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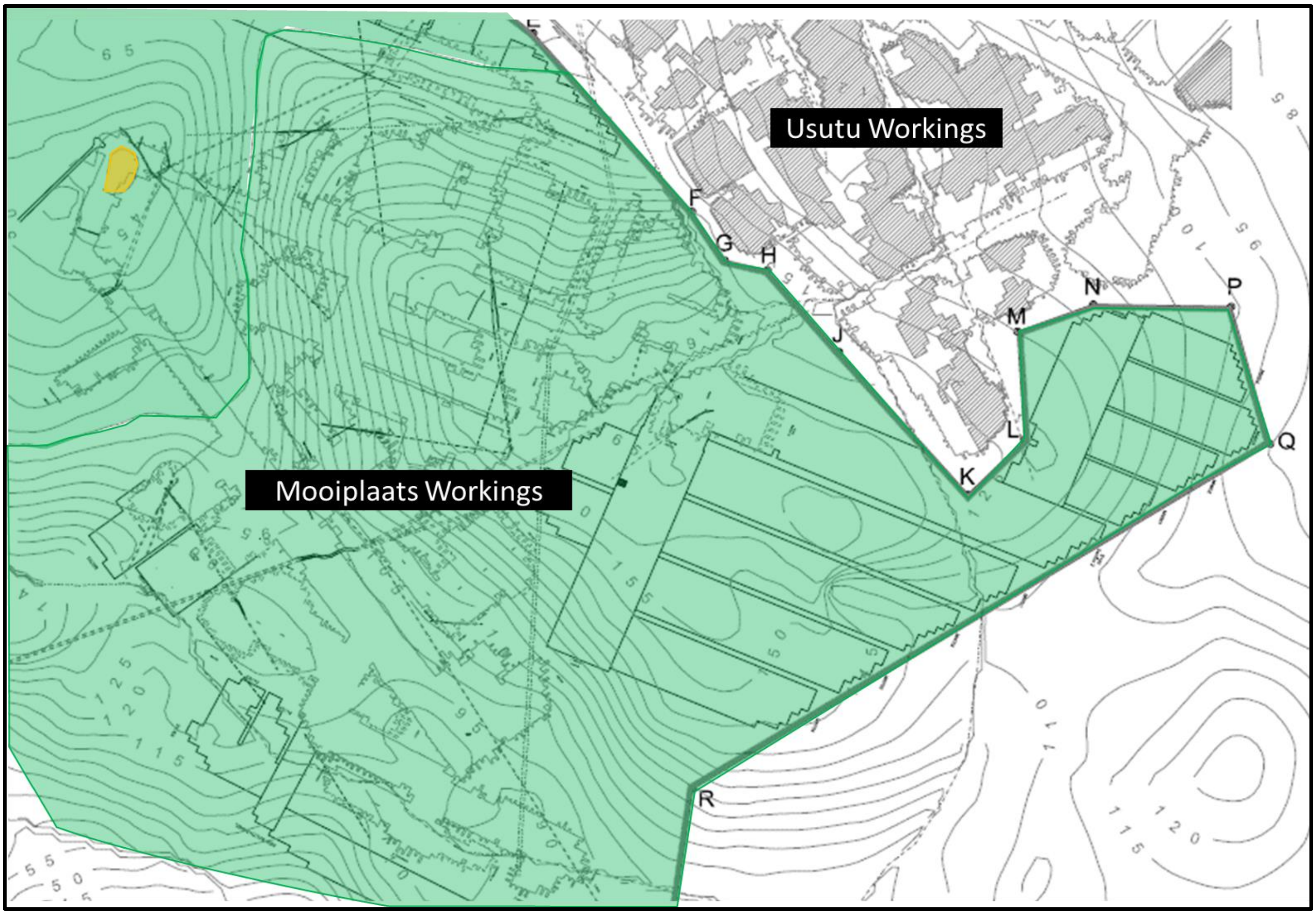
ROCK ENGINEERING REPORT – SUBSIDENCE RISK



This report was compiled for:

LANGCAREL INVESTMENTS (PTY) LTD

MOOIPLAATS COLLIERY

This Report was compiled by

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EXECUTIVE SUMMARY

A risk assessment for the likelihood of surface subsidence to occur, for both current and future planned workings at Mooiplaats Colliery were conducted. The investigation showed that in general, the risk of subsidence to occur at Mooiplaats Colliery is low, however some areas do have a slightly elevated risk of subsidence to occur, based on the cover depth of the coal seam. It was shown that shallower workings are at a slightly elevated risk of subsidence to occur in the long term.

