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STABILITY RISK ASSESSMENT for PROPOSED LEACHATE LEVEL INCREASE at MILTON LANDFILL SITE

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for
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Project Quality Assurance
Information Sheet

Stability Risk Assessment
Proposed Leachate Level Increase
MILTON LANDFILL SITE

Stability Risk Assessment	:	WR7788/SRA	**Report Status**	:	Revision 2 based on meeting with FCC
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1 INTRODUCTION

1.1 Report Context

In February 2021, **Sirius Environmental Limited** (Sirius) were commissioned by **FCC Environment (UK) Limited** (FCC) to prepare a Stability Risk Assessment (SRA) for Milton Landfill Site to support an Environmental Permit Variation Application (EPVA) for the increase in permitted leachate levels in the existing Phase 1, Phase 2, and Phase 3 areas of the landfill.

This Stability Risk Assessment (SRA) has been prepared to support an Environmental Permit Variation Application (EPVA) which includes the proposal to increase the permitted leachate levels in Phase 1 and Phase 2 at Milton Landfill Site to **8mAOD**, and the increase the permitted leachate levels in Phase 3 at Milton Landfill Site to **9mAOD**. This SRA also considers the long-term settlement of the waste mass at the site.

No design changes associated with the waste, containment system or capping system at Milton Landfill Site are proposed in this SRA.

This SRA has been prepared using guidance contained within the **Environment Agency R&D Technical Report P1-385/TR2** (hereinafter referred to as 'The Guidance').

1.2 The Site

Milton Landfill Site is situated approximately 1km west of the village of Milton and 5km north of Cambridge city centre, at National Grid Reference TL 465 632. The site is accessed off Butt Lane close to the A10.

The address of the site is:

Milton Landfill Site,
Butt Lane,
Milton,
Cambridgeshire
CB24 6DQ

1.3 Development History

The site has been developed for landfilling operations since ~1980 and forms an L-shaped plot of land comprising of 3 development phases. Phase 1 comprises the northern section of the south-east corner of the site and was developed between ~1980 - ~1990. Phase 2 comprises the southern section of the south-east corner of the site, containing Cells 1-11, and was developed between ~1990 - ~1994. Phase 3 comprises the remainder of the site and was developed between ~1994 – present. The cells of the site have been excavated/constructed on undeveloped Greenfield land, much of which was previously used as arable land.

The site has accepted both hazardous and non-hazardous wastes during its lifetime, but current accepts only non-hazardous waste (household, industrial, commercial and inert). The site has been progressively filled and capped in phases.

The site was originally operated by Cambridgeshire County Council, followed by East Waste Limited, which was acquired by WRG PLC, which was subsequently taken over by FCC Environment (UK) Limited (FCC). FCC currently operate the site. Landfilling operations at Milton Landfill Site are currently permitted under the Environmental Permit: BV4584IU/V009 which was issued in 2004.

1.4 Summary of Previous Work

Several documents have been provided by FCC, giving a summary of the geological and hydrogeological condition of the site. A summary of those which have been referenced in completing this risk assessment follows.

1.4.1 Milton Landfill Site - PPC Application Volume 2 - Section C: Stability Risk Assessment Milton Landfill Site - by Golder Associates in December 2003

The Stability Risk Assessment (SRA) for the site, prepared by Golder Associates (UK) Limited in December 2003 (Document Ref: 03523331.502), was submitted in support of the original PPC Application. This SRA considered the stability and integrity issues associated with landfilling activities with Phases 1, 2, and 3 at Milton Landfill Site.

The SRA found that acceptable factors of safety were achieved for basal heave and critical slopes in the side-slope subgrade, the side-slope liner and the capping system. Analysis of existing temporary waste flanks returned factors of safety below the required 1.3, and therefore recommended cutting back existing slopes/building slopes to a maximum gradient of 1:2, as well as limiting leachate recirculation in some areas.

Slope stability calculations were undertaken in the program Slope/W.

1.4.2 Milton Landfill Site - PPC Application Volume 2 - Section B: Hydrogeological Risk Assessment Milton Landfill Site - by Golder Associates in December 2003

The Hydrogeological Risk Assessment (HRA), undertaken by Golder Associates (UK) Limited in December 2003, was submitted in support of the original PPC Application. The HRA confirms that the site works under the principle of hydraulic containment. The hydrology of the site is complex, with groundwater within the superficial River Terrace Gravel Deposits (where present), and artesian groundwater in the Lower Greensand Beds below. The report considered the leachate levels for the site, the contaminants within the leachate, and the risk of ingress of these contaminants groundwater.

The HRA established control levels for contaminants in groundwater monitoring boreholes at the site, and sets out an action plan for the case when these level are breached, to determine the potential impact on groundwater in the River Terrace Gravel Deposits and Lower Greensand Beds.

1.5 Stability Section

Two sections have been used for this stability risk assessment. **Section 1** runs through the southern part of the ‘L’ shape of Milton Landfill Site, from north-west to south-east. **Section 2** runs through the northern part of the ‘L’ shape of Milton Landfill Site, from south-west to north-east. The section positions are marked on **Drawing WR7788/SRA/01** in **Appendix SRA1**. Each section runs through multiple landfill cells, and **Section 2** includes the stockpile in the northern area of the site and the phases/cells in the northern area of the site which are currently being completed or yet to be completed. The geometry of each section is presented in **Appendix SRA2**.

The section positions have been chosen to ensure that old and new areas of the landfill are analysed, the steepest and highest areas of side-slope liner on the perimeter of the landfill site are analysed, that different thicknesses of side-slope liner are analysed, and that the increases to both final leachate compliance levels are analysed. **Section 1** includes both the increase in leachate level to **8mAOD** (in **Phase 1**) and the increase in leachate level to **9mAOD** (in **Phase 3**). **Section 2** includes the increase in leachate level to **9mAOD** in **Phase 3**.

The worst-case locations selected for analysis are around the perimeter of the landfill where the side-slopes are constructed to full height (See Section 2.1.4). The locations selected for analysis are as follows:

- **Location A** – the side-slope located on the right side of Section 1;
- **Location B** – the side-slope located on the left side of Section 1;
- **Location C** – the side-slope located on the left side of Section 2; and
- **Location D** – the side-slope located on the right side of Section 2.

The approximate positions of the analysis locations on site are shown on Drawing **WR7788/SRA/01** in **Appendix SRA1**, and the positions of the analysis locations on **Section 1** and **Section 2** are shown on the geometry printouts in **Appendix SRA2**.

1.6 Leachate Head Increase

The permitted leachate levels are proposed to be increased to **8mAOD** is Phase 1 and Phase 2 and to **9mAOD** in Phase 3. The current maximum permitted leachate level is **6.5mAOD**.

1.7 Conceptual Stability Model

The following sub-sections present a summary of the natural geological, engineered clay, waste, and fill materials (in the stockpile) used in the model, relating specifically to the components identified in guidance contained within the **Environment Agency R&D Technical Report P1385/TR2**.

The information present in this report has been compiled from a combination of ground investigation data, site-specific values determined from historical design, as built surveys, and CQA validation reports.

1.7.1 Geological and Hydrogeological Setting

The following information sources have been used as part of this review in addition to the references:

- British Geological Survey (BGS) Geology Maps (1:50,000 sheet 188) and available online BGS data;
- Previous HRA and SRA reports (See Section 1.4); and
- Borehole logs and Groundwater monitoring borehole water level data provided by FCC.

Geology

BGS data shows the site to be underlain by Gault Clay. The BGS Sheet 188 and the previous HRA and SRA reports show the Gault Clay to be underlain by a layer of Lower Greensand.

BGS data shows that superficial deposits are present on the site in some areas. These are named as 'River Terrace Gravel Deposits (RTGD) in the previous HRA and SRA reports. The RTGD have been shown to be present in boreholes around the perimeter of the site, and have therefore been modelled as part of this SRA.

The level of the base of the RTGD varies around the site. At the locations modelled in this SRA, the level of the base of the RTGD has been chosen based on the nearest borehole information to each location, and varies between **6.7mAOD** and **10.5mAOD**.

The depth of the Gault Clay was not definitively established in the original PPC SRA, although it states that the site investigation data and the BGS Sheet 188 indicate a thickness of at least 13m of Gault Clay beneath the site, although probably much greater. Based on this information, the Lower Greensand Beds haven been excluded from the modelling in this SRA, as they are too far below the base of the cells to impact on stability/integrity.

Table SRA1 below provides a summary of the geological succession for the site.

<table>
<tr><th colspan="3">TABLE SRA1 - SUMMARY OF GEOLOGICAL SUCCESSION</th></tr>
<tr><th>Age/Group</th><th>Formation</th><th>Description</th></tr>
<tr><td colspan="2">River Terrace Gravel Deposits</td><td>Sand and gravel deposits, ranging from coarse to fine grained.</td></tr>
<tr><td rowspan="2">Cretaceous Period</td><td>Gault Clay</td><td>Grey clay or marl, highly calcareous in the upper part of the formation, shallow-marine in origin with interbedded sequences.</td></tr>
<tr><td>Lower Greensand Beds</td><td>Fossiliferous medium to coarse-grained ochreous brown to greenish-yellow loosely cemented glauconitic sandstones or unconsolidated pebbly sands.</td></tr>
</table>

No known faults influence the site. The site is not in an area affected by historical coal mining.

Hydrogeology

The original HRA report states that groundwater is present within the superficial River Terrace Gravel Deposits and the Lower Greensand Beds where the groundwater is artesian. The groundwater in the Lower Greensand Beds is confined by the Gault Clay and was shown by the original SRA as unlikely to cause any basal heave in the cells of the site as the depth of the Gault Clay is too great. Groundwater data from site shows that there is groundwater present in the sands and gravels of the River Terrace Gravel Deposits. This groundwater occasionally flows laterally towards the cells of the landfill but is picked up by backwall drainage systems and pumped out of the site. Therefore, this groundwater does not exert any pressure on the side-slope liner around the perimeter of the site. This groundwater has been modelled in the finite element models used in this SRA, at varying levels based on average levels from groundwater data, being lowest at **Location A** (**7.9mAOD**) and highest at **Location D** (**9.7mAOD**). The default groundwater level used in the finite element modelling (which applies to the soils which have not been assigned a specific groundwater of leachate level) has been set to well below the base of the landfill cells so that it has no impact on the landfill area.

1.7.2 Basal Sub Grade Model

The basal subgrade in Phase 1, Phase 2, and Phase 3 consists of in situ Gault Clay. This material is generally incompressible and provides a firm subgrade for the waste and basal lining system.

1.7.3 Side Slope sub-grade model

The side-slope subgrade in Phase 1, Phase 2, and Phase 3 consists of in situ Gault Clay with River Terrace Gravel Deposits in the upper section. The River Terrace Gravel Deposits also make up the upper subgrade for some of the intercell bunds in Phase 3. These materials are generally of low compressibility (high stiffness) and provide a firm subgrade for the waste and side-slope lining system.

The upper side-slope subgrade in the eastern area of Phase 1 (as shown at **Location A** on **Section 1**) consists of made ground, which has been predominantly described as 'firm clay fill' on borehole logs at this location. These materials are likely to have a lower stiffness (made ground) than the Gault Clay/River Terrace Gravel Deposits and therefore may lead to a greater movement of the waste/liner above.

The upper side-slope subgrade in the northern area of Phase 3 (as shown at **Location D** on **Section 2**) consists of stockpiled material, which is generally cohesive with a gravelly/cohesive horizontal band of softer material near the base. These materials are likely to have a lower stiffness (made ground) than the Gault Clay/River Terrace Gravel Deposits and therefore may lead to a greater movement of the waste/liner above.

In order to preserve the stability/integrity of the side-slope liner during the construction phases, the side-slope liner has been constructed in multiple stages at each of the critical locations in the modelling. A similar construction methodology is likely to have taken place on site, particularly where the side-slope liner is 3m thick.

1.7.4 Basal Lining System Model

The basal lining system modelled generally consists of:

- 1,000mm (1m) minimum thickness engineered clay liner with a permeability lower than $k=1x10^{-9}m/s$.

The basal levels of the cells vary with the lowest being ~1m AOD in Phase 1 and the highest ~7m AOD in Cell 22.

Based on information in the original HRA, it is doubtful whether a basal liner exists in Phase 1 or Phase 2 Cells 1-5. Therefore, at **Location A** on **Section 1** (in Phase 1), a basal liner has not been modelled.

1.7.5 Side Slope Lining System Model

The side-slope lining system modelled consists of:

- **Location A**: 1,000mm (1m) minimum thickness engineered clay liner with a permeability lower than $k=1x10^{-9}$m/s on the lower cell side-slope, constructed against the Gault Clay, 3,000mm (3m) minimum thickness engineered clay liner with a permeability lower than $k=1x10^{-9}$m/s on the upper cell side-slope, constructed against the River Terrace Gravel Deposits/Made Ground;
- **Location B**: 3,000mm (3m) minimum thickness engineered clay liner with a permeability lower than $k=1x10^{-9}$m/s on the cell side-slope; constructed against the Gault Clay / River Terrace Gravel Deposits;
- **Location C**: 1,000mm (1m) minimum thickness engineered clay liner with a permeability lower than $k=1x10^{-9}$m/s on the cell side-slope; constructed against the Gault Clay / River Terrace Gravel Deposits;
- **Location D**: 3,000mm (3m) minimum thickness engineered clay liner with a permeability lower than $k=1x10^{-9}$m/s on the lower cell side-slope; constructed against the Gault Clay and River Terrace Gravel Deposits, 1,000mm (1m) minimum thickness engineered clay liner with a permeability lower than $k=1x10^{-9}$m/s on the upper cell side-slope; constructed against the Stockpile.

The side-slope liner has been modelled as present in Phase 1 (on **Section 1**), as the original HRA states that the sidewalls of this cell were not originally lined; they were retrospectively lined in order to control the leachate levels.

The thicknesses of the side-slope lining systems modelled at **Location B**, **Location C**, and **Location D** are based on the CQA Method Statements, Specifications and Drawings produced for the design of the cells in these locations.

1.7.6 Waste Model

The waste in-filling at Milton Landfill Site has been modelled over a period of approximately 41 years, assuming waste in-filling began in ~1981 and will be completed in early 2022.

In the model, waste cells have been constructed/infilled progressively along **Section 1** and **Section 2**. The construction/waste in-filling of **Section 1** has been modelled as being undertaken between 1990 and 2012. The construction/waste in-filling of **Section 2** has been modelled as being undertaken between 2006 and mid-2022 (finishing with final capping of the site). The modelling of the construction/infilling sequence is based on the available site information/drawings. The modelling of this sequence allows for the conditions on site at the time of the leachate level increase to be represented as accurately as possible.

In both **Section 1** and **Section 2**, the leachate level rise has been modelled to take place in 2021, over a period of 6 months.

Volume reduction of the waste mass (due to biodegradation and creep) has also been modelled, during the lifetime of the site and after site closure, as described in Section 2.4 below.

1.7.7 Capping System Model

This will not be assessed (in isolation) in this SRA. No changes to the stability or integrity of the capping system (itself) are anticipated as a result of the proposed leachate level head increases, as the proposed leachate level is well below the capping system. However, the stability of the capped perimeter waste flanks will be analysed as part of the assessment.

The capping system modelled generally consists of:

- 1000mm (1m) minimum thickness engineered clay liner with a permeability lower than $k=1x10^{-9}$m/s; and
- 1000mm (1m) minimum thickness of restoration soils.

2 STABILITY RISK ASSESSMENT

The six principal components of the conceptual stability site model have been considered and the various elements of that component have been assessed concerning stability and integrity.

The principal components considered are:

- The basal subgrade;
- The side-slope subgrade;
- The basal lining system;
- The side-slope lining system;
- The waste; and
- The capping system.

2.1 Risk Screening

Issues relating to the stability and integrity for each principal component of the landfill due to the proposed increase in leachate levels have been subjected to a preliminary review, to determine the need to undertake further detailed geotechnical analyses. The following sections present the results of this screening exercise.

2.1.1 Basal Subgrade Screening

The basal subgrade comprises in situ Gault Clay. The key considerations for the basal subgrade and the implications for stability and integrity are presented in **Table SRA2**:

TABLE SRA2 - STABILITY COMPONENTS FOR BASAL SUBGRADE		
Excessive Deformation	Compressible subgrade	The immediate subgrade for the basal lining system comprises in situ Gault Clay, which has a very high stiffness (resistance to consolidation). Therefore any further compression related to the increase in leachate level will be extremely low. An appropriate stiffness has been used in the analysis to reflect this.
Excessive Deformation	Basal Heave	*Groundwater:* The groundwater within the underlying Lower Greensand Beds is confined and therefore does contain an upward component of velocity. The original SRA shows that basal heave is unlikely to occur due to this confined groundwater level. This groundwater level has not been modelled in this SRA as it is outside the boundaries of the model (deep beneath the cells). As previously discussed in this report, a default groundwater level has been modelled in the finite element analyses which applies to the soils which have not been assigned a specific groundwater or leachate level (such as the Gault Clay). This default groundwater level is well below the base of the landfill cells, therefore heave as a result of groundwater is considered low and has not been assessed further in this report.
Excessive Deformation	Cavities in subgrade	None anticipated.
Filling on Waste	Compressible Waste	Not Applicable.
Filling on Waste	Cavities in Waste	None anticipated.

2.1.2 Side-Slope Subgrade Screening

The key considerations for the side-slope subgrade and the implications for stability and integrity are presented in **Table SRA3** below:

TABLE SRA3 - STABILITY COMPONENTS FOR SIDE-SLOPE SUBGRADE		
Excessive Deformation	Compressible subgrade	The subgrade for the side-slope lining systems comprises in situ Gault Clay, the River Terrace Gravel Deposits, Made Ground (predominantly clay) adjacent to Phase 1, and the stockpile in the northern area of the site. The natural sub-grade materials are not considered to be particularly compressible and have previously been assessed at the slope angles used on site. Therefore, analysis of this subgrade will not be included in this assessment. It is anticipated that the stiffness of the made ground adjacent to Phase 1 and the stockpile material subgrade will be lower than that of the Gault Clay/River Terrace Gravel Deposits, therefore the made ground and stockpile subgrade may be significantly compressible. The leachate level increase could potentially lead to significant deformations in the made ground or stockpile subgrade, which could compromise the integrity of the side-slope liner. The made ground and stockpile subgrade will be modelled using suitable stiffness parameters to allow the impact of deformations in the made ground or stockpile on the integrity of the side-slope liner to be assessed.
	Heave	Groundwater levels have been included in the finite element modelling based on the available borehole data, however, as the side-lining system has been fully constructed and confined with waste, no heave is anticipated during the leachate level increase phase or long-term settlement of the waste. Therefore, heave of the side-slope lining system as a result of groundwater is considered low and has not been assessed further in this report.
	Cavities in subgrade	None anticipated.
Filling on Waste	Compressible Waste	Not Applicable.
	Cavities in Waste	None anticipated.

2.1.3 Basal Lining System Screening

The controlling factors that influence the stability and integrity in the basal lining system are given in **Table SRA4** below:

TABLE SRA4 - STABILITY COMPONENTS FOR BASAL LINING SYSTEM		
Mineral Liner	Stability and Integrity	Any consolidation in the basal subgrade (Gault Clay) due to the increase in leachate levels will be extremely low. Any strain in the basal liner due the increase in leachate levels will be very low (much lower than strains in the side-slope liner). Therefore, analysis of the stability/integrity of the basal liner will not be included within this assessment.
	Compressible subgrade	The immediate subgrade for the basal lining system comprises in situ Gault Clay, which has a very high stiffness (resistance to consolidation). Therefore any further compression related to the increase in leachat,e level will be extremely low. An appropriate stiffness has been used in the analysis to reflect this.
	Cavities	None anticipated.
	Basal Heave	*Groundwater:* The groundwater within the underlying Lower Greensand Beds is confined and therefore does contain an upward component of velocity. The original SRA shows that basal heave is unlikely to occur due to this confined groundwater level. This groundwater level has not been modelled in this SRA as it is outside the boundaries of the model (deep beneath the cells). As previously discussed in this report, a default groundwater level has been modelled in the finite element analyses which applies to the soils which have not been assigned a specific groundwater or leachate level (such as the Gault Clay). This default groundwater level is well below the base of the landfill cells, therefore heave as a result of groundwater is considered low and has not been assessed further in this report.

2.1.4 Side-Slope Lining System Screening

The key considerations for the side slope lining system and the implications for stability and integrity as a result of the increased leachate levels are presented in **Table SRA5**:

TABLE SRA5 - STABILITY COMPONENTS FOR SIDE-SLOPE LINING SYSTEM		
Un-confined	Stability	No un-unconfined side-slopes are anticipated on site during the leachate level increase; analysis of the stability of the un-confined side-slope liner will not be included within this assessment.
Confined	Stability	Confinement of the side-slope lining system will increase the factor of safety from that of the un-confined system, as the stiffness of the waste will provide added stability for the system. Instability could potentially occur through the top of the side-slope liner in conjunction with the capping system, although it is unlikely that any such failure surfaces would be affected by the leachate level increase as they would likely be above the leachate level. Although instability of the confined side-slope lining system due to the leachate level increase is not anticipated, stability analyses will be run for both sections used in this assessment to verify that the critical failure slopes remain above the leachate level and are not affected by the leachate level increase. Stability analyses will also be run for the long-term situation (following volume reductions in the waste), to verify that stability is not adversely affected by this settlement.
	Integrity	The leachate level increase may lead to significant strains in the side-slope lining system during the leachate level phase. These shear strains could potentially lead in integrity issues in the side-slope lining system, particularly in locations where there are relatively large pre-existing strains. The side-slope lining system is present around the perimeter of the landfill, and also between cells in the landfill (on intercell bunds/slopes). Pre-existing strains in the side-slope lining system are likely to be greatest in the engineered clay liner around the perimeter of the landfill where the side-slope lining system has been constructed to full height. Therefore, an assessment will be made of the shear strains in the side-slope lining system at these locations (**Location A**, **Location B**, **Location C**, and **Location D**). Integrity analyses will also be run for the long-term situation (following volume reductions in the waste), to verify that the integrity of the engineered clay liner of the side-slope lining system is not adversely affected by this settlement. The results of these analyses will be compared with the work of the most recent published papers concerning the long-term integrity of liners.

2.1.5 Waste Screening

The key considerations for the waste mass and the implications for stability and integrity as a result of increased leachate levels are presented in **Table SRA6**:

<table>
<tr><th colspan="4">TABLE SRA6 - STABILITY COMPONENTS OF WASTE SLOPES</th></tr>
<tr><td>Failure wholly in waste</td><td colspan="2">Stability</td><td>Stability of the waste mass is unlikely to be affected as the leachate levels are increased, as there are no unconfined waste slopes. The stability of the waste mass will be assessed further in this report to verify that there will be no stability issues due to the leachate level increase.

Stability analyses will also be run for the long-term situation (following volume reductions in the waste), to verify that stability is not adversely affected by this settlement.</td></tr>
<tr><td rowspan="2">Failure involving liner and waste</td><td rowspan="2">Mineral Clay</td><td>Stability</td><td>Increased leachate levels could potentially allow the waste to fail along (or through) the side-slope lining system and/or capping lining system. This is unlikely as the waste is completely confined below the leachate level and the waste immediately below the capping system is above the leachate level. The stability of the waste in conjunction with the lining and capping systems will need to be assessed further in this report to verify that there will be no stability issues due to the leachate level increase.

Stability analyses will also be run for the long-term situation (following volume reductions in the waste), to verify that stability is not adversely affected by this settlement.</td></tr>
<tr><td>Integrity</td><td>Increased leachate levels may induce additional strains within the clay liner on the side-slopes of the cells which may impact on the long-term integrity of the side-slope lining system. This will be assessed in the report.

Integrity analyses will also be run for the long-term situation (following volume reductions in the waste), to verify that the integrity of the engineered clay liner of the side-slope lining system is not adversely affected by this settlement.</td></tr>
</table>

2.1.6 Capping System Screening

This is not assessed (in isolation) in this SRA. The proposed leachate levels of **8mAOD** and **9mAOD** following the leachate level rise shall remain below the levels of the top of the perimeter sidewall at all locations, so therefore there shall be no change to the saturated level in the waste of the unconfined slope below the capping system. Therefore, the unconfined slope of the waste above the engineered sidewall shall remain unsaturated; no changes to the stability or integrity of the capping system (itself) are anticipated as a result of the proposed leachate level head increases. However, the stability of the capped perimeter waste flanks in conjunction with the upper side-slope lining systems will be analysed as part of the assessment. It is anticipated that the critical failure surfaces found in the analyses for the stability of the waste/side-slope lining system will occur at the analysis locations where capped perimeter waste flanks are present.

2.2 Justification for Modelling Approach and Software

To perform a comprehensive stability risk assessment (SRA), the components of the landfill development should be considered not only individually, but also in conjunction with one another, where relevant. Any analytical techniques adopted for such an assessment should adequately represent all the considered scenarios for both the un-confined and confined conditions (where appropriate). The methodology and the software should also achieve the desired output parameters for the assessment. This equates to the determination of factors of safety for stability assessments, or the calculation of strains within liner components, for integrity assessments.

The analytical methods used in this summary stability risk assessment include:

(a) **Finite element analyses** for the **calculation of factors of safety** for the waste, side-slope lining system, and capping system, using an effective stress approach, to determine the **stability of the landfill**; and

(b) **Finite element analyses** for the **determination of shear strains** in the mineral side-slope lining system, and the calculation of factors of safety, to assess the **integrity of the side-slope lining system**.

2.2.1 Finite Element Analyses

The proprietary software **PLAXIS 2D (2020)** has been used for the stability and integrity assessments. This is a two-dimensional finite element programme intended for the analysis of deformation and stability in geotechnical engineering. It is equipped for the simulation of non-linear, time dependent and anisotropic behaviour of soils and rock. In addition, since soil is multi-phase material, special procedures are required to deal with hydrostatic and non-hydrostatic pore pressures in the soil. **PLAXIS 2D** was originally developed for geotechnical engineers studying river embankments on the soft soils of the lowlands of Holland. In subsequent years, **PLAXIS 2D** has been extended to cover most other areas of geotechnical engineering. It is therefore well suited for application to the Milton Landfill Site stability risk assessment.

2.2.2 Phi-C Reduction

A safety analysis in PLAXIS is undertaken by reducing the strength parameters of the soils. This process is termed 'Phi-C reduction' and is carried out as a separate calculation mode. Phi-C reduction is used when it is required to calculate a factor of safety, for the situation under consideration.

In the Phi-C reduction approach, the strength parameters tanφ and c of the soil are incrementally reduced until failure of the system occurs. The strengths of interfaces, if used, are reduced in the same way. The strength of structural objects like plates and anchors are not influenced by the Phi-C reduction.

The total multiplier ΣMsf is used to define the value of the soil strength parameters as a given stage in the analysis:

$$\sum Msf = \frac{\tan\varphi_{input}}{\tan\varphi_{reduced}} = \frac{c_{input}}{c_{reduced}}$$

A Phi-C reduction calculation is performed using the load advancement number of steps procedure. The incremental multiplier M_{sf} is used to specify the increment of the strength reduction of the first calculation step. The increment is by default set to 0.1, which is generally found to be a good starting value. The strength parameters are successively reduced automatically until all additional steps have been performed. If this case, the factor of safety can be given by:

$$SF = \frac{\textit{available strength}}{\textit{strength at failure}} = \text{value of } \sum Msf \text{ at failure}$$

If a failure mechanism has not fully developed, then the calculation is repeated with a larger number of additional steps. To capture the failure of the system accurately, the use of arc-length control in the iteration procedure is required. The use of a tolerated error of no more than 3% is also required. Both requirements are complied with when using the Standard setting of the Iterative procedure.

