PRELIMINARY SITE-WIDE SLOPE STABILITY ASSESSMENT

Barnsley West

Reference	**4848-JPG-SW-XX-RP-G-0608-S2-P01**
Date	**May 2021**
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Bond Bryan. Barnsley West Masterplan. Proposed Site Plan. Drawing No: BWM-BBA-ZZ-XX-DR-A-1004-S2-P05, dated May 2021 for Strata Sterling Barnsley West Limited.

JPG (Leeds) Limited. Barnsley West. Slope Stability Assessment Site Sections. Drawing ref. 4848-JPG-SW-00-DR-G-1321 S2 P01. Dated January 2021.

JPG (Leeds) Limited. Barnsley West. Proposed Levels with Developable Plateaus. Drawing No: 4848-JPG-XX-00-DR-C-1207-S4-P07, dated April 2021.

JPG (Leeds) Limited. Barnsley West. Site Wide Cut/Fill Analysis. Drawing No: 4848-JPG-XX-00-DR-C-1208-S4-P07, dated April 2021.

Appendix B Rocscience Slide2 (v 9.012) Results

CONFIDENTIALITY STATEMENT

This report is addressed to and may be relied upon by the following:

Strata Sterling Barnsley West Limited
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This report has been prepared for the sole use and reliance of the above-named party. This report shall not be relied upon or transferred to any other parties without the express written authorisation of JPG (Leeds) Limited. No responsibility will be accepted where this report is used, either in its entirety or in part, by any other party.

DOCUMENT HISTORY

Rev	Date	Revision Details	Status	Author	Approved
P01	28.05.2021	First issue - (for planning)	Final	JAM	JBW

1.0 INTRODUCTION

1.1 Background

JPG (Leeds) Limited (JPG) has been instructed by the Strata Sterling Barnsley West Limited to assess the stability of the cut slopes and embankment slopes which will be formed as part of the earthworks associated with the new development plateaus, balancing ponds and associated road network of the proposed mixed-use development (commercial and residential) within the overall Barnsley West development site.

1.2 Objective

The objective of this report is to provide an assessment of the stability of the cut slopes and embankments which will be created as a result of the earthworks associated with the proposed development plateaus and the balancing ponds.

The proposed development plateaus and attenuation ponds will be constructed using appropriate site-won materials placed and compacted in accordance with the JPG earthworks strategy referenced in Section 1.6 of this report. Where slopes do not achieve the appropriate factor of safety and may be unstable, mitigation methodology is outlined to ensure landform stability.

The geotechnical parameters used in this assessment have been selected based on empirical data, geotechnical testing results of similar materials from similar sites and engineering judgement.

1.3 Development Proposals

It is proposed to develop the site for a mixed end use, comprising residential with school in the northern two thirds of the site, industrial/commercial land use including a pub/hotel in the southern third and residential in the east (land adjacent to Pogmoor). The development also includes balancing ponds (SUDS) in the east and associated highways and infrastructure.

A drawing of the proposed development has been provided, which is referenced below, and a copy is containing in Appendix A.

- Bond Bryan. Barnsley West Masterplan. Proposed Site Plan. Drawing No: BWM-BBA-ZZ-XX-DR-A-1004-S2-P05, dated May 2021 for Strata Sterling Barnsley West Limited.

1.4 Location

The site is located approximately 3km to the west of Barnsley town centre. The approximate centre of the site is located at NGR 431800 407100.

The site is located between Higham and Gawber, with the M1 motorway located to the west and south of the site. The A635 Barugh Green Road is located to the north of the site.

A site location plan is provided as Figure 1 in Appendix A.

1.5 Proposed Earthworks

Earthworks cut/fill and proposed levels drawings have been produced for the site. These drawings are referenced below, and copies are provided in Appendix A.

- JPG (Leeds) Limited. Barnsley West. Site Wide Cut/Fill Analysis. Drawing No: 4848-JPG-XX-00-DR-C-1208-S4-P07, dated April 2021.
- JPG (Leeds) Limited. Barnsley West. Proposed Levels with Developable Plateaus. Drawing No: 4848-JPG-XX-00-DR-C-1207-S4-P07, dated April 2021.

As part of the enabling works, it is proposed to construct eight development plateaus across the entire site. A total of seven balancing ponds are proposed to be constructed in east of the site: three to the north east, two to the immediate west of the land adjacent to Pogmoor and two in the south east of the site.

It is proposed to excavate materials from the western edge of the site, as well as areas in the south, the centre east (north of Hermit Lane) and in the east, adjacent to Pogmoor. The material is to be re-engineered across the north east, centre and the land immediately south of Hermit Lane.

The construction of the development plateaus and balancing ponds in the residential area to the north of Hermit Lane will result in embankment slopes extending along the north-eastern boundary and along the boundaries of the wooded area which bisects the northern half of the site. The heights of these newly formed slopes will range between 1m and 10m. The gradient of the proposed slopes is no greater than 1v:3h.

The development plateaus and balancing ponds in the residential areas and commercial areas to the south and east of Hermit Lane will result in cuttings and embankment slopes which extend along the southern and south-eastern boundaries of the site as well as through the central-southern part of the site and skirting either side of the existing eastern watercourse. The heights of these newly formed cuttings and embankments will range between 4m and 34m. The gradients of the proposed slopes vary between 1v:2.5h and 1v:3h.

1.6 Previous Reports

A desk study report for the site has been prepared by JPG, which is referenced below:

- JPG (Leeds) Limited. Geoenvironmental Desk Study Report. Barnsley West. Report Ref. JBW/DS/4848.v3. Dated July 2019 for Strata Sterling Barnsley West Ltd.

The desk study report includes a summary of potential geotechnical and environmental issues and should be read in conjunction with this report.

As part of the JPG Desk Study report, a review of the following Eastwood & Partners Consulting Engineers report was carried out. This report is referenced below:

- Eastwood and Partners Consulting Engineers. Geotechnical and Geo-Environmental Site Appraisal Commentary. Barnsley West. Report Ref. 36284. Dated 4 October 2013 for Strata.

A preliminary geoenvironmental ground investigation report and three coal mining risk assessment reports have been prepared by JPG, which are referenced below.

- JPG (Leeds) Limited. Coal Mining Risk Assessment and Coal Recovery Report. Residential Development (Remainder of Site), Barnsley West. Report Ref. 4848-JPG-Z1-XX-RP-G-1101-S2-P02. Dated August 2019 for Strata Sterling Barnsley West Ltd.
- JPG (Leeds) Limited. Coal Mining Risk Assessment and Coal Recovery Report. Employment Land, Barnsley West. Report Ref. 4848-JPG-Z2-XX-RP-G-1102-S2-P02. Dated August 2019 for Strata Sterling Barnsley West Ltd.
- JPG (Leeds) Limited. Coal Mining Risk Assessment and Coal Recovery Report. Proposed Residential Development (Pogmoor), Barnsley West. Report Ref. 4848-JPG-Z3-XX-RP-G-1103-S1-P02. Dated August 2019 for Strata Sterling Barnsley West Ltd.
- JPG (Leeds) Limited. Preliminary Geoenvironmental Ground Investigation. Barnsley West. Report Ref. 4848-JPG-SW-XX-RP-G-0603-S2-P02. Dated July 2019 for Strata Sterling Barnsley West Ltd.
- JPG (Leeds) Limited. Site Preparation and Earthworks Strategy. Barnsley West. Report Ref. 4848-JPG-SW-XX-SP-G-0605-S4-P01. Dated May 2021 for Strata Sterling Barnsley West Ltd.

Previous reports for two proposed roundabouts have been prepared by JPG, these reports are referenced below.

- JPG (Leeds) Limited. Geoenvironmental Desk Study Report. Higham Common Road Roundabout, Barnsley West. Report Ref: 4848-JPG-ZZ-XX-RP-G-0602-S2-P01. Dated December 2019 for Strata Sterling Barnsley West Limited.
- JPG (Leeds) Limited. Geoenvironmental Ground Investigation Report. Higham Common Road Roundabout, Barnsley West. Report Ref: 4848-JPG-HC-XX-RP-G-0603-S2-P02. Revision dated March 2021 for Strata Sterling Barnsley West Limited.
- JPG (Leeds) Limited. Coal Mining Risk Assessment and Coal Recovery Report. Higham Common Road Roundabout, Barnsley West. Report Ref: 4848-JPG-XX-XX-RP-G-0607-S2-P02. Revision dated March 2021 for Strata Sterling Barnsley West Limited.
- JPG (Leeds) Limited. Geoenvironmental Desk Study Report. Barugh Green Road Roundabout, Barnsley West. Report Ref: 4848-JPG-ZZ-XX-RP-G-0602-S2-P01. Dated December 2019 for Strata Sterling Barnsley West Limited.

- JPG (Leeds) Limited. Geoenvironmental Ground Investigation Report. Barugh Green Road Roundabout, Barnsley West. Report Ref: 4848-JPG-HC-XX-RP-G-0603-S2-P02. Revision dated March 2021 for Strata Sterling Barnsley West Limited.
- JPG (Leeds) Limited. Coal Mining Risk Assessment and Coal Recovery Report. Barugh Green Road Roundabout, Barnsley West. Report Ref: 4848-JPG-XX-XX-RP-G-0607-S2-P02. Revision dated March 2021 for Strata Sterling Barnsley West Limited.

1.7 Geotechnical Category

The proposed development has been categorized as Geotechnical Category 2 and 3 as defined by British Standard EN 1997-1:2004 Eurocode 7 – Geotechnical Design.

This is because the development includes conventional types of geotechnical structures, earthworks and loading conditions.

However, there are large parts of the site which may involve unforeseen/difficult ground conditions associated with the significant thickness of opencast backfill, potential mine shafts, and high loading conditions associated with the placement of engineered fill, including fill used for surcharging.

2.0 GEOENVIRONMENTAL GROUND INVESTIGATION REVIEW

2.1 General

A preliminary phase ground investigation was carried out in 2019 by JPG for the entire development site.

Subsequently, two individual roundabout ground investigations for Barugh Green Road roundabout and Higham Common Road roundabout were carried out in June 2020 by JPG.

All three ground investigations comprised the excavation of trial pits and the drilling of rotary boreholes. The works included the installation and monitoring of extensometers and groundwater wells and submission of soil samples to the laboratory for geotechnical and chemical testing.

2.2 Review of JPG Ground Conditions

2019 Ground Investigation

The site was split into three separate areas for the purpose of summarising the ground conditions. Generally, the ground conditions across the whole site were found to comprise the anticipated sequence of strata.

Employment Land (Southern Third)
Ground conditions comprised reworked topsoil over localised pockets of made ground, outwith the boundary of the opencast coal sites (OCCS). The localised pockets of made ground were encountered to depths of between 0.50m bgl and 2.80m bgl along the western boundary, adjacent to Higham lane.

Colliery spoil, comprising predominantly of soft to firm cohesive material and occasional dark brownish grey granular material, was encountered in the central part of the employment land associated with the Hunters Cottage OCCS. The colliery spoil was encountered to depths of between 1.50m bgl and 13.00m bgl.

The natural strata underlying the made ground and colliery spoil comprised firm, medium strength residual soils of the Pennine Middle Coal Measures formation to depths of between 1.10m bgl and 3.40m bgl.

Bedrock was found to comprise extremely weak mudstone overlying stronger interbedded mudstone, sandstone and coal seams of the Pennine Middle Coal Measures Formation.

To date no underground coal workings have been encountered within the employment land area.

Residential Land Adjacent to Pogmoor in the East
Reworked topsoil was generally found over localised pockets of made ground, outwith the boundary of the Farmhouse Lane OCCS, to a maximum depth of 1.05m bgl.

Colliery spoil, comprising predominantly firm to stiff cohesive material and occasional pockets of granular material was encountered across the majority of the area adjacent to Pogmoor. Colliery spoil was encountered to depths of between 2.00m bgl and 11.50m bgl.

The natural strata comprised stiff cohesive residual soils overlying interbedded mudstone, sandstone and coal seams of the Pennine Middle Coal Measures Formation.

The intact Barnsley coal seam was encountered in encountered in four of the 10 boreholes, with thicknesses ranging between 1.40m and 3.00m. However, there remains a residual risk from underground coal workings in the Barnsley coal seam below the highwall in the east, south and west, where insufficient rock cover is present. The delineation of the Farmhouse Lane OCCS highwall was confirmed during drilling and found to coincide with the abandonment plans.

Most of the adits in this part of the site are likely to have been removed during the opencast extraction of the Barnsley coal seam. However, there remains a risk from the adit (CA reference 432406-017) outwith the opencast. The mineshaft in the east (CA reference 432406-014) was removed during the opencast operations. However, it will need to be confirmed that the mineshaft does not extend below the Barnsley coal seam.

There is also the potential for unrecorded mine entries in this area.

Residential Land (Remainder of Site)

Reworked topsoil was generally found overlying localised pockets of cohesive made ground to depths of between 0.50m bgl and 1.00m bgl. A possible capping layer consisting of soft to firm and stiff cohesive material was encountered in the areas of Craven I and II OCCS overlying the colliery spoil.