Notwithstanding the initial risk levels however, by implementing an accepted pillar and support design strategy for the workings, will effectively mitigate the slightly elevated risk to an acceptable limit.

1. INTRODUCTION

The Mine Manager (T Bleeker) of Mooiplaats Colliery requested Big C Rock Engineering to conduct a risk assessment, to determine the likelihood of subsidence to occur at the mine. The study focuses on current workings, and future planned mining extents.

2. PROJECT OUTLINES/MILESTONES

The following outlines and milestones were identified:

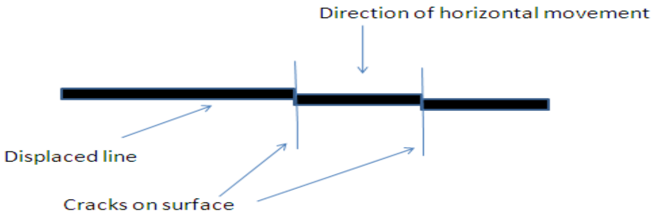
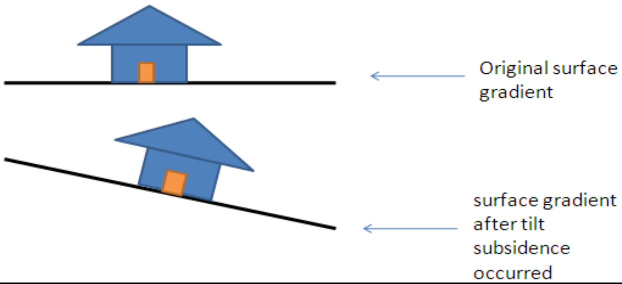
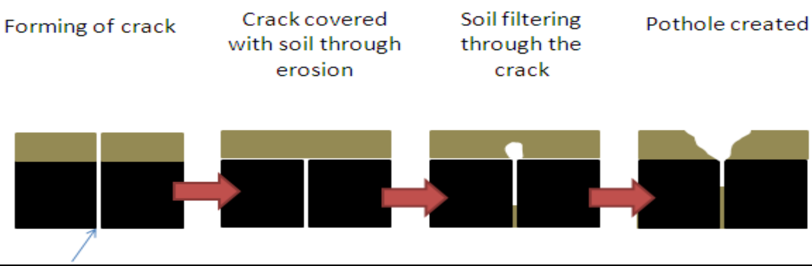
- Discuss and describe the nature of the overburden and significant geological features which may affect subsidence and sinkhole risks.
- Factors influencing the probability of subsidence.
- Risk of Subsidence at Mooiplaats.
- Identify and describe mitigation measures.
- Identification of subsidence/sinkhole monitoring measures.

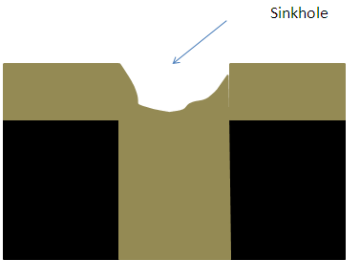
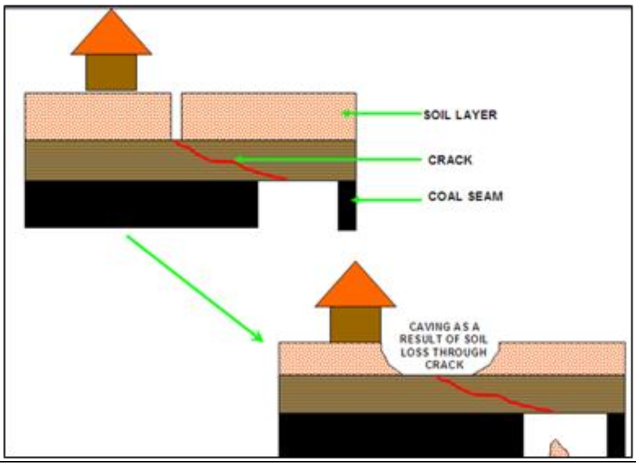
3. TERMS AND DEFINITIONS

