# MEMORANDUM

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| **To:** | Ross Gooley |
| **Company:** | Sojitz Green Pty Ltd |
| **From:** | Walter Keilich |
| **Copy:** | Peter O'Donnell |
| **Date:** | 07/02/2022 |
| **Project:** | PRJ016_Sojitz_Minerva |
| **Subject:** | Minerva Final Void Stability Assessment |

## 1 Executive Summary

WK Geotechnical (WKG) was requested to undertake a final void highwall stability assessment (limit equilibrium) for the Minerva Mine. Section geometry, Q1000 location, a ground water inflow study and design reports were supplied to WKG, which were reviewed for this assessment. An assessment of kinematically admissible failures has not been undertaken.

Given the modelling assumptions and qualifications, the slope stability assessment has found that the FoS = 1.50 critical slip surface does not impact the Q1000 location in all sections analysed. No re-shaping or remedial changes are recommended.

## 2 Introduction

WK Geotechnical (WKG) was requested to undertake a final void highwall stability assessment by Sojitz Green Pty Ltd (Sojitz) for the Minerva Mine (Minerva).

This memorandum contains a description of relevant supplied data and the results of the stability assessment and associated recommendations.

## 3 Supplied Data and Comments

Table 1 summarises the data supplied to WKG.

**Table 1: Supplied data**

| Item | Description & Key Points |
|---|---|
| G1753D_Minerva_final_void_GW_inflow_V04.01.pdf | A memorandum dated 21/07/2021 containing groundwater inflow calculations (and other related items) for the Minerva final voids.<br>• Western residual void water level average 195 mRL (max 210 m AHD, min 185 m AHD). Predicted to be below the base of the basalt exposed in the highwall of the western void. The max void water equilibrium level is predicted to remain about 60 m below the elevation of the regional groundwater table (270 m AHD), therefore a hydraulic gradient is expected to be maintained in perpetuity towards the western void.<br>• Southern residual void water level averages 175 mRL (max 200 m AHD, min 150 m AHD). Predicted to be at least 70 m below the elevation of the regional groundwater table (270 m AHD), therefore a hydraulic gradient is expected to be maintained in perpetuity towards the southern residual void.<br>• Also, a hydraulic gradient is expected to form towards the southern void from the western void. |
| Minerva – MJV Design V2 Total Plus Ramp – 1m Contour Plan with Q1000.pdf | A plan showing the pit voids and Q1000 location. |
| Q1000_Strings_AGD84.dxf | Design strings containing Q1000 location. |
| LIDAR21t_Topo.dxf | Topographical contours, subsequently triangulated for this memorandum. |
| MJV FINAL VOID SECTIONS.pdf | A plan with section locations, and geological arrangement of each section. |
| PSM2432-010L.pdf | A memorandum dated 11/10/2016 containing updated design parameters for final walls.<br>• South wall:<br>– Faulting sub-parallel to the highwall<br>– Potential risk with steepening the south wall as structure could not be mapped.<br>• West wall:<br>– Absence of major structures |

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| | – Up to 20 m of Tertiary Clay based on borehole data, however only approx. 3 m thick in exposures. Exposures indicate that weathered Permian erroneously logged as clays and low strength materials<br>– Seepage from base of Tertiary.<br>• Weathered Permian highly structured.<br>• Geology model noted not to capture base of Tertiary Clay, assumed to be 4 m below the base of Basalt based on exposure observations. |
| PSM2432-014L.pdf | A memorandum dated 17/05/2017 containing an assessment of optimised highwall offset from the South Pit creek diversion.<br>• Material shear strengths provided.<br>• On western wall of south pit:<br>– Little to no Basalt expected<br>– Clay logged in one borehole to a depth of 5 m<br>– Depth of weathering extends to between 15 m and 25 m below surface.<br>• On southern wall of south pit:<br>– Approx. 20 m thick basalt logged in one borehole<br>– Extremely weathered clay horizon logged in one borehole, from 25 – 35 m depth. Likely to be the Tertiary Clay and/or Tertiary Tuff units.<br>• On eastern wall of south pit:<br>– Dolerite intrusion present. Typically known to undergo intense weathering and strength degradation after exposure and will be a final void stability risk.<br>• Groundwater assumptions result in a pressurised highwall face.<br>• Observations on main pit performance:<br>– Weathering within Tertiary Clays can undercut the basalt<br>– Fresh Basalt can be cut near vertical, weathered Basalt requires shallower batter angles<br>– Circular failures commonly observed within the Tertiary Clay units |

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|---|---|
| | – Tension cracking in columnar weathered basalt common when clay beneath fails. Slabbing common along sub vertical joints<br>– Dolerite intrusions expected to become problematic over time due to degradation upon exposure. |
| PSM2432-122L.pdf | A memorandum dated 27/07/2021 containing findings/observations from a site visit on the 22 July 2021.<br>• Geotechnical inspection of Minerva in its last stages.<br>• Main pit well behaved, and no significant hazards observed.<br>• South pit:<br>– Faulting that contributed to the S11 failure expected to occur in remaining mining area but not expected to cause any geotechnical issues due to limited bench height<br>– Eastern endwall failure bunded. Water recommended to be diverted<br>– Entire surface water catchment above the eastern endwall recommended to be modified. |
| SMGC Geotech Report M0607_190707_v4.pdf | A report dated July 2007 containing an evaluation of geotechnical conditions.<br>• Minerva Seams noted as containing carbonaceous mudstones described as 'slicked', or soft and laminated.<br>• Largely a report focusing on laboratory testing, kinematic assessment, and observation of pit conditions at the time. |

# 4 Slope Stability Assessment

Stability analyses of the supplied cross sections were undertaken with SLIDE2[1] using the limit equilibrium Morgenstern-Price method of slices. All sections were analysed using randomly generated non-circular paths. All non-circular analyses employed automated optimising techniques of paths returning the minimum Factor of Safety (FoS) to check for alternative paths returning a lower FoS.

[1] Rocscience, 2021. SLIDE2 V9. www.rocscience.com

During the operational phase of mining, the Design Acceptance Criteria (DAC) applied to short term mining slopes is generally a minimum FoS of 1.20. The DAC for this assessment has been set at FoS ≥ 1.50. This higher FoS criteria is generally used for final void studies, but it is not a definitive rule. In this context, slip surfaces with a FoS ≥ 1.50 define the location of the closure bund or a 'no crack' zone behind the final pit void crest.

Long-term erosion of the pit wall and effects of significant hydrological events are difficult to quantify, hence it is assumed that a higher DAC provides at least some consideration for this requirement.

If the DAC have not been satisfied, an attempt has been made to provide an alternate profile for Sojitz's consideration.

An assessment of kinematically admissible failures has not been undertaken in this assessment.

Highwalls tend to be formed for the most part in bedded coal measure rocks which are too strong to permit shear failure to occur. Slope failure is invariably a consequence of the presence of adverse discontinuities. The upper part of the highwall, which may be benched, is generally formed in weaker, weathered or unconsolidated material. This material could be subject to slumping or shear failure without affecting the underlying rock mass.

## 4.1 Material Shear Strength

Table 2 summarises the material shear strength[2] used in this assessment.

**Table 2: Material shear strength**

| Geotechnical Domain | Unit Weight ($kN/m^3$) | Cohesion (kPa) | Friction Angle (°) |
|---|---|---|---|
| Basalt | 27 | 100 | 35 |
| Tertiary Clay | 20 | 25 | 2 |
| Weathered Permian | 22 | 80 | 30 |
| Fresh Permian | 22 | 450 | 45 |
| Coal | 15 | 100 | 35 |
| BMA Category 3 Spoil Dry^ | 18 | 30 | 28 |
| BMA Category 3 Spoil Wet^ | 20 | 15 | 23 |

*^ assumed by WKG and taken from Simmons and McManus[3]*

[2] PSM, 2017. Highwall offset from South Pit creek diversion. PSM memorandum to Simon Budden, Minerva Joint Venture, document number PSM2432-014L, dated 17/05/2017.
[3] Simmons, JV and DA McManus 2004. "Shear strength framework for design of dumped spoil slopes for open pit coal mines". Proceedings, Advances in Geotechnical Engineering The Skempton Conference, London, March 2004 RJ Jardine, DM Potts, and KG Higgins eds, Thomas Telford Limited, Volume 2, pp 981 – 991.

### 4.2 Stability Sections

Figure 1 to Figure 6 present the cross section locations and stratigraphic arrangement, as supplied to WKG.

### 4.3 Modelling Assumptions and Qualifications

The following assumptions and qualifications were used in this assessment:

- The geology in the cross sections is representative.
- The material shear strengths are representative.
- The Basalt is underlain by a 4 m thick layer of Tertiary Clay.
- Where Basalt is present, the observed[2] failure mechanism can be replicated by incorporating tension cracks. From previous experience at other Bowen Basin mine sites that contain columnar Basalt, a tension crack depth of approximately 15 m has been modelled.
- No bedding shears within the lithology as advised by Minerva.
- The regional ground water level is located at 270 mRL.
- Where Basalt is present, water draws down to the base of the Basalt. Elsewhere, water draws down to the base of Weathered Permian.
- The stability models were built using the supplied section screenshots. The resolution of the supplied sections is not high, and due to the number of seams, there may be some erroneously allocated coal seams, however this should not significantly affect the stability assessment results.
- A higher DAC provides at least some consideration for the long-term erosion of the pit pall and effects of significant hydrological events.