The colliery spoil, which predominantly comprised firm to stiff cohesive material with pockets of granular material, was encountered to depths of between 8.20m bgl and 13.00m bgl in Craven I and to depths of between 31.00m bgl and 38.50m bgl in Craven II.

The natural strata comprised firm to very stiff, high strength residual soil overlying mudstone, sandstone and coal seams of the Pennine Middle Coal Measures Formation.

To date no underground coal workings were encountered within the residential land area.

During the 2019 ground investigation, groundwater was not generally encountered in the trial pits within the shallow natural ground. However, on occasion, shallow perched groundwater was encountered as seepages in the trial pits.

The majority of rotary open holed boreholes encountered groundwater strikes from depths between 3.00m bgl to 31.00m bgl. Shallow groundwater with a fast flow was noted in Hunters Cottage OCCS, in BH108. Additionally, natural springs are noted across the southern half of the site.

It will be required to confirm the existing ground model, including the presence of mine entries and underground coal workings with additional ground investigations. If any mine workings (including mine entries) are encountered, they will require mitigation.

3.0 SLOPE STABILITY ASSESSMENT

3.1 General Overview

As stated previously, as part of the enabling works, it is proposed to construct development plateaus and balancing ponds.

In order to assess the stability of the slopes a ground model has been developed and geotechnical parameters assigned to each strata type using geotechnical testing results of similar materials from similar sites and engineering judgement.

A plan showing the locations of the proposed slopes and lines of cross-section has been provided. This shows the profiles of the existing ground level, proposed ground level and the base of opencast along each section. This drawing is referenced below, and a copy is provided in Appendix A.

- JPG (Leeds) Limited. Barnsley West. Slope Stability Assessment Site Sections. Drawing Ref. 4848-JPG-SW-00-DR-G-1321 S2 P01. Dated January 2021.

3.2 Design Parameter Values

Geotechnical (soil/rock) parameters are based on geotechnical testing results of similar materials from similar sites, engineering judgement and empirical data. A summary of the geotechnical parameters which have been selected for use in the model are provided in Table 3.2.1.

Table 3.2.1 – Geotechnical Parameters

Stratum	Strength Type	Unit Weight	Saturated Unit Weight	Effective Cohesion	Effective Angle of Friction
		(kN/m³)	(kN/m³)	(kPa)	(degrees)
Engineered Fill Material	Mohr-Coulomb	20	21	0	30
Treated Colliery Spoil	Mohr-Coulomb	20	21	0	25
Untreated Colliery Spoil	Mohr-Coulomb	20	21	0	20
Weathered Pennine Middle Coal Measures (PMCM)	Mohr-Coulomb	18	19	1	27
Pennine Middle Coal Measures (PMCM)	Mohr-Coulomb	22	23	5	40

As part of the detailed design, prior to development, sensitivity analysis of the geotechnical parameters is recommended to assess the likely effects of future changes to the ground conditions, i.e. climate change and increased weathering of clay soils (both natural and fill).

4.0 SLOPE STABILITY ANALYSIS RESULTS

4.1 Methods of Analysis and Design

The Rocscience "Slide2" (v 9.012) software package has been used to assess the stability of the slopes.

Ten cross sections, as shown on the JPG drawing which is referenced in Section 3.1 of this report and presented in Appendix A, have been selected for analysis. These ten sections are considered to represent a range of cases, including the 'worst case', i.e. the steepest sections of slope with high groundwater and untreated colliery spoil present.

In addition to the worst-case scenarios, selected sections extend through areas of historical opencast sites which are to be the subject of ground improvement, i.e. surcharging/pre-loading.

Slope stability section 01 is oriented south west to north east, commencing at the south western site boundary and extending through the south west edge of the southern balancing pond.

Slope stability section 02 is oriented north west to south east, commencing in the southern part of the employment land and extending through a balancing pond towards the south eastern site boundary.

Slope stability section 03 is oriented south west to north east, commencing on the southern development plateau of the employment land area, extending through the proposed embankment and cutting, towards the northern development plateau of the employment land area.

Slope stability section 04 is oriented south west to north east, commencing on the north west development plateau of the employment land area towards the lower development plateau of the residential area.

Slope stability section 05 is orientated south to north, commencing on the northern development plateau of the employment land and extending towards the lower development plateau of the residential area.

Slope stability section 06 is oriented south west to north east, commencing on the northern development plateau of the employment land and extending through one of the longest and steepest slopes towards the lower development plateau of the residential area.

Slope stability section 07 is oriented south east to north west, commencing on the northern development plateau of the employment land and extending through one of the longest and steepest slopes towards the lower development plateau of the residential area.

Slope stability section 08 is oriented north west to south east, commencing on the lower residential development plateau and extends through the existing watercourse and a balancing pond and finishes on the development plateau of the proposed residential area adjacent to Pogmoor.

Slope stability section 09 is oriented south west to north east, commencing on the residential development plateau north of Hermit Lane and extends through a balancing pond towards the existing eastern watercourse.

Slope stability section 10 is oriented south west to north east, commencing in the north eastern residential development plateau and extends through the north eastern balancing pond towards the north eastern site boundary and the adjacent existing residential area.

The analysis has been carried out using the Bishops Simplified and Janbu Simplified Methods.

For cuttings, a minimum Factor of Safety (FoS) of 1.45 is considered applicable, while for embankments a minimum FoS of 1.55 is considered applicable for this analysis. Additionally, any mixed slopes, i.e. embankments above cuttings, a minimum FoS of 1.55 is also applied.

The Factor of Safety is derived from tables 13.1, 13.2, 13.5 and 13.6 of the ICE *Earthworks, A Guide* (second edition, 2017).

The analysis has been carried out based on the proposed slope profiles following completion of the earthworks.

4.2 Assumptions

The following assumptions have been made when carrying out the analysis:

- Based on the current assessment of the ground conditions, only site-won cohesive materials will be used in the construction of the embankments.
- Based on the observed groundwater characteristics – including the presence of natural springs, a high groundwater table has been used in this assessment.
- Based on the absence of site specific laboratory results or in-site geotechnical data, the effective stress parameters have been taken from test results of similar materials from similar sites, engineering judgement and empirical data.
- All commercial buildings will be off set at least 5m from the crest of a slope with an imposed load of 125kPa.
- Due to the unknown proposed residential layout, no loading has been applied to the crest and toe of the slopes which span the proposed residential areas.
- The imposed loads are based on the latest development layout.
- The analysis does not take into account the long-term changes in pore water pressure due to construction, rainfall infiltration or climate change.

- Sensitivity analysis, i.e. changes to geotechnical parameters, has not been carried out as part of this assessment.
- Steady state groundwater finite element modelling has not been carried out as part of this assessment.
- Where required, assessments of treated colliery spoil have been carried out. This is based on 3.00m of re-engineered colliery spoil and the influence of surcharging/preloading.
- It is assumed that if any reprofiling of existing slopes (e.g. in the east of the site) is required, then any loose, soft or potentially unstable materials shall be removed.

4.3 Results of the Assessment

Slope Stability Section 01 (FoS 1.45)
Analysis of slope stability section 01 confirms a minimum Factor of Safety (FoS) of 1.343 in accordance with the Bishop simplified method and 1.249 in accordance with Janbu simplified method. This assessment shows a cut slope with 3.00m of re-engineered colliery spoil and groundwater level below the base of the impermeable re-engineered colliery spoil. The minimum FoS is noted for a potential global failure in the untreated colliery spoil beneath the re-engineered material, adjacent to the site boundary.

Slope Stability Section 02 (FoS 1.45)
Analysis of slope stability section 02 has confirmed a minimum FoS of 1.782 and 1.728 in accordance with Bishop simplified and Janbu simplified, respectively. As this section is representing the cutting along the south eastern boundary, the resultant minimum FoS suggests the slope is favourable.

Slope Stability Section 03 (FoS 1.55)
Analysis of slope stability section 03, with treated colliery spoil and high groundwater, has confirmed a minimum FoS of 1.359 and 1.215 for Bishop simplified and Janbu simplified methods, respectively. The lower FoS is most likely attributable to the high groundwater level beneath the toe of the proposed cutting and the remaining untreated colliery spoil below the 3.00m re-engineered material.

Slope Stability Section 04 (FoS 1.55)
Analysis of slope stability section 04, with Hunters Cottage Extension OCCS removed and replaced with compacted "treated" colliery spoil, shows an initial minimum FoS of 1.160 and 1.162 for Bishop simplified and Janbu simplified methods, respectively. The potential slip surfaces are localised in the base of the slope and are attributable to the high groundwater. The high groundwater in this area is representative of the natural springs.

Slope Stability Section 05 (FoS 1.55)
Analysis of slope stability section 05, with the colliery spoil treated by surcharging/pre-loading or by removal and recompaction, confirms a minimum FoS of 1.160 for Bishop simplified and Janbu simplified methods. The potential slip surfaces appear to be confined to the treated colliery spoil material of Hunters Cottage Extension OCCS at the toe of the slope, possibly due to the slope angle of 1v:2.5h.

Slope Stability Section 06 (FoS 1.55)
Analysis of slope stability section 06, with treated colliery spoil, confirms a minimum FoS of 1.011 and 0.968 for Bishop simplified and Janbu simplified methods, respectively. However, the potential slip surfaces are confined to the engineered fill material and are due to the loading. It should be noted that this model does not show any FoS below 1.55 within the slope face, suggesting the cutting and the embankment is favourable.

Slope Stability Section 07 (FoS 1.55)
Analysis of slope stability section 07 confirms a minimum FoS of 1.448 and 1.347 for Bishop simplified and Janbu simplified methods, respectively. However, the potential slip surfaces are confined to the engineered fill material and are due to the loading. It should be noted that this model does not show any FoS below 1.55 within the slope face, suggesting the cutting and the embankment is favourable.

Slope Stability Section 08 (FoS 1.55)
Analysis of slope stability section 08, with treated colliery spoil in the area of proposed residential land adjacent to Pogmoor, confirms a minimum FoS of 1.547 and 1.487 for Bishop simplified and Janbu simplified methods, respectively. The potential slip surfaces are present in the weathered Pennine Middle Coal Measures adjacent to the existing watercourse in the north west of the section. This area of the site already shows evidence of potential shallow slip surfaces; therefore, care should be taken when loading the weathered coal measures with engineered fill. Any reprofiling of existing slopes should include the removal of loose, soft or potentially unstable materials.

Slope Stability Section 09 (FoS 1.55)
Analysis of slope stability section 09 confirms a minimum FoS of 1.473 and 1.477 for Bishop simplified and Janbu simplified methods, respectively. The potential shallow slip surfaces are present only locally at the very toe of the embankment and are most likely attributed to the high groundwater level. The overall FoS for the slope is >1.55.

Slope Stability Section 10 (FoS 1.55)
Analysis of slope stability section 10 confirms a minimum FoS of 1.693 and 1.694 for Bishop simplified and Janbu simplified methods, respectively. The minimum FoS for both methods are above the required FoS of 1.55 and therefore this embankment is favourable.

5.0 CONCLUSION

Based on the results of this assessment, six of the proposed slopes which will form part of the development plateaus and embankments for the balancing ponds do not achieve the required Factor of Safety (FoS), and therefore pose a risk to the development from instability. This may be due to high groundwater levels, untreated colliery spoil remaining below treated colliery spoil (i.e. areas not treated with surcharging or where the 3.00m re-engineering does not extend to the base of the opencast e.g. slope stability section 01) and slope gradients without reinforcement.

In order to achieve the required Factor of Safety, mitigation measures should be incorporated into the detailed design of these embankments and cuttings. The mitigation measures can include, but not be limited to, the following:

- Introducing surface protection to the slope in order to mitigate against shallow and minor failures.
- On slopes where the potential instability is confined to the toe of the slope (i.e. Slope Stability Sections 04 and 05), locally lessening the slope angle will increase the FoS.
- Where the required FoS is not achieved due to untreated colliery spoil remaining under the slope or development platform, then mitigation measures could include the removal and re-engineering of all the untreated colliery spoil, locally.
- Where the treated colliery spoil (re-engineered material) does not achieve suitable effective stress parameters, consideration should be given to improving the materials to achieve better effective stress parameters or using alternative materials in the construction of the slopes.
- Geogrid reinforcement can be installed to create reinforced earth embankments. By using geogrids, slopes of up to 70 degrees can be achieved (depending on the geogrids and fill materials used).
- Where the required FoS is not achieved due to groundwater levels, vertical and horizontal interceptor drains may be installed and/or granular fill to form a capillary break layer at the base of the embankment. Where groundwater may break out of the proposed slope, e.g. on the sides of the proposed balancing ponds or where natural springs occur, impermeable barriers may be required or groundwater level lowered by diverting.
- Where the required FoS is not achieved due to steepness of the existing slopes, then reprofiling works be carried out. During the reprofiling works, any loose, soft or potentially unstable materials should be removed.

The remaining four slopes do achieve the required FoS. This may be due to a number of attributes, i.e. the cut sections are into natural soils and rock, there is limited amount of engineered fill and a lower groundwater table.