Subsidence *can be defined as the downward movement of the surface lying above an underground excavation such as bord and pillar workings. The extent of subsidence is affected by the mining depth, mining height, panel width, mining method and overburden composition.*

Subsidence = 0.39 x mining height x (width to height ratio) ^0.32

There are various different forms of subsidence which can be differentiated upon the manner in which it occurs:

Subsidence Type	Description and illustration
Horizontal Displacement	Horizontal displacement can occur in various directions often resulting in discontinuous lines on the surface. When, for instance horizontal displacement occurred on a road, it would look like the painted lines on the road has been cut off and placed back or bended. 
Tilt	Subsidence tilt is when the slope of the surface has changed usually due to a collapse of pillars. The amount of tilt determines the visibility of the subsidence with the naked eye. 
Strain	Subsidence strain occurs when the surface has deformed (shortened or lengthened from its original size). This can be describes as simply a bend in the surface. 
Potholes	Potholes are one of the effects of long term subsidence. Potholes are formed when erosion occurs. A subsidence crack is formed on surface, over time the crack closes and transports the surrounding soil deeper down the crack eventually ending up in a surface pothole. 

Sinkholes	The formation of sinkholes is known as sub-surface erosion. They are usually formed where shallow mining occurred. They are usually the same size and depth as the collapsed underground intersection. Sinkholes are responsible for supplying underground fires with oxygen, which could lead to pillar failure.	
Secondary Caving	Secondary caving (Figure 6), refers to the crack being formed in the immediate roof strata of the underground workings, and this crack then spreads away from the workings, in this case towards the surface structures. The soil is then eroded with the assistance of water on the surface, into any cavities underground. This erosion can also occur along slip or fault planes, without a physical crack being formed. Secondary caving can be considered as a special case of potholing, however, it will result in a much larger surface depression.	

4. GEOLOGY OF THE MINING AREA

Regional Geology

The mining area falls within the Ermelo Coalfield (formerly known as the Eastern Transvaal Coalfield) which is located between the Carolina and Dirkiesdorp districts of Hendrina, Breyten, Davel, Ermelo and Morgenzon in the Mpumalanga Province of South Africa. It is bounded by the Witbank, Highveld, Klip River and Utrecht Coalfields in the northwest, west, southwest and south

The seams in the coalfield are generally flat lying with a gentle dip to the southwest. Major faulting occurs in the areas and increases in a southerly direction with displacements of as much as 250 m. These faults are commonly associated with dolerite intrusions. Dykes are common throughout the Coalfield and the frequency of sills increases southwards. Dolerite sills displace the coal seams causing structural complications and also cause devolatilisation of the coal (destruction of quality).

Local Geology

The B Upper Seam has an average thickness of about 1.5 m and is undulating in nature and, although dips are generally less than 2°, it may steepen in localised areas. Anomalous, abrupt changes in the elevation of the Seam have been attributed to sill breakthroughs with resultant displacement, or have been interpreted as dislocations through faulting.

A number of dolerite sills have been intersected in boreholes. The sills are, for the most part, concordant but may transgress to differing stratigraphic levels, resulting in displacement of the coal seams. Coal seams occurring in proximity above and below sills are also devolatilised to varying degrees. A number of dolerite dykes have also been recorded in outcrop, boreholes and mine workings. The frequency of dykes is illustrated below in relation to the mine workings in red.

Map illustration of the major geological features within the mining area

The depth to floor varies across the mining area from 30m below surface to 170m below surface. Generally mining below 30m from surface will not be conducted with underground mining methods due to the risks and hazards involved when mining at shallow depth.

Typical roof conditions of the seam includes a thin sandstone band (0cm to 10cm) followed by a thicker weak shale layer (generally less than 1m thick). In older areas the shale layer was mined to eliminate the poor roof conditions associated with it, exposing the glauconitic grey-green sandstone layer (more or less 3m to 4m thick). Glauconite material indicates a historic aquafer (water rich) layer.