### 4.4 Modelled Scenarios

For each section, the following scenarios were modelled:

- The current slope 'as is' from the supplied sections.
- A maximum Standing Water Level (SWL) of 210 mRL in the western residual void (Section 1, Section 2 and Section 3).
- A maximum SWL of 200 mRL in the southern void (Section 4 and Section 5).

### 4.5 Stability Assessment Results and Recommendations

Table 3 summarises the stability assessment results. The minimum FoS is reported (often localised to the weaker units), as well as the 'global' FoS for pit wall scale stability.

Table 3: Stability assessment results

| Section | Scenario | Min FoS | Comment |
|---|---|---|---|
| Section 1 | As-is | 0.57 | Critical slip surfaces indicate localised failure in Basalt & Tertiary Clay. Global FoS = 1.94 |
| | 210 mRL SWL | 0.57 | Critical slip surfaces indicate localised failure in Basalt & Tertiary Clay. Global FoS = 2.16 |
| Section 2 | As-is | 1.12 | Critical slip surfaces indicate marginal stability in Basalt, Tertiary Clay & Weathered Permian. Global FoS = 2.07 |
| | 210 mRL SWL | 1.21 | Critical slip surfaces return FoS < 1.50 in Basalt, Tertiary Clay & Weathered Permian. Global FoS = 2.43 |
| Section 3 | As-is | 0.69 | Critical slip surfaces indicate localised failure in Basalt & Tertiary Clay. Global FoS = 1.28 |
| | 210 mRL SWL | 0.67 | Critical slip surfaces indicate localised failure in Basalt & Tertiary Clay. Global FoS = 1.61 |
| Section 4 | As-is | 1.66 | Critical slip surfaces indicate satisfactory FoS |
| | 200 mRL SWL | 1.78 | Critical slip surfaces indicate satisfactory FoS |
| Section 5 | As-is | 1.72 | Critical slip surfaces indicate satisfactory FoS |
| | 200 mRL SWL | N/A | Maximum water level below pit floor |

The stability assessment results are illustrated in Figure 7 to Figure 15.

The results indicate:

- Localised stability ranges from unstable to marginal in the western residual void, regardless of pit water level. This is generally restricted to the weaker units and may be acceptable to Minerva. There are minor discrepancies with the minimum FoS in the Section 3 scenarios however this is a modelling artefact without any implication on final results.
- Global stability in Section 1 and Section 2 is acceptable for both as-is and with maximum pit water level scenarios.
- The Section 2 FoS = 1.50 slip surface does not intersect the creek diversion.
- Section 3 returns an as-is global FoS of 1.28, which does not satisfy the DAC, however this slip surface does not intersect the creek diversion. The FoS = 1.50 slip surface intersects the topography immediately east of the creek diversion (Figure 11). The global FoS increases to 1.61 when the pit water level is at the maximum predicted SWL however this will take many years to be achieved.
- A proposed closure bund location is illustrated in Figure 16. This is based on the 'as-is' stability assessment results. An attempt has been made to locate the bund approximately halfway between the crest and the Q1000 boundary. The exception is Section 3, where the FoS = 1.50 critical slip surface intersects close to the Q1000 and creek diversion. Note there is flexibility in bund placement between the northern and southern residual voids.

- Section 4 and Section 5 in the southern residual void satisfy the DAC.

Both voids satisfy the DAC and no re-shaping changes or remedial actions are recommended.

Global stability is noted to increase with a rising pit water level as expected.

# 5 Disclaimer

This memorandum has been prepared by WKG for Sojitz and may only be used and relied upon by Sojitz for the purpose agreed between WKG and Sojitz as set out in relevant sections of this report. WKG otherwise disclaims responsibility to any person other than Sojitz arising in connection with this memorandum.

It has been assumed that all data supplied by Sojitz is true and accurate and that all available and relevant data has been supplied. WKG has not independently verified or validated the data supplied by Sojitz and does not accept liability in connection with unverified information, including errors and omissions in this memorandum which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations provided in this memorandum are based on conditions encountered and information reviewed at the date of preparation of the memorandum.

If it is known, or subsequently becomes known, that any of the qualifications, assumptions or interpretations made in this memorandum are incorrect, WKG must be notified immediately, and the applicability of the slope stability analysis and any associated recommendations reviewed. WKG will then advise Sojitz, based on the information notified to it, whether this memorandum needs to be updated or varied.

If there are any questions regarding the contents of this memorandum, please contact the undersigned.

