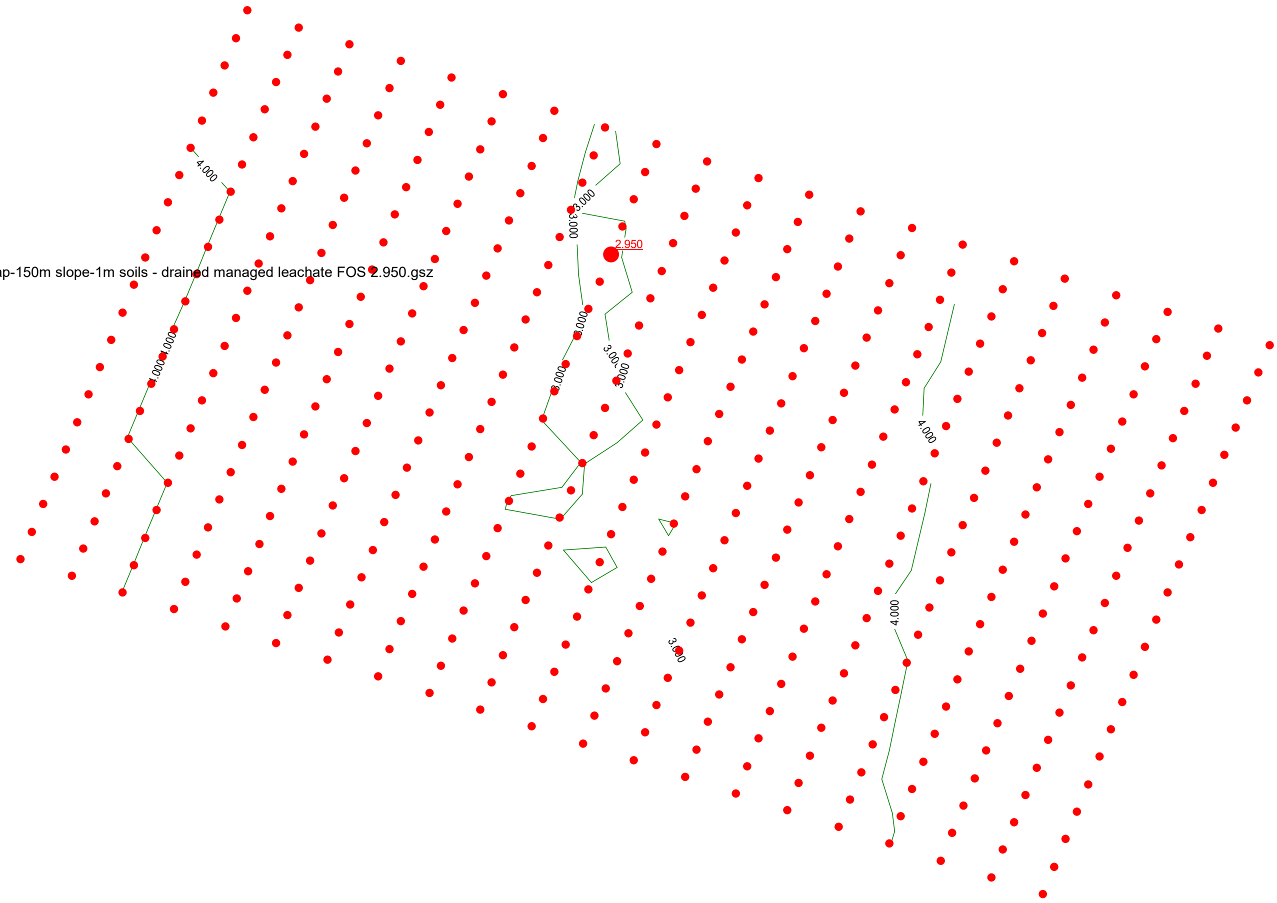


Plot 5b

ENRMF western extension area

File Name: 05b_Geosynthetic Cap-150m slope-1m soils - drained managed leachate FOS 2.950.gsz

Method: Spencer
FOS: 2.950



Name: Restoration materials - drained
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

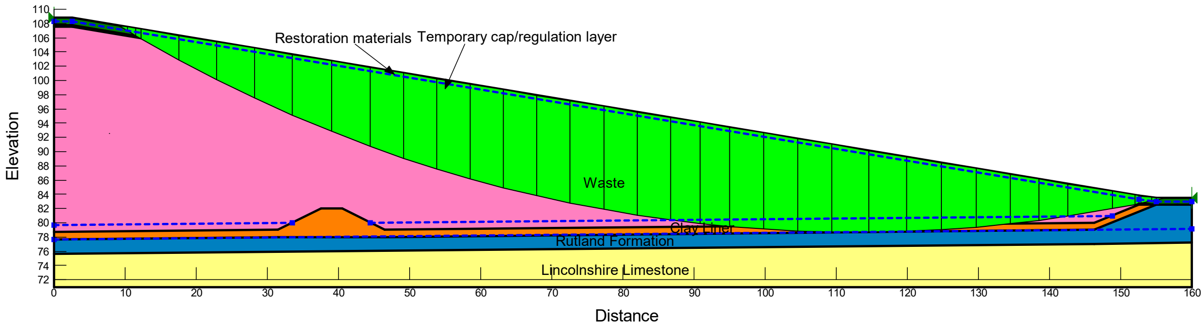
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)



Plot 5c
ENRMF western extension area
File Name: 05c_Geosynthetic Cap-12m slope-1m cover-undrained managed leachate FOS 2.278.gsz
Method: Spencer
FOS: 2.278

Name: Restoration materials - drained
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

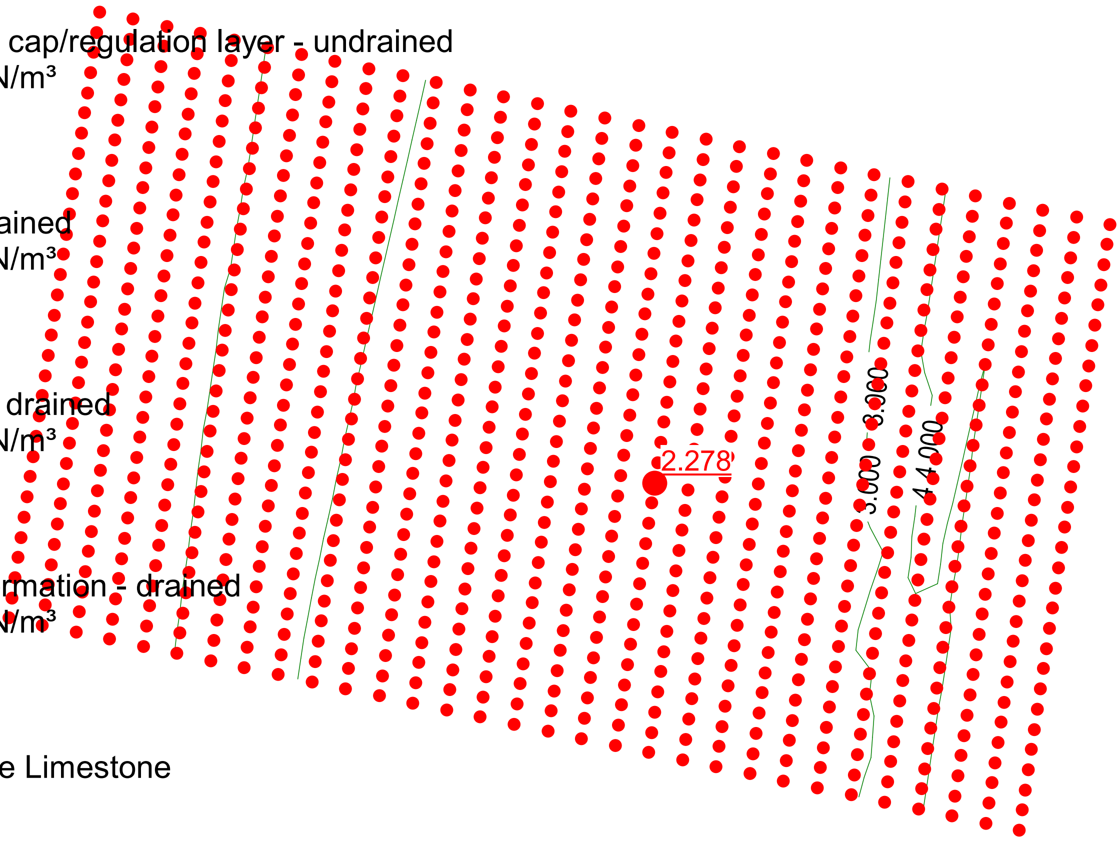
Name: Temporary cap/regulation layer - undrained
Unit Weight: 20 kN/m³
Cohesion: 50 kPa
Phi: 0 °

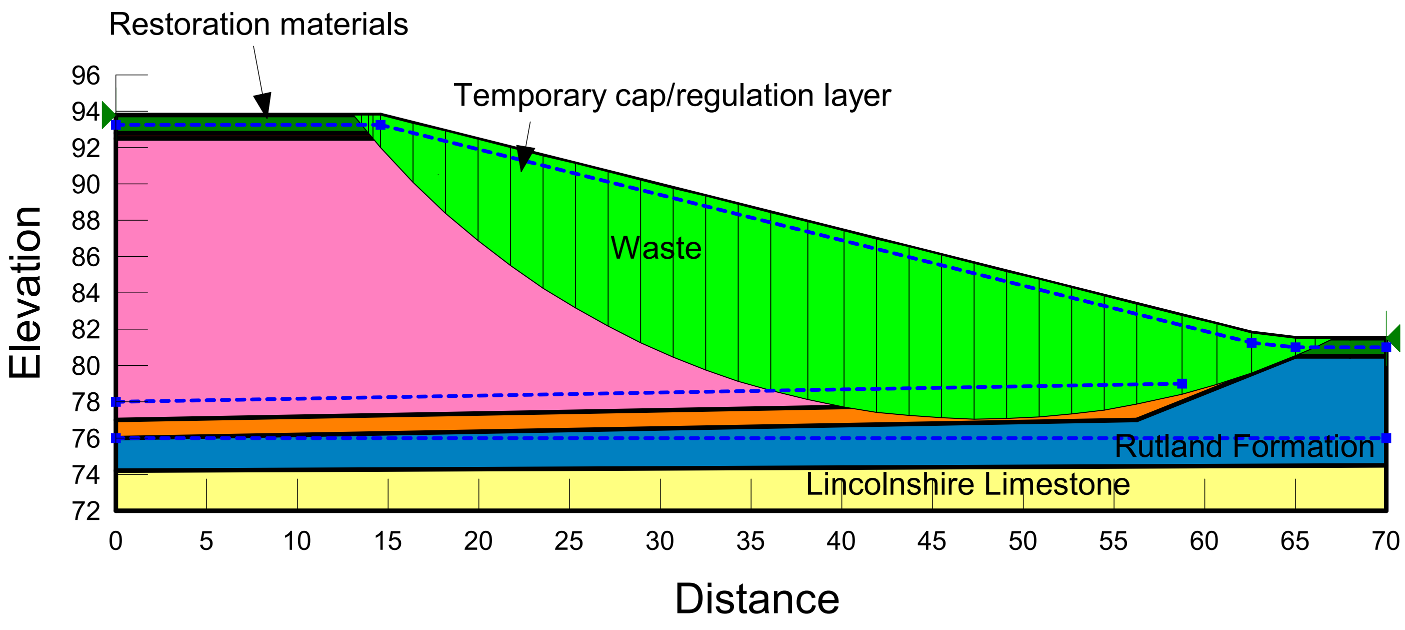
Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

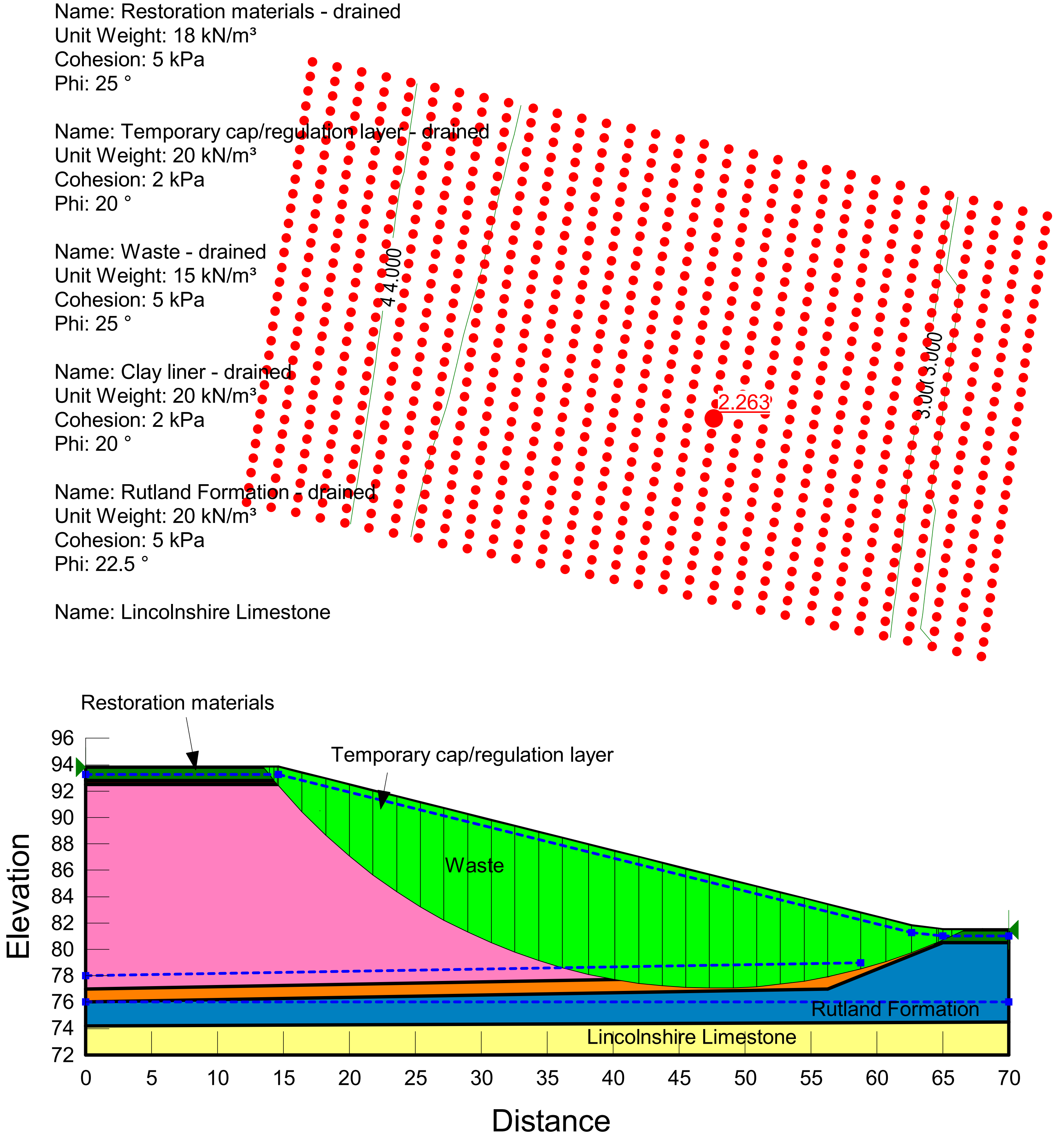
Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone





Plot 5d
ENRMF western extension area
File Name: 05d_Geosynthetic Cap - steep slope-1m cover - drained managed leachate FOS 2.263.gsz
Method: Spencer
FOS: 2.263

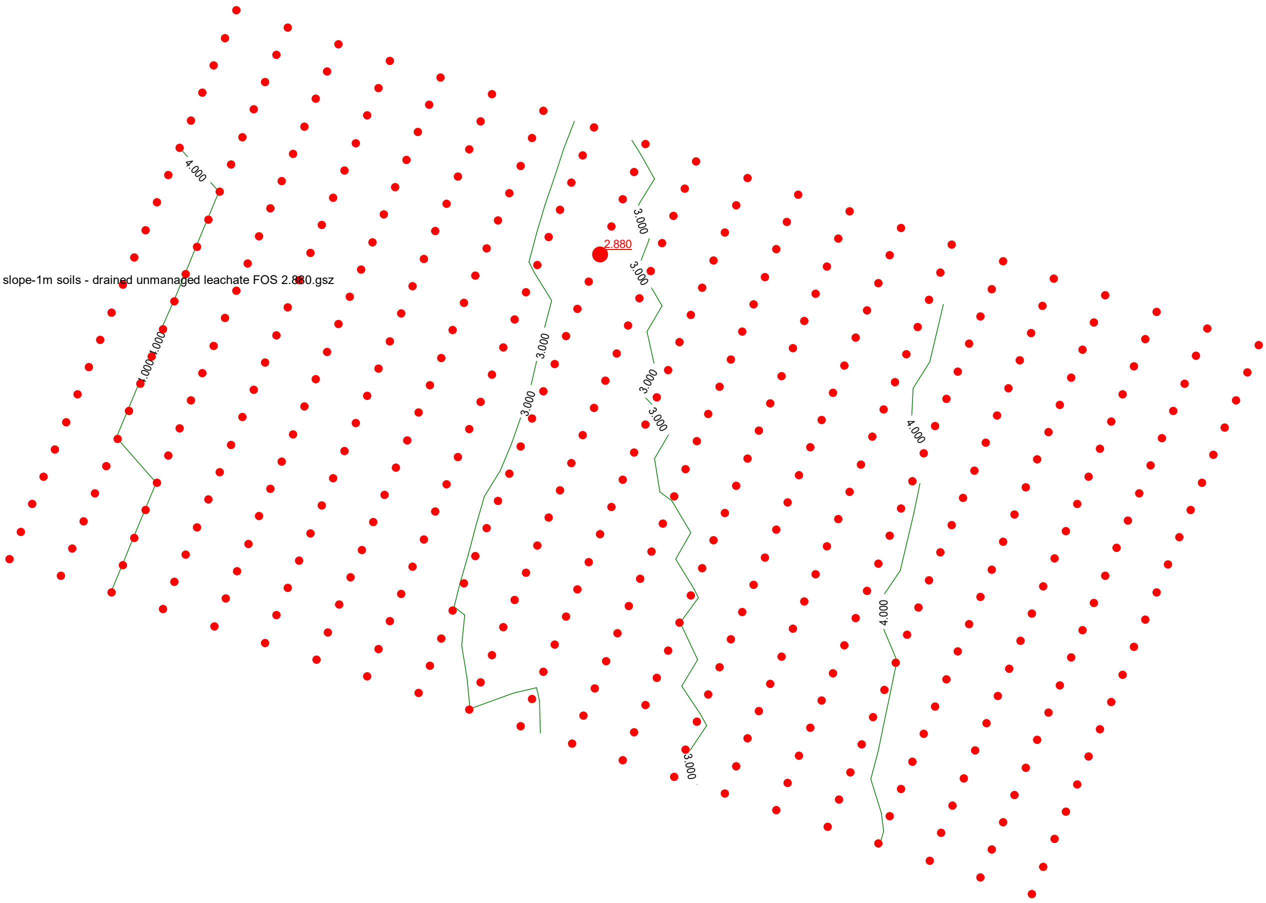


Plot 6a

ENRMF western extension area

File Name: 06a_Geosynthetic Cap-150m slope-1m soils - drained unmanaged leachate FOS 2.880.gsz

Method: Spencer
FOS: 2.880



Name: Restoration materials - drained
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

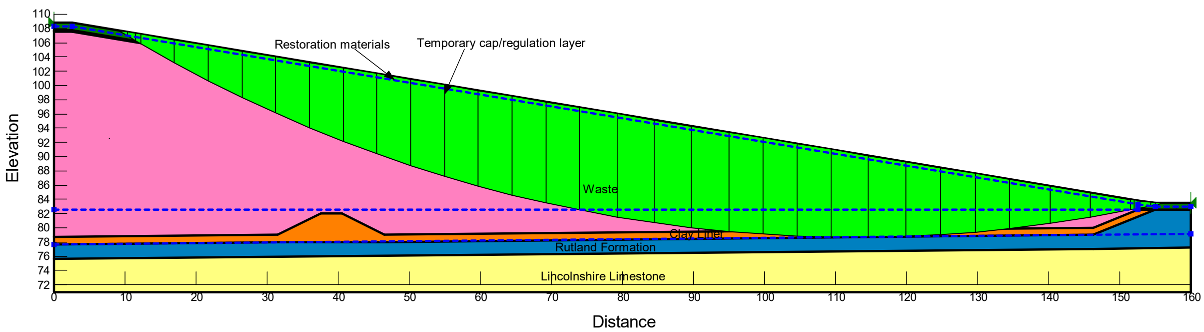
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)



Plot 6b
ENRMF western extension area
File Name: 06b_Geosynthetic Cap - steep slope-1m cover - drained unmanaged leachate FOS 2.206.gsz
Method: Spencer
FOS: 2.206

Name: Restoration materials - drained
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

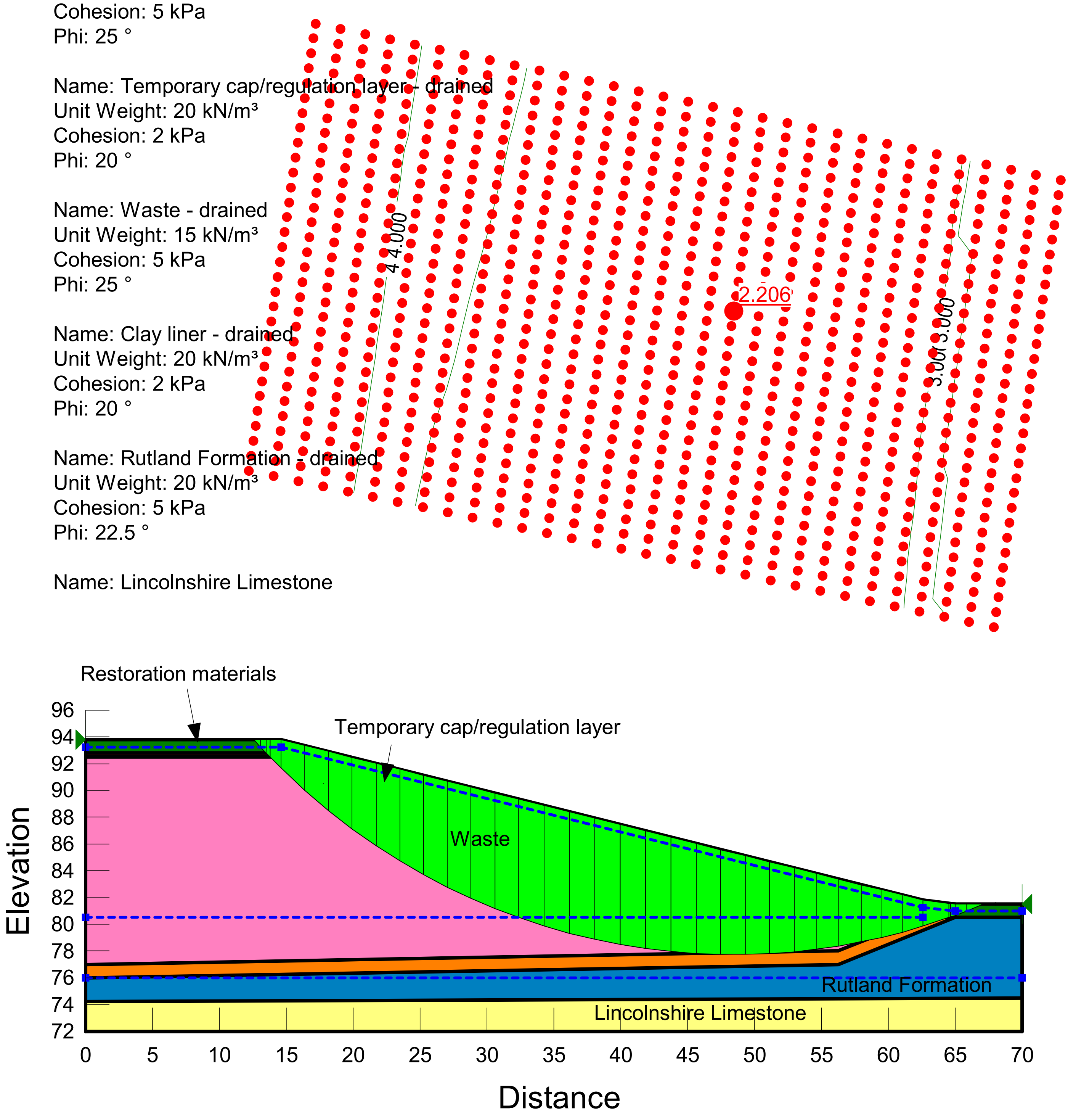
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