At detailed design stage, each slope which does not achieve the appropriate FoS will need to be assessed and the requirement for mitigation built into the design to ensure future slope stability. The proposed embankments and cuttings can be achieved using site-won materials, if the mitigation measures outlined above are incorporated into the design.

In order to undertake the detailed design of the proposed slopes, further assessment of the geotechnical properties of the materials proposed to be used in the embankment construction (to include effective stress parameters), the groundwater regime and the loading arrangement, is required.

Additional ground investigation of the soils/rock below the proposed embankments will also be required. Where embankments are located over significant thicknesses of backfilled opencast materials, the geotechnical properties of these soils will need to be confirmed/verified following treatment and/or improvement.

On completion of the earthworks, it is recommended that further ground investigation is carried out to confirm that the mitigation measures recommended for the high groundwater table have been successful in lowering the groundwater to a level where it no longer poses a risk to the long-term stability of the earthworks.

Appendix A Figures and Drawings

Figure 1 – Site Location Plan	
Site	**Barnsley West**
Client	**Strata Sterling Barnsley West Ltd**
Job Number	**4848**
Scale	**NTS**

Figure 2 – Aerial Photograph	
Site	**Barnsley West**
Client	**Strata Sterling Barnsley West Ltd**
Job Number	**4848**
Scale	**NTS**

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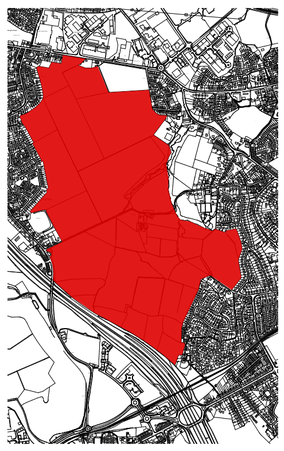
If in doubt ASK. Drawing measurements shall not be obtained by scaling. Verify all dimensions prior to construction.
Immediately report any discrepancies on this document to the Originator. This document shall be read in conjunction with associated models, specifications and related consultants' documents.

Native model: 19028-BBA-ZZ-ZZ-M3-A-0002_Site Model_Reshared_A

North

Key Plan



Site Area: 116.50 ha

Key

- Local Plan Boundary
- Private Garden
- Public Landscape
- Highway - Roads & Side Walk
- Homezone
- Formal Play
- Informal Play
- Existing Pedestrian Access
- Proposed Pedestrian Access
- **1** Commercial
- **2** School
- **3** Employment Zone

0 20 40 60 80 100 120m
1:2500

Note:
The drawing is based upon survey information provided by others, no guarantee of its accuracy can be given

rev	description	drawn	checked	date
P05	Consultation issue.	AS	TR	12/05/21
P04	Consultation issue.	YF	TR	11/05/21
P03	Revised layout to suit proposed levels	AG	TR	11/09/19
P02	Consultation issue	AG	TR	12/08/19
P01	First issue	AM	TR	02/08/19

B

B O N D B R Y A N

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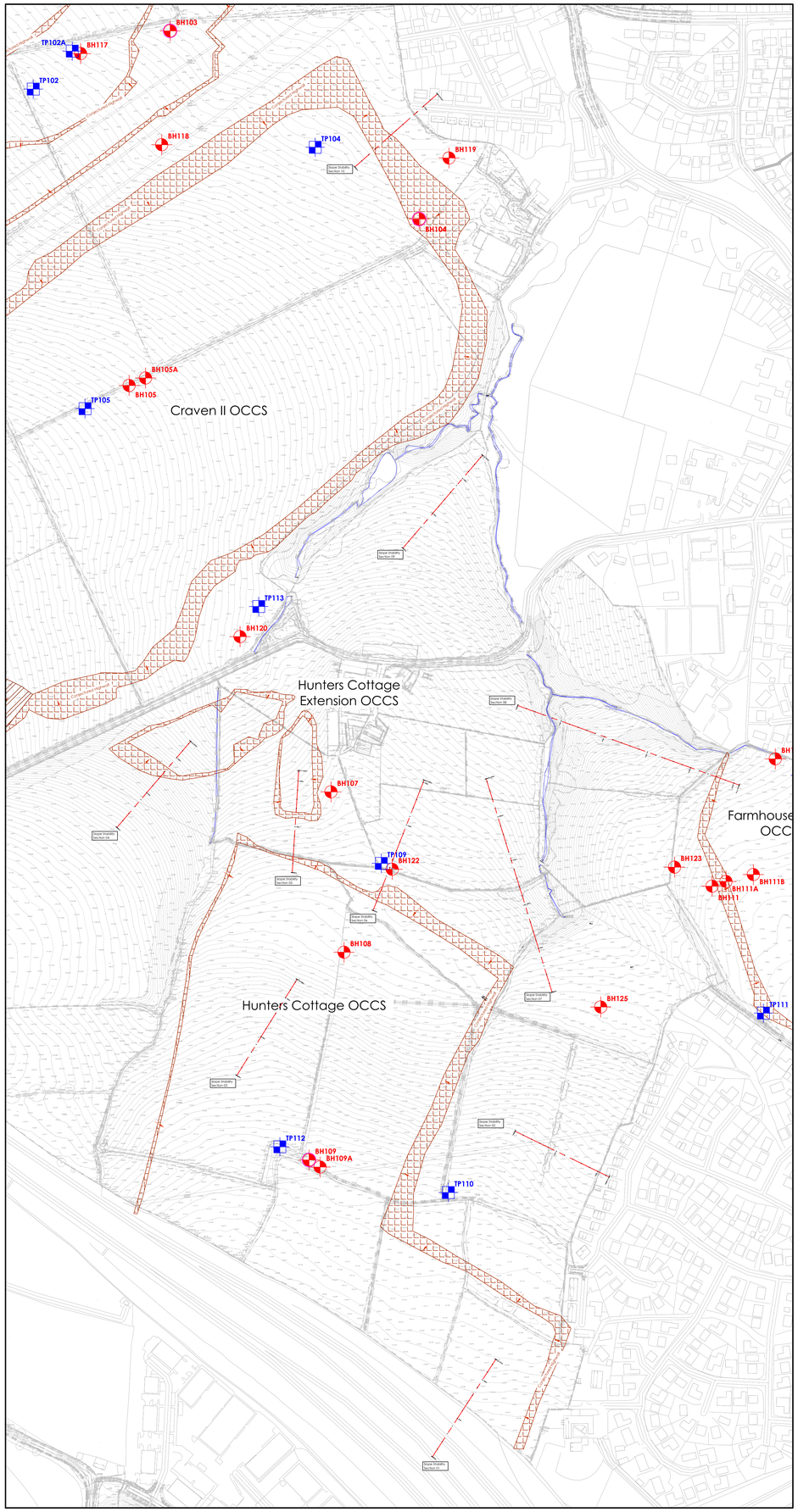
Strata Sterling Barnsley West Ltd

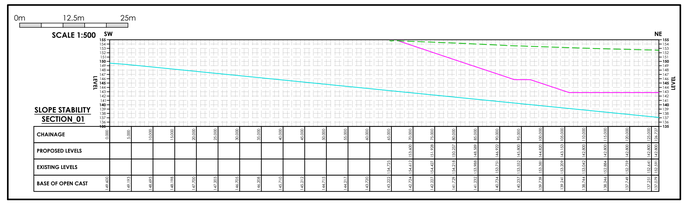
Barnsley West Masterplan

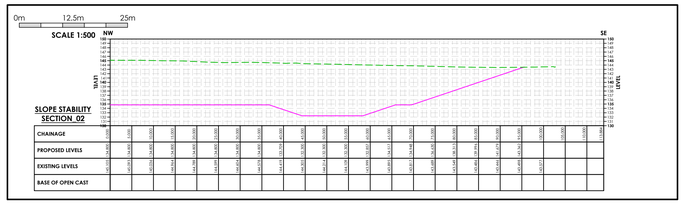
Proposed Site Plan

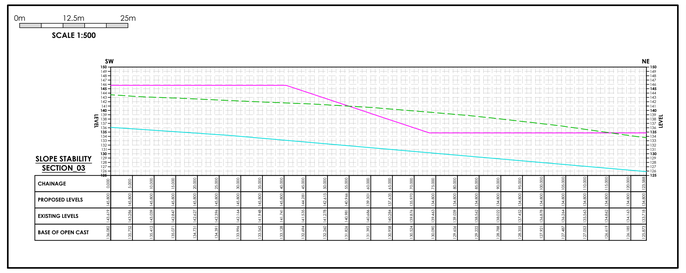
Originator project ref	Purpose of Issue
19028	**CONSULTATION**
Scale(s)	Status
1:2500	**S2 SUITABLE FOR INFORMATION**
Paper size	Revision
A1	**P05 PRELIMINARY**

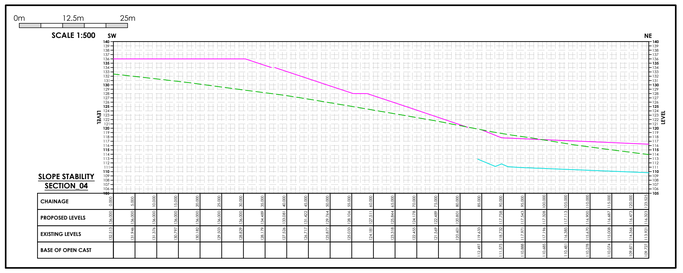
project	originator	volume	level	type	role	number	status	revision
BWM	BBA	ZZ	XX	DR	A	1004	S2	P05