Walter Keilich

Director

MAusIMM CP (Geotech) RPEQ 15356

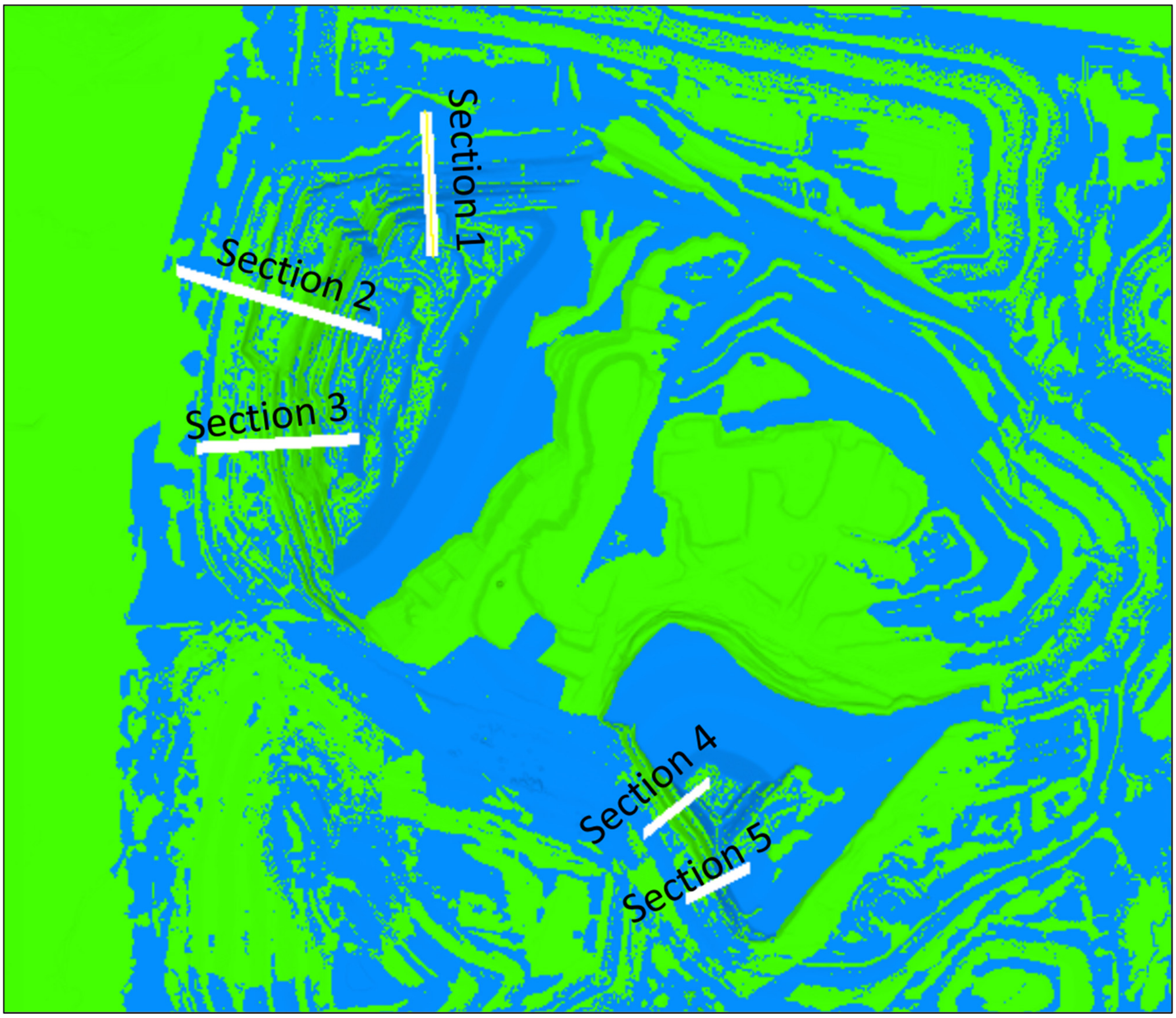



Figure 1: Stability section locations

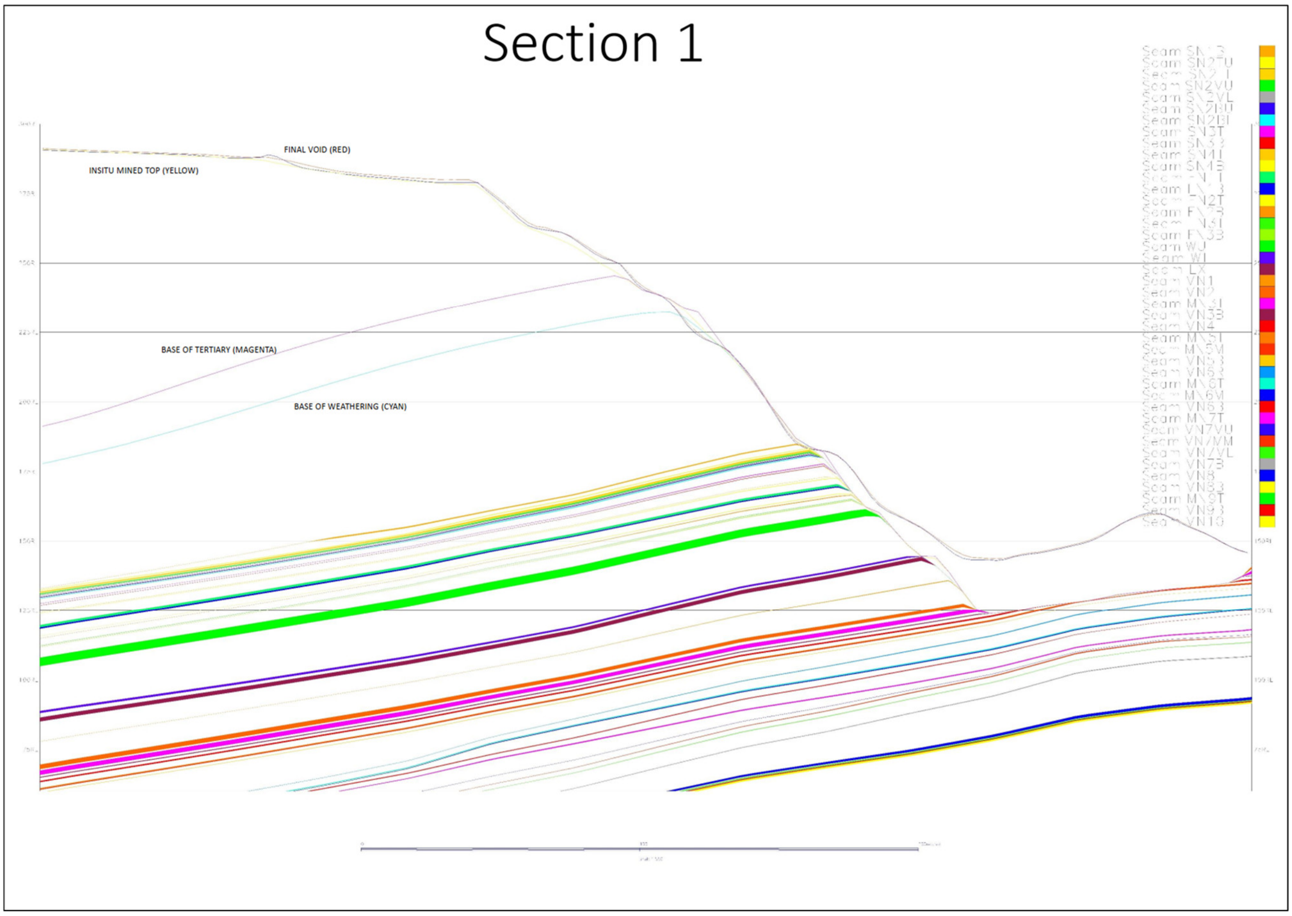



Figure 2: Section 1 geometry and stratigraphic arrangement

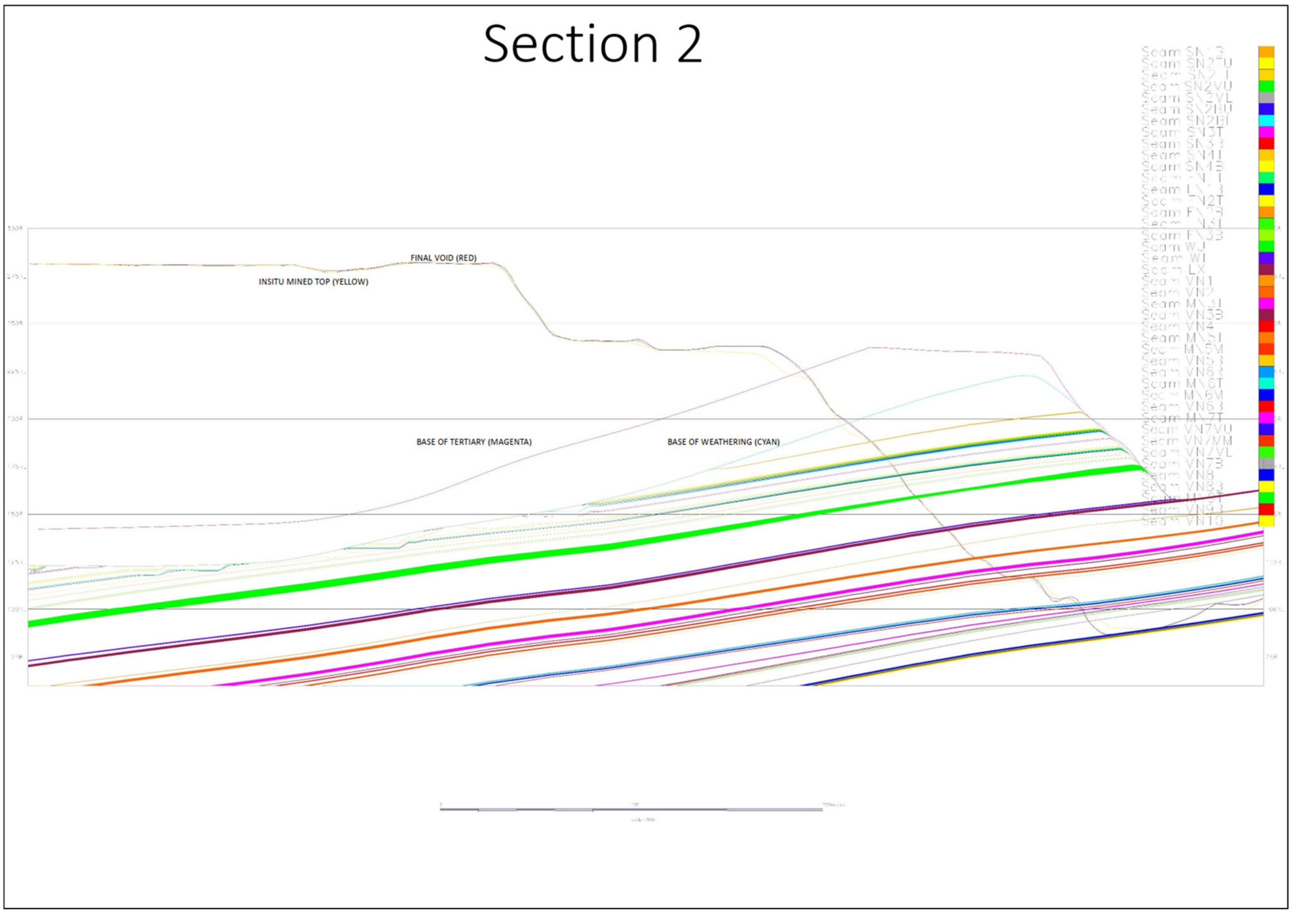



