Investigating The Effects of Rainy Season On Open Cast Mining Operation: The Case of Wescoal Khanyisa Colliery

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Case study

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Abstract

The aim of this study was to investigate the impact of rainy season in open cast mining and possible factors that could contribute to production loses during these rainy periods. The major issue at Wescoal's Khanyisa Colliery is the impact that rainfall has on the coal extraction process during the rainy season. The opencast mine operation loses a significant amount of time that is supposed to be used to run the mining value chain by trying to deal with the effects of the rainfall. This study made use of acquired data from Khanyisa Colliery between the period of December 2019 and January 2020 rainy months in South Africa. This data includes, the amount of daily and weekly rainfall, the water pumping rate, frequency of breakdowns and success rate of load and haul. The average weekly rainfall was found to be 69 mm over the 8 weeks of the summer season. However, the adopted method of managing the mine water was not efficient enough as a result of a low capacity pump and their pumping rate in comparison to the volume of water in the pit. This has affected some sections in the mine as productivity dropped due to reduction in loading and hauling activities from the pit to the stockpiles. In order to improve the productivity, the authors made some suggestions than can enhance production during rainy seasons.

1. Introduction

Opencast mining production is affected by many factors such as internal and external structures of the slope, soil softening, seepage, stress redistribution, rainfall pattern and erosion (Wu et al 2015; Zhou et al 2009). Of all these factors, rainfall infiltration has been described as the major cause of slope failure that can result in harmful incidents in open pit mining operation and loss of ore reserve. Consequently, it can result in premature closure of the mine. Presence of water in the mine as a result of heavy or non-stop rainfall poses threat on the production of coal which might endanger the sustainability of coal production at the mine. As rainfall is regarded as a major and common factor that massively contribute to slope failure in open pit mining all over the world, it is therefore necessary to have in depth understanding and way of mitigating the effect of rainfall on mineral extraction process (Zhao & You, 2020).

A great number of scholars have studied problems related to water in open pit mines, with most of them stimulating interest on the consequences of heavy downpour and contamination migration during open pit coal mining operation (Tiwary 2001; Rapantova et al 2007; Haque et al 2018; Zhao et al 2017; Soni and Manwatkar 2015; Park et al 2019). The most common ways through which rainwater affects the stability of the pit wall includes loss of pore-water suction, erosion, and building up of positive excess pore-water at shallow depths (Zhou, et al., 2009). However, Kamzi et al (2017) listed erosion, floods, earthquakes, precipitation and human activities as complex mechanisms that drive geological disaster in open pit mining operation. In most cases, if the slope wall is properly designed, there is no way failure will take place unless water table and pore water pressure exceed the design limit. There is no doubt that, if rainfall continues, it may trigger slope instability and cause disruption in the mineral extraction process. Although, if the mine is designed according to the hydrogeological conditions, it is unlikely for the mine to encounter instability during heavy rainfall. The mechanical properties of the ground plays important role in determining the fracture and aquifer zone that can influence the stability of the ground (Kolapo, 2020).

In short, the mechanical properties of the ground is considered as one of the major parameters in designing a stable, safe and economical pit wall (Kolapo & Munemo, 2021). Therefore, it is consider necessary to define the mechanical properties and hydrogeological conditions of the ground during feasibility study for a robust and competent wall design.

However, if the underground water level is above the table water, the deep groundwater level will change the moisture content of the upper vadose zone (Lian, et al., 2021). In most open pit coal mining environment, the common practices to prevent the ecological threat of groundwater is the drainage and dewatering process which brings about a significant drop in groundwater level around the mining area. The importance of these processes is that it will prevent distribution of soil moisture that will lead a significant decrease in groundwater level.

The aim of this study is to investigate the impact of rainfall on coal extraction process at Wescoal Khanyisa colliery. The run of mine (ROM) mining performance at Khanyisa colliery was poor in December 2019, that is, 83% below budget as a result of heavy rainfall experienced at the mine (Wescoal, 2020). This can be detrimental to any opencast operations as it significantly affects the cash flow of the business. Therefore, it is critical to analyze the rainfall data to better understand the impact of the heavy downpour on the productivity of Khanyisa coal mine. Likewise, acquisition of rainfall and production data will assist in carrying out the influence of rainfall on the mine transport system such as the truck and shovel operation at Khanyisa colliery. This will proffer a solution on how to improve mining operations in opencast coal mining environment and to enhance recovery once the rain stops.