When using Phi-C reduction in combination with advanced soil models, these models will behave as a standard Mohr-Coulomb model, since stress-dependant stiffness behaviour and hardening effects are excluded. The stress-dependent stiffness modulus (where this is specified in the advanced model) at the end of the previous step is used as a constant stiffness modulus during the Phi-C reduction calculation.

For slopes, the **Phi-C reduction** approach resembles the method of calculating safety factors as conventionally adopted in traditional slip-circle analyses.

2.3 Selection of Appropriate Factors of Safety

The factor of safety is the numerical expression of the degree of confidence that exists for a given set of conditions, against a failure mechanism occurring. It is commonly expressed as the ratio of the load or action that would cause failure against the actual load or actions likely to be applied during service. This is readily determined for some types of analysis, for example in limit equilibrium slope stability analyses. However, greater consideration must be given to analyses that do not report factors of safety directly. For example, a finite difference analysis of strains within a capping system would not usually indicate overall failure of the model even though the strains could be high enough to indicate a failure of the integrity of the system. In such cases, it is necessary to define an upper limit for shear strains and to express the factor of safety as the ratio of allowable strain to actual strain.

For the integrity assessment, it is proposed to present the maximum strains determined from the analyses and compare these with the conclusions of the latest research relating to this aspect of landfill design, in order to determine acceptability. Assessing the integrity of the mineral side-slope lining system will be based on the work of Arch et al (1996) as well as the Guidance.

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

BS6031 - Code of Practice for Earthworks (Clause 6.5.1.2 Safety Factors) states that suitable safety factors in a case can only be arrived at after careful consideration of all the relevant factors, and the exercise of sound engineering judgement. The factors to be considered include:

a) The complexity of the soil conditions;
b) The adequacy of the site investigation;
c) The certainty with which the design parameters represent the actual in-situ conditions;
d) The length of time over which the stability should be assured;
e) The likelihood of unfavourable changes in groundwater regime in the future;
f) The likelihood of unfavourable changes in the surface profile in the future;
g) The speed of any movement which might take place; and
h) The consequences of any failure.

A minimum factor of safety of **1.3** is considered acceptable for stability and integrity, if reasonably conservative values are used. The shear strength parameters for landfill waste presented within the Guidance are considered conservative and can be considered to already include an element of partial factoring. Therefore, it is appropriate to adopt a factor of safety of **1.3** if adopting these shear strength parameters in combination with the traditional approach (Section 2.2.4 of the Guidance).

2.4 Justification for Geotechnical Parameters Selected for Analyses

Geotechnical data for the stability and integrity analyses associated with the proposed leachate level rise in Phase 1, Phase 2, and Phase 3 at Milton Landfill Site has been obtained from several sources including the previous stability risk assessments, site investigation information, design documents, and published (conservative) data applicable to the analyses.

Waste is typically a heterogeneous material with engineering properties (density, permeability, shear strength and stiffness) that change over time. The waste exhibits strain hardening behaviour (increasing stiffness and shear strength) resulting from the decreasing volume of the waste over time. As Jones and Dixon (2001) demonstrate, waste in a landfill becomes stiffer with age, and burial depth. In long-term (effective stress) analyses, the materials are reliant on their frictional properties for shear strength (i.e. ϕ' and c').

In terms of non-hazardous (MSW) waste strength, Sirius adopts conservative values of effective shear strength parameters as derived from a study of geotechnical properties of municipal waste by Van Impe and Bouazza (1995) these values being backed up in later work by Kavazanjian et al (1996) and later confirmed in a research summary by Jotisankasa (2001). The typical values for c' and ø' adopted throughout the modelling were 5kPa and 25° respectively.

The original 2003 SRA adopted a unit weight (for the waste) of 12kN/m^3. The unit weight of waste usually adopted by Sirius (based on our design experience) is 10.5kN/m^3. A unit weight of 11kN/m^3 has been used for the waste in the modelling, assuming that the unit weight of the waste will have increased slightly over time due to self-weight settlement (creep) and biodegradation. For MSW, a permeability of k=1x10^{-5} m/s is typically adopted by Sirius and has been used for the waste. The stiffness parameters for the waste have been based on **Environment Agency R&D Technical Report P1385/TR1.** A value of 12MPa was adopted to reflect the average stiffness of the waste over the lifetime of the site, taking that MSW waste stiffness will (typically) increase with age.

Volume reduction of the waste due to biodegradation / creep was modelled in various cells in order to reduce the waste levels / top of capping soils levels to the approximate levels recorded along **Section 1** and **Section 2** in site surveys following waste deposition, to improve the accuracy of the modelling.

Volume reduction of the waste due to biodegradation / creep was modelled post-2022 during a 50-year long settlement phase. The volume reductions of each phase / cell of waste were estimated using an estimate of the total volume reduction (over the lifetime of the waste) of 25%, and a suitable example a relationship between volume reduction and time since waste placement, for non-hazardous waste. Both the 25%

value and the relationship between volume reduction and time used are considered to be conservative in that they predict that relatively high amounts of settlement due to volume reduction are yet to take place in each of the waste phases / cells at Milton Landfill Site.

The parameters used in the modelling for the Gault Clay, River Terrace Gravel Deposits, Firm Clay Made Ground, Clay Liner, Restoration Soils, and Stockpile material have been based on Sirius' recent design experience and available site information including the original 2003 SRA for Milton Landfill Site. The stockpiled material contains a band of soft and weak mixed granular/cohesive material near the base of the stockpile, in the northern area of the site.

Table SRA7 below summarises the parameters utilised in the effective stress analyses.

The full set of material parameters used in the modelling is presented within **Appendix SRA2**.

TABLE SRA7 - SUMMARY OF EFFECTIVE STRESS MATERIAL PARAMETERS FOR FINITE ELEMENT ANALYSES USING THE HARDENING SOIL MODEL

Material	Unit Weight (Dry, Saturated)	Cohesion	Internal Angle of Friction	Hydraulic Conductivity (Permeability)	E_{50}^{ref}	E_{oed}^{ref}	E_{ur}^{ref}	Power (m)
	kN/m³	kN/m²	°	m/s	kN/m²	kN/m²	kN/m²	-
Gault Clay	20.0	10.0	20.0	3×10^{-10}	35,000	35,000	105,000	1.0
River Terrace Gravel Deposits	19.0, 20.0	0.0	33.0	1×10^{-5}	15,000	15,000	45,000	0.5
Clay Liner	20.0	5.0	25.0	1×10^{-9}	8,000	8,000	24,000	1.0
Waste (MSW)	11.0	5.0	25.0	1×10^{-5}	12,000	12,000	36,000	0.75
Restoration Soils	18.0, 19.0	5.0	25.0	1×10^{-7}	4,000	4,000	12,000	0.75
Stockpile	21.0	5.0	26.0	1×10^{-9}	7,000	7,000	21,0000	0.9
Stockpile Soft	21.0	1.0	20.0	5×10^{-8}	3,000	3,000	9,000	0.9
Made Ground - Firm Clay (adjacent to Phase 1)	19.0, 20.0	7.0	30.0	1×10^{-8}	10,000	10,000	30,000	1.0

3 ANALYSIS

The key areas of Milton Landfill Site which require analysis are:

- **Effective Stress Stability Analysis** - The stability of the side-slope lining system, capping system, and waste in **Section 1** and **Section 2**, as the leachate is raised to 8mAOD in Phase 1 and Phase 2, and 9mAOD in Phase 3, and following long term settlement of the waste mass; and

- **Side-Slope Liner Integrity Analysis** - The integrity of the side-slope lining system, at **Location A**, **Location B**, **Location C** and **Location D**, as the leachate is raised to 8mAOD in Phase 1 and Phase 2, and 9mAOD in Phase 3, and following long term settlement of the waste mass.

For both the stability and integrity analyses, the leachate level rise has been modelled as a phase (using Plaxflow for transient groundwater flow modelling) taking place in 2021, over a period of 6 months. An alternative phase where there is no leachate rise has also been modelled over the same time period, allowing the impact of the increased leachate levels on stability and integrity (of the containment system) to be assessed comparatively.

3.1 Effective Stress Stability Analysis

Table SRA8 below highlights the factors of safety from the PLAXIS Phi-C reduction runs for stability in **Section 1** and **Section 2**, comparing the situations before the leachate level rise, following the leachate level rise, and no leachate level rise. A further factor of safety has been included for each section to show the impact of the 50-year waste settlement phase on stability.

TABLE SRA8 - SUMMARY OF PHI-C REDUCTION RUNS FOR STABILITY		
Description	**Critical slope identified during analysis**	**Factor of Safety**
Section 1 – Pre-Leachate Rise (During Winter 2021 Waiting Phase)	Circular Failure through landfill cap/waste/top of side-slope liner at Location B above the leachate level	3.872
Section 1 – Immediately after Leachate Rise Leachate level raised to 8mAOD in Phase 1 and Phase 2 and 9m AOD in Phase 3 over the course of 6 months	Circular Failure through landfill cap/waste/top of side-slope liner at Location B above the leachate level	3.860
Section 1 – No Leachate Rise Leachate levels remain the same over the course of 6 months	Circular Failure through landfill cap/waste/top of side-slope liner at Location B above the leachate level	3.864
Section 1 – After 50-Year Settlement phase Volume reductions applied to each waste cell to represent long-term biodegradation / creep	Circular Failure through landfill cap/waste/top of side-slope liner at Location B above the leachate level	3.814
Section 2 – Pre-Leachate Rise (During Winter 2021 Completion of Waste in Cell 24A Phase)	Circular Failure through landfill cap/waste/top of side-slope liner at Location C above the leachate level	4.736
Section 2 – Immediately after Leachate Rise Leachate level raised to 9m AOD in Phase 3 over the course of 6 months	Circular Failure through landfill cap/waste/top of side-slope liner at Location C above the leachate level	4.703
Section 2 – No Leachate Rise Leachate levels remain the same over the course of 6 months	Circular Failure through landfill cap/waste/top of side-slope liner at Location C above the leachate level	4.750
Section 2 – After 50-Year Settlement phase Volume reductions applied to each waste cell to represent long-term biodegradation / creep	Deep Near-Circular Failure through landfill cap/waste/top of side-slope liner at Location C above and below the leachate level	4.342

Graphical representations of the analyses showing the most likely failure modes and PLAXIS calculation sheets are presented in **Appendix SRA3**.

3.2 Side-slope Lining System Integrity Analysis

The following analysis is for the integrity of the side-slope lining system because of the proposed increase in leachate level. Analysis was undertaken for **Location A**, **Location B**, **Location C** and **Location D**, around the perimeter of the landfill site. Strains within the clay liner itself can be directly analysed within the PLAXIS model. The locations analysed cover a variety of 1m thick sections of clay liner and 3m thick sections of clay liner at different heights and gradients, with a combination of both thicknesses at **Location A** and **Location D**, to ensure that all relevant scenarios have been assessed. A summary of the maximum shear strains in the side-slope lining system at each analysis location (before the leachate level rise phase, following the leachate level rise phase, and with no leachate level rise), are presented in **Table SRA9, Table SRA10, Table SRA11,** and **Table SRA12** below. The factors of safety when the highest strains at each location are compared to the relevant strain guidance limit of 10% (see Section 4.2) are also presented. The no leachate rise scenario has been run as an alternative phase to the leachate rise phase, with the same duration of 6 months, in order to more exactly assess the impact of the increased leachate level on integrity.

A further shear strain result has been included at each location to show the impact of the 50-year waste settlement phase on integrity.

TABLE SRA9: SUMMARY OF MAXIMUM STRAINS & LOWEST FACTOR OF SAFETY FOR THE LANDFILL SIDE-SLOPE LINING SYSTEM – LOCATION A		
Description	**3m & 1m Side-Slope Liner**	
	Location of Maximum Shear Strain	**Maximum Shear Strain**
Location A – Pre-Leachate Rise (During Winter 2021 Waiting Phase) **Total Shear Strain in Liner**	Upper 3m Section of Side-Slope Liner, constructed against the River Terrace Gravel Deposits, maximum location is below the leachate level	7.465%
Location A – Leachate Rise Phase Leachate level raised to 8mAOD in Phase 1 and Phase 2 and 9m AOD in Phase 3 over the course of 6 months **Total Shear Strain in Liner**	Upper 3m Section of Side-Slope Liner, constructed against the River Terrace Gravel Deposits, maximum location is below the leachate level	7.465%
Location A – No Leachate Rise Phase Leachate levels remain the same over the course of 6 months **Total Shear Strain in Liner**	Upper 3m Section of Side-Slope Liner, constructed against the River Terrace Gravel, maximum location is below the leachate level	7.446%
Location A – After 50-Year Settlement phase Volume reductions applied to each waste cell to represent long-term biodegradation / creep **Total Shear Strain in Liner**	Upper 3m Section of Side-Slope Liner, constructed against the River Terrace Gravel Deposits, maximum location is below the leachate level	7.291%
Strain Guidance Limit (Arch et al, 1996)	-	**10%**
Lowest Factor of Safety	-	**1.34**

TABLE SRA10: SUMMARY OF MAXIMUM STRAINS & LOWEST FACTOR OF SAFETY FOR THE LANDFILL SIDE-SLOPE LINING SYSTEM – LOCATION B		
Description	**3m & 1m Side-Slope Liner**	
	Location of Maximum Shear Strain	**Maximum Shear Strain**
Location B – Pre-Leachate Rise (During Winter 2021 Waiting Phase) **Total Shear Strain in Liner**	Lower Section of 3m Side-Slope Liner, constructed against the Gault Clay, maximum location is below the leachate level	4.149%
Location B – Leachate Rise Phase Leachate level raised to 8mAOD in Phase 1 and Phase 2 and 9m AOD in Phase 3 over the course of 6 months **Total Shear Strain in Liner**	Lower Section of 3m Side-Slope Liner, constructed against the Gault Clay, maximum location is below the leachate level	4.149%
Location B – No Leachate Rise Phase Leachate levels remain the same over the course of 6 months **Total Shear Strain in Liner**	Lower Section of 3m Side-Slope Liner, constructed against the Gault Clay, maximum location is below the leachate level	4.149%
Location B – After 50-Year Settlement phase Volume reductions applied to each waste cell to represent long-term biodegradation / creep **Total Shear Strain in Liner**	Upper Section of 3m Side-Slope Liner, constructed against the River Terrace Gravel Deposits, maximum location is above the leachate level	5.681%
Strain Guidance Limit (Arch et al, 1996)	-	**10%**
Lowest Factor of Safety	-	**1.76**

TABLE SRA11: SUMMARY OF MAXIMUM STRAINS & LOWEST FACTOR OF SAFETY FOR THE LANDFILL SIDE-SLOPE LINING SYSTEM – LOCATION C		
Description	3m & 1m Side-Slope Liner	
	Location of Maximum Shear Strain	Maximum Shear Strain
Location C – Pre-Leachate Rise (During Winter 2021 Completion of Waste in Cell 24A Phase) **Total Shear Strain in Liner**	Upper Section of 1m Side-Slope Liner, constructed against the River Terrace Gravel Deposits above the leachate level	3.315%
Location C – Leachate Rise Phase Leachate level raised to 9mAOD in Phase 3 over the course of 6 months **Total Shear Strain in Liner**	Upper Section of 1m Side-Slope Liner, constructed against the River Terrace Gravel Deposits above the leachate level	3.300%
Location C – No Leachate Rise Phase Leachate levels remain the same over the course of 6 months **Total Shear Strain in Liner**	Upper Section of 1m Side-Slope Liner, constructed against the River Terrace Gravel Deposits above the leachate level	3.315%
Location C – After 50-Year Settlement phase Volume reductions applied to each waste cell to represent long-term biodegradation / creep **Total Shear Strain in Liner**	Upper Section of 1m Side-Slope Liner, constructed against the River Terrace Gravel Deposits above the leachate level	4.215%
Strain Guidance Limit (Arch et al, 1996)	-	**10%**
Lowest Factor of Safety	-	**2.37**

TABLE SRA12: SUMMARY OF MAXIMUM STRAINS & LOWEST FACTOR OF SAFETY FOR THE LANDFILL SIDE-SLOPE LINING SYSTEM – LOCATION D		
Description	3m & 1m Side-Slope Liner	
	Location of Maximum Shear Strain	Maximum Shear Strain
Location D – Pre-Leachate Rise (During Winter 2021 Completion of Waste in Cell 24A Phase) **Total Shear Strain in Liner**	Lower 3m Section of Side-Slope Liner, constructed against the Gault Clay, maximum location is below the leachate level	7.437%
Location D – Leachate Rise Phase Leachate level raised to 9mAOD in Phase 3 over the course of 6 months **Total Shear Strain in Liner**	Lower 3m Section of Side-Slope Liner, constructed against the Gault Clay, maximum location is below the leachate level	7.426%
Location D – No Leachate Rise Phase Leachate levels remain the same over the course of 6 months **Total Shear Strain in Liner**	Lower 3m Section of Side-Slope Liner, constructed against the Gault Clay, maximum location is below the leachate level	7.437%
Location D – After 50-Year Settlement phase Volume reductions applied to each waste cell to represent long-term biodegradation / creep **Total Shear Strain in Liner**	Lower 3m Section of Side-Slope Liner, constructed against the Gault Clay, maximum location is below the leachate level	7.017%
Strain Guidance Limit (Arch et al, 1996)	-	**10%**
Lowest Factor of Safety		**1.34**

Graphical representations of the analyses showing the strains in the side-slope lining system are presented in **Appendix SRA4**.

4 ASSESSMENT

The assessments are presented in the order described in the analysis section.

4.1 Effective Stress Stability Assessment

Table SRA8 above outlines the lowest factors of safety and the most likely failure modes for stability in **Section 1** and **Section 2**, before the leachate level rise, following the leachate level rise, and if there is no leachate level rise, as well as the long-term factors of safety and failure modes following waste settlement.

For the situations before the leachate level rise, following the leachate level rise, and if there is no leachate level rise, the critical failure surface in **Section 1** consistently occurs through the capping system, waste and upper side-slope lining system, well above the raised leachate level (at **Location B**). For the same phases, the critical failure surface in **Section 2** consistently occurs through the capping system, waste, and upper side-slope lining system, well above the raised leachate level (at **Location C**). The factors of safety of these critical slopes remain almost unchanged from before the leachate level rise, with the factors of safety for the situation where there is a leachate rise being only marginally lower for the situation where there is no leachate rise. The lowest factor of safety at this stage occurs in **Section 1**, following the leachate level rise, with a value of **FOS=3.860**.

The results of this analysis confirm that as the side-slope lining system is already ‘confined’ around the site, the leachate level rise will have a negligible impact on the stability of the confined side-slope lining system/waste. The leachate level rise will have a negligible impact on the stability of the capping system/waste/side-slope lining system above the leachate level, with factors of safety for such slopes remaining well above the required **FOS=1.3**.

Following the 50-year settlement phase, utilising the increased leachate levels of **8mAOD** and **9mAOD**, the shape of the critical failure surface for **Section 1** remains the same, with a very small reduction to the factor of safety. The reduced factor of safety has a value of **FOS=3.814**, which remains well above the required **FOS=1.3**. For the same phase, the critical failure surface for **Section 2** changes shape, passing deeper into the waste, although it passes through the capping system and upper side-slope lining system in the same position, and the factor of safety is reduced. It is likely that the large volume reductions modelled in the waste mass led to a change in the failure surface and factor of safety at this location. This factor of safety has a value of **FOS=4.342**, which remains well above the required **FOS=1.3**. Therefore, the long-term settlement of the waste mass with the increased leachate levels of **8mAOD** and **9mAOD** is unlikely to have a detrimental effect on the stability of the landfill.

4.2 Side-Slope Lining System Integrity Assessment

It is important that the permeability of the mineral side-slope liner is maintained during the operation of the landfill, to prevent downward migration of leachate into the underlying aquifer. PLAXIS cannot model changes in permeability with time, only strains within the soils. Therefore, it is necessary to be able to assess how the strains within the clay liner affect the permeability of the material.

No site-specific data on the relationship between strain and permeability exists. However, research by Arch et al (1996) has shown that the permeability of compacted clay decreases for shear strains up to the yield point of the material (typically 6%), after which increases in permeability are exhibited. Considering the initial decrease in permeability, values above the original permeability of the compacted clay are only achieved after strains of around 11%. For the purposes of this report, a design value of **10% shear strain** has been adopted, since this represents a point at which permeability remains adhering to the as-built specification.

Table SRA9, **Table SRA10**, **Table SRA11**, and **Table SRA12** present the maximum shear strains anticipated in the side-slope liner at **Location A**, **Location B**, **Location C**, and **Location D** respectively.

The highest maximum shear strain generated following the leachate rise phase is **7.465%**, occurring at **Location A**, providing a factor of safety of **FOS=1.34** when compared to the 10% limit on shear strain. This factor of safety is higher than the required **FOS=1.3** required by Sirius for shear strains in a liner. Therefore, all the shear strains which occur during the leachate level rise phase are deemed to be acceptable.

The pre-leachate rise maximum shear strains are calculated estimates of the pre-existing shear strains in the side-slope liner which are generated predominantly during the construction and waste deposition phases of the liner at each analysis location. At each analysis location, the maximum shear strains following the leachate level rise are either exactly the same as the pre-leachate rise strains or have decreased by a very small amount. The locations of the maximum shear strains remain the same as before the leachate rise phase.

Likewise, the maximum shear strains following the alternative phase analysed (where there is no leachate level rise) are either exactly the same as the pre-leachate rise strains or have decreased by a very small amount. The locations of the maximum shear strains remain the same as before.

The graphical printouts presented in **Appendix SRA4** show that, at each analysis location, the distribution of shear strains in the side-slope liner has not noticeably changed during either the leachate level rise phase, or the no leachate level rise phase. These results confirm that any changes to the shear stains in the side-slope liner during the leachate level increase are likely to be very small.

Following the 50-year settlement phase, utilising the increased leachate levels of **8mAOD** and **9mAOD**, the maximum shear strains in the side-slope liner at the analysis locations change by a greater amount, decreasing at **Location A** and **Location D**, and increasing at **Location B** and **Location C**. At each location, an increase in the shear strains in the upper areas of the side-slope liner is evident, as can been seen from the graphical printouts presented in **Appendix SRA4**. At **Location B**, the location of the maximum shear strain shifts to the top of the side-slope liner. These changes to the distributions of the shear strains are caused by large movements in the waste adjacent to the side-slope liner, due to the volume reductions modelled. Compared to the existing levels of shear strain in the side-slope liner, the changes in shear strain during the 50-year settlement phase remain fairly small. The highest shear strain remains a **Location A**, with a value of **7.291%**. When compared to the 10% limit on shear strain, this provides a factor of safety of **FOS=1.37** which remains higher than the required **FOS=1.3**. Therefore, the long-term settlement of the waste mass with the increased leachate levels of **8mAOD** and **9mAOD** is unlikely to have a detrimental effect on the integrity of the landfill.

5 CONCLUSIONS

This stability risk assessment (SRA) has addressed the stability and integrity of the containment system as a result of the proposed increase to the leachate levels within Phase 1, Phase 2, and Phase 3, at Milton Landfill Site.

Specifically, the following scenarios have been considered as part of the assessment:

- An increase in the leachate level to **8mAOD** in **Phase 1** and **Phase 2**, and an increase in the leachate level to **9mAOD** in **Phase 3**, over a period of 6 months;
- No change to the leachate levels in **Phase 1**, **Phase 2**, and **Phase 3**, over a period of 6 months; and
- The long-term scenario following the settlement of the waste mass at Milton Landfill Site.

Analyses have been based on the available site investigation information, conservative material parameters, and a worst-case interpretation of the geometry and timescales.

The assessments have indicated that the proposed increases to the leachate levels and the long-term settlement of the waste mass are likely to have a very small impact on the stability of the side-slope lining system, waste, and capping system at Milton Landfill Site. The reported factors of safety remain significantly greater than the minimum requirement of 1.3.

The assessments have indicated that the proposed increases to the leachate levels and the long-term settlement of the waste mass are likely to have a very small impact on the integrity of the side-slope lining system at Milton Landfill Site. The shear strains following the increase in leachate levels are almost identical to those calculated before the increase in leachate levels (or those calculated for the situation where there is no leachate level increase). Any increases of the shear strains following the long-term settlement of the waste mass are likely to be fairly small compared to the shear strains which already exist in the side-slope liner. Following the increases in the leachate levels and the long-term settlement of the waste mass, the maximum shear strains in the side-slope lining system remain below the allowable limit, with the reported factors of safety being greater than the minimum requirement of 1.3.

For this reason, the proposed increases to the leachate levels and the long-term settlement of the waste at the site should have no detrimental impact on the integrity of the landfill lining containment system, ensuring that the permeability values assumed in the HRA can be relied upon.

In conclusion, the stability and integrity of the side-slope lining system, the capping lining system, and the waste at Milton Landfill Site will be maintained within acceptable limits should the leachate level be raised to **8mAOD** in **Phase 1** and **Phase 2**, and **9mAOD** in **Phase 3**, and following the long-term settlement of the waste mass.