Figure 3: Section 2 geometry and stratigraphic arrangement

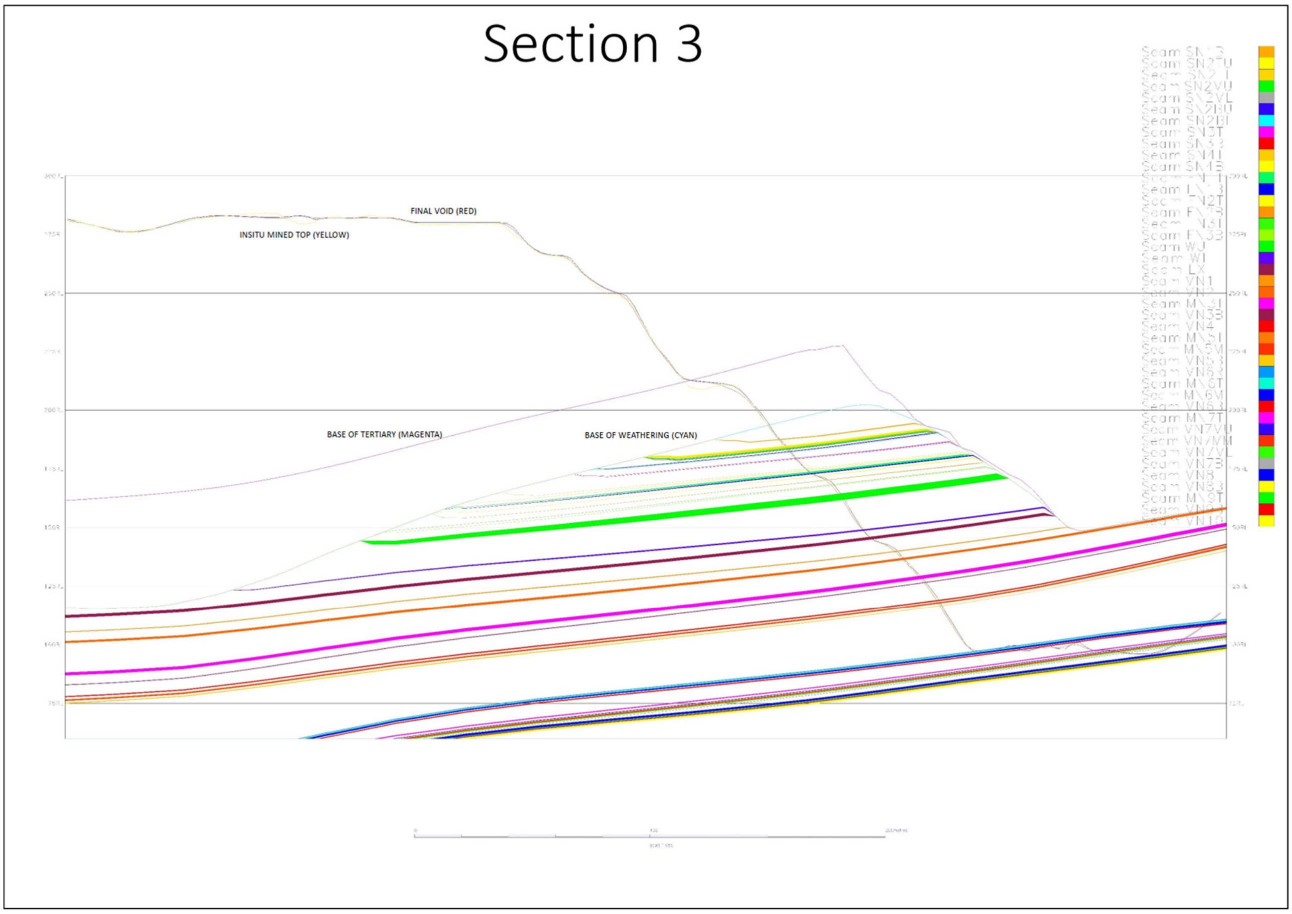



Figure 4: Section 3 geometry and stratigraphic arrangement

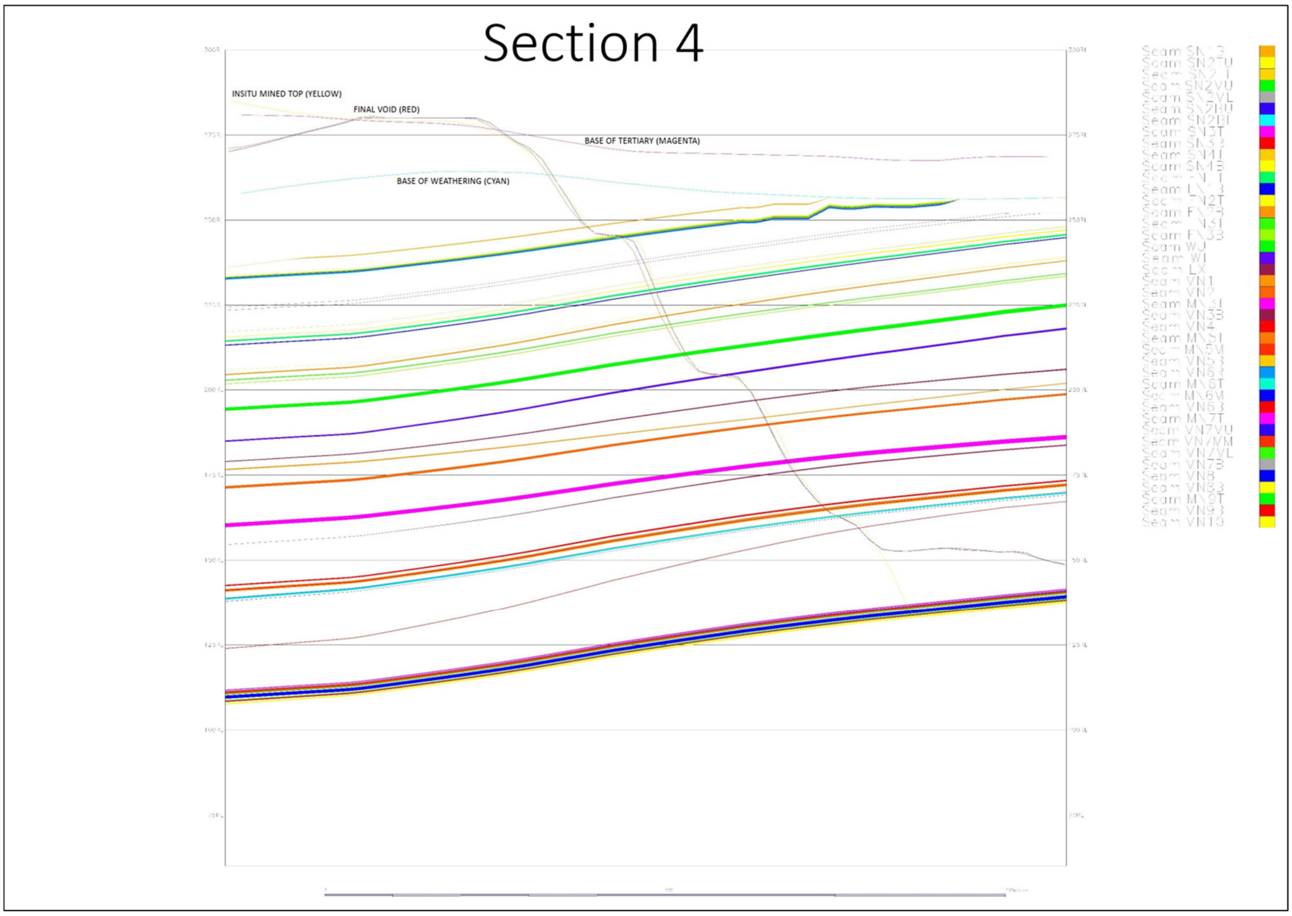



Figure 5: Section 4 geometry and stratigraphic arrangement

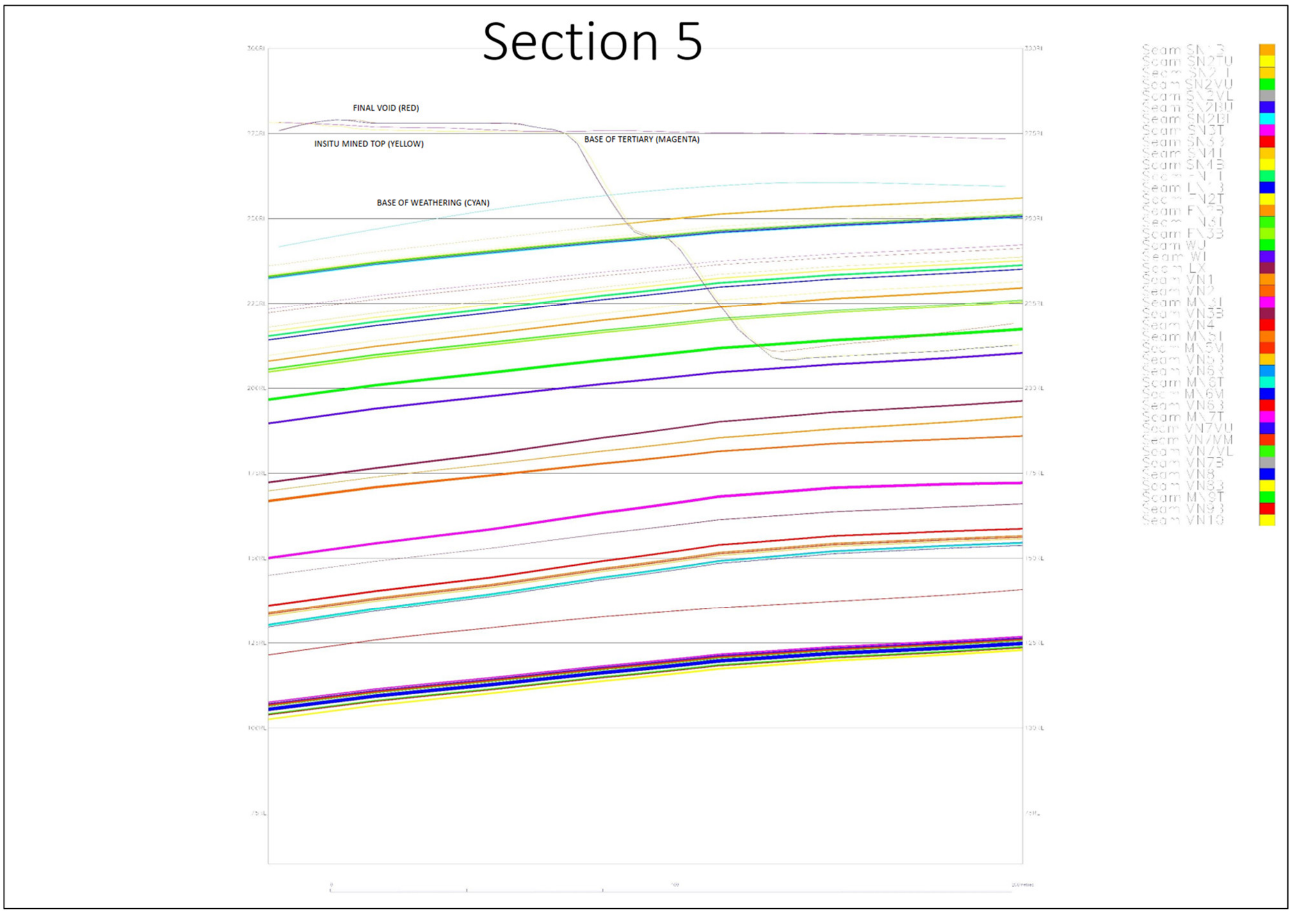



