GroundSolve Ltd
Consulting Geotechnical Engineers

Cellars Clough, Marsden
GEOTECHNICAL DESIGN REPORT

Prepared for Angela Broadhurst

DOCUMENT CONTROL

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These calculations have been prepared by GroundSolve Ltd with all reasonable care and diligence, within the best practice and guidance current at the time of issue and within the construction proposals provided by the client.

This design is confidential to the Client and GroundSolve Ltd accepts no responsibility whatsoever to third parties to whom this report is presented.

Version No.	Description	Date of Issue	Author	Reviewed By	Approved By
03	REMOVE SHEET PILED WALL & L SECTIONS, ADD ANCHORED GABION WALLS	05/03/2026	O Rhodes BEng (Hons) MSc FGS	S Imiolczyk BSc (Hons) MSc FGS CEng MICE RoGEP	S Imiolczyk BSc (Hons) MSc FGS CEng MICE RoGEP
02	AMENDED DRAWINGS	30/01/2026	O Rhodes BEng (Hons) MSc FGS	S Imiolczyk BSc (Hons) MSc FGS CEng MICE RoGEP	S Imiolczyk BSc (Hons) MSc FGS CEng MICE RoGEP
01	FINAL	18/12/2025	O Rhodes BEng (Hons) MSc FGS	S Imiolczyk BSc (Hons) MSc FGS CEng MICE RoGEP	S Imiolczyk BSc (Hons) MSc FGS CEng MICE RoGEP

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1.0 INTRODUCTION

1.1 Background and Scope

GroundSolve Ltd (GSL) were commissioned by Angela Broadhurst (the client) to undertake a geotechnical design for proposed landslip remedial works and reconstruction/modification of outbuildings at Cellars Clough, Marsden.

The objectives of the geotechnical design are:

1. To provide a buildable solution to stabilise a section of slope, following a landslip in 2019.
2. Maximise useable space on at the base of the slope, which shall be used by the downslope neighbour as a private garden.
3. Provide temporary works design of retaining structures for the proposed redevelopment at the top of the slope.
4. To provide geotechnical recommendations for the design of foundations for the proposed redevelopment.

1.2 Previous Work

Several ground investigations have been undertaken and the following previous reports should be read in conjunction with this document for a full understanding of the previous investigation works and ground conditions:

- GeoAssist Limited, 2019. Ground Investigation Report – Geotechnical. 6018/CCZ-G v1.0.
- Campbell Reith, 2025. Interpretative Geotechnical Report – 14242-CRH-XX-XX-RP-GE-0003-P01_IGR.

2.0 GROUND MODEL

2.1 Site Description

The site is a residential property comprising a late 19th / early 20th century house with associated outbuildings and landscaped areas. A landslide occurred along the western site boundary in 2019, with some debris from the slide still present on the slope face, but has been largely cleared from the neighbouring property below. The landslide scarp at the top of the slope is approximately 173mOD with the base of the slope in the neighbouring property to the north west ranging between approximately 163mOD and 165mOD. The slope face is undulating and a narrow access track is present, entering from the south. There is a stacked stone retaining wall along the base of the slope of approximately 2m to 3m height.

Slope instability was first identified several years ago and was immediately preceded by a period of heavy rainfall and failed drainage. The principal triggering factor therefore is considered to be excessive water within the slope, backed up by the fact that the slope has remained relatively stable for several years following the drainage repairs, despite the backscar being overly steep. The landslide slipe surface appears to daylights out of the slope face with the downslope retaining wall visually unaffected by the landslide, however large sections of the wall were covered in vegetation during site inspections and therefore the full condition of the wall is not known.

Several rounds of ground investigation have been carried out, comprising window sampling, rotary boreholes and dynamic probing. The investigations proved the site to be underlain by a variable thickness of Landslide Deposits containing both cohesive and granular soil units. This was underlain in turn by Head Deposits and bedrock of the Marsden Formation. Groundwater was generally identified within the Landslide Deposits, just above the contact with the underlying Head Deposits.

2.2 Geotechnical Design Parameters

Geotechnical design parameters for the site are provided in Table 1. These are considered to be moderately conservative, characteristic parameters, relevant for the assessment of slope stability and soil nail design at the site.

Table 1. Geotechnical design parameters

Stratum	Unit weight, γ (kN/m³)	Internal Angle of Friction, ϕ (°)	Effective Cohesion, c' (kPa)	Undrained Shear Strength, c_u (kPa)	UCS (MPa)
Landslide Deposits	17	26	0	30	-
Head Deposits	19	27	1	120	-
Marsden Formation	20	-	-	-	2

Groundwater will be set to the monitored level from the ground investigation when calculating stability, with a resting level of typically 0.5m above the top of the head Deposits.

3.0 GEOTECHNICAL DESIGN

3.1 Design Approach

The existing slope condition has been analysed using Rocscience Slide2, using Bishop's simplified method for circular slip surfaces.

Loadings shall be applied to the slope to account for structures and traffic. A constant distributed load of 25kPa shall be applied to the existing main house footprint within the slope stability calculations. Where appropriate, construction traffic shall also be considered with inclusion of a variable distributed load of 10kPa, however this should be reviewed once the plant proposed for use in construction is confirmed.

3.2 Slope Stability Analyses

Four slope sections (A-A', B-B', C-C', and D-D') have been analysed for stability and are shown in plan in Figure 1.

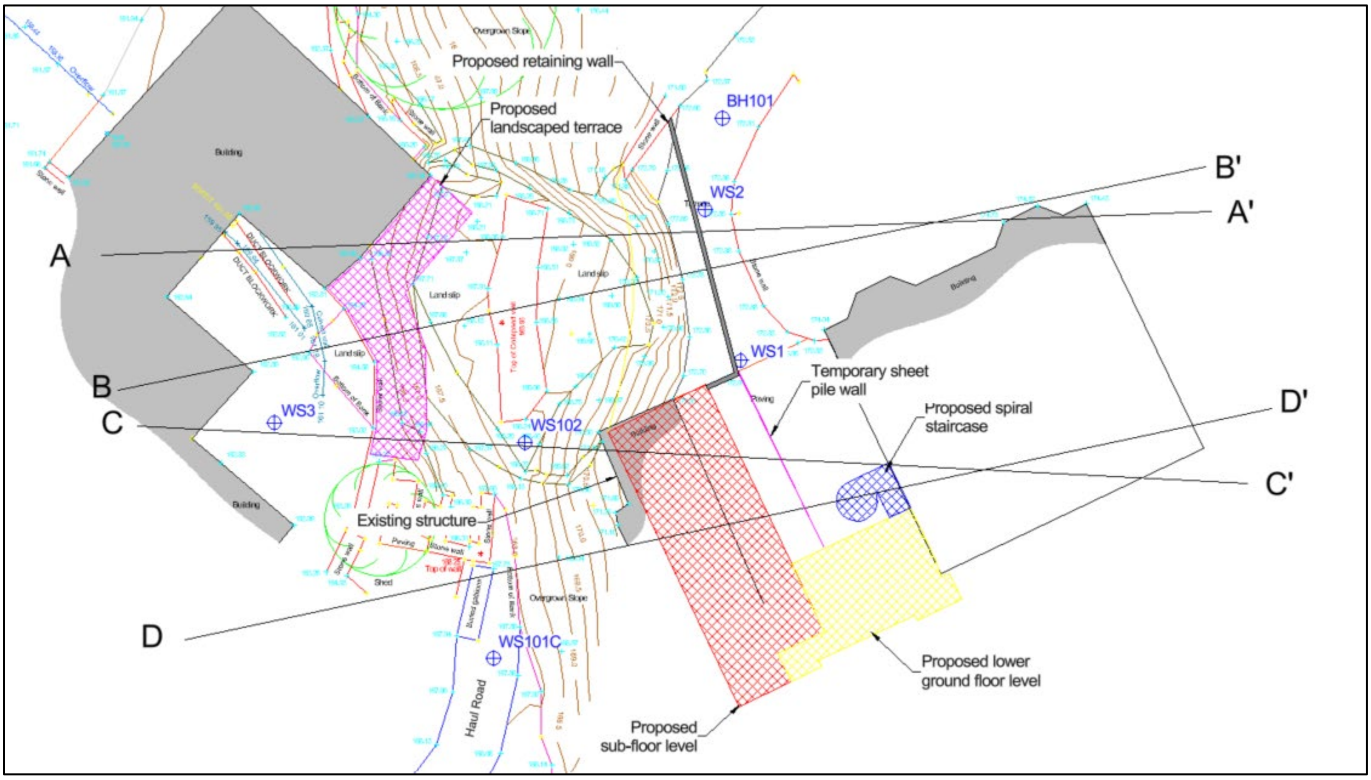


Figure 1. Slope stability section lines

The rationale for each slope section is given below in Table 2.