The need for this study was raised by Wescoal Khanyisa colliery when there was a massive drop in production as a result of rainfall during the rainy season. The heavy downpour caused delays that affects all levels of the mine value chain from the drilling and blasting to crushing and hauling of coal to different destinations. The rainfall has a significant impact on the mine revenue due to reduction in the amount of production time which makes it difficult for the mine to meet their daily production target. This study contains first, a literature review on the impact of rainfall on open cast mining operations. This is followed by factors affecting mineral extraction during rainy season. The data used in this study consist of daily rainfall report and production report from December 2019 to January 2020. Notably, from the acquired data, the trend on the impact of rain on production can be easily observed. The data collected include amongst others, number and type of machinery and daily rainfall measurements.

2. Impacts Of Raining Season On Mineral Extraction In Open Cast Mining Operations

Apart from the disruption that water can cause in open cast mining operations, other consequences could lead to generation of acid water drainage, enlargement of cracks, instability of slope and initiation of landslide that can severely pose threat on lives and properties around the mine. In Bo et al (2019) study, it was discovered that rainfall infiltration was a major factor affecting the slope stability in open pit coal mining operations. There is a significant change in the distribution of pore water pressure and a noticeable variation in the value of safety factor under different rainfall conditions at Haizhou open pit coal mine in the southeastern Fuxin city of Liaoning province in China. The effects of rainy season in mineral extraction process cannot be overemphasized as the impact varies from loss of production to increase in health and safety of mineworkers. These become a leading problem when different climate changes were not considered at the mine planning and design stages.

However, there is formation of pit-lake in open cast mining operation during raining season. That is, water filling the mined-out area during or upon completion of mining activities. Gammon et al (2000 categorised formation and filling into two, namely; natural and artificial flooding. Natural flooding is when the pits are filled hydrologically and a pit filled by rain is regarded as a natural pit lake. Rainfall is a natural phenomenon which is impossible to prevent and therefore causes water to settle at the mine pit bottom. According to Bargawa et al. (2019), excessive mine water from rainfall and mud has the potential to create mud accumulation. A combination of the wet mining area, water accumulation, and mud sediments result in a major problem which complicates mining activities in coal mines leading to failure in reaching production targets as shown in Fig. 1. This makes it impossible for the day to day activities in the mine to continue until the water accumulation issue is resolved.

According to Mason et al (2013) study, the impact of the flooded pit can be categorised as directly or indirectly which can be further classified into immediate and long-term impacts. Under immediate impacts, the affected areas include production, overtopping of levy banks and damage of coal conveyors while the long-term impacts include delay in coal production and strict monitoring by the officials.

Furthermore, heavy and consistence rainfall during rainy season also affects the haulage of materials from mining face to the muckpile. Material handling in surface mining involves transporting the fragmented rocks from the pits to the dumping site using excavators, fronts end loaders, draglines and trucks (Adam & Bansa, 2016). The haulage road system is one of the most vital and critical components in open pit production process, most especially the truck-based system (Thompson & Visser, 2000). During the rainy seasons, rain tends to cause underperformance of haul roads and this has an impact on mining productivity and road-related costs. Productivity, the safety of operations and equipment life all depend on a properly designed and well-maintained road.

One of the disadvantages of opencast mining is the regular maintenance of haul roads, this problem worsens during rainfalls. Eventually, all roads in an opencast mine will deform after some time due to the frequency of their use, the weather conditions such as rainy periods, and the nature of equipment operating on them (Nuric, 2011). In short, surface mines do experience delays in production as a result of bad haul road design and maintenance. Having appropriate haul roads management and maintenance strategy can limit the impact rain has on roads while increasing production and saving on costs. During these periods, the haul roads become muddy and slippery and this requires frequent maintenance. Most time is used focusing on maintaining haul roads than using them for hauling. This means that even though the equipment is available they are not being used and this affect the planned production. Tannant & Regensburg (2001) stated that there are two major concerns in terms of haul road integrity during extreme weather conditions (typically heavy rainfall). These are tyres adhesion to the road (traction) and rolling resistance.

In addition, during rainy season, there possibility of experiencing lightning as a result of heavy downpour. According to Kithil and Alzamora (2013), the lightning also cause havoc in mining operations as this can affect mine communication systems, explosive storage, load and haul stations, drilling and fuel farm which contributes massively to extraction process. The impact of the lightning on various areas that contribute to production losses in mining is presented in Table 1.

Table 1
Factors affecting production as a result of lightening (Kithil & Alzamora, 2013).