Figure 6: Section 5 geometry and stratigraphic arrangement

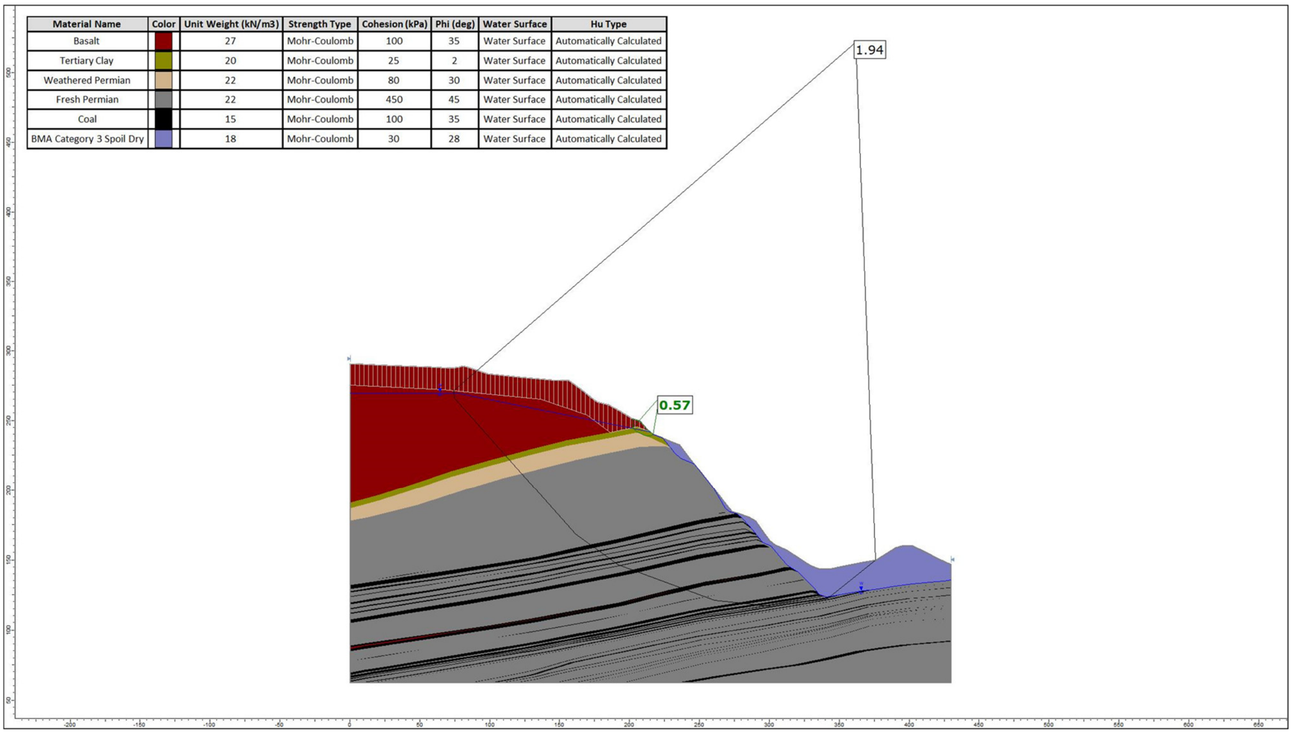



Figure 7: Section 1 ‘as is’ stability analysis, minimum FoS = 0.57, global FoS = 1.94

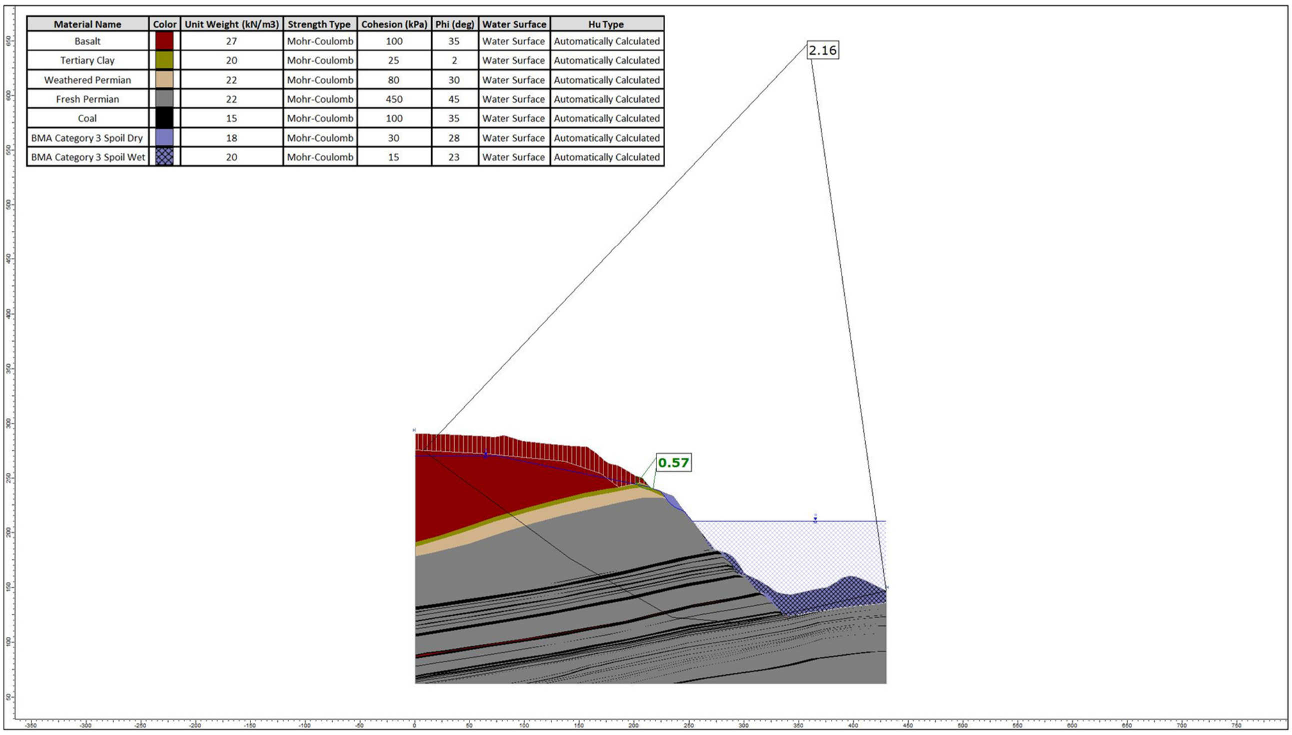



Figure 8: Section 1 ‘pit water’ stability analysis, minimum FoS = 0.57, global FoS = 2.16