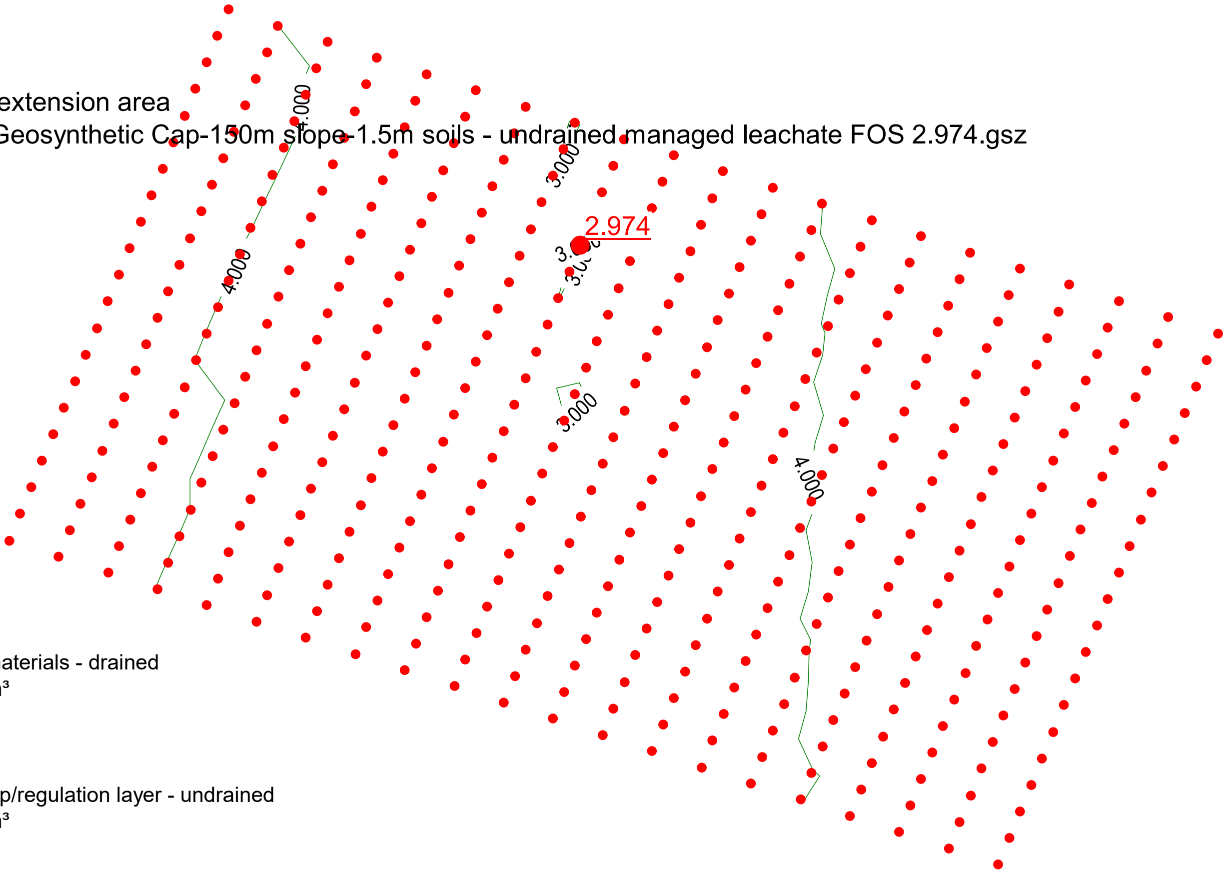
Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone



Plot 7a
ENRMF western extension area
File Name: 07a_Geosynthetic Cap-150m slope-1.5m soils - undrained managed leachate FOS 2.974.gsz
Method: Spencer
FOS: 2.974



Name: Restoration materials - drained
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

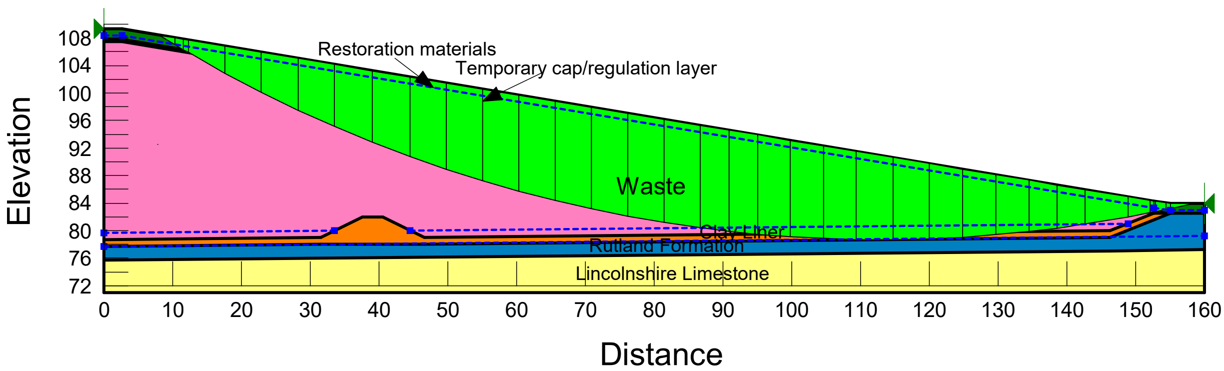
Name: Temporary cap/regulation layer - undrained
Unit Weight: 20 kN/m³
Cohesion: 50 kPa
Phi: 0 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)

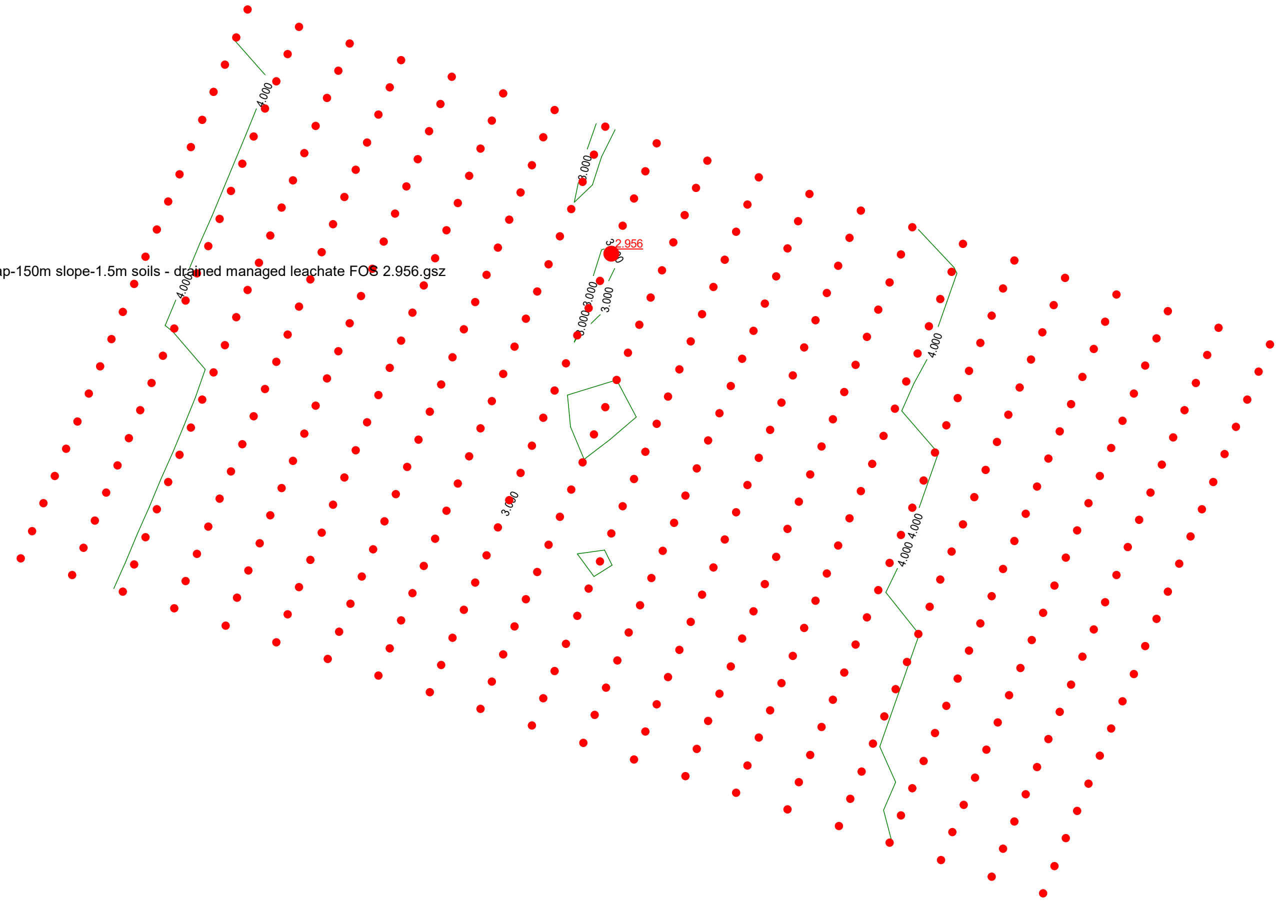


Plot 7b

ENRMF western extension area

File Name: 07b_Geosynthetic Cap-150m slope-1.5m soils - drained managed leachate FOS 2.956.gsz

Method: Spencer
FOS: 2.956



Name: Restoration materials - drained
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

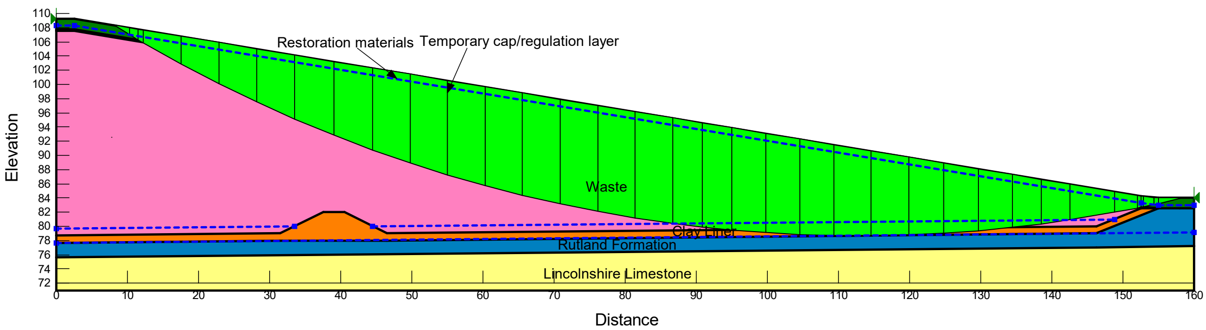
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

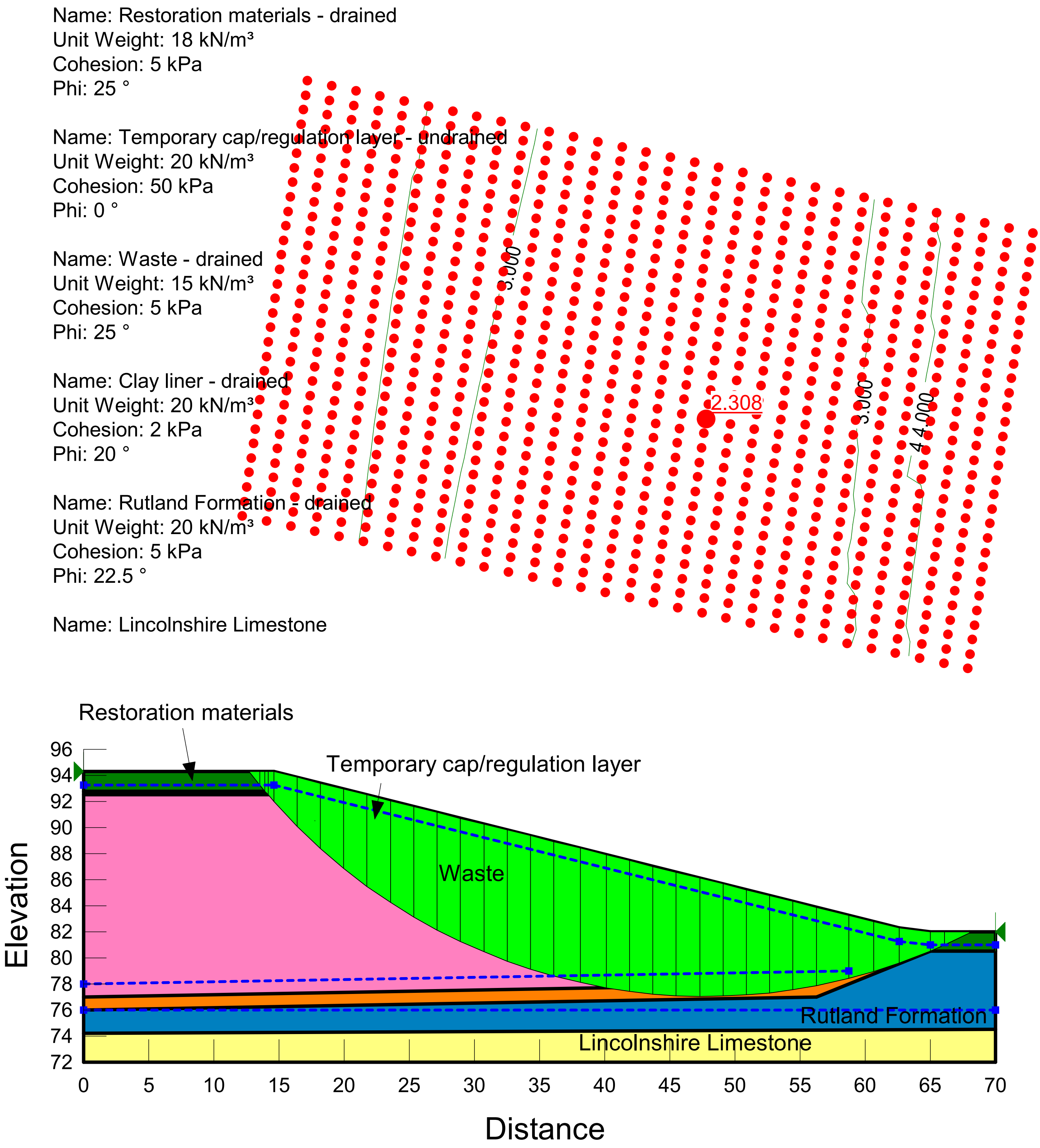
Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)



Plot 7c
ENRMF western extension area
File Name: 07c_Geosynthetic Cap-12m slope-1.5m cover-undrained managed leachate FOS 2.308.gsz
Method: Spencer
FOS: 2.308



Plot 7d
ENRMF western extension area
File Name: 07d_Geosynthetic Cap-12m slope-1.5m cover-drained managed leachate FOS 2.293.gsz
Method: Spencer
FOS: 2.293

Name: Restoration materials - drained
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

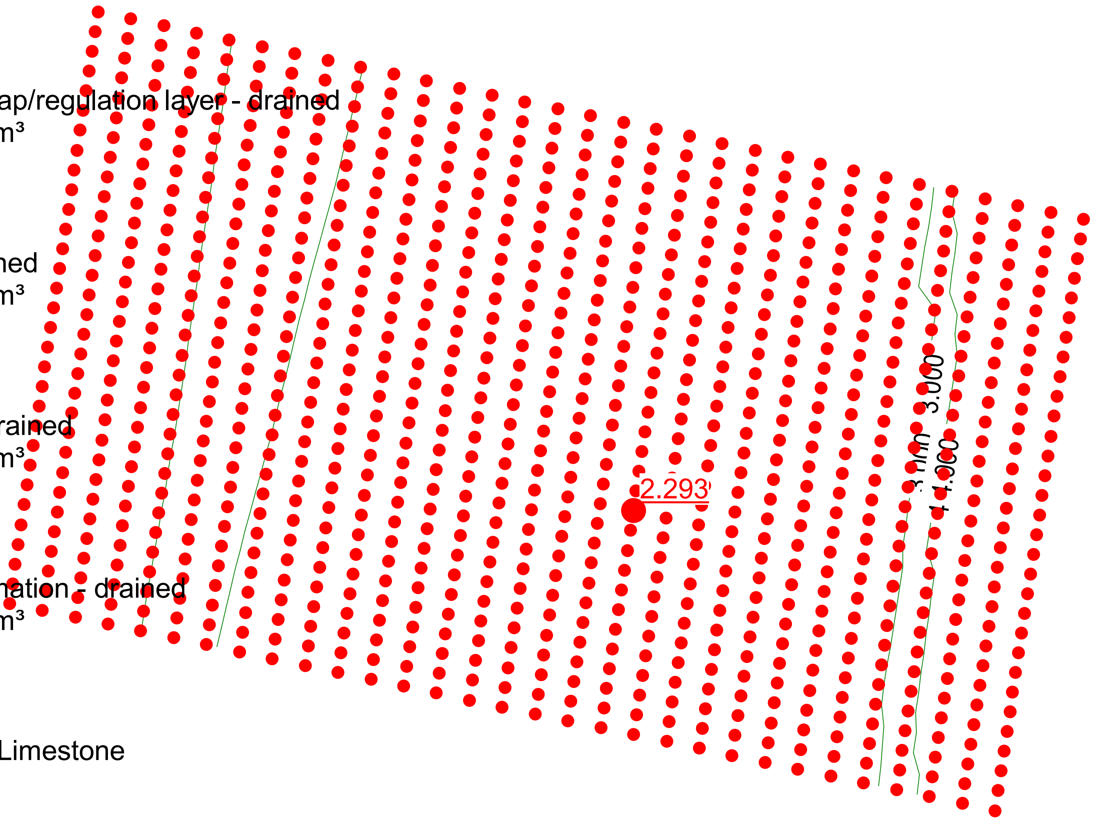
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

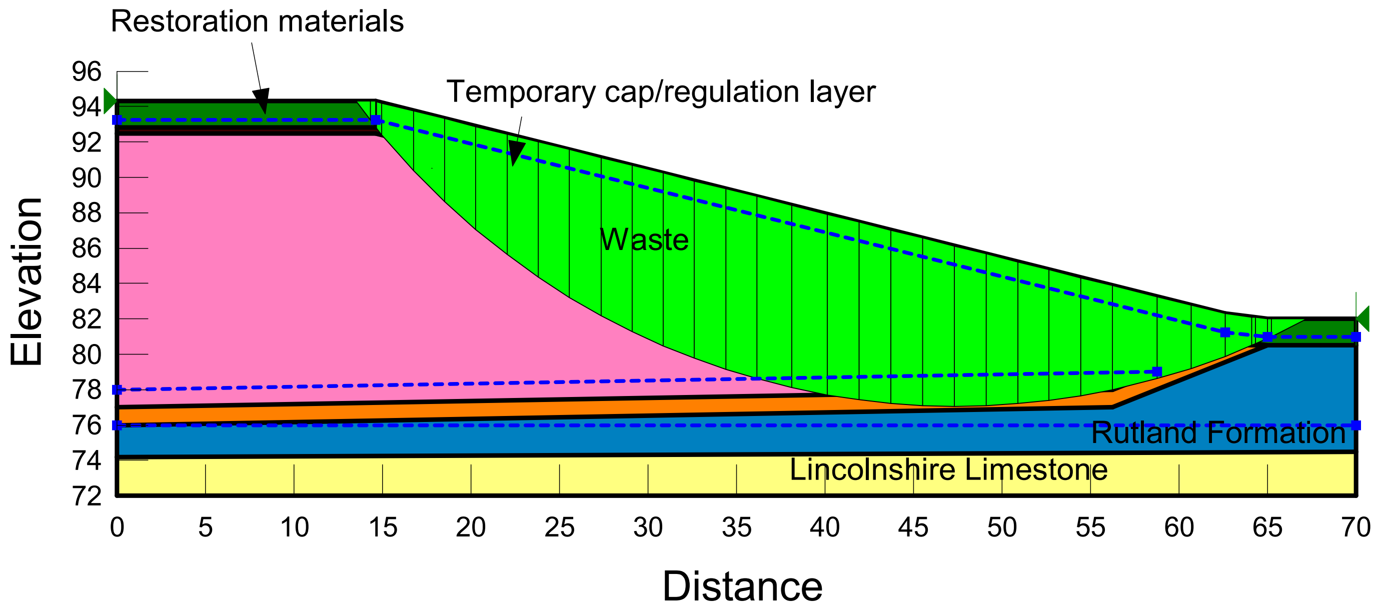
Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone



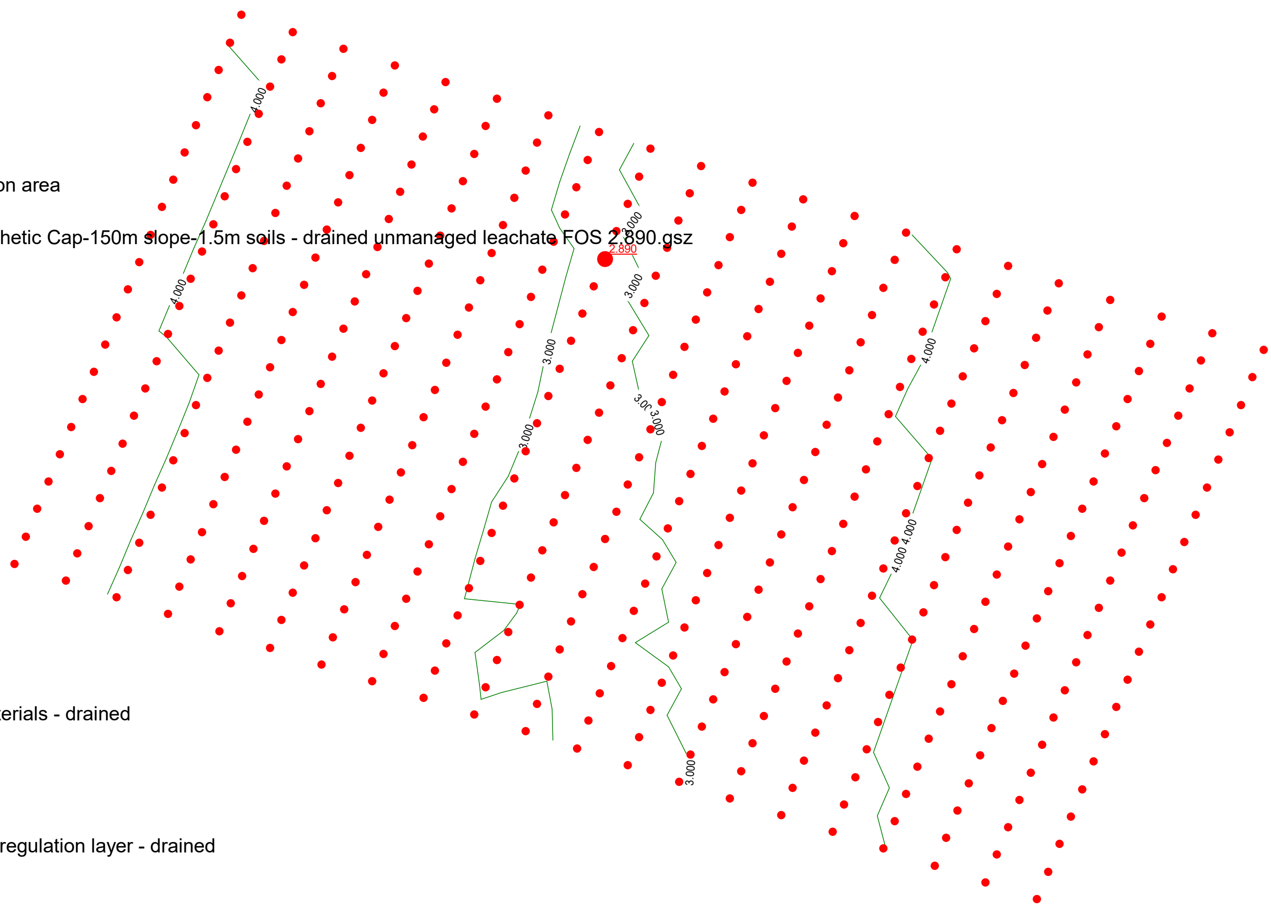


Plot 8a

ENRMF western extension area

File Name: 08a_Geosynthetic Cap-150m slope-1.5m soils - drained unmanaged leachate FOS 2.890.gsz