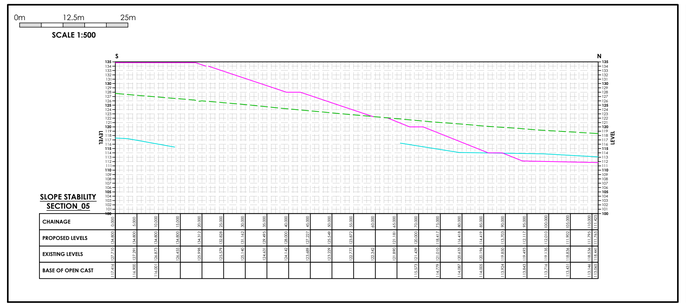


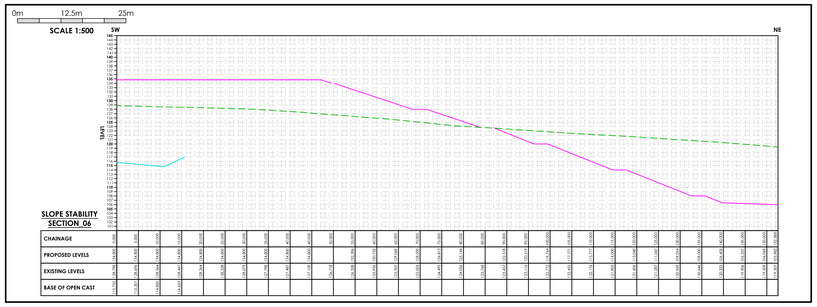


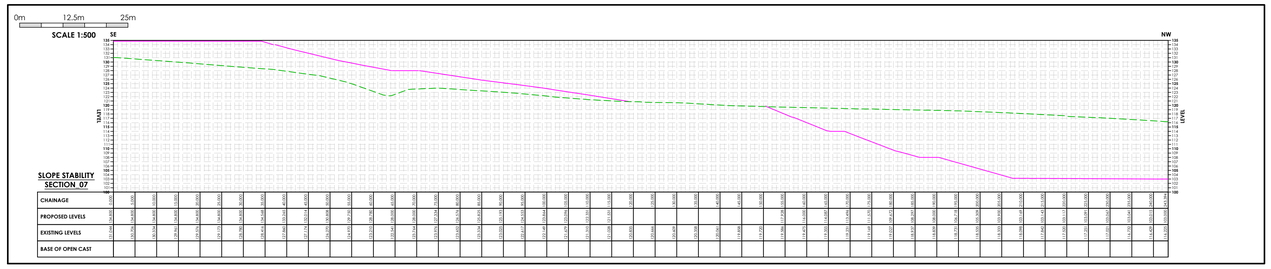


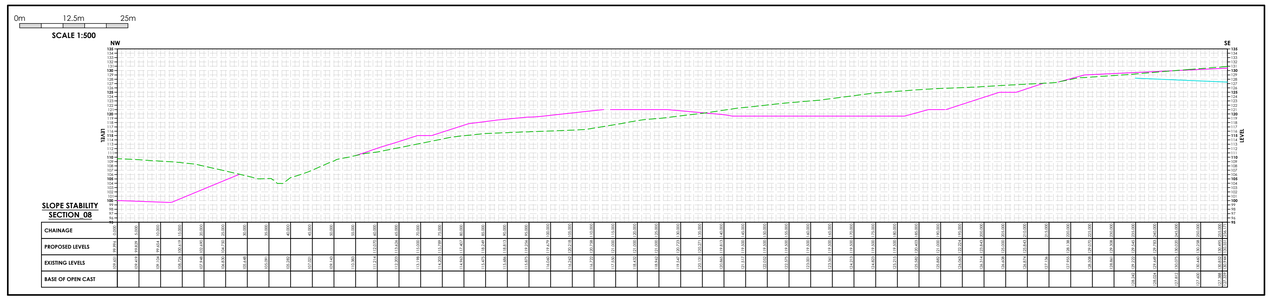


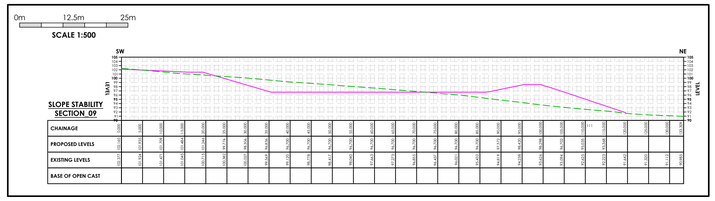


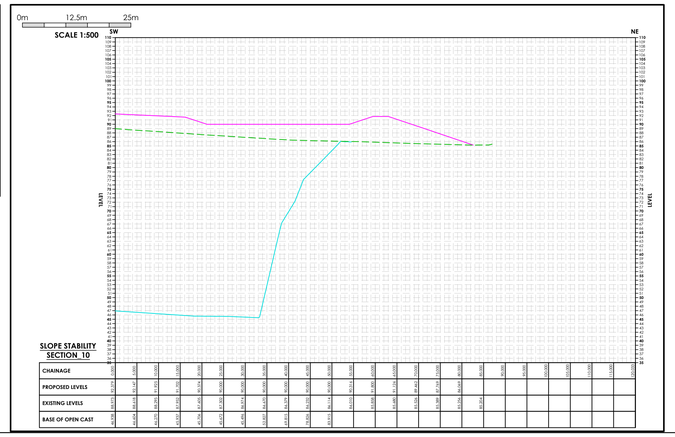












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NOTES

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3. TOPOGRAPHICAL SURVEY INFORMATION USED TO GENERATE PROJECTED EXISTING TOPOGRAPHIC LEVELS HAS BEEN TAKEN FROM: HAYCOCK & TODD LAND SURVEY CONSULTANTS, TOPOGRAPHICAL SURVEY, DRAWING NO. SB315.
4. CONJECTURED BASE OF MADE GROUND AND HIGHWALL LOCATIONS HAVE BEEN DETERMINED USING AVAILABLE OPENCAST COAL OPERATION COMPLETION & ABANDONMENT PLANS;

   A) NATIONAL COAL BOARD OPENCAST EXECUTIVE, CRAVEN I & II, DRAWING NO. OE/COMP/03/3/11.
   B) NATIONAL COAL BOARD OPENCAST EXECUTIVE, HUNTERS COTTAGE & EXTENSION, DRAWING NO. OE/COMP/03/1/21.
   C) FENNELL GREEN & BELBY, FARM HOUSE LANE COLLIERY NO. 2 MINE, BARNSLEY BED PILLARS.
   D) F.J. SWAIN LTD, FARM HOUSE LANE- PRIVATE OPENCAST SITE, DRAWING NO. N.E.415.

SECTIONS

- DENOTES EXISTING GROUND LEVEL
- DENOTES PROPOSED DEVELOPMENT LEVEL
- DENOTES CONJECTURED BASE OF MADE GROUND

REV	DESCRIPTION	DATE	CHK	BY
P01	FIRST ISSUE.	21.01.21	JAM	OLT

Project
BARNSLEY WEST

Drawing Title
SLOPE STABILITY ASSESSMENT
SITE SECTIONS

INFORMATION ISSUE

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4848-JPG-SW-00-DR-G-1321 | S2 | P01

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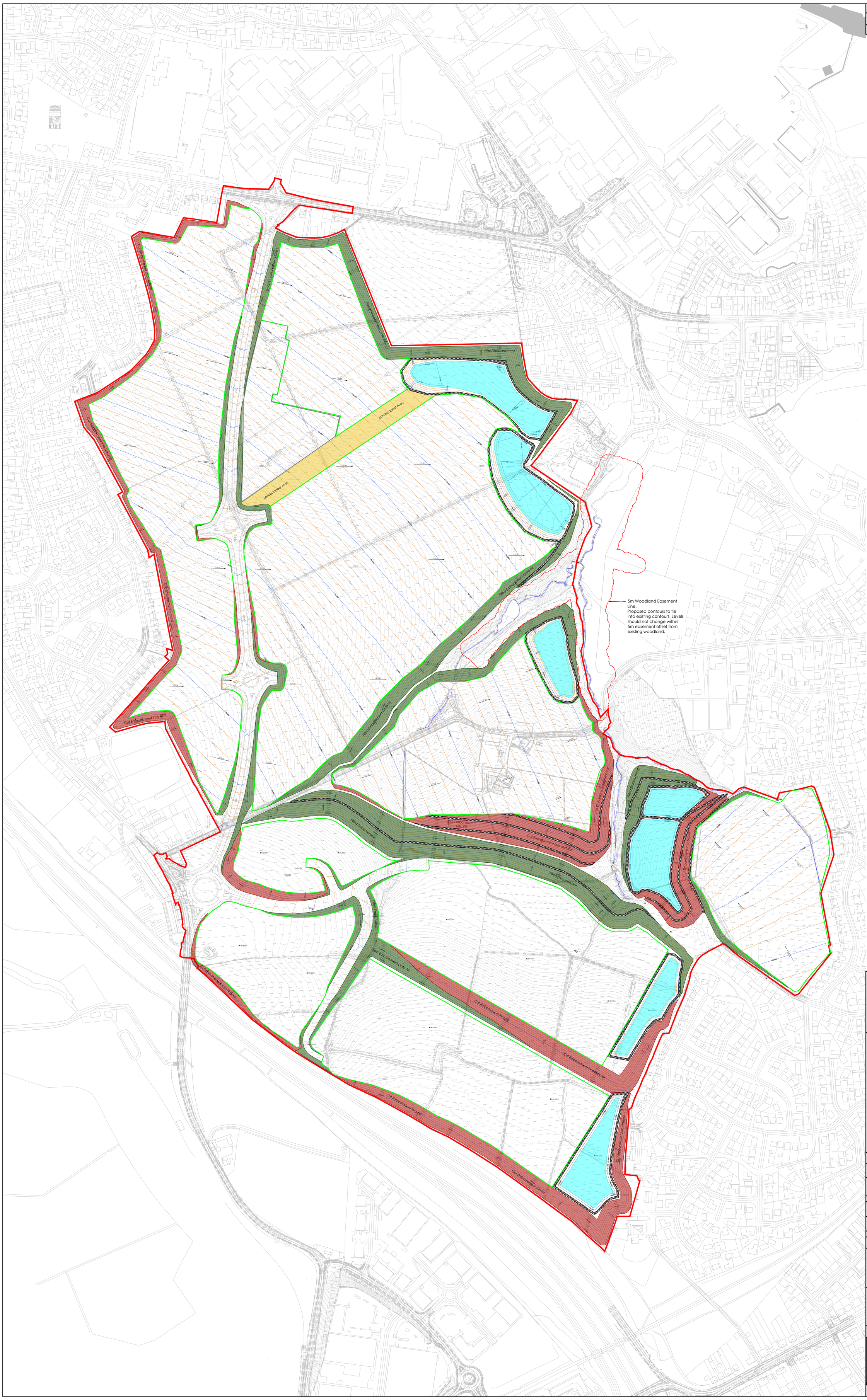
NOTES



0m 50m 100m

SCALE 1:2000

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3. ANY DISCREPANCIES SHOULD BE REPORTED TO THE ENGINEER IMMEDIATELY SO THAT CLARIFICATION CAN BE SOUGHT PRIOR TO COMMENCEMENT OF WORKS.

LEGEND

- 0.000 — DENOTES PROPOSED MAJOR CONTOURS
- 0.000 — DENOTES PROPOSED MINOR CONTOURS
- 1:40 — DENOTES PROPOSED GRADIENTS
- DENOTES DEVELOPABLE PLATEAU
- DENOTES ATTENUATION BASINS
- DENOTES LANDSCAPING AREA
- DENOTES FILLED EMBANKMENT
- DENOTES CUT EMBANKMENT

REV	DESCRIPTION	DATE	CHK	BY
P07	UPDATED LEVELS TO ACCOMMODATE FOOTPATHS.	15.04.21	CPH	OLT
P06	UPDATED COMMERCIAL LAYOUT. UPDATED LINK ROAD LAYOUT AND LEVELS.	04/02/21	CPH	OLT
P05	UPDATED TO INCLUDE DETAILED HIGHWAYS, EMBANKMENT AND DRAINAGE DESIGN.	24/11/20	CPH	OLT
P04	ADDITIONAL NOTES ADDED.	16/04/20	OLT	OLT
P03	AMENDMENTS TO SITE BOUNDARY. ALTERATION TO LINK ROAD ALIGNMENT.	24/02/20	CPH	OLT
P02	AMENDMENTS TO LAYOUT IN LINE WITH ARCHITECTS COMMENTS.	17/10/19	CPH	OLT
P01	FIRST ISSUE.	23/08/19	CPH	OLT

Project
BARNSLEY WEST

Drawing Title
PROPOSED LEVELS WITH DEVELOPABLE PLATEAUS

PLANNING

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4848-JPG-XX-00-DR-C-1207 | S4 | P07

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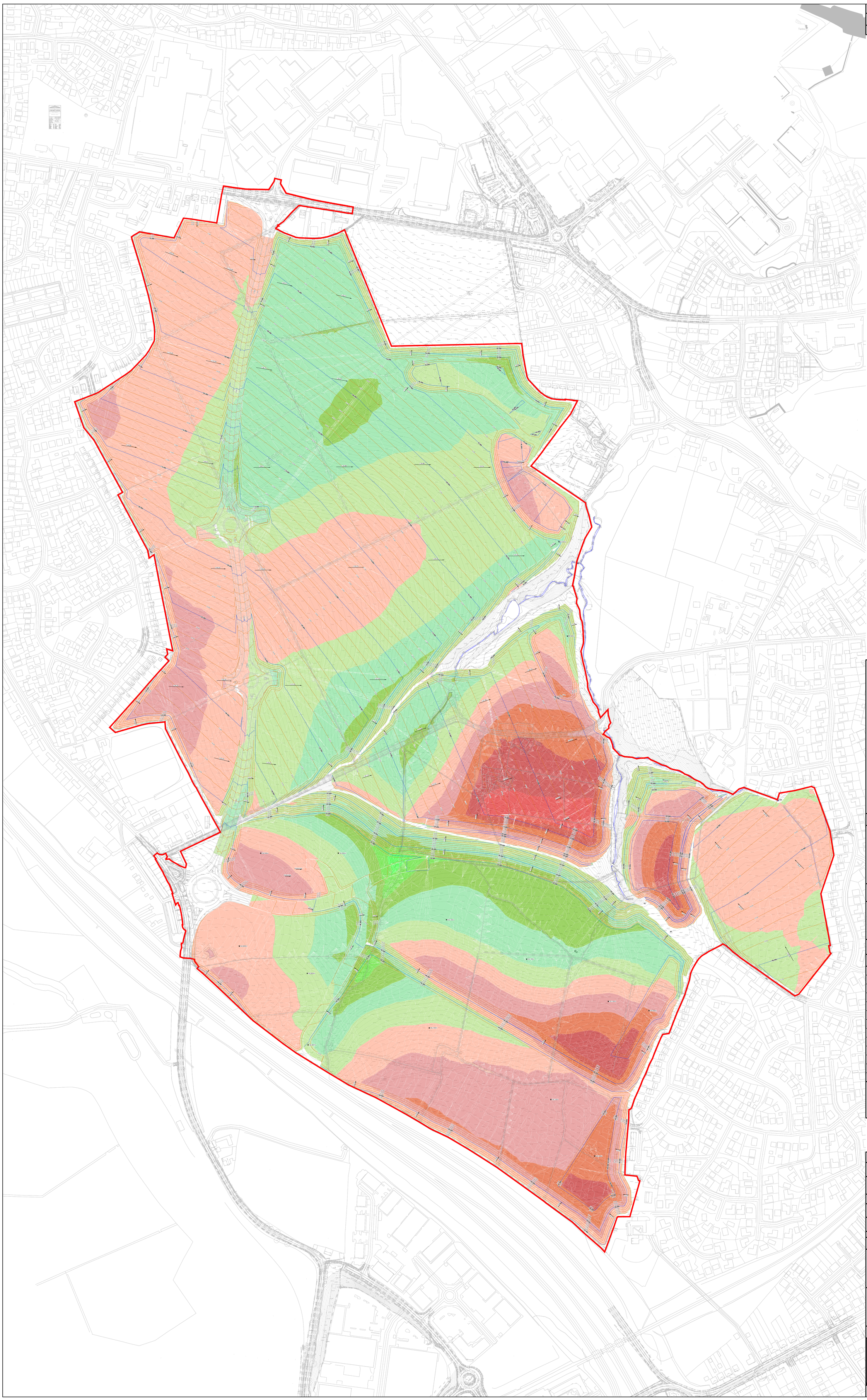
NOTES