S/No	Sources	Percentage Contribution
1.	Load and haul	35
2.	Drilling	25
3.	Radio communications	15
4.	Explosive storage	13
5.	Fuel farm	10
6.	Others	2

Similarly, lightning has resulted in many fatalities and injuries in the mines and this can lead to mine closure which affects the overall production. According to Kithil & Alzamora (2013), education is an important tool to be given to outdoor employees and contractors. To avoid having to halt mining operations as a result of lightning-related injuries or fatalities, safety measures should be taken. Using lightning detectors, avoiding water and metal contact, avoiding trees, staying of telephones, are some of the measures to reduce the impact on employees. To reduce the damage that rain has on the haul roads, the design and management of the roads must be properly done. The three basic steps to properly design haul roads that can withstand operating conditions in mining are shown in Fig. 2.

Significantly, construction of drainage could also help in reducing the impacts of heavy rainfall on haulage road. According to Adams (2019), V- drains are more often located next to the majority of the haul roads and are a critical component of a proper drainage system. The main function of these drains is to maintain the haul roads integrity and thus should always be in good conditions to ensure maximum protection of the roads. During rainy season, the V-drains tends to have a huge amount of water to accommodate and even though sometimes the water flow can be very much considerable. This can result in the loss of drain lining condition and can even cause scouring, hence the frequent maintenance of the drains.

One of the most common techniques used in managing water in the pit during rainy season is dewatering method. This process entails pumping out of water from the pit at regular intervals. This is important as it helps to remove mine water from accessibility of production (Sahoo, et al., 2014). It is essential for the open pit mine to have pumps that are ready to run at any moment as water must be pumped out of the pit to allow mining operations to continue immediately after rain. Pit dewatering is an essential operation for safety and efficiency purposes in quarries, open pit and opencast mines that extend below the groundwater level. The diagram in Fig. 3 shows the approach to which mine water can be managed in an open pit mining environment.

Over the years, mining companies have realized that heavy rains, flooding, and lightning and high temperature pose threat to the safety of personnel, equipment and structures. The most reliable tool that is often under-leveraged by sites and operations managers is accurate weather forecasting. Having access to consistent reliable weather reports provide a better criterion in assessing when to remobilise certain operations and how certain resources can be allocated away from heavily affected and dangerous site areas.

3. Materials And Methodology

This study is both qualitative and quantitative since it considers the quality of the methods that are used to improve production and how these methods relate to other methods in different regions. The quality of precautions and preparations that are made during rainfalls. The quantity of amount of resources like pumps and pumping stations, water storage facilities and their capacities, the width and depth of haul roads and how different measures of rainfall affect production.

Data used in this paper is collected at Wescoal's Khanyisa Colliery. The collected data consist of daily rainfall reports and production reports from December 2019 to January 2020. The data only ranges from December 2019 to January 2020 which represents the rainy season while the comparison data from June to July 2019 represents the non-rainy season. From the data obtained, the trend on the impact of rainfall on mineral extraction can easily be observed. These data include amongst others, number and type of machinery and daily rainfall measurements. For instance, the data for rainfall between December 2019 and January 2020 is presented in Table 2.

Table 2
Acquired rainfall data from December 2019 to January 2020

S/No	Week Number	Rainfall (mm)
1.	1	65
2.	2	69
3.	3	90
4.	4	73
5.	5	66
6.	6	72
7.	7	69
8.	8	55
Average		**69**

However, due to high level of rainfall during December 2019 and January 2020, this has resulted into the pit being filled with water. Most of the operations in the pit were forced to stop as a result of presence of water in the pit. Table 3 shows the rain event in millimeters over a depth of 1000mm, volume of water and number of days required to pump the water out of the pit. This represents a typical pit that was in an ongoing operation that was halted due to the rainfall.

Table 3
Showing the correlation between the ratio of rain to depth and volume of water

Event of rain (mm)	Volume of Water (m^3)	No of days to pump
1000	11 250	2.14
1500	16 875	3.21
2000	22 500	4.29
3000	33 750	6.43
4000	45 000	8.57
4500	50 625	9.64
5000	56 250	10.71

Pumping process at Khanyisa Colliery was simultaneously occurring at the three active mining pits, located at Triangle 1, Triangle 2 and Catwalk. Triangle 1 and Catwalk each had 2 pumps while triangle 2 had only one since it was still a new operation. Table 4 indicates the number of pumps and their pump identities at different locations. The pumping rate of the pumps is 120 cubic meters hourly for 5 of the 6 pumps in the table and the last one was of 80 cubic meters per hour. The availability and utilization are variable and too low. Only 2 pumps of the 6 performed satisfactorily while about 50 percent of the pumps were breakdown.