Table 2. Slope analysis section rationale

Section	Rationale
A-A’	Assess stability of landslip remedial works with attention paid to main structure of downslope neighbour.
B-B’	Assess stability of landslip remedial works with attention paid to largest retained height of downslope stacked-stone retaining wall.
C-C’	Assess stability of proposed new sub-floor construction temporary works with attention paid to steepest slope section and downslope stacked-stone retaining wall.
D-D’	Assess stability of proposed new sub-floor construction temporary works with attention paid to buried gabion wall.

The slope sections have been analysed in their existing case as well as with slope stability measures included on Sections A-A’ and B-B’ and temporary works included in Sections C-C’ and D-D’ (the temporary case being the most onerous, due to construction plant loading and presence of excavations). The slope stability calculation outputs are included in Appendix A.

Table 3. FoS summary

Section	Minimum Factor of Safety	
	Existing	Proposed
A-A’	0.90	1.20
B-B’	0.84	1.20
C-C’	0.65	1.10*
D-D’	0.79	1.20

**This does not reach the target FoS of 1.2 (see below) – however the model includes building loads applied at surface, which although conservative is unrealistic. The arrangement is likely to be satisfactory for temporary works, subject to review of the contractor’s proposed methods).*

Critical slip circles for the existing case range between 0.65 and 0.90, indicating the slope to be unstable in its existing condition. A target minimum long-term factor of safety of 1.2 shall be used for all slope sections.

It can be observed that the calculated FoS is significantly below unity for some sections, whereas in reality this is likely to be only marginally below unity as evidenced by minimal ongoing slope movement in recent years. This is a conservative assessment that does not account for the suction in partially saturated soils which is considered appropriate for long-term assessments where soil suction cannot be relied upon.

Soil nail have been applied at 1m out of plane spacing (except for below the pool house, where a 1.5m spacing has been adopted, subject to review of potential clashes with pile positions) and with lengths determined based on requirements to stabilise the existing and proposed retaining walls, as well as to provide a global stability to the slope. Nail bond stress has been set at 7.5kN/m and therefore require a length of 9m, adopting a 75mm diameter bore. It should be noted that where the nails encounter relatively shallow rock, a rock socket of 1m will be sufficient to take the anticipated design loads, and therefore the lengths of nails shall be 9m or 1m into competent rock, whichever is the shortest length. However, it may be necessary to over-drill the socket to provide sufficient confidence that rock has actually been encountered, depending on the drilling conditions experienced.

The tendon tensile capacity has been taken as 139kN, conservatively assuming 120 years sacrificial corrosion. The actual nail capacity will be the lesser of the pull out resistance, plate capacity, and tendon strength. The soil nail layout and typical sections are provided in drawing 3324_GDR_DWG_001. The required total number of nails is 35.

3.3 Soil Nail Design

The soil nail maximum anticipated load has been taken from the slope model, which assumes the force applied to a soil nail is that required to achieve moment equilibrium on a given slip plane. The additional capacity available from the nail shaft acting in shear has been conservatively discounted. This maximum anticipated soil nail load has been determined as 41kN which is the load required to balance the moment equilibrium of anticipated potential slip surfaces and achieve the required factor of safety of 1.2.

The maximum possible forces in the tendon shall be compared to available resistance, assuming corrosion of the tendon. From BS EN ISO 14713-1 Table 1, the corrosion category for the atmospheric environment is classified as C3 (medium). As the anchor heads and plates will be exposed to air and variable moisture conditions, galvanised components shall be adopted to increase their corrosion resistance. The first 1m length of the anchor tendon itself should also be galvanised, as grout may not fully reach the surface, and the end of the bar will be exposed where it passes through the plate.

From BS EN ISO 14713-1, the galvanising should be a minimum of 85µm thick. BS EN ISO 14713-1 gives a corrosion rate for zinc coatings of 0.7-2.0µm per year for class C3.

The galvanising will therefore provide protection for:

$$\frac{85\mu m}{0.7\mu m/yr} = 121.4\ years$$

Therefore, the required design life will be achieved for components exposed to air.

Conservatively assuming a high corrosion environment, the ultimate strength of a R32-280 tendon is 139kN. This may be compared to the maximum resistance for a 9m long nail indicating that the nail resistance is not tendon strength limited.

The factors on soil bond strength are summarised below along with the calculated utilisation of soil grout interface resistance.

Table 4. EC7 partial factors for soil nails

Factor	DA1-C1	DA1-C2
Bond stress, γ_{tb}	1.1	1.5
Tendon strength, γ_k	1.0	1.15

Self weight of soil, γ_G	1.35	1.0
Model Factor, γ_{Sd}	1.0	1.0

Table 5. EC7 factored forces/resistances

Force/resistance	DA1-C1	DA1-C2
Factored force acting on soil nail	55	41
Factored resistance	61	45
Utilisation on soil bond strength	0.90	0.91

3.4 Upper Retaining Wall Design

It is proposed to construct a 1.5m high retaining wall at the top where the existing landslide scarp is to allow the ground level towards the top of the slope to be lowered by 1.5m thereby reducing the overall slope angle, whilst still maintaining pedestrian access in this area of the site. The wall will be constructed using gabion baskets, with a minimum embedment below finished ground level of 0.5m. Anchors are required for the global slope stability, and these can also be used to provide additional restraint against sliding to the gabions.

The anchor shall be installed at half the height of the wall i.e. 0.75m from the top of the wall. The gabion baskets will not require a structural foundation to resist overturning however a lean mix concrete blinding will be required to provide a stable construction surface and to provide sufficient friction to resist sliding in the temporary works.

As the wall will require at least 2 gabion baskets, a detailed gabion design check shall be carried out prior to construction, to ensure that as well as remaining globally stable, the exact arrangement of basket sizes provides suitable internal stability.

Fill behind the gabions shall comprise good quality Type 1 MOT / Class 6N that achieves a minimum friction angle of 35°.

All gabion stone should be Class 6G, or similar approved, to achieve a minimum bulk unit weight in the baskets of 16kN/m^3.

A typical section through the retaining wall is shown in GSL3324_GDR_DWG001.

3.5 Earthworks

It has been noted that the lower neighbour requires a useable area to the rear of their property which has been sketched out indicatively as 2.5m width. This area has been included in slope stability modelling and is shown in GSL3324_GDR_DWG001 and can be achieved through the incorporation of a single row of gabions. Additionally, it has been requested that additional intermediate terraces be constructed within the slope between the site and the neighbours property below. A proposed layout is presented on the enclosed drawings, GSL3324_GDR_DWG001 and GSL3324_GDR_DWG002, with two lines of gabions forming a mid-level terrace at around 169mOD.

Whilst a single design is presented here, it is likely that additional terraces could be possible provided that overall slope gradients remain unchanged. Retained heights of greater than 1m are not recommended, and additionally, each intermediate terrace must consider changes in loading that may affect the retaining structures above and below, as well as drainage/runoff.

Some reprofiling of the slope will be required to achieve an even surface between retaining structures. The ground conditions are not anticipated to be difficult for standard earth moving plant to cut slopes back to the required gradients. Small areas of filling may be required to achieve the required gradients, which should use suitable site won fill or imported well graded granular fill such as 6N/6F2, or MOT Type 1.