0m 50m 100m
SCALE 1:2000

EARTHWORKS NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, M & E CONSULTANTS AND JPG CONSULTANTS DRAWINGS AND REPORTS.
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3. ANY EARTHWORKS SHOULD BE CARRIED OUT IN ACCORDANCE WITH THE EARTHWORKS SPECIFICATION.
4. JPG PROPOSED EARTHWORKS ANALYSIS IS INDICATIVE ONLY. IT IS BASED ON THIRD PARTY INFORMATION AND THEREFORE JPG DO NOT ACCEPT RESPONSIBILITY FOR VARIATIONS IN THE ACTUAL DEPTH OF SITE STRIP OR ANY OTHER ONSITE EATHWORKS PARAMETERS THAT MAY EFFECT FINAL CUT AND FILL VOLUMES.
5. ISOPACHYTE COLOUR BANDINGS DENOTE APPROXIMATE CUT AND FILL VOLUMES BETWEEN THE EXISTING SITE STRIP AND PROPOSED FORMATION LEVELS. REFER TO EARTHWORKS ANALYSIS TABLE.
6. AREAS NOT SHADED WITH ISOPACHYTE COLOUR BANDINGS HAVE NOT BEEN INCLUDED IN THE CUT/FILL ANALYSIS.
7. APPROXIMATE EARTHWORK VOLUMES HAVE BEEN DETERMINED BASED ON THE FOLLOWING CAVEATS:

- BULKING FACTOR HAS BEEN ACCOUNTED FOR.
- ARISINGS FROM ATTENUATION BASIN FORMATION HAS BEEN ACCOUNTED FOR.
- ARISINGS FROM DRAINAGE AND FOUNDATION EXCAVATIONS HAVE NOT BEEN ACCOUNTED FOR.
- DEMOLISHED MATERIAL FROM EXISTING BUILDINGS/STRUCTURES HAVE NOT BEEN ACCOUNTED FOR.

EARTHWORKS ANALYSIS

EXISTING SITE STRIP

ANALYSIS HAS ALLOWED FOR A 200mm DEEP SITE STRIP OF EXISTING TOPSOIL.
TOTAL AREA = 1088604.442m²
TOTAL VOLUME = 217720.888m³
SITE STRIP MATERIAL DEEMED TO BE UNSUITABLE FOR RE-USE AS ENGINEERING FILL.
TOPOGRAPHICAL SURVEY INFORMATION USED IN THE EARTHWORKS ANALYSIS TAKEN FROM: HAYCOCK & TODD LAND SURVEY CONSULTANTS, TOPOGRAPHICAL SURVEY, DRAWING NO. S8315.

ANALYSIS BETWEEN EXISTING SITE STRIP & PROPOSED PLATEAU LEVELS

2D AREA	1088604.442m²
CUT	1747876.481m³
BULKING FACTOR (5%)	87393.824m³
FILL	1838645.243m³
NET (SHORTFALL)	3374.938m³
MAXIMUM CUT DEPTH	-14.850m
MAXMIUM FILL DEPTH	14.580m

SURFACE LEVEL DATA

MIN. LEVEL	MAX. LEVEL	COLOUR
-18.000m	-15.000m	
-15.000m	-12.000m	
-12.000m	-9.000m	
-9.000m	-6.000m	
-6.000m	-3.000m	
-3.000m	0.000m	
0.000m	3.000m	
3.000m	6.000m	
6.000m	9.000m	
9.000m	12.000m	
12.000m	15.000m	
15.000m	18.000m	

LEGEND

0.000 DENOTES PROPOSED MAJOR CONTOURS
0.000 DENOTES PROPOSED MINOR CONTOURS
1:40 DENOTES PROPOSED GRADIENTS

REV	DESCRIPTION	DATE	CHK	BY
P07	UPDATED LEVELS TO ACCOMMODATE FOOTPATHS.	15/04/21	CPH	OLT
P06	UPDATED COMMERCIAL LAYOUT. UPDATED LINK ROAD LAYOUT AND LEVELS.	04/02/21	CPH	OLT
P05	UPDATED TO INCLUDE DETAILED HIGHWAYS, EMBANKMENT AND DRAINAGE DESIGN.	25/11/20	CPH	OLT
P04	UPDATED RED-LINE BOUNDARY.	17/11/20	CPH	OLT
P03	ALTERATION TO SITE BOUNDARY. ALTERATION TO LINK ROAD ALIGNMENT.	24/02/20	CPH	OLT
P02	AMENDMENTS TO LAYOUT IN LINE WITH ARCHITECTS COMMENTS.	17/10/19	CPH	OLT
P01	FIRST ISSUE.	23/08/19	CPH	OLT

Project
BARNSLEY WEST

Drawing Title
SITE WIDE CUT/FILL ANALYSIS

PLANNING

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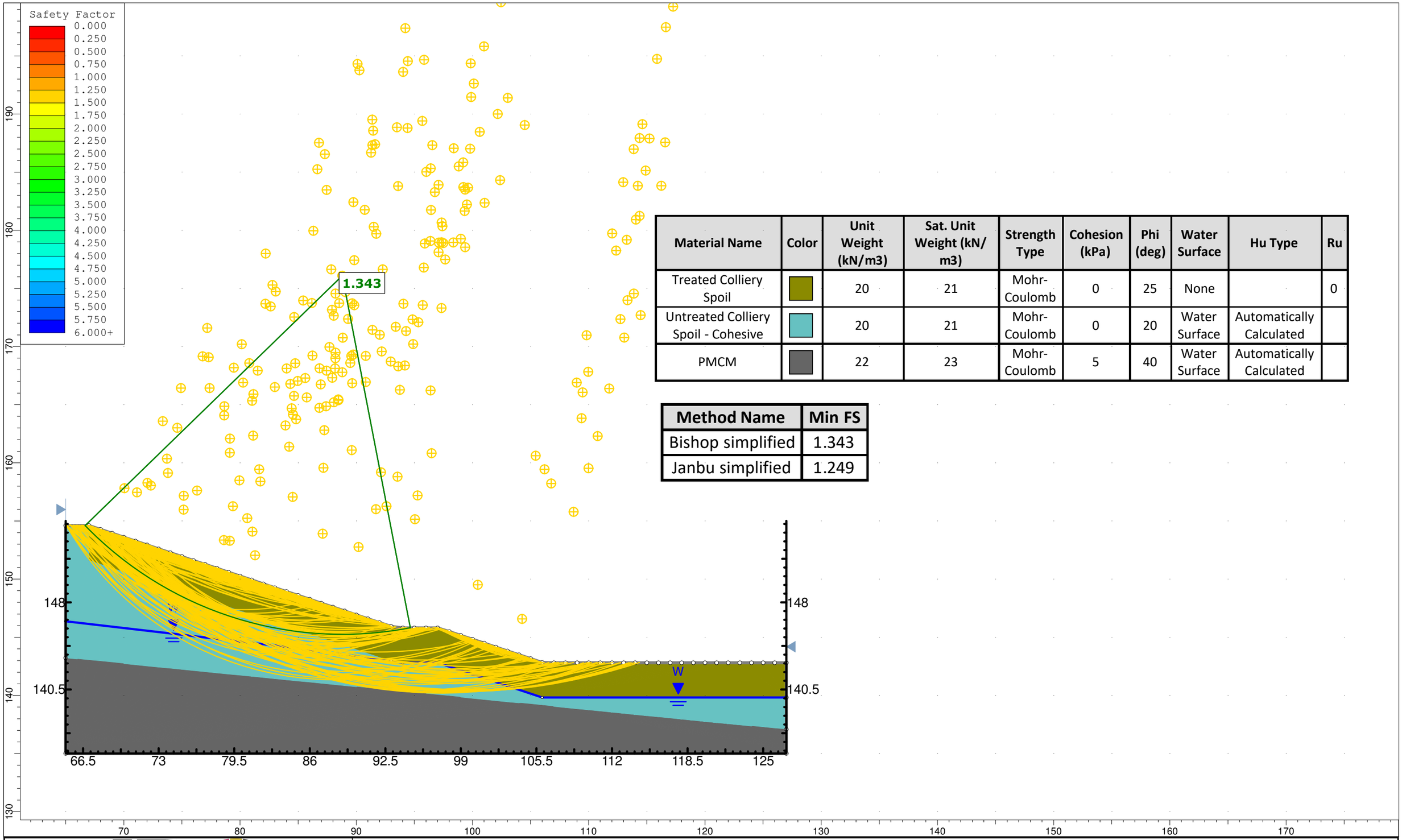
4848-JPG-XX-00-DR-C-1208 | S4 | P07

Appendix B Rocscience Slide2 (v 9.012) Results



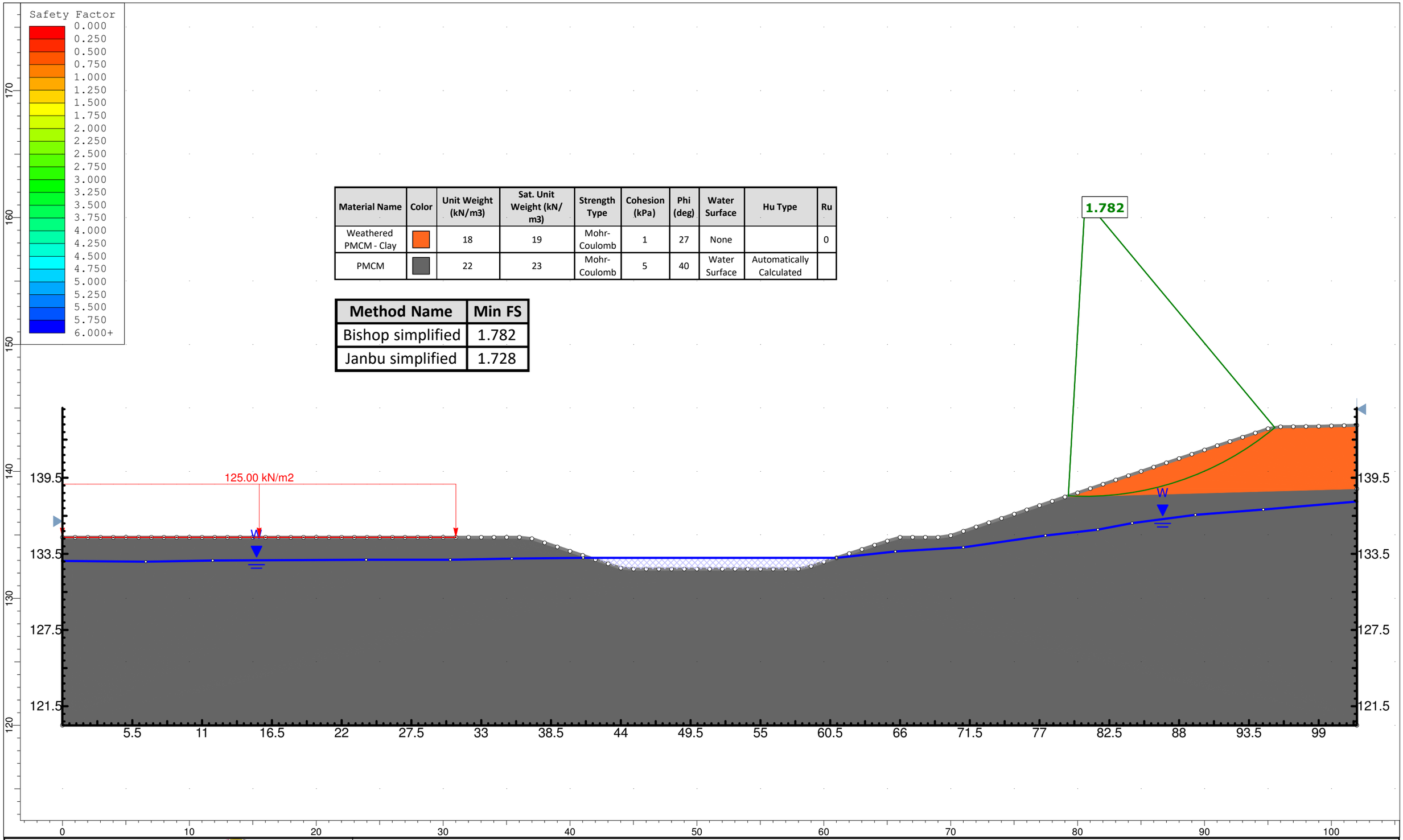
Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Ru
Treated Colliery Spoil		20	21	Mohr-Coulomb	0	25	None		0
Untreated Colliery Spoil - Cohesive		20	21	Mohr-Coulomb	0	20	Water Surface	Automatically Calculated	
PMCM		22	23	Mohr-Coulomb	5	40	Water Surface	Automatically Calculated	