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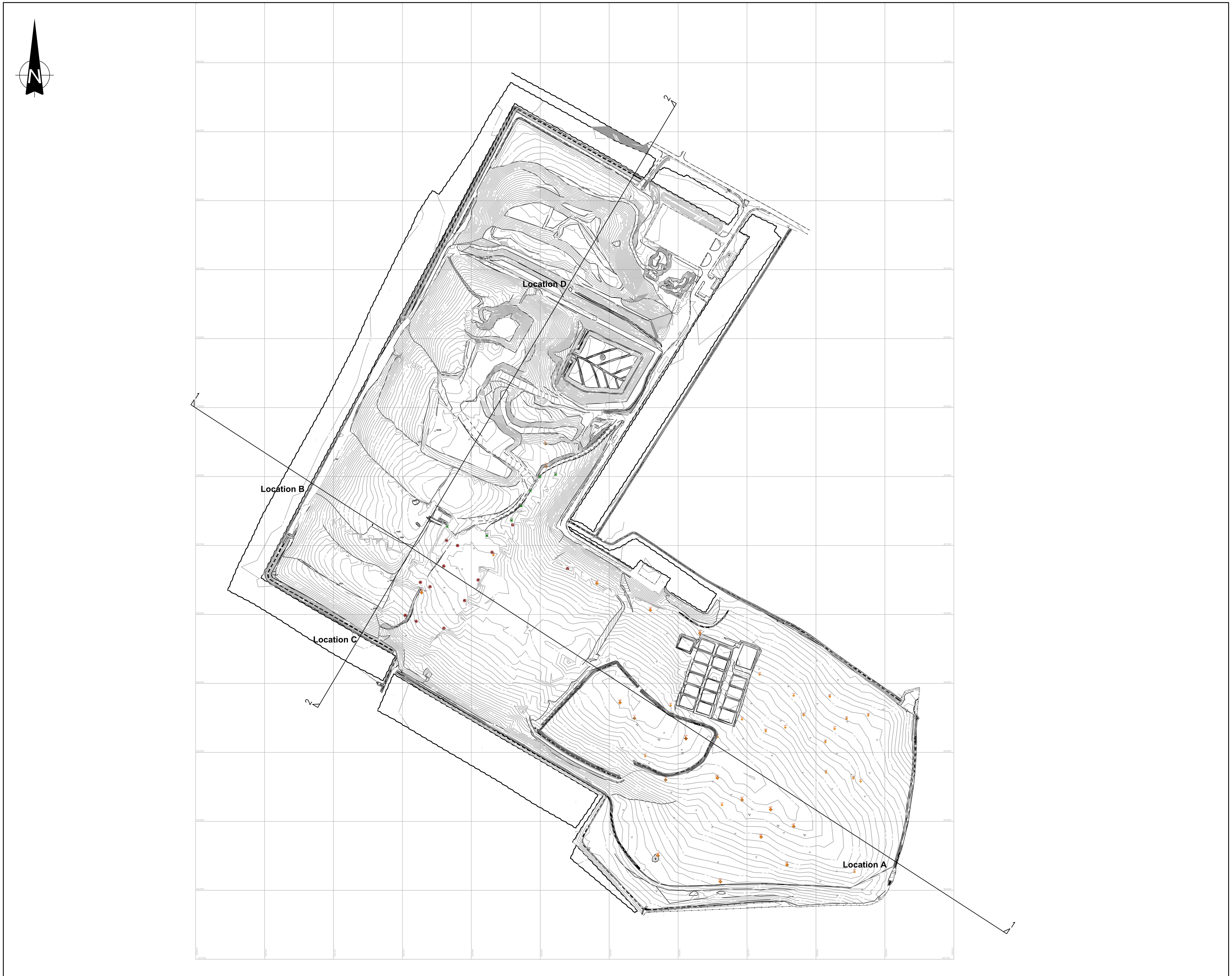
APPENDIX SRA1

DRAWINGS



NOTES

1. ALL DIMENSIONS IN MILLIMETRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM.

2. DO NOT SCALE FROM THIS DRAWING.

3. ANY ANOMALIES IDENTIFIED WITH THE DETAILS SHOWN ON THIS DRAWING ARE TO BE BROUGHT TO THE ATTENTION OF SIRIUS ENVIRONMENTAL PRIOR TO CONSTRUCTION WORKS COMMENCING.

KEY

REV	DESCRIPTION	DATE	BY

CLIENT

FCC Environment

FCC Environment (UK) Limited
Ground Floor West, 900 Pavilion Drive, Northampton Business Park, Northampton, NN4 7RG

sirius Environmental

4245 Park Approach, Thorpe Park, Leeds. LS15 8GB. 0113 264 9960

JOB TITLE

MILTON LANDFILL SITE
Leachate Level Increase SRA

DRAWING TITLE

Section Location Plan

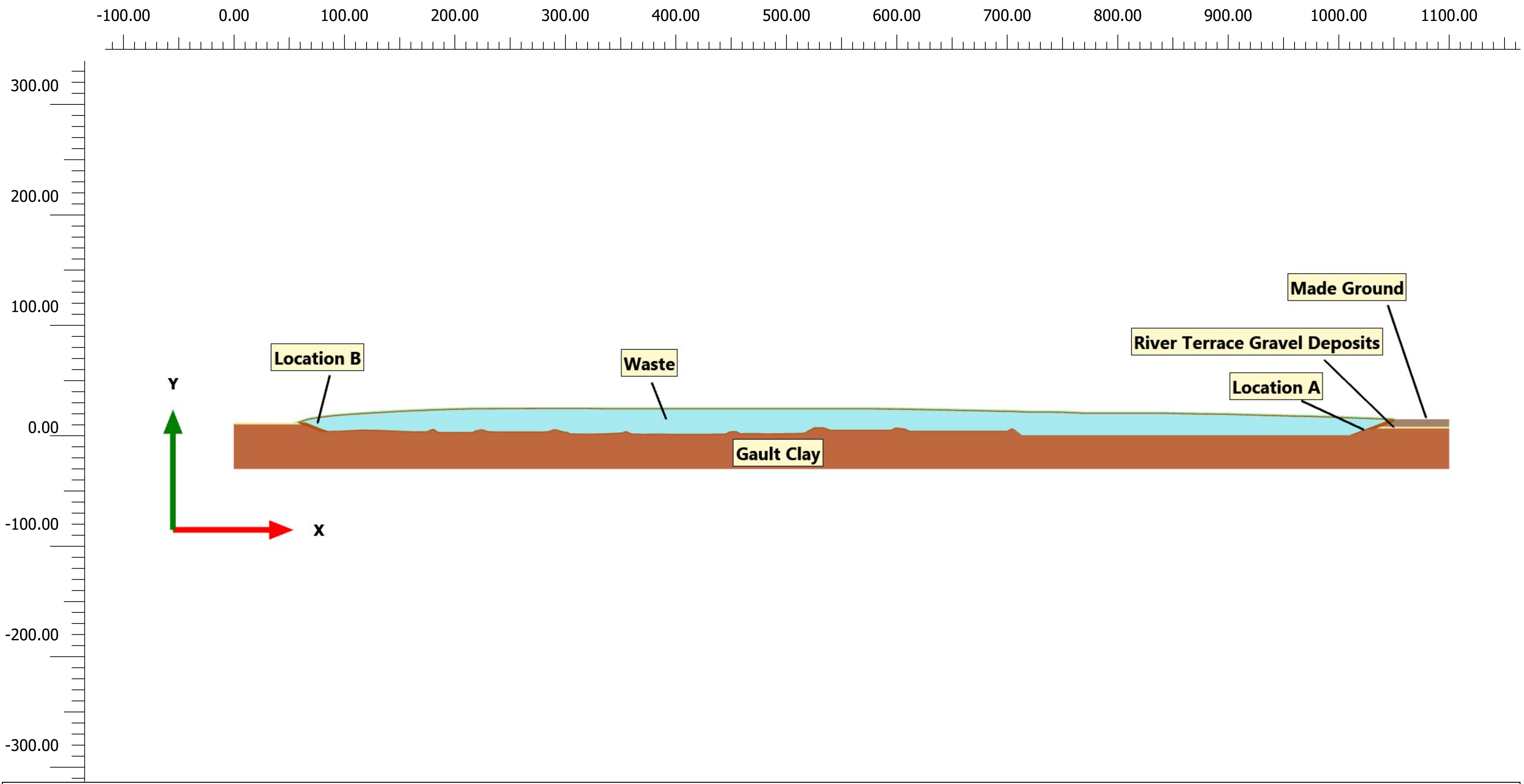
DRAWN	DATE	APPROVED	DATE
M.C	10/03/2021	J.C	10/03/2021

SCALE	SHEET	DRAWING NUMBER	REVISION
1:2500	A1L	WR7788 /SRA/01	0

APPENDIX SRA2

MODEL GEOMETRY AND MATERIAL PARAMETERS

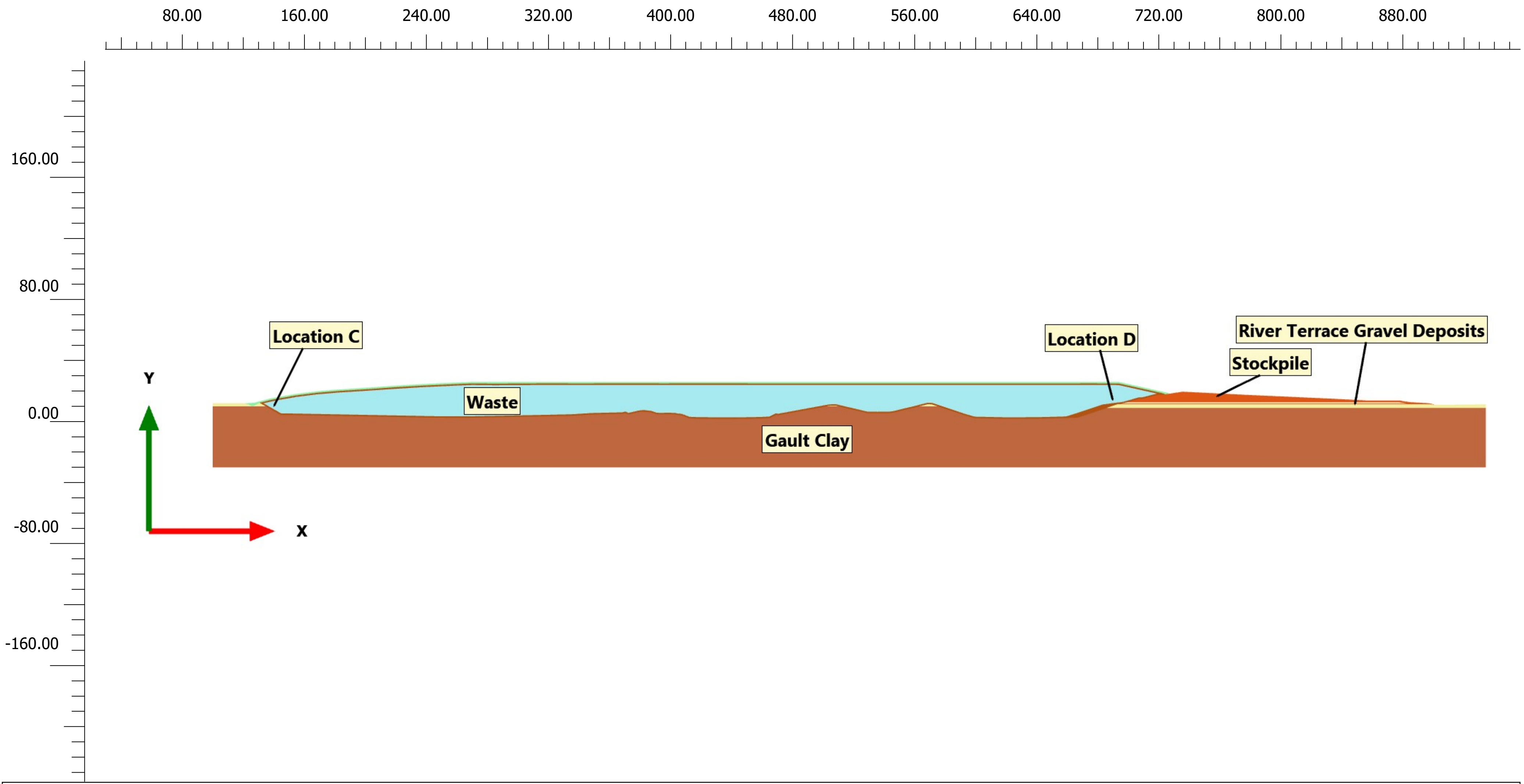
Output Version 21.1.0.479



Section 1 Geometry

Sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 08/07/2021
	Project filename Section 1 R2	*Step* 225	*Company* Sirius Environmental

Output Version 21.1.0.479

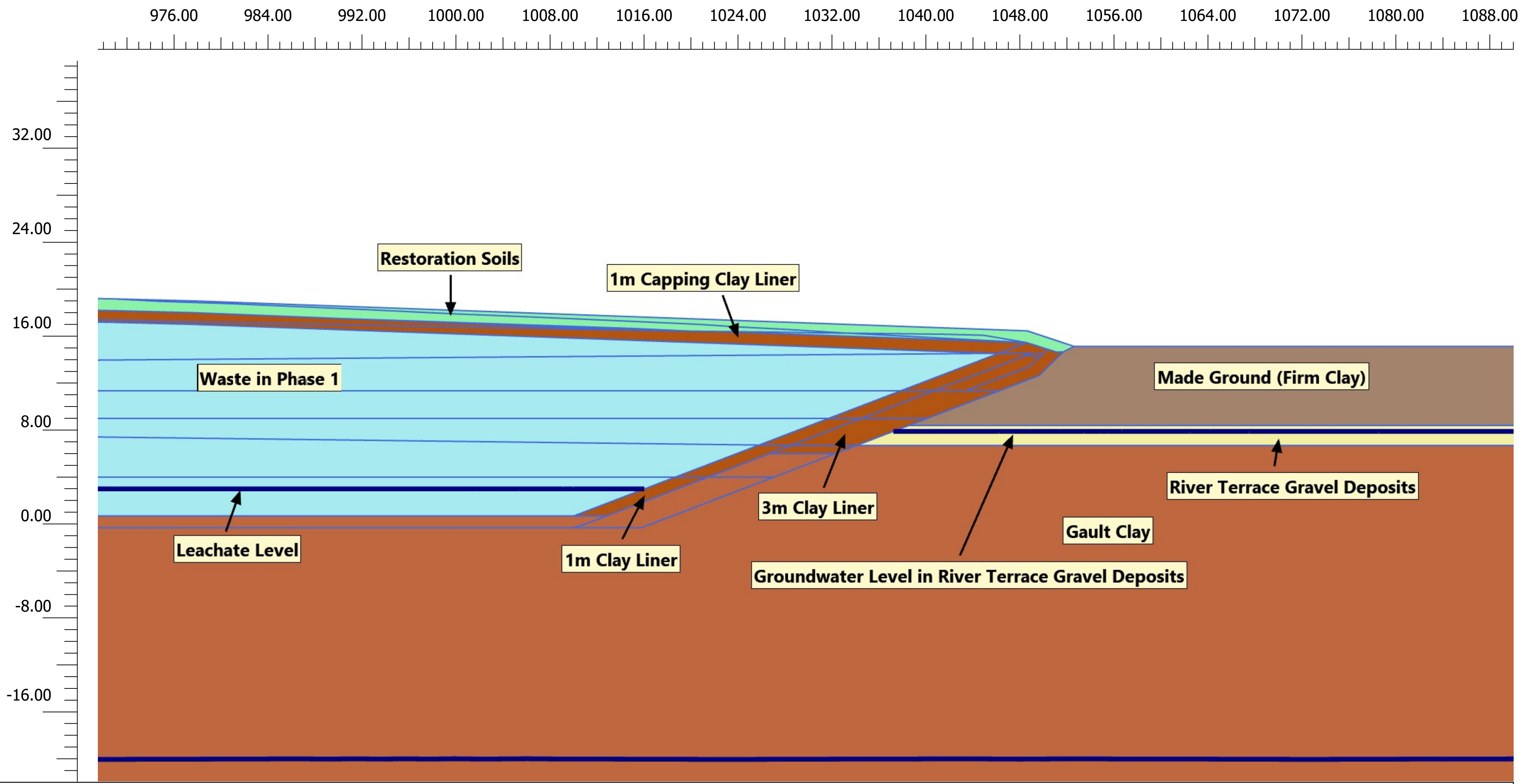


Section 2 Geometry

Project description	Date
Milton Leachate Rise SRA	13/07/2021

Project filename	Step	Company
Section 2 R2	205	Sirius Environmental

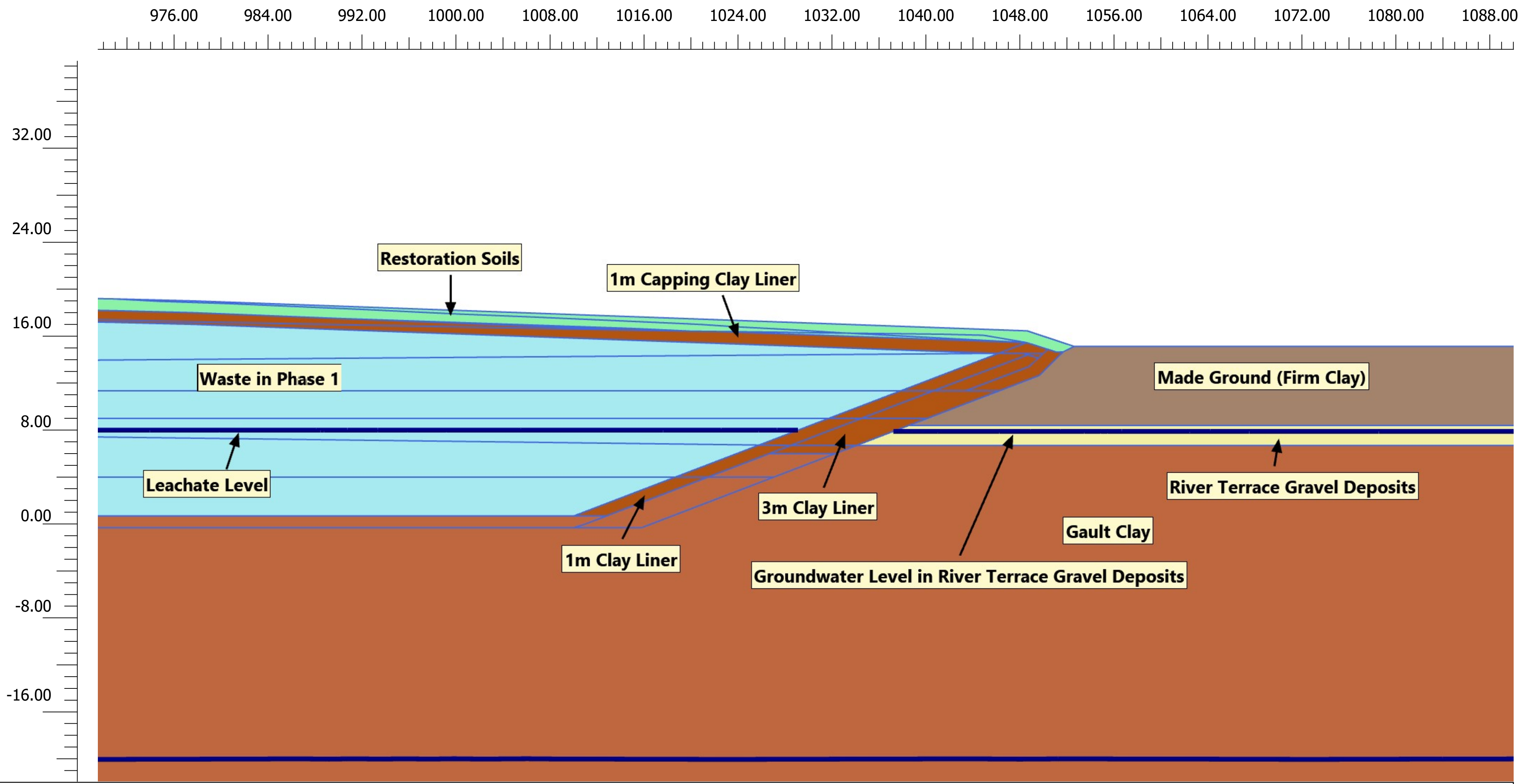
Output Version 21.1.0.479



Location A Pre Leachate Rise

Project description Milton Leachate Rise SRA			*Date* 08/07/2021
Project filename Section 1 R2	*Step* 163	*Company* Sirius Environmental	

Output Version 21.1.0.479

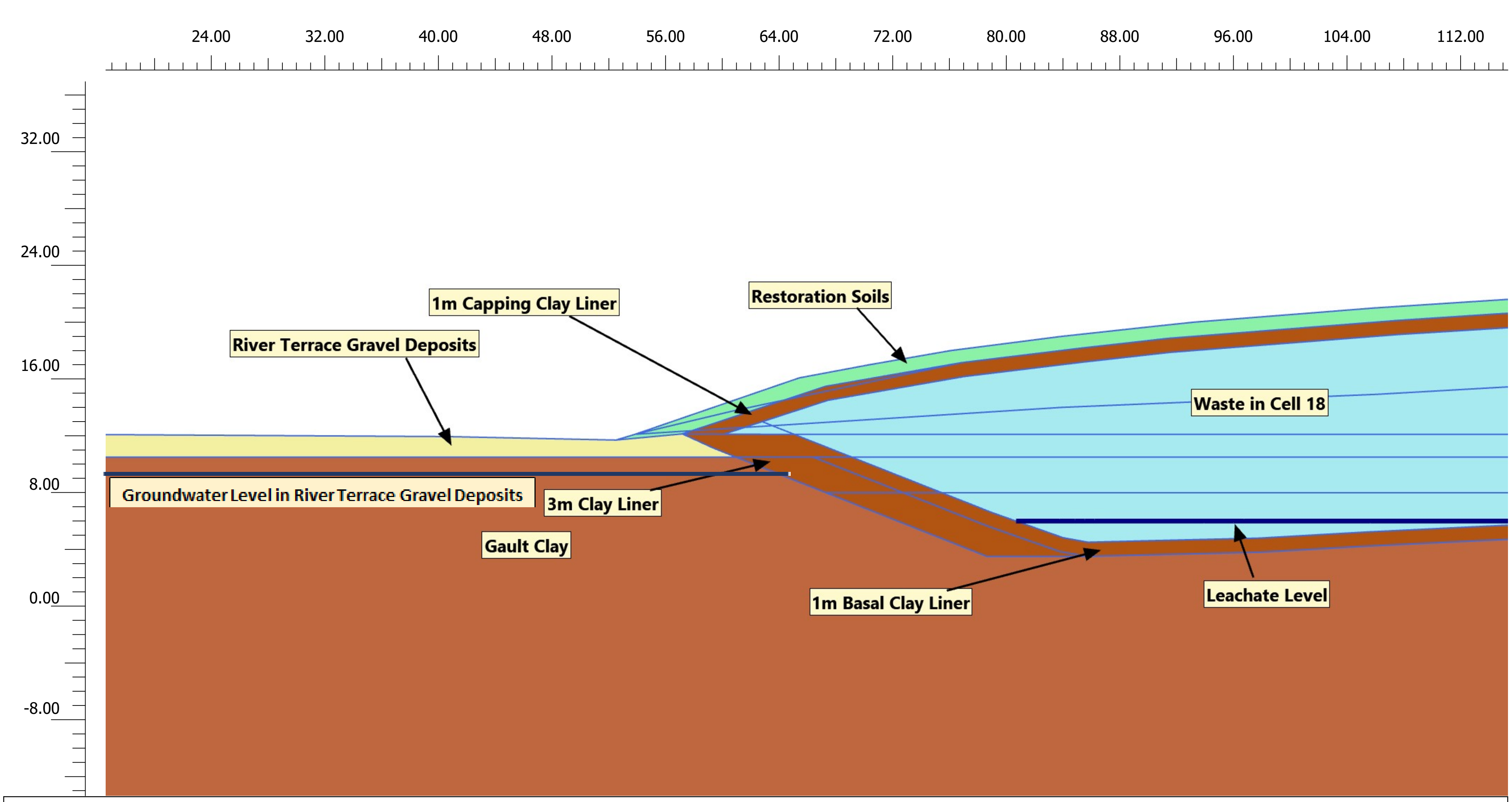


Location A Post Leachate Rise

Project description Milton Leachate Rise SRA		*Date* 08/07/2021
Project filename Section 1 R2	*Step* 187	*Company* Sirius Environmental

sirius Environmental

Output Version 21.1.0.479

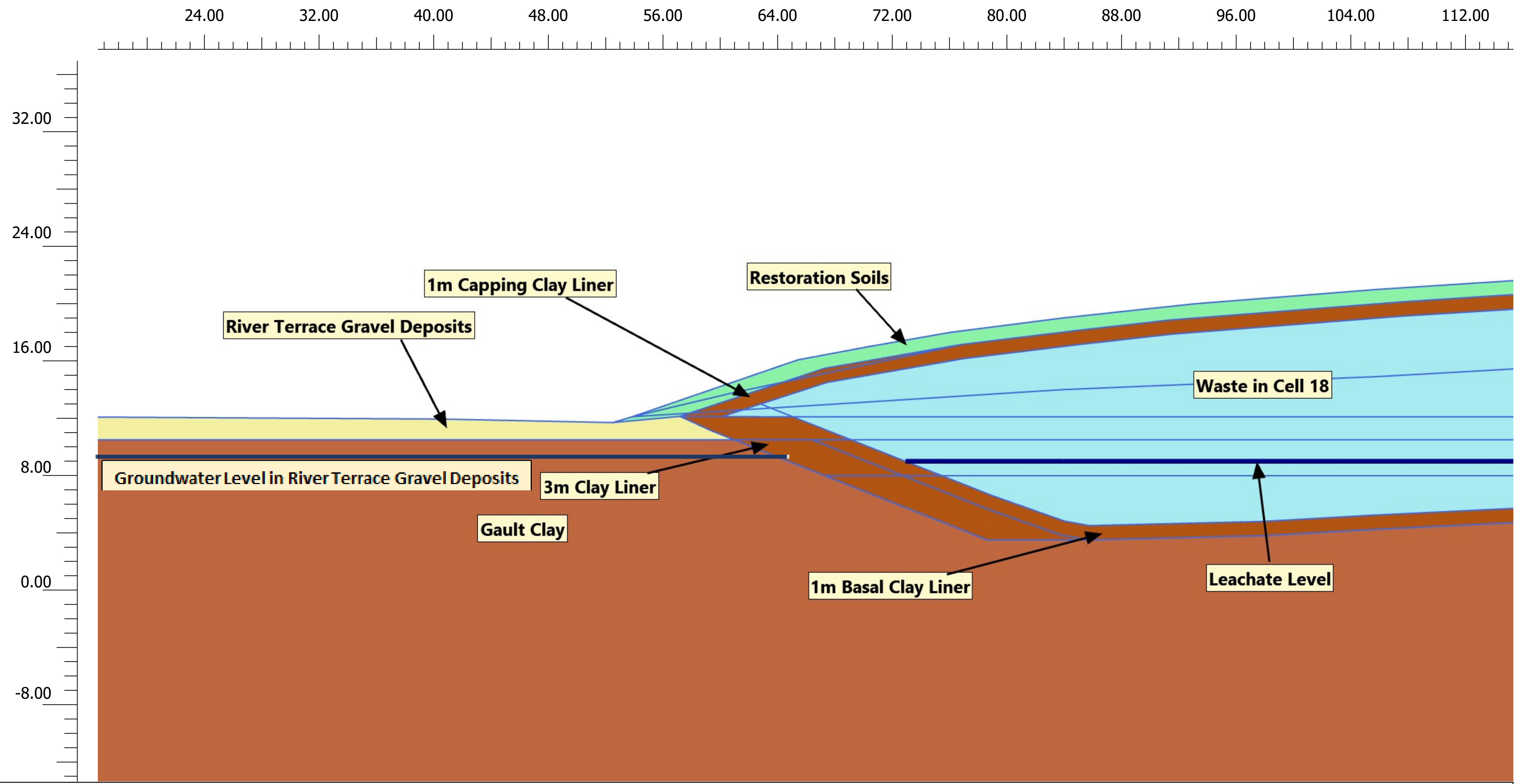


Location B Pre Leachate Rise

Project description Milton Leachate Rise SRA			*Date* 09/07/2021
Project filename Section 1 R2	*Step* 163	*Company* Sirius Environmental	