Compaction of fill to the upper retaining wall may be achieved with lightweight compaction plant in accordance with Manual Contract for Highways Works Series 600. Fill placed on the slope may also be compacted with compaction plant where small benches can be cut into the slope face. Where this is not achievable due to slope gradients, any placed fill should be tamped down with an excavator bucket in 100mm thick layers.

The proposed slope gradients for the completed works are as follows:

- Main slope between upper retaining wall and lower retaining wall: typically 1V in 2.8H or 19.5°.
- Slope below pool house: 1V in 2.5H or 21.5°.

3.6 Temporary Batter for Pool House Slab Construction

A simple earth batter is now proposed to allow excavation for the slab construction. The exact form of the batter will depend on the contractor's access requirements, proposed method of working, and any constraints due to underground services that are not being protected and/or diverted.

Initial calculations indicate that a batter of around 24° is achievable and appropriate. However the contractor may wish to adopt other forms, trench sheets, localised steepenings, etc – which should be confirmed prior to adoption.

3.7 Pool House Path

In order to provide an access path around the pool house for maintenance purposes, a 2.1m wide path is proposed. This can be accommodated by construction of a 1.0-1.5m gabion wall, anchored in place with a single soil nail (similar to the Upper Retaining Wall Design, see Section 3.4). The exact ground profile in this area needs to be determined to enable a full design check to be carried out.

Based on the current ground profile, the anchor spacing can be widened to 1.5m, however it will be necessary to adjust the positions to ensure that there are no clashes with the proposed pile positions.

3.8 Pool House Foundations

It is recommended that the pool house be constructed on pile/micropile foundations with suspended slabs in order to transfer the structural loads below the landslide deposits and into competent bedrock strata.

At the time of reporting structural design loads have not been provided and so pile lengths cannot be determined. It is anticipated that the 1m rock sockets may be required and therefore pile lengths of the order of 12m may be required. Geotechnical design of piles should be undertaken following receipt of structural loadings.

4.0 DESIGN SUMMARY

A summary of the geotechnical design is provided below:

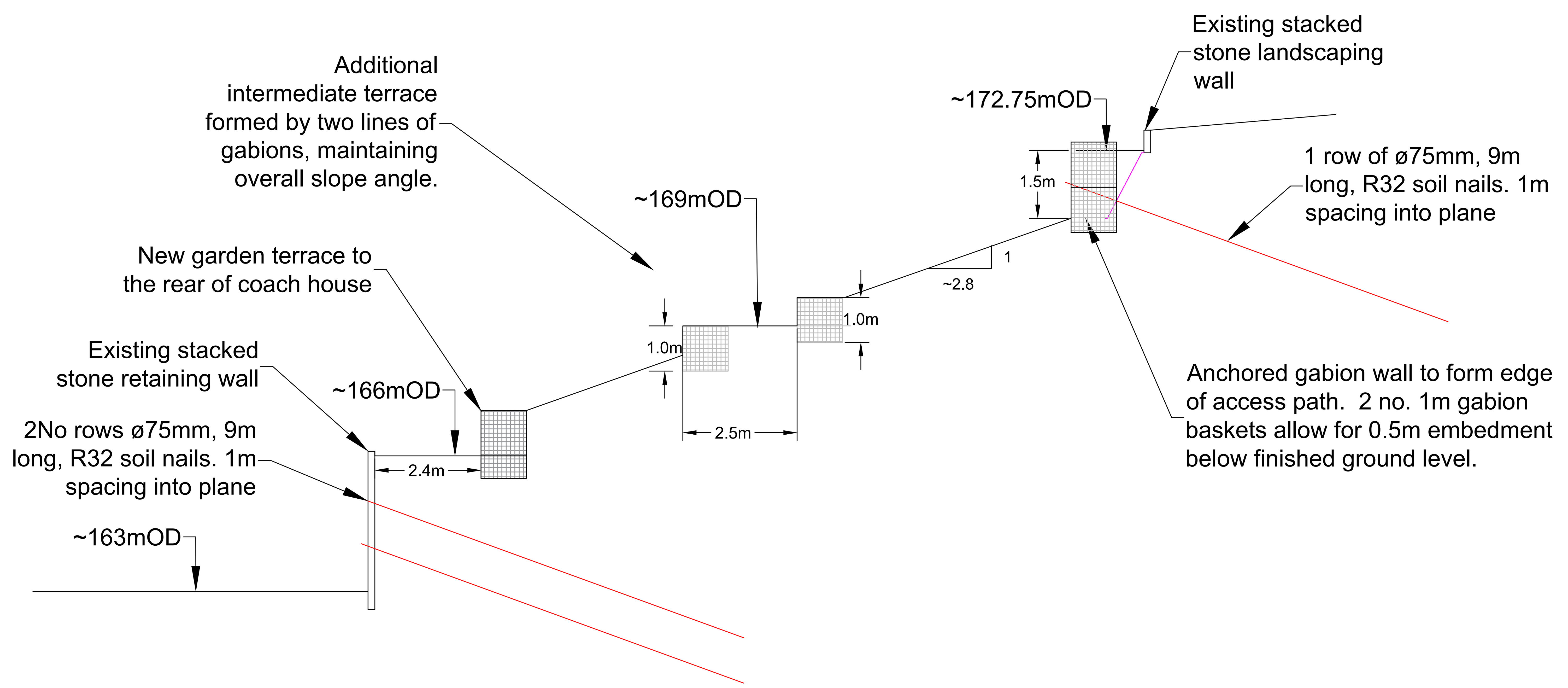
- Soil nails:
  - 35 No. Dywidag R32-280 / Minova R32L tendon or similar approved (16 nails on the existing lower retaining wall, 11 nails on the new upper retaining wall, 8 on the pool house path wall), drilled using a 75mm diameter drill bit.
  - Soil nail embedment of 9m, or 1m (min) into competent rock, whichever is the shortest length, subject to engineer approval.
  - 200mm square headplate. Headplate to be domed/slotted/or angled washers provided to accommodate articulation.
  - Upper 1m of tendon and all headplate and nut assembly to be galvanised.
  - Cement grout to achieve minimum 40N/mm^2 28 day strength.
  - Soil nail spacing of 1m horizontally (upper and lower retaining walls) and 1m vertically (lower retaining wall only). May be increased to 1.5m horizontally for the pool house wall.
  - Testing of a minimum of three soil nails to a design test load (DTL) of 61.5kN.
- Gabion Baskets:
  - 4mm galvanised welded mesh baskets.
  - Anchored using slope soil nails where required (see above).
  - Wall lengths will vary depending on exact start points, walls to be graded into existing levels or to include a short return if this is not feasible.
  - Gabion fill to be Class 6G or similar approved, to achieve minimum bulk density once filled of 16kN/m^3
  - Suitable geotextile separation membrane to be laid behind baskets (non-woven type).
- Earthworks:
  - Remediation of the main landslide is anticipated to require excavation and removal of approximately 100m^3 to 150m^3 (non-bulked) to achieve a typical slope gradient of 1V in 2.8H.
  - Fill to the rear of the upper retaining wall may comprise approximately 20m^3 to 25m^3 of imported granular fill.
  - Excavation to the pool house subfloor slab foundation level is anticipated to generate approximately 250m^3 to 300m^3 (un-bulked)of soils for off-site disposal to achieve a dig level of approximately 170.5mOD and a slope below that level of typically 1V in 2.5H.

- All the earthworks volumes provided have not had any bulking factors applied. The final volumes may vary significantly, particularly in the area of landslide remediation, as additional excavation may be required if soft spots are identified in during site clearance. Additionally the volumes do not account for the removal of vegetation and trees.