Method Name	Min FS
Bishop simplified	1.343
Janbu simplified	1.249

JPG CIVIL & STRUCTURAL ENGINEERING

SLIDEINTERPRET 9.012

Project	4848_Barnsley_West_Slope_Stability_Assessment		
Group	Treatment Scenario - Cut Slope	*Scenario*	Master Scenario - Section 01
Drawn By	JPG (Leeds) Limited	*Company*	JPG (Leeds) Limited
Date	25/01/2021, 11:09:05	*File Name*	4848_Slope_Section_01_V2.slmd



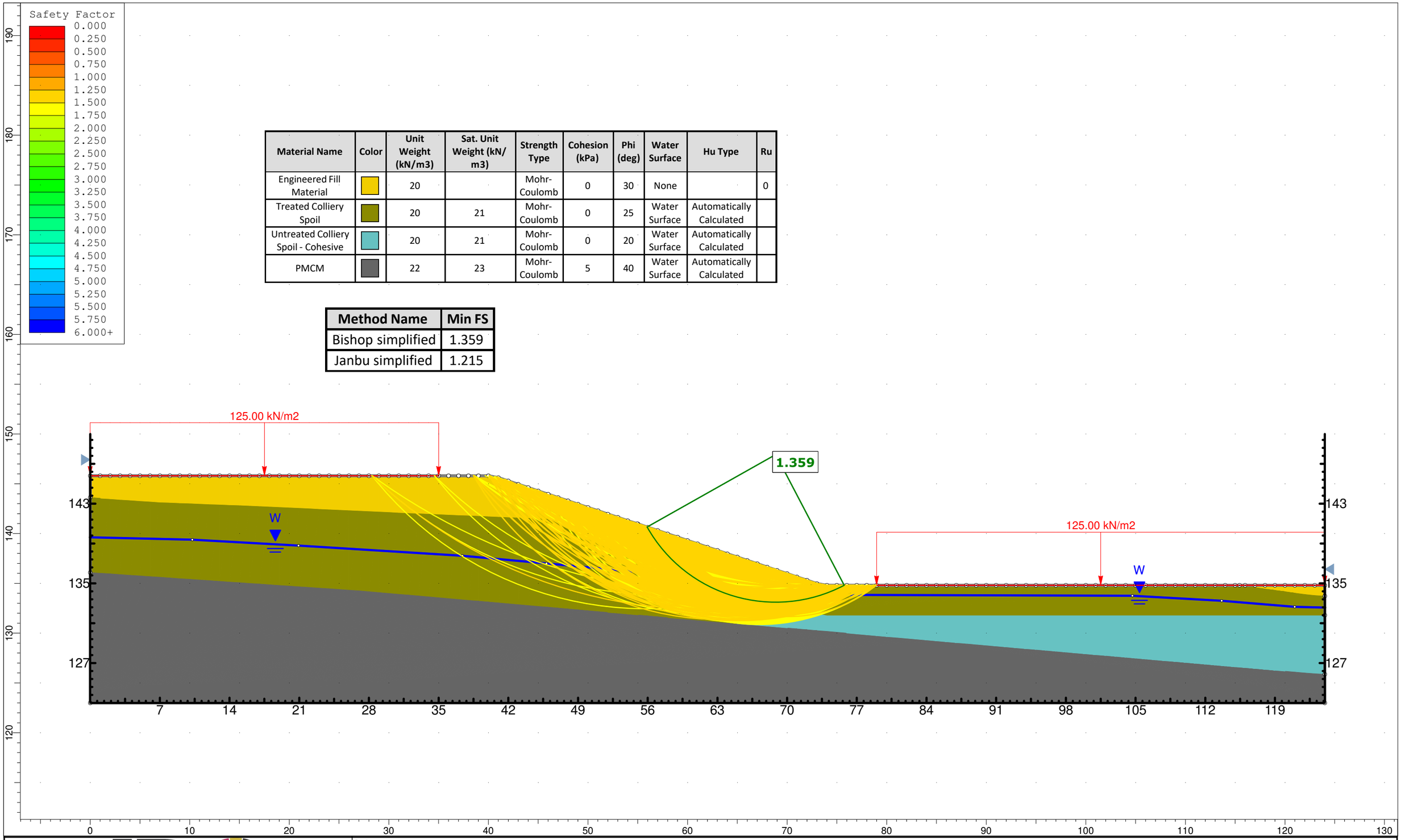
Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Ru
Weathered PMCM - Clay		18	19	Mohr-Coulomb	1	27	None		0
PMCM		22	23	Mohr-Coulomb	5	40	Water Surface	Automatically Calculated	

Method Name	Min FS
Bishop simplified	1.782
Janbu simplified	1.728

SLIDEINTERPRET 9.012

CIVIL & STRUCTURAL ENGINEERING

Project	4848_Barnsley_West_Slope_Stability_Assessment		
Group	No Treatment and High Groundwater Scenario - Cut Slope	*Scenario*	Master Scenario - Section 02
Drawn By	JPG (Leeds) Limited	*Company*	JPG (Leeds) Limited
Date	22/02/2021, 14:44:04	*File Name*	4848_Slope_Section_02_V2.slmd



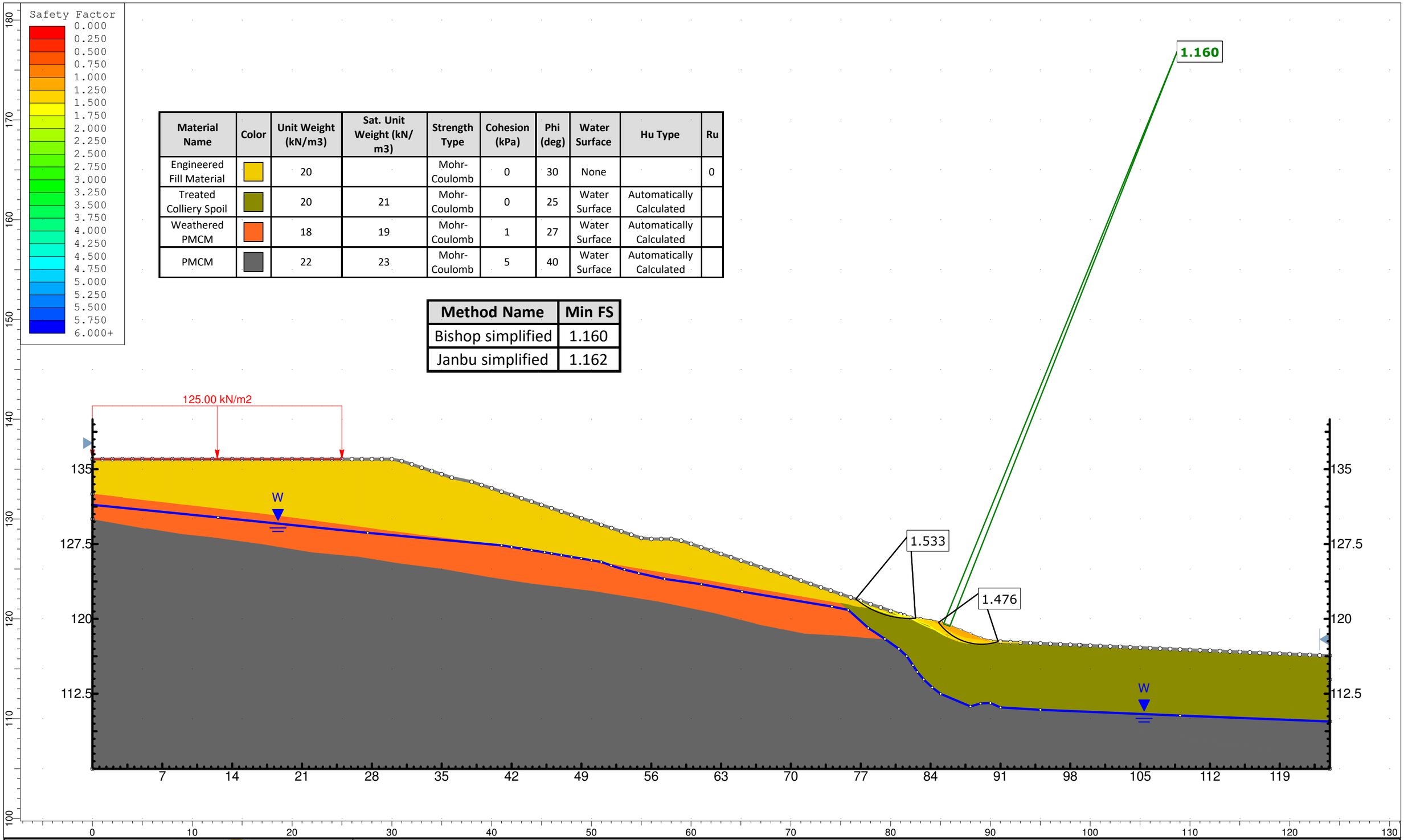
Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Ru
Engineered Fill Material		20		Mohr-Coulomb	0	30	None		0
Treated Colliery Spoil		20	21	Mohr-Coulomb	0	25	Water Surface	Automatically Calculated	
Untreated Colliery Spoil - Cohesive		20	21	Mohr-Coulomb	0	20	Water Surface	Automatically Calculated	
PMCM		22	23	Mohr-Coulomb	5	40	Water Surface	Automatically Calculated	

Method Name	Min FS
Bishop simplified	1.359
Janbu simplified	1.215

JPG CIVIL & STRUCTURAL ENGINEERING

SLIDEINTERPRET 9.012

Project	4848_Barnsley_West_Slope_Stability_Assessment		
Group	Treatment Scenario - Cut & Fill Slope	*Scenario*	Master Scenario - Section 03
Drawn By	JPG (Leeds) Limited	*Company*	JPG (Leeds) Limited
Date	23/02/2021, 14:48:25	*File Name*	4848_Slope_Section_03_V2.slmd



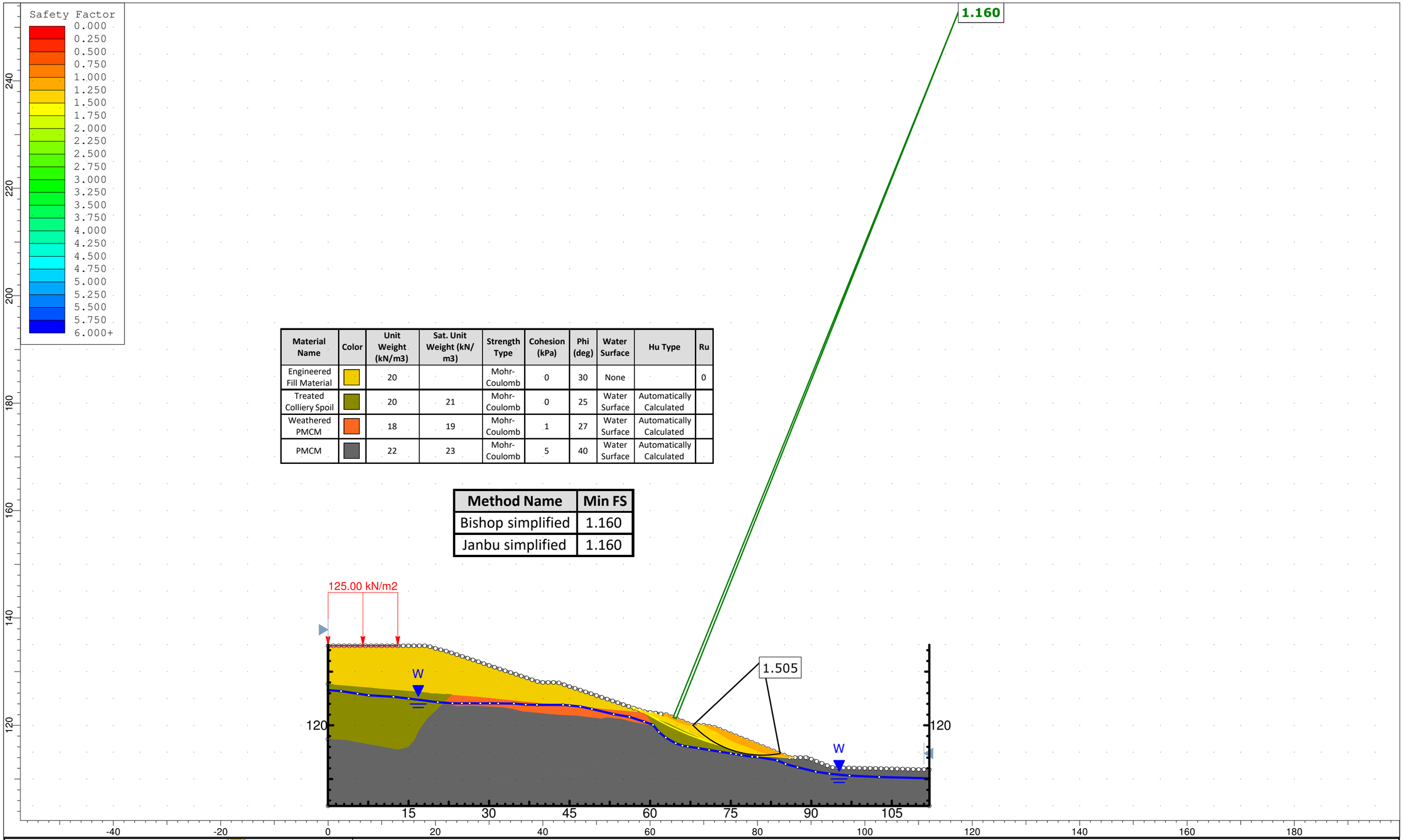
Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Ru
Engineered Fill Material		20		Mohr-Coulomb	0	30	None		0
Treated Colliery Spoil		20	21	Mohr-Coulomb	0	25	Water Surface	Automatically Calculated	
Weathered PMCM		18	19	Mohr-Coulomb	1	27	Water Surface	Automatically Calculated	
PMCM		22	23	Mohr-Coulomb	5	40	Water Surface	Automatically Calculated	

