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Quantifying the overburden material types at Grootegeluk Coal Mine

by

Mietha Chubella Poley
2512447

A research report submitted to the Faculty of Science, University of Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the award of

Master of Science
in

Economic Geology

Supervisor
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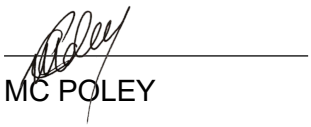
December, 2025

DECLARATION

I declare that this research report is my own unaided work. It is being submitted in fulfilment of the degree of Master of Science (Economic Geology) to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.



MC POLEY

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Signed on the 25th day of December year 2025.

ABSTRACT

Grootegeluk Coal Mine exploits approximately 58 Mtpa of run-of-mine through a bulk open cast mining method. According to the latest mine scheduling information, a yield of 50% is attained. Consequently, half of the ROM produced annually will be redirected to discard after beneficiation. For this reason, equal effort must be given to manage the waste material.

The rehabilitation methodology implemented utilises a continuous feed of waste material to the backfill area for construction. The backfill operation is designed in terraces to accommodate for sealing of the spontaneous combustible discard material, and for practical design constraints for the extendable units. Currently, the only material types available that are deemed appropriate for the platforms' construction are the interburden sandstone, and the competent shale material from the overburden. If the construction of these platforms were to cease due to a lack of available competent material for placement, the mine will struggle to find appropriate areas to stack large volumes of the plants' discard. This may lead to a halt in production pending alternative solutions.

The focus of this study is to quantify the overburden material types for the coal resource, utilising two different methodologies, namely a vertical distribution and quantification model of the overburden material types in the middle-pit, and an updated overburden classification map for the Grootegeluk coal resource area. The aim is not only to quantify the overburden material types for the medium to long-term period, but also to find practical solutions to allocate the correct overburden material types for backfill construction.

The vertical distribution model ("project model") depicts significant differences in competent shale tonnes when compared to the 2022_2D overburden classification within the middle-pit model boundary. This however is not an indication of loss in practical mineable tonnes since the project model includes the volumes of each lithological unit within the overburden, whilst 2022_2D model condensed the material types to three main categories. The project model indicates that competent shale can be identified within highly weathered areas where clay and weathered shale are predominant. The updated overburden resource classification map of 2023 delineated the areas within the life-of-mine where competent shale is intersected close to topographic surface. This information indicates a potential of unlocking 55 Mt of competent shale within the middle-pit that were previously classified and scheduled to be directed to the backfill terraces for sealing discard. These results from both of the models indicate that value can be unlocked by selectively loading competent shale material within highly weathered overburden. It requires short-term operational measures to be enforced and the need for competent shale loading to be synchronised within the mining schedule.

ACKNOWLEDGEMENTS

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I also thank my supervisor John Hancox P.hD. for sharing his depth of knowledge, constructive criticism and for underpinning perseverance to finalise this project. It is greatly appreciated. Lastly, I thank everyone who gave me moral support during this journey, my colleagues at Grootegeluk, my mentor, my father and mother, and my dearest husband, without whom this would not have been possible.

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CHAPTER ONE – INTRODUCTION

1.1 Waste material management at Grootegeluk Mine

Grootegeluk Coal Mine ("GCM" or "Grootegeluk"), the only operating coal mine within the Waterberg Coalfield, is situated approximately 15 km west of the town Lephalale (Figure 1). The mine is the largest opencast coal mine in South Africa and operates the biggest coal beneficiation complex in the southern hemisphere (Hancox and Götz, 2014), producing some 28 Mtpa of coal products from 58 Mtpa run-of-mine ("ROM"). Based on a long-term agreement between Eskom's Matimba and Medupi Power Stations, GCM also supplies the thermal coal products used to generate the majority of South Africa's coal-fired energy. Hence, a lot of effort is invested along the value chain to ensure that the coal reserves from the mining operations are dispatched to the correct beneficiation plants to obtain optimal coal product specifications.

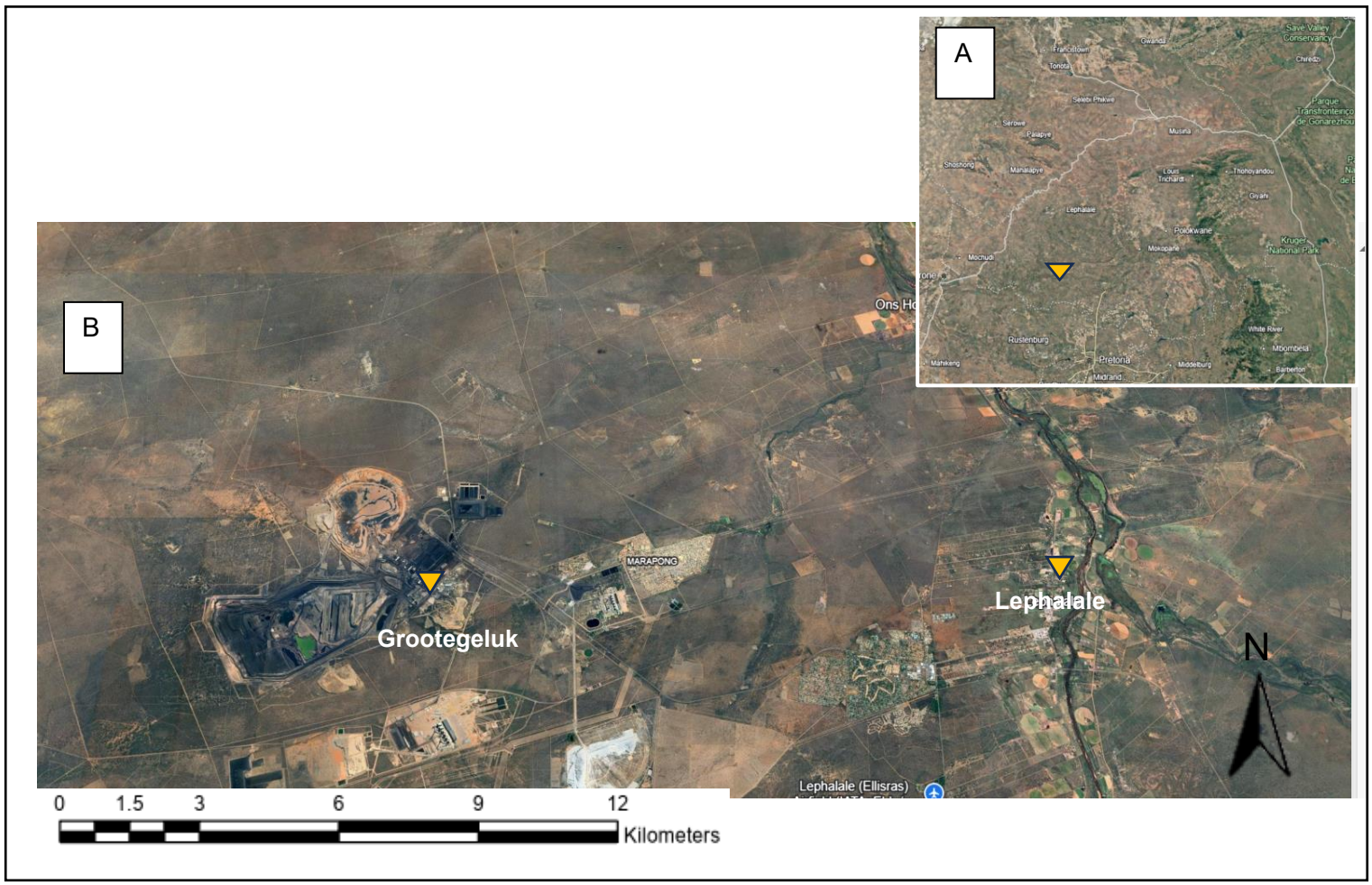

Figure 1. A) Map indicating location of the town Lephalale. B) Map depicting the location of GCM relative to Lephalale. Maps constructed in ArcGIS Pro.

The current combined ROM yield is estimated at 50%, which translates to half of the annually produced ROM being redirected to discard after beneficiation. For this reason, much emphasis is placed on managing both sectors of the mining operation; the coal reserve exploitation and waste material handling. Waste material management is employed based on volumes of material moved, the method utilised to move the material, and appropriate areas for placement. For the first fifteen years of mining Grootegeluk's waste material was stockpiled (Dippenaar *et al.*, 1983). This strategy only changed once the dimensions of the mined-out void created in-pit were large enough for it to be economically feasible to continuously place waste material from the mining operation to this void.

The current rehabilitation strategy comprises the construction of the backfill operation from waste material, which consist of inert overburden material (Bench 1A and Bench 1B), reactive overburden material (Bench 1C), interburden benches, and plant discard material. Waste material is placed based on the backfill design, where the different waste material types are allocated to different sectors within its construction. This operation mandates the demand for information on the different types and quantities of waste material present along the operation's value chain.

The focus of this study is threefold:

1. Firstly, it is to quantify the overburden material types on a vertical scale for the middle-pit and to find practical solutions, in support of the Grootegeluk Alternative Mining Solutions ("GGAMS") (discussed in 2.1.4.3.), to allocate the correct overburden material types for backfill construction;
2. Secondly, to update the overburden classification map and identify areas within the Grootegeluk coal resource area where competent shale attains mineable thickness close to the topographic surface, and
3. Thirdly, to compare the quantities of overburden material based on the vertical model and the updated overburden resource model for the middle pit.

1.2. Problem statement overview

The inherent risk in utilising the overburden material within the backfill, and the subsequent allocation of competent shale in the northern extensions (discussed in 2.1.4.4.), mandates the need for increased resolution in the overburden material type distribution across the LOM area. Although the numerical model (discussed in 2.1.7.) has yielded positive outcomes, and is still used for mine scheduling purposes, it lacks vertical resolution for overburden material type quantification. This short coming may lead to either over or under estimation of the

major overburden material types, which will have practical operational implications. There is a need to investigate whether the current methodology can be improved.

This overburden quantification project developed over the course of two years with two outcomes in mind. Firstly, the development of a detailed 3D overburden model of the middle-pit for specific applications in the Bankable Feasibility Study ("BFS") for the GGAMS Mega Project of 2022. Secondly, a revision of the existing 2022 overburden classification model (2D model) to produce an update of the overburden material type distribution map over the LOM for 2023. The updated map includes information from the 2022 and 2023 exploration programmes. Both these projects address possible solutions to combat overburden material type distribution, each for its own applications.

1.2.1 Quantifying overburden on a vertical scale – 2022

The 2022 project was initiated as a base case to address the current challenges experienced in quantifying the overburden material types for the middle-pit. The objective was to gain resolution within the Bench 1 geological profile, and to utilise that information to determine practical design constraints within the proposed in-pit crusher system of GGAMS. The project aimed to:

- Classify the overburden material on a vertical scale;
- Quantify the material types for Bench 1A, Bench 1B and Bench 1C, vertically;
- Introduce an overburden block model for the short to medium-term mining blocks for Bench 1A, Bench 1B and Bench 1C;
- Determine the variability between the overburden material quantities between the numerical overburden model and the 3D middle-pit overburden model ("project model"); and
- To investigate the impact that the difference between the current numerical- and project overburden models' *mining block overburden material type classification* will have on the availability of competent shale material.

1.2.2 Updated 2D classification and overburden distribution maps for GG resource area

The most recent update of the overburden distribution (2023) aimed to include explored areas of the 2022 to 2023 two-year exploration window. The resultant classification depicts the overburden material type distribution as geological maps and identifies areas in Bench 1A where competent shale attains excavatable thicknesses close to the topographic surface. The updated overburden classification map aims to assist in identifying previously overlooked areas with competent shale and to optimise on the competent shale quantities

available within clay- and weathered shale dominant areas for the middle-pit and the northern box cut areas. The resultant 2023 update depicts the material type distribution in the middle-pit and north-pit, and highlights areas where competent shale may be excavated close to the surface at a sufficient thickness constraint of ≥ 6 m.

1.3. Report chapter outline

The contents of this research report follow the post-graduate report guideline to ensure a logical structure for the reader. Chapter 1 introduces the topic, outlines the problem statements, provides an overview of the methodology applied, and highlights the sections addressed within the background. Chapter 2 summarises the geology of GCM, provides insight into current mining practices, details overburden material handling practices, and reviews historical studies related to overburden material classification. Chapter 3 details the methodologies employed to address the problem statements. The results and discussion are presented in Chapter 4 and should be read in conjunction with the Appendix. The final chapter, Chapter 5, presents the concluding remarks.

CHAPTER TWO- BACKGROUND

2.1. Background on Grootegeluk Coal Operation

2.1.1 Regional geology

The Waterberg Basin, which formed during the first order-cycle (Late Carboniferous to Early Triassic) assembly and breakup of the supercontinent Pangaea, obtained its characteristic intracratonic/sag morphology due to the extensional setting coeval with the Late Permian to Early Triassic boundary. Apart from the tectonic palaeo-allogenic control on basin development and basin infill, the Main Karoo Basin and the Waterberg Basin correlate on lithology on a regional scale (Catuneanu et al.,2005). The stratigraphic units of the Waterberg Basin are synonymous with those of the Main Karoo Basin, except for the Upper Ecca/ Volksrust Formation (Faure, 1993).

The sedimentary-volcanic succession of the Karoo Supergroup within the Waterberg Basin lies discordantly on the Archaean rocks of the Limpopo Mobile Belt and the Waterberg Group (Faure, 1993). The contact between the Dwyka Group and basement varies laterally across the basin, with the basin underlain by gneiss north of the Zoetfontein fault, to the east by granites, gabbros and norites, coeval with the Bushveld Complex, and to the south of the fault, by metaquartzites and metaconglomerates of the Early Proterozoic Waterberg Group (Faure, 1993, Fourie et al., 2009). The coal-bearing Ecca Group overlies the Dwyka Group and is subdivided into three formations:

i. Pietermaritzburg Formation (Lower Ecca): This prodelta clastic shale and siltstone bearing lithology unit, coarsens upward and contains glaciogenic debris flows;

ii. Vryheid Formation (Middle Ecca): This formation is composed of delta front coarse sandstones and/or delta plain coarse sandstone channel deposits, with splays of siltstones. The accumulation of these clastic units was interrupted by the formation of coal seams, which had resulted from intermitted periods of proximal flood plain development; and

iii. Volksrust Formation (Upper Ecca): The formation overlies the Vryheid Formation and comprises a repetitious sequence of carbonaceous mudstones and shale, with bright coal bands on a centimetre scale. The intercalated nature of this formation is unique to the Waterberg Basin, and is interpreted to have formed on a poorly drained, and densely vegetated flood plain.

The intercalated coal-mudstone/shale is overlain by the purple to greenish mudstones of the Beaufort Group and the formations within the Stormberg Group (Faure, 1993). A summary of the lithostratigraphic units is provided in Table 1 and a map depicting the regional extent of the Ecca Group within the Waterberg Coalfield is depicted in Figure 2.

Table 1. Regional stratigraphy of the Karoo Supergroup (van Heerden, 2018).

GROUP	FORMATION (SACS,1980)	REPRESENTATIVE ROCK TYPE	AVERAGE THICKNESS
DRAKENSBERG	Drakensberg	Lava, amygdaloidal, purplish to red.	95m
STORMBERG	Clarens	Sandstone, fine grained, white to yellow-brown to reddish.	80m
	Elliot	Mudstaone, clayey, red to chocolate brown.	90m
	Molteno	Sandstone, medium to coarse grained, white.	15m
BEAUFORT	Beaufort	Mudstone, alternating at top, purple and greenish grey, light grey at base.	90m
ECCA	Volksrust	Intercalated shale and bright coal.	60m
	Vryheid	Sandstone and grit, intercalated carbonaceous shale, siltstone, few thick, mainly dull coal seams.	55m
	Pietermaritzburg	Shale and sandstone.	150m
DWYKA	Dwyka	Tillite	3m

2.1.2. Structural geology

The formation of the Waterberg Coalfield is structurally defined by embayments created due to normal faulting. The fault-bounded coalfield hosts numerous horst and graben structures created by minor conjugate faults throughout the basin. These graben structures are infilled with sediment coinciding with the stratigraphy of the Karoo Supergroup (Table 1). The boundaries of the Waterberg Coalfield are structurally confined by three major faults, namely the Eenzaamheid Fault (associated with the Waterberg Group era) to the south, the Zoetfontein Fault to the north (active from post-Waterberg Group to post-Karoo era), and the Daarby Fault (post-Karoo fault, displaces Triassic formations) (Faure, 1993, Mtimkulu, 2010) which cross-cut the depository along a north-south trend (Figure 2) (Vermeulen et al., 2009). The sinuous-shaped Daarby Fault has a throw of ~350 m and divides the Waterberg Coalfield into a shallow south-western portion, and a deep north-eastern portion. The shallow portion is suitable for opencast mining, while the deeper portions can only be extracted through the deployment of underground mining methodologies (Faure, 1993, Mtimkulu,

2010). Ample dykes are encountered towards the south-eastern portion of the Waterberg Coalfield as outcrops, but to date no sills have been mapped within the basin (Faure, 1993).