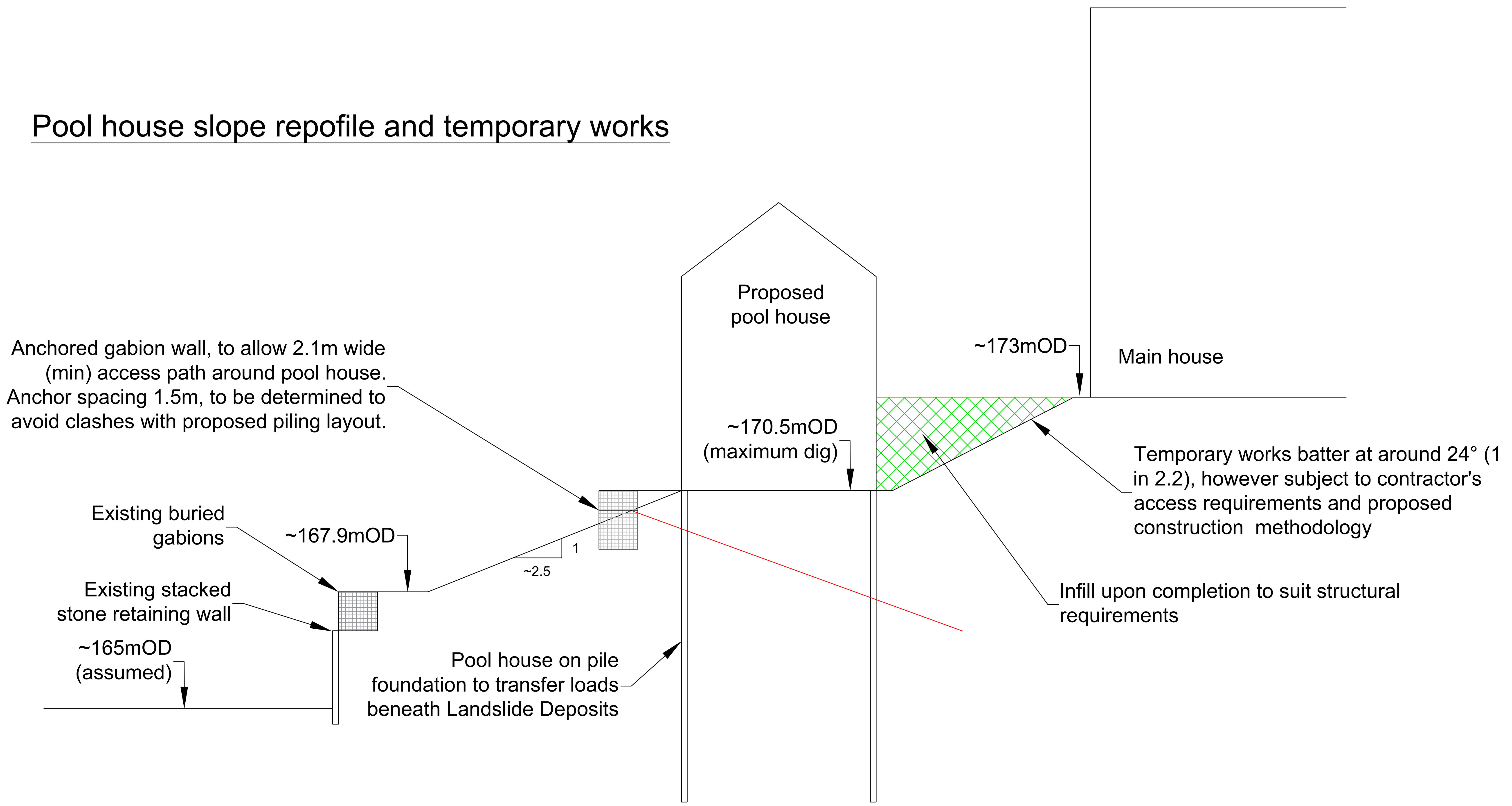
DRAWINGS

A1

Main landslide remedial works



Pool house slope repofile and temporary works



Revision	Description	Date
A	Original for planning purposes	05/03/2026

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Unit 1, 85 Station Road
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Tel: 01244 592295

Job Title: Cellar's Clough, Marsden

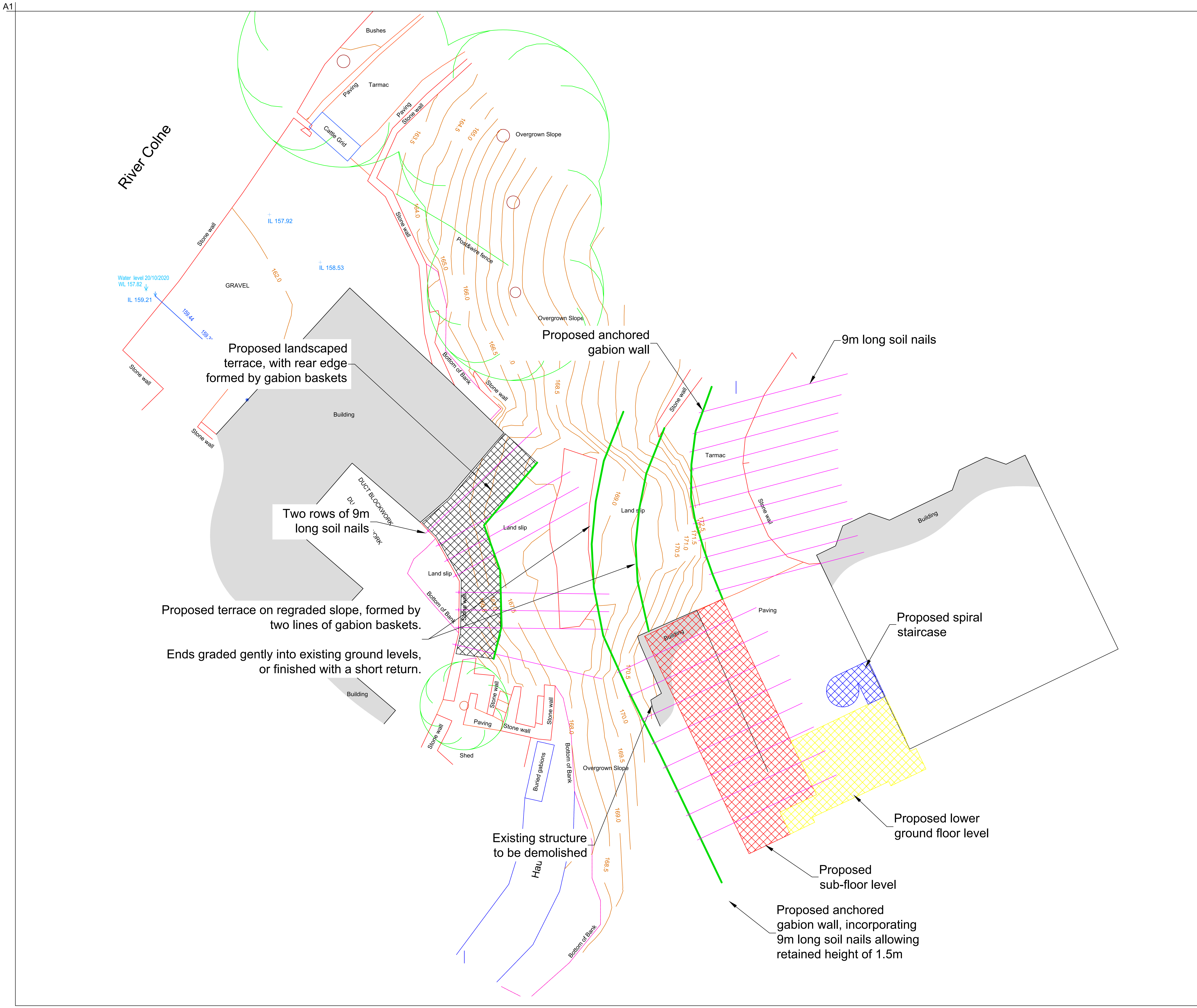
Drawing Title: Typical slope sections

Drawing Scale	Drawn By	Approved By
NTS @ A1	OJR	SDI

Drawing Status	Date of Issue
PLANNING	05/03/2026

Drawing No	Revision
GSL3324_GDR_DWG001	A

A1



A	Original for planning purposes	05/03/2026
Revision	Description	Date

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Job Title
Cellar's Clough, Marsden