Planned mining dimensions for the current mined-out underground workings:

- Pillar centres: 13m x 13m (minimum, increases towards deeper panels)
- Bord Width: 6m -6.5m
- Intersection diagonals: 9.4m – 10.1m
- Mining Height: 1.4m - 3m
- Mining Depth: 40m – 130m
- Pillar Safety Factor: The safety factor was calculated with the designed calculations to be 3.03 for areas with 6m bords and 2.56 for areas with 6.5m boards
- Pillar width to mining height ratio: 2.33 – 2.17 (6.5m boards)

5. FACTORS INFLUENCING PROBABILITY OF SUBSIDENCE

Subsidence will occur predominantly as a result of either underground pillar failure or underground roof failure. There are several factors that contributes to the probability and extend of subsidence:

- **The depth of the workings**. Shallow mining will result in a higher probability of subsidence. The magnitude of subsidence where mining is conducted below 80m from surface is within 80% of the effective mining height (the actual mining height multiplied by the extraction ratio). At greater depth the amount of subsidence is significantly less. Sinkholes occur where mining has been conducted at shallow depth (<40m) primarily as result of intersection collapse. Sinkholes is therefore a concern in the shallow mining areas.
- **Composition of the overburden material**. The composition of the overburden also plays a role in the likelihood of the material to fail and cause subsidence. The following factors contributes to the likelihood of failure:

- Strengths of the overburden material. The strength of the overburden will determine if the overburden will be able to resist failure over mining spans. Dolerite in the roof (sills) can assist in resisting failure if the dolerite material is competent and intact.
- Presence of geological discontinuities. Increased geological discontinuities increases the probability of failure. Material that are blockier is more likely to fail.
- Presence of water. The presence of water can increase the probability of failure since it can affect the strength of rocks materials (such as mica rich rocks) that are susceptible to deterioration when in contact with water and it increases the weight which forms part of the stress acting in on the roof.
- Depth of weathering. Rocks that are weathered has decreased strength and resultantly also a decrease ability to resist failure.
- Massive or laminated immediate roof conditions. Laminated material is more susceptible to delamination and failure. Massive rock tends to be stronger and less susceptible to failure.

- **Pillar stability (safety factor and width to height ratio)**. The following factors contributes to pillar instability:
  - Low pillar safety factor (less than 1.6 for long term pillars)
  - Low pillar width to mining height ratio (less than 3)
  - Altered pillar conditions, such areas where the pillars consists of burnt coal or where increased jointing has affected the stability of the pillars.
  - Areas where any form of secondary extraction has been conducted, increases the probability of subsidence.

6. ASSESS THE RISK OF SUBSIDENCE AT MOOIPLAATS

The following discussion of the conditions at Mooiplaats are considered applicable to this investigation:

- It must be noted that no subsidence has occurred or has been recorded on the mining area.
- **The depth of the workings**: The underground workings although initially shallow at the boxcut and entrance to the mine, quickly increases in mining depth. Most of the mining is conducted in areas more than 80m deep.
- **Composition of the overburden material**: The roof composition of the overburden generally consists laminated shale overlain by bedded sandstone in the immediate roof. These laminated roofs are prone to failures as the underground workings has experienced

multiple falls of ground however it is not expected that localized intersection and bord collapses will extend to surface in areas situated more than 40m below surface. The remainder of the overburden consists of alternating bands of sandstone, shale and dolerite. Should pillar failure occur, failure can be restricted to some extend by the overlying sills. In shallow lying areas where the overburden is less than 40m thick weathering can be expected to affect the overburden conditions.

- **Pillar stability (safety factor and width to height ratio):** The combination of the pillar safety factor and pillar width to mining height ratio is considered sufficient in most of the underground workings. Although some pillars at the entrance to the mine workings is of questionable dimensions. The mine does not practice any secondary form of extraction and therefore does not jeopardize the stability of the primary support which is the pillars. The mining property lying adjacent to the mining area (Usutu) has practiced secondary extraction and subsidence is therefore likely in those areas.