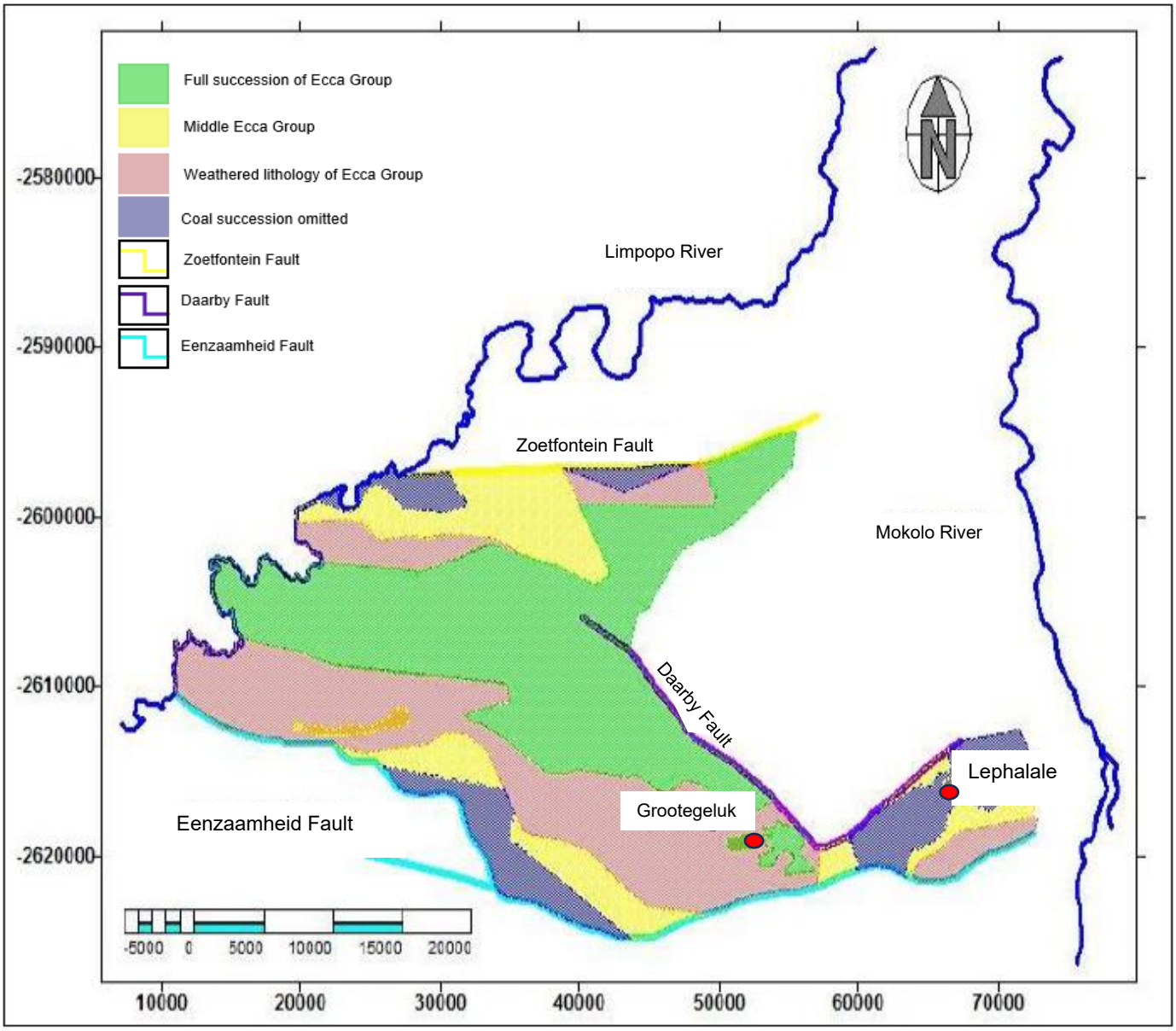

Figure 2. Map depicting lithostratigraphic units of the Ecca Group in the Waterberg Coalfield (modified after Vermeulen et al., (2009)).

2.1.3. Local geology

GCM is situated south-west of the Daarby Fault (Figure 2). Since it is the only active mining operation in the area, geological sightings are confined to the local geology of the mine. Coal is exploited from two formations, namely the Vryheid Formation and the overlying Volksrust Formation. The two formations extend over a stratigraphic thickness of approximately 115 m and are divided into 11 distinct coal zones (Alberts,1982). Each zone represents a

depositional cycle, which is further sub-divided into geological sample(s). The zones are numbered from the base of the Vryheid Formation upwards to the top of the Volksrust Formation, while the geological samples are numbered in the opposite manner (Dippenaar *et al*., 1983, Fourie *et al*., 2009, Hancox and Götz, 2014). For the purposes of exploitation, the zones are grouped together to form mining benches, with the express aim of achieving optimal product extraction (Figure 3).

The Vryheid Formation can be classified as a Multiple Seam Deposit Type according to SANS 10320:2020 and is characterised by a discrete number of coal seams, which are separated by interburden layers that consist of sandstone. The typical thickness of the five coal seams ranges between 1.5m to 7.0m, while the interburden thickness exceeds that of the coal. The typical interburden thickness range expected varies between 3-14 m. The five coal zones that make up the Vryheid Formation (zones 1 to 4, and 4A) are mined in seven benches (Bench 6 to Bench 11). Four of the benches are exploited for coal (Bench 6, 7B, 9 and 11) and the remainder three benches, Bench 7A, 8 and 10, for interburden. Currently, Benches 12 and 13 are not mined. The coal-bearing seams of the lower mining benches at Grootegeluk are typically defined as lower quality, dull coal seams, and are beneficiated to produce the Power station coal (“PSC”) and metallurgical products.

The Volksrust Formation can be classified as a Thick Interbedded Seam Deposit Type according to SANS 10320:2020. It comprises multiple layers of intercalated coal and shale with an average thickness ranging between 40-70 m. The seven coal zones that make up the Volksrust Formation (zone 5 to 11) are mined in four coal benches (Bench 2 to Bench 5) and one overburden bench (Bench 1). These coal benches are beneficiated to produce PSC and semi-soft coking coal (‘SSCC”).

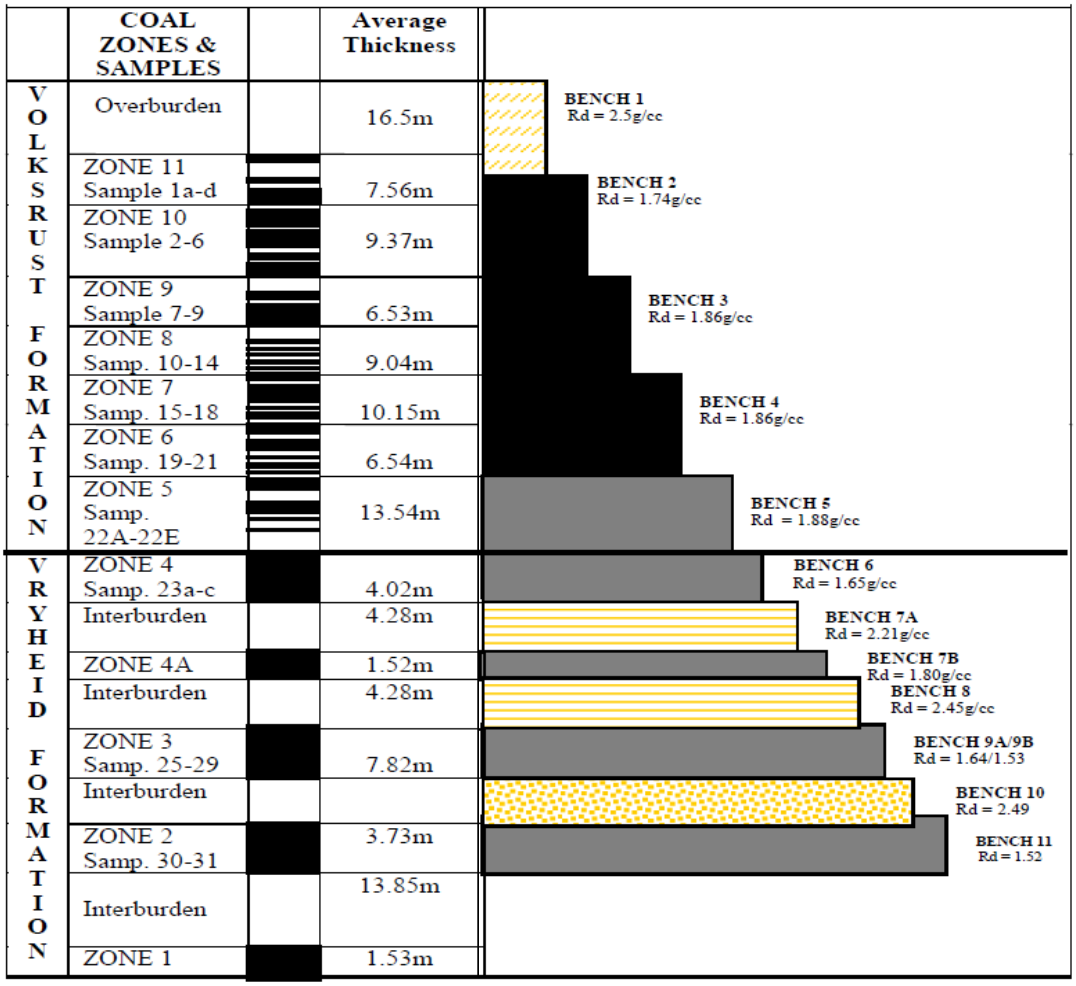

Figure 3. Stratigraphy and mining benches of GCM.

2.1.4 Mining operations

2.1.4.1 Overview of mining practices for waste material management

GCM is designed to exploit its coal reserve through the bulk opencast or terrace mining method using conventional truck and shovel fleets. The pit was developed in 1980 and is currently divided into 14 mining benches (at varying heights between 14 to 17 metres for Benches 2 to 5, and 1.5 to 6 metres for Bench 6 to 11), whereby the mining bench definitions coincide with the geological contacts of the layered coal deposit. The pit waste material consists of five benches, namely the overburden of Bench 1 and the interburden of Bench 7A, Bench 8 and Bench 10 (Figure 3). The waste material generated through the beneficiation of the coal-bearing benches is termed the discard. The discard is dispatched to be sealed within the backfill area.

For classification purposes, Bench 1 has been characterised into three main overburden material types, namely shale, weathered shale and clay. The overburden does, however, contain a minority proportion of other weathered lithology types. For practical mining exploitation, Bench 1 is subdivided into three sub-benches based on thickness constraints, namely Bench 1A, Bench 1B and Bench 1C. Bench 1A is defined as 12 m thickness from the topography, while Bench 1C is modelled as a 3 m buffer above top-of-coal ("TOC") or the first coal sample. This is to account for and segregate carbonaceous material in an attempt to avoid contamination. The remainder material in the bench is defined as Bench 1B (Figure 4). Both Bench 1A and Bench 1B are considered to be devoid of carbonaceous material, hence it is allocated for sealing the discard in the backfill.

Depending on the degree of weathering in the overburden, the mining procedure to liberate the material in these benches will differ. In most instances no drilling and blasting are required to excavate the material from Bench 1 for coal seam exposure. In fact, blasting of weathered areas in the pit advance, especially in the southwestern area, increases the volumes of the fines and enhances the degree of difficulty to excavate the material.

The interburden benches consist of shale and siltstone (Bench 7A and Bench 8) as well as sandstone (Bench 10 and Bench 12). To exploit these benches the shale and sandstone are drilled and blasted to the agreed upon fragmentation requirements. After blasting, the material is loaded and dispatched to the backfill area

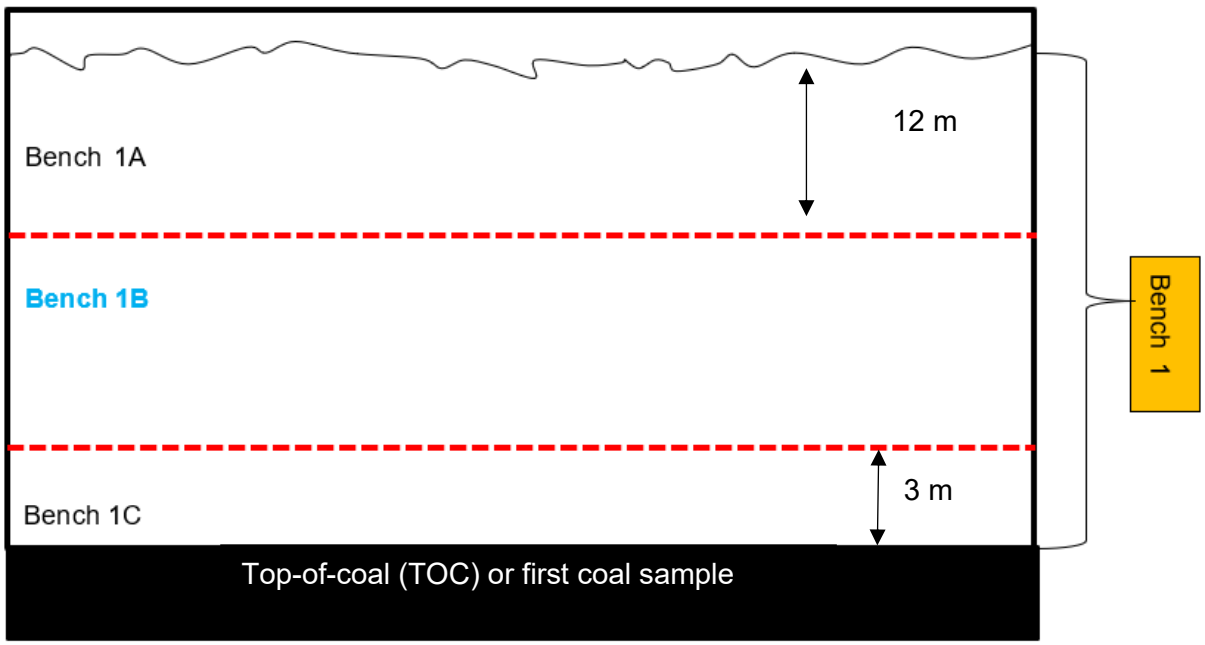

Figure 4. Simplified schematic of Bench 1 subdivision.

2.1.4.2 Overview of overburden handling

The following procedure is followed when handling the overburden:

First, the topsoil is stripped and transported to suitable locations outside the pit. This material is kept separate for final rehabilitation purposes. Thereafter, stripping of the overburden material types commences through the deployment of hydraulic shovels and is transported using truck fleets. Weathered overburden material can either be placed along the southern portion of the backfill area or be used to seal the discard at the 860 m and 900 m elevation levels (refer to 2.1.4.4.). The inert overburden and interburden material, devoid of carbonaceous material, is placed to seal the discard in the backfill.

2.1.4.3 Grootegeluk Alternative Mining Solutions (GGAMS)

The current backfill management strategy is based on the movement of the overburden and interburden material from the pit face to the backfill area by utilising truck fleets. However, since 2017 alternative solutions for optimal transport of waste material to the backfill area have been revised to off-set and include the impacts of long-term operational factors that influence some of the optimisation strategies at the operation. Some of these factors include:

- The completion of the expansion of the GG6 and development of the GG7 and 8 plants, and the subsequent increase in discard material created within the beneficiation process;
- The Life of Mine ("LOM") pit-layout and direction of mining influencing the quantities of waste material liberated in proportion to the coal benches (Figure 5);
- Variability in the distribution of the overburden and interburden over the LOM area; and
- Allocation of waste material types for the continuous backfill construction.

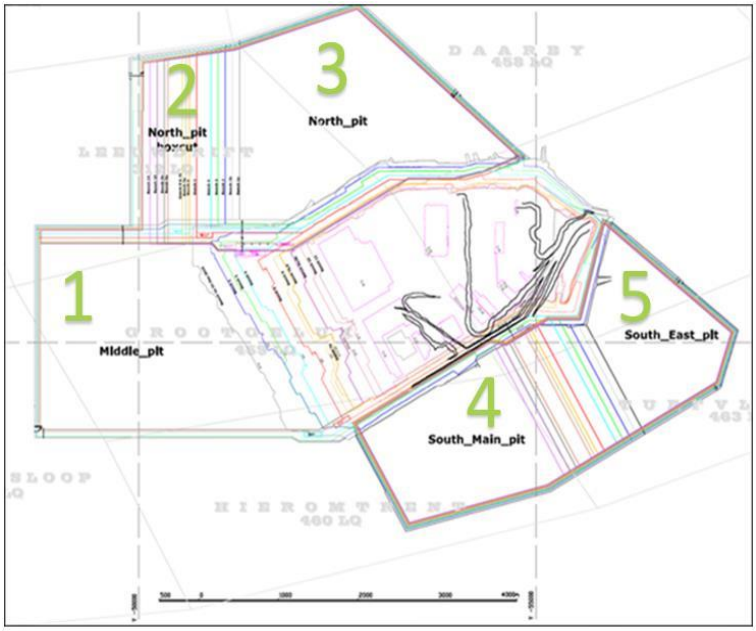

Figure 5. Map depicting the pit-layout and sequence of mining over the LoMP.

To mitigate the expected increase in mining operation costs, a study was conducted to include varying scenarios for optimal transport of the waste benches to the backfill area. Initially, the study was termed the in-pit crusher and conveyor system ("IPCC"), whereby the sole focus was to develop practical transport mechanism from the pit face, at minimum cost over the LOM, to the backfill area which included a primary in-pit crusher and a conveyor belt to the existing conveyor systems within the backfill area. The inclusion of the multiple waste material handling scenarios within the broader scope of the IPCC, led to the renaming of the initial study to the Grootegeluk Alternative Mining Solutions ("GGAMS").

2.1.4.4 Overview of backfill construction

The backfill area is constructed as terraces in three stockpile levels comprising of beneficiation discard, and overburden and interburden material. From the base, at 820 m elevation, the backfill is stacked in 40 m-interval thicknesses to the last stockpile at 900 m above sea level (Figures 6 and 7). Waste material types are allocated to specific areas within the backfill. The aim is both to seal the beneficiation discard to prevent spontaneous combustion, and to construct an extendable stable platform for conveyor infrastructure as mining progresses westwards. The construction of the backfill commences via a stacker and conveyor system, which consists of:

- A transport conveyor system for the beneficiation discard;
- Shiftable conveyors, orientated north-south, for the stackers at the 860 m and 900 m terrace levels; and
- Two extendable conveyors, orientated east-west, are located along the northern boundary of the backfill area.

Two extension platforms are constructed for the extendable conveyors, namely the upper extendable north ("UEN") and the lower extendable north ("LEN"). These platforms are constructed ahead of the backfill to ensure that no differential settlement occurs when conveyor infrastructure is placed. The long-term mining requirements mandates that competent waste material needs to be allocated for the LEN and UEN construction. Currently, the only material types available that are deemed appropriate for the platforms' construction are the interburden sandstone and the competent shale material from the overburden. Should construction activities of these platforms cease due limited supply of competent material for placement, then the mine will experience a backlog for discard stacking. This will have a direct impact on the production.