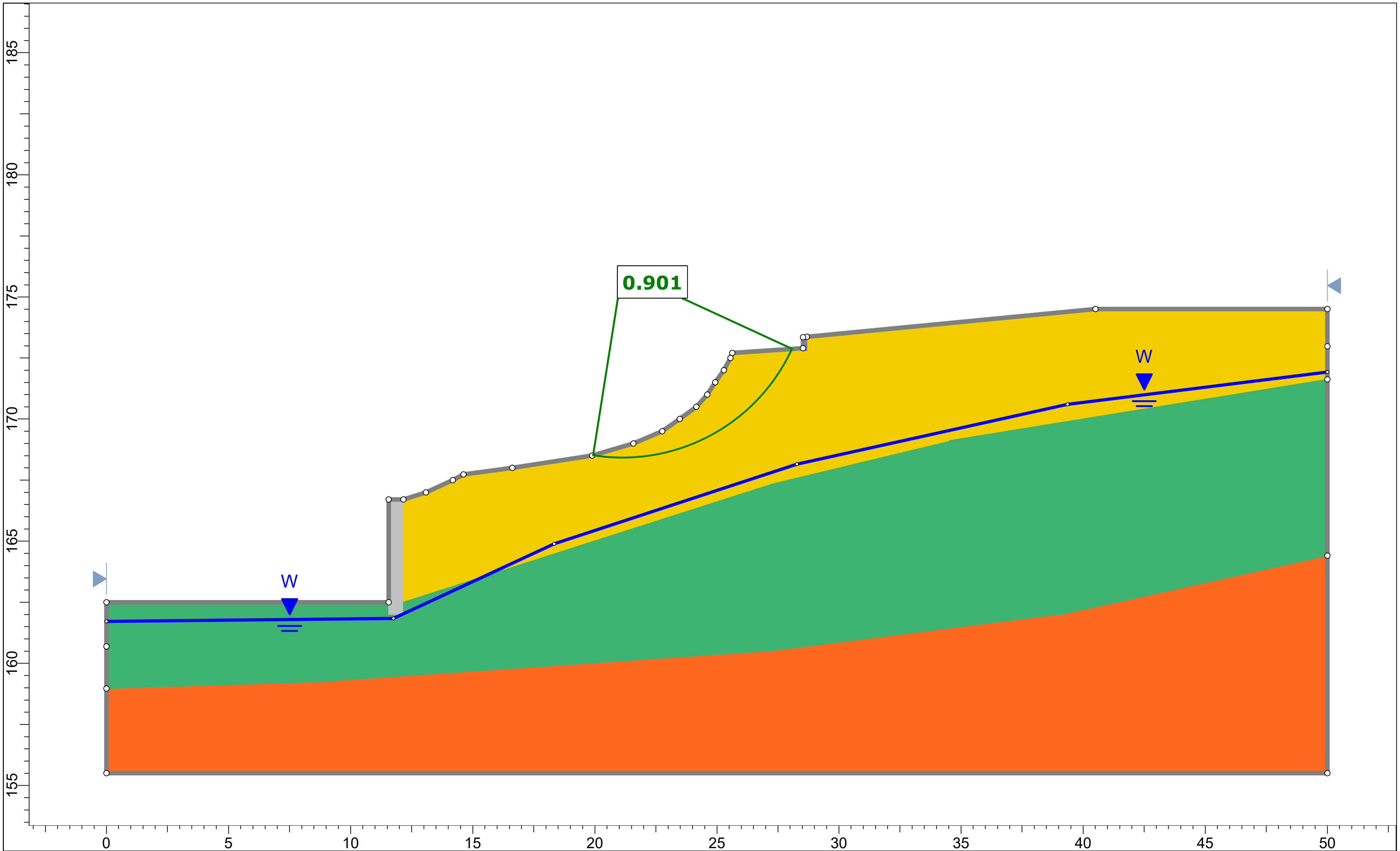
Drawing Title
Plan of Proposed Works

Drawing Scale	Drawn By	Approved By
1:100 @ A1	SDI	SDI

Drawing Status	Date of Issue
PLANNING	25/01/2026

Drawing No	Revision
GSL3324_GDR_DWG002	A

APPENDIX A – SLOPE STABILITY CALCULATION OUTPUTS



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SLIDEINTERPRET 9.038

Project	GSL3324 - Cellar's Clough		
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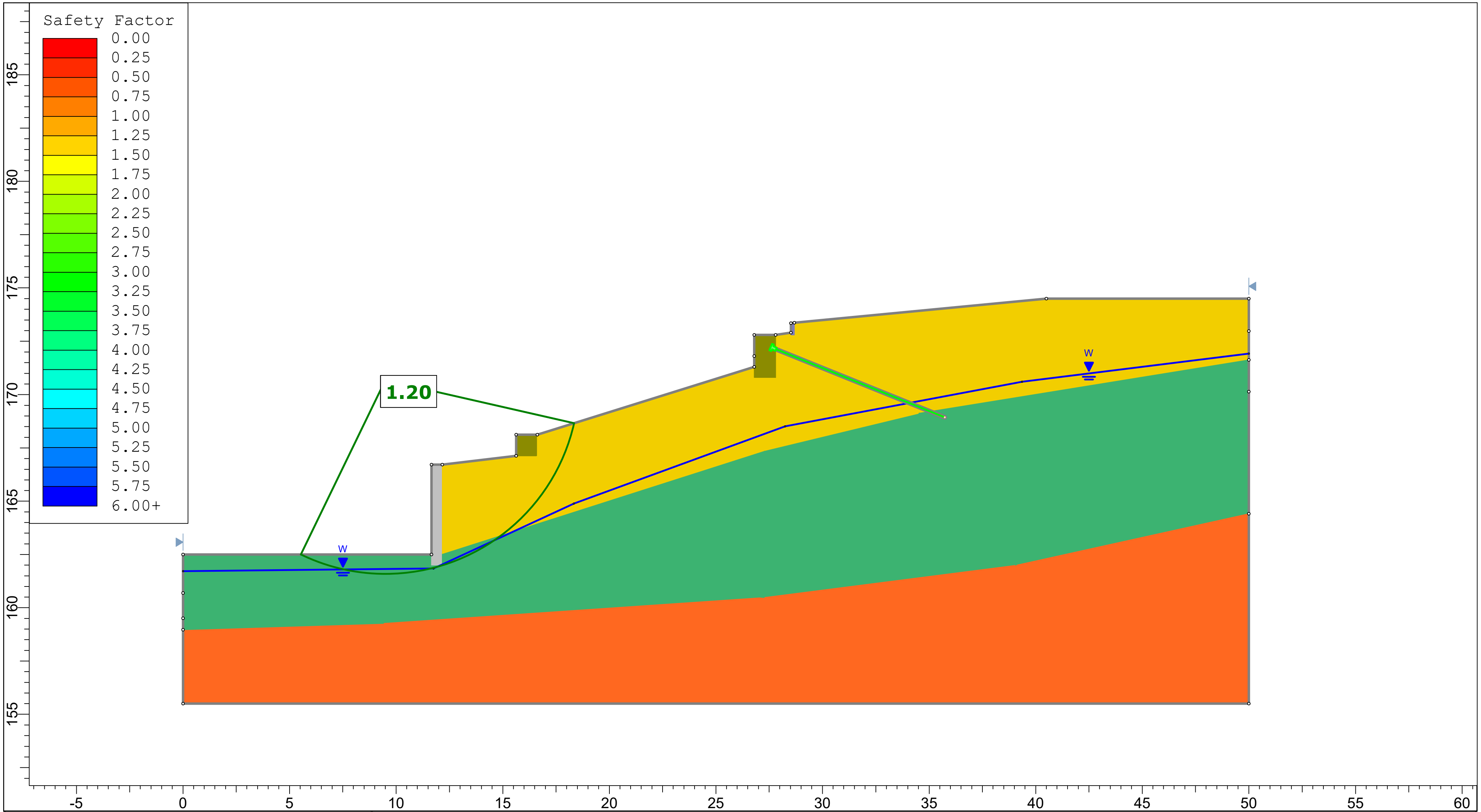
Date		*File Name*	Slope sections_final.slmd