Method: Spencer
FOS: 2.890



Name: Restoration materials - drained
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

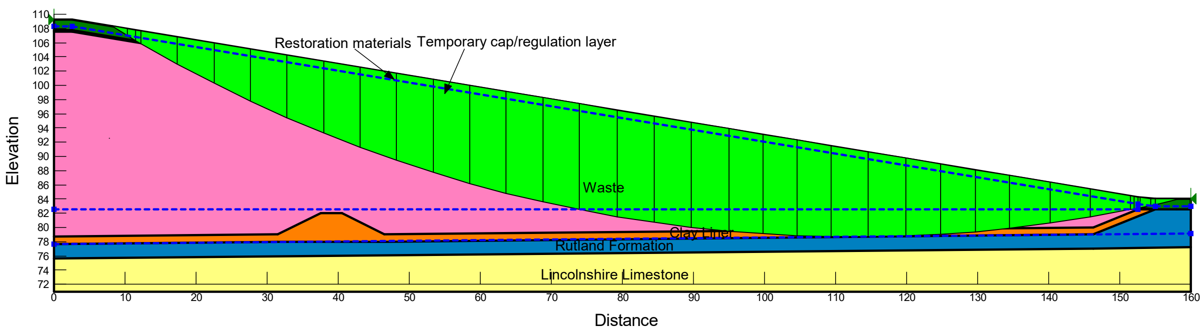
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)



Plot 8b
ENRMF western extension area
File Name: 08b_Geosynthetic Cap-12m slope-1.5m cover-drained unmanaged leachate FOS 2.243.gsz
Method: Spencer
FOS: 2.243

Name: Restoration materials - drained
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

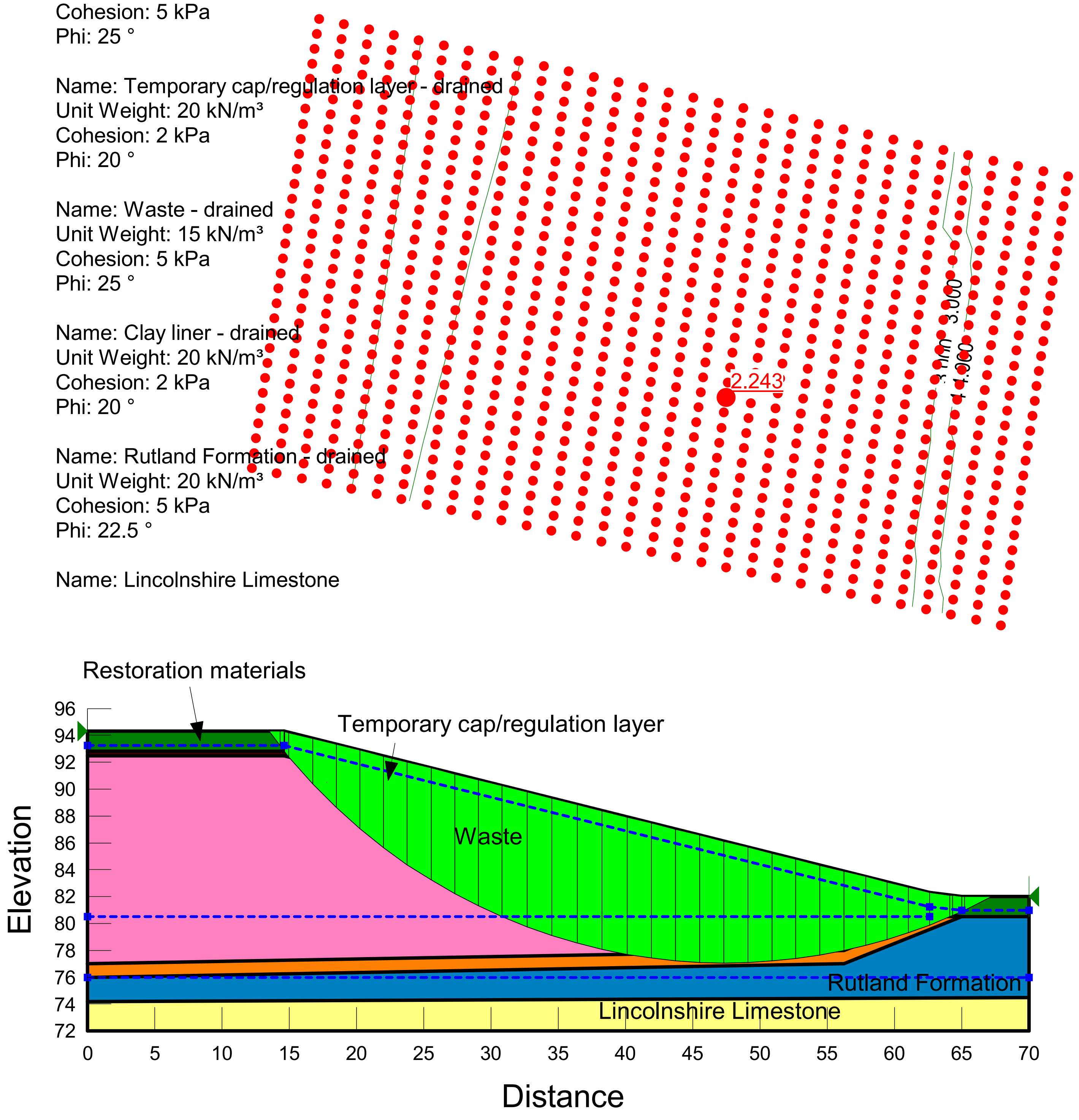
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone

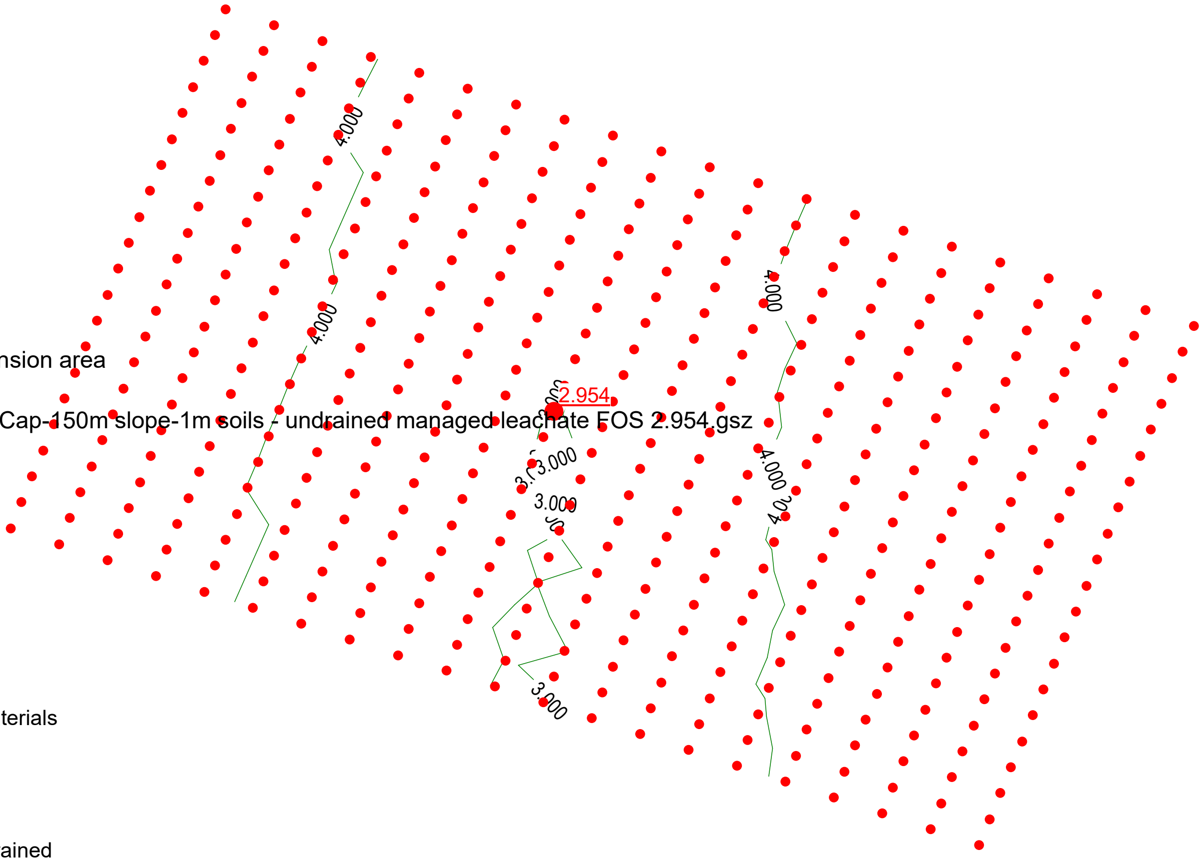


Plot 9a

ENRMF western extension area

File Name: 09a_Clay Cap-150m slope-1m soils - undrained managed leachate FOS 2.954.gsz

Method: Spencer
FOS: 2.954



Name: Restoration materials
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay cap - undrained
Unit Weight: 20 kN/m³
Cohesion: 50 kPa
Phi: 0 °

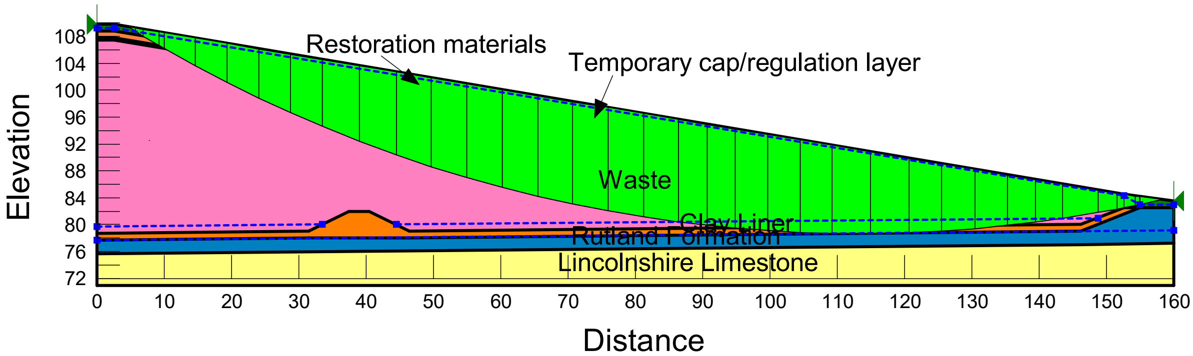
Name: Temporary cap/regulation layer - undrained
Unit Weight: 20 kN/m³
Cohesion: 50 kPa
Phi: 0 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)

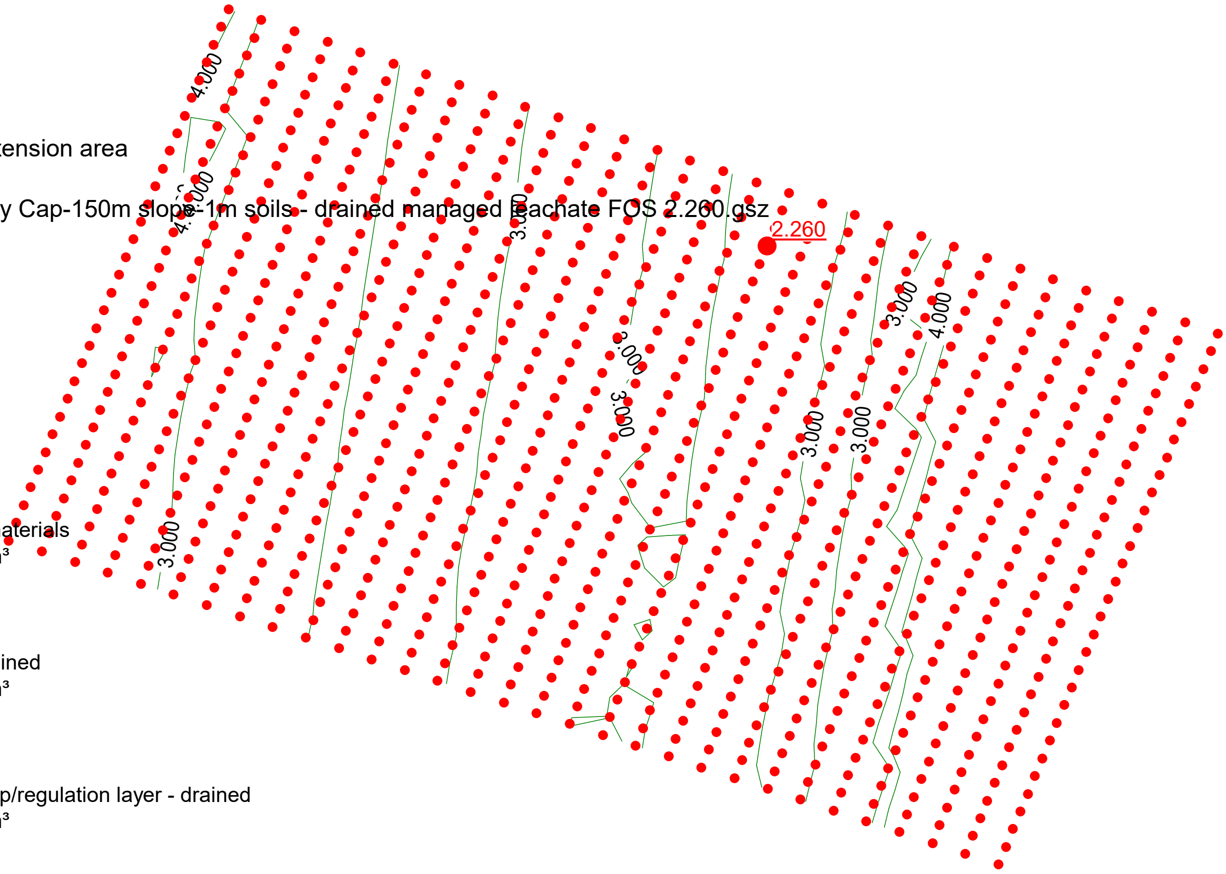


Plot 9b

ENRMF western extension area

File Name: 09b_Clay Cap-150m slope-1m soils - drained managed leachate FOS 2.260.gsz

Method: Spencer
FOS: 2.260



Name: Restoration materials
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay cap - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

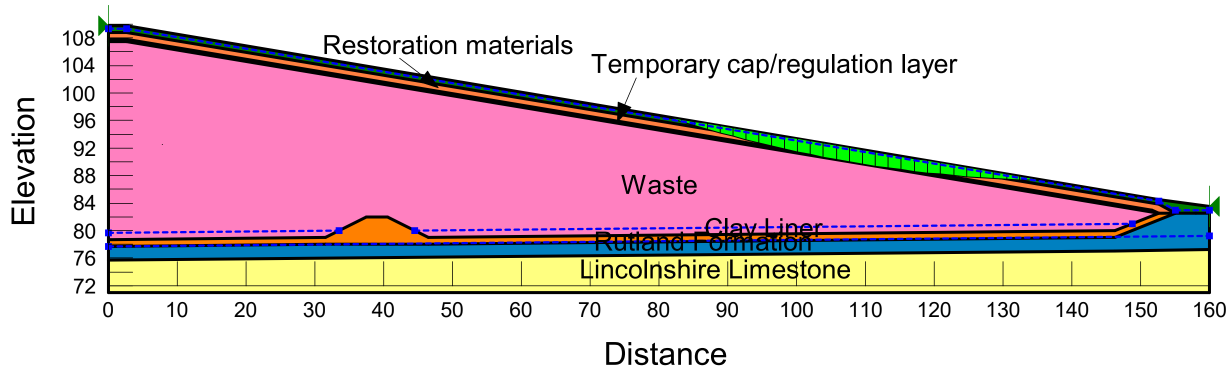
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

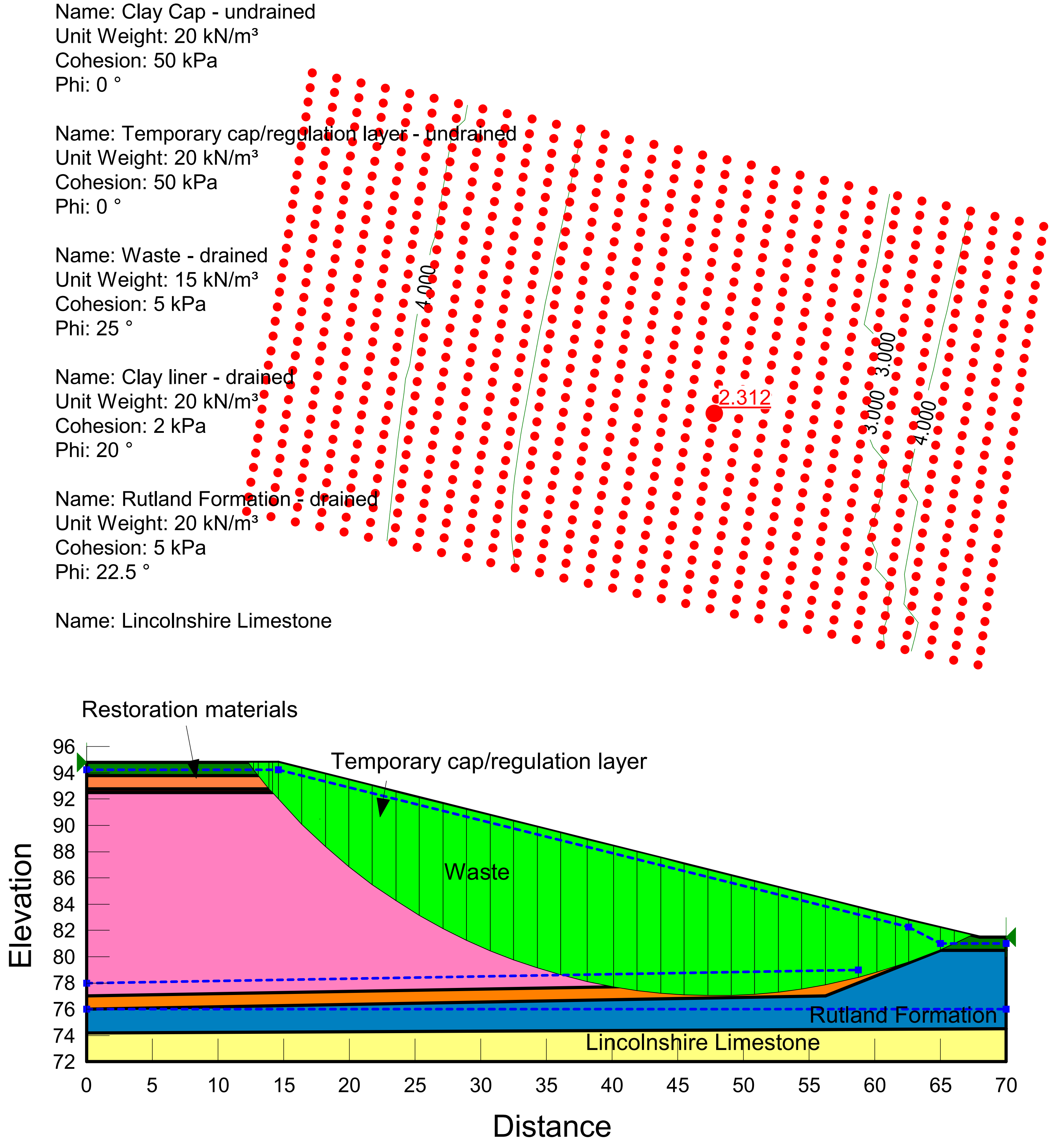
Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

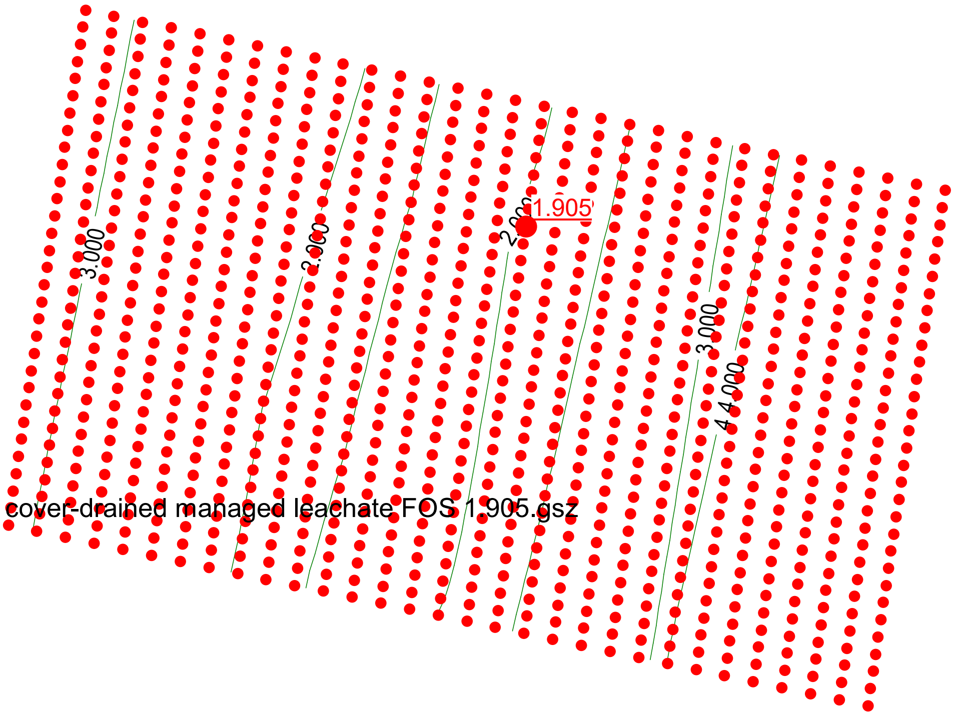
Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)



Plot 9c
ENRMF western extension area
File Name: 09c_Clay Cap-12m slope-1m cover-undrained managed leachate FOS 2.312.gsz
Method: Spencer
FOS: 2.312



Plot 9d
ENRMF western extension area
File Name: 09d_Clay Cap-12m slope-1m cover-drained managed leachate FOS 1.905.gsz
Method: Spencer
FOS: 1.905