The following risk assessment was conducted to determine the risk of roof failure and pillar failure which may result in subsidence based on the above discussion and knowledge of the mining area. The risk matrix used in the risk assessment is attached as Appendix 1 to this report:

Hazards	Hazard Consequences	Initial Risk Value			
		P	S	E	R
Pillar failure – Square pillars (<40m deep)	Pillar failure resulting in large scale catastrophic subsidence occurring unexpectedly.	3	4	5	60
Pillar failure – square pillars (>40m Deep)	Pillar failure resulting in large scale catastrophic subsidence occurring unexpectedly.	2	3	5	30
Pillar failure – long pillars	Pillar failure resulting in large scale catastrophic subsidence occurring unexpectedly.	2	3	5	30
Roof failure – intersections	Roof failure in intersections resulting in sinkholes and other forms of subsidence.	2	3	5	30
Roof failure - bords	Roof failure in bords resulting in sinkholes and other forms of subsidence.	1	3	5	15

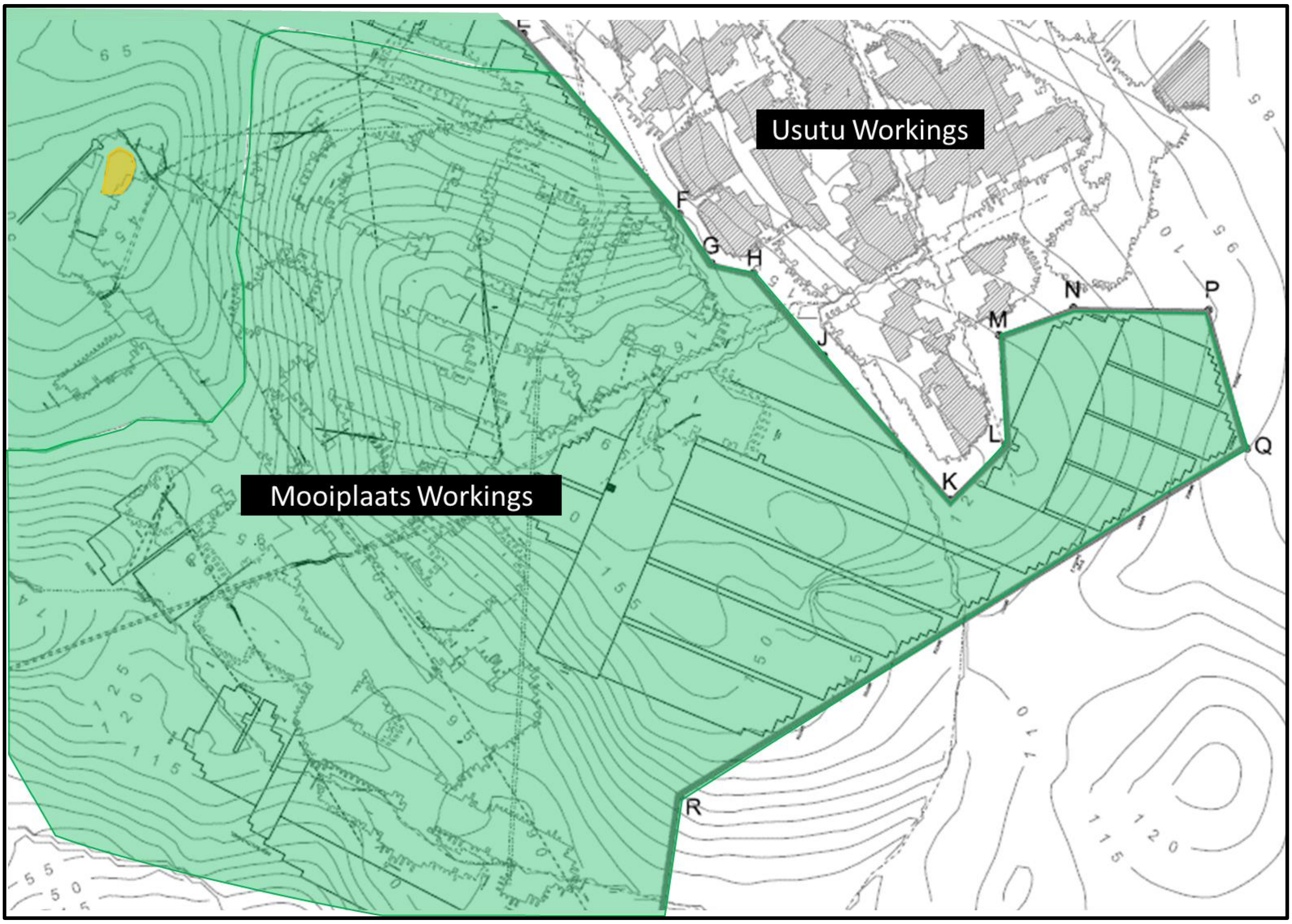


Figure 1: Illustration of the risk assessment outcome - subsidence

Although subsidence is unlikely to occur it cannot be excluded over the long term, it is for this reason that areas more prone to subsidence was identified based on the levels discussed below and illustrated in Figure 2.

Levels	Description
Green	The mining area is situated well below surface (>80m), pillars are stable, no secondary extraction has been conducted and the overall roof composition consists of predominantly "good" rock. Subsidence will only occur in the event of large scale pillar failure.
Yellow	The mining area is situated 40m to 80m below surface, pillars are stable, no secondary extraction has been conducted and the overall roof composition consists of predominantly "good" rock. Subsidence will only occur in the event of pillar failure and will be in the range of 80% of the mining height.

Red	The mining area is situated below 40m from surface, pillars are stable, no secondary extraction has been conducted and the overall roof composition is considered weathered. Subsidence can occur as a result of pillar and roof failure. All types of subsidence can be expected in these areas in the event of roof or pillar failure and will be in the range of 80% of the mining height.