Method Name	Min FS
Bishop simplified	1.160
Janbu simplified	1.162

JPG CIVIL & STRUCTURAL ENGINEERING

SLIDEINTERPRET 9.012

Project	4848_Barnsley_West_Slope_Stability_Assessment		
Group	Treatment and High Groundwater (Spring) Scenario - Cut & Fill Slope	*Scenario*	Master Scenario - Section 04
Drawn By	JPG (Leeds) Limited	*Company*	JPG (Leeds) Limited
Date	23/02/2021, 15:46:40	*File Name*	4848_Slope_Section_04_V2.slmd



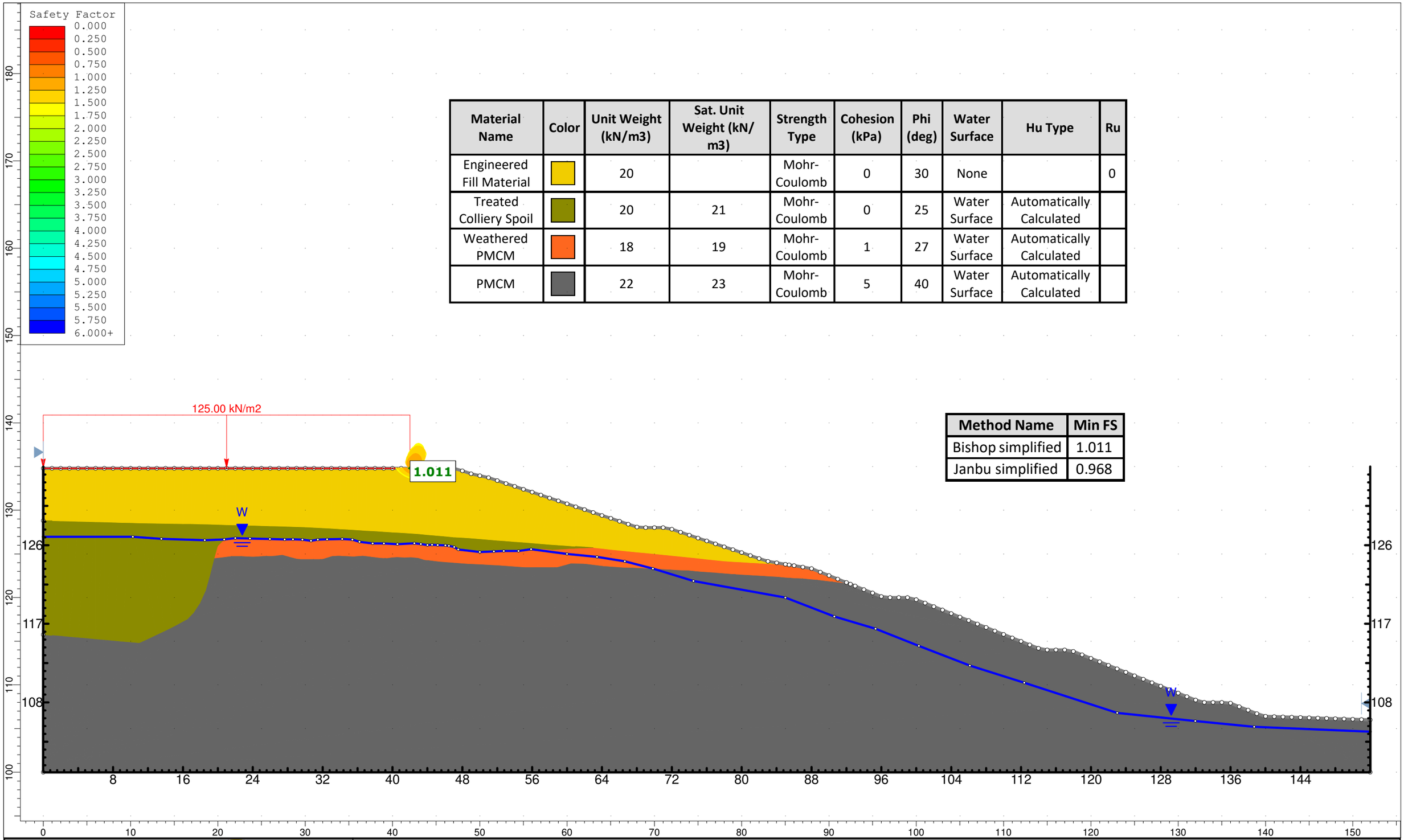
Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Ru
Engineered Fill Material		20		Mohr-Coulomb	0	30	None		0
Treated Colliery Spoil		20	21	Mohr-Coulomb	0	25	Water Surface	Automatically Calculated	
Weathered PMCM		18	19	Mohr-Coulomb	1	27	Water Surface	Automatically Calculated	
PMCM		22	23	Mohr-Coulomb	5	40	Water Surface	Automatically Calculated	

Method Name	Min FS
Bishop simplified	1.160
Janbu simplified	1.160

JPG CIVIL & STRUCTURAL ENGINEERING

SLIDEINTERPRET 9.012

Project	4848_Barnsley_West_Slope_Stability_Assessment		
Group	Treatment and High Groundwater (Spring) Scenario - Cut & Fill Slope	*Scenario*	Master Scenario - Section 05
Drawn By	JPG (Leeds) Limited	*Company*	JPG (Leeds) Limited
Date	24/02/2021, 13:47:31	*File Name*	4848_Slope_Section_05_V2.slmd



Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Ru
Engineered Fill Material		20		Mohr-Coulomb	0	30	None		0
Treated Colliery Spoil		20	21	Mohr-Coulomb	0	25	Water Surface	Automatically Calculated	
Weathered PMCM		18	19	Mohr-Coulomb	1	27	Water Surface	Automatically Calculated	
PMCM		22	23	Mohr-Coulomb	5	40	Water Surface	Automatically Calculated	

Method Name	Min FS
Bishop simplified	1.011
Janbu simplified	0.968

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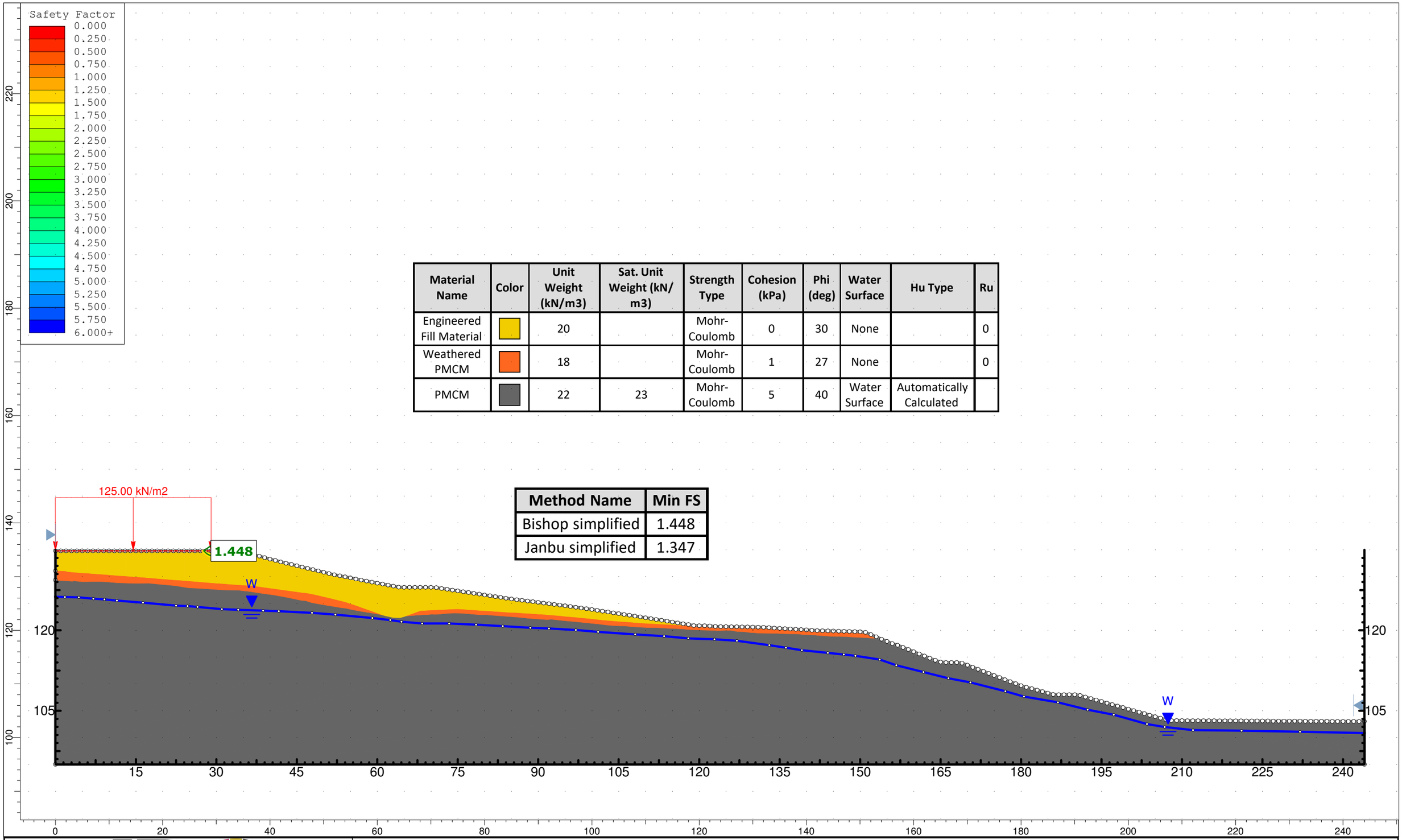
SLIDEINTERPRET 9.012

Project	4848_Barnsley_West_Slope_Stability_Assessment		
Group	Treatment and High Groundwater Scenario - Cut & Fill Slope	Scenario	Master Scenario - Section 06
Drawn By	JPG (Leeds) Limited	Company	JPG (Leeds) Limited
Date	25/02/2021, 08:36:20	File Name	4848_Slope_Section_06_V2.slmd



Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Ru
Engineered Fill Material		20		Mohr-Coulomb	0	30	None		0
Weathered PMCM		18		Mohr-Coulomb	1	27	None		0
PMCM		22	23	Mohr-Coulomb	5	40	Water Surface	Automatically Calculated	

Method Name	Min FS
Bishop simplified	1.448
Janbu simplified	1.347

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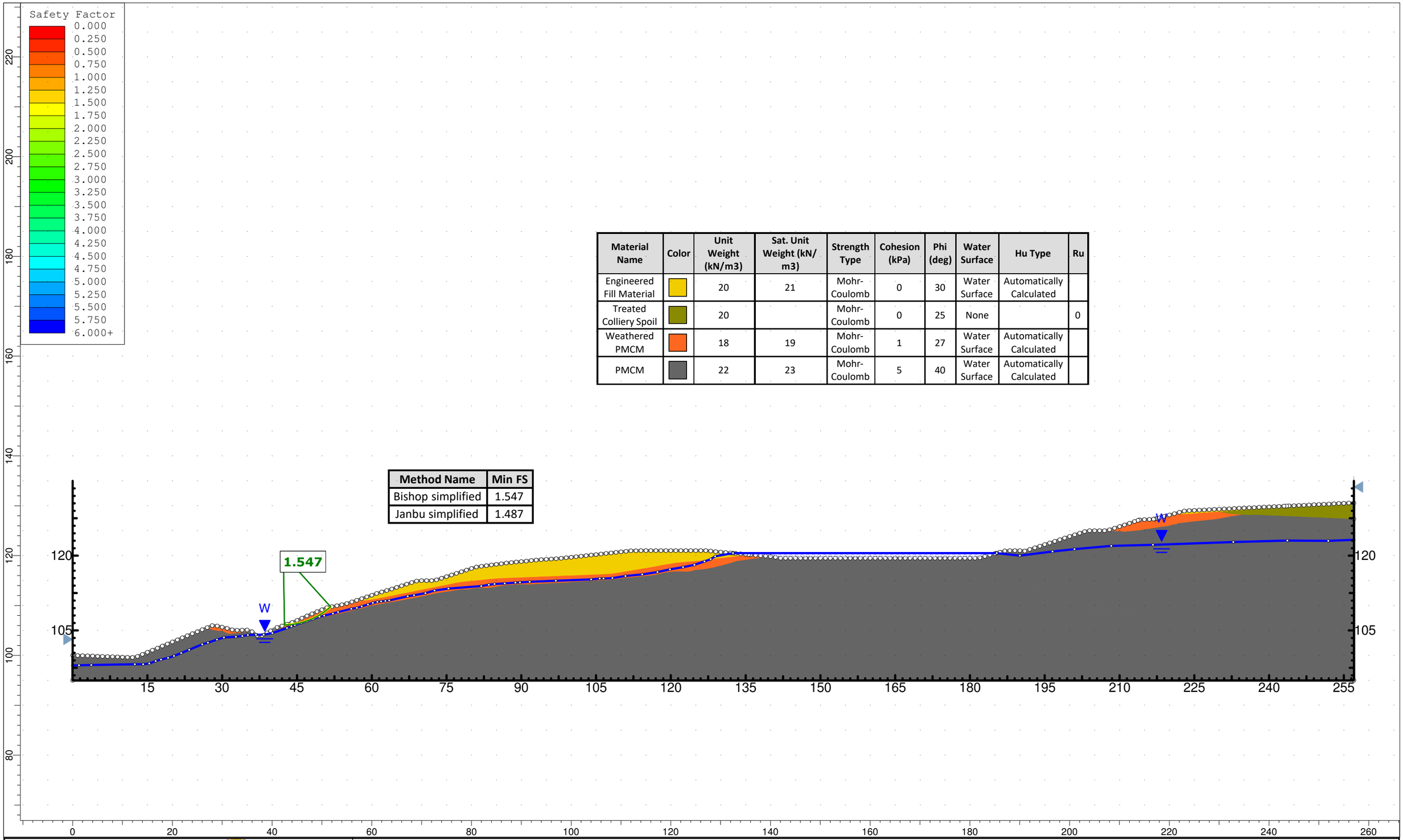
SLIDEINTERPRET 9.012