sirius Environmental

Output Version 21.1.0.479

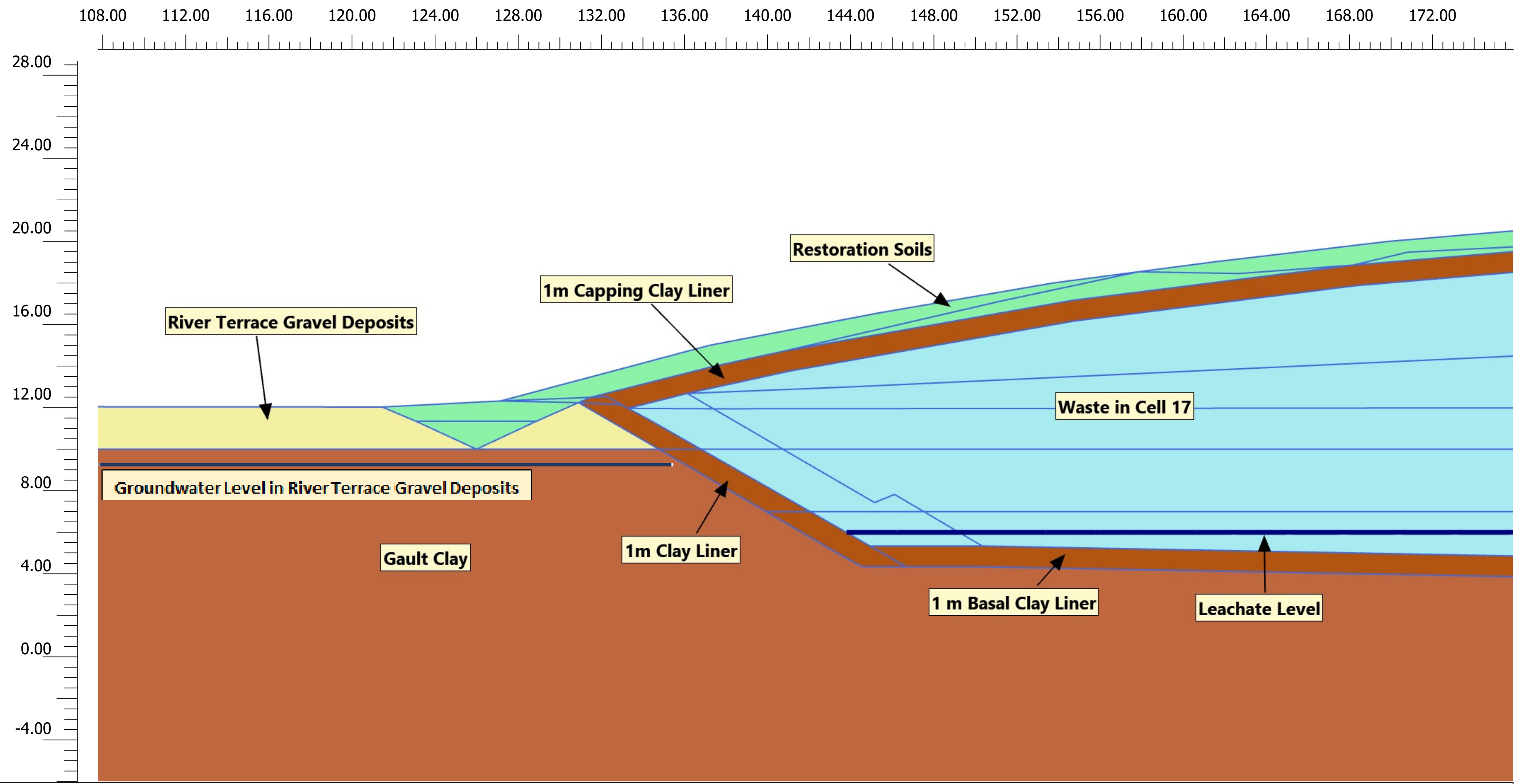


Location B Post Leachate Rise

Project description	Date
Milton Leachate Rise SRA	09/07/2021

Project filename	Step	Company
Section 1 R2	187	Sirius Environmental

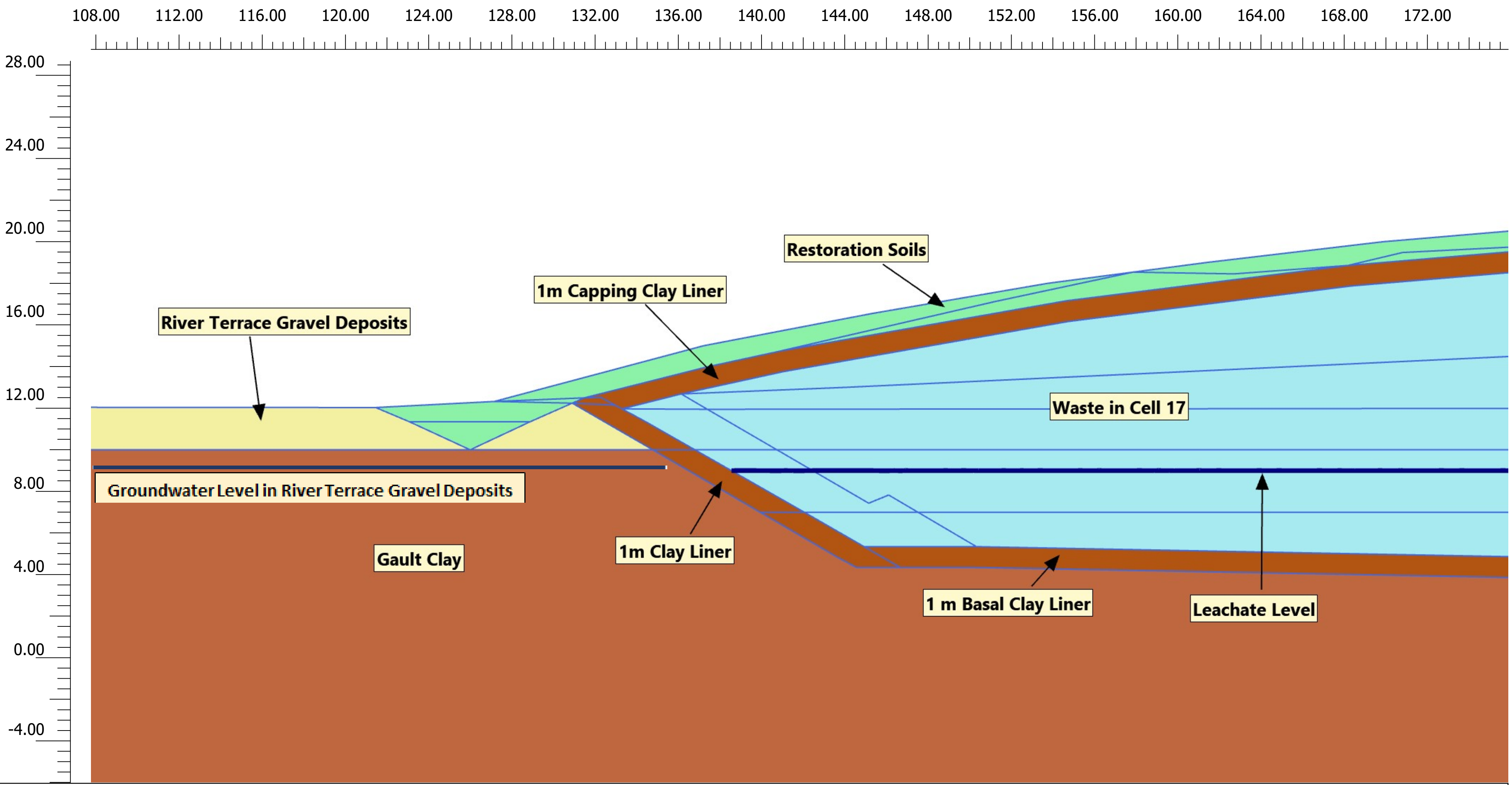
Output Version 21.1.0.479



Location C Pre Leachate Rise

Sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 13/07/2021
	Project filename Section 2 R2	*Step* 79	*Company* Sirius Environmental

Output Version 21.1.0.479

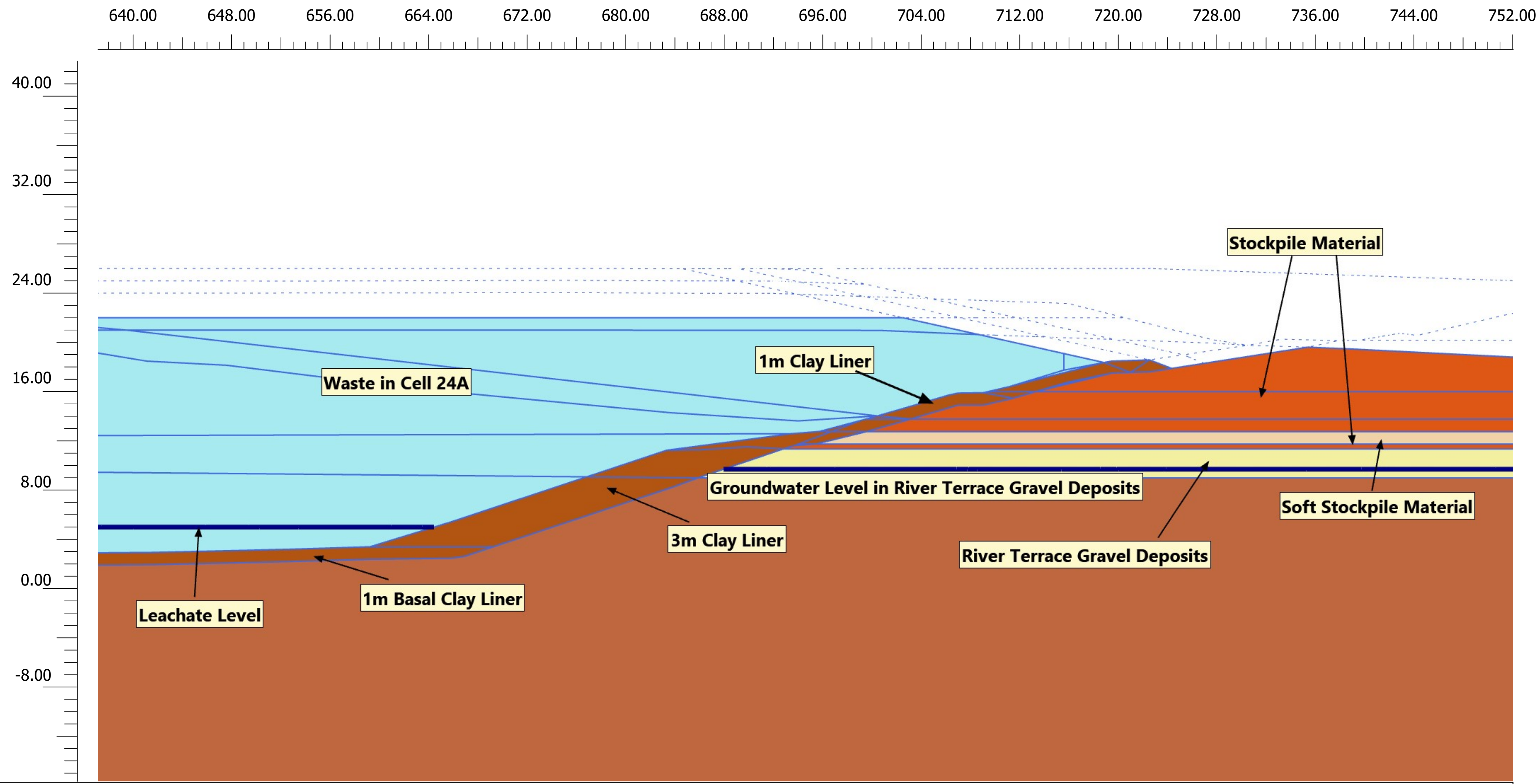


Location C Post Leachate Rise

Project description	Date
Milton Leachate Rise SRA	13/07/2021

Project filename	Step	Company
Section 2 R2	85	Sirius Environmental

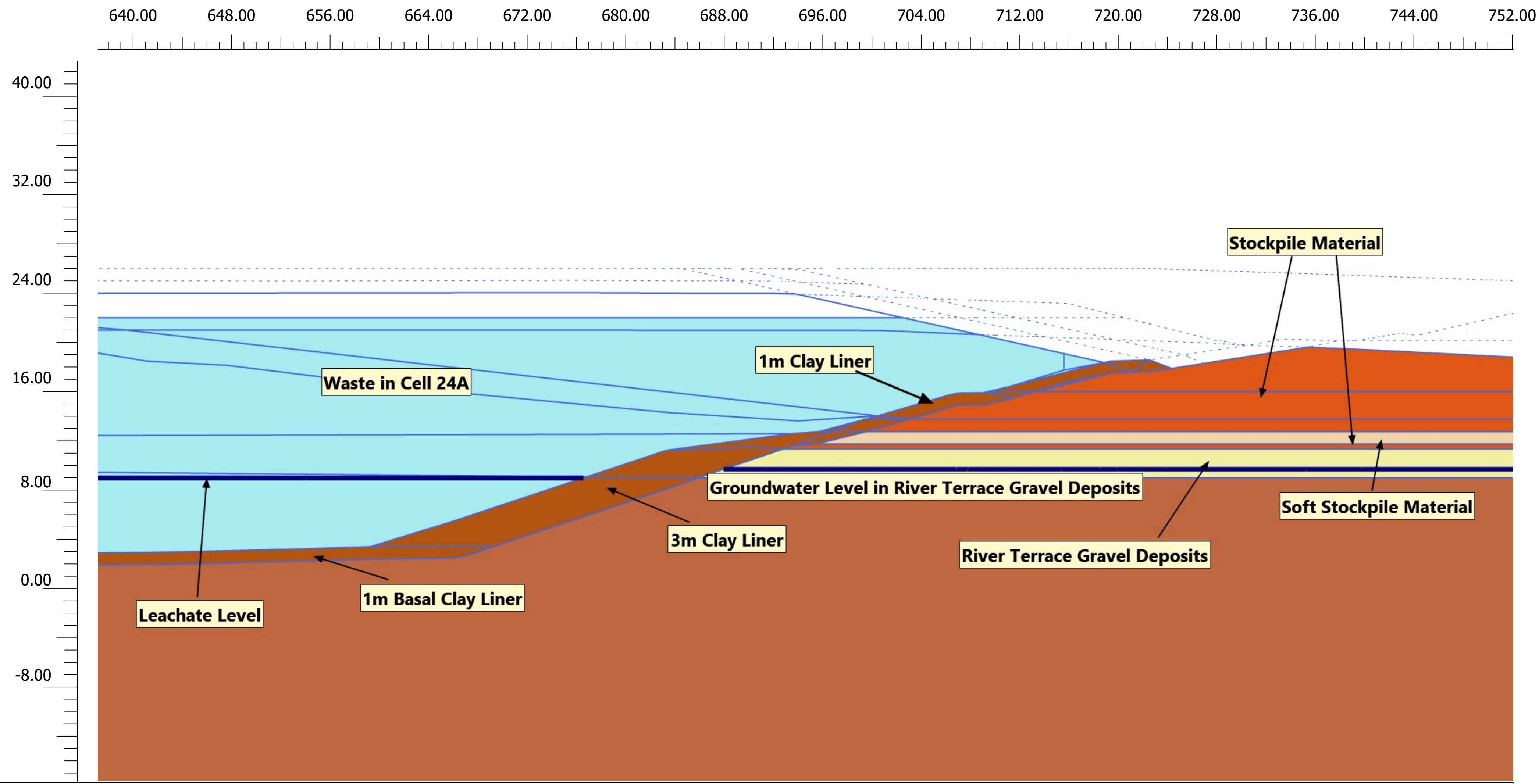
Output Version 21.1.0.479



Location D Pre Leachate Rise

Sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 13/07/2021
	Project filename Section 2 R2	*Step* 79	*Company* Sirius Environmental

Output Version 21.1.0.479



Location D Post Leachate Rise

Sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 13/07/2021
	Project filename Section 2 R2	*Step* 85	*Company* Sirius Environmental

Material set			
Identification number		1	2
Identification		Gault Clay	Stockpile
Material model		Hardening soil	Hardening soil
Drainage type		Undrained (A)	Undrained (A)
Colour		RGB 185, 100, 60	RGB 216, 84, 19
Comments			
General properties			
γ_{unsat}	kN/m³	20.00	21.00
γ_{sat}	kN/m³	20.00	21.00
Advanced			
Void ratio			
Dilatancy cut-off		No	No
e_{init}		0.5000	0.5000
e_{min}		0.000	0.000
e_{max}		999.0	999.0
Damping			
Rayleigh α		0.000	0.000
Rayleigh β		0.000	0.000
Stiffness			
E_{50}^{ref}	kN/m²	35.00E3	7000
E_{oed}^{ref}	kN/m²	35.00E3	7000
E_{ur}^{ref}	kN/m²	105.0E3	21.00E3
power (m)		1.000	0.9000
Alternatives			
Use alternatives		No	No
C_c		9.857E-3	0.04929
C_s		2.957E-3	0.01220
e_{init}		0.5000	0.5000
Strength			
c_{ref}	kN/m²	10.00	5.000
φ (phi)	°	20.00	26.00
ψ (psi)	°	0.000	0.000

Identification		Gault Clay	Stockpile
Advanced			
Set to default values		Yes	No
Stiffness			
ν_{ur}		0.2000	0.3000
p_{ref}	kN/m²	100.0	100.0
K_0^{nc}		0.6580	0.5616
Strength			
c_{inc}	kN/m²/m	0.000	0.000
y_{ref}	m	0.000	0.000
R_f		0.9000	0.9000
Tension cut-off		Yes	Yes
Tensile strength	kN/m²	0.000	0.000
Undrained behaviour			
Undrained behaviour		Standard	Standard
Skempton-B		0.9866	0.9783
ν_u		0.4950	0.4950
$K_{w,ref}$ / n	kN/m²	4.302E6	787.5E3
Stiffness			
Stiffness		Standard	Standard
Strength			
Strength		Rigid	Rigid
R_{inter}		1.000	1.000
Consider gap closure		Yes	Yes
Real interface thickness			
δ_{inter}		0.000	0.000
Groundwater			
Cross permeability		Impermeable	Impermeable
Drainage conductivity, dk	m³/day/m	0.000	0.000
Thermal			
R	m² K/kW	0.000	0.000

Identification		Gault Clay	Stockpile
K0 settings			
K_0 determination		Automatic	Automatic
$K_{0,x} = K_{0,z}$		Yes	Yes
$K_{0,x}$		0.6580	0.5616
$K_{0,z}$		0.6580	0.5616
Overconsolidation			
OCR		1.000	1.000
POP	kN/m²	0.000	0.000
Model			
Data set		Standard	Standard
Soil			
Type		Coarse	Coarse
< 2 μm	%	10.00	10.00
2 μm - 50 μm	%	13.00	13.00
50 μm - 2 mm	%	77.00	77.00
Flow parameters			
Use defaults		None	None
k_x	m/day	0.02592E-3	0.08640E-3
k_y	m/day	0.02592E-3	0.08640E-3
$-\psi_{unsat}$	m	10.00E3	10.00E3
e_{init}		0.5000	0.5000
S_s	1/m	0.000	0.000
Change of permeability			
c_k		1000E12	1000E12

Identification		Gault Clay	Stockpile
Parameters			
c_s	kJ/t/K	0.000	0.000
λ_s	kW/m/K	0.000	0.000
ρ_s	t/m³	0.000	0.000
Solid thermal expansion		Volumetric	Volumetric
α_s	1/K	0.000	0.000
D_v	m²/day	0.000	0.000
f_{Tv}		0.000	0.000
Unfrozen water content		None	None

Material set			
Identification number		3	4
Identification		Stockpile Soft	Waste
Material model		Hardening soil	Hardening soil
Drainage type		Undrained (A)	Undrained (A)
Colour		RGB 232, 204, 161	RGB 161, 226, 232
Comments			
General properties			
γ_{unsat}	kN/m³	21.00	11.00
γ_{sat}	kN/m³	21.00	11.00
Advanced			
Void ratio			
Dilatancy cut-off		No	No
e_{init}		0.5000	0.5000
e_{min}		0.000	0.000
e_{max}		999.0	999.0
Damping			
Rayleigh α		0.000	0.000
Rayleigh β		0.000	0.000
Stiffness			
E_{50}^{ref}	kN/m²	3000	12.00E3
E_{oed}^{ref}	kN/m²	3000	12.00E3
E_{ur}^{ref}	kN/m²	9000	36.00E3
power (m)		0.9000	0.7500
Alternatives			
Use alternatives		No	No
C_c		0.1150	0.02875
C_s		0.02848	8.625E-3
e_{init}		0.5000	0.5000
Strength			
c_{ref}	kN/m²	1.000	5.000
φ (phi)	°	20.00	25.00
ψ (psi)	°	0.000	0.000

Identification		Stockpile Soft	Waste
Advanced			
Set to default values		No	Yes
Stiffness			
ν_{ur}		0.3000	0.2000
p_{ref}	kN/m²	100.0	100.0
K_0^{nc}		0.5613	0.5774
Strength			
c_{inc}	kN/m²/m	0.000	0.000
y_{ref}	m	0.000	0.000
R_f		0.9000	0.9000
Tension cut-off		Yes	Yes
Tensile strength	kN/m²	0.000	0.000
Undrained behaviour			
Undrained behaviour		Standard	Standard
Skempton-B		0.9783	0.9866
ν_u		0.4950	0.4950
$K_{w,ref}$ / n	kN/m²	337.5E3	1.475E6
Stiffness			
Stiffness		Standard	Standard
Strength			
Strength		Rigid	Rigid
R_{inter}		1.000	1.000
Consider gap closure		Yes	Yes
Real interface thickness			
δ_{inter}		0.000	0.000
Groundwater			
Cross permeability		Impermeable	Impermeable
Drainage conductivity, dk	m³/day/m	0.000	0.000
Thermal			
R	m² K/kW	0.000	0.000

Identification		Stockpile Soft	Waste
K0 settings			
K_0 determination		Automatic	Automatic
$K_{0,x} = K_{0,z}$		Yes	Yes
$K_{0,x}$		0.5613	0.5774
$K_{0,z}$		0.5613	0.5774
Overconsolidation			
OCR		1.000	1.000
POP	kN/m²	0.000	0.000
Model			
Data set		Standard	Standard
Soil			
Type		Coarse	Coarse
< 2 µm	%	10.00	10.00
2 µm - 50 µm	%	13.00	13.00
50 µm - 2 mm	%	77.00	77.00
Flow parameters			
Use defaults		None	None
k_x	m/day	4.320E-3	0.8640
k_y	m/day	4.320E-3	0.8640
$-\psi_{unsat}$	m	10.00E3	10.00E3
e_{init}		0.5000	0.5000
S_s	1/m	0.000	0.000
Change of permeability			
c_k		1000E12	1000E12

Identification		Stockpile Soft	Waste
Parameters			
c_s	kJ/t/K	0.000	0.000
λ_s	kW/m/K	0.000	0.000
ρ_s	t/m³	0.000	0.000
Solid thermal expansion		Volumetric	Volumetric
α_s	1/K	0.000	0.000
D_v	m²/day	0.000	0.000
f_{Tv}		0.000	0.000
Unfrozen water content		None	None

Material set			
Identification number		5	6
Identification		Clay Liner	Restoration Soils
Material model		Hardening soil	Hardening soil
Drainage type		Undrained (A)	Undrained (A)
Colour		RGB 172, 81, 17	RGB 134, 234, 162
Comments			
General properties			
γ_{unsat}	kN/m³	20.00	18.00
γ_{sat}	kN/m³	20.00	19.00
Advanced			
Void ratio			
Dilatancy cut-off		No	No
e_{init}		0.5000	0.5000
e_{min}		0.000	0.000
e_{max}		999.0	999.0
Damping			
Rayleigh α		0.000	0.000
Rayleigh β		0.000	0.000
Stiffness			
E_{50}^{ref}	kN/m²	8000	4000
E_{oed}^{ref}	kN/m²	8000	4000
E_{ur}^{ref}	kN/m²	24.00E3	12.00E3
power (m)		1.000	0.7500
Alternatives			
Use alternatives		No	No
C_c		0.04312	0.08625
C_s		0.01294	0.02587
e_{init}		0.5000	0.5000
Strength			
c_{ref}	kN/m²	5.000	5.000
φ (phi)	°	25.00	25.00
ψ (psi)	°	0.000	0.000

Identification		Clay Liner	Restoration Soils
Advanced			
Set to default values		Yes	Yes
Stiffness			
ν_{ur}		0.2000	0.2000
p_{ref}	kN/m²	100.0	100.0
K_0^{nc}		0.5774	0.5774
Strength			
c_{inc}	kN/m²/m	0.000	0.000
y_{ref}	m	0.000	0.000
R_f		0.9000	0.9000
Tension cut-off		Yes	Yes
Tensile strength	kN/m²	0.000	0.000
Undrained behaviour			
Undrained behaviour		Standard	Standard
Skempton-B		0.9866	0.9866
ν_u		0.4950	0.4950
$K_{w,ref}$ / n	kN/m²	983.3E3	491.7E3
Stiffness			
Stiffness		Standard	Standard
Strength			
Strength		Rigid	Rigid
R_{inter}		1.000	1.000
Consider gap closure		Yes	Yes
Real interface thickness			
δ_{inter}		0.000	0.000
Groundwater			
Cross permeability		Impermeable	Impermeable
Drainage conductivity, dk	m³/day/m	0.000	0.000
Thermal			
R	m² K/kW	0.000	0.000

Identification		Clay Liner	Restoration Soils
K0 settings			
K_0 determination		Automatic	Automatic
$K_{0,x} = K_{0,z}$		Yes	Yes
$K_{0,x}$		0.5774	0.5774
$K_{0,z}$		0.5774	0.5774
Overconsolidation			
OCR		1.000	1.000
POP	kN/m²	0.000	0.000
Model			
Data set		Standard	Standard
Soil			
Type		Coarse	Coarse
< 2 µm	%	10.00	10.00
2 µm - 50 µm	%	13.00	13.00
50 µm - 2 mm	%	77.00	77.00
Flow parameters			
Use defaults		None	None
k_x	m/day	0.08640E-3	8.640E-3
k_y	m/day	0.08640E-3	8.640E-3
$-\psi_{unsat}$	m	10.00E3	10.00E3
e_{init}		0.5000	0.5000
S_s	1/m	0.000	0.000
Change of permeability			
c_k		1000E12	1000E12

Identification		Clay Liner	Restoration Soils
Parameters			
c_s	kJ/t/K	0.000	0.000
λ_s	kW/m/K	0.000	0.000
ρ_s	t/m³	0.000	0.000
Solid thermal expansion		Volumetric	Volumetric
α_s	1/K	0.000	0.000
D_v	m²/day	0.000	0.000
f_{Tv}		0.000	0.000
Unfrozen water content		None	None

Material set			
Identification number		7	8
Identification		River Terrace Gravel Deposits	Clay Fill
Material model		Hardening soil	Hardening soil
Drainage type		Undrained (A)	Drained
Colour		RGB 236, 232, 156	RGB 158, 128, 103
Comments			
General properties			
γ_{unsat}	kN/m³	19.00	19.00
γ_{sat}	kN/m³	20.00	20.00
Advanced			
Void ratio			
Dilatancy cut-off		No	No
e_{init}		0.5000	0.5000
e_{min}		0.000	0.000
e_{max}		999.0	999.0
Damping			
Rayleigh α		0.000	0.000
Rayleigh β		0.000	0.000
Stiffness			
E_{50}^{ref}	kN/m²	15.00E3	10.00E3
E_{oed}^{ref}	kN/m²	15.00E3	10.00E3
E_{ur}^{ref}	kN/m²	45.00E3	30.00E3
power (m)		0.5000	1.000
Alternatives			
Use alternatives		No	No
C_c		0.02300	0.03450
C_s		6.900E-3	0.01035
e_{init}		0.5000	0.5000
Strength			
c_{ref}	kN/m²	0.000	7.000
φ (phi)	°	33.00	30.00
ψ (psi)	°	0.000	0.000