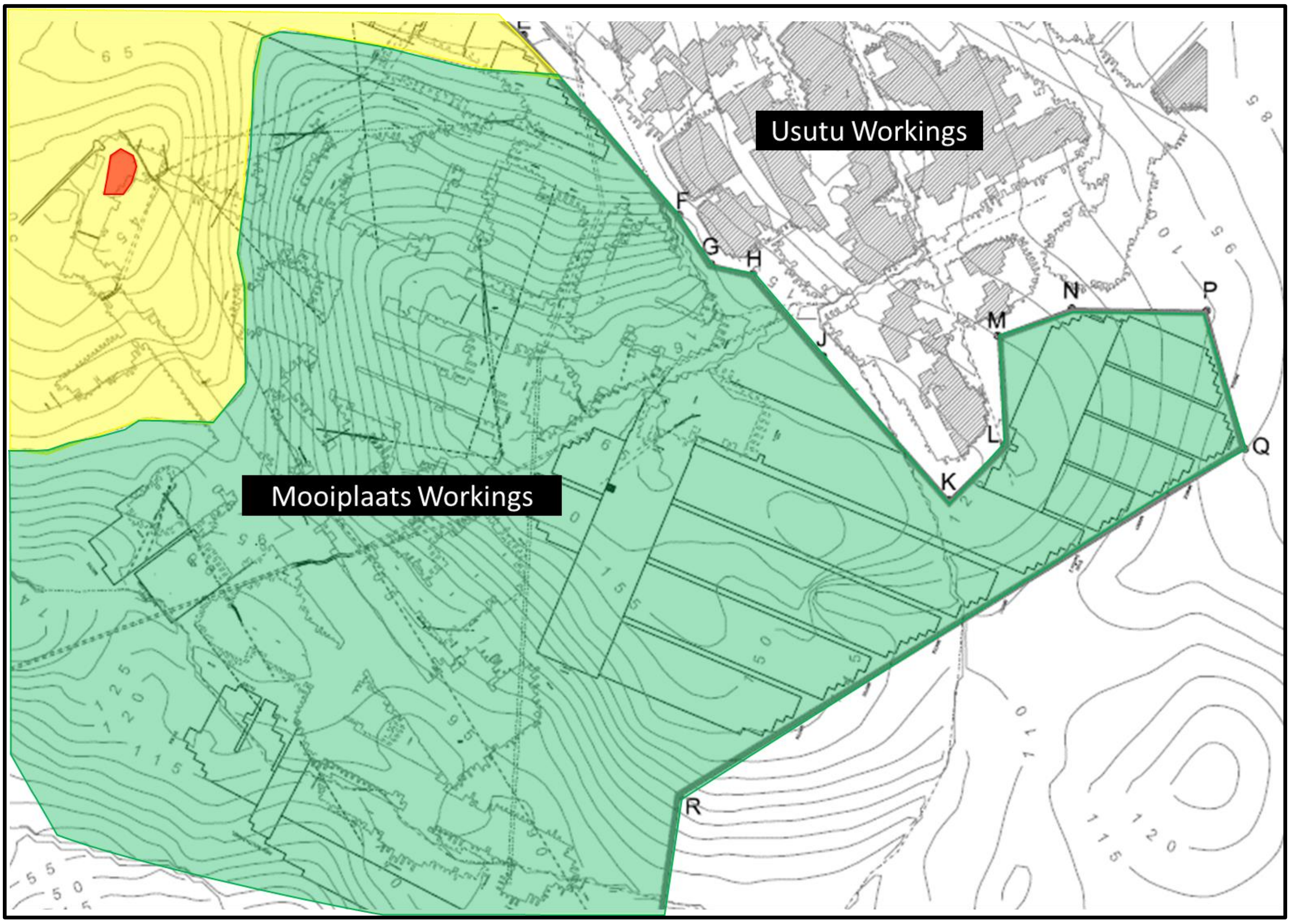


Figure 1: Illustration of the areas more prone to subsidence

7. MITIGATING MEASURES TO PREVENT SUBSIDENCE

The following mitigating measures are recommended to assist in the prevention of subsidence:

- A proper industry accepted pillar design must be accepted and followed at the mine, developed by a rock engineering practitioner.
- Barrier pillars must be included into the pillar design of the mining area and panel widths should be limited with respect to the critical mining span.

- Underground assessments to monitor adherence to designed dimensions. The Mine Manager must implement disciplinary measures in cases where the mine dimensions was not adhered to.
- Mining in areas less than 40m deep should not be attempted beneath areas where subsidence is unwanted, such as below critical surface structures.
- In areas where subsidence is likely backfilling methods can be implemented to decrease the effect of subsidence. Site specific recommendations must be conducted by the rock engineering practitioner in such an event.

8. SUBSIDENCE MONITORING METHODS

To detect surface subsidence surface survey techniques can be used. Once subsidence has been detected these areas must be noted on a map and investigated to determine the cause of the subsidence. Access to the subsidence area must be barricaded off until it has been made safe and the risk of extending of the subsidence has been established. Hereafter subsidence can be monitored with survey techniques to determine if the subsidence is extending.