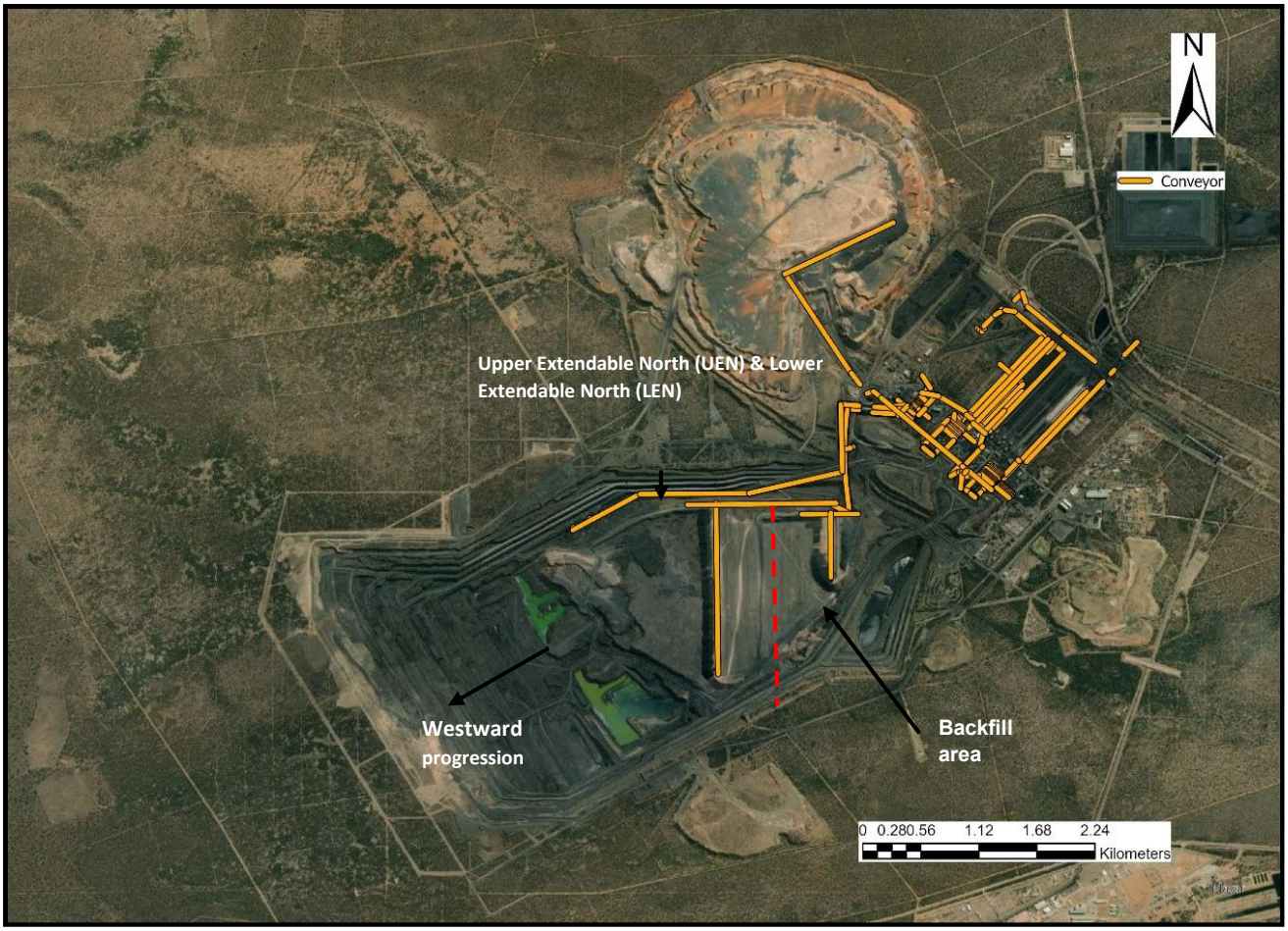

Figure 6. Map of the conveyor infrastructure.

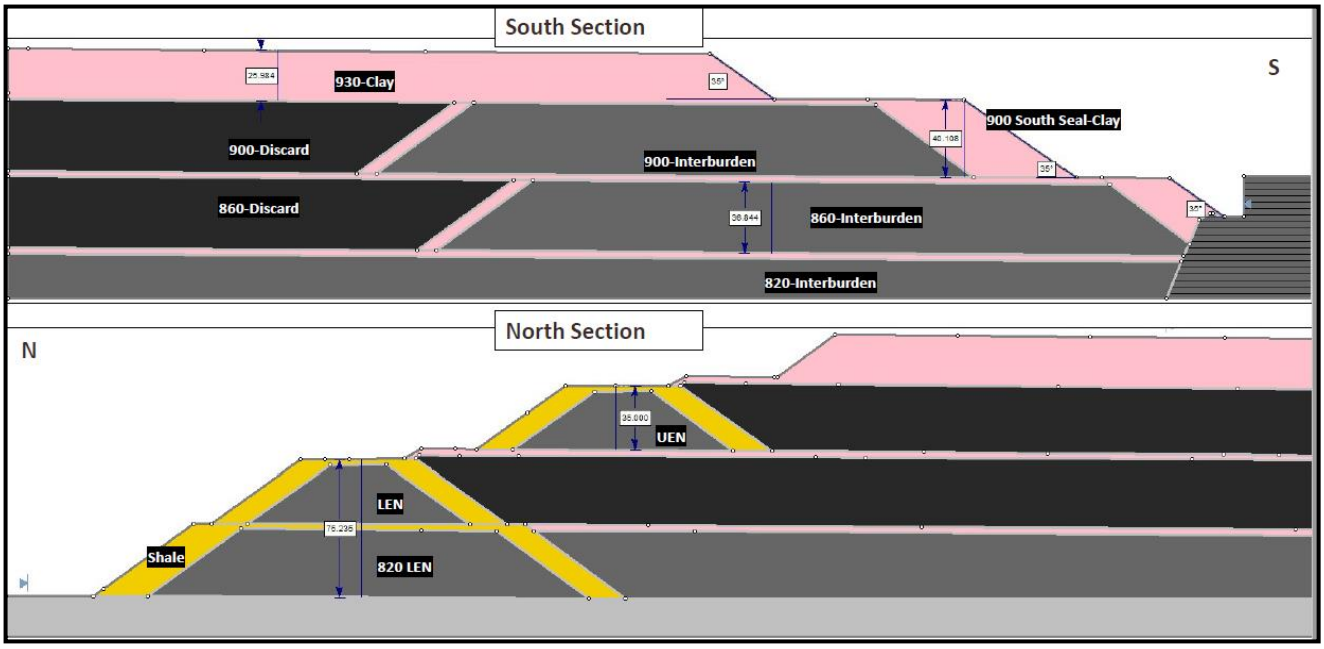

Figure 7. Cross-section of the backfill indicating the different stockpiles and material types. Section taken as indicated in red in Figure 6.

2.1.5 Challenges associated with the overburden management

2.1.5.1 Mining operation challenges

A) Degree of weathering

The increase in depth of weathering is problematic due to the difficulty associated with the excavation of deep seated clay. A substantial area in the pit layout is affected by the depth of oxidation that extends into the upper coal of Bench 2 and Bench 3. This weathered material must be selectively removed before the fresh coal can be dispatched to the beneficiation plant.

B) Overburden classification for practical mining applications

Bench 1A and Bench 1B are mined according to mining equipment constraints. The current practice is to classify each mining block, per bench, based on the majority proportion of overburden material type present. The challenge is to optimise the material type quantities available within each mining block when only one overburden lithology is assigned to it. No selective mining of the overburden occurs, even if mineable thicknesses per material type are present vertically.

C) Mine scheduling and mining tempo sequencing

To allocate the required material for backfill construction, both the overburden and interburden material types need to be dispatched in a synchronised mining schedule. Currently, the mining operation's tempo and mining schedule do not always align with those of the backfill construction. Failure to provide sealing and construction material at the required time for backfill constrains discard material movement, and leads to sub-optimal usage of waste material.

2.1.5.2 Challenges experienced in the backfill area

A) Availability of competent material for the extendable north conveyors' construction

The current overburden numerical model (overburden classification map, refer to Figure 9 in 2.1.7.) predicts competent shale overburden material ahead of the mining face in limited blocks. However, an in-pit inspection of the material's weathering intensity properties indicates that not all the shale material in these blocks can be allocated to the extendable units in the backfill. If stringent mining and backfill operation control measures are not followed, the material types are dispatched to the wrong areas in the backfill. Therefore, the challenge is to ensure that only competent shale and sandstone are used to construct the LEN and UEN. Should highly weathered

material, such as clay, be stacked for this construction platform, it may lead to slope instability and differential settlement.

B) Spontaneous combustion

The design of the backfill is based on the risk associated with stockpiling the different waste material types. The discard, Bench 1C material and some of the interburden material types have the propensity to spontaneously combust. This occurrence is mainly due to the waste material types' inherent physical and chemical properties ascribed to the high carbon content, high concentration of oxidised pyrite, and due to the coal rank properties.

2.1.6. Exploration planning

Grootegeluk Mine plans its exploration plans based on the minimum number of boreholes required to maintain the five year of Measured Coal Resource category ahead of the mining face, and to identify areas within the resource where gaps within existing borehole grids can be filled. The aim is to drill across the resource within a grid pattern that will satisfy the confidence in the resource, upgrade the coal resource (and reserves), and focus on drilling in structurally complex areas. Where upgrading the resolution of structurally complex areas is necessary the mine also utilises percussion drilling. To increase the geological confidence of the percussion boreholes, it is standard practice that these holes are geophysically logged.

More recently, there has been an increase in the demand for information regarding overburden tonnage estimates, and a delineation of different overburden material types for the mine's backfill strategy. The exploration plan, therefore, includes an overburden logging programme in conjunction with the current coal resource definition drilling programme. The plan includes the detailed logging of overburden of the percussion boreholes, as well as the logging of the weathered air-drilled, non-sampled, lithology of the diamond boreholes, before core drilling (of 123 mm core size) commences.

2.1.7 History of overburden project development

The first information on the overburden was gathered in 2016 ahead of the advancing pit face and was included within the geological model in support of a two-year production window. Since then, the methodology executed by Janse van Rensburg (2016), was incorporated across the entire resource for overburden logging. The initial study drilled two rows of percussion drillholes on the Hieromtrent and Grootegeluk farm portions at a spacing of 100 m x 350 m. The overburden was described based on material types, grain size, degree of weathering and the reactiveness of the material (carbonaceous material dominant in the layer or not). Seven groups of overburden stratigraphy were identified as:

- Topsoil (SL);
- Calcrete (CC);
- Clay (CLA);
- Shale and clay interburden layers (CLASH, a mining term);
- Shale (S);
- Weathered shale;
- Weathered, non-reactive carbonaceous material (CMW); and
- Carbonaceous material (CM).

Resultant isopach maps, which displayed the varying thickness of overburden materials, were produced.

Following this study, an exploration campaign, which included the drilling of 70 additional percussion drillholes was launched. Based on the information obtained, an investigation was conducted whereby the 2017 and 2018 geological information was used to delineate the major overburden material types based on weathering intensity. The aim was to obtain information for pragmatic application for mine planning and mine scheduling purposes. The methodology followed (Table 2), aimed to:

- Assign a weathering intensity as described by the lithological logs to a numerical equivalent (weathering intensity description modified after Collis and Smith (1993); and
- Calculate a weighted weathering intensity for the overburden stratigraphic thickness based on the weighted weathering intensity calculated per characterised lithological unit across the Grootegeluk resource area (modified after Gerber (2017) and adapted from du Plessis (2019)).

To obtain the final weighted weathering intensity numerical value, the following process was followed:

1. Assign a numerical weathering intensity value for a lithological unit within the overburden (based on the lithological data obtained from the diamond drill and percussion borehole logs).
2. Transfer the numerical value as a percentage weighting for the lithological unit.
3. Multiply the thickness of the overburden lithological unit by the weighting of the weathering intensity to obtain the weighted value for the defined thickness.
4. Sum the weighted values of all the overburden units to obtain the total weathering in metres. The weathering intensity percentage for the stratigraphic unit of the overburden thickness is obtained by dividing the “weathering in metres” by the limit of weathering (“LOW”) depth (in metres). The resultant weathering intensity of the overburden material for the boreholes located within the medium-term mining window was calculated and is presented in Figure 8.

Table 2. Weathering intensity calculation workflow.

Weathering intensity		
Unweathered (UW-)	Unchanged	0%
Slightly weathered (SW-)	Partial discolouration	25%
Moderately weathred or in mining terms "weathered" (MW/WD-)	Partial to complete discolouration, not friable except poorly cemented rocks	50%
Highly weathered (HW-)	Friable and possibly pitted	75%
Completely/Totally weathered or decomposed (CW/TW-)	Resembles soil	100%

Template for calculation				
BH_ID	From	To	Weighting	Weighted
Top soil (SL)				
Calcrete (CC)				
Clay (CLA)				
Shale (S)				
Weathered shale				
Weathered,non-reactive carbonaceous material (CMW)				
Carbonaceous material, reactive (CM)				
Sandstone (SS)				
Sand				
Fresh coal (TOCSR)				
			Weathering in metres	
			Percentage weathered	

By utilising the weathering intensity maps, each major overburden material type could be delineated across the resource (Figure 8 and Table 3). Polyline features, which outline the geological contacts between these three main overburden lithologies, were mapped based on the inverse distance weighted ("IDW") interpolated contacts (Figure 9) and annual updates have since been utilised for mine scheduling. This model is termed the *numerical overburden resource classification model*.

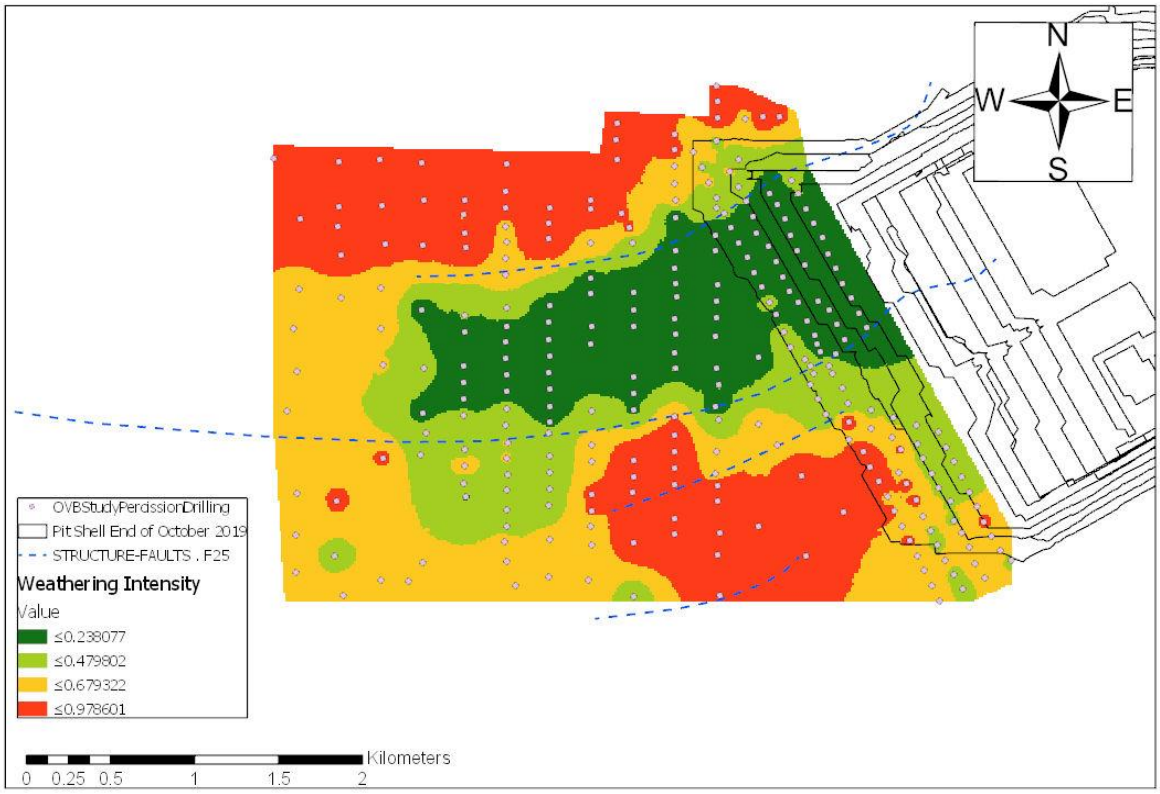

Figure 8. Weathering intensity map for the overburden material types ahead of mining (Gerber, 2017).

Table 3. Numerical classification of the major overburden material types (Gerber, 2017).

Overburden material type	Weighted weathering intensity (%)
Shale	X ≤ 25
Weathered shale	25 ≤ X ≤ 50
Clay	X ≥ 50

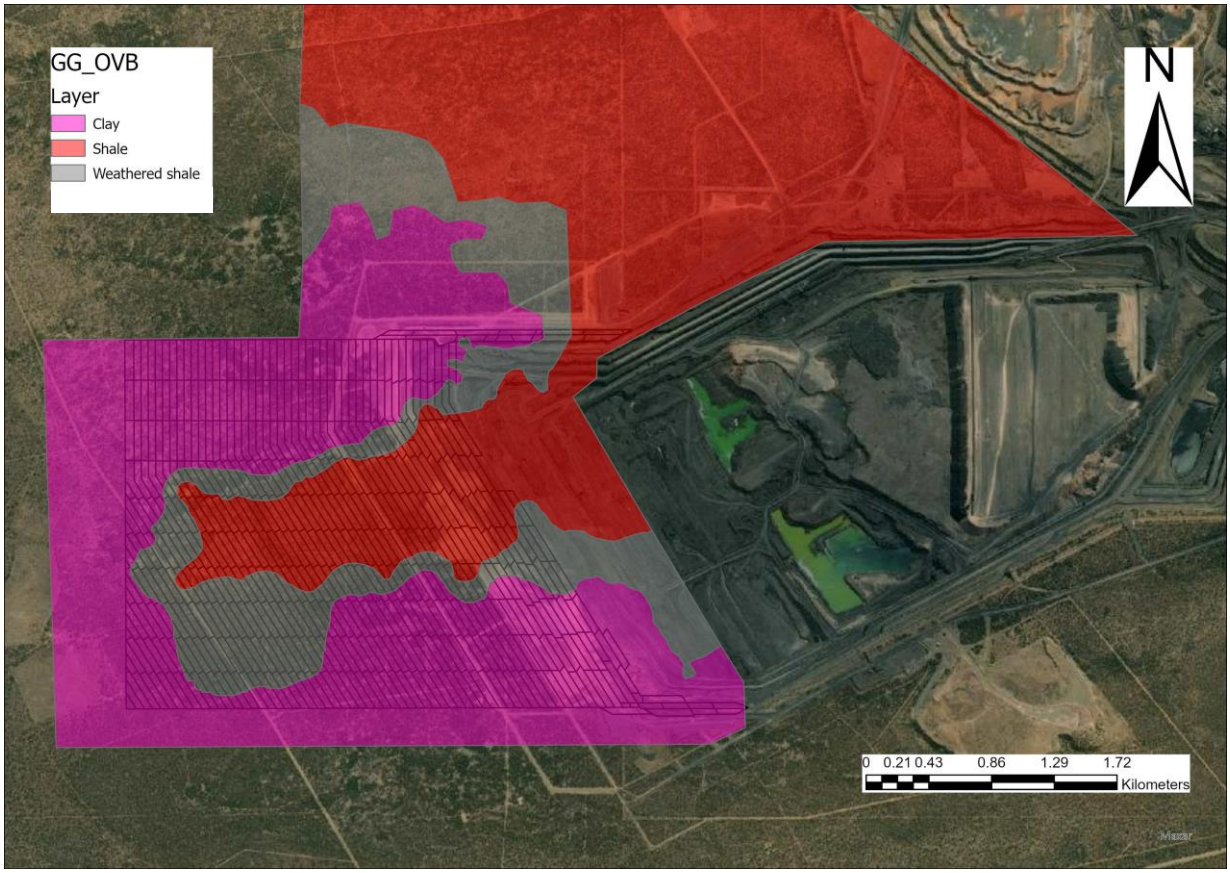

Figure 9. Aerial map of the three main overburden material types created by the numerical model adopted from Gerber (2017).