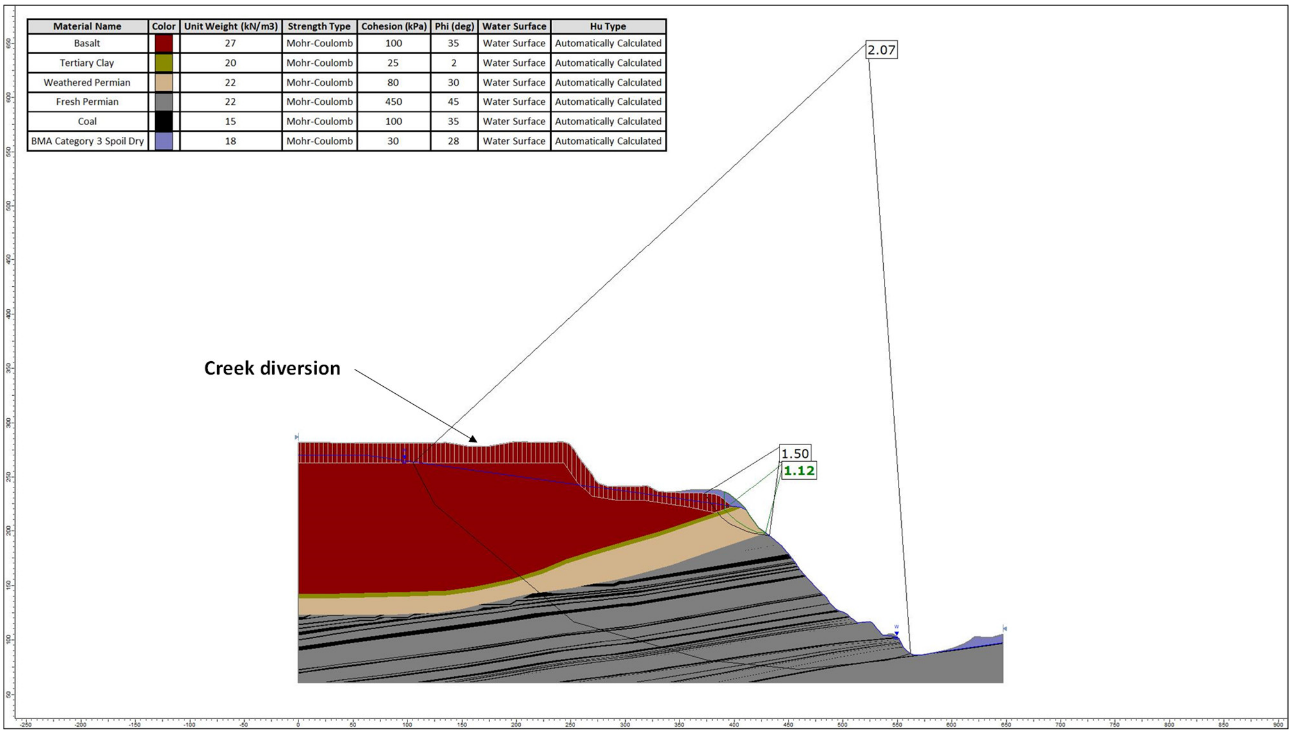



Figure 9: Section 2 'as is' stability analysis FoS = 1.50 critical surface displayed, minimum FoS = 1.12, global FoS = 2.07

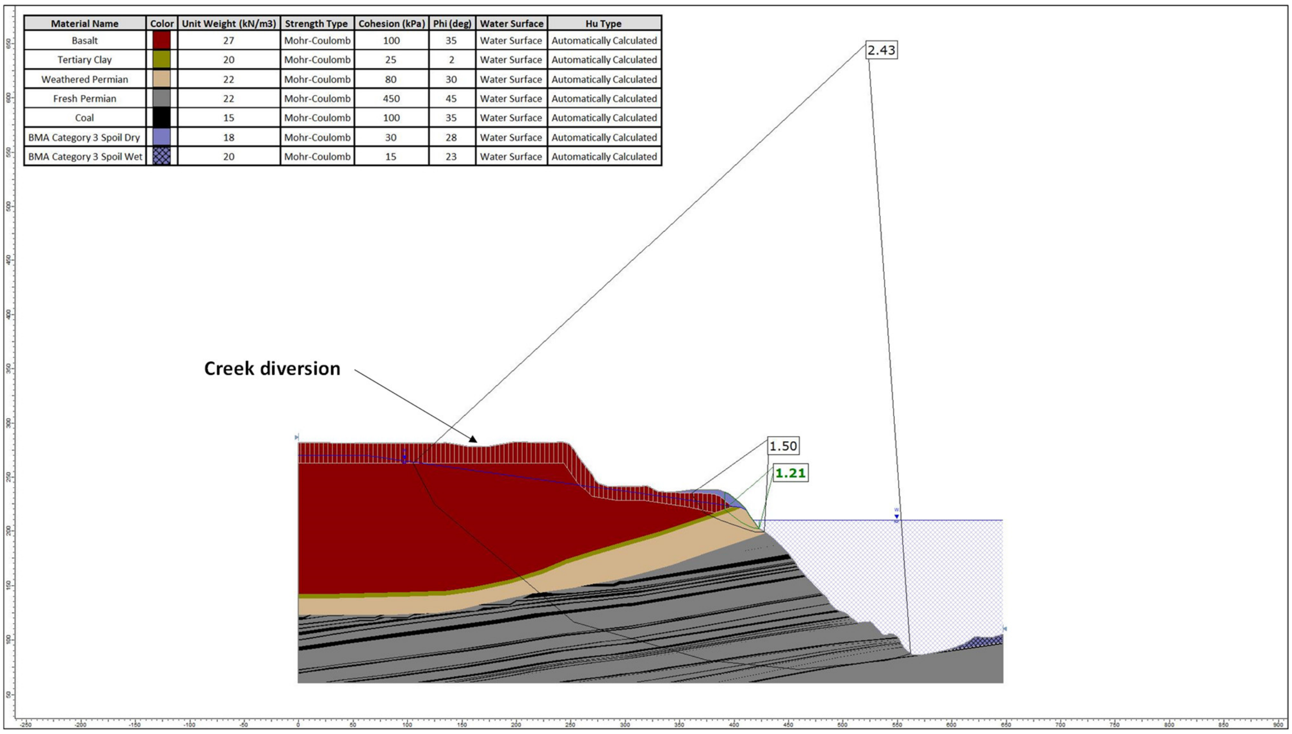
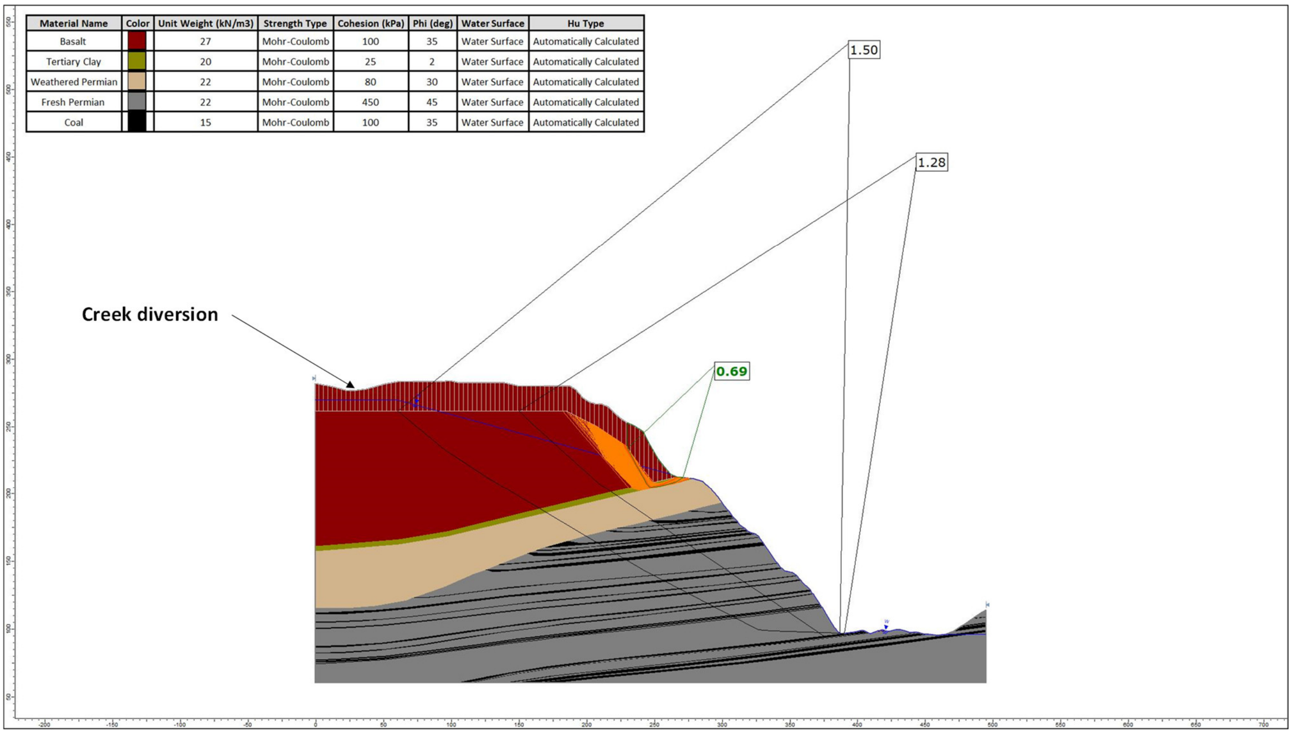
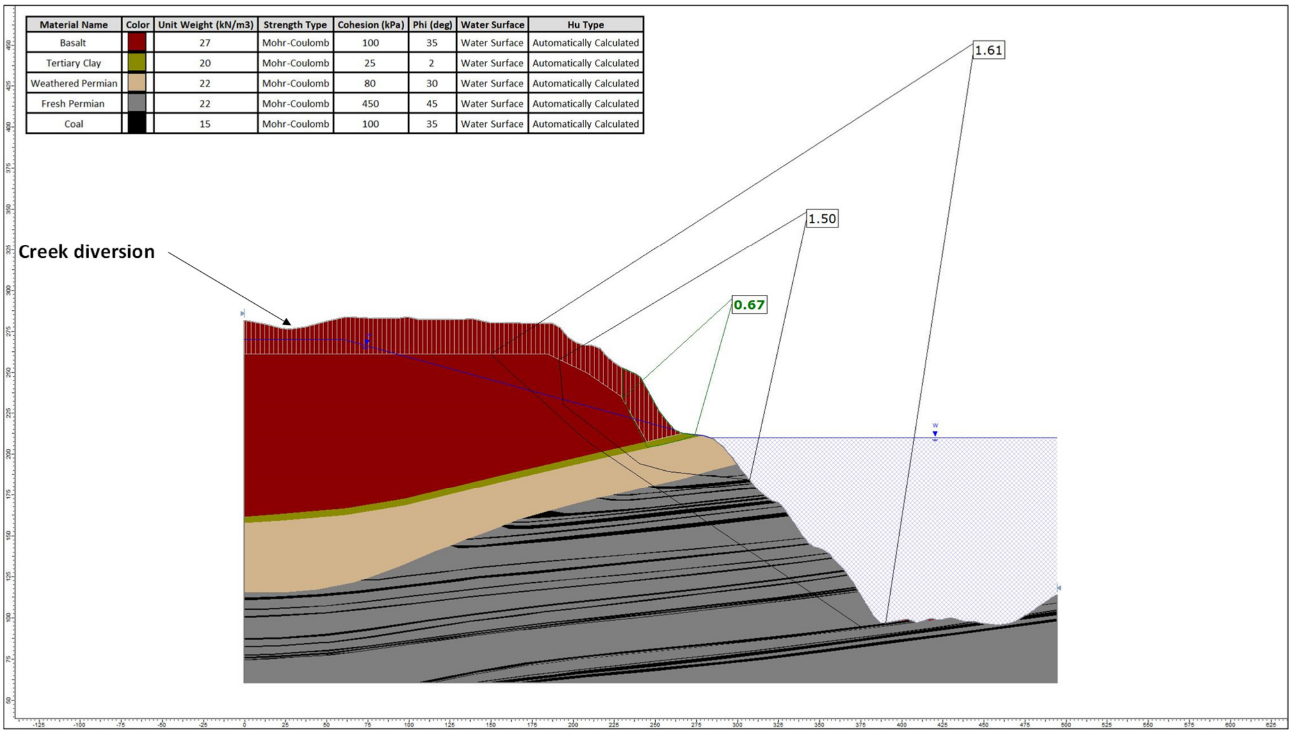