9. CONCLUSION

The mining method followed at Mooiplaats is not likely to cause subsidence as mining is conducted according to an acceptable pillar design. Some areas within the mining area are more prone to subsidence although subsidence is not expected to occur at Mooiplaats. Should any form of secondary extraction be planned in the future subsidence will be more likely to occur.

APPENDIX 1: RISK MATRIX

Risk (R) = Probability (P) x Consequence (S) x Exposure (E)

Probability (P)	Certain that it will occur	5
	Likely that it will occur	4
	Possible that it will occur	3
	Rare that it will occur	2
	Very unlikely that it will occur	1
Severity (S)	Minor property loss	1
	Causing multiple injuries or property loss that result in production loss for the neighbouring party	2
	Causing fatalities to at least 1 person and or damage to equipment of less than R1 mil	3
	Causing multiple fatalities and or significant property loss of more than R1 mil	4
	Causing fatalities, injuries or significant damage to neighbouring properties and civilians resulting in the production and money loss in the macro environment.	5
Exposure (E)	Continuous exposure	5
	Frequent exposure	4
	Occasionally exposed	3
	Rarely exposed	2
	Very rarely exposed	1
Risk Level	High risk – high probability of occurring, immediate action needed	>60
	Substantial Risk – medium probability of occurring action needed.	>40-60
	Low Risk – low probability of occurring	0-40

Risk Matrix