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CHAPTER THREE- METHODOLOGY

3.1 Method to quantify overburden on vertical scale – 3D model

The method of investigation was approached in four phases. The first three phases aimed to model and quantify the overburden material types ahead of the mining face on a vertical scale, and in phase 4 an overburden classification per bench, per mining block was determined.

3.1.1 Input data

Four data types were utilised as input for the geological model, that is:

- Point data,
- Polyline features,
- Table data and
- Surfaces exported from the 2022 Grootegeluk Long Term Model (“GGLTM”).

The study area included a total of 223 drillholes, consisting of 171 percussion and 52 diamond drilled holes, drilled until 2021. These drillholes were exported from the acQuire database. The eight consecutive drill lines, with a drillhole spacing of 100 m x 350 m, along with the Short-Term Geological Model (“STM”) faults are confined by a newly created geological model boundary (Figure 10).

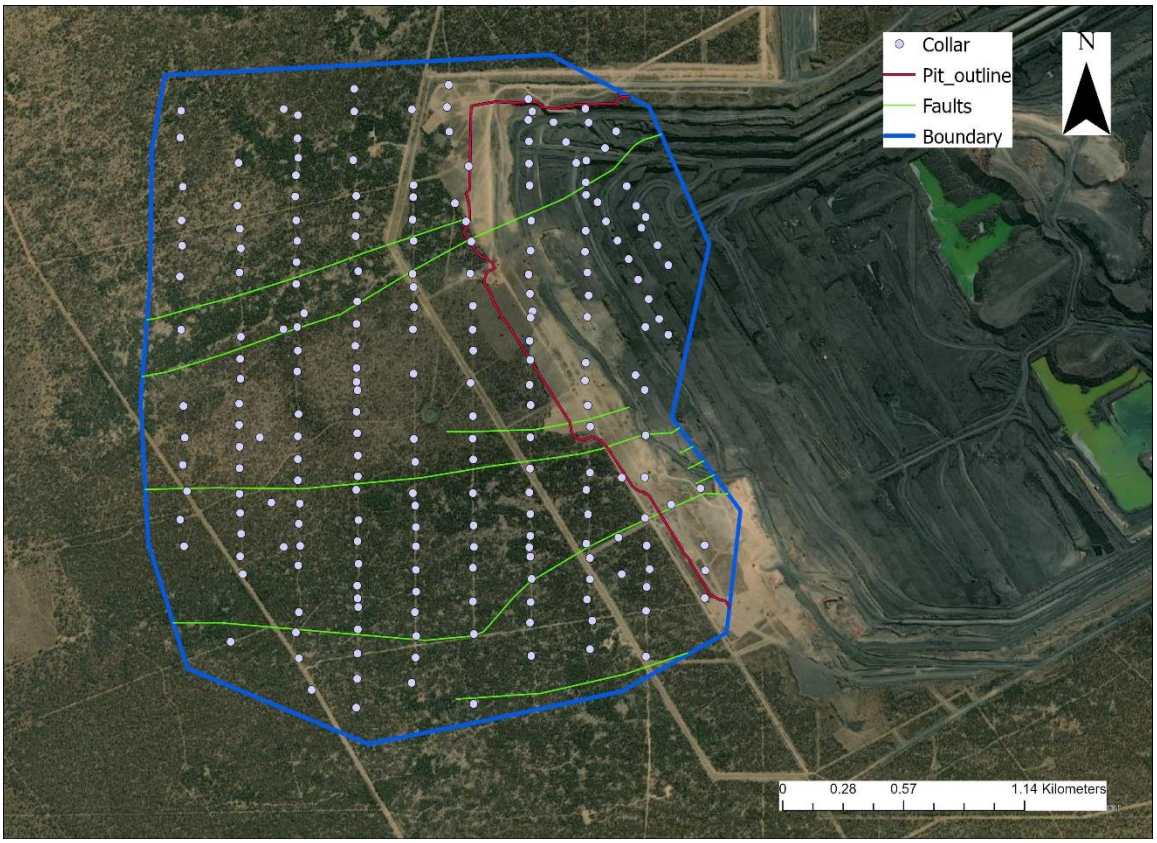


Figure 10. Map indicating the point data and polyline features used as inputs for the project overburden model.

Both the drillhole and structural data within the boundary were limited to the medium-term LOM window. The surfaces exported from the GG LTM include:

- Bench 1A seam floor (B1ASF);
- Bench 1B seam floor (B1BSF);
- Bench 1C seam floor (B1CSF); and
- TOC floor.

The drillhole data consists of the collar and lithology information. The project model extents were confined by the:

- Topography surface created by the collar information;
- TOC GG LTM surface; and
- The new project overburden model boundary.

All the data was validated and imported to the project overburden geological modelling software in phase 2.

3.1.2 Overburden resource modelling

3.1.2.1Software selection

Since it is characteristic of the overburden geology to be highly variable, with little to no lateral continuity, a creative approach to model these material types was required. The overburden lithology can be described as lenses, with pockets of clay and calcrete. The difficulty in modelling the overburden lies in the fact that:

- No chronology exists for the overburden succession;
- The lithology can be considered as weathered surfaces; and
- The lenses create “pinch-outs” with no orientation assigned to the horizontal extent.

To model the overburden material types, inherent to its characteristics, the geological modelling software needs to have the following capabilities:

- The ability to model in 3D;
- Ability to edit the chronology manually along a trend;
- Functionality to edit roof and floor vertices to create the “lense-effect”;
- Ability to assign the horizontal extent of the lenses and not confine it to a surrounding borehole’s lithology contacts; and
- Continually be able to draw cross-sections to validate the model constructed.

The geology software packages used by the Grootegeluk Geology Department, namely Minex and Surpac, are limited by one or more of the requirements above. Initially, open source software such as GemPy and ParaviewGeo was considered. Both software packages can model the overburden, but need extensive programming to meet all the requirements stated above.

The final option and solution was to utilise the Leapfrog Geo software. The software can model lenses in a 3D Scene View and the modeller can edit the vertices to adjust the horizontal extent. Hence, the software was utilised to model the different overburden material types either as lenses, or as erosion/weathered surfaces.

3.1.2.2 Summary on the steps taken to build the geological model

Prior to building the model, the Leapfrog Geo interface on the Seequent webpage (https://my.seequent.com/) was studied. The approach in building the overburden project model was to section it in phases. The first phase was to prove the model concept. A small area towards the south was identified and modelled by:

- Confining the upper and lower extent of that portion to the topography and the GG LTM TOC surface;
- Constraining the area to the first fault block and the model boundary to the south; and
- To determine trends within the lithology of the boreholes to assign a geological model chronology.

The project overburden model was constructed by subdividing the model area based on lithological trends identified concurrent with the STM faults. From south to north the model was divided into four fault blocks, (Figure 11). Each fault block was modelled separately, and subsequently amalgamated to form the final project model. A combination of implicit and explicit modelling tools was used to construct the model. The final overburden project model was exported in csv., grid surface dxf., and solid volume dxf. formats.

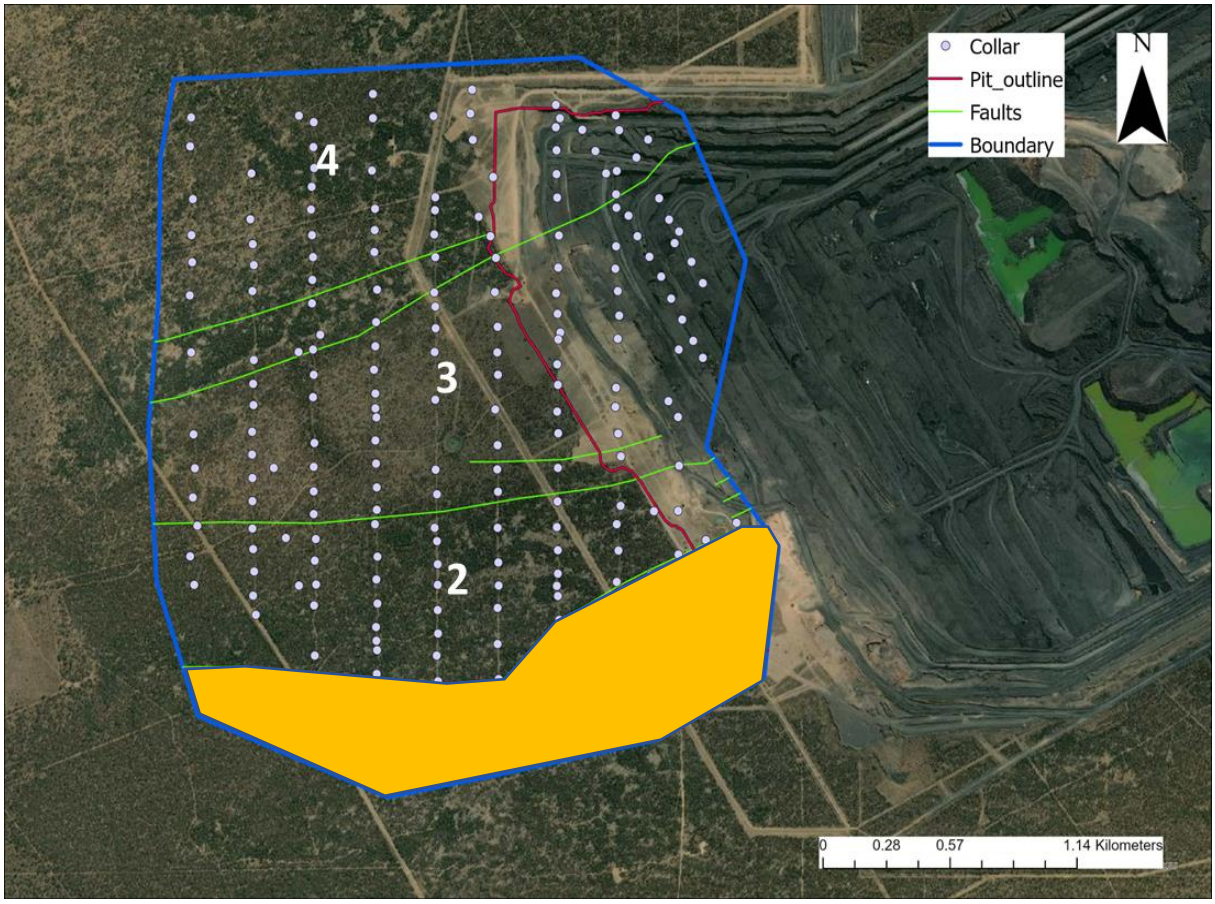


Figure 11. Schematic of the first fault block modelled as a proof of concept (highlighted in yellow).

3.1.2.3 Validations

The fault block models were continually validated by constructing cross-sections in the Leapfrog Geo Scene View (Figure 12). The general trend in lithology is to expect more clay in the south, with an increase in weathered shale in the middle portion of the middle-pit, and clays to the north. The cross-sections mainly outlined erroneous lithology trends inherent to Leapfrog Geo's software's resultant method of interpolation. The potential cause was investigated and solutions to identified errors were obtained. The methodologies employed to correct the interpolation errors within this project model included manually confining the horizontal extent of the lenses and investigating lithological unit thicknesses. The cross-section below is an example of a section taken from the south to the north and includes fault blocks 1 to 3.

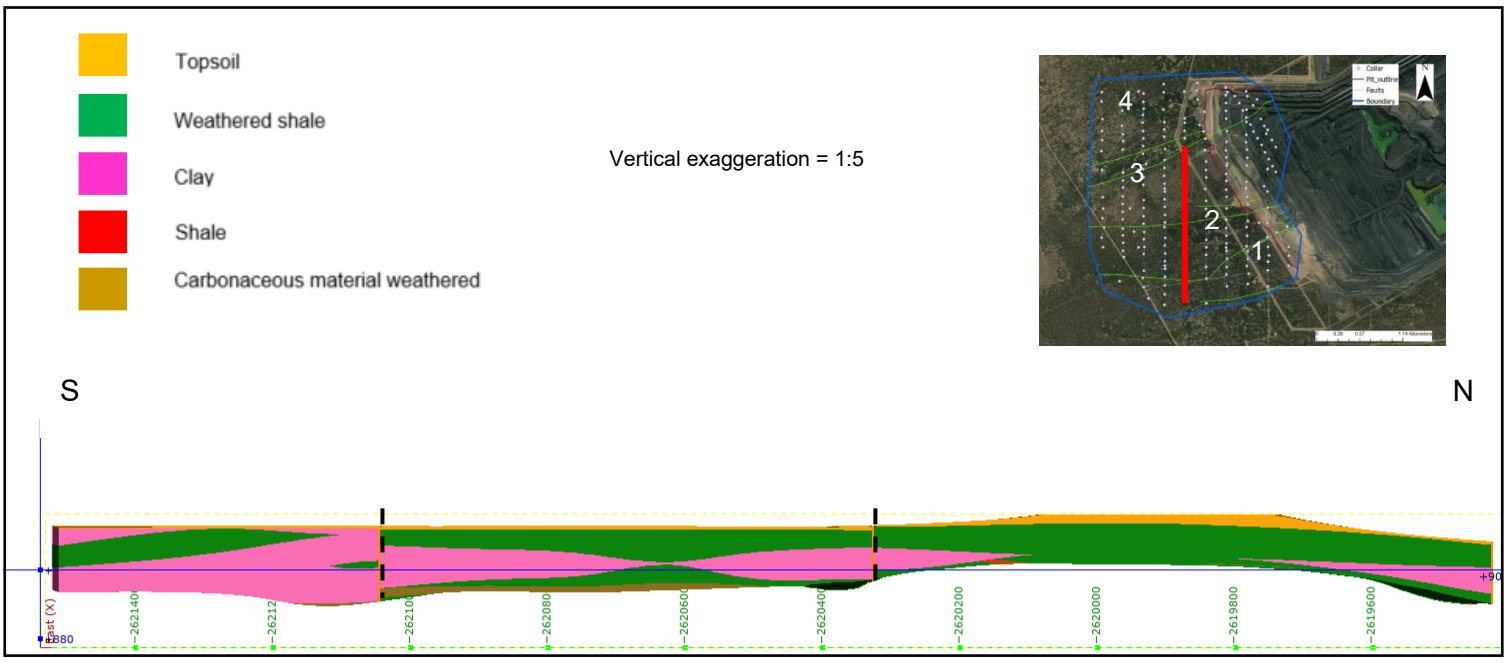


Figure 12. Example of a cross-section drawn from south to north directly ahead of the mining face.

3.1.3 Block model reserving

An unconventional method to reserve the overburden resource model was followed. Since the overburden can only be modelled representatively as lenses, the pinching-out characteristic of these material types also need to be reflected in the reserve model. Hence, the solid volumes for each overburden material type per fault block was imported into the Open Cast Coal Solution ("OCCS") software to reserve the project model.

Each solid volume unit per material type was interpreted as a separate mining pit. By doing so, the overburden resource project model could be sectioned with the 2022 GGLTM surfaces, namely the topography, B1ASF, B1BSF, B1CSF, TOC and the current medium-term mining block lay-out. The resultant data included the material types per bench and per mining block. The quantities of each material type were expressed as a volume. To calculate the overburden material-type tonnes per block, the following relative density factors were applied:

- Bench 1A and Bench 1B: 2.2 g/cm^3;
- Bench 1C: 2.1 g/cm^3.

The final data was exported as a csv file for phase 4. An example of the resultant overburden project block model is displayed in Figure 13.

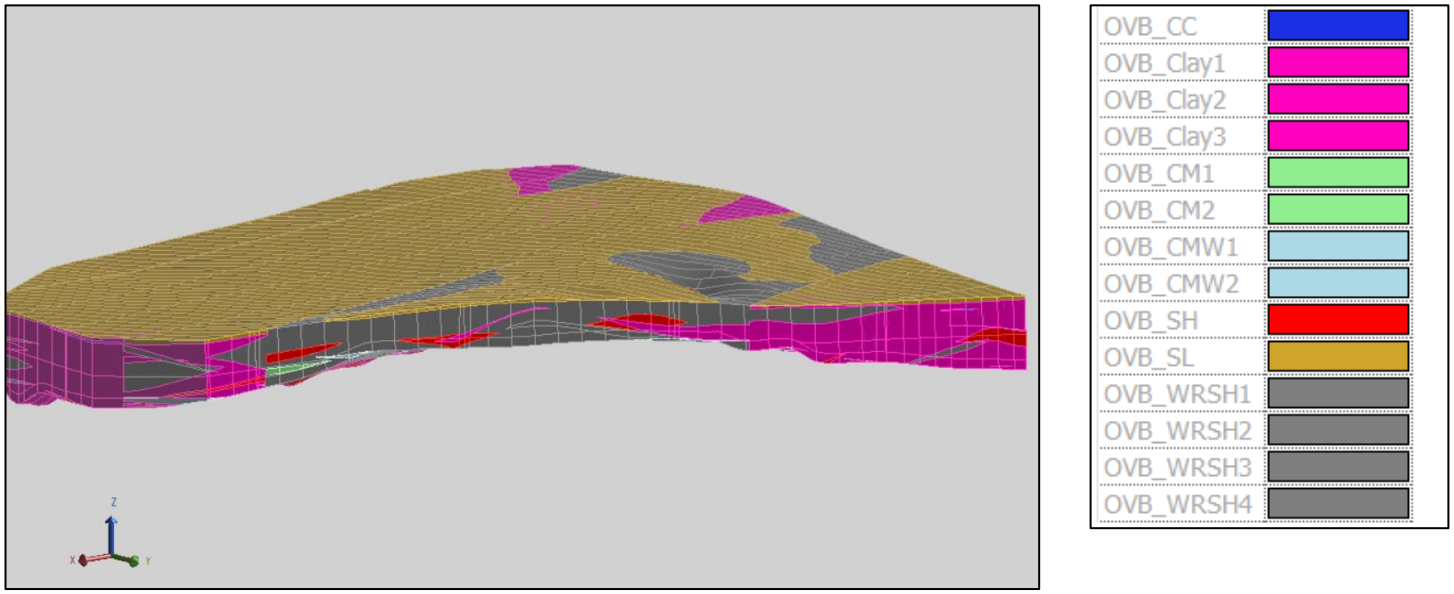


Figure 13. Picture on a section view of the overburden block model, as reserved in OCCS.

The legend acronym meanings are as follows: CC: calcrete; CM: Carbonaceous material; CMW: carbonaceous material weathered ; SH: shale ; SL: Top soil ; WRSH: weathered shale

3.1.3.1 Validations

The material-type volumes of the *project overburden resource model* were calculated per bench and reported from Point Studio. The *block model reserved* material-type volumes were also exported and compared with the resource volume totals. The total percentage difference in volume between these two models is 0.56%. Applicable commentary is noted and will be investigated (Table 4).