Name: Clay Cap - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

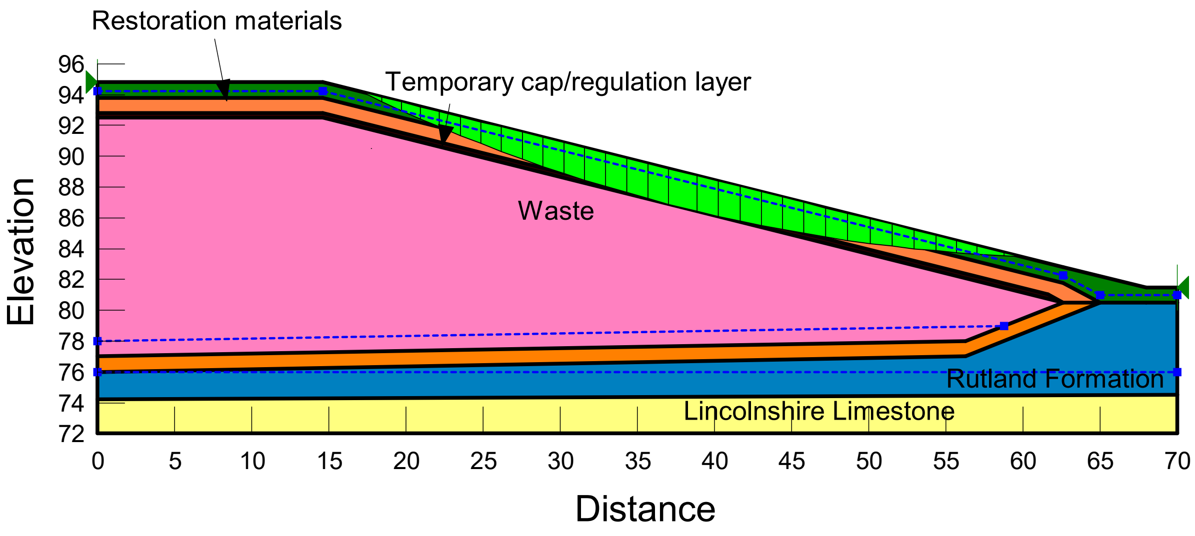
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone

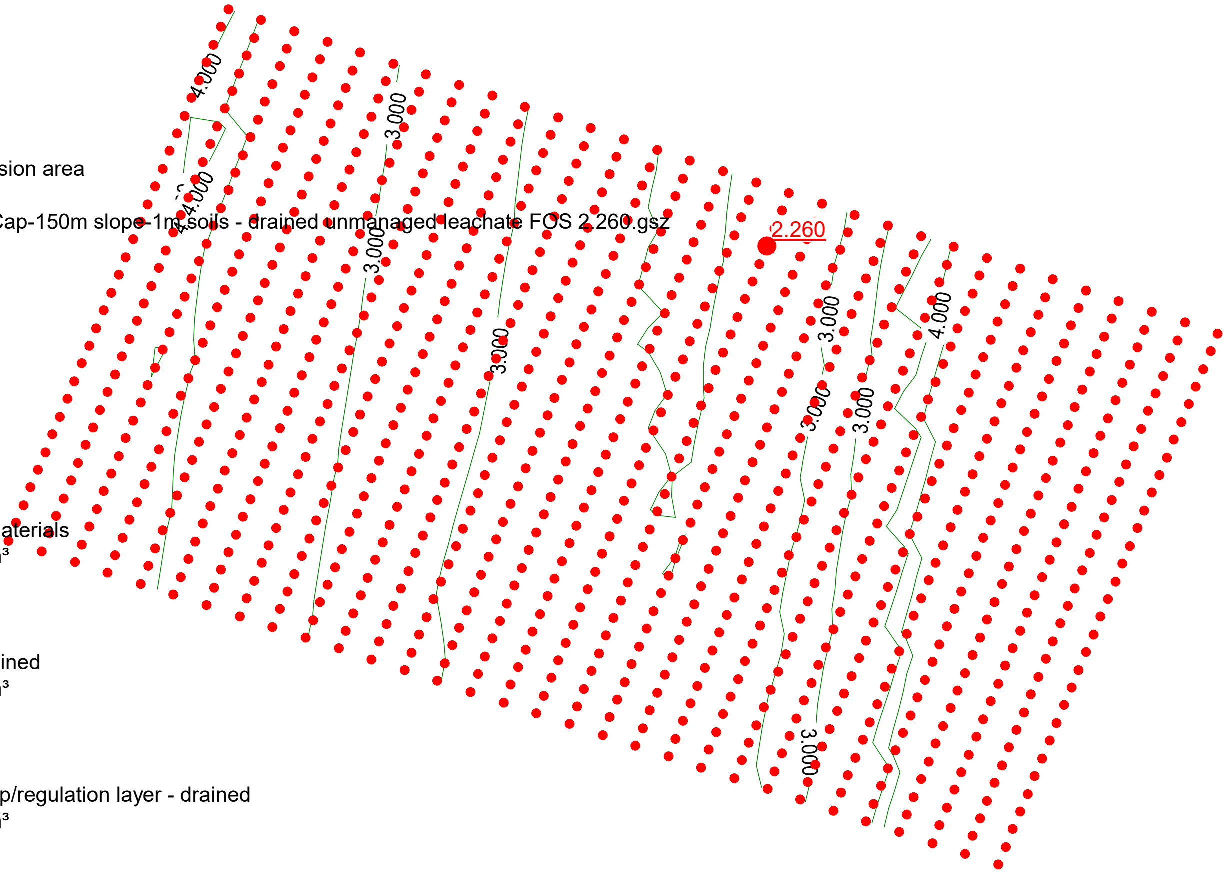


Plot 10a

ENRMF western extension area

File Name: 10a_Clay Cap-150m slope-1m soils - drained unmanaged leachate FOS 2.260.gsz

Method: Spencer
FOS: 2.260



Name: Restoration materials
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay cap - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

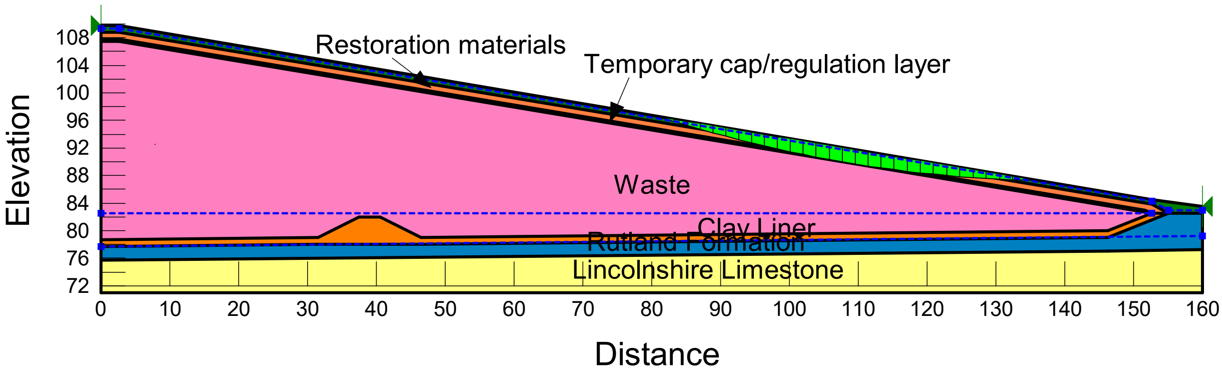
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

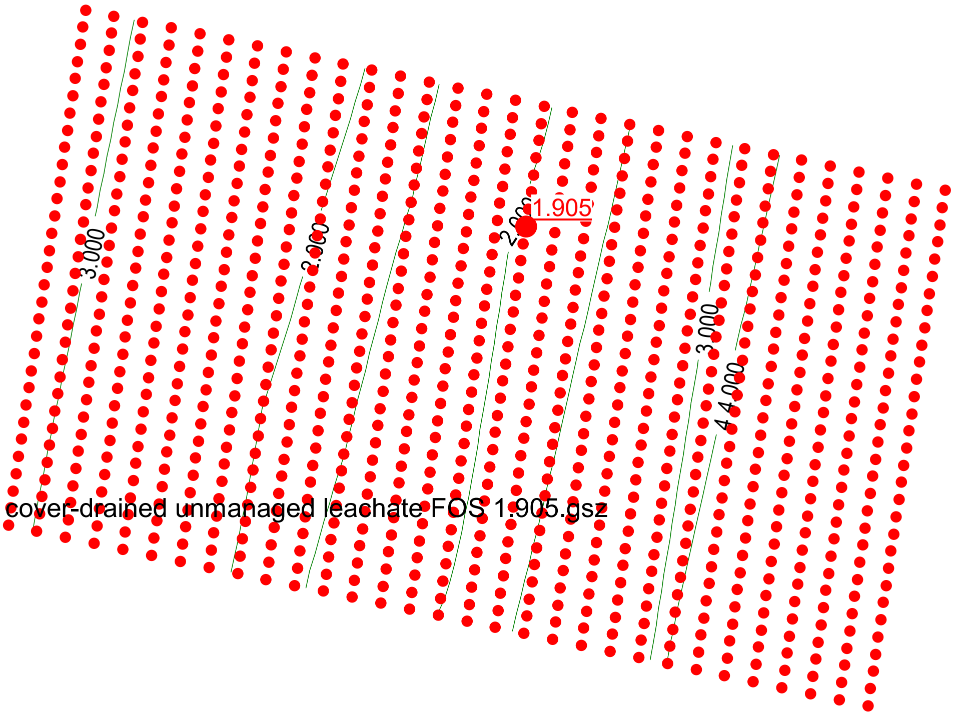
Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)





Plot 10b
ENRMF western extension area
File Name: 10b_Clay Cap-12m slope-1m cover-drained unmanaged leachate FOS 1.905.gsz
Method: Spencer
FOS: 1.905

Name: Clay Cap - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

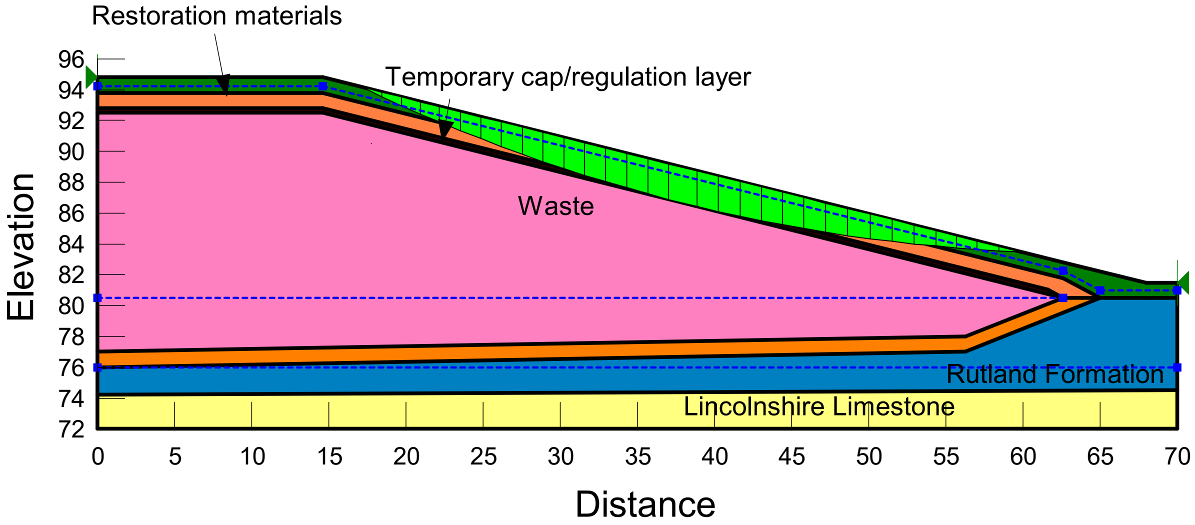
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone

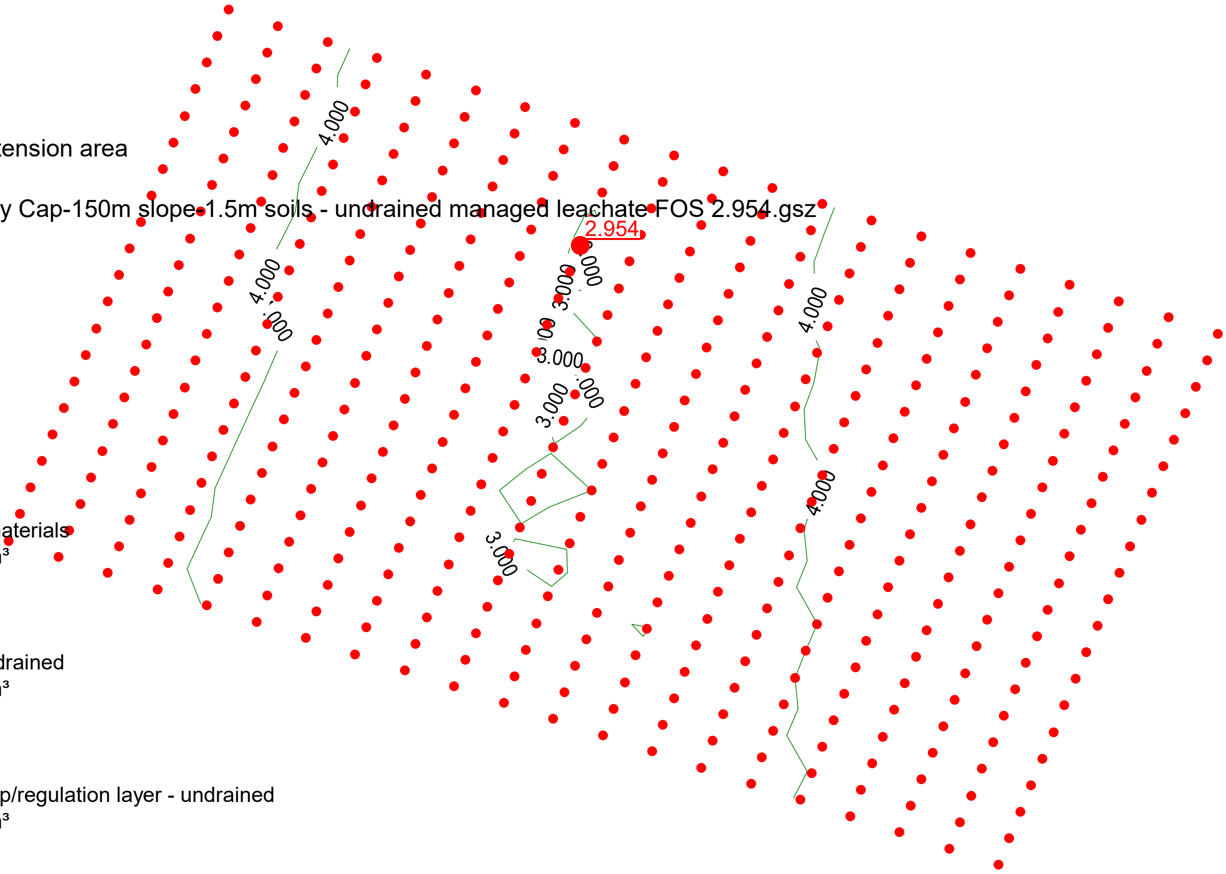


Plot 11a

ENRMF western extension area

File Name: 11a_Clay Cap-150m slope-1.5m soils - undrained managed leachate FOS 2.954.gsz

Method: Spencer
FOS: 2.954



Name: Restoration materials
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay cap - undrained
Unit Weight: 20 kN/m³
Cohesion: 50 kPa
Phi: 0 °

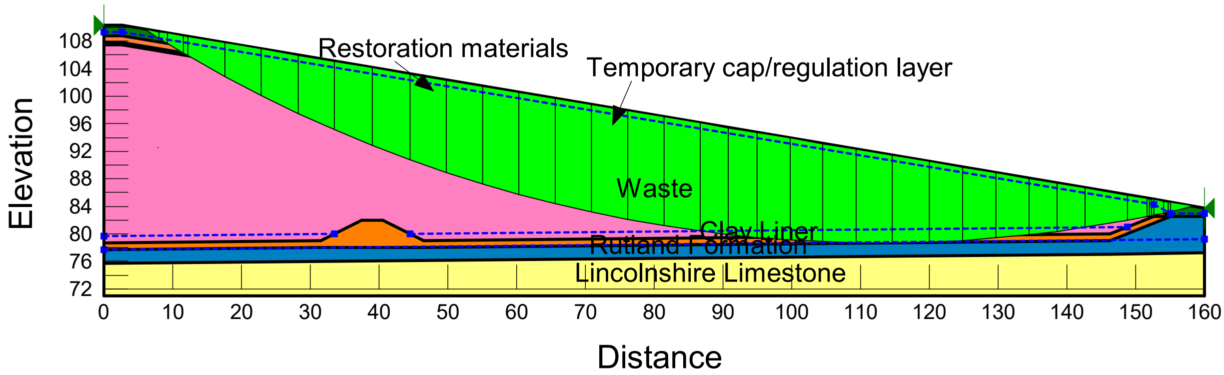
Name: Temporary cap/regulation layer - undrained
Unit Weight: 20 kN/m³
Cohesion: 50 kPa
Phi: 0 °

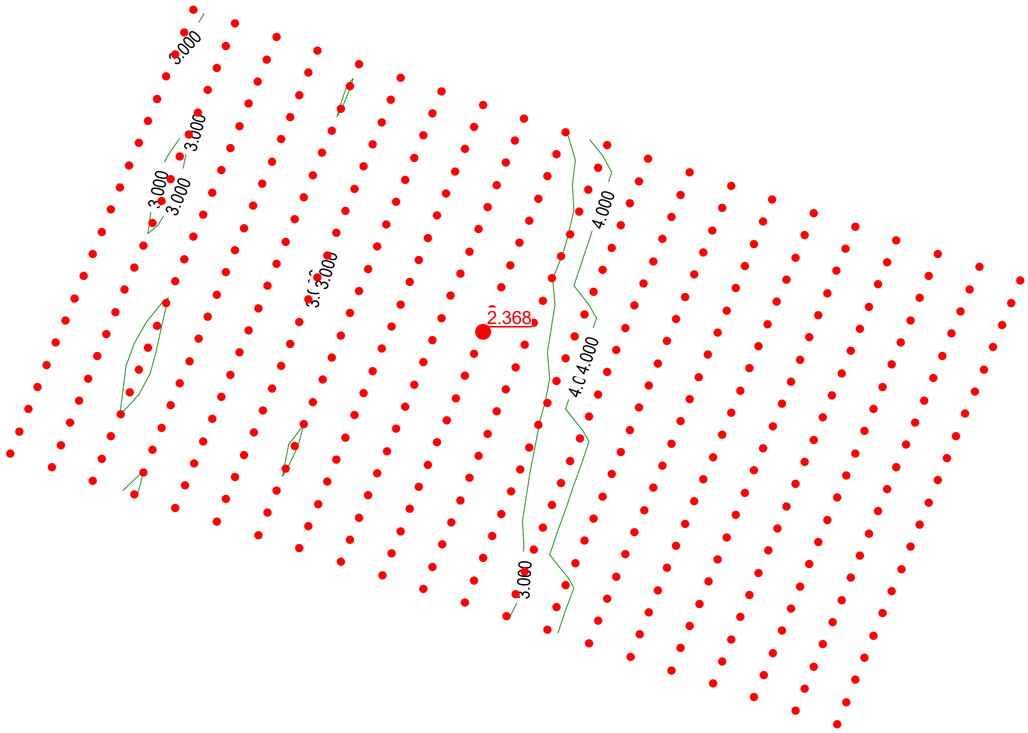
Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)





Plot 11b

ENRMF western extension area

File Name: 11b_Clay Cap-150m slope-1.5m soils - drained managed leachate FOS 2.368.gsz

Method: Spencer
FOS: 2.368

Name: Restoration materials
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay cap - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

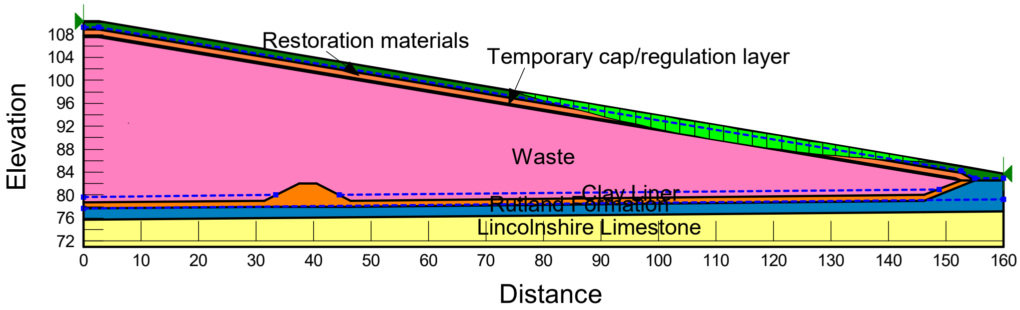
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)



Plot 11c
ENRMF western extension area
File Name: 11c_Clay Cap-12m slope-1.5m cover-undrained managed leachate FOS 2.323.gsz
Method: Spencer
FOS: 2.323

Name: Clay Cap - undrained
Unit Weight: 20 kN/m³
Cohesion: 50 kPa
Phi: 0 °

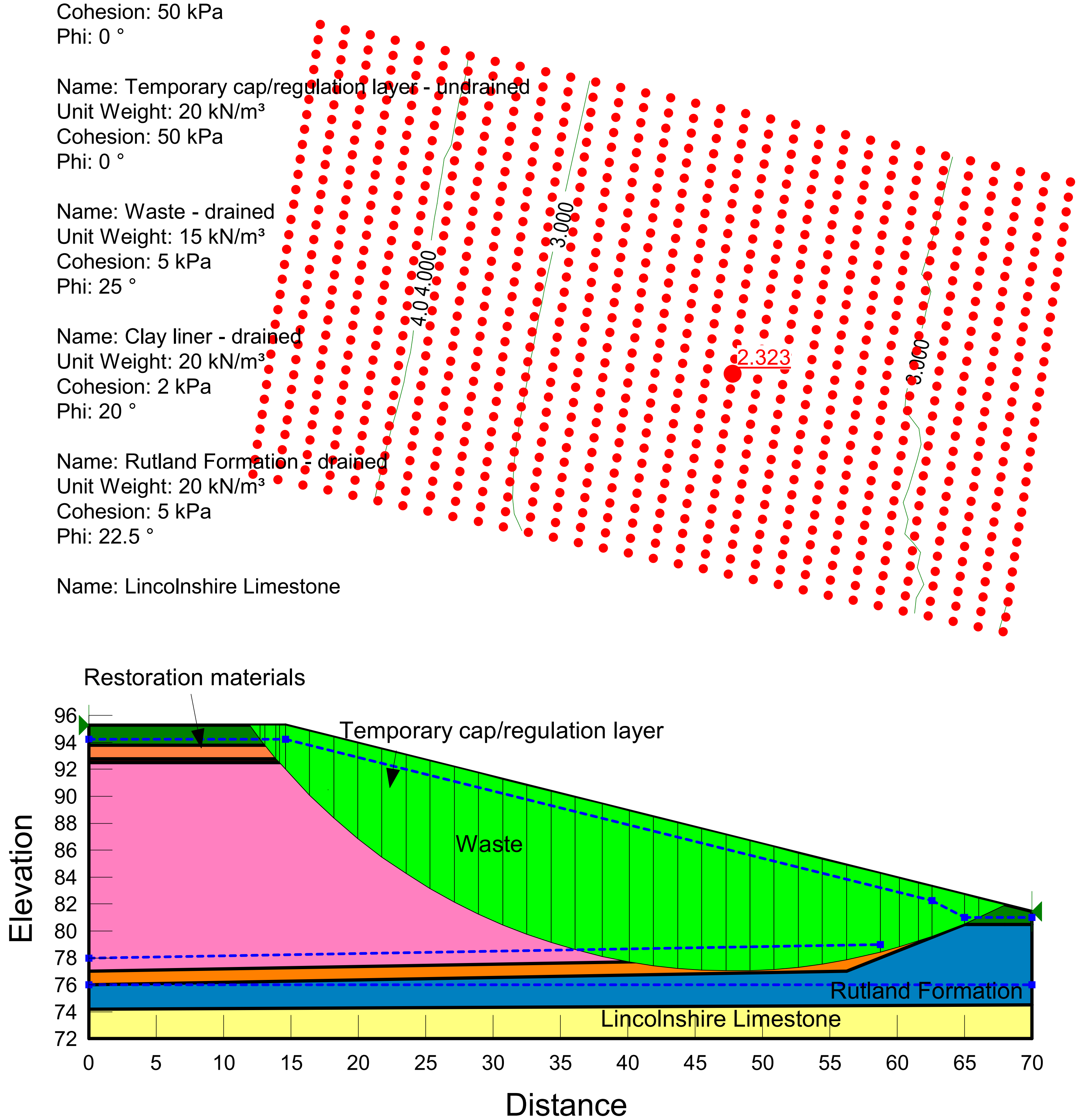
Name: Temporary cap/regulation layer - undrained
Unit Weight: 20 kN/m³
Cohesion: 50 kPa
Phi: 0 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