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SLIDEINTERPRET 9.040

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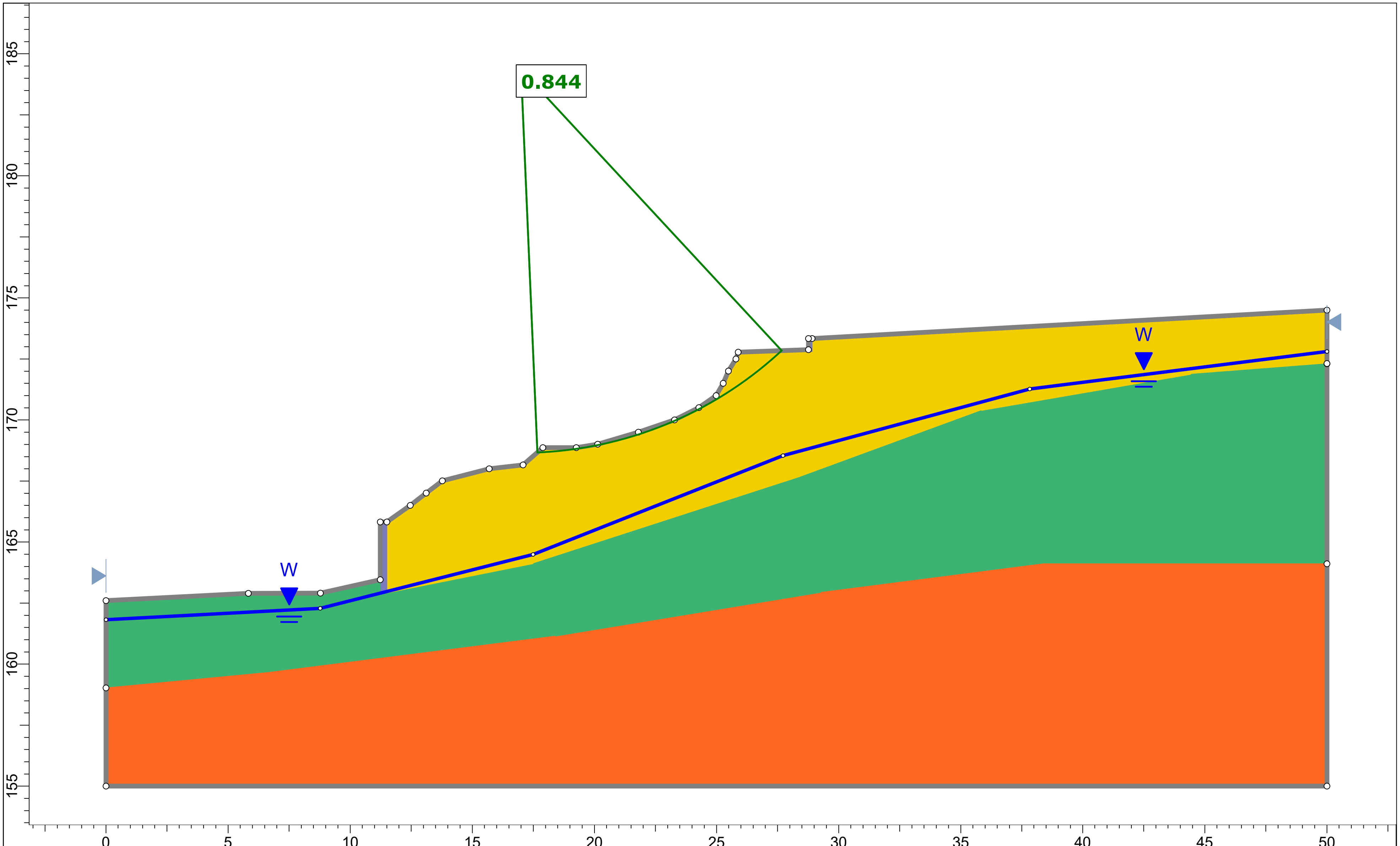

GroundSolve Ltd Consulting Geotechnical Engineers	Project	GSL3324 - Cellar's Clough	
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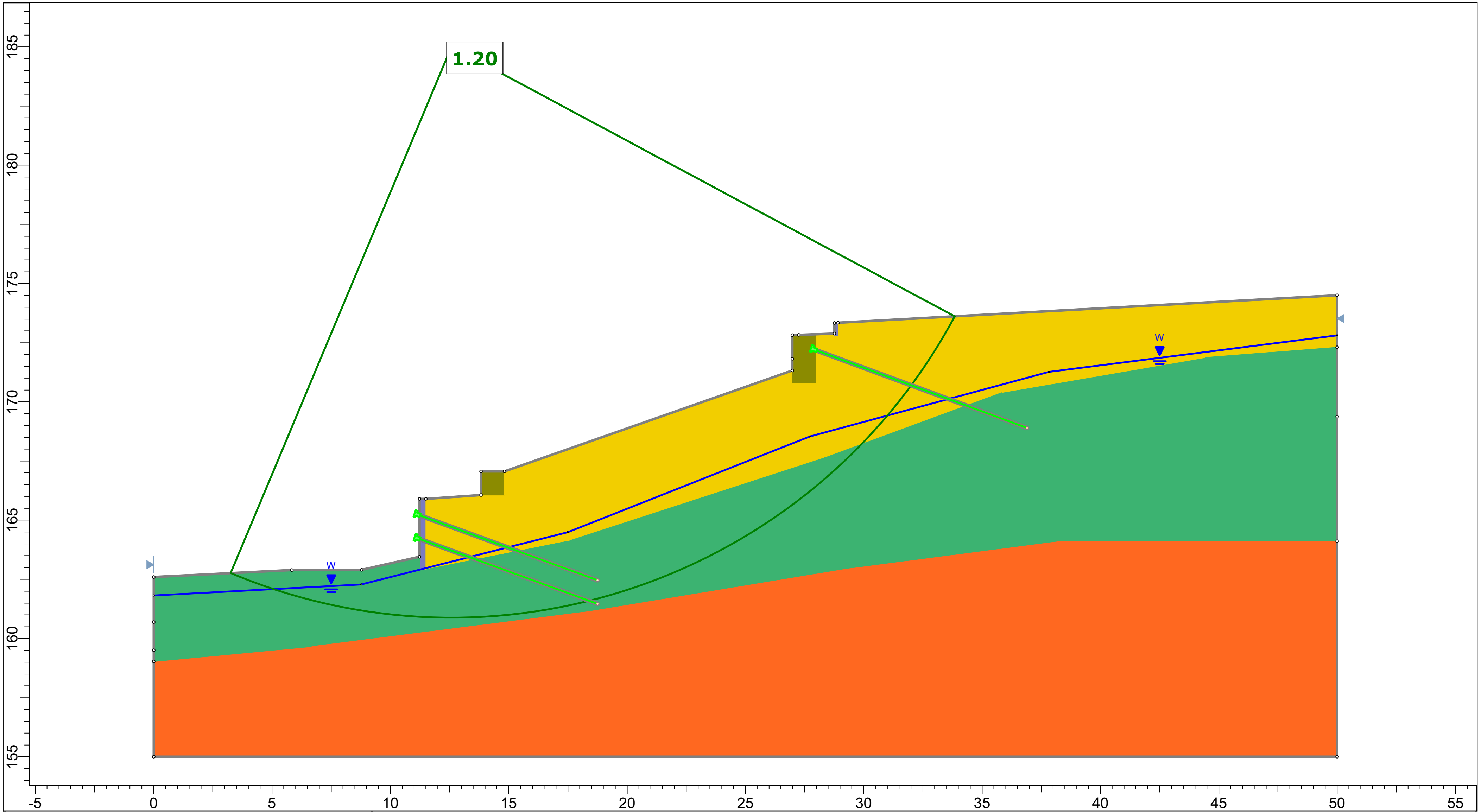