Identification		River Terrace Gravel Deposits	Clay Fill
Advanced			
Set to default values		Yes	Yes
Stiffness			
ν_{ur}		0.2000	0.2000
p_{ref}	kN/m²	100.0	100.0
K_0^{nc}		0.4554	0.5000
Strength			
c_{inc}	kN/m²/m	0.000	0.000
y_{ref}	m	0.000	0.000
R_f		0.9000	0.9000
Tension cut-off		Yes	Yes
Tensile strength	kN/m²	0.000	0.000
Undrained behaviour			
Undrained behaviour		Standard	Standard
Skempton-B		0.9866	0.9866
ν_u		0.4950	0.4950
$K_{w,ref}$ / n	kN/m²	1.844E6	1.229E6
Stiffness			
Stiffness		Standard	Standard
Strength			
Strength		Rigid	Rigid
R_{inter}		1.000	1.000
Consider gap closure		Yes	Yes
Real interface thickness			
δ_{inter}		0.000	0.000
Groundwater			
Cross permeability		Impermeable	Impermeable
Drainage conductivity, dk	m³/day/m	0.000	0.000
Thermal			
R	m² K/kW	0.000	0.000

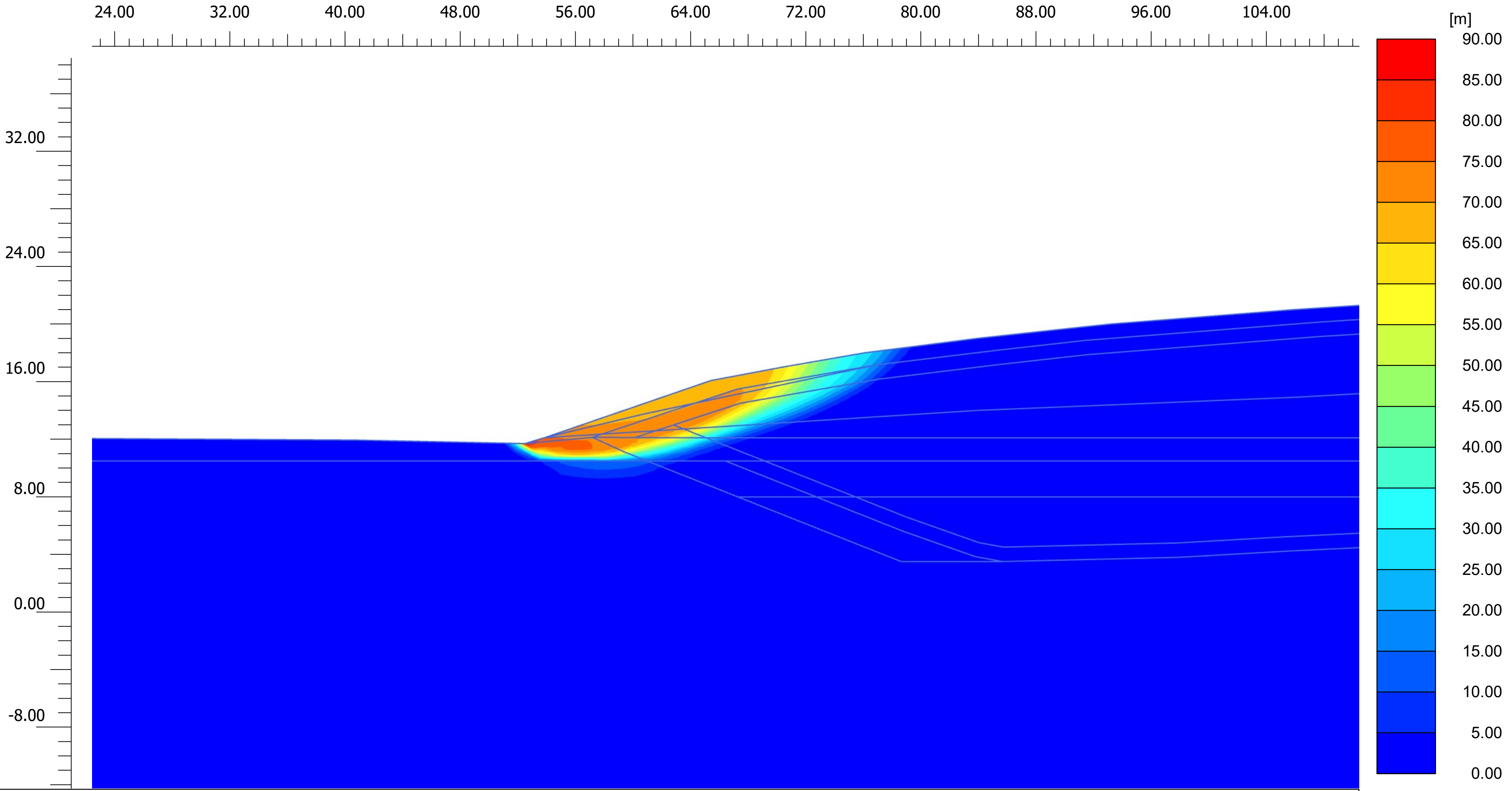
Identification		River Terrace Gravel Deposits	Clay Fill
K0 settings			
K_0 determination		Automatic	Automatic
$K_{0,x} = K_{0,z}$		Yes	Yes
$K_{0,x}$		0.4554	0.5000
$K_{0,z}$		0.4554	0.5000
Overconsolidation			
OCR		1.000	1.000
POP	kN/m²	0.000	0.000
Model			
Data set		Standard	Standard
Soil			
Type		Coarse	Coarse
< 2 µm	%	10.00	10.00
2 µm - 50 µm	%	13.00	13.00
50 µm - 2 mm	%	77.00	77.00
Flow parameters			
Use defaults		None	None
k_x	m/day	0.8640	0.8640E-3
k_y	m/day	0.8640	0.8640E-3
$-\psi_{unsat}$	m	10.00E3	10.00E3
e_{init}		0.5000	0.5000
S_s	1/m	0.000	0.000
Change of permeability			
c_k		1000E12	1000E12

Identification		River Terrace Gravel Deposits	Clay Fill
Parameters			
c_s	kJ/t/K	0.000	0.000
λ_s	kW/m/K	0.000	0.000
ρ_s	t/m³	0.000	0.000
Solid thermal expansion		Volumetric	Volumetric
α_s	1/K	0.000	0.000
D_v	m²/day	0.000	0.000
f_{Tv}		0.000	0.000
Unfrozen water content		None	None

APPENDIX SRA3

PLAXIS STABILITY PRINTOUTS

Output Version 21.1.0.479



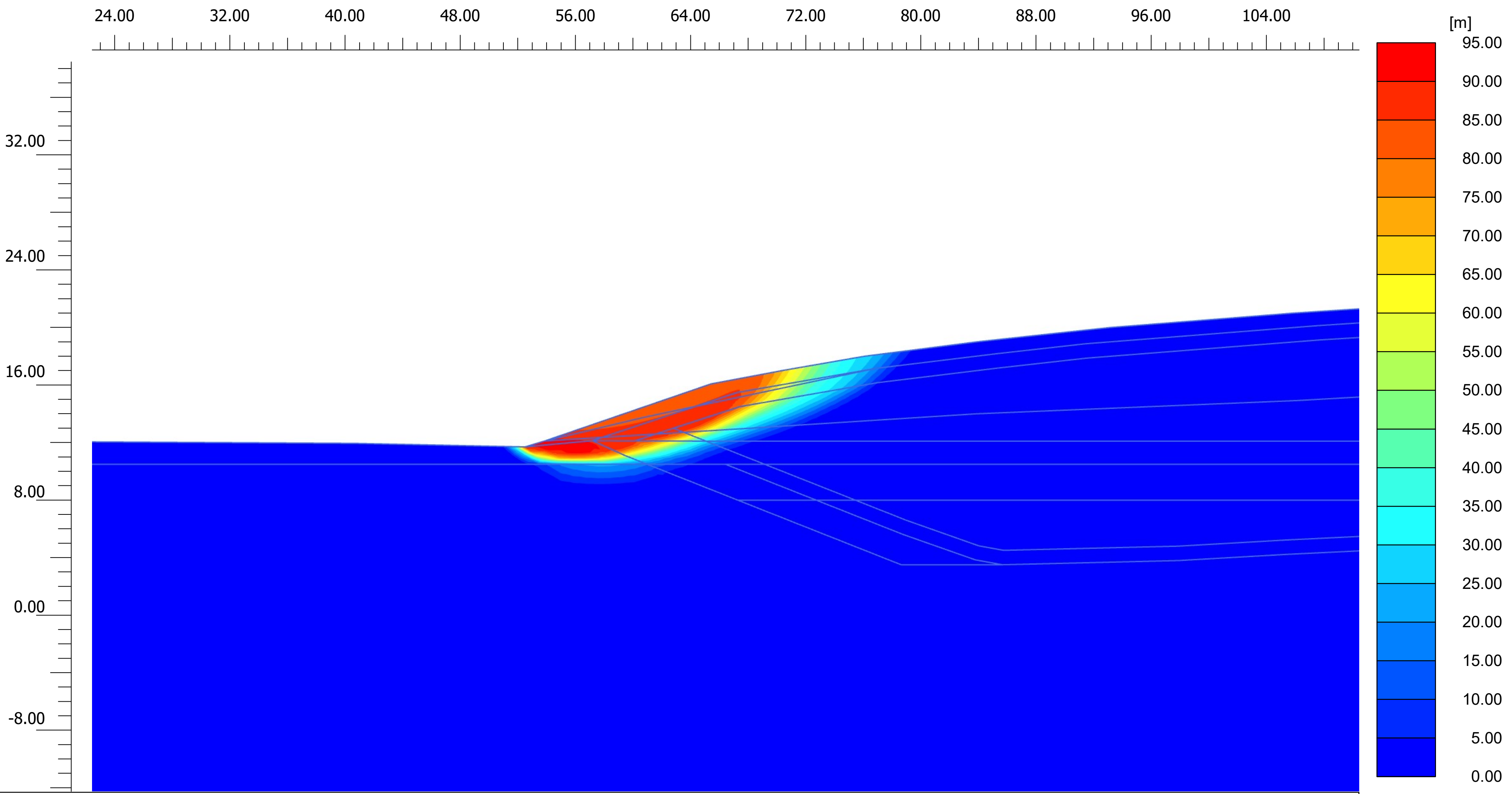
Incremental displacements |Δu| (scaled up 0.500 times)

Maximum value = 86.16 m (Element 3274 at Node 6849)

Project description Milton Leachate Rise SRA			*Date* 09/07/2021
Project filename Section 1 R2	*Step* 633	*Company* Sirius Environmental	

Step info				
Phase	Pre-Leachate Rise Safety [Phase_48]			
Step	Initial			
Calulation mode	Classical mode			
Step type	Safety			
Updated mesh	False			
Solver type	Picos			
Kernel type	64 bit			
Extrapolation factor	2.000			
Relative stiffness	1.226E-9			
Multipliers				
Soil weight			ΣM_{Weight}	1.000
Strength reduction factor	M_{sf}	0.1457E-3	ΣM_{sf}	3.872
Time	Increment	0.000	End time	15.09E3
Staged construction				
Active proportion total area	M_{Area}	0.000	ΣM_{Area}	0.9996
Active proportion of stage	M_{Stage}	0.000	ΣM_{Stage}	0.000
Forces				
F_X	0.000 kN/m			
F_Y	0.000 kN/m			
Consolidation				
Realised $P_{Excess,Max}$	4069 kN/m^2			

Output Version 21.1.0.479



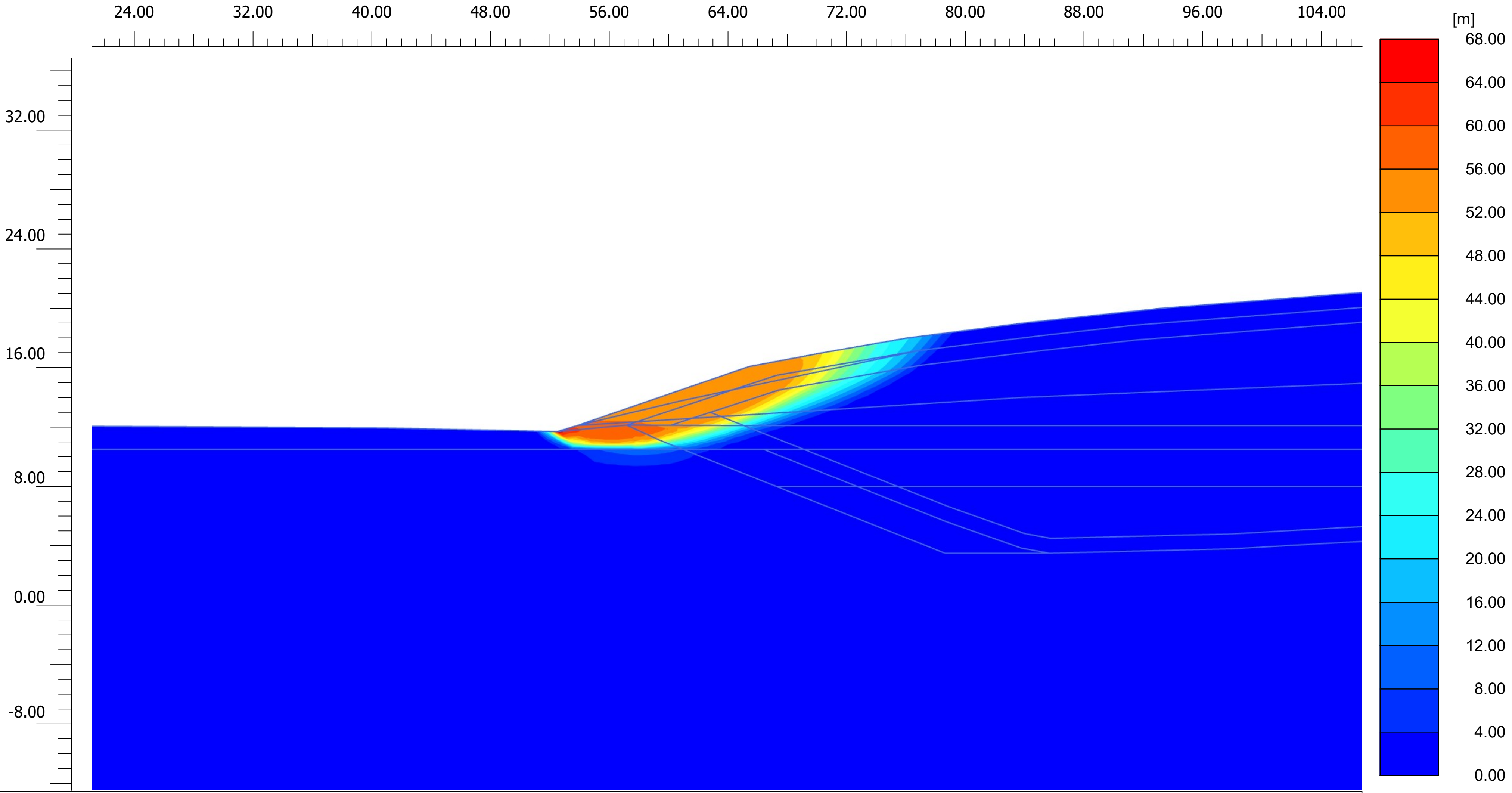
Incremental displacements |Δu| (scaled up 0.500 times)

Maximum value = 94.77 m (Element 3274 at Node 6119)

Project description Milton Leachate Rise SRA			*Date* 09/07/2021
Project filename Section 1 R2	*Step* 425	*Company* Sirius Environmental	

Step info				
Phase	Leachate Rise Safety [Phase_43]			
Step	Initial			
Calulation mode	Classical mode			
Step type	Safety			
Updated mesh	False			
Solver type	Picos			
Kernel type	64 bit			
Extrapolation factor	2.000			
Relative stiffness	2.726E-9			
Multipliers				
Soil weight			ΣM_{Weight}	1.000
Strength reduction factor	M_{sf}	-0.5735E-3	ΣM_{sf}	3.860
Time	Increment	0.000	End time	15.27E3
Staged construction				
Active proportion total area	M_{Area}	0.000	ΣM_{Area}	0.9996
Active proportion of stage	M_{Stage}	0.000	ΣM_{Stage}	0.000
Forces				
F_X	0.000 kN/m			
F_Y	0.000 kN/m			
Consolidation				
Realised $P_{Excess,Max}$	5766 kN/m^2			

Output Version 21.1.0.479



Incremental displacements |Δu| (scaled up 0.500 times)

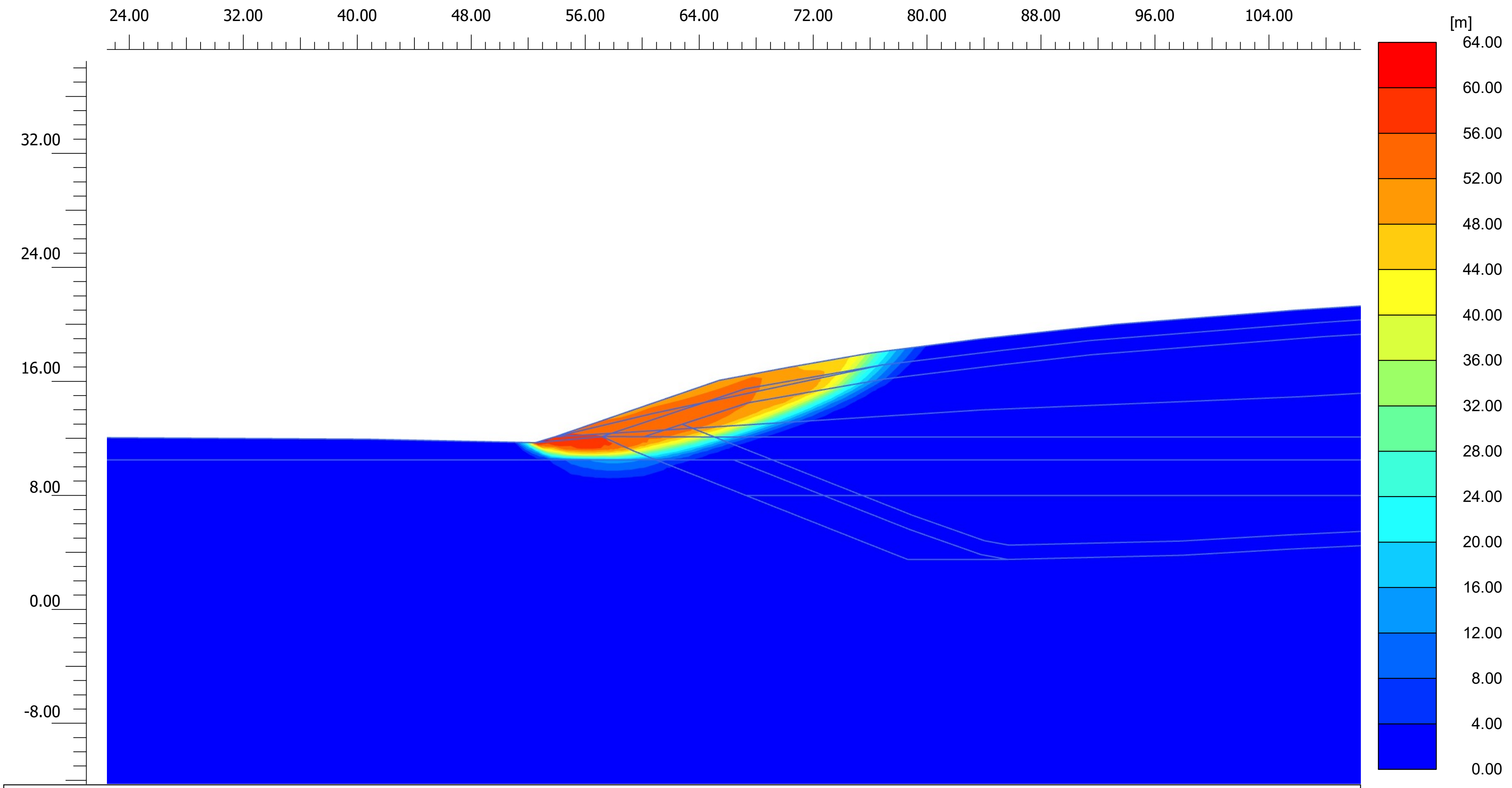
Maximum value = 67.07 m (Element 3274 at Node 6849)

Project description	*Date*
Milton Leachate Rise SRA	13/07/2021

Project filename	*Step*	*Company*
Section 1 R2	528	Sirius Environmental

Step info				
Phase	No Leachate Rise Safety [Phase_45]			
Step	Initial			
Calulation mode	Classical mode			
Step type	Safety			
Updated mesh	False			
Solver type	Picos			
Kernel type	64 bit			
Extrapolation factor	2.000			
Relative stiffness	0.7894E-9			
Multipliers				
Soil weight			ΣM_{Weight}	1.000
Strength reduction factor	M_{sf}	0.1849E-3	ΣM_{sf}	3.864
Time	Increment	0.000	End time	15.27E3
Staged construction				
Active proportion total area	M_{Area}	0.000	ΣM_{Area}	0.9996
Active proportion of stage	M_{Stage}	0.000	ΣM_{Stage}	0.000
Forces				
F_X	0.000 kN/m			
F_Y	0.000 kN/m			
Consolidation				
Realised $P_{Excess,Max}$	4355 kN/m^2			

Output Version 21.1.0.479



Incremental displacements |Δu| (scaled up 0.500 times)

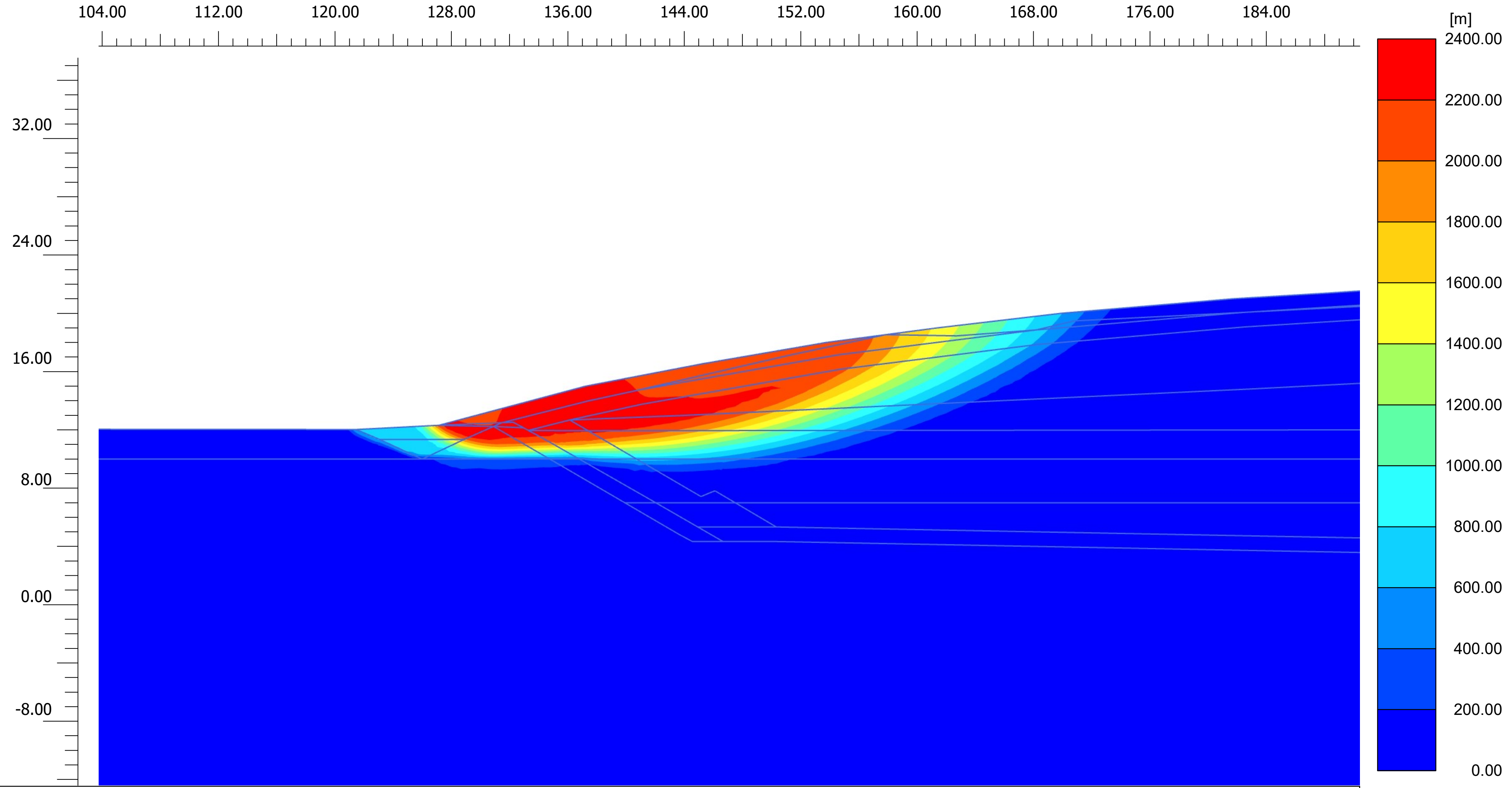
Maximum value = 61.75 m (Element 3274 at Node 6849)

Sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 09/07/2021
	Project filename Section 1 R2	*Step* 325	*Company* Sirius Environmental

Project description	: Section 1 R2		**Output Version 21.1.0.479**
Company	: Sirius Environmental		
Project filename	: Section 1 R2		Date : 09/07/2021
Output	: Calculation information		Page : 1

Step info				
Phase	50 Years Site Settlement Safety [Phase_56]			
Step	Initial			
Calulation mode	Classical mode			
Step type	Safety			
Updated mesh	False			
Solver type	Picos			
Kernel type	64 bit			
Extrapolation factor	2.000			
Relative stiffness	1.500E-9			
Multipliers				
Soil weight			ΣM_{Weight}	1.000
Strength reduction factor	M_{sf}	0.6252E-3	ΣM_{sf}	3.814
Time	Increment	0.000	End time	33.80E3
Staged construction				
Active proportion total area	M_{Area}	0.000	ΣM_{Area}	0.9996
Active proportion of stage	M_{Stage}	0.000	ΣM_{Stage}	0.000
Forces				
F_X	0.000 kN/m			
F_Y	0.000 kN/m			
Consolidation				
Realised $P_{Excess,Max}$	3559 kN/m^2			