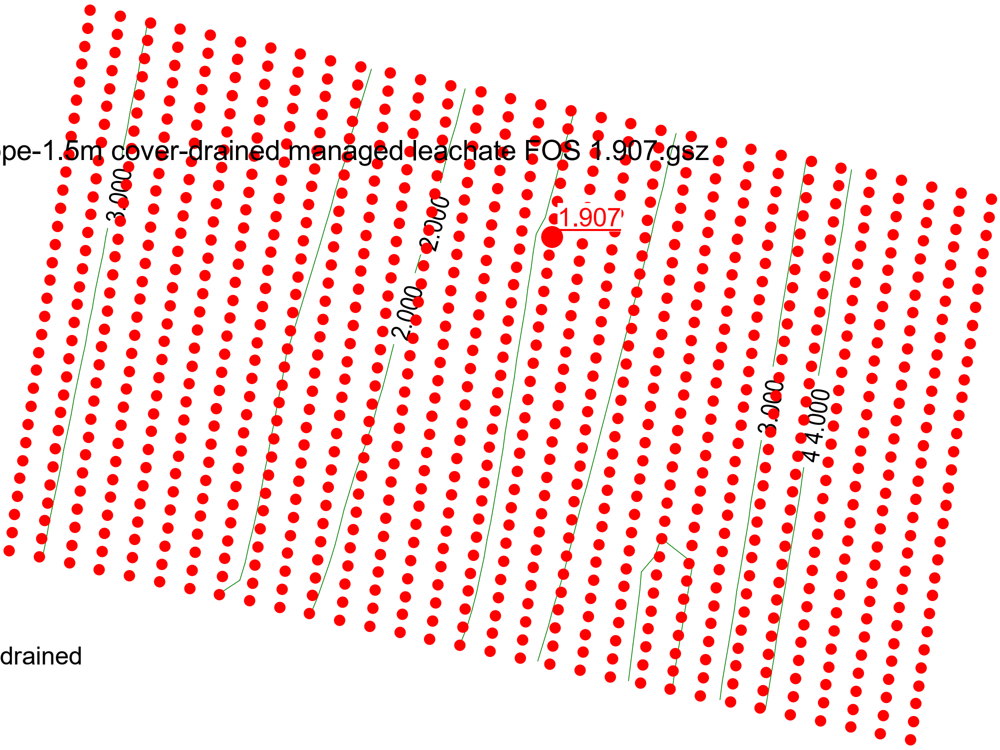
Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone



Plot 11d
ENRMF western extension area
File Name: 11d_Clay Cap-12m slope-1.5m cover-drained managed leachate FOS 1.907.gsz
Method: Spencer
FOS: 1.907



Name: Clay Cap - undrained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

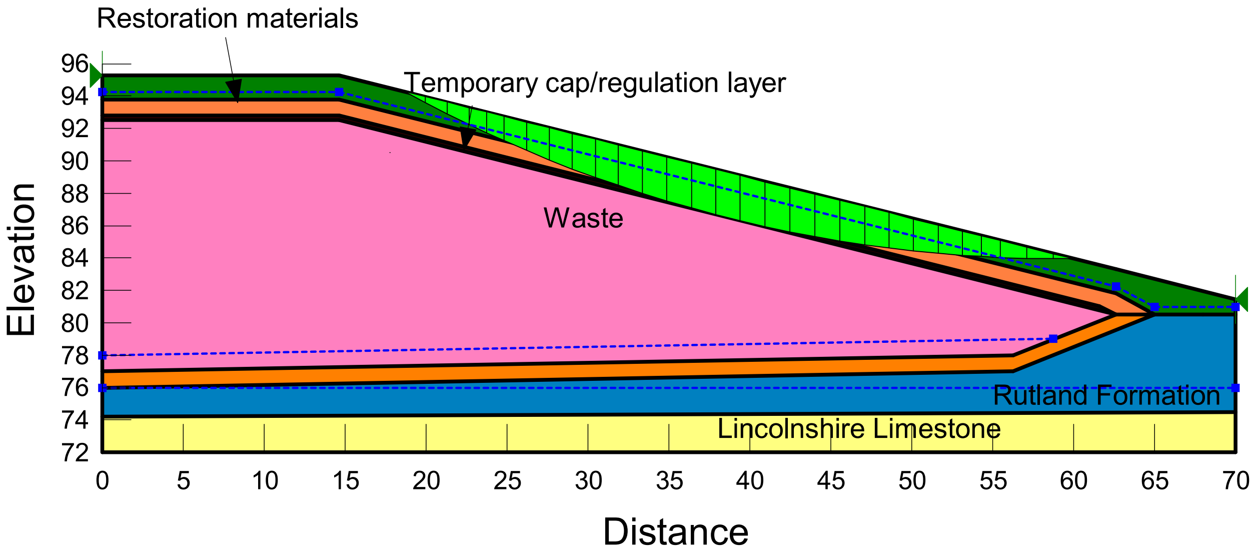
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

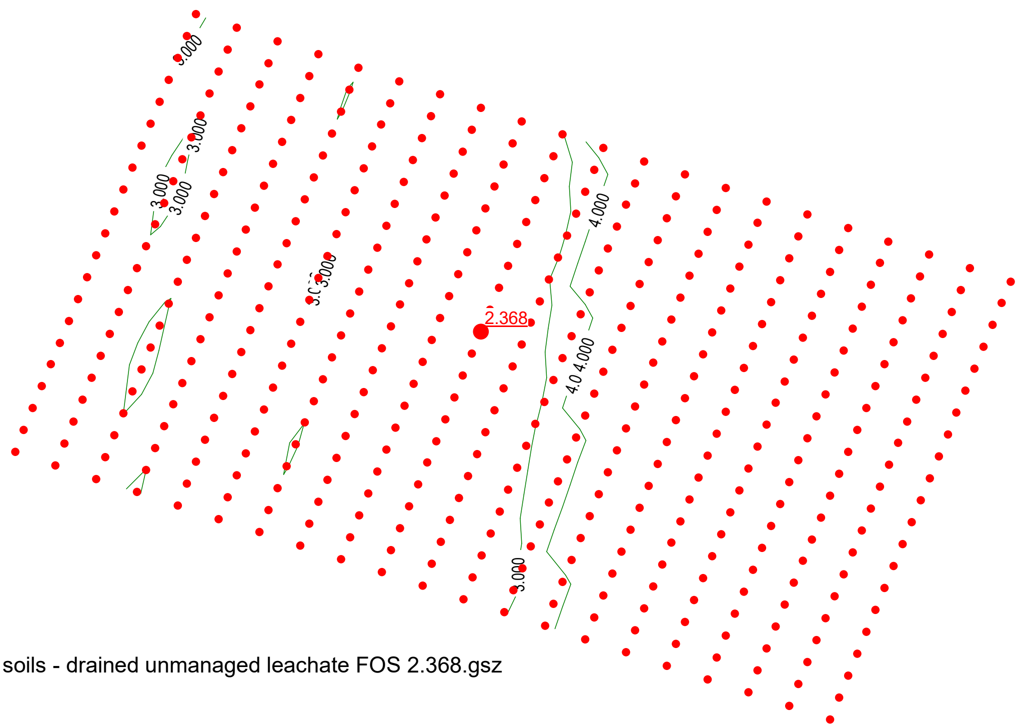
Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone





Plot 12a

ENRMF western extension area

File Name: 12a_Clay Cap-150m slope-1.5m soils - drained unmanaged leachate FOS 2.368.gsz

Method: Spencer
FOS: 2.368

Name: Restoration materials
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay cap - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

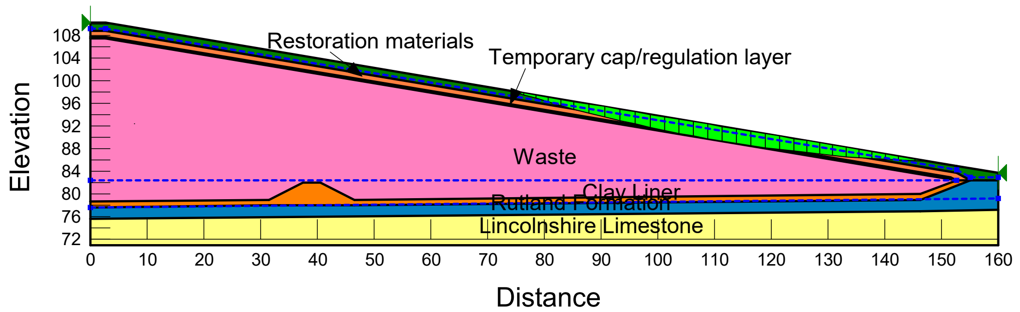
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

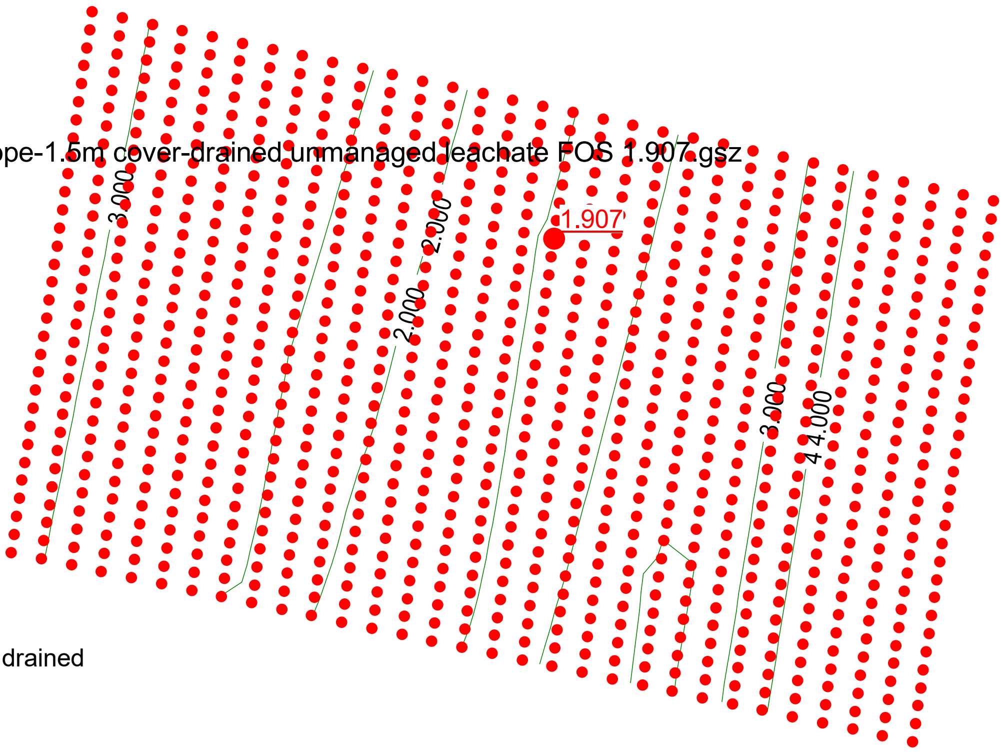
Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone
Model: Bedrock (Impenetrable)



Plot 12b
ENRMF western extension area
File Name: 12b_Clay Cap-12m slope-1.5m cover-drained unmanaged leachate FOS 1.907.gsz
Method: Spencer
FOS: 1.907



Name: Clay Cap - undrained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

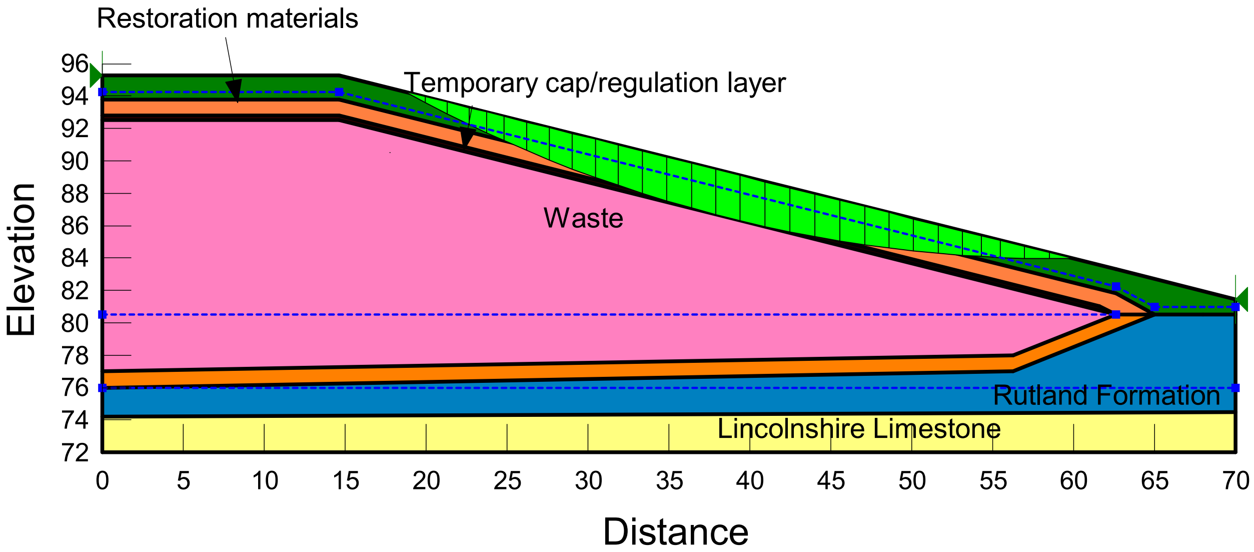
Name: Temporary cap/regulation layer - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Waste - drained
Unit Weight: 15 kN/m³
Cohesion: 5 kPa
Phi: 25 °

Name: Clay liner - drained
Unit Weight: 20 kN/m³
Cohesion: 2 kPa
Phi: 20 °

Name: Rutland Formation - drained
Unit Weight: 20 kN/m³
Cohesion: 5 kPa
Phi: 22.5 °

Name: Lincolnshire Limestone



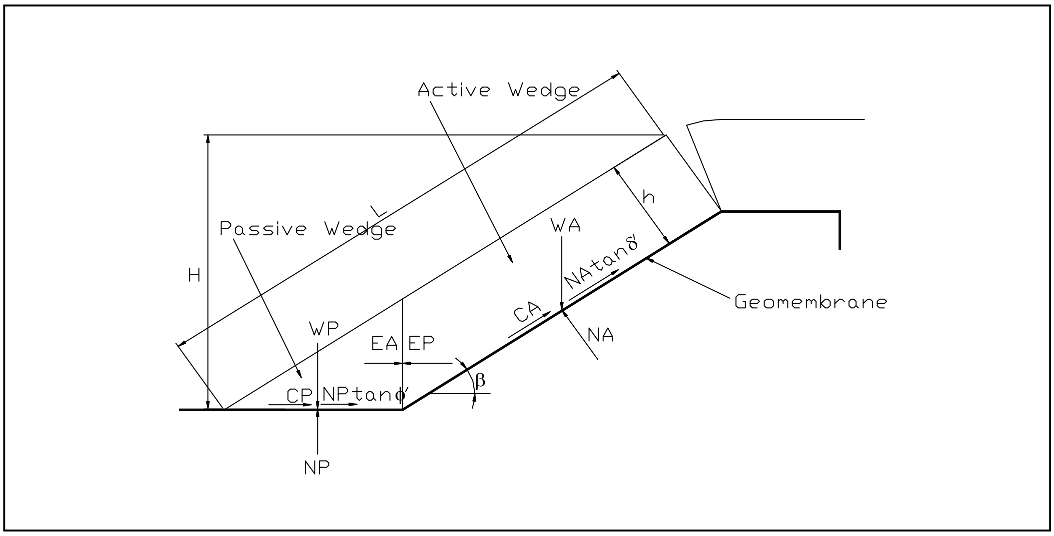
APPENDIX SRA4

RESULTS OF THE TRANSLATIONAL AND INTEGRITY ASSESSMENTS

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	26	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	7	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* *1.535*

Factor of Safety against leachate drainage blanket sliding **1.53**

PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-47.98	kN
Tension developed in geomembrane, T	-203.09	kN

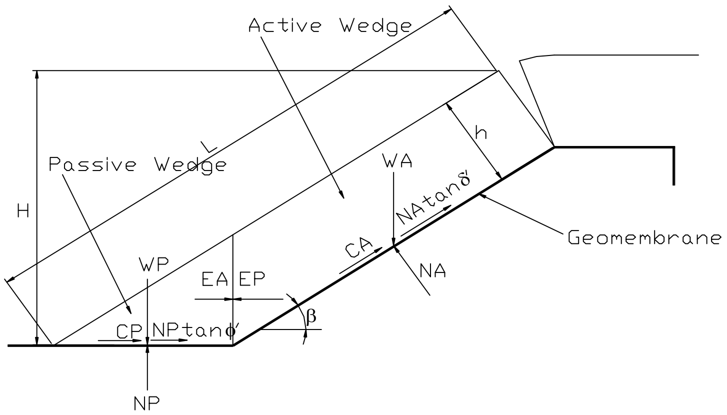
Conclusion:

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.

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	26	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	7	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	-47.98	kN
Tension developed in geomembrane, T	-144.34	kN

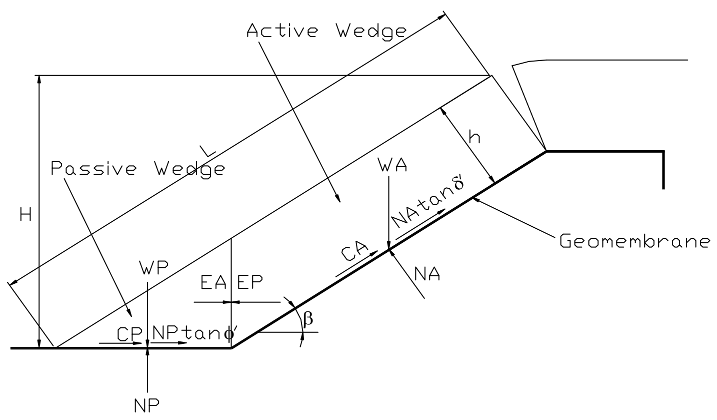
Conclusion:

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.

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	26	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	7	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	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* *1.959*

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

PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-41.22	kN
Tension developed in geomembrane, T	-169.99	kN

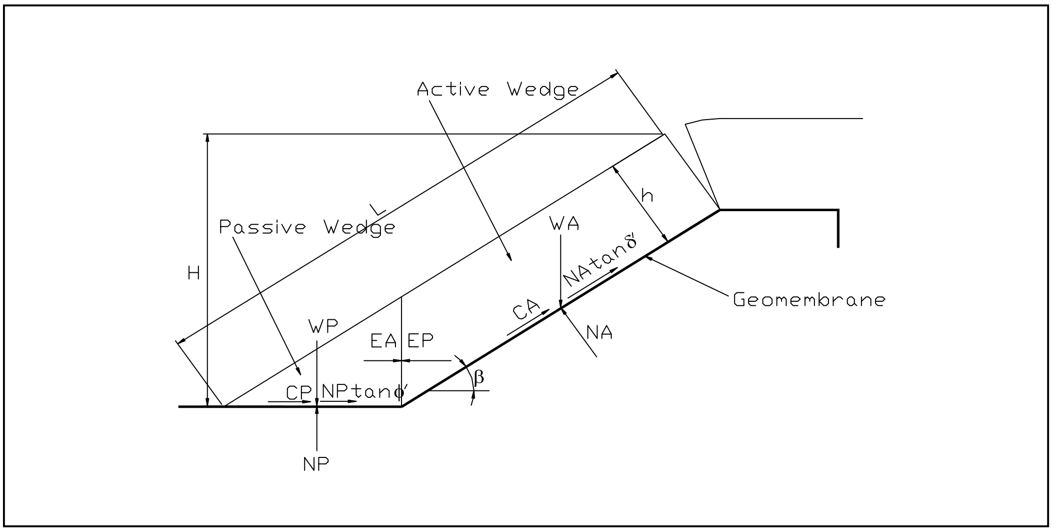
Conclusion:

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.

Integrity of geosynthetic lining system on inter-cell bund (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	26	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	7	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* *1.959*

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

PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-41.22	kN
Tension developed in geomembrane, T	-122.93	kN

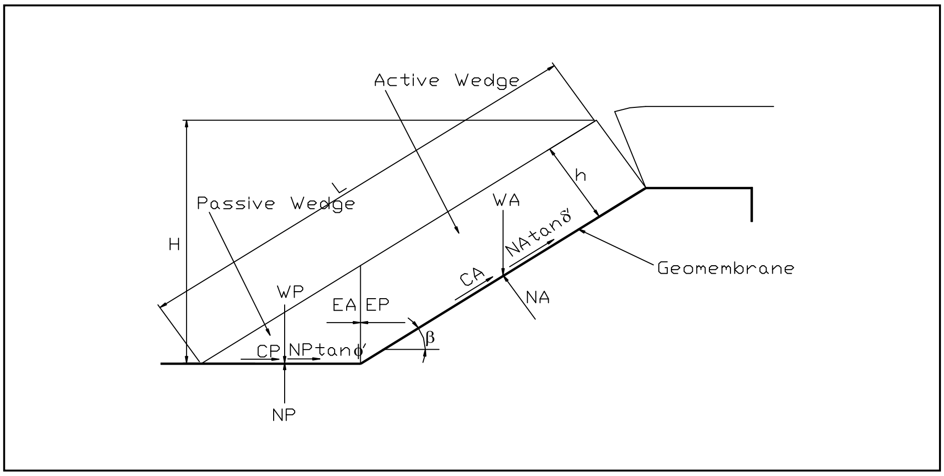
Conclusion:

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.