Table 4. Comparison of the material-type volumes for the overburden resource model and the reserved block model.

Material types	Point Studio Volumes	OCCS Volumes	Percentage similarity	Variance	Comment
Carbonaceous material weathered_1	1223406	1223406	100.00	0.00	
Carbonaceous material weathered_2	211318	211318	100.00	0.00	
Calcrete	891488	891488	100.00	0.00	
Clay_1	70932505	70928079	99.99	0.01	
Clay_2	1714692	1714692	100.00	0.00	
Clay_3	62604	62604	100.00	0.00	
Carbonaceous material_1	353788	353788	100.00	0.00	
Carbonaceous material_2	57393	57393	100.00	0.00	
Shale	8868081	8868081	100.00	0.00	
Top soil	5823928	5171114	88.79	11.21	Topography need to be adjusted to the 2022 GG LTM
Weathered shale_1	35608434	32169548	90.34	9.66	Point Studio volume need to be revised
Weathered shale_2	2562496	2562496	100.00	0.00	
Weathered shale_3	814084	814084	100.00	0.00	
Weathered shale_4	10617	10617	100.00	0.00	
Total volumes from topo to TOC	125747636	125038708	99.44	0.56	

3.1.4 Mining block overburden classification

In the final phase each mining block for Bench 1A and Bench 1B was assigned an overburden material-type value based on the proportion of material quantities available within it. The major overburden material types, which either consist of clay, weathered shale or competent shale, were mapped in ArcGIS Pro. Bench 1C was excluded from this classification since the average thickness of this bench is 3.29 m for the modelled area. All material from Bench 1C is considered to be carbonaceous and is dispatched to be sealed within the backfill.

3.2 Updated overburden classification and defining competent shale areas – 2D geological maps

3.2.1 Exploration plans and execution

A total of 20 diamond and 104 percussion drillholes (Figure 14) were drilled and logged from 2022 to 2023. In support of classifying the overburden, all diamond drillholes' weathered material and the percussion chips from percussion drillholes (Figure 15) were logged, and interpreted based on the historical overburden classification methodology. The resultant information was used to update the existing overburden resource classification maps.

3.2.2 Geological logging of percussion drillholes

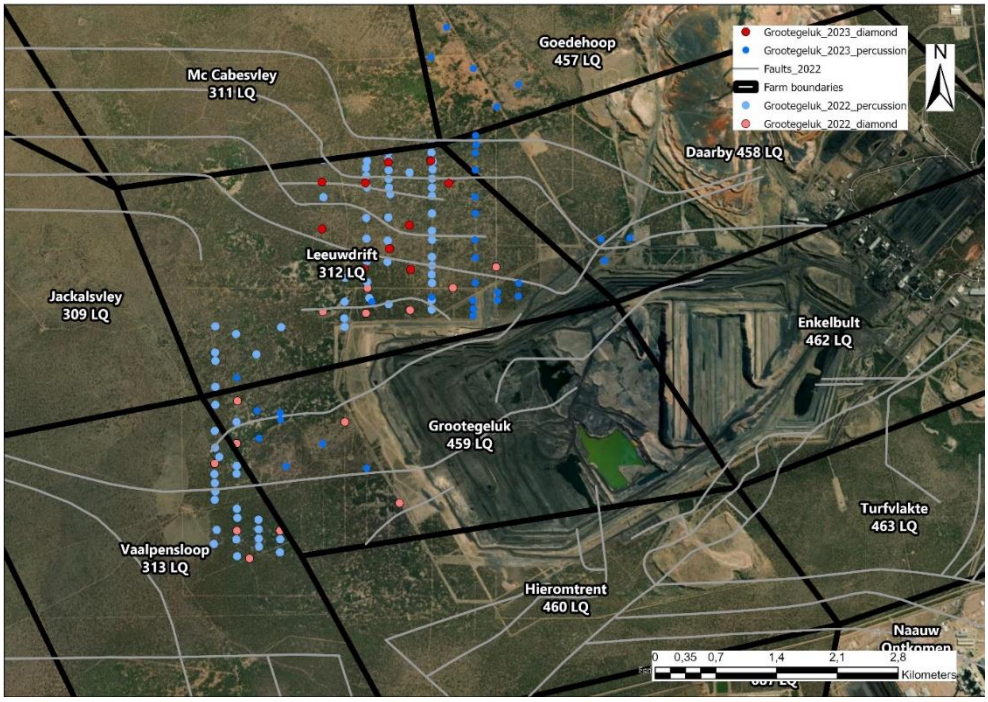


Figure 14. Map of diamond and percussion drillholes logged in 2022 and 2023.

The percussion chips are drilled on a metre interval and placed on a ten-metre grid to log geologically. The standard field logging parameters are noted, which includes:

- The depth intervals,
- Main lithology,
- Sub-lithology with proportions,
- Grain size,
- Degree of weathering,
- Colour,
- Moisture in sample,
- Bench intervals,
- Top-of-coal depth, and
- Suspected structures.

The overburden material types are characterised based on the methodology used in section 2.1.7.

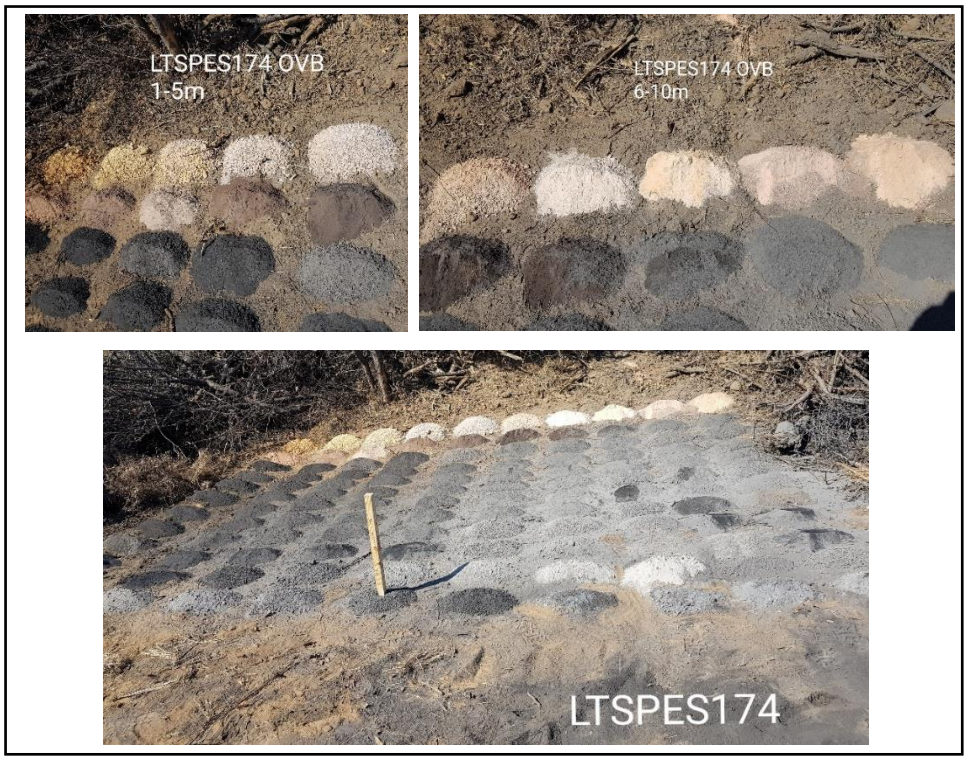


Figure 15. Photo of percussion chips from a percussion drillhole.

3.2.3. Methodology to update overburden classification resource maps

All the geological interpretations of the overburden material types consolidate to the three main types for ease of mining. The geological descriptions of the rock types within the entire stratigraphic profile of the overburden in a drillhole are classified as either shale, weathered shale, or clay. For the 2023 classification this was accomplished by including both the weathering intensity methodology, in conjunction with the majority proportion

material type present in terms of thickness:

- Shale – where the material in the overburden is predominantly unweathered shale material (>75% in thickness proportion and/or ≤25% weathering intensity) with minor amounts of other rock types like weathered shale and/or calcrete;
- Weathered Shale – where the material in the overburden consists of predominantly weathered shale material (>50% in thickness and/or between 25-50% weathering intensity) but can also contain some shale, clay, and/or other rock types; and
- Clay – where the material in the overburden consists of predominantly clay material (>50% in thickness and/or ≥50% weathering intensity) but can also contain other rock types like weathered shale and/or weathered carbonaceous material.

Once classified, the main overburden lithology types are spatially visualised by modelling the shale, weathered shale, and clay, in ArcGIS Pro. The 2D polygons are subsequently exported for mine planning purposes.

3.3 Overburden material type quantities comparison

Two overburden quantity comparisons are drawn:

1. The comparison of the 2022 3D project overburden model and the 2022 2D overburden classification map. The aim is to depict the variance in the overburden material types' quantities with an increase in lithological resolution on a vertical scale. The reporting is standardised to the 3D models' block model boundary and results are confined to the middle-pit; and

2. The comparison between the 2022 and updated 2023 overburden resource classification maps. The 2023 map includes the interpreted overburden classification for the 2022-2023 exploration programme. The figures presented are inclusive over/of the LOM area.

CHAPTER FOUR - RESULTS AND DISCUSSION

The results for both quantification methodologies, as described in section 3.3., with the addition of the shale potential for the overburden resource classification maps (2022-2023), are provided in Table 5.

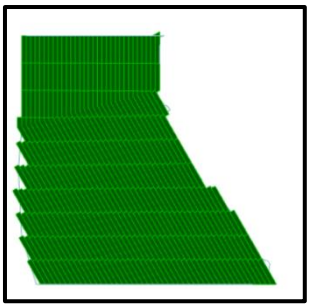
Table 5. Resultant quantities for the middle pit's shale, weathered shale and clay overburden material for the project overburden model of 2022 (2022_3D) and the standard numerical model updated for 2022 (2022_2D) and the overburden classification maps for 2022 and 2023.

Middle-pit						
	Block models			LOM		
Total	2022_2D	2022_3D	Variance	2023 Overburden classification	2022 Overburden classification	Variance
Units	Mt	Mt	Mt	Mt	Mt	Mt
Weathered shale	35.01	38.49	3.48	19.86	35.01	-15.14
Shale	21.64	8.64	-13.00	17.41	21.64	-4.23
Clay	99.98	96.91	- 3.08	129.31	99.98	29.33
Total	156.63	144.04		166.58	156.63	
			-12.59			9.95
Shale potential				55.75		
B1A	2022_2D	2022_3D	Variance	2023 Overburden classification	2022 Overburden classification	Variance
Units	Mt	Mt	Mt	Mt	Mt	Mt
Weathered shale	28.99	36.52	7.53	16.98	28.99	-12.01
Shale	21.03	6.91	-14.13	17.00	21.03	-4.03
Clay	62.66	57.72	- 4.93	82.23	62.66	19.57
Total	112.68	101.15		116.20	112.68	3.52
			-11.53			3.52
Shale potential				38.19		
B1B	2022_2D	2022_3D	Variance	2023 Overburden classification	2022 Overburden classification	Variance
Units	Mt	Mt	Mt	Mt	Mt	Mt
Weathered shale	6.02	1.97	-4.05	2.89	6.02	-3.13
Shale	0.61	1.74	1.13	0.41	0.61	-0.20
Clay	37.33	39.18	1.85	47.09	37.33	9.76
Total	43.95	42.89		50.38	43.95	6.43
			-1.06			6.43
Shale potential				17.56		

4.1. 2D vs. 3D volume comparison for middle pit

Table 6. Comparison of the current numerical block model and project block model shale, weathered shale and clay quantities for Bench 1A.

Current overburden block model	Tonnes
B1A Weathered Shale	28 989 730
B1A Shale	21 034 313
B1A Clay	62 655 900
Total	112 679 943



Overburden project block model	Volumes	RD	Tonnes
B1A Weathered Shale	16 601 484	2.2	36 523 264
B1A Shale	3 139 239	2.2	6 906 326
B1A Clay	26 237 813	2.2	57 723 189
B1A Calcrete	826 256	2.2	1 817 764
B1A Top soil	3 310 410	2.2	7282903
B1A Carbonaceous material	13 475	2.2	29646
B1A Carbonaceous material weathered	3 414	2.2	7511
Total	50 132 092	2.2	110 290 602

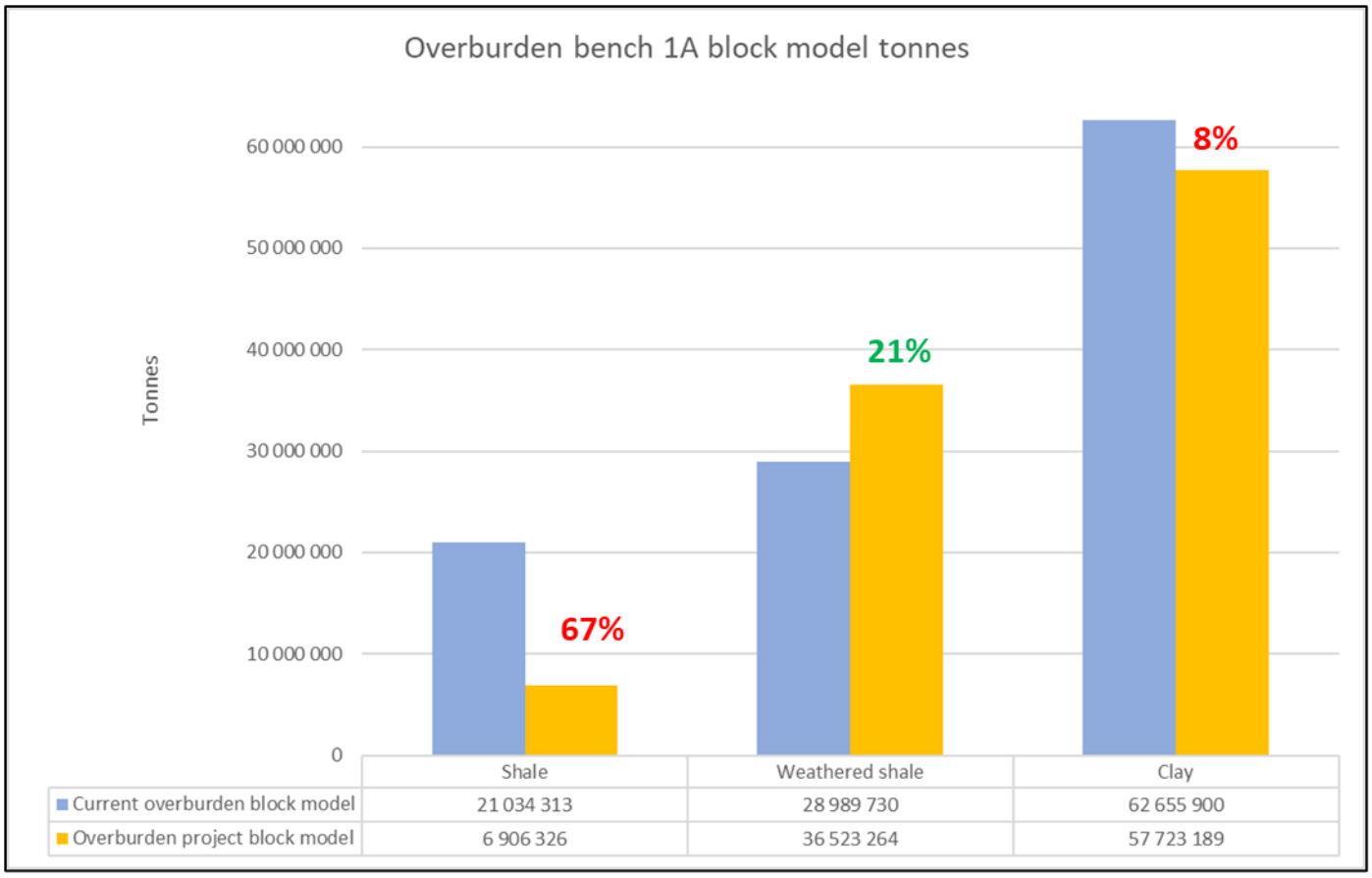


Figure 16. Graph depicting variability in numerical model and the vertical model for the major overburden material-type tonnes obtained in Bench 1A.

Table 7. Comparison of the current numerical block model and project block model shale, weathered shale and clay quantities for Bench 1B.

Current overburden block model	Tonnes
B1B Weathered Shale	6 015 882
B1B Shale	605 860
B1B Clay	37 328 846
Total	43 950 588



Overburden project block model	Volumes	RD	Tonnes
B1B Weathered Shale	893 943	2.2	1 966 675
B1B Shale	790 222	2.2	1 738 487
B1B Clay	17 810 080	2.2	39 182 175
B1B Carbonaceous material	16 889	2.2	37 156
B1B Carbonaceous material weathered	92 710	2.2	203 961
Total volume	19 603 843	2.2	43 128 455

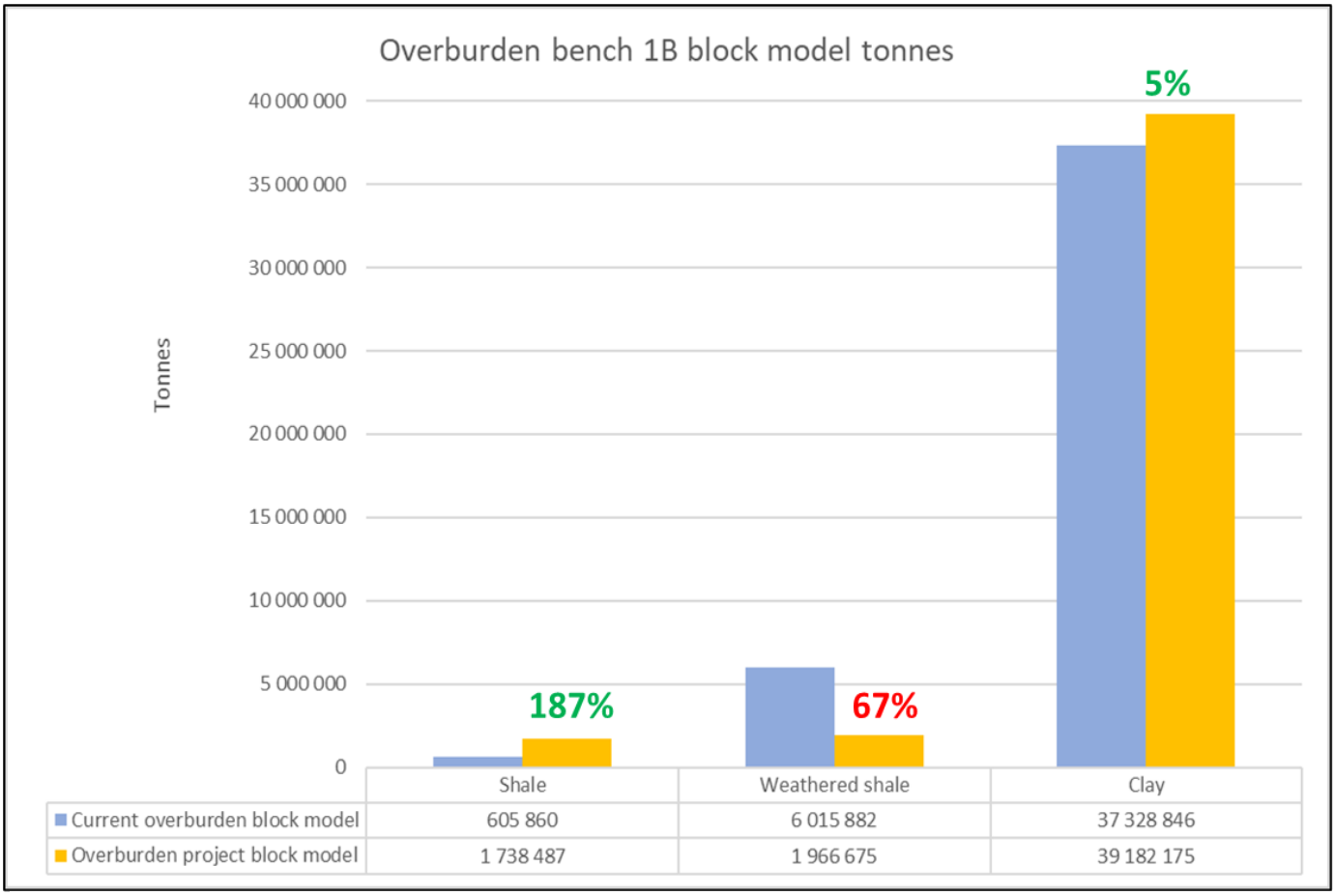


Figure 17. Graph depicting variability in numerical model and the vertical model for the major overburden material-type tonnes obtained in Bench 1B.