Figure 10: Section 2 'pit water' stability analysis FoS = 1.50 critical surface displayed, minimum FoS = 1.21, global FoS = 2.43




| Material Name | Color | Unit Weight (kN/m3) | Strength Type | Cohesion (kPa) | Phi (deg) | Water Surface | Hu Type |
|---|---|---|---|---|---|---|---|
| Basalt | | 27 | Mohr-Coulomb | 100 | 35 | Water Surface | Automatically Calculated |
| Tertiary Clay | | 20 | Mohr-Coulomb | 25 | 2 | Water Surface | Automatically Calculated |
| Weathered Permian | | 22 | Mohr-Coulomb | 80 | 30 | Water Surface | Automatically Calculated |
| Fresh Permian | | 22 | Mohr-Coulomb | 450 | 45 | Water Surface | Automatically Calculated |
| Coal | | 15 | Mohr-Coulomb | 100 | 35 | Water Surface | Automatically Calculated |

Figure 11: Section 3 'as is' stability analysis, FoS = 1.50 critical surface displayed, minimum FoS = 0.69, global FoS = 1.28, all surfaces with FoS < 1 displayed




| Material Name | Color | Unit Weight (kN/m3) | Strength Type | Cohesion (kPa) | Phi (deg) | Water Surface | Hu Type |
|---|---|---|---|---|---|---|---|
| Basalt | | 27 | Mohr-Coulomb | 100 | 35 | Water Surface | Automatically Calculated |
| Tertiary Clay | | 20 | Mohr-Coulomb | 25 | 2 | Water Surface | Automatically Calculated |
| Weathered Permian | | 22 | Mohr-Coulomb | 80 | 30 | Water Surface | Automatically Calculated |
| Fresh Permian | | 22 | Mohr-Coulomb | 450 | 45 | Water Surface | Automatically Calculated |
| Coal | | 15 | Mohr-Coulomb | 100 | 35 | Water Surface | Automatically Calculated |

Figure 12: Section 3 'pit water' stability analysis, FoS = 1.50 critical surface displayed, minimum FoS = 0.61, global FoS = 1.61