Integrity of geosynthetic capping system - 1v:6h slope 1m thick restoration - Short term with peak interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic capping system (PSR = 0)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17

Geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / geomembrane friction angle	δ_2	26	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	7	kN/m²	
Geomembrane / undrained regulation layer friction angle	δ_3	4.4	°	0.08
Geomembrane / undrained regulation layer cohesion inte	α_3	36	kN/m²	

Parallel submergence ratio, PSR 0

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	2682.40	kN
Weight and Effective Weight of Passive Wedge, W_P	55.51	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	2645.92	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 434.88
b -1589.96
c 116.54

aF²+bF+c=0 *0.07* *3.58*

Factor of Safety against restoration material sliding **3.58**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-1947.44	kN
Tension developed in geomembrane, T	-5018.51	kN

Conclusion:

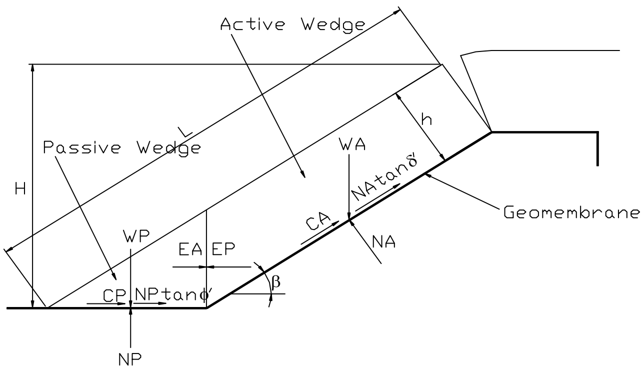
The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

MJCA Technical advisers on environmental issues	**Job No:**	AU/KCW/DFR/3230/01		
	Date:	April 2021	**Engineer:**	DFR
	Sheet	11	**Checked:**	SK
	of	72	**Project reference**	
Baddesley Colliery Offices, Main Road, Baxterley Atherstone Warwickshire CV9 2LE Tel: 01827 717891 Fax: 01827 718507	Western Extension Area ENRMF Stability Risk Assessment			

Integrity of geosynthetic capping system - 1v:6h slope 1m thick restoration - Long term with peak interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic capping system (PSR = 0.5)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	*0.44*
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	*0.17*

Geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	33	°	*0.58*
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / geomembrane friction angle	δ_2	26	°	*0.45*
Geotextile / geomembrane cohesion intercept	α_2	7	kN/m²	
Geomembrane / drained regulation layer friction angle	δ_3	10.7	°	*0.19*
Geomembrane / drained regulation layer cohesion interce	α_3	26.7	kN/m²	

Parallel submergence ratio, PSR 0.5

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0.5	m
Weight and Effective Weight of Active Wedge , W_A	2832.96	kN
Weight and Effective Weight of Passive Wedge, W_P	57.06	kN
Pore pressure perp to slope, Un	742.58	kN
Pore pressure in interwedge surface, Uh	1.250	kN
Force Normal to Active Wedge, N_A	2051.85	kN
Vert Pore Pressure on Passive Wedge, Uv	7.50	kN

a 459.32

b -1208.44

c 86.97

$aF^2+bF+c=0$ *0.07* *2.56*

Factor of Safety against restoration material sliding **2.56**

PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T	-1808.42	kN
Tension developed in geomembrane, T	-3639.66	kN

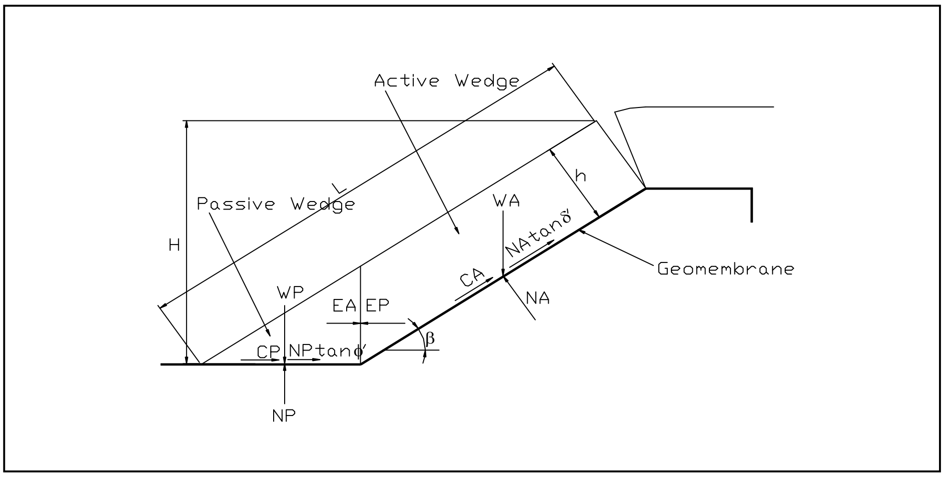
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of geosynthetic capping system - 1v:6h slope 1m thick restoration - Short term with residual interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic capping system (PSR = 0), using residual values for the geotextile/geomembrane and geotextile/restoration materials interface.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17

Residual geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / geomembrane friction angle	δ_2	13	°	0.23
Geotextile / geomembrane cohesion intercept	α_2	4	kN/m²	
Geomembrane / undrained regulation layer friction angle	δ_3	4.4	°	0.08
Geomembrane / undrained regulation layer cohesion inte	α_3	36	kN/m²	

Parallel submergence ratio, PSR 0

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	2682.40	kN
Weight and Effective Weight of Passive Wedge, W_P	55.51	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	2645.92	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 434.88
b -2674.28
c 200.79

$aF^2+bF+c=0$ *0.08* *6.07*

Factor of Safety against restoration material sliding **6.07**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-795.63	kN
Tension developed in geomembrane, T	-5480.79	kN

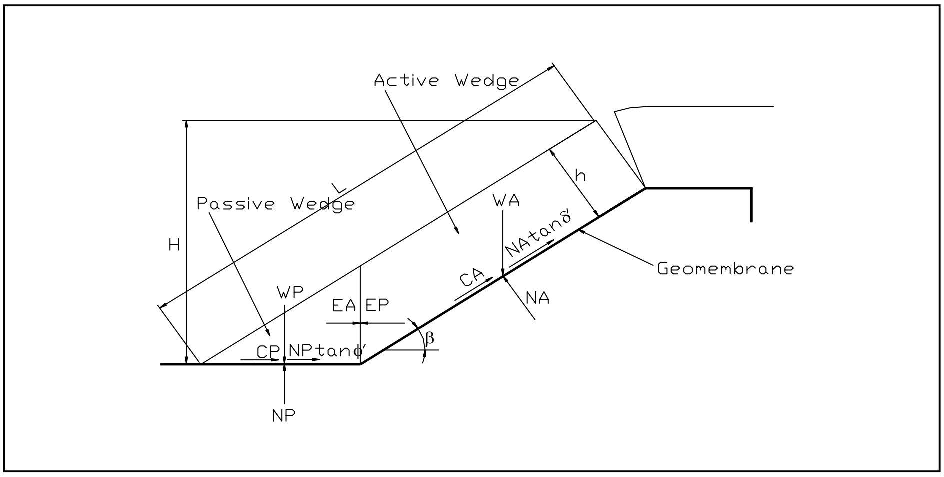
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

Integrity of geosynthetic capping system - 1v:6h slope 1m thick restoration - Long term with residual interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic capping system (PSR = 0.5), using residual values for the geotextile/geomembrane and geotextile/restoration material interface.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17

Residual geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / geomembrane friction angle	δ_2	13	°	0.23
Geotextile / geomembrane cohesion intercept	α_2	4	kN/m²	
Geomembrane / drained regulation layer friction angle	δ_3	10.7	°	0.19
Geomembrane / drained regulation layer cohesion interc	α_3	26.7	kN/m²	

Parallel submergence ratio, PSR 0.5

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0.5	m
Weight and Effective Weight of Active Wedge , W_A	2832.96	kN
Weight and Effective Weight of Passive Wedge, W_P	57.06	kN
Pore pressure perp to slope, Un	742.58	kN
Pore pressure in interwedge surface, Uh	1.250	kN
Force Normal to Active Wedge, N_A	2051.85	kN
Vert Pore Pressure on Passive Wedge, Uv	7.50	kN

a 459.32
b -2352.49
c 175.86

$aF^2+bF+c=0$ *0.08* *5.05*

Factor of Safety against restoration material sliding **5.05**
PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T	-725.13	kN
Tension developed in geomembrane, T	-4348.86	kN

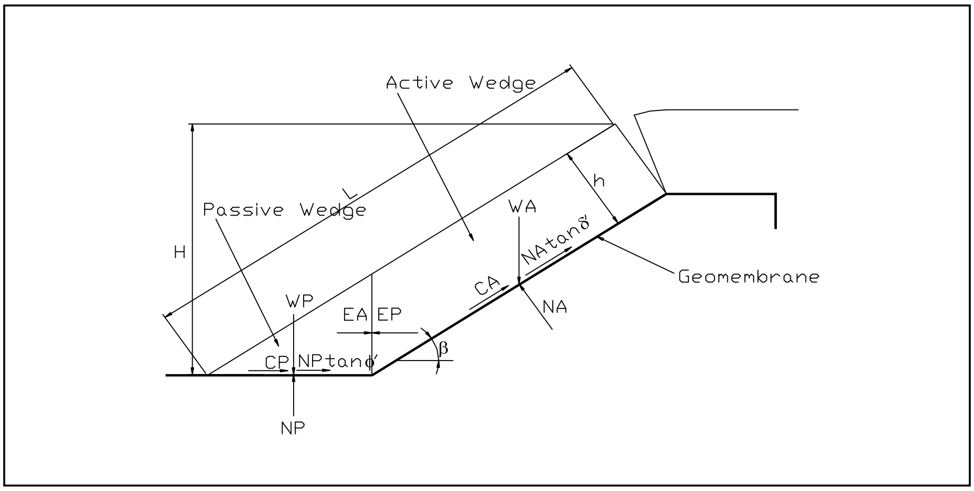
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of geosynthetic capping system - 1v:6h slope 1.5m thick restoration - Short term with peak interface shear strength values

Aim: To assess the short term stability and integrity of the geosynthetic capping system (PSR = 0)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17

Geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / geomembrane friction angle	δ_2	26	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	7	kN/m²	
Geomembrane / undrained regulation layer friction angle	δ_3	4.4	°	0.08
Geomembrane / undrained regulation layer cohesion int	α_3	36	kN/m²	

Parallel submergence ratio, PSR 0

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	3981.96	kN
Weight and Effective Weight of Passive Wedge, W_P	124.90	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	3927.81	kN
Vert Pore Pressure on Passive Wedge, U'	0.00	kN

a 645.57
b -2475.05
c 180.34

$aF^2+bF+c=0$ *0.07* *3.76*

Factor of Safety against restoration material sliding **3.76**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-2393.40	kN
Tension developed in geomembrane, T	-4978.78	kN

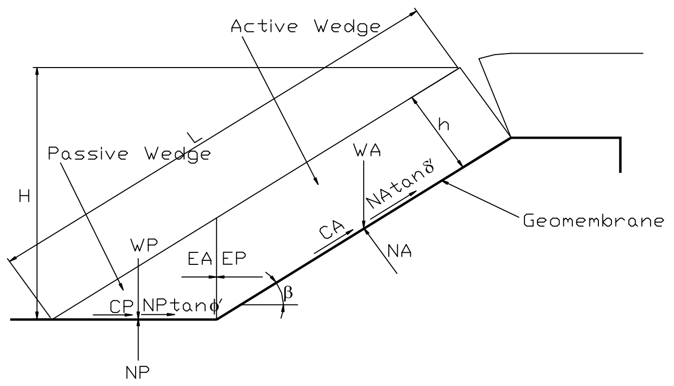
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1.5m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

Integrity of geosynthetic capping system - 1v:6h slope 1.5m thick restoration - Long term with peak interface shear strength values

Aim: To assess the long term stability and integrity of the geosynthetic capping system (PSR = 0.5)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17

Geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / geomembrane friction angle	δ_2	26	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	7	kN/m²	
Geomembrane / drained regulation layer friction angle	δ_3	10.7	°	0.19
Geomembrane / drained regulation layer cohesion interc	α_3	26.7	kN/m²	

Parallel submergence ratio, PSR 0.5

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0.75	m
Weight and Effective Weight of Active Wedge , W_A	4206.65	kN
Weight and Effective Weight of Passive Wedge, W_P	128.37	kN
Pore pressure perp to slope, Un	1108.17	kN
Pore pressure in interwedge surface, Uh	2.813	kN
Force Normal to Active Wedge, N_A	3041.27	kN
Vert Pore Pressure on Passive Wedge, U'	16.88	kN

a 682.07
b -1903.52
c 136.21

$aF^2+bF+c=0$ *0.07* *2.72*

Factor of Safety against restoration material sliding **2.72**
PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T	-2201.15	kN
Tension developed in geomembrane, T	-3709.84	kN

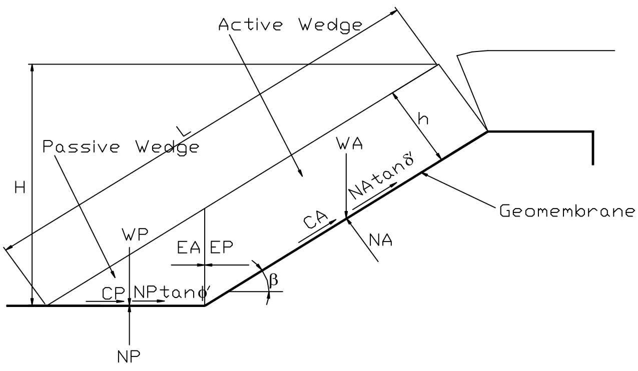
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1.5m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of geosynthetic capping system - 1v:6h slope 1.5m thick restoration - Short term with residual interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic capping system (PSR = 0), using residual values for the geotextile/geomembrane and geotextile/restoration materials interface.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.436
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.165
Residual geosynthetics interface shear strengths:				
Restoration materials / geotextile friction angle	δ_1	28.7	°	0.501
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / geomembrane friction angle	δ_2	13	°	0.227
Geotextile / geomembrane cohesion intercept	α_2	4	kN/m²	
Geomembrane / undrained regulation layer friction angle	δ_3	4.4	°	0.077
Geomembrane / undrained regulation layer cohesion inte	α_3	36	kN/m²	
Parallel submergence ratio, PSR		0		
Geosynthetic tensile strengths:				
Geotextile		19	kN/m	
Geomembrane (1mm thick)		15	kN/m	

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	3981.96	kN
Weight and Effective Weight of Passive Wedge, W_P	124.90	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	3927.81	kN
Vert Pore Pressure on Passive Wedge, U\	0.00	kN

a 645.57
b -3430.49
c 254.58

$aF^2+bF+c=0$ *0.08* *5.24*

Factor of Safety against restoration material sliding **5.24**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-896.73	kN
Tension developed in geomembrane, T	-5492.85	kN

Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1.5m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

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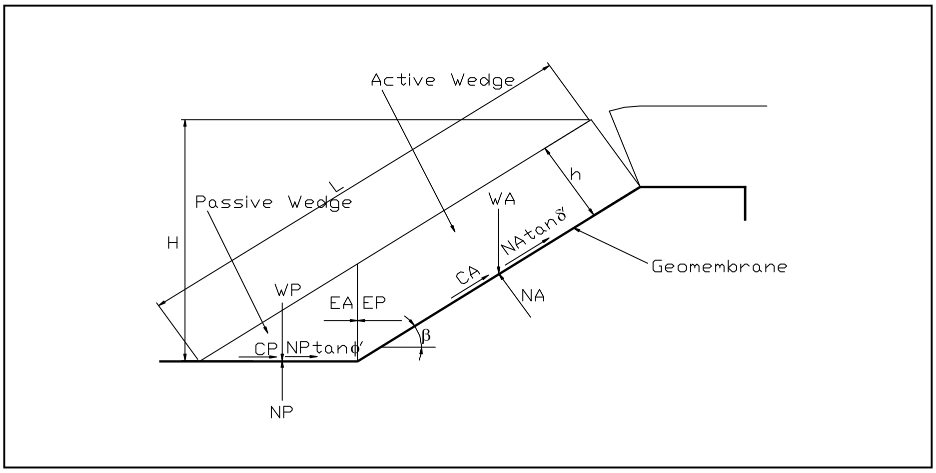
Integrity of geosynthetic capping system - 1v:6h slope 1.5m thick restoration - Long term with residual interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic capping system (PSR = 0.5), using residual values for the geotextile/geomembrane and geotextile/restoration materials interface.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	φ'	25	°	0.436
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.165

Residual geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	28.7	°	0.501
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / geomembrane friction angle	δ_2	13	°	0.227
Geotextile / geomembrane cohesion intercept	α_2	4	kN/m²	
Geomembrane / drained regulation layer friction angle	δ_3	10.7	°	0.187
Geomembrane / drained regulation layer cohesion interc	α_3	26.7	kN/m²	

Parallel submergence ratio, PSR 0.5

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0.75	m
Weight and Effective Weight of Active Wedge , W_A	4206.65	kN
Weight and Effective Weight of Passive Wedge, W_P	128.37	kN
Pore pressure perp to slope, Un	1108.17	kN
Pore pressure in interwedge surface, Uh	2.813	kN
Force Normal to Active Wedge, N_A	3041.27	kN
Vert Pore Pressure on Passive Wedge, U\	16.88	kN

a 682.07
b -2948.09
c 217.38

$aF^2+bF+c=0$ *0.08* *4.25*

Factor of Safety against restoration material sliding **4.25**
PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T	-768.67	kN
Tension developed in geomembrane, T	-4493.51	kN

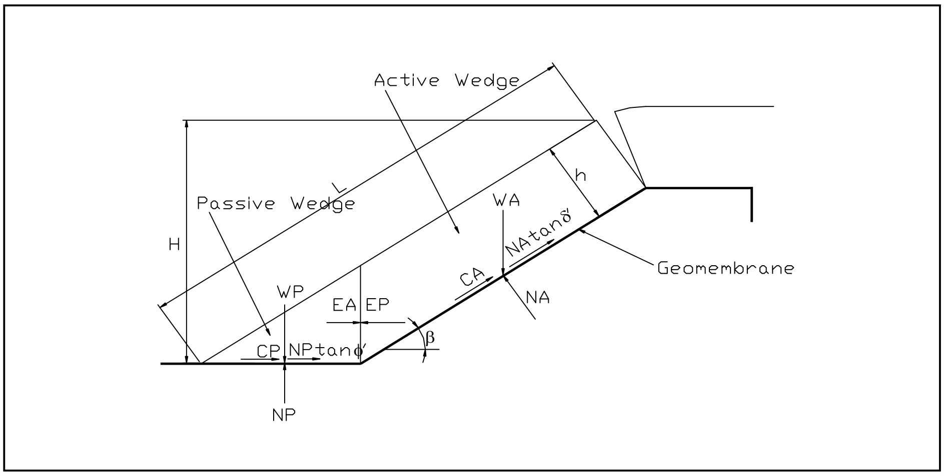
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1.5m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of geosynthetic capping system - 1v:4h slope 1m thick restoration - Short term with peak interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic capping system (PSR = 0)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24

Geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / geomembrane friction angle	δ_2	26	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	7	kN/m²	
Geomembrane / undrained regulation layer friction angle	δ_3	4.4	°	0.08
Geomembrane / undrained regulation layer cohesion inte	α_3	36	kN/m²	

Parallel submergence ratio, PSR 0

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	852.34	kN
Weight and Effective Weight of Passive Wedge, W_P	38.25	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	826.89	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a	200.55
b	-520.39
c	53.46

$aF^2+bF+c=0$ *0.11* *2.49*

Factor of Safety against restoration material sliding **2.49**

PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-568.05	kN
Tension developed in geomembrane, T	-1539.04	kN

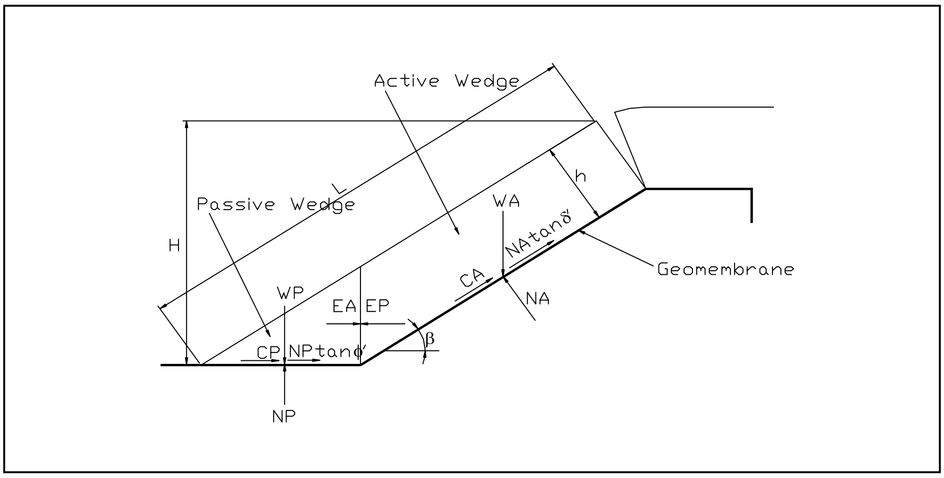
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

Integrity of geosynthetic capping system - 1v:3h slope 1m thick restoration - Long term with peak interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic capping system (PSR = 0.5)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24

Geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / geomembrane friction angle	δ_2	26	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	7	kN/m²	
Geomembrane / drained regulation layer friction angle	δ_3	10.7	°	0.19
Geomembrane / drained regulation layer cohesion interc	α_3	26.7	kN/m²	

Parallel submergence ratio, PSR 0.5

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0.5	m
Weight and Effective Weight of Active Wedge , W_A	900.76	kN
Weight and Effective Weight of Passive Wedge, W_P	39.31	kN
Pore pressure perp to slope, Un	234.85	kN
Pore pressure in interwedge surface, Uh	1.250	kN
Force Normal to Active Wedge, N_A	639.02	kN
Vert Pore Pressure on Passive Wedge, Uv	5.00	kN

a 212.02
b -401.38
c 39.66

aF²+bF+c=0 *0.1* *1.79*

Factor of Safety against restoration material sliding **1.79**

PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T	-495.98	kN
Tension developed in geomembrane, T	-1051.03	kN

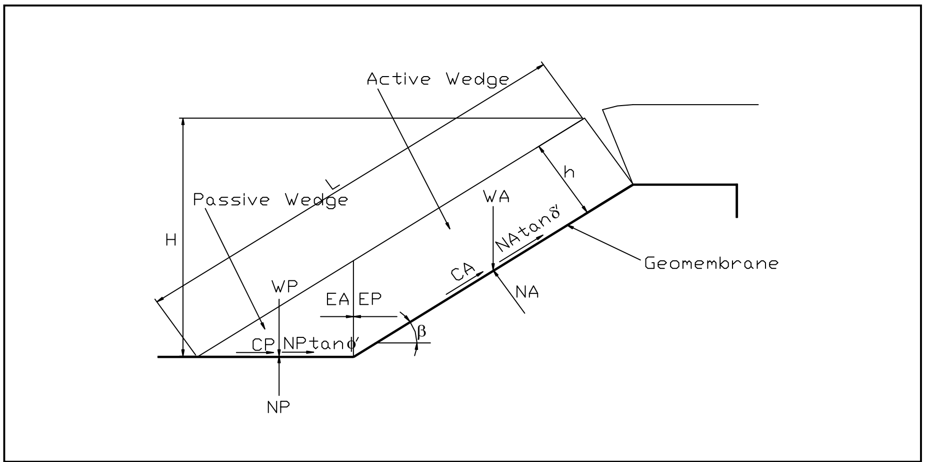
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of geosynthetic capping system - 1v:4h slope 1m thick restoration - Short term with residual interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic capping system (PSR = 0), using residual values for the geotextile/geomembrane and geotextile/restoration materials interface.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24

Residual geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / geomembrane friction angle	δ_2	13	°	0.23
Geotextile / geomembrane cohesion intercept	α_2	4	kN/m²	
Geomembrane / undrained regulation layer friction angle	δ_3	4.4	°	0.08
Geomembrane / undrained regulation layer cohesion inte	α_3	36	kN/m²	

Parallel submergence ratio, PSR 0

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	852.34	kN
Weight and Effective Weight of Passive Wedge, W_P	38.25	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	826.89	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 200.55
b -870.62
c 94.29

$aF^2+bF+c=0$ *0.11* *4.23*

Factor of Safety against restoration material sliding **4.23**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-195.49	kN
Tension developed in geomembrane, T	-1753.72	kN