The project overburden model was initiated to quantify the overburden material types on a vertical scale to alleviate some of the short comings experienced with the current numerical model utilised. By comparing the material volumes from both the current overburden model and the project overburden model, the following findings are apparent:

- Bench 1A

  The total volume variance between the current overburden block model and the project model is 2.12%. This is ascribed to the different interpolation methodologies employed by each model. The current overburden model was interpolated based on the IDW function, while the project overburden model was modelled on the radial basis function ("RBF");

  The two block models' comparison of the major overburden material-type quantities shows a decrease of 67% competent shale tonnes and 8% decrease in clay tonnes (Table 6 and Figure 16). The weathered shale quantities, however, increased by 21%. The remaining volume variance between the block models is due to the inclusion of calcrete, topsoil, carbonaceous material and carbonaceous material weathered on the vertical scale;

- Bench 1B

  Over an average thickness of 4.3 m, this bench's quantification of its material types on a vertical scale indicates an increase in competent shale tonnes by 187% (Table 7 and Figure 17). In contrast, the weathered shale quantities decreased by 67%. The clay material volumes remained fairly constant at a 5% variance.

The difference in reported tonnages for the shale, weathered shale and clay for Bench 1A and Bench 1B is due to the *inclusion of the full lithological succession in the project model.* By comparison, the volumes of the three main material types will differ based on the volume proportions of the different overburden material types present. This however is not an indication of the variance in practical mineable tonnes. To obtain an indication of the variance in practical mineable tonnes, the mining block overburden classification for Bench 1A and Bench 1B were mapped. Bench 1A indicates a notable decrease in mineable competent shale tonnes ahead of the mining face in comparison to the current numerical model (Figures 18 and 19). This presents a risk as diminished quantities of competent shale material will effectively stop the construction of the LEN and UEN. As a result, if no practical solutions are implemented, production will be impacted. The overall increase in weathered shale material is also highlighted by the fact that for the past three years, competent shale has been

exploited (Figure 20). The weathered shale material ahead of the face does not have the same physical properties as the competent shale and cannot be allocated to the LEN and UEN without the approval of the on-site Rock Engineer.

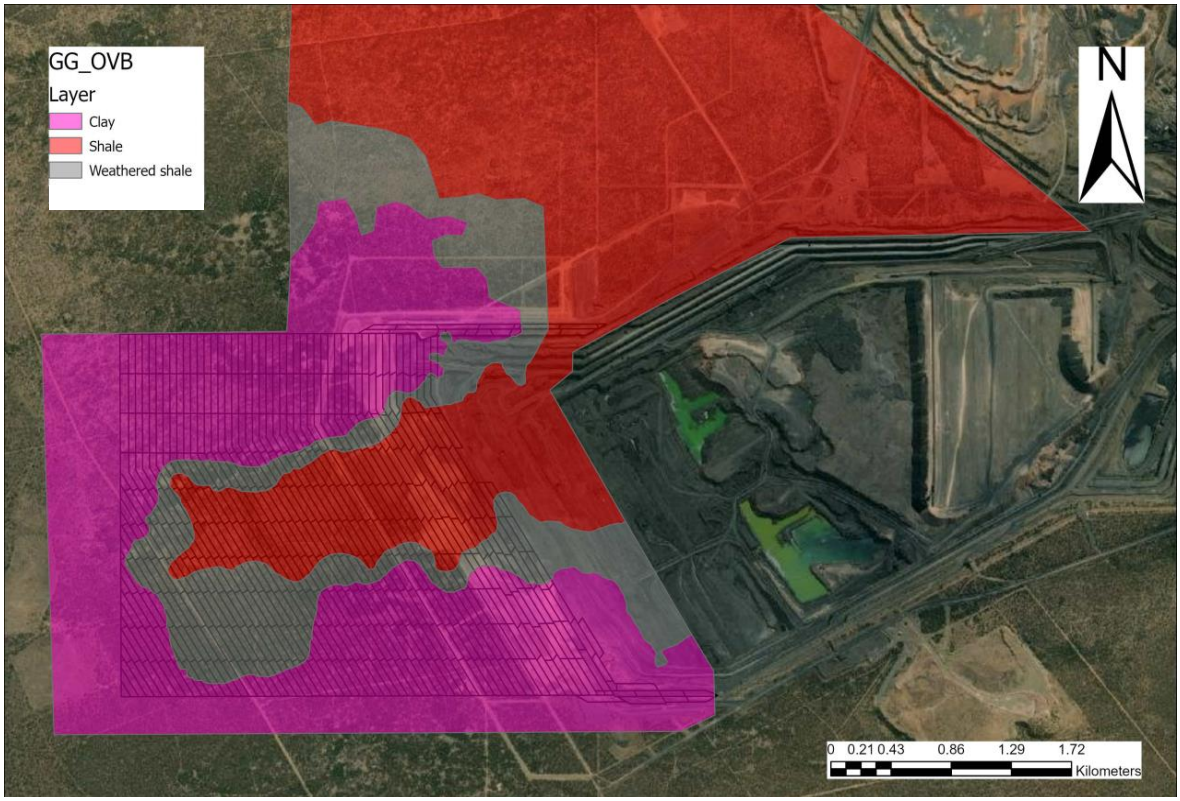


Figure 18. Aerial map of the three main overburden material types created by the numerical model.

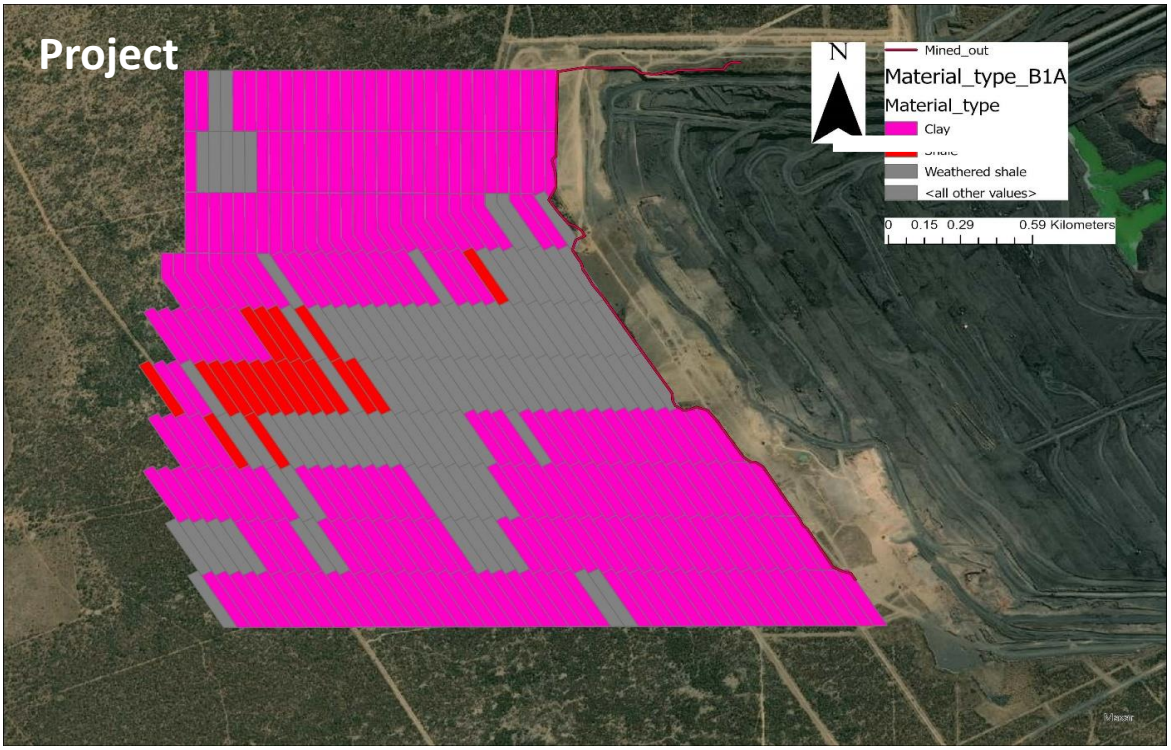


Figure 19. Map of the mining block overburden classification for the project block model in Bench 1A ahead of the mining face.

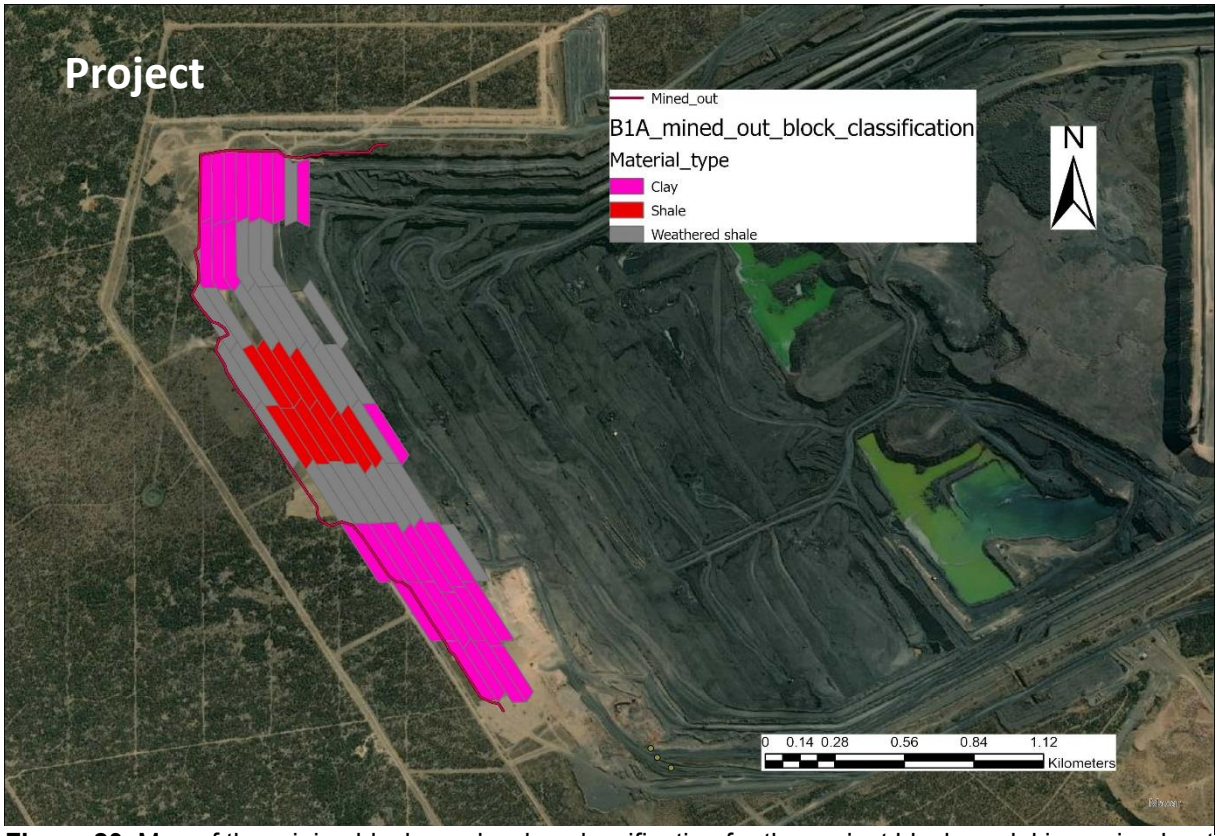


Figure 20. Map of the mining block overburden classification for the project block model in a mined-out portion of Bench 1A.

Likewise, the results indicate that Bench 1B is also depleted of competent shale quantities (Figures 21 and 22). Based on the current overburden model, the long-term mine scheduling plan indicates that along the most western bounds, and towards the start of the northern box-cut (Appendix Figure 4), there is an estimated three-year period where only clay and weathered shale will be mined. A plan is in place to mitigate this risk by allocating a box-cut, comprising of two strips of Bench 1A, towards the northern boundary of the northern box-cut area. This area is currently planned to be exploited for the period of 2029 to 2032. In the project mining block overburden classification, however, the risk is immediate.

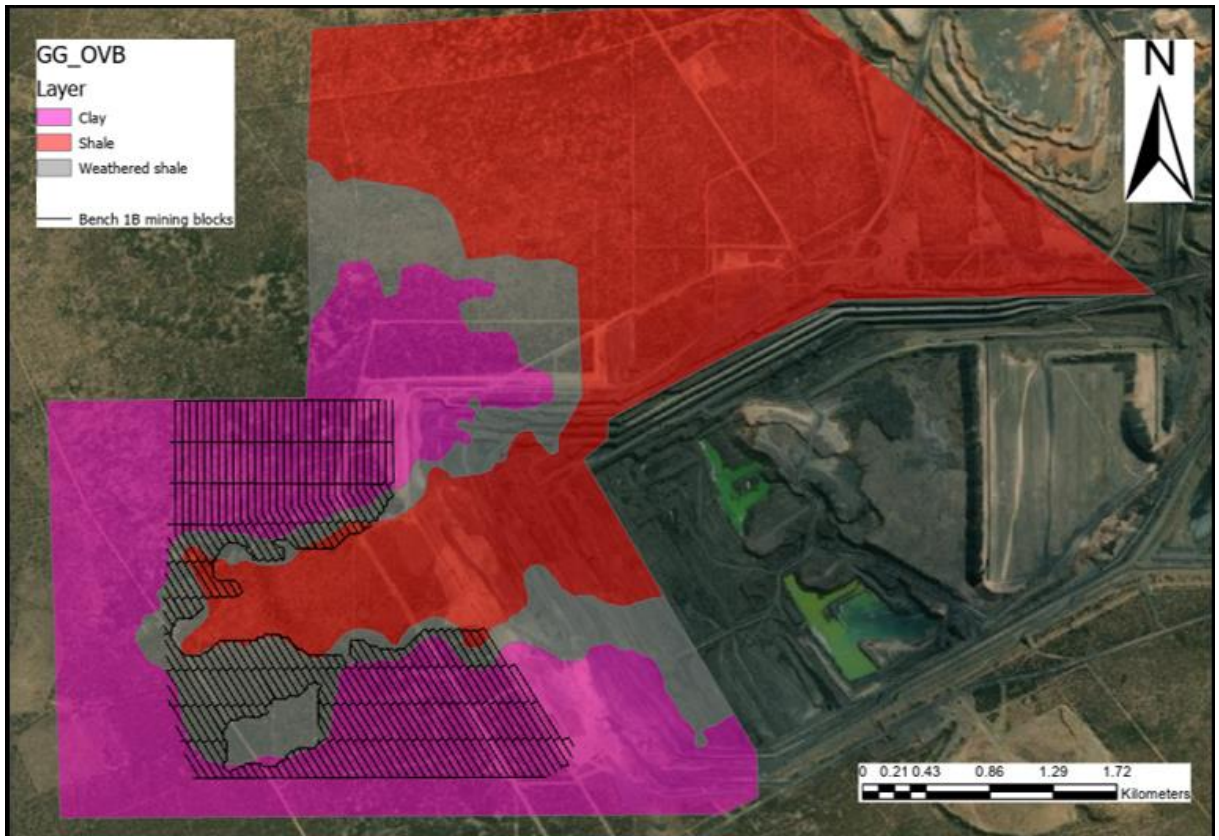


Figure 21. Aerial map of the three main overburden material types created by the numerical model with the 2022 Bench 1B mining block lay-out.