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Consulting Geotechnical Engineers

SLIDEINTERPRET 9.040

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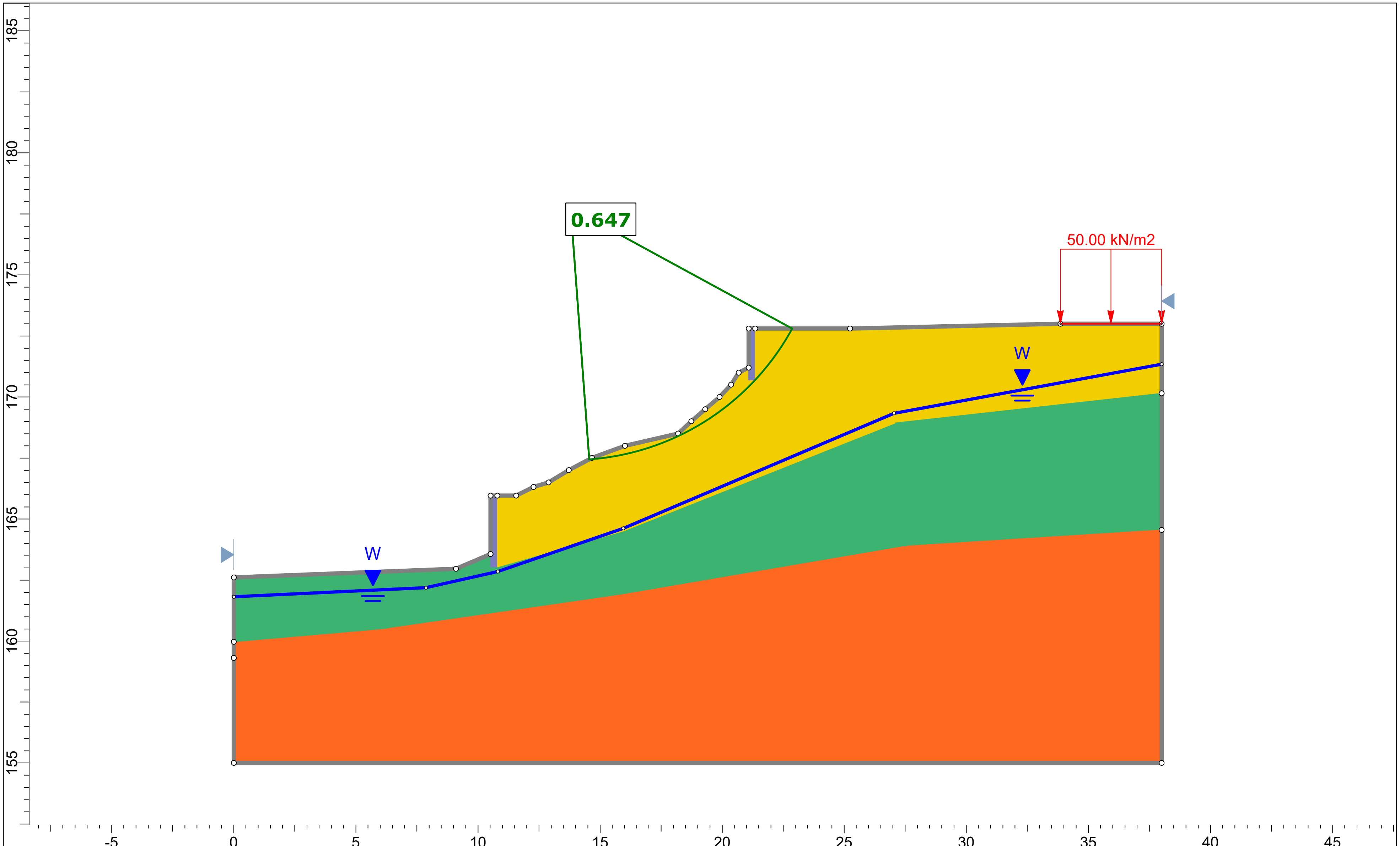

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Group	C-C' existing	Scenario	Master Scenario
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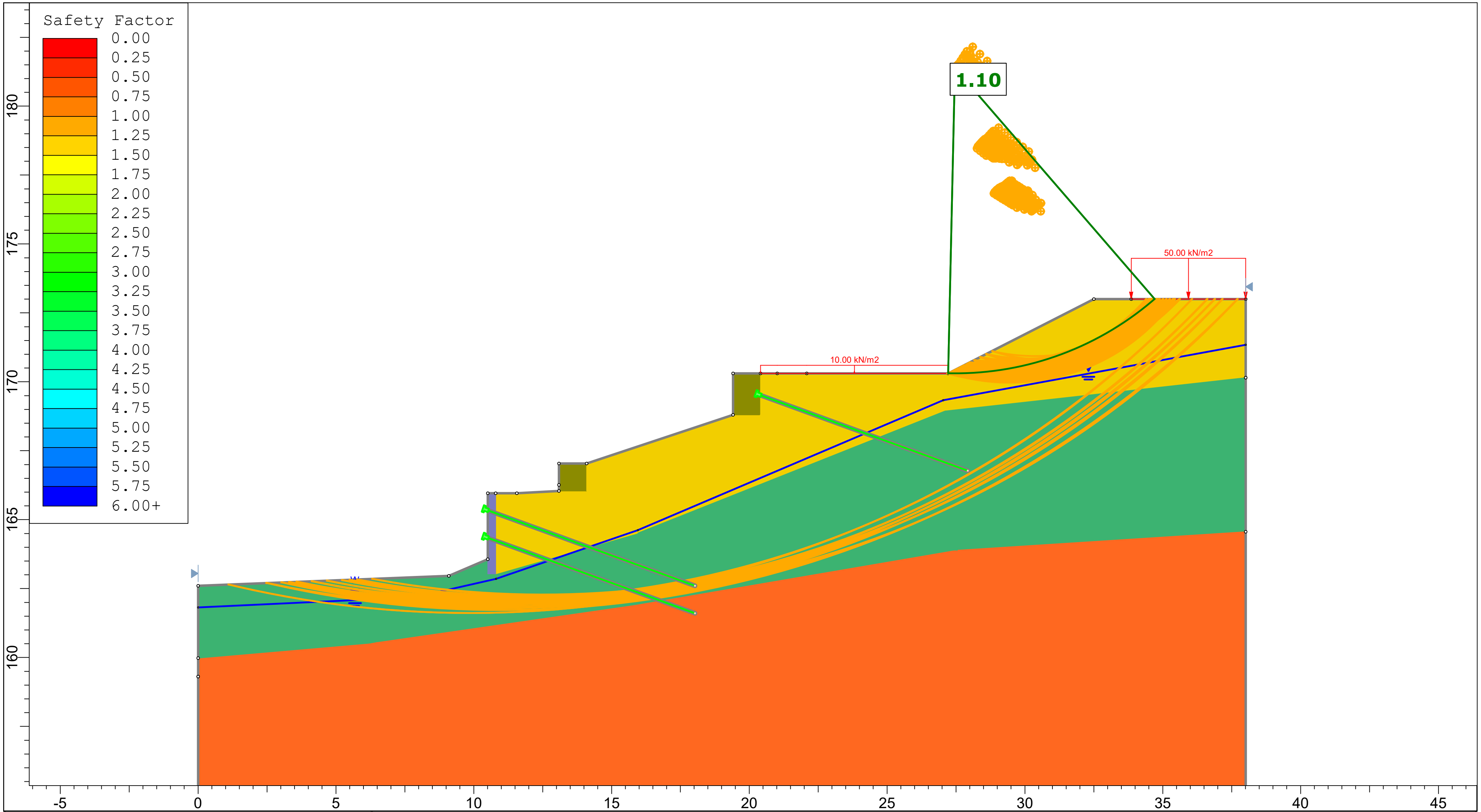
SLIDEINTERPRET 9.038