Output Version 21.1.0.479



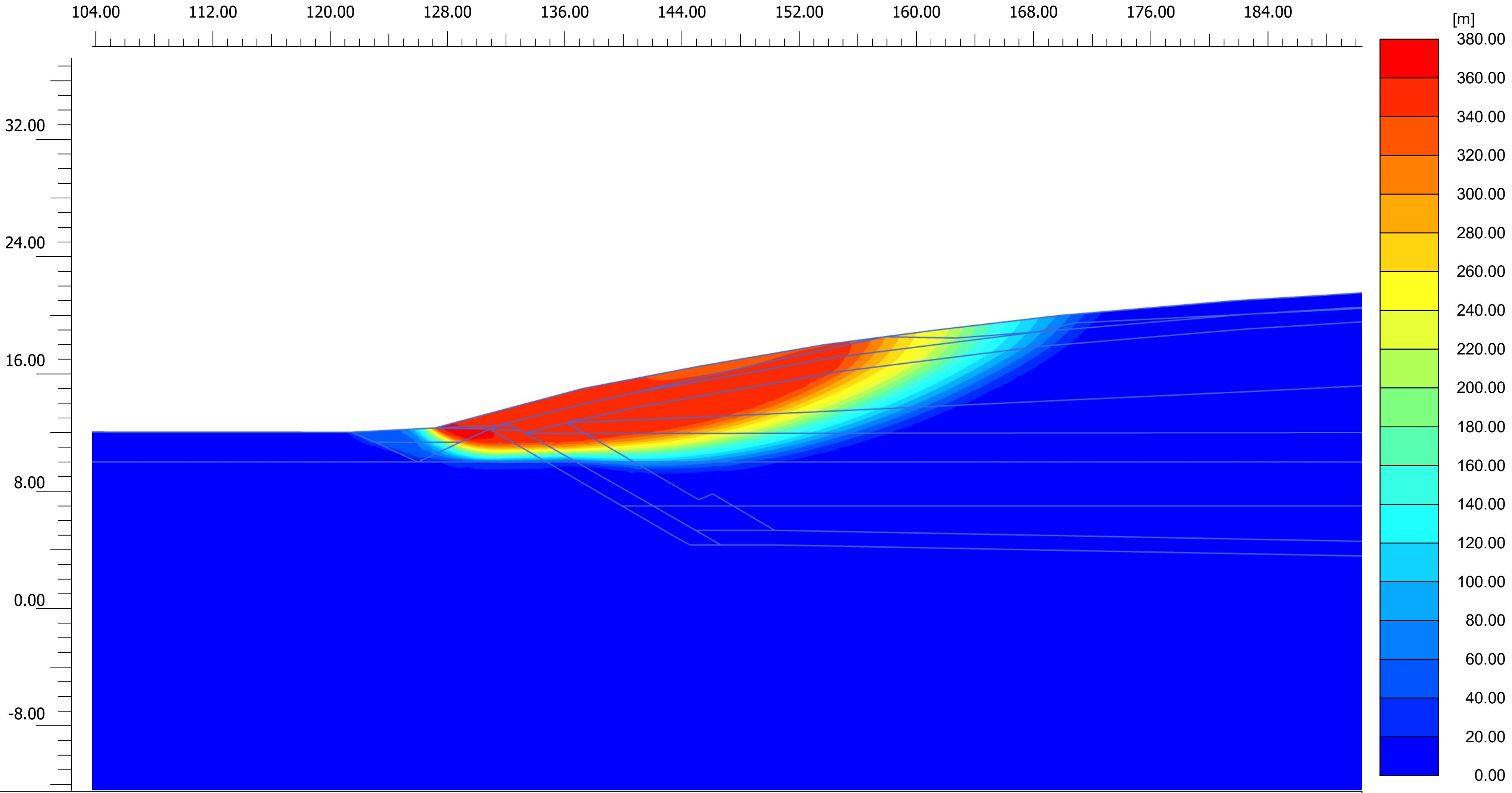
Incremental displacements |Δu| (scaled up 0.0100 times)

Maximum value = 2314 m (Element 4040 at Node 8061)

sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 13/07/2021
	Project filename Section 2 R2	*Step* 631	*Company* Sirius Environmental

Step info				
Phase	Pre-Rise Safety [Phase_33]			
Step	Initial			
Calulation mode	Classical mode			
Step type	Safety			
Updated mesh	False			
Solver type	Picos			
Kernel type	64 bit			
Extrapolation factor	2.000			
Relative stiffness	-0.02744E-9			
Multipliers				
Soil weight			ΣM_{Weight}	1.000
Strength reduction factor	M_{sf}	-0.9551E-3	ΣM_{sf}	4.736
Time	Increment	0.000	End time	5594
Staged construction				
Active proportion total area	M_{Area}	0.000	ΣM_{Area}	0.9563
Active proportion of stage	M_{Stage}	0.000	ΣM_{Stage}	0.000
Forces				
F_X	0.000 kN/m			
F_Y	0.000 kN/m			
Consolidation				
Realised $P_{Excess,Max}$	6702 kN/m^2			

Output Version 21.1.0.479



Incremental displacements |Δu| (scaled up 0.0500 times)

Maximum value = 374.3 m (Element 4040 at Node 8058)

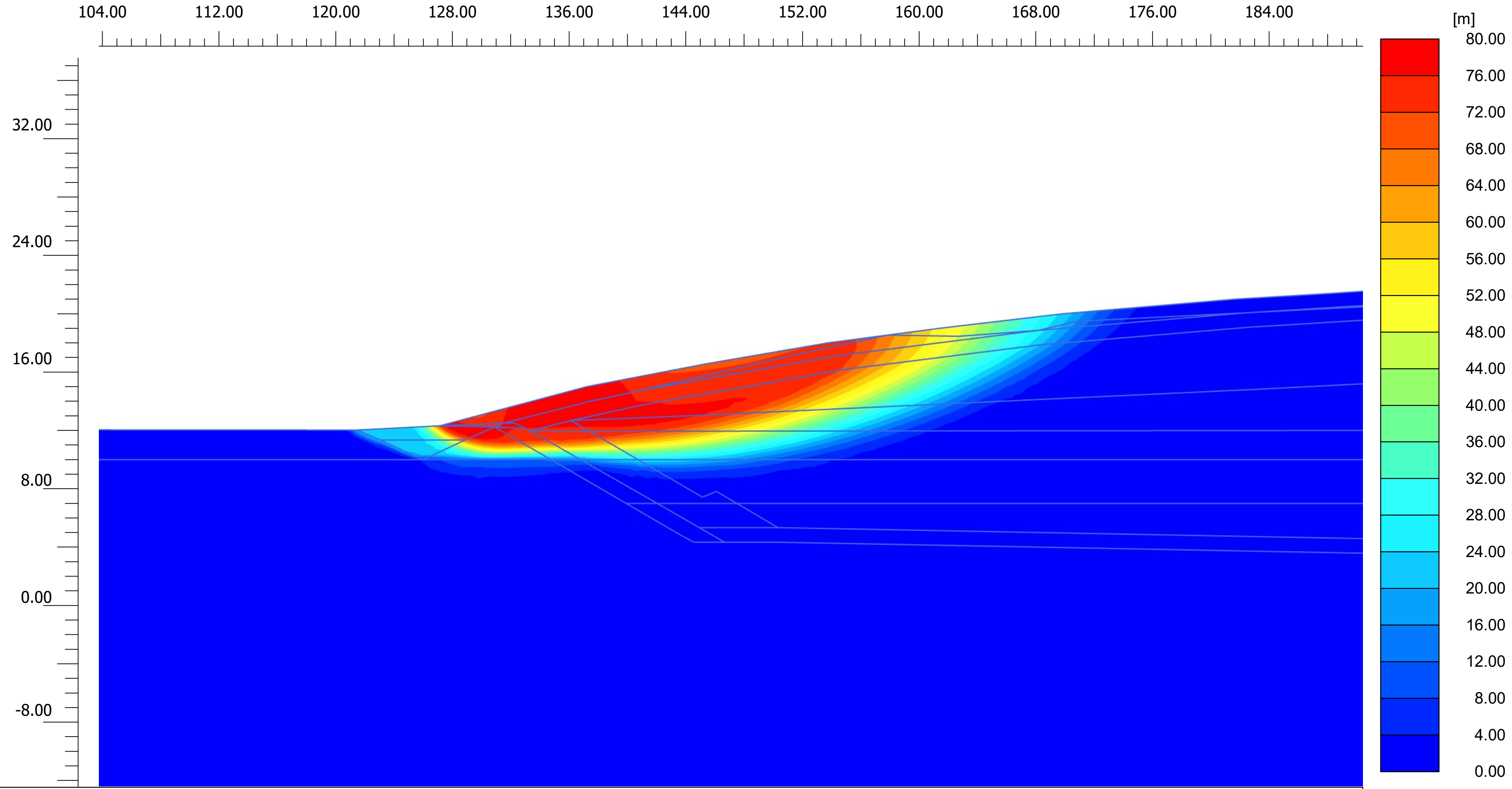
sirius Environmental

Project description		*Date*
Milton Leachate Rise SRA		13/07/2021

Project filename	*Step*	*Company*
Section 2 R2	321	Sirius Environmental

Step info				
Phase	Leachate Rise Safety [Phase_26]			
Step	Initial			
Calulation mode	Classical mode			
Step type	Safety			
Updated mesh	False			
Solver type	Picos			
Kernel type	64 bit			
Extrapolation factor	0.5000			
Relative stiffness	0.01038E-9			
Multipliers				
Soil weight			ΣM_{Weight}	1.000
Strength reduction factor	M_{sf}	0.2793E-3	ΣM_{sf}	4.703
Time	Increment	0.000	End time	5776
Staged construction				
Active proportion total area	M_{Area}	0.000	ΣM_{Area}	0.9563
Active proportion of stage	M_{Stage}	0.000	ΣM_{Stage}	0.000
Forces				
F_X	0.000 kN/m			
F_Y	0.000 kN/m			
Consolidation				
Realised $P_{Excess,Max}$	4480 kN/m^2			

Output Version 21.1.0.479



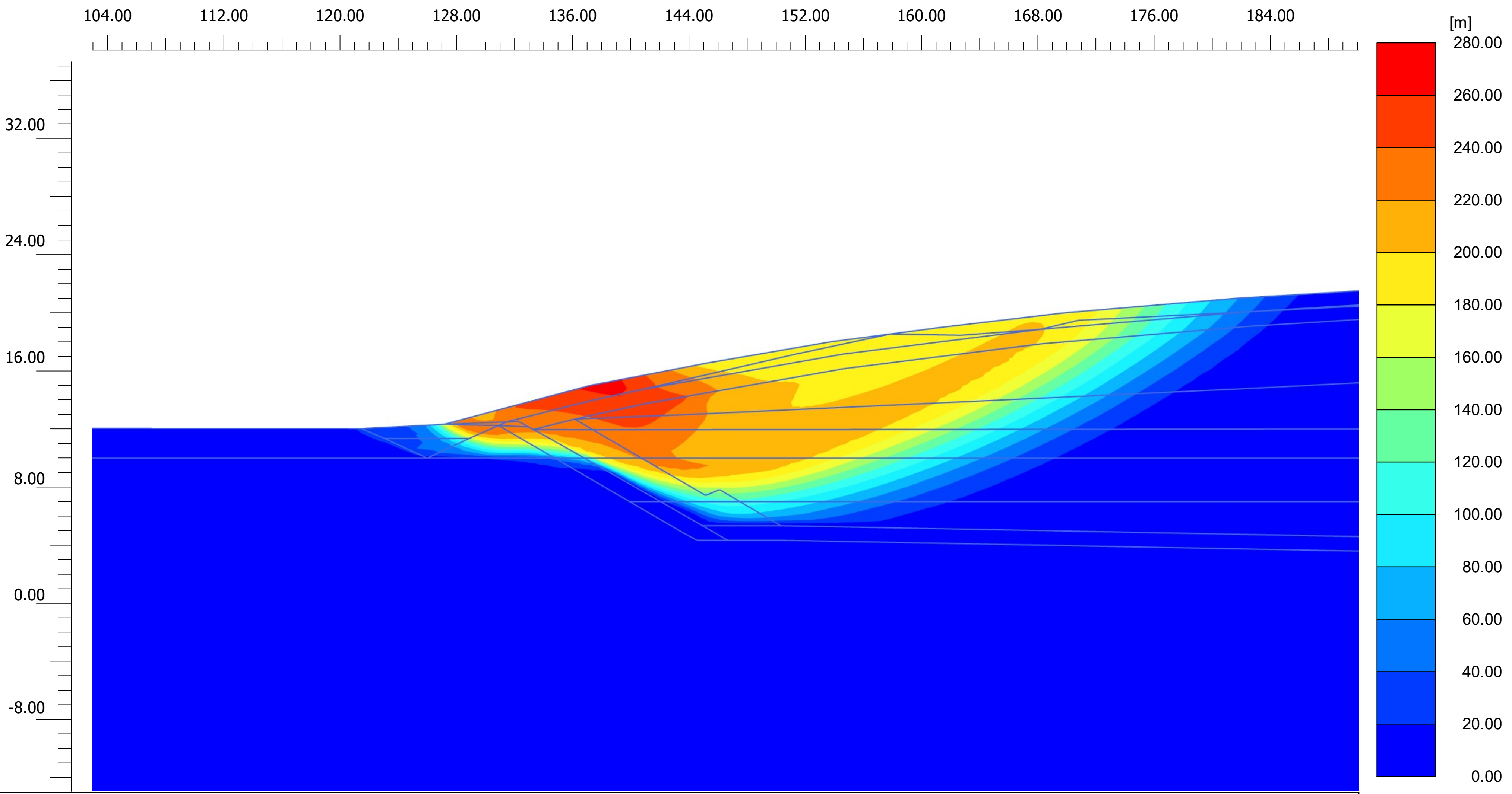
Incremental displacements |Δu| (scaled up 0.200 times)

Maximum value = 79.43 m (Element 4040 at Node 8061)

Project description Milton Leachate Rise SRA			*Date* 13/07/2021
Project filename Section 2 R2	*Step* 424	*Company* Sirius Environmental	

Step info				
Phase	No Leachate Rise Safety [Phase_28]			
Step	Initial			
Calulation mode	Classical mode			
Step type	Safety			
Updated mesh	False			
Solver type	Picos			
Kernel type	64 bit			
Extrapolation factor	0.5000			
Relative stiffness	-0.1032E-9			
Multipliers				
Soil weight			ΣM_{Weight}	1.000
Strength reduction factor	M_{sf}	-0.1601E-3	ΣM_{sf}	4.750
Time	Increment	0.000	End time	5776
Staged construction				
Active proportion total area	M_{Area}	0.000	ΣM_{Area}	0.9563
Active proportion of stage	M_{Stage}	0.000	ΣM_{Stage}	0.000
Forces				
F_X	0.000 kN/m			
F_Y	0.000 kN/m			
Consolidation				
Realised $P_{Excess,Max}$	10.71E3 kN/m^2			

Output Version 21.1.0.479



Incremental displacements |Δu| (scaled up 0.0500 times)

Maximum value = 266.4 m (Element 3435 at Node 1173)

Sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 13/07/2021
	Project filename Section 2 R2	*Step* 201	*Company* Sirius Environmental

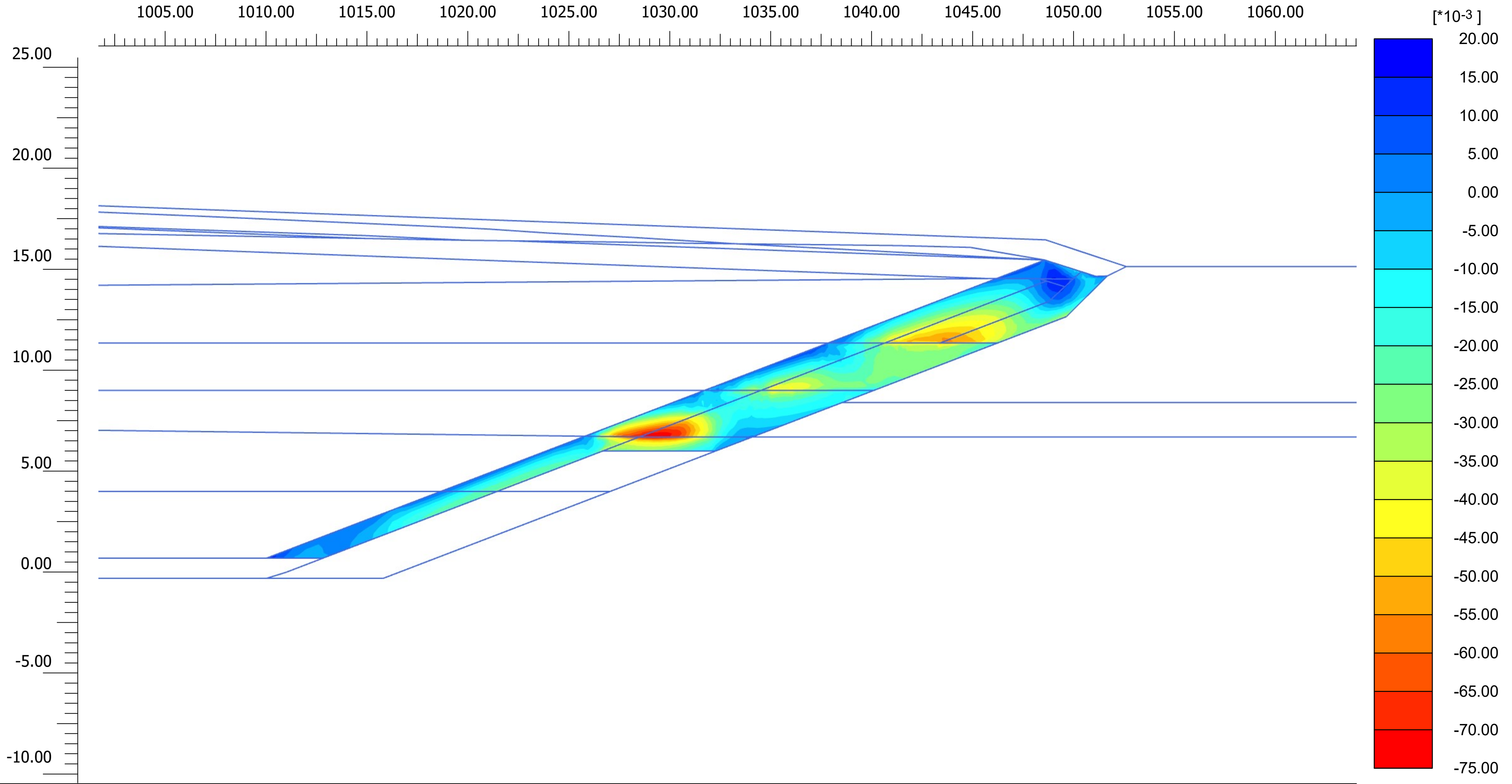
Step info

Phase	Final Settlement Safety [Phase_35]			
Step	Initial			
Calulation mode	Classical mode			
Step type	Safety			
Updated mesh	False			
Solver type	Picos			
Kernel type	64 bit			
Extrapolation factor	2.000			
Relative stiffness	2.211E-9			
Multipliers				
Soil weight			ΣM_{Weight}	1.000
Strength reduction factor	M_{sf}	3.404E-3	ΣM_{sf}	4.342
Time	Increment	0.000	End time	24.31E3
Staged construction				
Active proportion total area	M_{Area}	0.000	ΣM_{Area}	0.9765
Active proportion of stage	M_{Stage}	0.000	ΣM_{Stage}	0.000
Forces				
F_X	0.000 kN/m			
F_Y	0.000 kN/m			
Consolidation				
Realised $P_{Excess,Max}$	3372 kN/m^2			

APPENDIX SRA4

PLAXIS INTEGRITY PRINTOUTS

Output Version 21.1.0.479



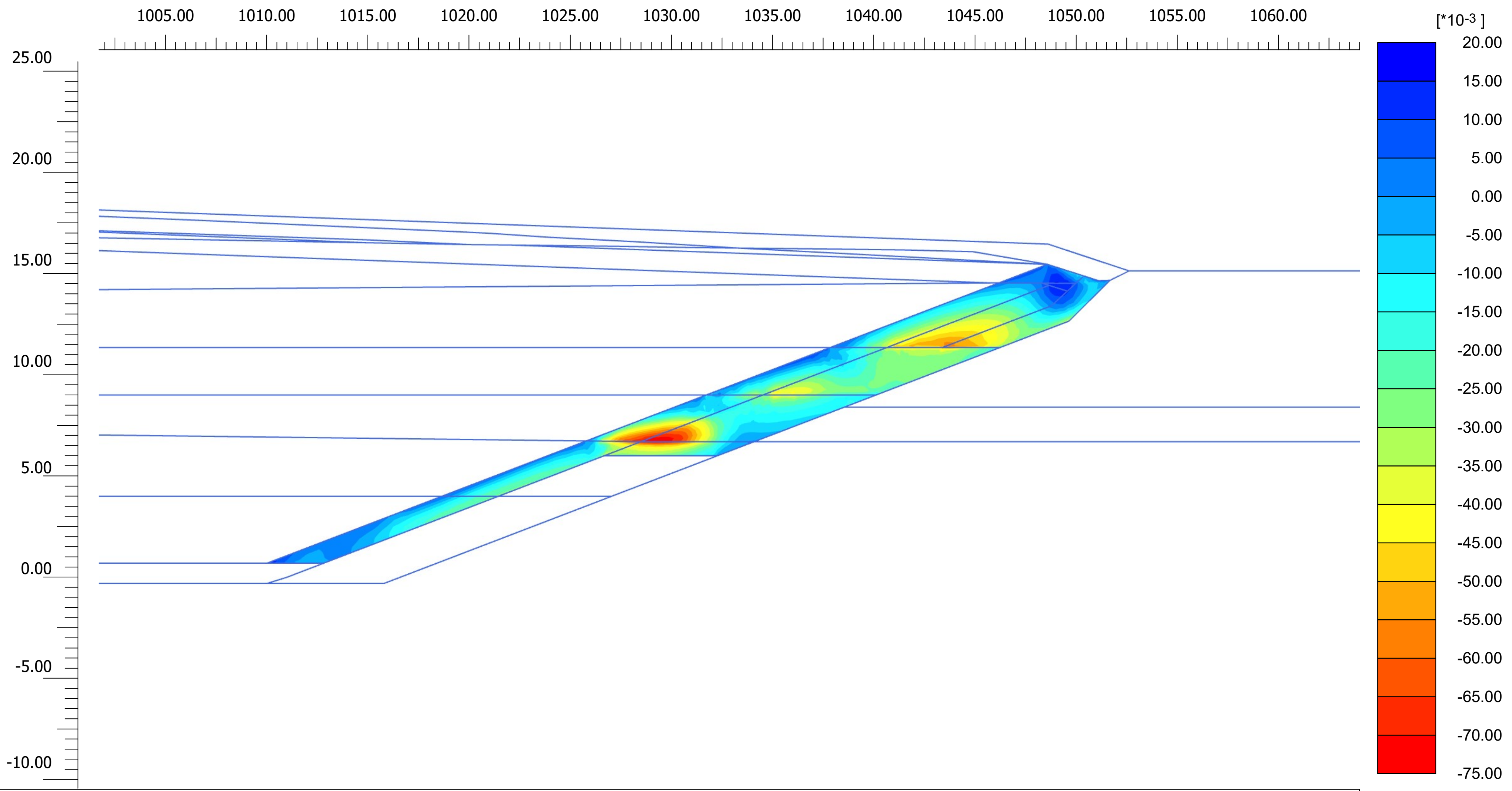
Total cartesian strain γ_{xy} (scaled up 500 times) (Time 15.09*10^3 day)

Maximum value = 0.01546 (Element 2931 at Node 60018)

Minimum value = -0.07465 (Element 4969 at Node 61102)

Sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 08/07/2021
	Project filename Section 1 R2	*Step* 163	*Company* Sirius Environmental

Output Version 21.1.0.479



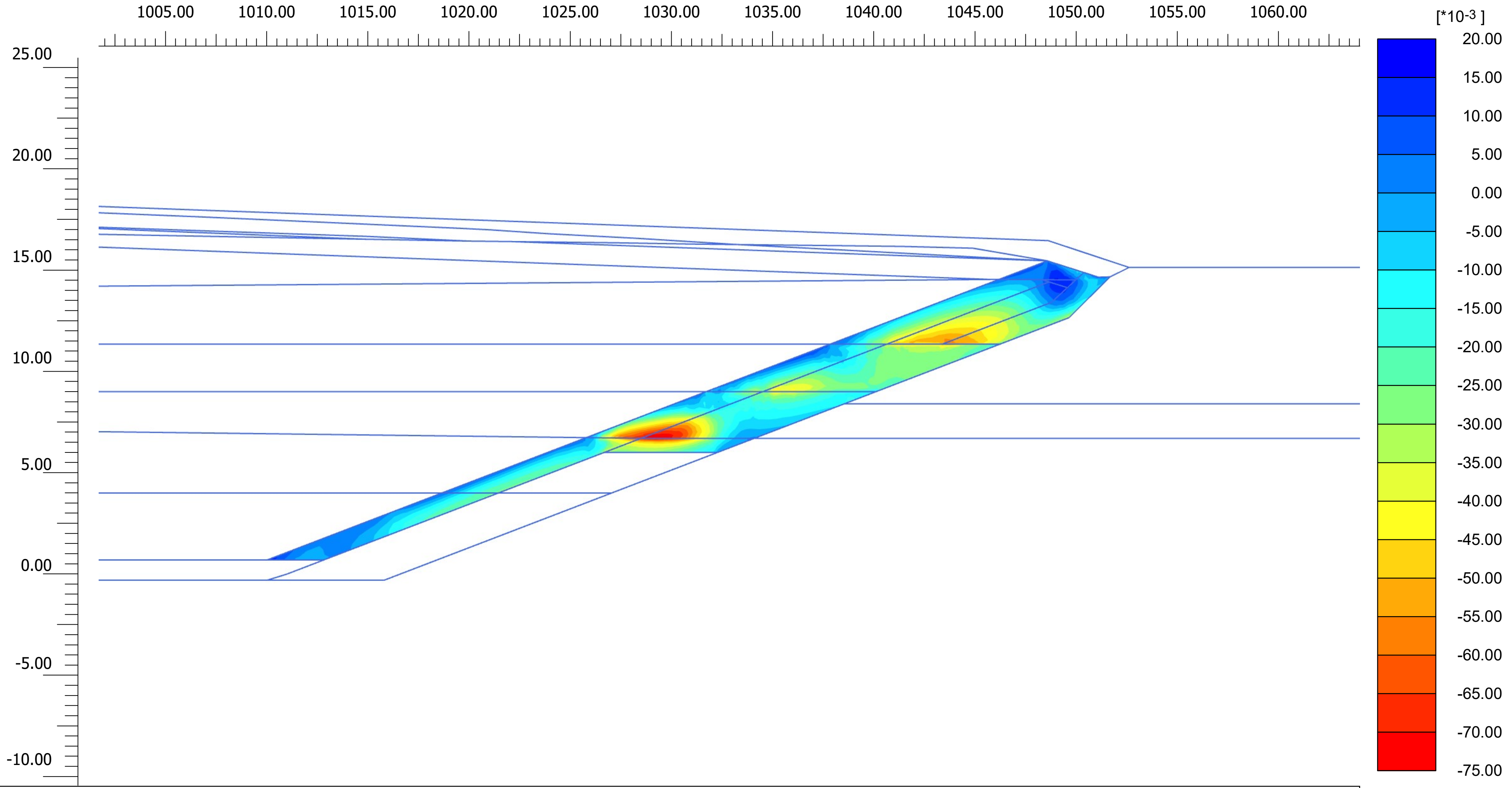
Total cartesian strain γ_{xy} (scaled up 500 times) (Time 15.27*10^3 day)

Maximum value = 0.01546 (Element 2931 at Node 60018)

Minimum value = -0.07465 (Element 4969 at Node 61102)

Project description		Date
Milton Leachate Rise SRA		08/07/2021
Project filename	Step	Company
Section 1 R2	180	Sirius Environmental