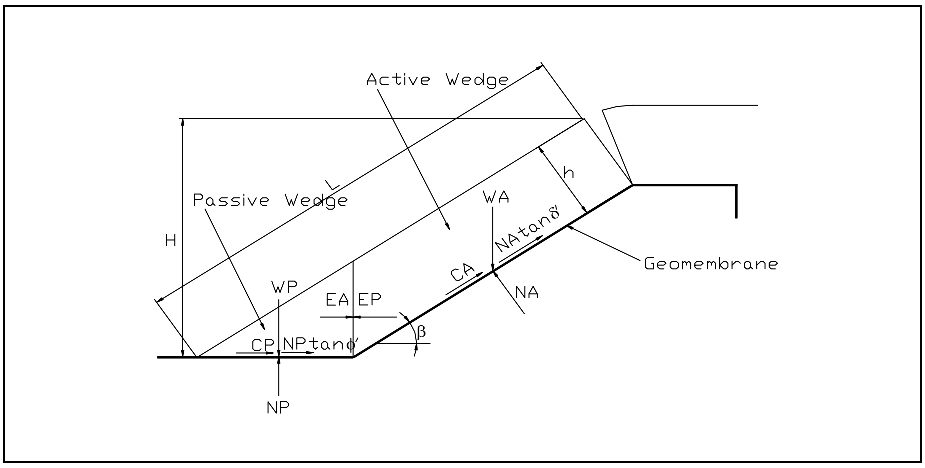
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

Integrity of geosynthetic capping system - 1v:4h slope 1m thick restoration - Long term with residual interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic capping system (PSR = 0.5), using residual values for the geotextile/geomembrane and geotextile/restoration materials interface.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	φ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24

Residual geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / geomembrane friction angle	δ_2	13	°	0.23
Geotextile / geomembrane cohesion intercept	α_2	4	kN/m²	
Geomembrane / drained regulation layer friction angle	δ_3	10.7	°	0.19
Geomembrane / drained regulation layer cohesion interce	α_3	26.7	kN/m²	

Parallel submergence ratio, PSR 0.5

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0.5	m
Weight and Effective Weight of Active Wedge , W_A	900.76	kN
Weight and Effective Weight of Passive Wedge, W_P	39.31	kN
Pore pressure perp to slope, Un	234.85	kN
Pore pressure in interwedge surface, Uh	1.250	kN
Force Normal to Active Wedge, N_A	639.02	kN
Vert Pore Pressure on Passive Wedge, Uv	5.00	kN

a 212.02

b -770.19

c 82.65

$aF^2+bF+c=0$ *0.11* *3.52*

Factor of Safety against restoration material sliding **3.52**

PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T	-158.52	kN
Tension developed in geomembrane, T	-1377.39	kN

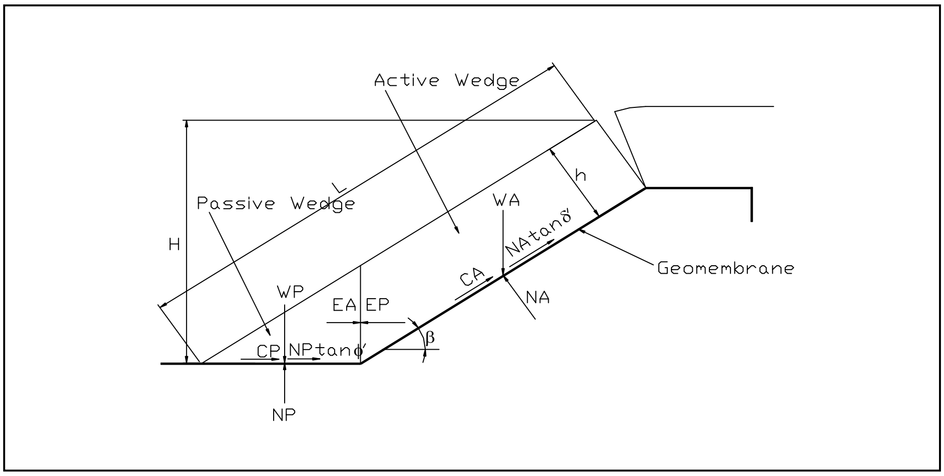
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of geosynthetic capping system - 1v:4h slope 1.5m thick restoration - Short term with peak interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic capping system (PSR = 0)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24
Geosynthetics interface shear strengths:				
Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / geomembrane friction angle	δ_2	26	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	7	kN/m²	
Geomembrane / undrained regulation layer friction angle	δ_3	4.4	°	0.08
Geomembrane / undrained regulation layer cohesion inte	α_3	36	kN/m²	
Parallel submergence ratio, PSR		0		
Geosynthetic tensile strengths:				
Geotextile		19	kN/m	
Geomembrane (1mm thick)		15	kN/m	

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	1249.82	kN
Weight and Effective Weight of Passive Wedge, W_P	86.06	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	1212.51	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a	294.08
b	-806.84
c	81.78

$aF^2+bF+c=0$ *0.11* *2.64*

Factor of Safety against restoration material sliding **2.64**

PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-683.81	kN
Tension developed in geomembrane, T	-1510.03	kN

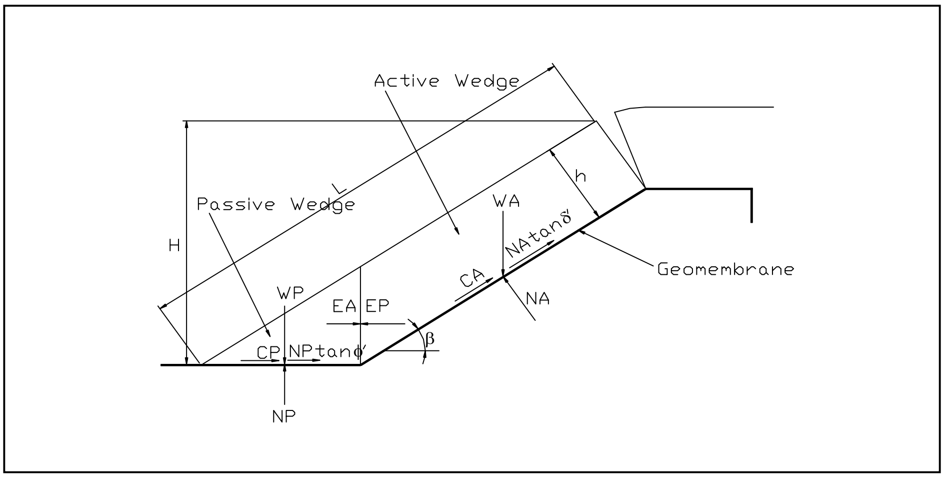
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1.5m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

Integrity of geosynthetic capping system - 1v:4h slope 1.5m thick restoration - Long term with peak interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic capping system (PSR = 0.5)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24
Geosynthetics interface shear strengths:				
Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / geomembrane friction angle	δ_2	26	°	0.45
Geotextile / geomembrane cohesion intercept	α_2	7	kN/m²	
Geomembrane / drained regulation layer friction angle	δ_3	10.7	°	0.19
Geomembrane / drained regulation layer cohesion interc	α_3	26.7	kN/m²	
Parallel submergence ratio, PSR		0.5		
Geosynthetic tensile strengths:				
Geotextile		19	kN/m	
Geomembrane (1mm thick)		15	kN/m	

Stability of restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0.75	m
Weight and Effective Weight of Active Wedge , W_A	1321.65	kN
Weight and Effective Weight of Passive Wedge, W_P	88.45	kN
Pore pressure perp to slope, Un	348.40	kN
Pore pressure in interwedge surface, Uh	2.813	kN
Force Normal to Active Wedge, N_A	933.78	kN
Vert Pore Pressure on Passive Wedge, Uv	11.25	kN

a 311.14

b -628.77

c 61.31

$aF^2+bF+c=0$ *0.1* *1.92*

Factor of Safety against restoration material sliding **1.92**

PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T	-583.93	kN
Tension developed in geomembrane, T	-1051.12	kN

Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1.5m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Technical advisers on environmental issues

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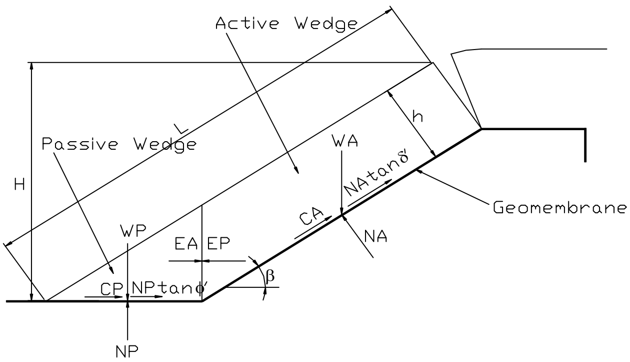
Western Extension Area ENRMF
Stability Risk Assessment

Integrity of geosynthetic capping system - 1v:4h slope 1.5m thick restoration - Short term with residual interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic capping system (PSR = 0), using residual values for the geotextile/geomembrane interface and restoration material/geotextile interface.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24

Residual geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / geomembrane friction angle	δ_2	13	°	0.23
Geotextile / geomembrane cohesion intercept	α_2	4	kN/m²	
Geomembrane / undrained regulation layer friction angle	δ_3	4.4	°	0.08
Geomembrane / undrained regulation layer cohesion inte	α_3	36	kN/m²	

Parallel submergence ratio, PSR 0

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	1249.82	kN
Weight and Effective Weight of Passive Wedge, W_P	86.06	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	1212.51	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 294.08
b -1118.95
c 118.16

$aF^2+bF+c=0$ *0.11* *3.7*

Factor of Safety against restoration material sliding **3.70**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T	-202.08	kN
Tension developed in geomembrane, T	-1746.41	kN

Conclusion:

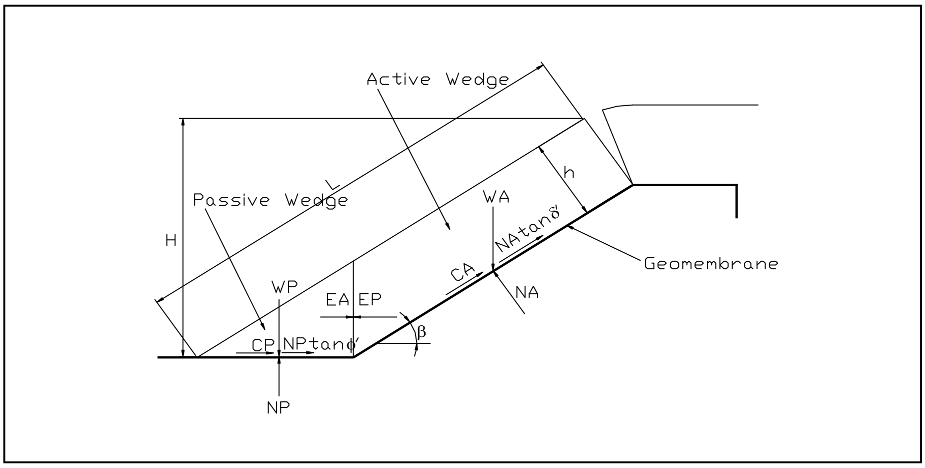
The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1.5m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

Technical advisers on environmental issues	Job No:	AU/KCW/DFR/3230/01		
	Date:	April 2021	Engineer:	DFR
	Sheet	39	Checked:	SK
	of	72	Project reference	
Baddesley Colliery Offices, Main Road, Baxterley Atherstone Warwickshire CV9 2LE Tel: 01827 717891 Fax: 01827 718507	Western Extension Area ENRMF Stability Risk Assessment			

Integrity of geosynthetic capping system - 1v:4h slope 1.5m thick restoration - Long term with residual interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic capping system (PSR = 0.5), using residual values for the geotextile/geomembrane interface and restoration material/geotextile interface.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24

Residual geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / geomembrane friction angle	δ_2	13	°	0.23
Geotextile / geomembrane cohesion intercept	α_2	4	kN/m²	
Geomembrane / drained regulation layer friction angle	δ_3	10.7	°	0.19
Geomembrane / drained regulation layer cohesion interce	α_3	26.7	kN/m²	

Parallel submergence ratio, PSR 0.5

Geosynthetic tensile strengths:

Geotextile	19	kN/m
Geomembrane (1mm thick)	15	kN/m

Stability of restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0.75	m
Weight and Effective Weight of Active Wedge , W_A	1321.65	kN
Weight and Effective Weight of Passive Wedge, W_P	88.45	kN
Pore pressure perp to slope, Un	348.40	kN
Pore pressure in interwedge surface, Uh	2.813	kN
Force Normal to Active Wedge, N_A	933.78	kN
Vert Pore Pressure on Passive Wedge, Uv	11.25	kN

a 311.14
b -968.44
c 100.91

aF²+bF+c=0 *0.11* *3*

Factor of Safety against restoration material sliding **3.00**
PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T	-137.67	kN
Tension developed in geomembrane, T	-1408.55	kN

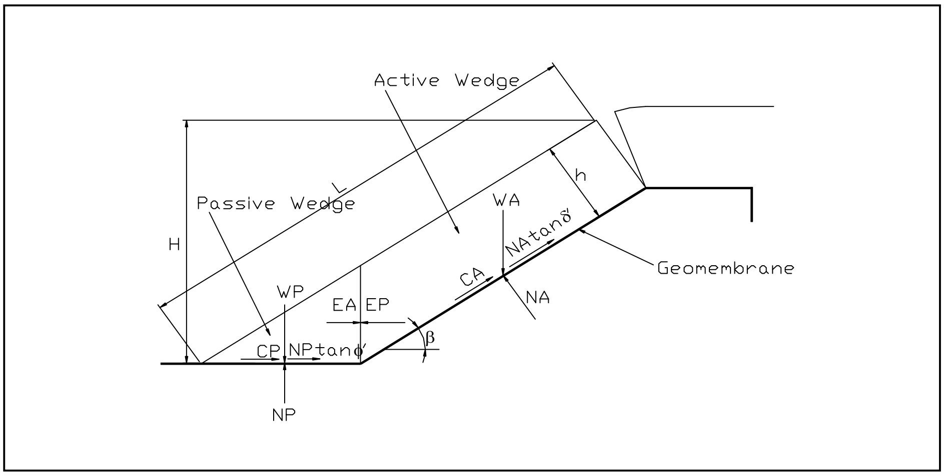
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1.5m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of clay capping system - 1v:6h slope 1m thick restoration - Short term with peak interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17

Geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / undrained clay cap friction angle	δ_2	4.4	°	0.08
Geotextile / undrained clay cap cohesion intercept	α_2	36	kN/m²	

Parallel submergence ratio, PSR 0

Geosynthetic tensile strengths:

Geotextile 19 kN/m

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	2682.40	kN
Weight and Effective Weight of Passive Wedge, W_P	55.51	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	2645.92	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 434.88
b -1589.96
c 116.54

$aF^2+bF+c=0$ *0.07* *3.58*

Factor of Safety against restoration material sliding **3.58**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T -5249.11 kN

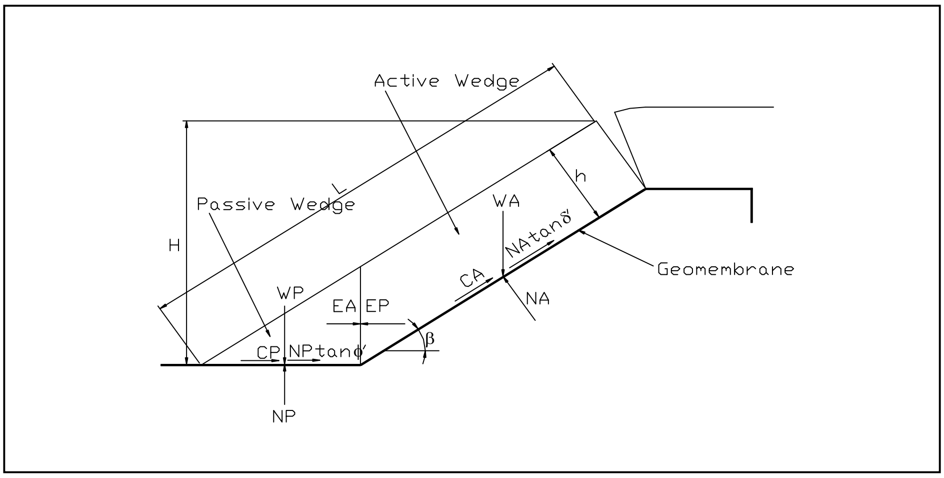
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

Integrity of geosynthetic capping system - 1v:6h slope 1m thick restoration - Long term with peak interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0.5)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17
Geosynthetics interface shear strengths:				
Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / drained clay cap friction angle	δ_2	10.7	°	0.19
Geotextile / drained clay cap cohesion intercept	α_2	26.7	kN/m²	
Parallel submergence ratio, PSR		0.5		
Geosynthetic tensile strengths:				
Geotextile		19	kN/m	

Stability of restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0.5	m
Weight and Effective Weight of Active Wedge , W_A	2832.96	kN
Weight and Effective Weight of Passive Wedge, W_P	57.06	kN
Pore pressure perp to slope, Un	742.58	kN
Pore pressure in interwedge surface, Uh	1.250	kN
Force Normal to Active Wedge, N_A	2051.85	kN
Vert Pore Pressure on Passive Wedge, Uv	7.50	kN

a 459.32
b -1208.44
c 86.97

$aF^2+bF+c=0$ *0.07* *2.56*

Factor of Safety against restoration material sliding **2.56**
PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T -3953.17 kN

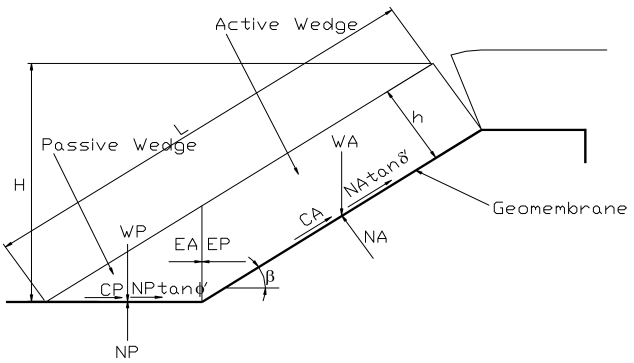
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of clay capping system - 1v:6h slope 1m thick restoration - Short term with residual interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0), using residual values for the geotextile/geomembrane and geotextile/restoration materials interface.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17
Residual geosynthetics interface shear strengths:				
Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / undrained clay cap friction angle	δ_2	4.4	°	0.08
Geotextile / undrained clay cap cohesion intercept	α_2	36	kN/m²	
Parallel submergence ratio, PSR		0		
Geosynthetic tensile strengths:				
Geotextile		19	kN/m	

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	2682.40	kN
Weight and Effective Weight of Passive Wedge, W_P	55.51	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	2645.92	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 434.88
b -2674.28
c 200.79

$aF^2+bF+c=0$ *0.08* *6.07*

Factor of Safety against restoration material sliding **6.07**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T -5247.33 kN

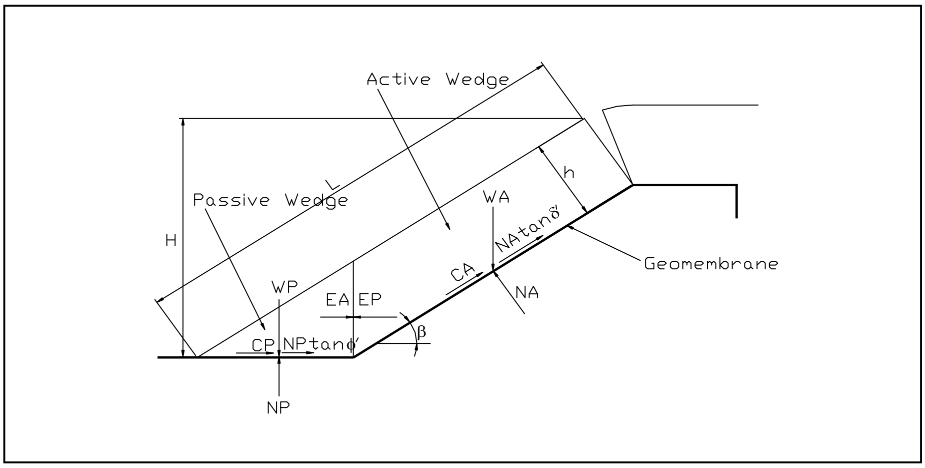
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

Integrity of clay capping system - 1v:6h slope 1m thick restoration - Long term with residual interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0.5), using residual values for the geotextile/geomembrane and geotextile/restoration material interface.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17

Residual geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / drained clay cap friction angle	δ_2	10.7	°	0.19
Geotextile / drained clay cap cohesion intercept	α_2	26.7	kN/m²	

Parallel submergence ratio, PSR 0.5

Geosynthetic tensile strengths:

Geotextile 19 kN/m

Stability of restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0.5	m
Weight and Effective Weight of Active Wedge , W_A	2832.96	kN
Weight and Effective Weight of Passive Wedge, W_P	57.06	kN
Pore pressure perp to slope, Un	742.58	kN
Pore pressure in interwedge surface, Uh	1.250	kN
Force Normal to Active Wedge, N_A	2051.85	kN
Vert Pore Pressure on Passive Wedge, Uv	7.50	kN

a 459.32
b -2352.49
c 175.86

$aF^2+bF+c=0$ *0.08* *5.05*

Factor of Safety against restoration material sliding **5.05**

PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T -4058.45 kN

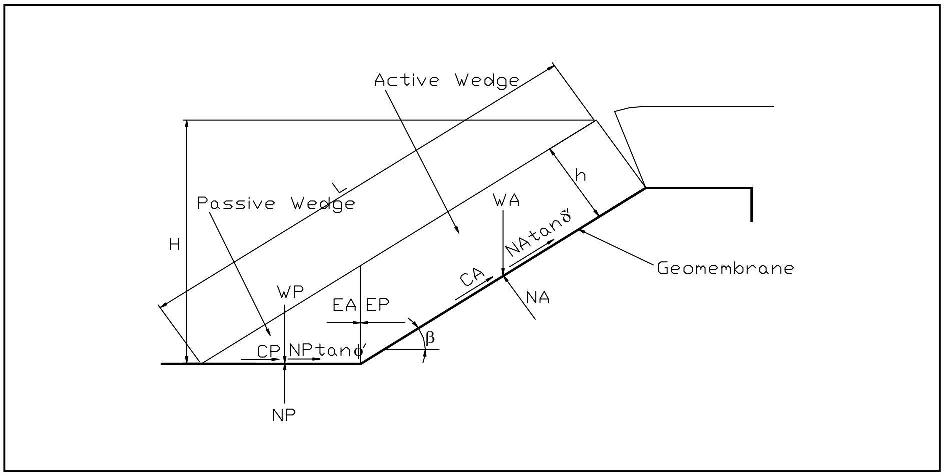
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of clay capping system - 1v:6h slope 1.5m thick restoration - Short term with peak interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17
Geosynthetics interface shear strengths:				
Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / undrained clay cap friction angle	δ_2	4.4	°	0.08
Geotextile / undrained clay cap cohesion intercept	α_2	36	kN/m²	
Parallel submergence ratio, PSR		0		
Geosynthetic tensile strengths:				
Geotextile		19	kN/m	

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	3981.96	kN
Weight and Effective Weight of Passive Wedge, W_P	124.90	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	3927.81	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 645.57
b -2475.05
c 180.34

$aF^2+bF+c=0$ *0.07* *3.76*

Factor of Safety against restoration material sliding **3.76**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T -5140.38 kN