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SLIDEINTERPRET 9.040

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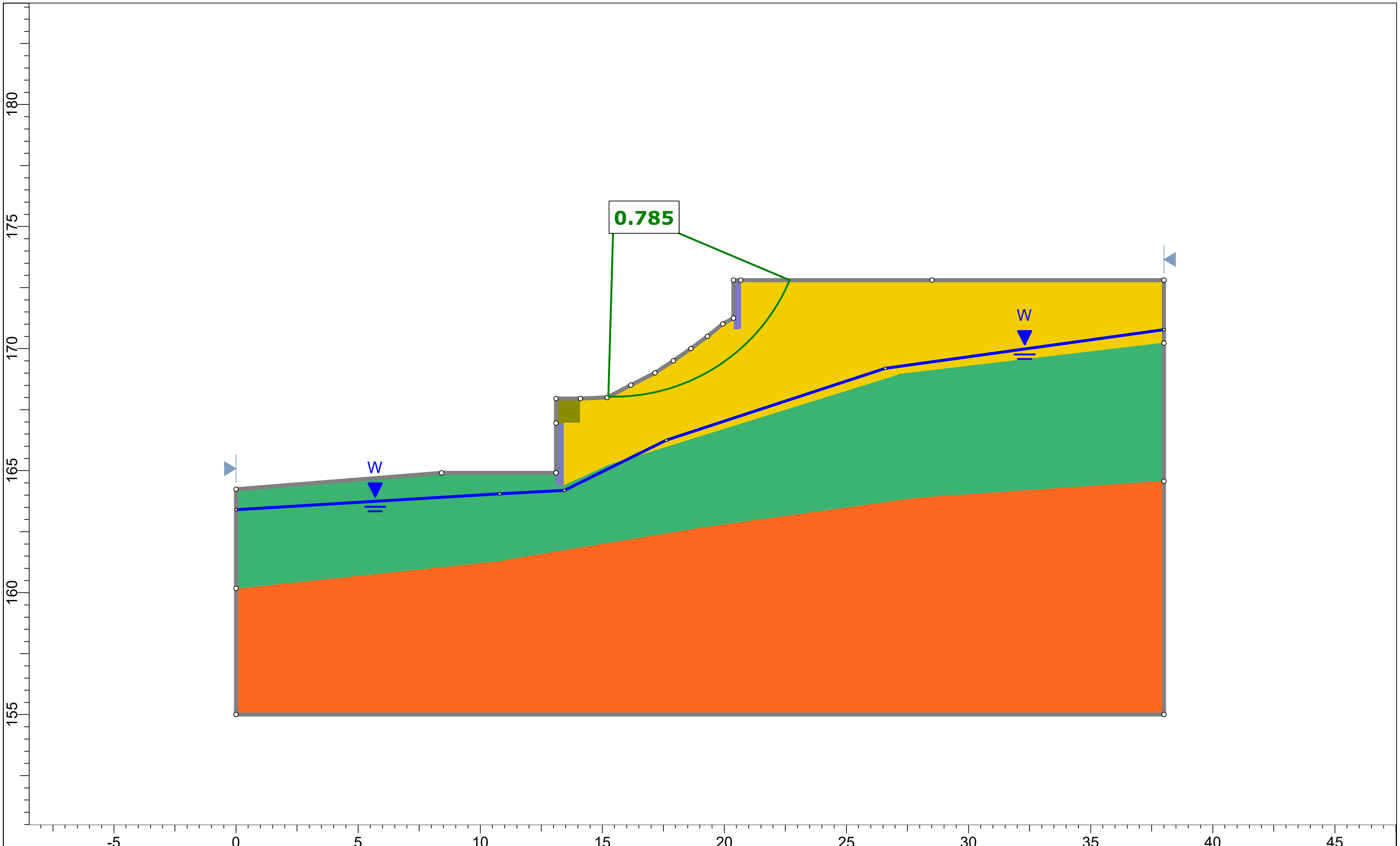

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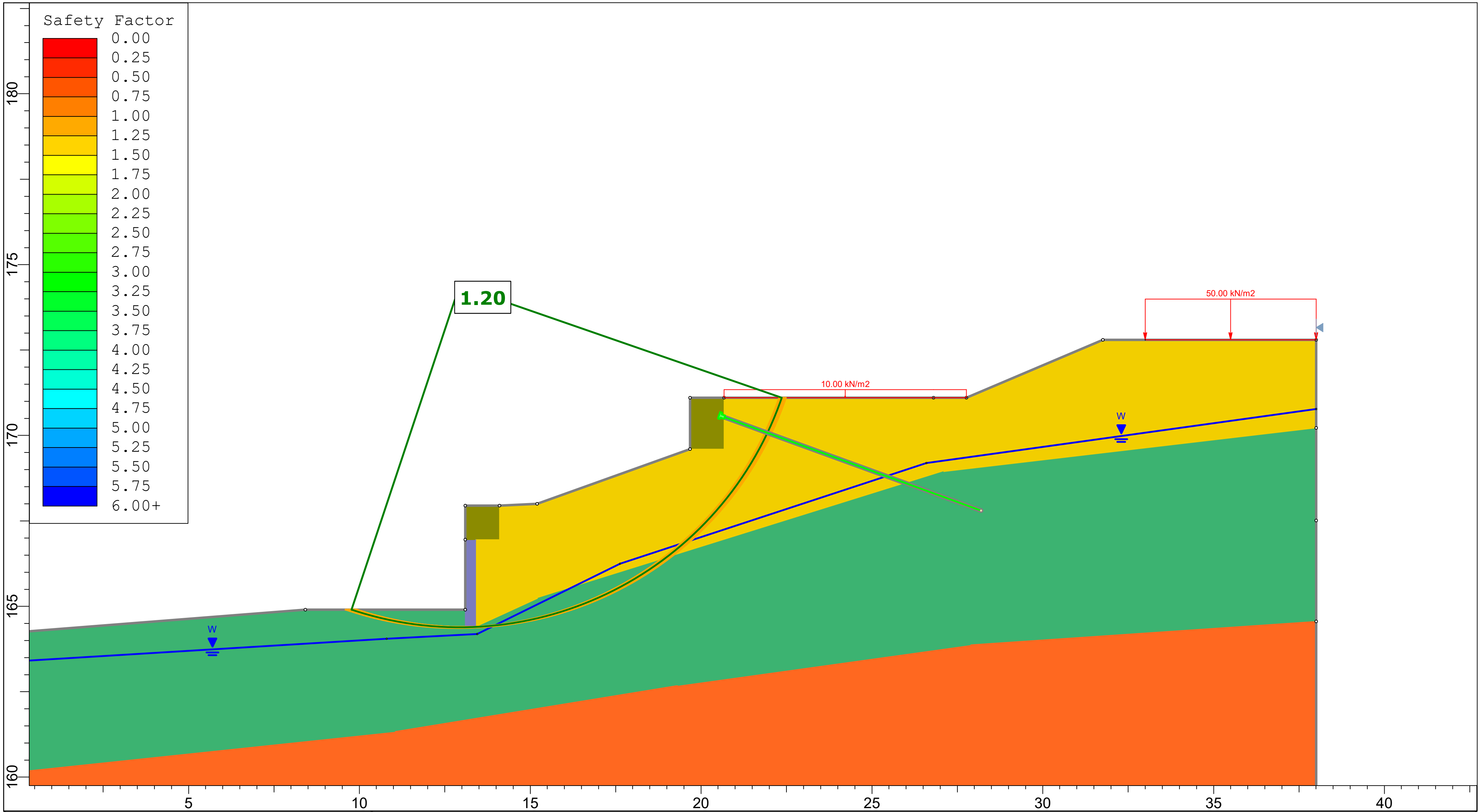

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SLIDEINTERPRET 9.040

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Date	
Scenario	D-D' temp works - Master Scenario