Output Version 21.1.0.479



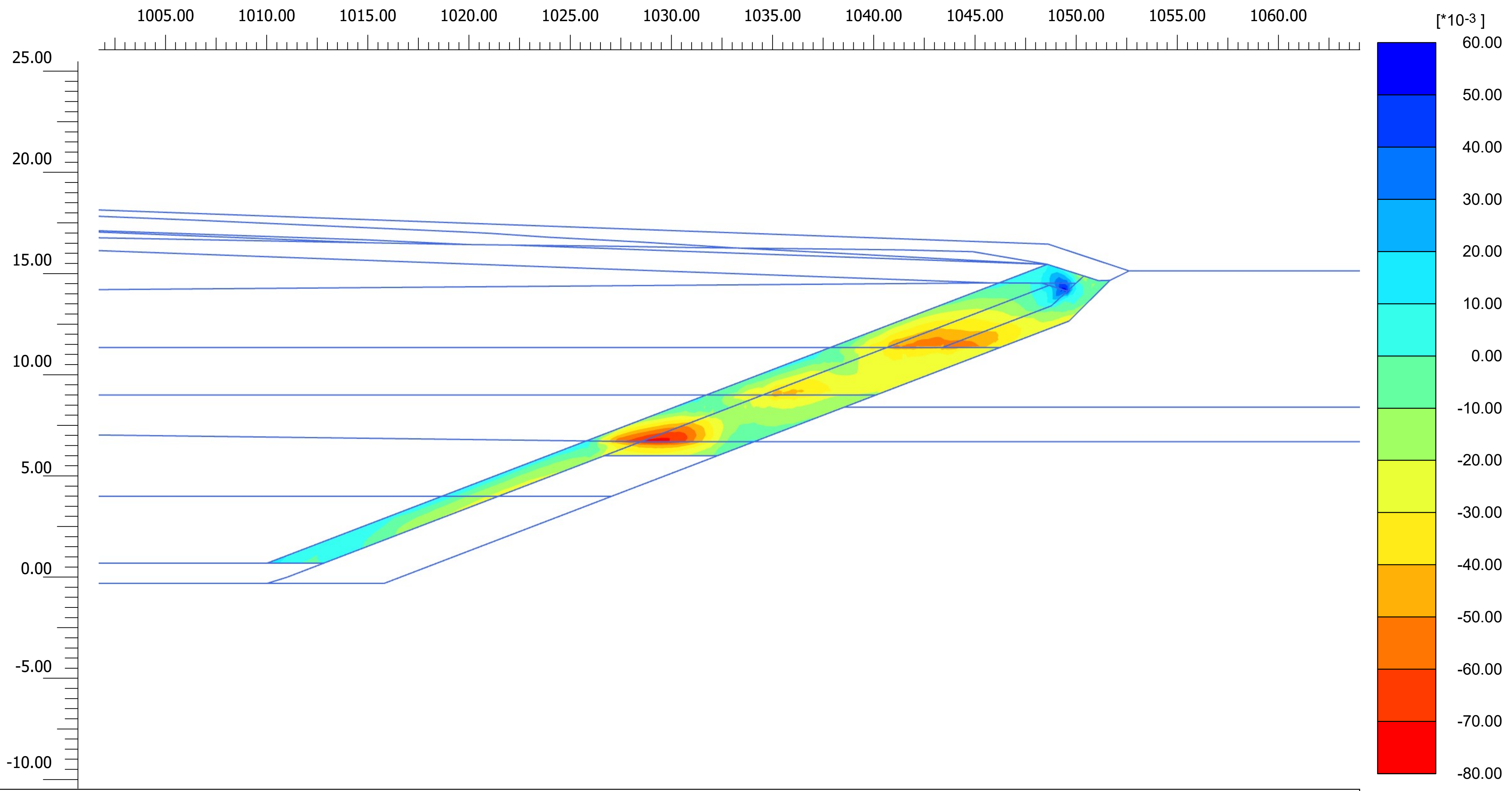
Total cartesian strain γ_{xy} (scaled up 500 times) (Time 15.27*10^3 day)

Maximum value = 0.01548 (Element 2931 at Node 60018)

Minimum value = -0.07446 (Element 4969 at Node 61102)

sirius Environmental	Project description Milton Leachate Rise SRA		Date 08/07/2021
	Project filename Section 1 R2	Step 428	Company Sirius Environmental

Output Version 21.1.0.479



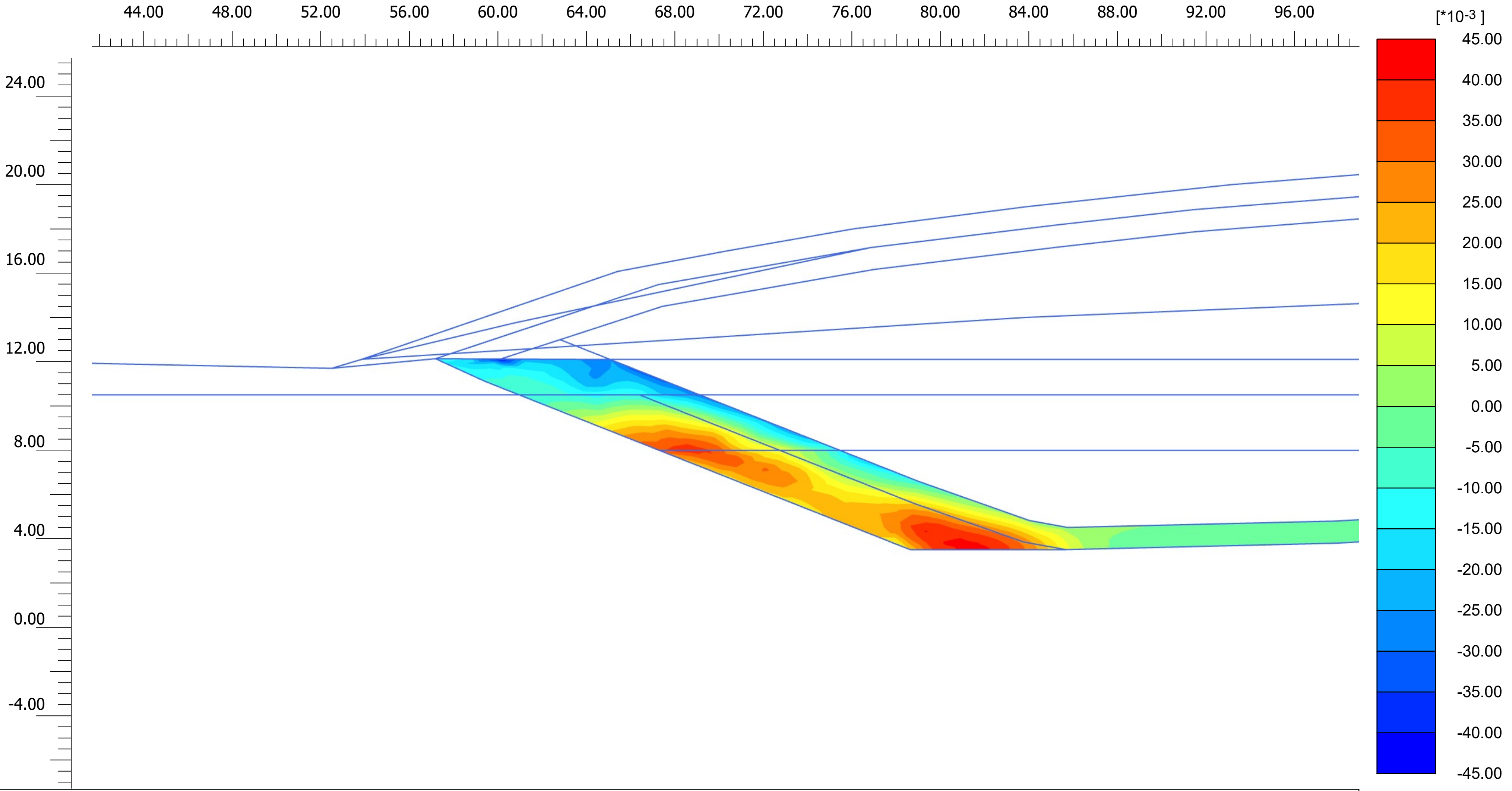
Total cartesian strain γ_{xy} (scaled up 200 times) (Time 33.80*10^3 day)

Maximum value = 0.05710 (Element 3020 at Node 59004)

Minimum value = -0.07291 (Element 4969 at Node 61102)

Sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 08/07/2021
	Project filename Section 1 R2	*Step* 225	*Company* Sirius Environmental

Output Version 21.1.0.479



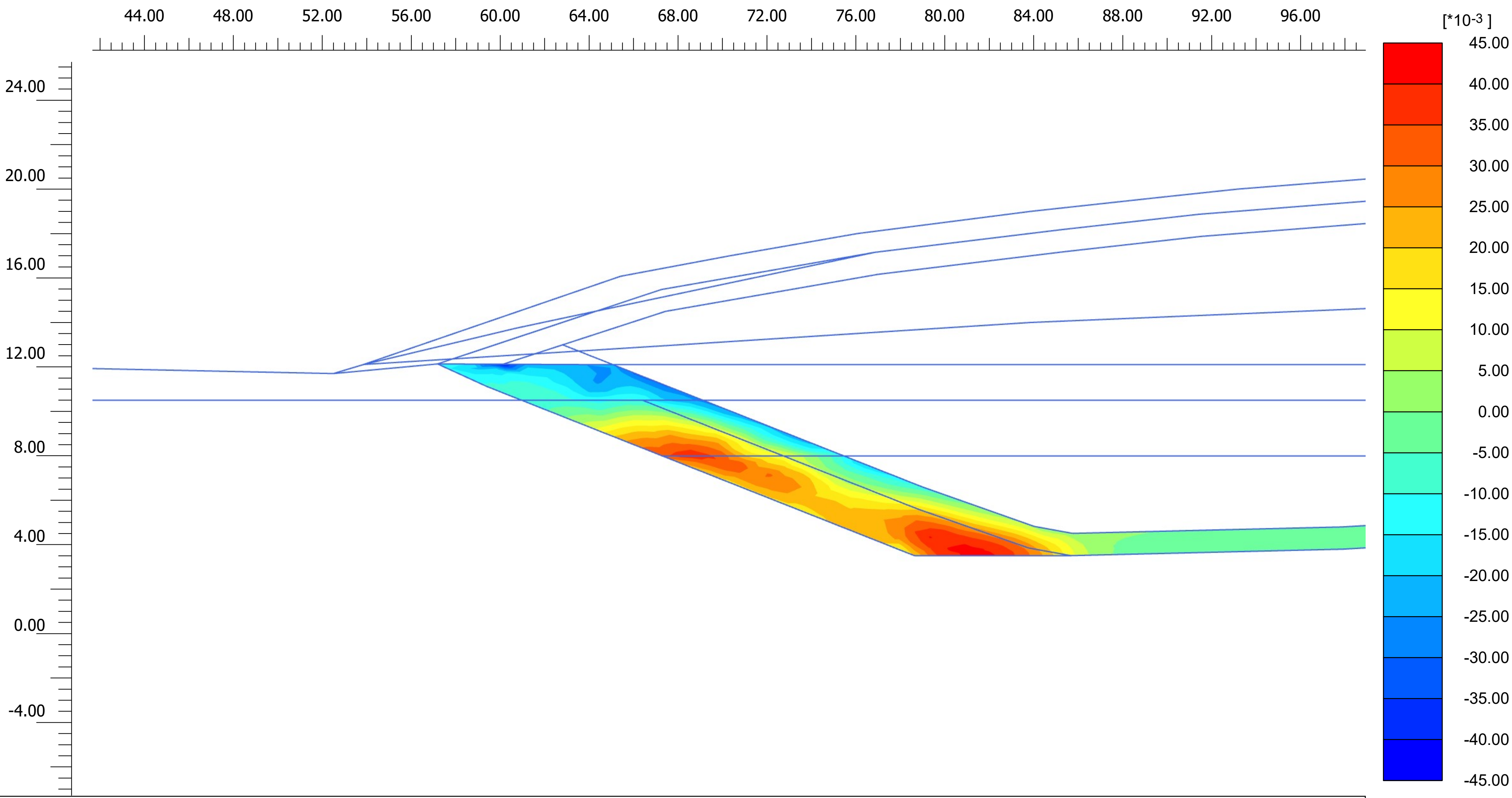
Total cartesian strain γ_{xy} (scaled up 500 times) (Time 15.09*10^3 day)

Maximum value = 0.04149 (Element 6340 at Node 11156)

Minimum value = -0.04060 (Element 3599 at Node 5751)

Project description Milton Leachate Rise SRA			*Date* 09/07/2021
Project filename Section 1 R2	*Step* 163	*Company* Sirius Environmental	

Output Version 21.1.0.479



Total cartesian strain γ_{xy} (scaled up 500 times) (Time 15.27*10^3 day)

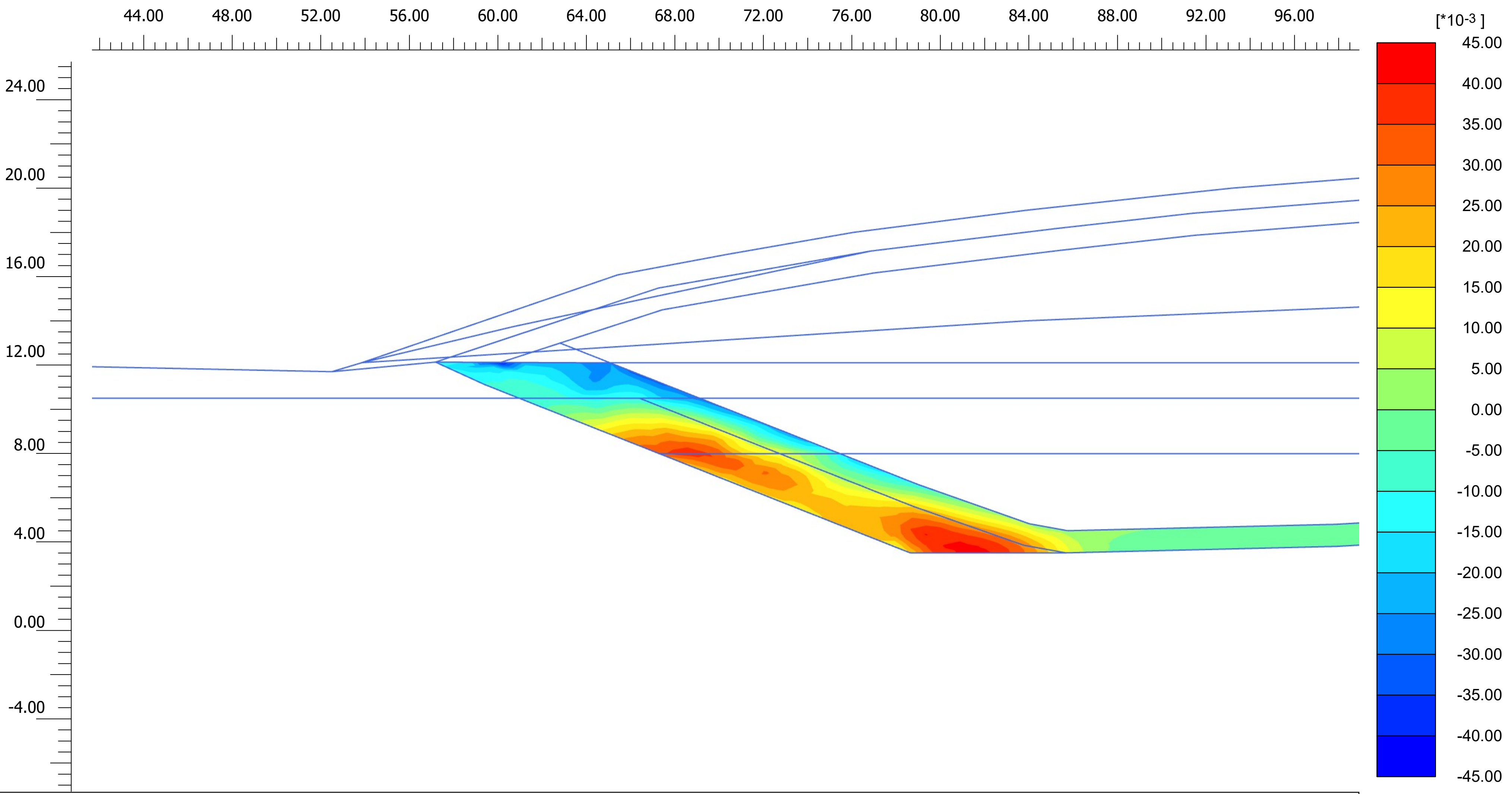
Maximum value = 0.04149 (Element 6340 at Node 11156)

Minimum value = -0.04082 (Element 3599 at Node 5751)

Project description	Date
Milton Leachate Rise SRA	09/07/2021

Project filename	Step	Company
Section 1 R2	180	Sirius Environmental

Output Version 21.1.0.479



Total cartesian strain γ_{xy} (scaled up 500 times) (Time 15.27×10^3 day)

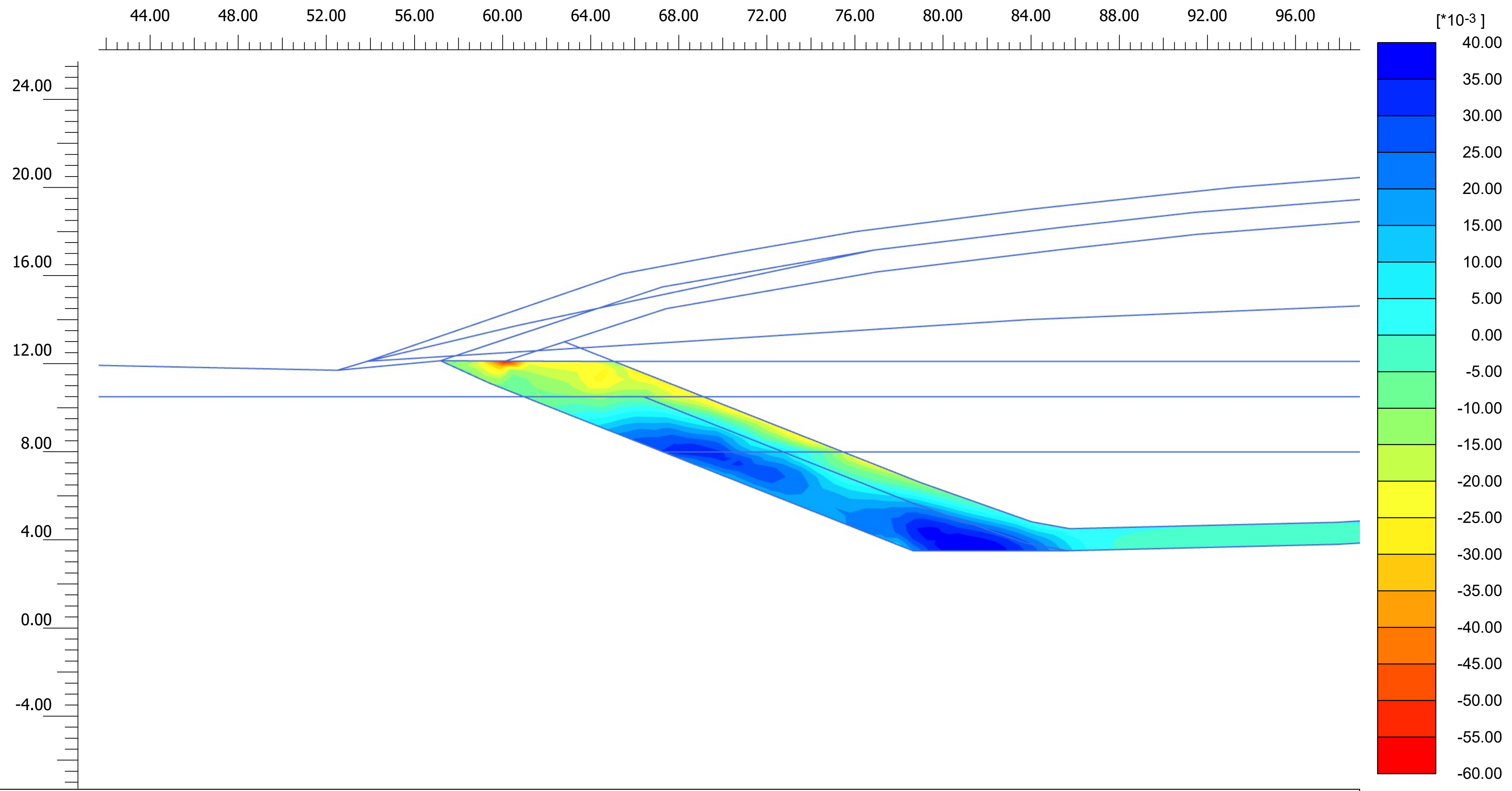
Maximum value = 0.04149 (Element 6340 at Node 11156)

Minimum value = -0.04060 (Element 3599 at Node 5751)

Project description		Date
Milton Leachate Rise SRA		09/07/2021

Project filename	Step	Company
Section 1 R2	428	Sirius Environmental

Output Version 21.1.0.479



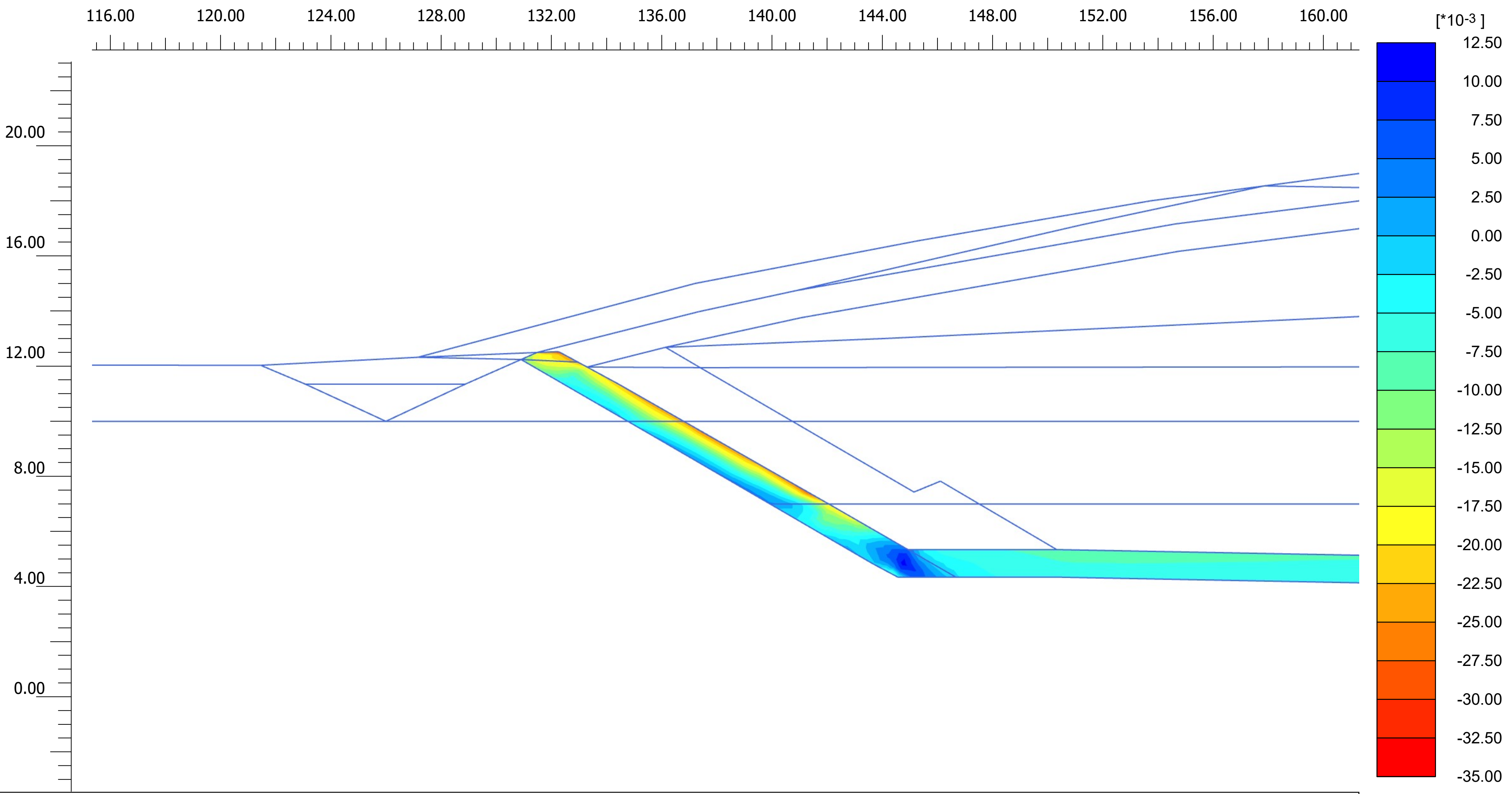
Total cartesian strain γ_{xy} (scaled up 500 times) (Time 33.80*10^3 day)

Maximum value = 0.03988 (Element 6340 at Node 11156)

Minimum value = -0.05681 (Element 3599 at Node 5751)

sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 09/07/2021
	Project filename Section 1 R2	*Step* 225	*Company* Sirius Environmental

Output Version 21.1.0.479



Total cartesian strain γ_{xy} (scaled up 500 times) (Time 5594 day)

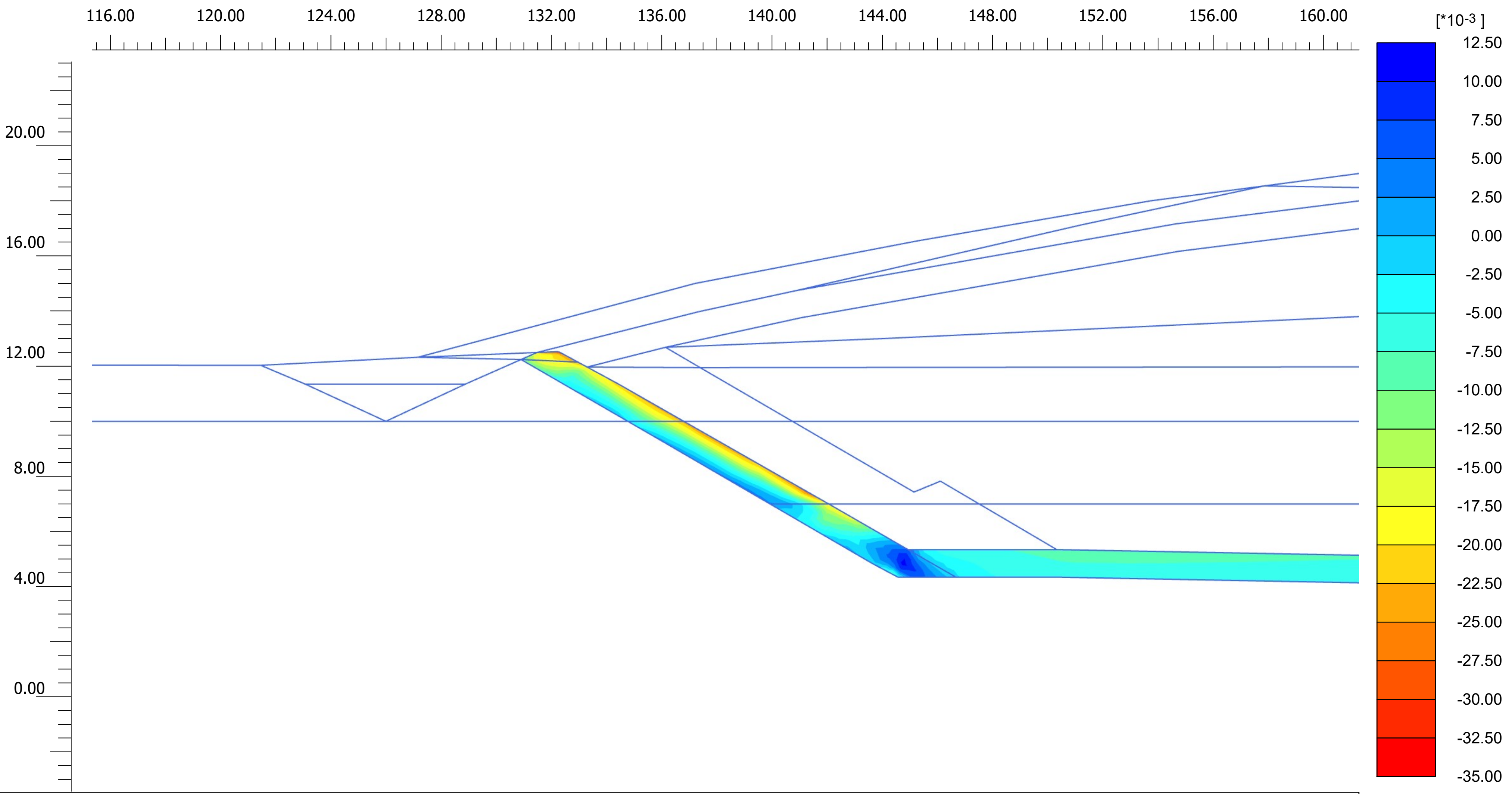
Maximum value = 0.01117 (Element 5521 at Node 12226)