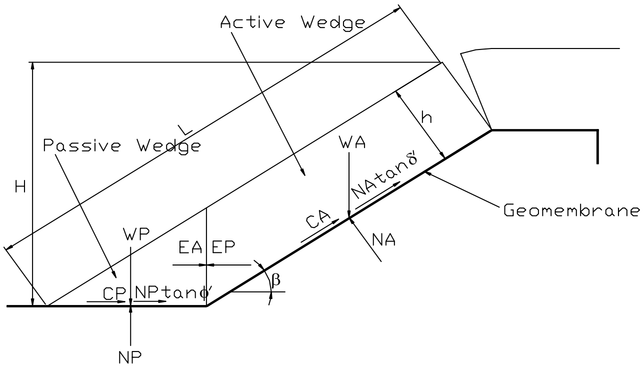
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1.5m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

Integrity of geosynthetic capping system - 1v:6h slope 1.5m thick restoration - Long term with peak interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0.5)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17
Geosynthetics interface shear strengths:				
Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / drained clay cap friction angle	δ_2	10.7	°	0.19
Geotextile / drained clay cap cohesion intercept	α_2	26.7	kN/m²	
Parallel submergence ratio, PSR		0.5		
Geosynthetic tensile strengths:				
Geotextile		19	kN/m	

Stability of restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0.75	m
Weight and Effective Weight of Active Wedge , W_A	4206.65	kN
Weight and Effective Weight of Passive Wedge, W_P	128.37	kN
Pore pressure perp to slope, Un	1108.17	kN
Pore pressure in interwedge surface, Uh	2.813	kN
Force Normal to Active Wedge, N_A	3041.27	kN
Vert Pore Pressure on Passive Wedge, Uv	16.88	kN

a 682.07
b -1903.52
c 136.21

$aF^2+bF+c=0$ *0.07* *2.72*

Factor of Safety against restoration material sliding **2.72**

PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T -3920.03 kN

Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1.5m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

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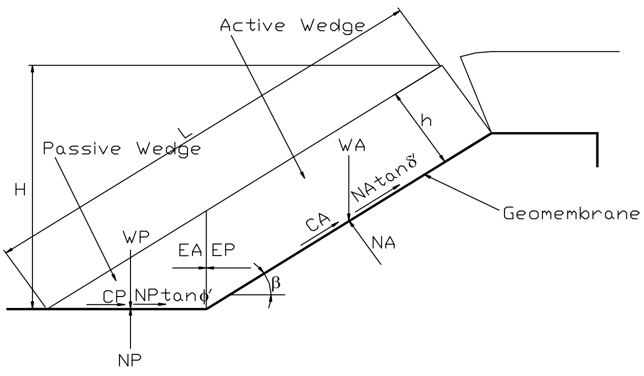
Integrity of clay capping system - 1v:6h slope 1.5m thick restoration - Short term with residual interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17

Residual geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / undrained clay cap friction angle	δ_2	4.4	°	0.08
Geotextile / undrained clay cap cohesion intercept	α_2	36	kN/m²	

Parallel submergence ratio, PSR 0

Geosynthetic tensile strengths:

Geotextile 19 kN/m

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	3981.96	kN
Weight and Effective Weight of Passive Wedge, W_P	124.90	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	3927.81	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 645.57
b -3430.49
c 254.58

$aF^2+bF+c=0$ *0.08* *5.24*

Factor of Safety against restoration material sliding **5.24**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T -5140.58 kN

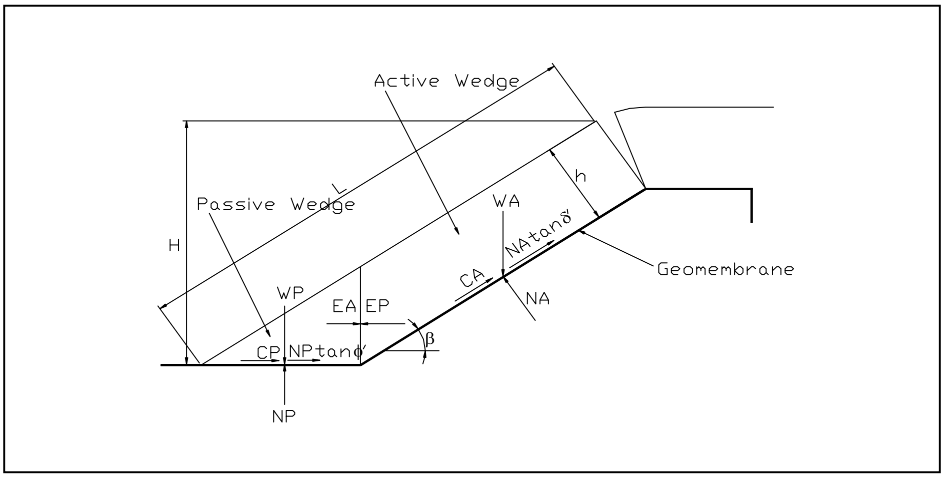
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

Integrity of clay capping system - 1v:6h slope 1.5m thick restoration - Long term with residual interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0.5)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	25	m	
Slope angle	β	9.46	°	0.17
Residual geosynthetics interface shear strengths:				
Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / drained clay cap friction angle	δ_2	10.7	°	0.19
Geotextile / drained clay cap cohesion intercept	α_2	26.7	kN/m²	
Parallel submergence ratio, PSR		0.5		
Geosynthetic tensile strengths:				
Geotextile		19	kN/m	

Stability of restoration materials

Calculated Parameters:

Length of slope, L	152.11	m
Effective thickness of water, h_w	0.75	m
Weight and Effective Weight of Active Wedge , W_A	4206.65	kN
Weight and Effective Weight of Passive Wedge, W_P	128.37	kN
Pore pressure perp to slope, Un	1108.17	kN
Pore pressure in interwedge surface, Uh	2.813	kN
Force Normal to Active Wedge, N_A	3041.27	kN
Vert Pore Pressure on Passive Wedge, Uv	16.88	kN

a 682.07
b -2948.09
c 217.38

$aF^2+bF+c=0$ *0.08* *4.25*

Factor of Safety against restoration material sliding **4.25**
PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T -4042.24 kN

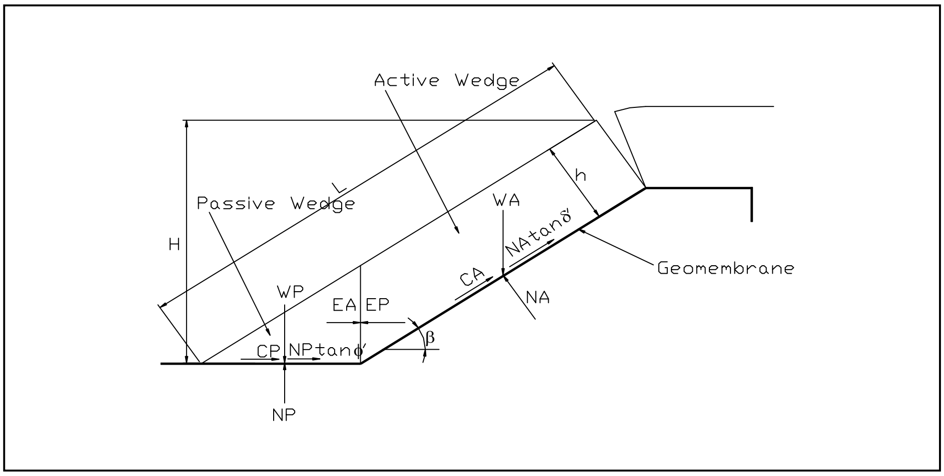
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of clay capping system - 1v:4h slope 1m thick restoration - Short term with peak interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24

Geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / undrained clay cap friction angle	δ_2	4.4	°	0.08
Geotextile / undrained clay cap cohesion intercept	α_2	36	kN/m²	

Parallel submergence ratio, PSR 0

Geosynthetic tensile strengths:

Geotextile 19 kN/m

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	852.34	kN
Weight and Effective Weight of Passive Wedge, W_P	38.25	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	826.89	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 200.55
b -520.39
c 53.46

aF²+bF+c=0 *0.11* *2.49*

Factor of Safety against restoration material sliding **2.49**

PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T -1647.97 kN

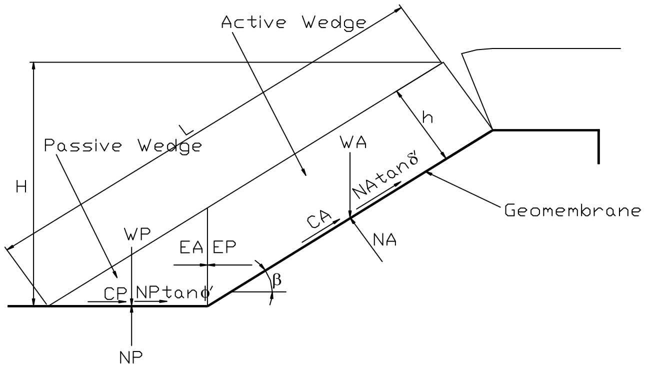
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

Integrity of geosynthetic capping system - 1v:4h slope 1m thick restoration - Long term with peak interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0.5)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24

Geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / drained clay cap friction angle	δ_2	10.7	°	0.19
Geotextile / drained clay cap cohesion intercept	α_2	26.7	kN/m²	

Parallel submergence ratio, PSR 0.5

Geosynthetic tensile strengths:

Geotextile 19 kN/m

Stability of restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0.5	m
Weight and Effective Weight of Active Wedge , W_A	900.76	kN
Weight and Effective Weight of Passive Wedge, W_P	39.31	kN
Pore pressure perp to slope, Un	234.85	kN
Pore pressure in interwedge surface, Uh	1.250	kN
Force Normal to Active Wedge, N_A	639.02	kN
Vert Pore Pressure on Passive Wedge, Uv	5.00	kN

a 212.02
b -401.38
c 39.66

$aF^2+bF+c=0$ *0.1* *1.79*

Factor of Safety against restoration material sliding **1.79**
PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T -1198.19 kN

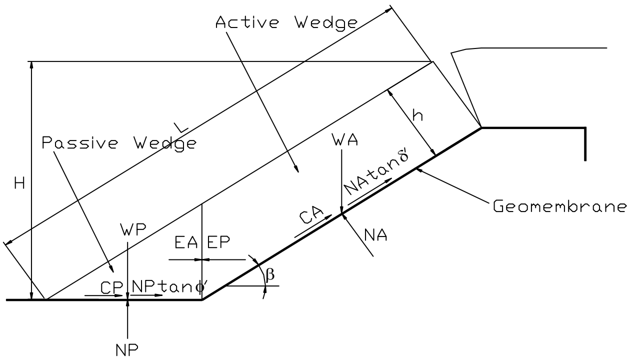
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of clay capping system - 1v:4h slope 1m thick restoration - Short term with residual interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0), using residual values for the geotextile/geomembrane and geotextile/restoration materials interface.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24
Residual geosynthetics interface shear strengths:				
Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / undrained clay cap friction angle	δ_2	4.4	°	0.08
Geotextile / undrained clay cap cohesion intercept	α_2	36	kN/m²	
Parallel submergence ratio, PSR		0		
Geosynthetic tensile strengths:				
Geotextile		19	kN/m	

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	852.34	kN
Weight and Effective Weight of Passive Wedge, W_P	38.25	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	826.89	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a	200.55
b	-870.62
c	94.29

$aF^2+bF+c=0$ *0.11* *4.23*

Factor of Safety against restoration material sliding **4.23**

PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T -1645.77 kN

Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

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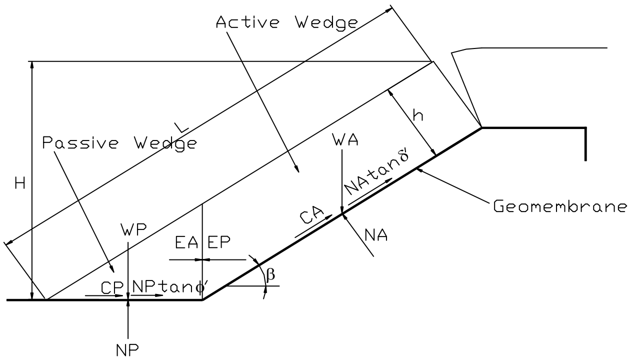
Integrity of clay capping system - 1v:4h slope 1m thick restoration - Long term with residual interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0.5), using residual values for the geotextile/geomembrane and geotextile/restoration material interface.

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24

Residual geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / drained clay cap friction angle	δ_2	10.7	°	0.19
Geotextile / drained clay cap cohesion intercept	α_2	26.7	kN/m²	

Parallel submergence ratio, PSR 0.5

Geosynthetic tensile strengths:

Geotextile 19 kN/m

Stability of restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0.5	m
Weight and Effective Weight of Active Wedge , W_A	900.76	kN
Weight and Effective Weight of Passive Wedge, W_P	39.31	kN
Pore pressure perp to slope, Un	234.85	kN
Pore pressure in interwedge surface, Uh	1.250	kN
Force Normal to Active Wedge, N_A	639.02	kN
Vert Pore Pressure on Passive Wedge, Uv	5.00	kN

a 212.02
b -770.19
c 82.65

$aF^2+bF+c=0$ *0.11* *3.52*

Factor of Safety against restoration material sliding **3.52**

PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T -1243.43 kN

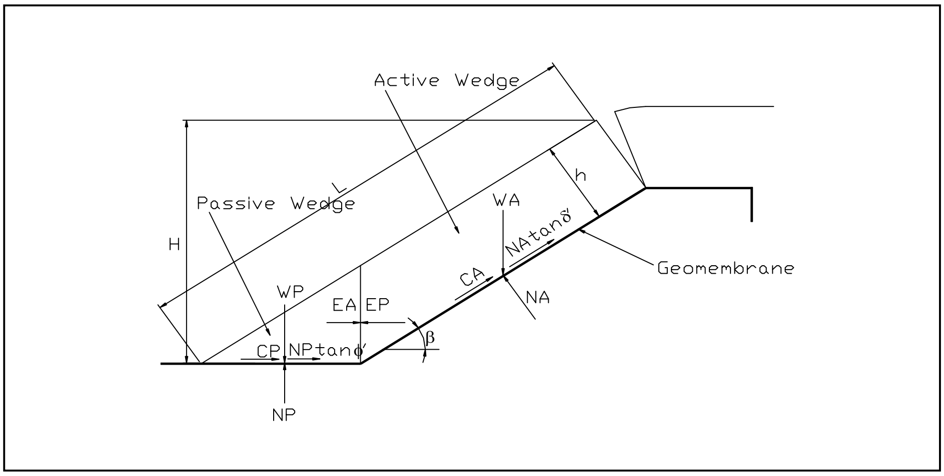
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of clay capping system - 1v:4h slope 1.5m thick restoration - Short term with peak interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24

Geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / undrained clay cap friction angle	δ_2	4.4	°	0.08
Geotextile / undrained clay cap cohesion intercept	α_2	36	kN/m²	

Parallel submergence ratio, PSR 0

Geosynthetic tensile strengths:

Geotextile 19 kN/m

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	1249.82	kN
Weight and Effective Weight of Passive Wedge, W_P	86.06	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	1212.51	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a	294.08
b	-806.84
c	81.78

$aF^2+bF+c=0$ *0.11* *2.64*

Factor of Safety against restoration material sliding **2.64**

PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T -1586.27 kN

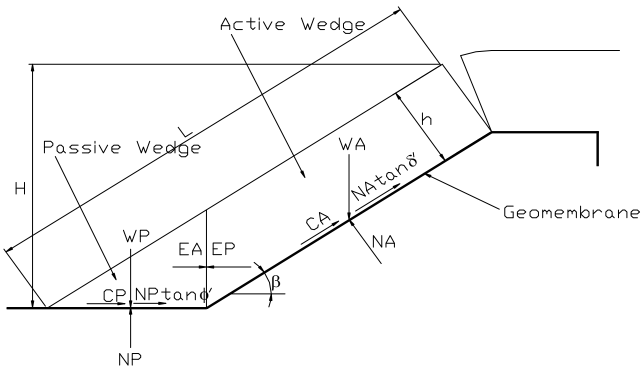
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1.5m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

Integrity of geosynthetic capping system - 1v:4h slope 1.5m thick restoration - Long term with peak interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0.5)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24

Geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	33	°	0.58
Restoration materials / geotextile cohesion intercept	α_1	-1.3	kN/m²	
Geotextile / drained clay cap friction angle	δ_2	10.7	°	0.19
Geotextile / drained clay cap cohesion intercept	α_2	26.7	kN/m²	

Parallel submergence ratio, PSR 0.5

Geosynthetic tensile strengths:

Geotextile 19 kN/m

Stability of restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0.75	m
Weight and Effective Weight of Active Wedge , W_A	1321.65	kN
Weight and Effective Weight of Passive Wedge, W_P	88.45	kN
Pore pressure perp to slope, Un	348.40	kN
Pore pressure in interwedge surface, Uh	2.813	kN
Force Normal to Active Wedge, N_A	933.78	kN
Vert Pore Pressure on Passive Wedge, Uv	11.25	kN

a 311.14

b -628.77

c 61.31

$aF^2+bF+c=0$ *0.1* *1.92*

Factor of Safety against restoration material sliding **1.92**

PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T -1149.91 kN

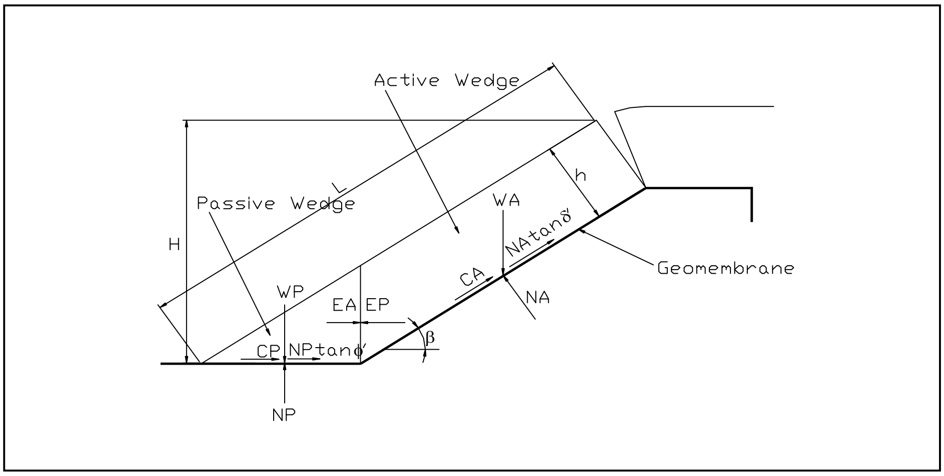
Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1.5m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.

Integrity of clay capping system - 1v:4h slope 1.5m thick restoration - Short term with residual interface shear strength parameters

Aim: To assess the short term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24
Residual geosynthetics interface shear strengths:				
Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / undrained clay cap friction angle	δ_2	4.4	°	0.08
Geotextile / undrained clay cap cohesion intercept	α_2	36	kN/m²	
Parallel submergence ratio, PSR		0		
Geosynthetic tensile strengths:				
Geotextile		19	kN/m	

Stability of the restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0	m
Weight and Effective Weight of Active Wedge , W_A	1249.82	kN
Weight and Effective Weight of Passive Wedge, W_P	86.06	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	1212.51	kN
Vert Pore Pressure on Passive Wedge, Uv	0.00	kN

a 294.08
b -1118.95
c 118.16

$aF^2+bF+c=0$ *0.11* *3.7*

Factor of Safety against restoration material sliding **3.70**
PSR = 0

Integrity of Geosynthetics

Tension developed in geotextile, T -1585.87 kN

Conclusion:

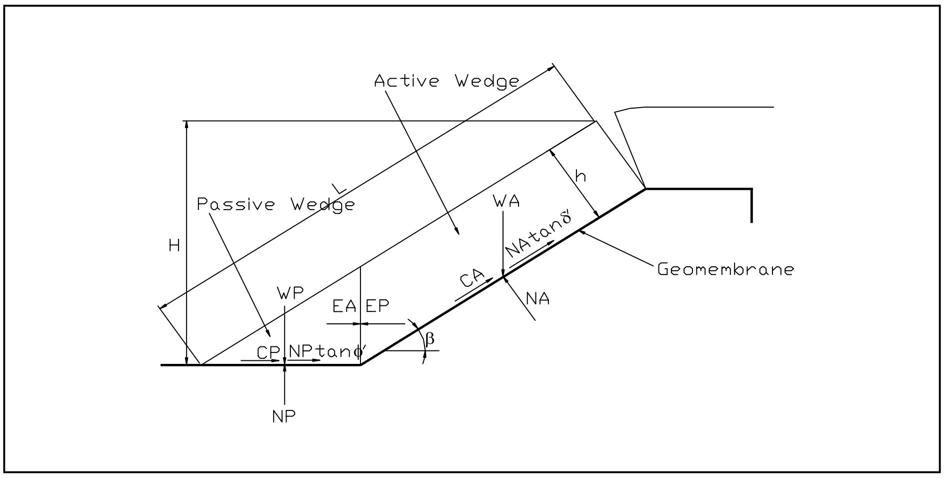
The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the short term following placement of the 1m thick restoration materials but prior to the build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to underlying layers.

	Job No:	AU/KCW/DFR/3230/01		
MJCA Technical advisers on environmental issues	Date:	April 2021	Engineer:	DFR
	Sheet	71	Checked:	SK
	of	72	Project reference	
Baddesley Colliery Offices, Main Road, Baxterley Atherstone Warwickshire CV9 2LE Tel: 01827 717891 Fax: 01827 718507	Western Extension Area ENRMF Stability Risk Assessment			

Integrity of clay capping system - 1v:4h slope 1.5m thick restoration - Long term with residual interface shear strength parameters

Aim: To assess the long term stability and integrity of the geosynthetic drainage layer of the clay capping system (PSR = 0.5)

Approach: Jones & Dixon (1998).



Input parameters

				radians
Restoration material unit weight (bulk)	γ_b	18	kN/m³	
Restoration material unit weight (saturated)	γ_{sat}	20	kN/m³	
Restoration material effective friction	ϕ'	25	°	0.44
Restoration material effective cohesion	c'	5	kN/m²	
Thickness of restoration material	h	1.5	m	
Height of slope	H	12	m	
Slope angle	β	14.04	°	0.24

Residual geosynthetics interface shear strengths:

Restoration materials / geotextile friction angle	δ_1	28.7	°	0.5
Restoration materials / geotextile cohesion intercept	α_1	7.7	kN/m²	
Geotextile / drained clay cap friction angle	δ_2	10.7	°	0.19
Geotextile / drained clay cap cohesion intercept	α_2	26.7	kN/m²	

Parallel submergence ratio, PSR 0.5

Geosynthetic tensile strengths:

Geotextile 19 kN/m

Stability of restoration materials

Calculated Parameters:

Length of slope, L	49.48	m
Effective thickness of water, h_w	0.75	m
Weight and Effective Weight of Active Wedge , W_A	1321.65	kN
Weight and Effective Weight of Passive Wedge, W_P	88.45	kN
Pore pressure perp to slope, Un	348.40	kN
Pore pressure in interwedge surface, Uh	2.813	kN
Force Normal to Active Wedge, N_A	933.78	kN
Vert Pore Pressure on Passive Wedge, Uv	11.25	kN

a 311.14
b -968.44
c 100.91

$aF^2+bF+c=0$ *0.11* *3*

Factor of Safety against restoration material sliding **3.00**
PSR = 0.5

Integrity of Geosynthetics

Tension developed in geotextile, T -1203.46 kN

Conclusion:

The geosynthetics provide sufficient interface friction to prevent instability of the capping and restoration system in the long term following placement of the 1m thick restoration materials and following build up of the water in the geocomposite drainage layer. No tension is mobilised in the geotextile or geomembrane components of the capping system. Forces are transferred to the underlying layers.