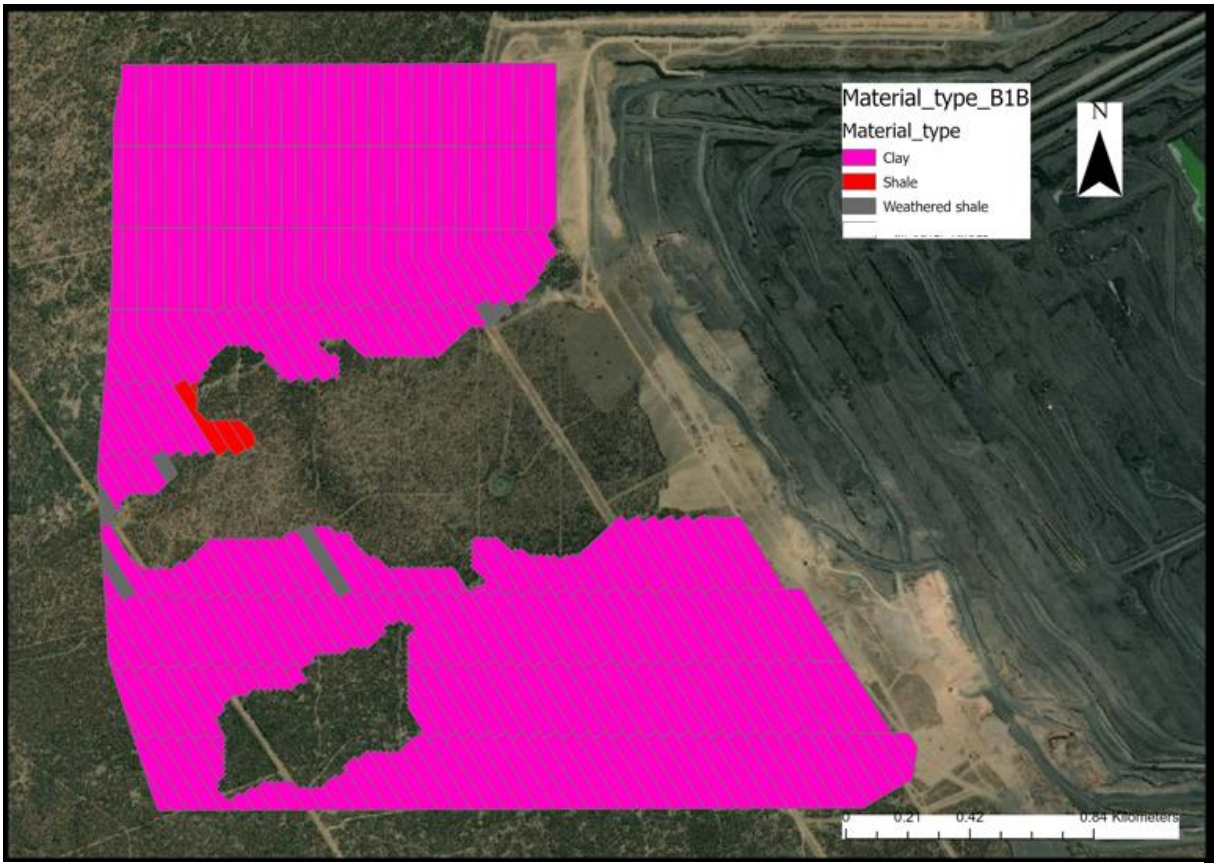


Figure 22. Map of the mining block overburden classification for the project block model in Bench 1B ahead of the mining face.

4.2. Overburden classification map for 2023

The overburden interpretation with the inclusion of the 2022-2023 exploration campaigns is depicted in Figures 23 and 24. There is a notable difference in the spatial distribution of the three main material types across the overburden resource area between the previous (Figure 18) and the updated overburden resource classification maps. The change in weathered shale portions is most noticeable with a decrease in both the middle-pit and northern box-cut areas. The approximately 15 Mt decrease (Table 5) in the weathered shale classification is off-set by an increase in the clay accompanied by a delineation of areas with shale potential. The middle-pit displays a trend of increasingly deeply weathered areas and increasing weathering intensity towards the south and north of the middle-pit. In the northern portions of the middle-pit and in the direction of the north pit, only clay material is dominant, with no competent material identified. This highlights the risk of mining in clay-dominant areas only for a significant period, as the middle-pit will migrate to open the northern-pit's boxcut.

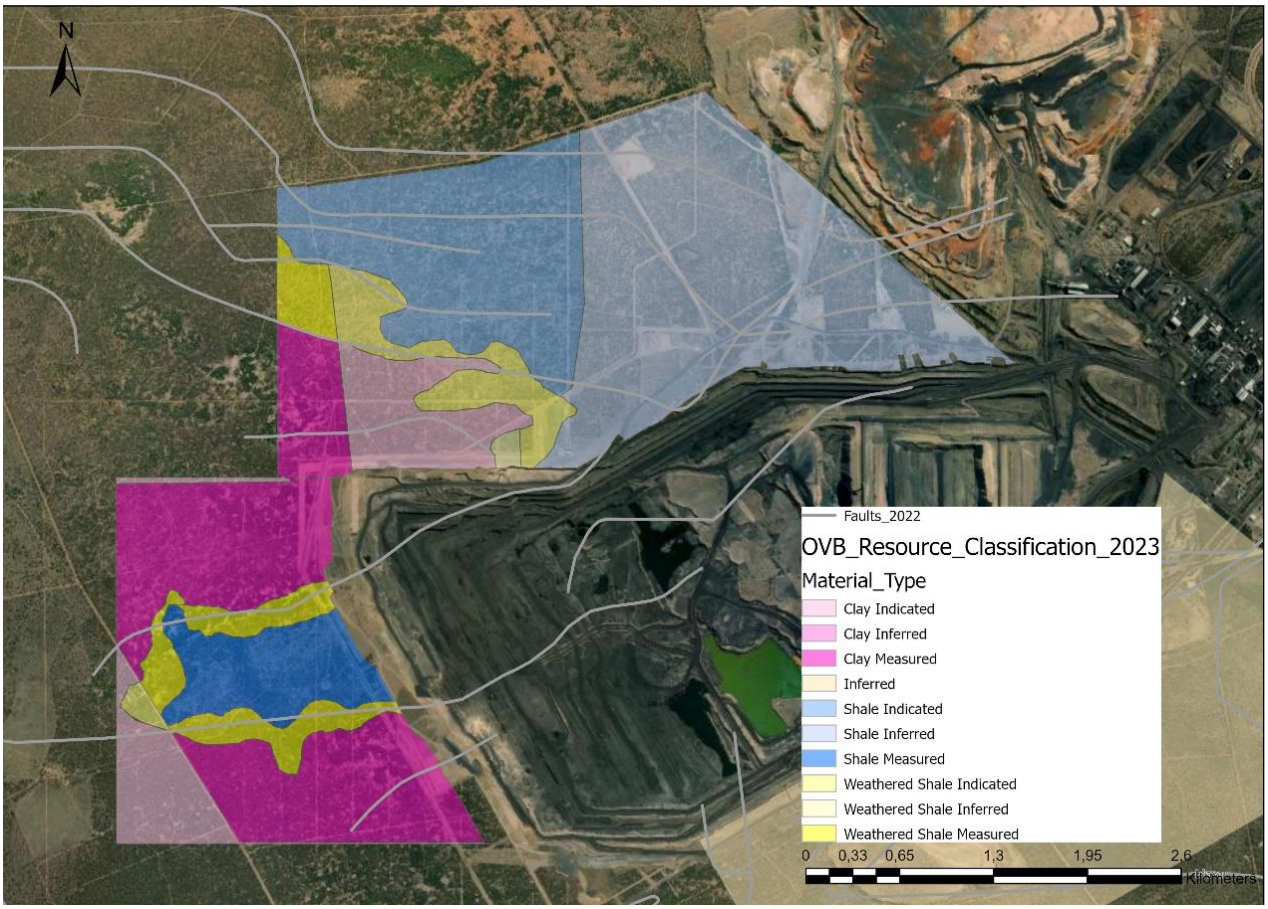


Figure 23. Overburden resource classification map for 2023.

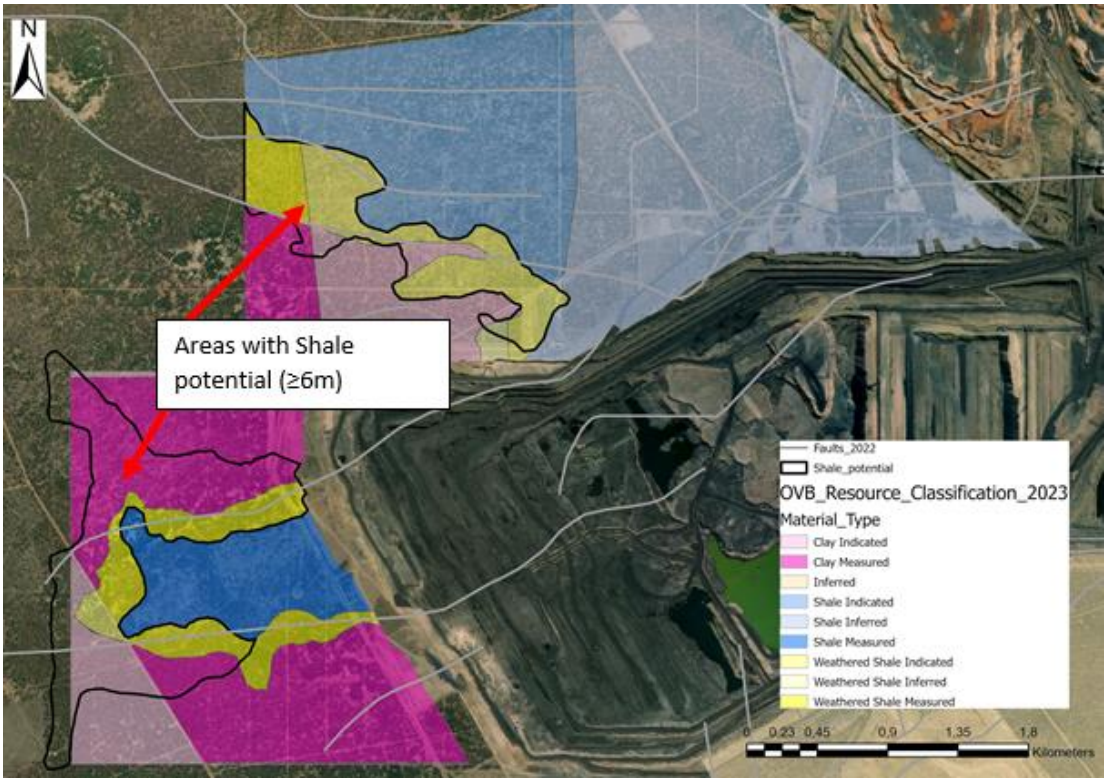


Figure 24. Overburden resource classification map for 2023 indicating areas where competent shale has a thickness ≥ 6m close to topographic surface.

The competent shale material classification has a slight difference for the middle-pit in the updated classification – a 4.23 Mt decrease (Table 5). The material value lies in the identification of the shale potential resource in the current mining direction. In addition to the approximately 17 Mt of competent shale dominant mining blocks identified, a 55 Mt shale potential area is delineated. If selective mining practices can be employed, a vast shale resource can be unlocked for the LEN and UEN's construction.

To increase the confidence in the shale's spatial distribution, and to alleviate some of the uncertainties in the variability of weathering profiles (Appendix Figures 1-5), there is a need to decrease the short-term drill spacing within Bench 1 to 20 m x 20 m lines at a 90 m interval. Additionally, continue to inspect and map the mining face, and communicate the allocation of the overburden material from specific mining blocks.

Across the LOM resource area it is noticeable that the majority of the usable shale is located within the northern-box cut areas (Figure 23), and the shale deepens towards the north, in the vicinity of the Daarby Fault (Appendix Figure 6-8). This information is however based on Indicated and Inferred overburden classification and will continue to be improved by increasing the confidence of the classification with the inclusion of additional drillholes. If the direction of mining for the northern-pit continues from west to east, then mine planning in sequence with the shallow (south) to deep (north) situated shale will aid in allocating the necessary quantities needed for constructing the backfill.

For the periods when mining will commence through the exploitation of areas dominated by clay and weathered shale, with limited to no competent shale in the overburden, the following solutions are proposed:

- Refine the mine schedule to synchronise the exploitation of competent shale material with the ROM, even if the competent shale material needs to be sourced from a feasible borrow pit;

- Optimise the utilisation of the blasted interburden material and conduct a cost analysis on the reduction of the blasted sandstone particle sizes. The options may include adjusting the fragmentation parameters on the drill and blast block designs and/or allocating an in-pit crusher for waste material sizing; and

- Investigate opportunities for material blending to construct the LEN and UEN.

CHAPTER FIVE- CONCLUSION

GCM has managed to maintain the balance between saleable coal product production and the generation of discard at the beneficiation plants. The rate of discard generation mandates the continuous backfill strategy. The design constraint of the backfill is within the extendable platforms, where only competent material can be placed. In the LOM area, the competent material for placement is readily available from the overburden and interburden as shale and sandstone. The challenge for material allocation from the overburden lies within the spatial distribution of the competent shale and the subsequent allocation thereof in line with mine scheduling. The 3D proof-of-concept overburden study for the middle-pit contributed to the vertical resolution and quantified the various weathered lithology types of Bench 1 in detail. This study contributes to the outcome of GGAMS and assists in delineating portions of competent material within the overburden that can be mined selectively in the middle-pit. The model can be expanded to include the northern box cut to support future cost-saving operational projects.

The overburden classification map categorises the overburden material types into three main types; this eases the execution of the current mine schedule. The addition of delineated areas of potential shale will support the operation to retrieve competent material when constrained in the mine sequence. The results from the two models indicate that classified shale areas ahead of the current mining face need to be consistently evaluated in the short-term for operational support, and the removal of competent shale needs to be synchronised within the mining schedule. The medium-term risk of unavailable competent shale can be managed by either allocating box cuts ahead of the five-year mining schedule or by selectively mining the Bench 1 during dry seasons. Additionally, the interburden sandstone can be stockpiled in advance as lower benches are exposed.

REFERENCES

Alberts, B. C. 1982. The planning and establishment of the Grootegeluk Coal Mine. *Journal of the South African Institute of Mining and Metallurgy,* 82*,* 341-352.

Catuneanu, O., Wopfner, H., Eriksson, P., Cairncross, B., Rubidge, B., Smith, R. & Hancox, P. 2005. The Karoo basins of south-central Africa. *Journal of African Earth Sciences,* 43, 211-253.

Collis, L. & Smith, M. R. 1993. *Aggregates: sand, gravel and crushed rock aggregates for construction purposes*, Geological Society.

Dippenaar, A., Esterhuysen, C. & De Wet, N. 1983. A mobile in-pit crushing system for overburden at Iscor's Grootegeluk coal mine.

Du Plessis, M.C. 2019. Characterization of overburden in the Grootegeluk Mining Rights Area (GGMRA), contained in its life of mine (LOM).

Faure, K. 1993. Minerology and geochemistry of the carbonaceous mudstones and coal petrogenesis of the Grootegeluk formation in the Waterberg coalfield, South Africa.

Fourie, C., Henry, G. & Maré, L, 2009. The structure of the Karoo-age Ellisras Basin in Limpopo Province, South Africa in the light of new airborne geophysical data: a preliminary report. 11th SAGA Biennial Technical Meeting and Exhibition.

Gerber, A. 2017. Interpretation of the Overburden Classification data for Grootegeluk Coal Mine. Exxaro Resources (Pty) Ltd.

Hancox, P. J. & Götz, A. E. 2014. South Africa's coalfields—A 2014 perspective. *International Journal of Coal Geology,* 132, 170-254.

Janse Van Rensburg, W. 2016. Overburden classification and weathering project. Exxaro Resources (Pty) Ltd.

Mtimkulu, M. N. 2010. *A provisional basinal study of the Waterberg-Karoo, South Africa.* University of Pretoria.

Vermeulen, PD., Bester, M., Cruywagen, L-M and Van Tonder, GJ. (2009). Scoping level assessment of how water quality and quantity will be affected by

mining method and mining of the shallow Waterberg coal reserves west of the Daarby fault. WRC Report No.K5/1830/

South African Committee for Stratigraphy (SACS) (1980). Stratigraphy of South Africa. Part 1 (Compiled by L.E. Kent). Lithostratigraphy of the Republic of South Africa, South West Africa / Namibia, and the Republics of Botswana, Transkei and Venda: Handbook Geological Survey South Africa 8.

SANS 10320 (2020). South African National Standard: South African Guide to systematic evaluation of coal resources and coal reserves. Standards South Africa, 40 pp.

Van Heerden C.W. 2018. Competent Persons Report: Exxaro Resources (Pty) Ltd, Grootegeluk Coal Mine.

APPENDIX

Cross-sections

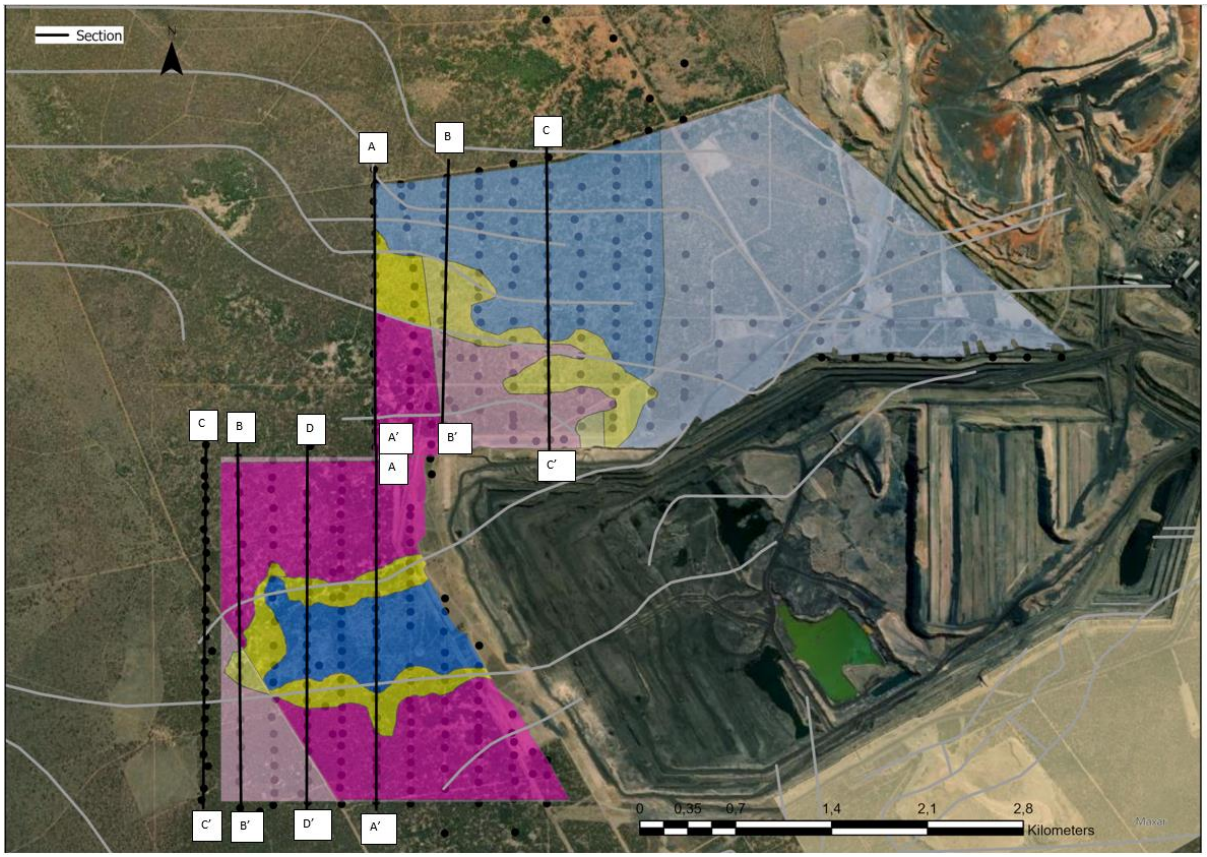


Figure 1. Overburden classification map of 2023 with section lines for the middle-pit and northern box cut areas.