Minimum value = -0.03315 (Element 3841 at Node 5197)

Project description	Date
Milton Leachate Rise SRA	13/07/2021

Project filename	Step	Company
Section 2 R2	79	Sirius Environmental

Output Version 21.1.0.479



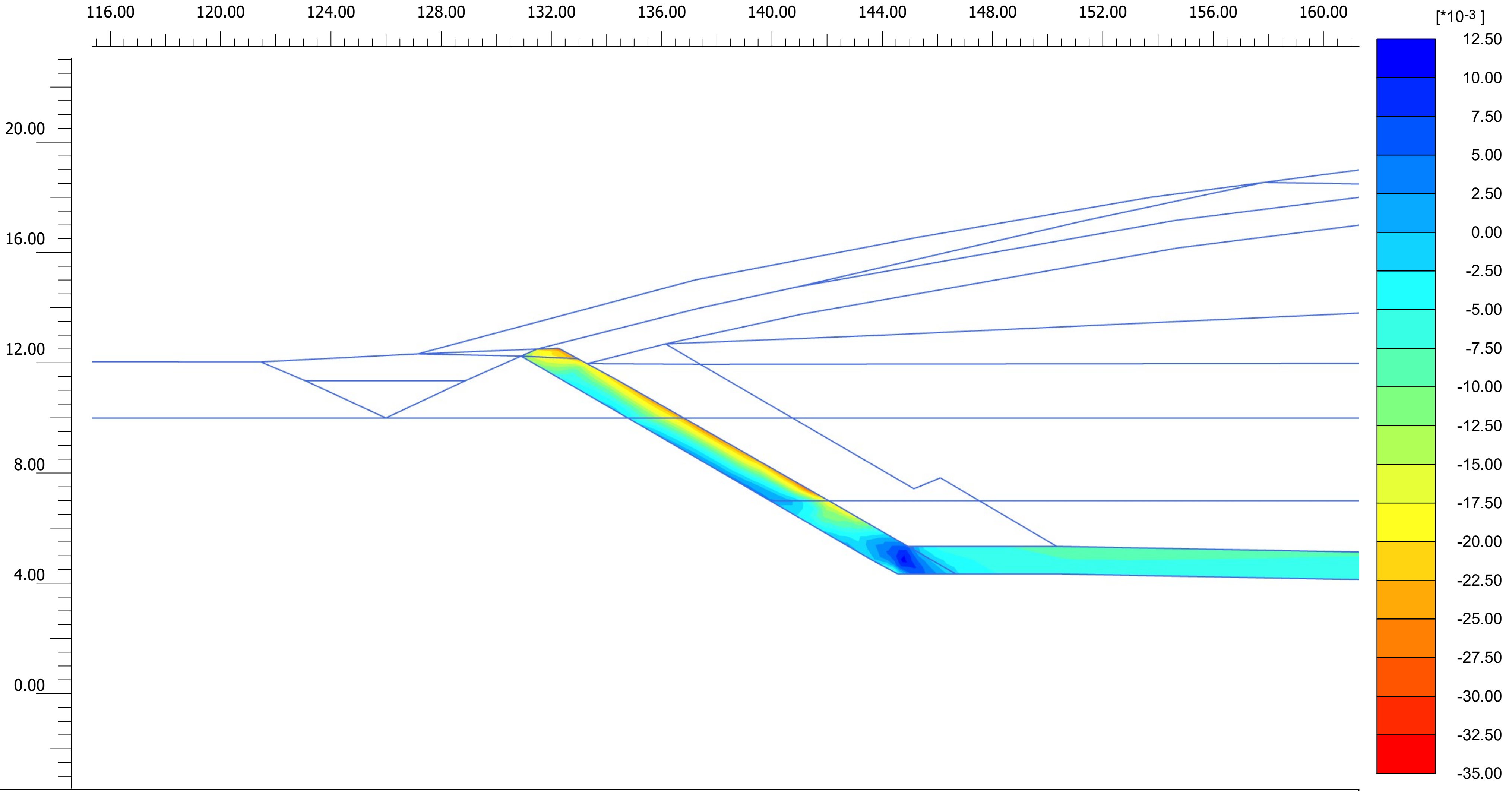
Total cartesian strain γ_{xy} (scaled up 500 times) (Time 5776 day)

Maximum value = 0.01118 (Element 5521 at Node 12226)

Minimum value = -0.03300 (Element 3841 at Node 5197)

sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 13/07/2021
	Project filename Section 2 R2	*Step* 221	*Company* Sirius Environmental

Output Version 21.1.0.479



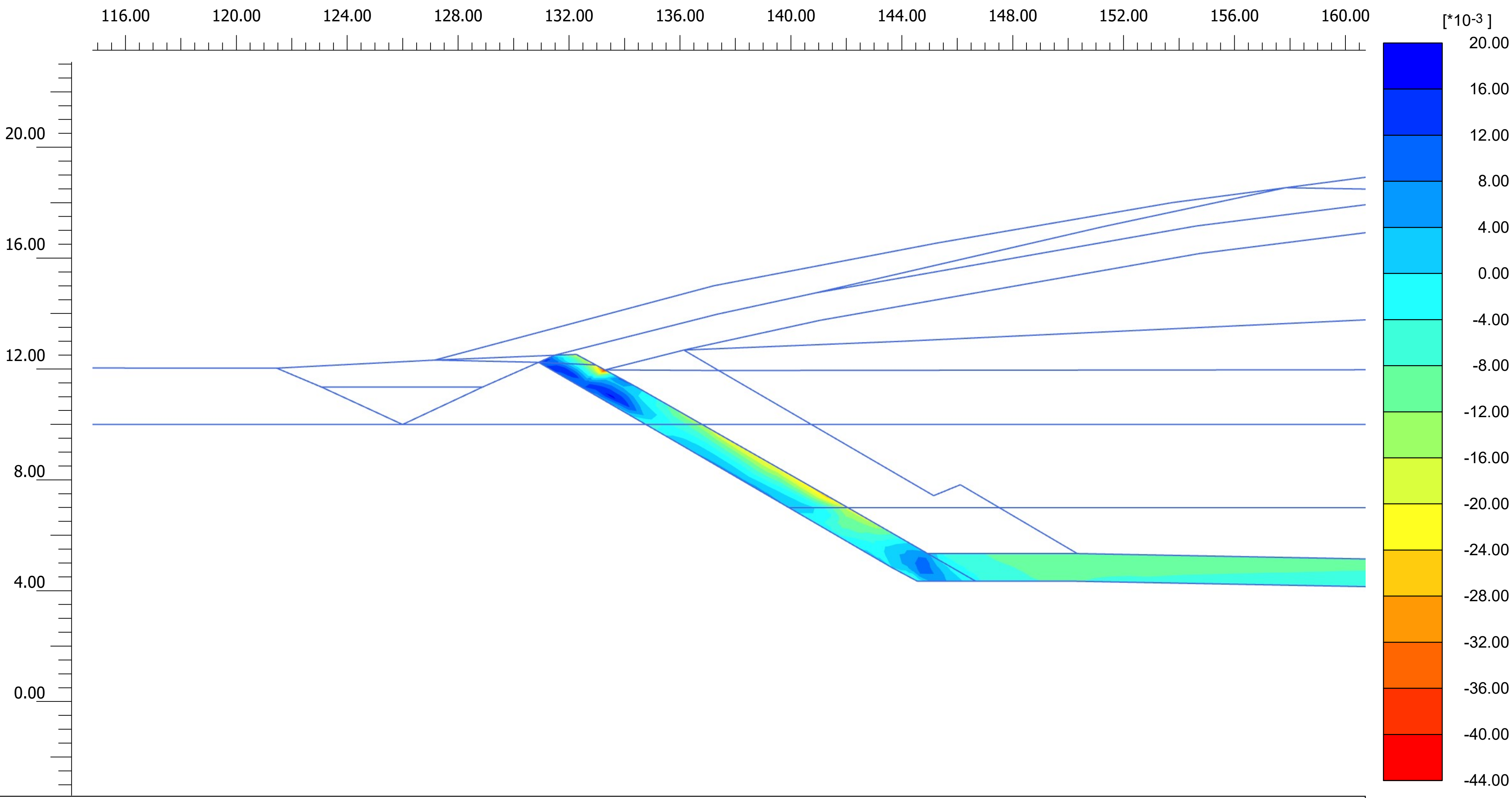
Total cartesian strain γ_{xy} (scaled up 500 times) (Time 5776 day)

Maximum value = 0.01117 (Element 5521 at Node 12226)

Minimum value = -0.03315 (Element 3841 at Node 5197)

Project description			*Date*
Milton Leachate Rise SRA			13/07/2021
Project filename	*Step*	*Company*	
Section 2 R2	324	Sirius Environmental	

Output Version 21.1.0.479



Total cartesian strain γ_{xy} (scaled up 500 times) (Time 24.31*10^3 day)

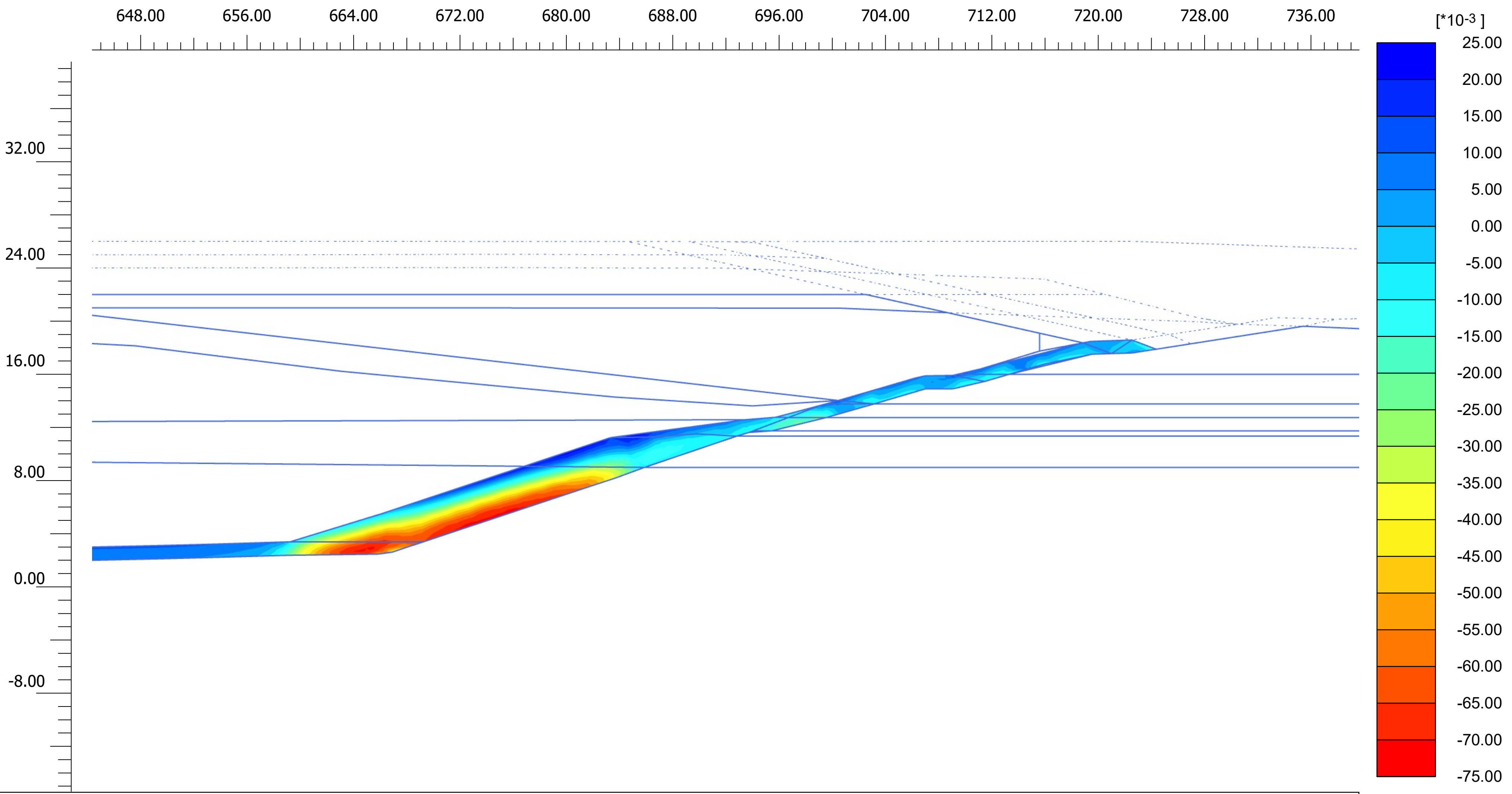
Maximum value = 0.01695 (Element 4326 at Node 7498)

Minimum value = -0.04215 (Element 4327 at Node 6651)

Project description	Date
Milton Leachate Rise SRA	13/07/2021

Project filename	Step	Company
Section 2 R2	101	Sirius Environmental

Output Version 21.1.0.479



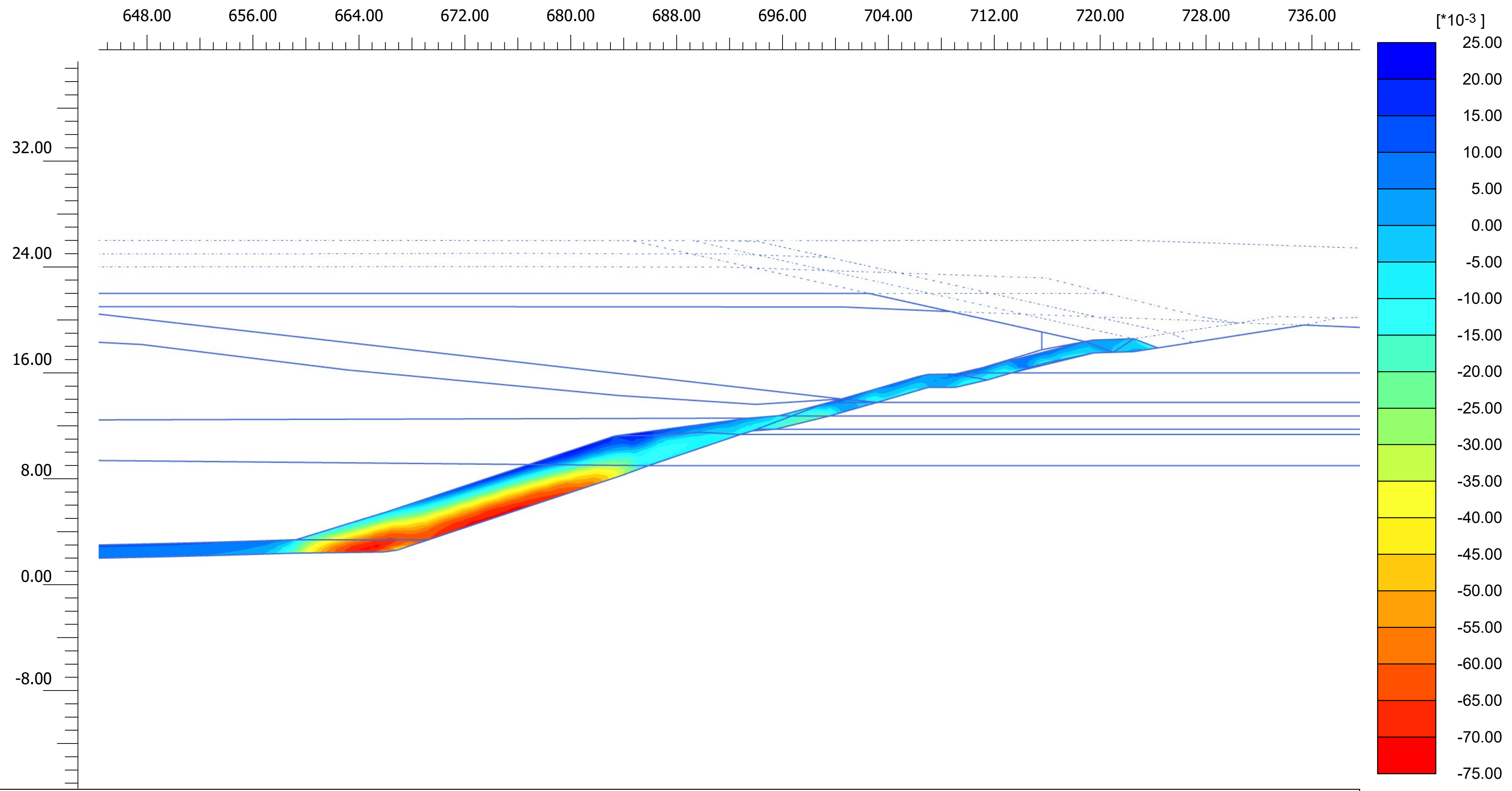
Total cartesian strain γ_{xy} (scaled up 200 times) (Time 5594 day)

Maximum value = 0.02318 (Element 4688 at Node 46817)

Minimum value = -0.07437 (Element 5431 at Node 38457)

sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 13/07/2021
	Project filename Section 2 R2	*Step* 79	*Company* Sirius Environmental

Output Version 21.1.0.479



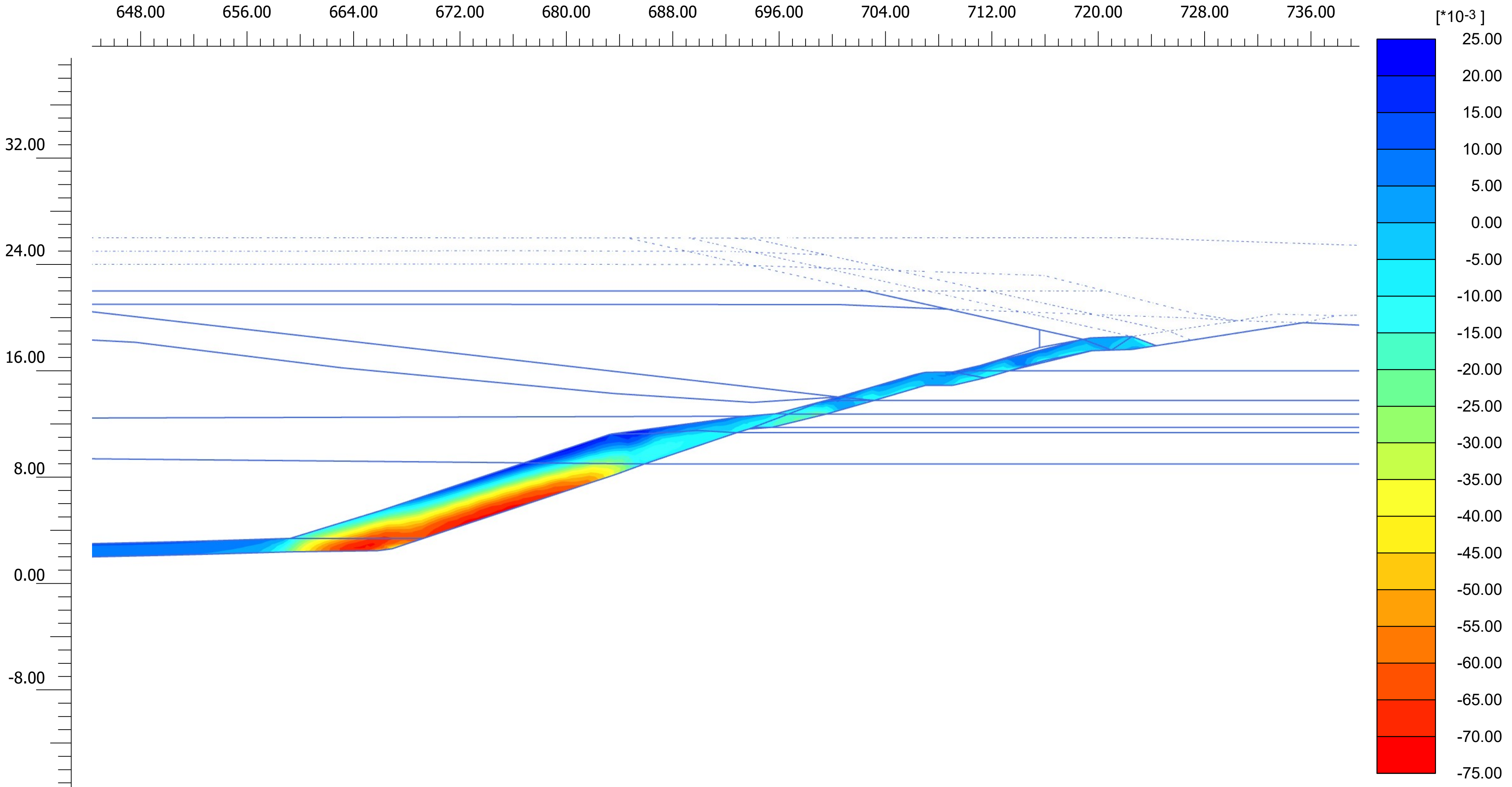
Total cartesian strain γ_{xy} (scaled up 200 times) (Time 5776 day)

Maximum value = 0.02313 (Element 4688 at Node 46817)

Minimum value = -0.07426 (Element 5431 at Node 38457)

sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 13/07/2021
	Project filename Section 2 R2	*Step* 221	*Company* Sirius Environmental

Output Version 21.1.0.479



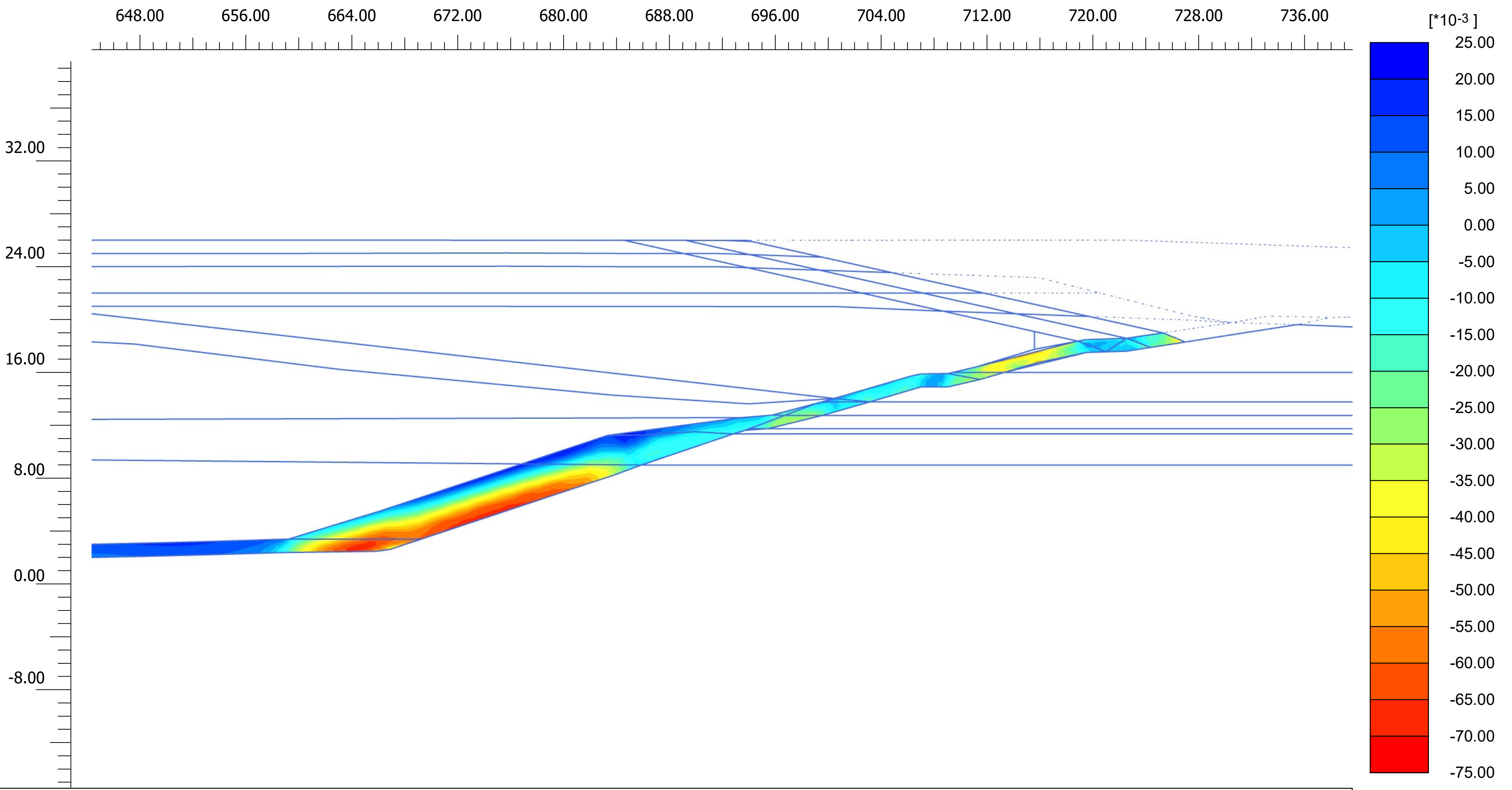
Total cartesian strain γ_{xy} (scaled up 200 times) (Time 5776 day)

Maximum value = 0.02318 (Element 4688 at Node 46817)

Minimum value = -0.07437 (Element 5431 at Node 38457)

sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 13/07/2021
	Project filename Section 2 R2	*Step* 324	*Company* Sirius Environmental

Output Version 21.1.0.479



Total cartesian strain γ_{xy} (scaled up 200 times) (Time 24.31*10^3 day)

Maximum value = 0.02391 (Element 4688 at Node 46817)

Minimum value = -0.07017 (Element 5431 at Node 38457)

sirius Environmental	*Project description* Milton Leachate Rise SRA		*Date* 13/07/2021
	Project filename Section 2 R2	*Step* 101	*Company* Sirius Environmental