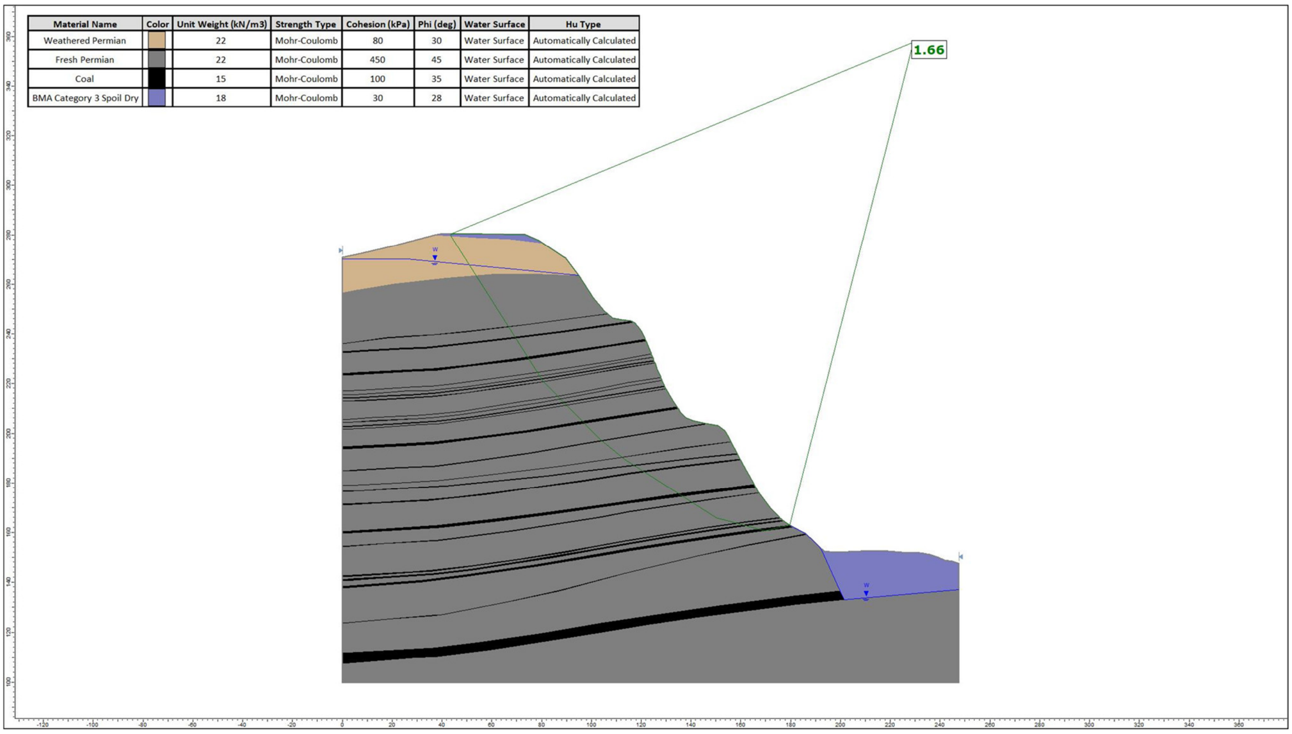



Figure 13: Section 4 ‘as is’ stability analysis, minimum FoS = 1.66

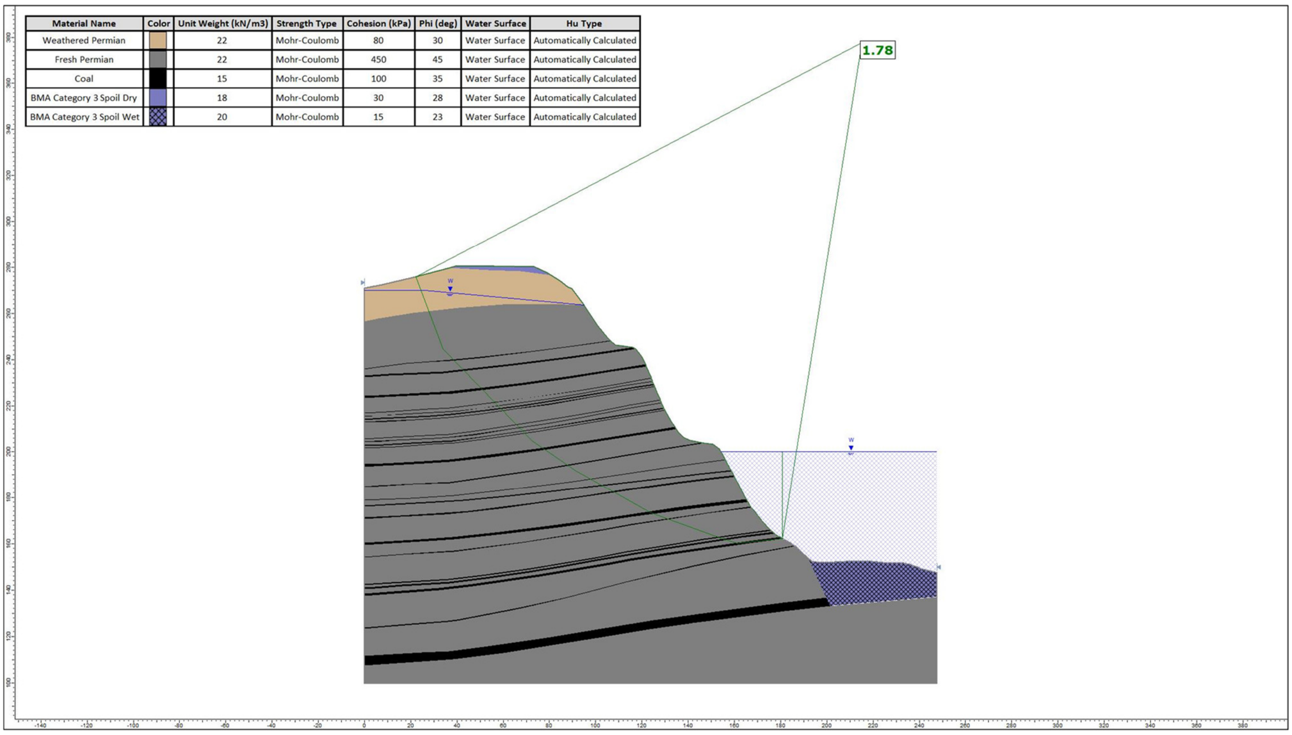
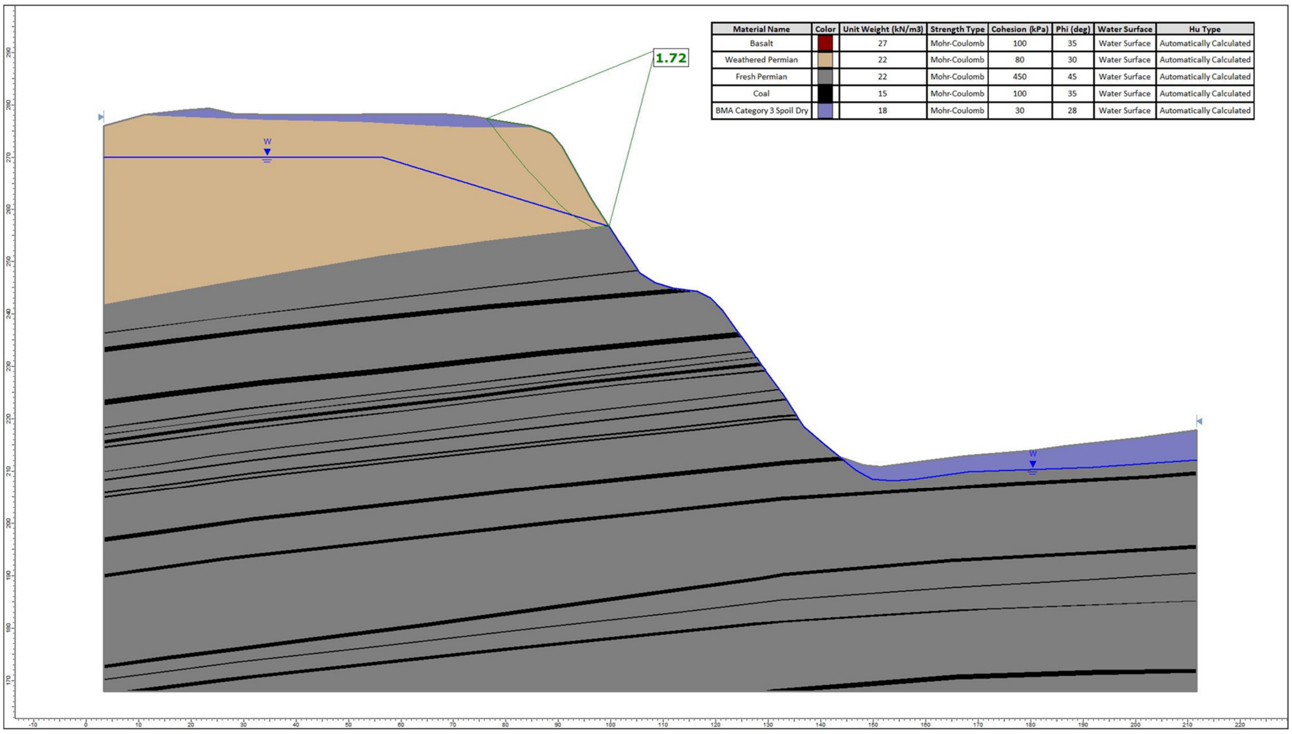



Figure 14: Section 4 ‘pit water’ stability analysis, minimum FoS = 1.78




| Material Name | Color | Unit Weight (kN/m3) | Strength Type | Cohesion (kPa) | Phi (deg) | Water Surface | Hu Type |
|---|---|---|---|---|---|---|---|
| Basalt | | 27 | Mohr-Coulomb | 100 | 35 | Water Surface | Automatically Calculated |
| Weathered Permian | | 22 | Mohr-Coulomb | 80 | 30 | Water Surface | Automatically Calculated |
| Fresh Permian | | 22 | Mohr-Coulomb | 450 | 45 | Water Surface | Automatically Calculated |
| Coal | | 15 | Mohr-Coulomb | 100 | 35 | Water Surface | Automatically Calculated |
| BMA Category 3 Spoil Dry | | 18 | Mohr-Coulomb | 30 | 28 | Water Surface | Automatically Calculated |

Figure 15: Section 5 'as is' stability analysis, minimum FoS = 1.72

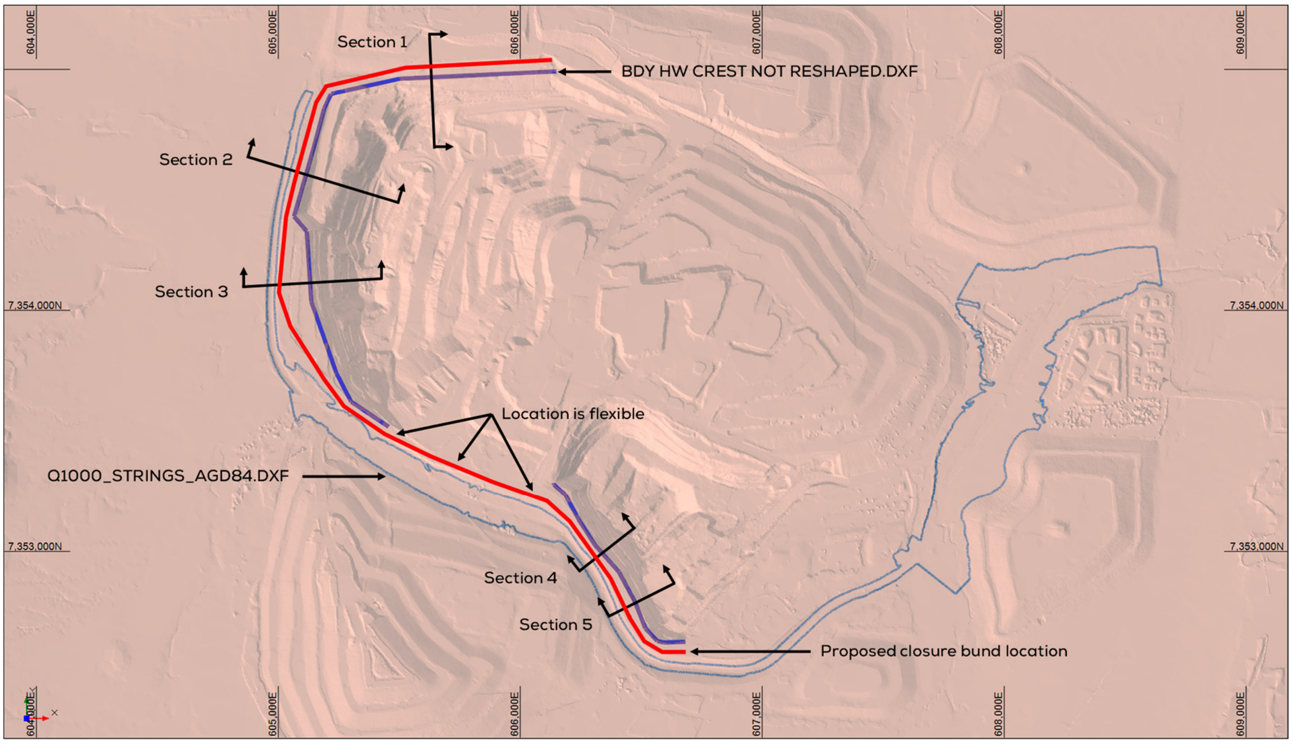



Figure 16: Proposed closure bund location (LIDAR21t_Topo.DXF used for topography)