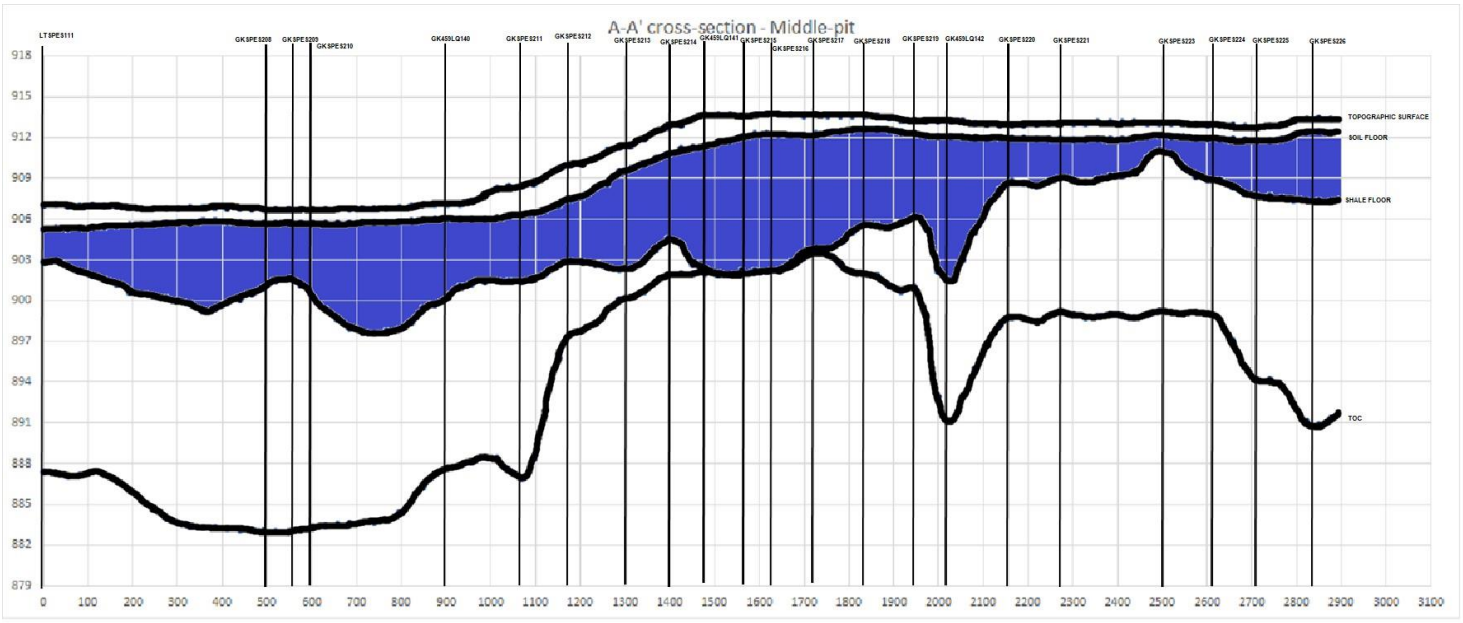


Figure 2. Cross-section of A-A’ in middle-pit.

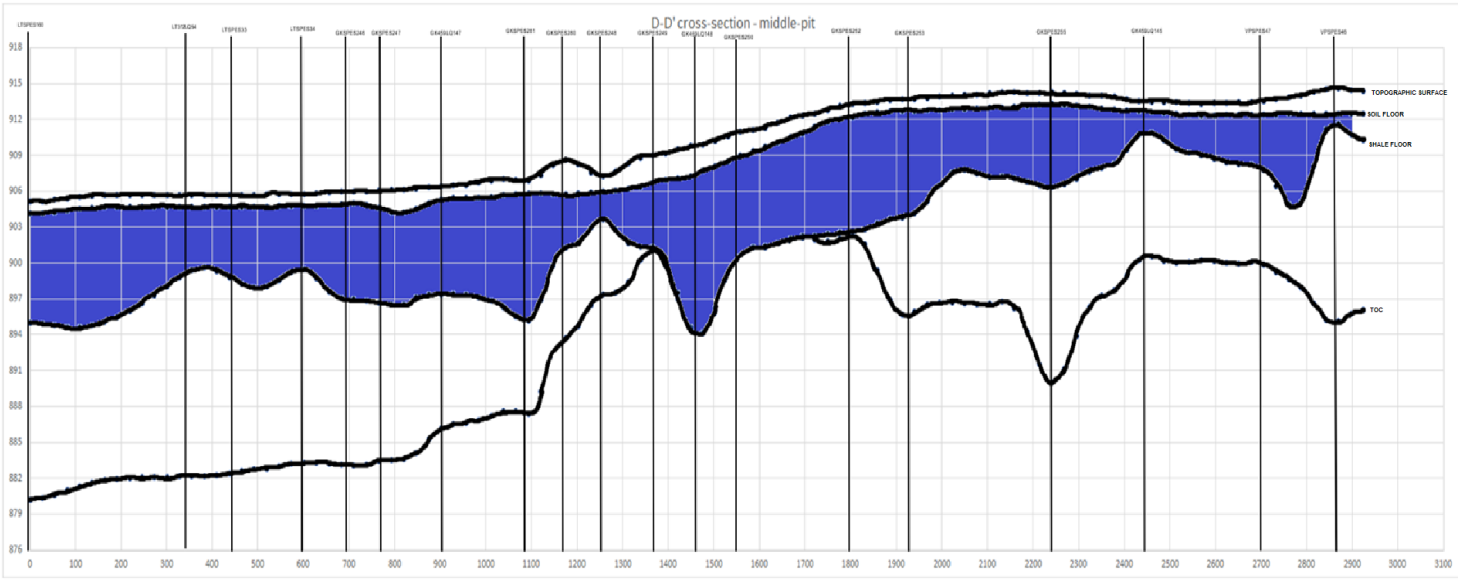


Figure 3. Cross-section of D-D’ in middle-pit.

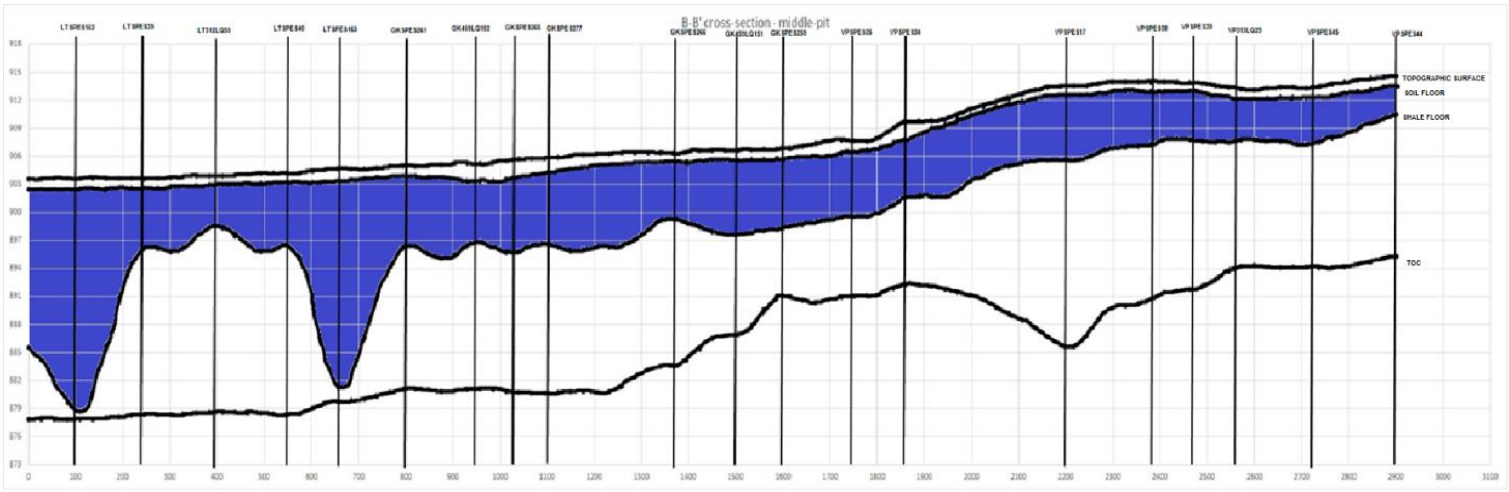


Figure 4. Cross-section of B-B’ in middle-pit.

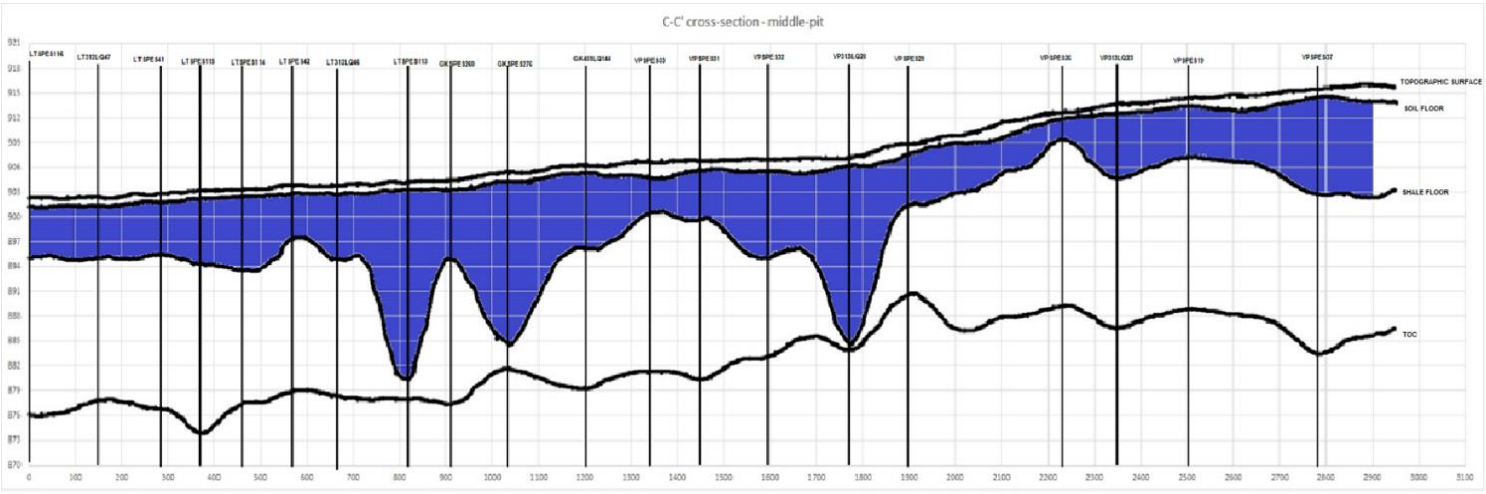


Figure 5. Cross-section of C-C’ in middle-pit.

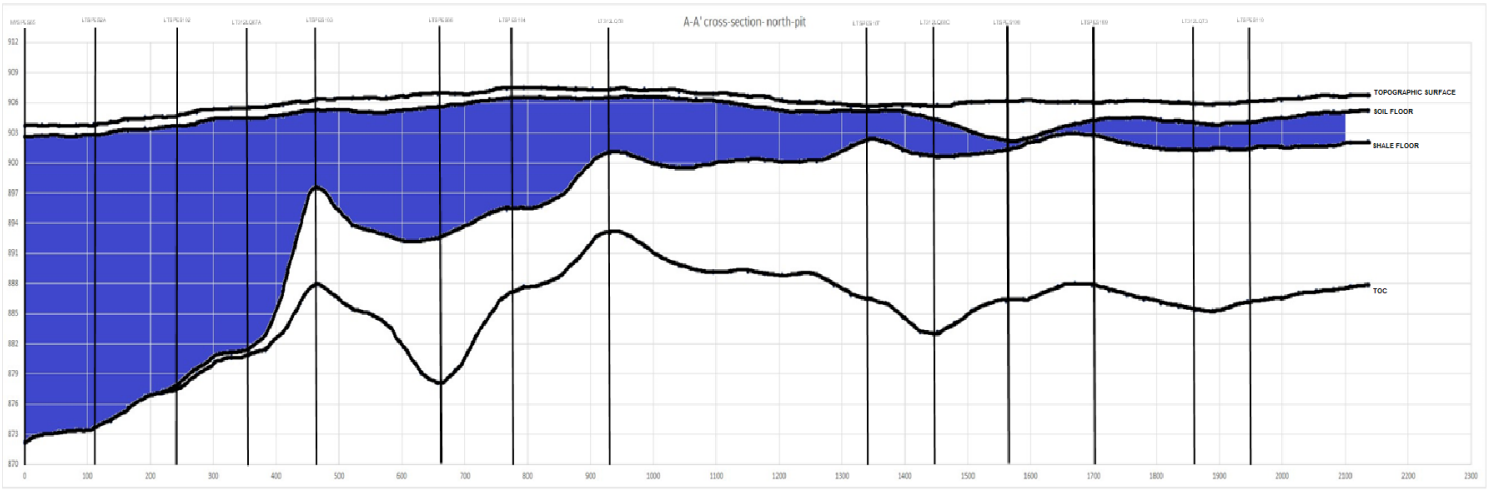


Figure 6. Cross-section of A-A’ in the northern box cut area.

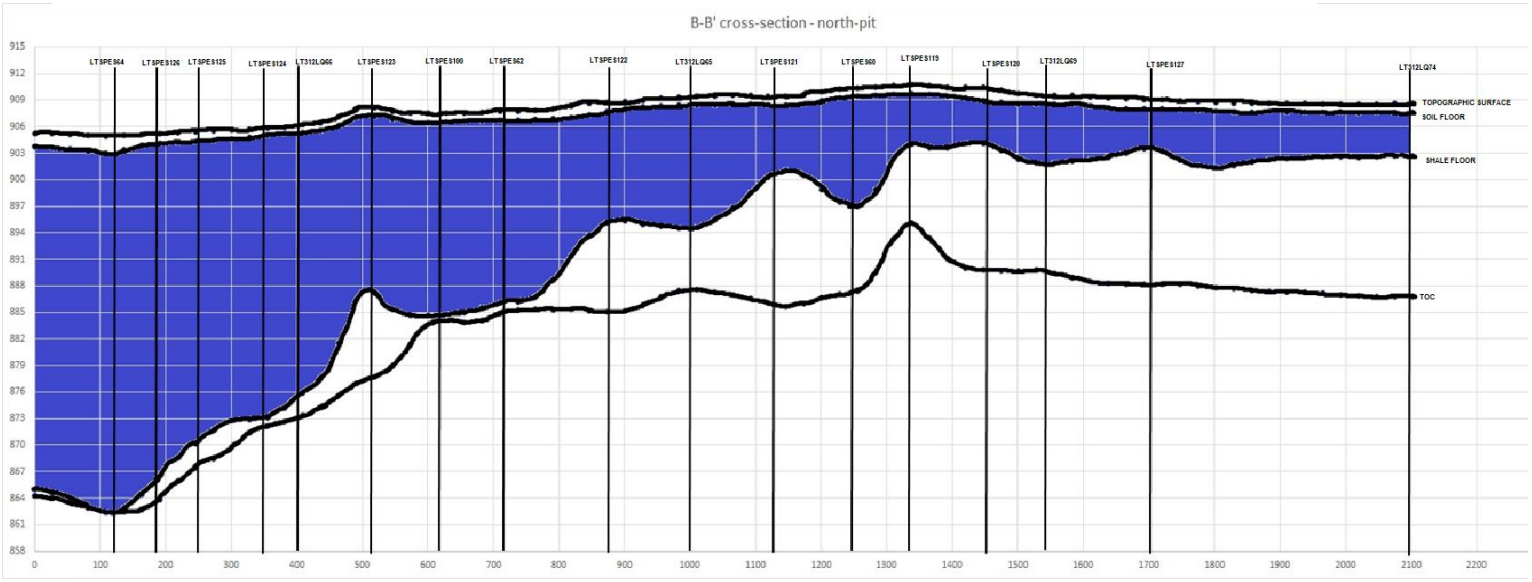


Figure 7. Cross-section of B-B’ in the northern box cut area.

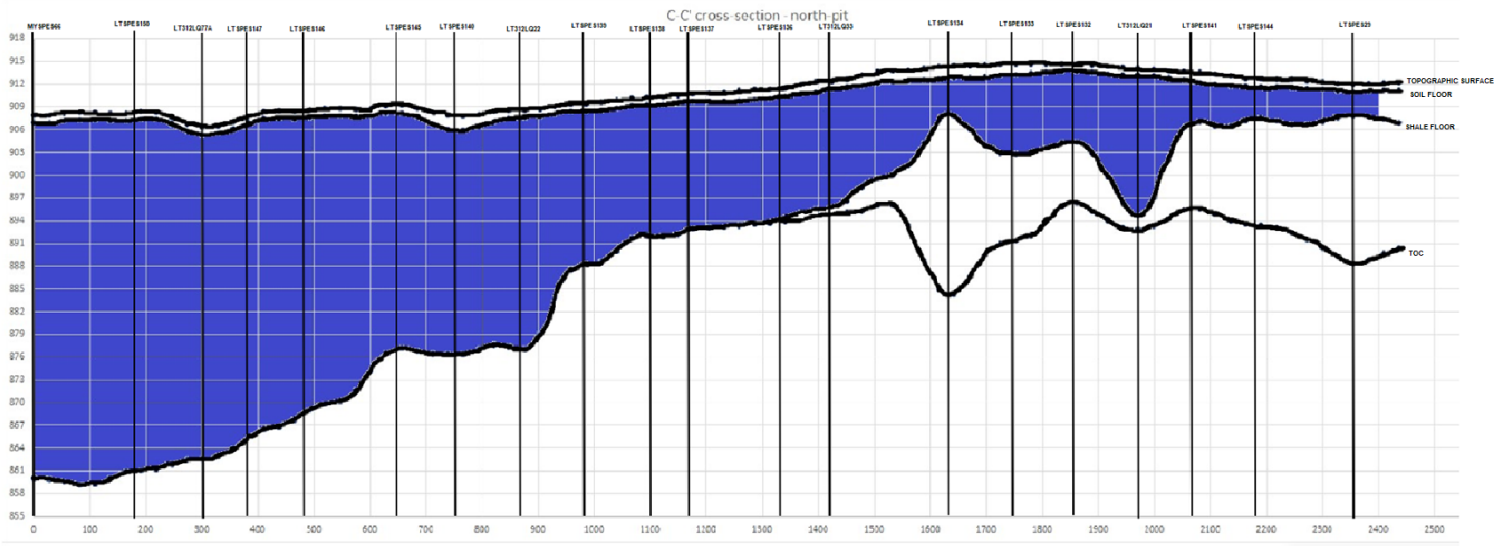


Figure 8. Cross-section of C-C’ in northern box cut area.