Project	4848_Barnsley_West_Slope_Stability_Assessment		
Group	No Treatment Scenario - Cut & Fill Slope	*Scenario*	Master Scenario - Section 07
Drawn By	JPG (Leeds) Limited	*Company*	JPG (Leeds) Limited
Date	25/02/2021, 09:52:32	*File Name*	4848_Slope_Section_07_V2.slmd



Method Name	Min FS
Bishop simplified	1.547
Janbu simplified	1.487

Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Ru
Engineered Fill Material		20	21	Mohr-Coulomb	0	30	Water Surface	Automatically Calculated	
Treated Colliery Spoil		20		Mohr-Coulomb	0	25	None		0
Weathered PMCM		18	19	Mohr-Coulomb	1	27	Water Surface	Automatically Calculated	
PMCM		22	23	Mohr-Coulomb	5	40	Water Surface	Automatically Calculated	

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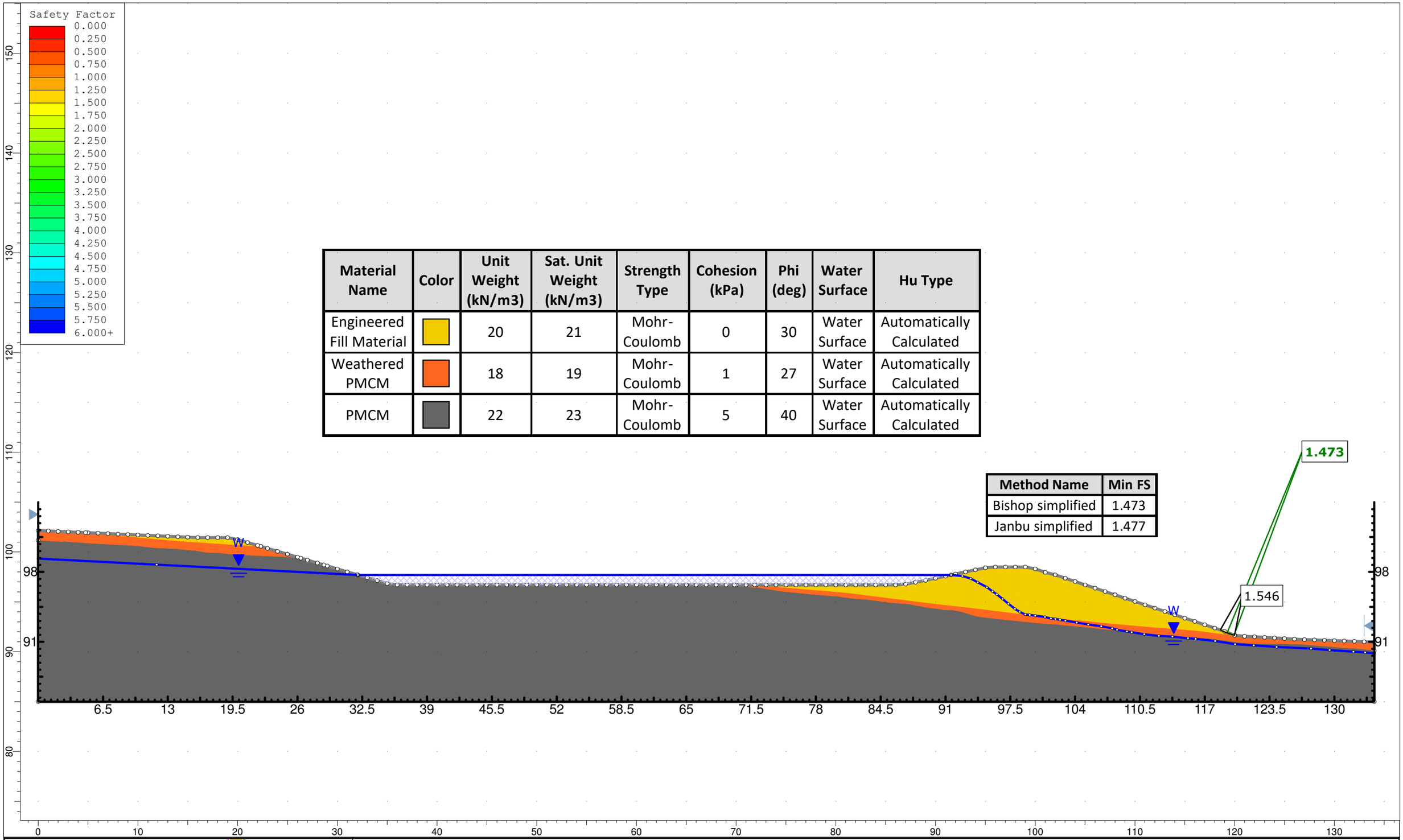
Project	4848_Barnsley_West_Slope_Stability_Assessment		
Group	Treatment and High Groundwater Scenario - Cut & Fill Slope	*Scenario*	Master Scenario - Section 08
Drawn By	JPG (Leeds) Limited	*Company*	JPG (Leeds) Limited
Date	25/02/2021, 10:26:18	*File Name*	4848_Slope_Section_08_V2.slmd



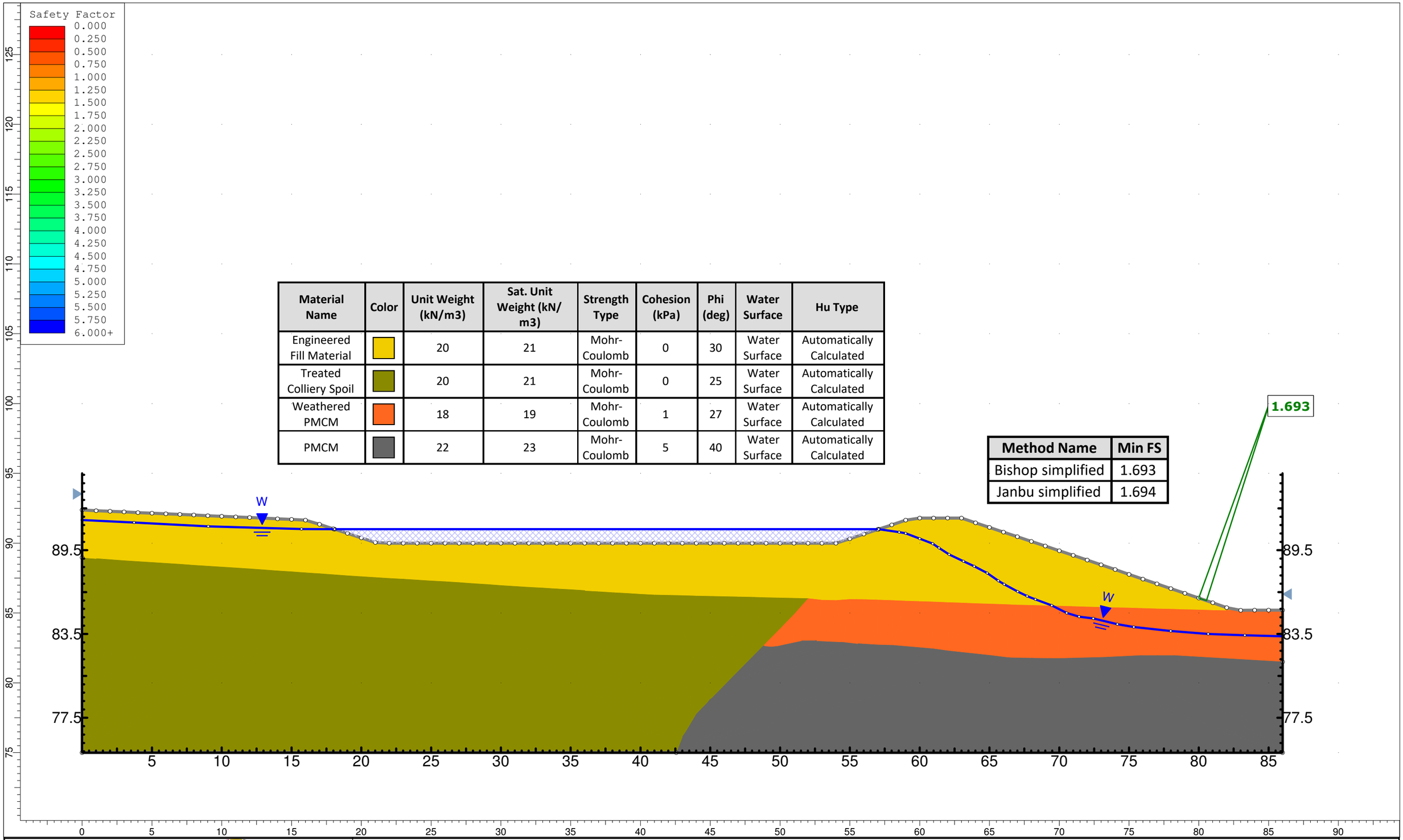
Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Engineered Fill Material		20	21	Mohr-Coulomb	0	30	Water Surface	Automatically Calculated
Weathered PMCM		18	19	Mohr-Coulomb	1	27	Water Surface	Automatically Calculated
PMCM		22	23	Mohr-Coulomb	5	40	Water Surface	Automatically Calculated

Method Name	Min FS
Bishop simplified	1.473
Janbu simplified	1.477

JPG CIVIL & STRUCTURAL ENGINEERING

SLIDEINTERPRET 9.012

Project	4848_Barnsley_West_Slope_Stability_Assessment		
Group	No Treatment and High Groundwater Scenario - Cut & Fill Slope	*Scenario*	Master Scenario - Section 09
Drawn By	JPG (Leeds) Limited	*Company*	JPG (Leeds) Limited
Date	25/02/2021, 12:08:41	*File Name*	4848_Slope_Section_09_V2.slmd



Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Engineered Fill Material		20	21	Mohr-Coulomb	0	30	Water Surface	Automatically Calculated
Treated Colliery Spoil		20	21	Mohr-Coulomb	0	25	Water Surface	Automatically Calculated
Weathered PMCM		18	19	Mohr-Coulomb	1	27	Water Surface	Automatically Calculated
PMCM		22	23	Mohr-Coulomb	5	40	Water Surface	Automatically Calculated

Method Name	Min FS
Bishop simplified	1.693
Janbu simplified	1.694

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SLIDEINTERPRET 9.012

Project	4848_Barnsley_West_Slope_Stability_Assessment		
Group	Treatment and High Groundwater Scenario - Embankment Slope	*Scenario*	Master Scenario - Section 10
Drawn By	JPG (Leeds) Limited	*Company*	JPG (Leeds) Limited
Date	25/02/2021, 14:14:42	*File Name*	4848_Slope_Section_10_V2.slmd

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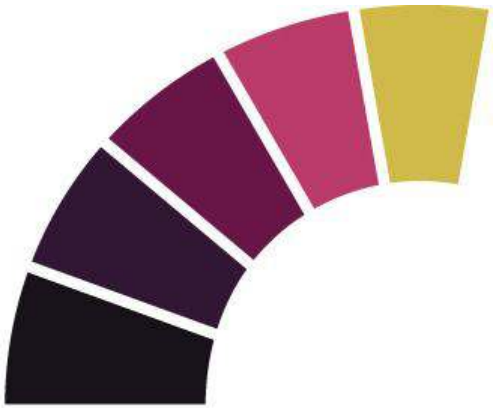
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