Table 4
Location of pump at Wescoal Khanyisa Colliery

Pumps @ Khanyisa	Pump ID	Location	Capacity (m^3/hr.)	Operational Status	December Availability	December operating hours
1	P64	Triangle 1	120	Breakdown	62%	178.5
2	P65	Triangle 1	120	Running	79%	63.5
3	P20	Triangle 2	120	Running	8.5%	61
4	P19	Catwalk	120	Breakdown	2.5%	19
5	P18	Standby	120	Breakdown	0%	0
6	P15	Catwalk	80	Running	100%	543

Likewise, the specification and the size of the pipeline that were used in transporting the water out of the pit is also important. Table 5 shows the specifications of the pipeline that were installed at Khanyisa colliery. The water was being pumped out of the pits to be stored temporarily at some of the old voids that were awaiting rehabilitation as there were issues in water storage facilities. The main storage facility that was available was the pollution control dam (PCD) which was almost full hence it could not accommodate the rainwater from the pits.

Table 5
Installed pipeline specification at Khanyisa colliery

	T1	T2	Catwalk
Pipelines	1.5km by 6 inches	800m, 6 inches lay flat	1 by 6 inches
	0.9km by 8 inches	700m, 6 inches pipeline	
Capacity	220m^3	110m^3	110m^3

4. Results And Discussion

The damaged haul road affected production as the mine was struggling to meet their daily target of production during the rainy season. Movement of materials from the pit to the stockpiles and from the stockpiles to the distances was affected causing stalling problems. Load and haul operations were poor, and the targeted trips were not made according to the schedules. Table 6 indicates the success rate of load and haul operations over the 8 weeks of the rainy seasons. The success rate, which under normal situations. When the haul roads are efficient is usually 100 percent but due to the delays caused by the rainfall specifically on the haul roads, the percentage dropped by more than 10 percent.

Table 6
Percentage of success rate of load and haul between December 2019 to January 2020

Week Number	% of success rate of load and haul
1	83%
2	88%
3	90%
4	78%
5	80%
6	76%
7	84%
8	88%

Haul roads did not only affect the load and haul operations, they also had a severe impact on the breakdown of the types of equipment that are used during the truck and shovel operation at Khanyisa Colliery. As it was indicated in the above sections that rainfall influences the conditions of the equipment, the following results on Figs. 4 and Fig. 5 show how breakdowns varied over non-rainy seasons and during rainy seasons. During non-rainy seasons the haul roads are responsible for about 20% of the breakdowns while during the rainy seasons the breakdown percentage doubled.

In order to understand how rainy seasons affect production, a thorough comparison is made between rainy and non-rainy seasons. The following Figures 6 and Figure 7 show how production differs between the two seasons when planned production is matched against the actual production over weekly periods. In Figure 6, there is a slight variation between planned production and the actual production which was achieved. The variation is both a positive and a negative one. In most of the weeks during this season production targets were met, and, in some weeks, productions were highly greater than the planned one.

Figure 7 shows weekly production during the rainy season when compared to the non-rainy season, the planned production varies much with the actual production. Production targets were never met during this season. During most of the weeks, production was below 50% of the planned targets as expected. The planned production accounted for this season as it differs with one of the non-rainy seasons and even in this case the results were still too bad. The main reason for the variation in production is due to pumping and haul roads. These factors only became an issue because of the rainfall. The time that was supposed to be used for the actual production of coal was either used to pump the water that was accumulated in the pit or fixing slippery and muddy road so that coal can be transported from the pit to stockpiles and different destinations.

5. Conclusion And Recommendations

5.1 Conclusion

Weather conditions do influence operations in the mining industry and this is far worse in surface mining such as opencast than in underground mining. Rainfall is one of the weather conditions that affects productivity in opencast mining operations. Wescoal's Khanyisa Colliery suffered a tremendous loss in production time due to the heavy and consistence rainfalls. The average rainfall that was recorded over the summer (8 weeks) was 69 mm. The mine experienced pit flooding which made it impossible for the activities in the pit to continue as a result of the heavy rainfall. Pit flooding had both the immediate and the long terms impacts on the operations in terms of productivity. A series of ongoing dewatering water systems are being practised in order to manage the water conditions in the pit.

Haul roads are one of the key components that were affected by the rainy season. The roads experienced a huge blow and required a lot of maintenance time that was dedicated to be dedicated production. The road integrity was compromised in which they were deemed unsatisfactory for the operations to continue as they posed risks to the health and safety of operators. Load and haul operations were therefore affected and slowed down, and this led to a drop in production and hence a drop in productivity. Construction of drainage systems and road pavement mitigate the impact of rainfall on haul roads and in consequence, increases production. The use of culverts and v-shaped drains are one way of improving the haul road condition during rainfall seasons. The haul roads also affected the percentages of breakdown of equipments, which is more than twice the number in non-rainy periods. This led to a drop in the utilization of equipment and hence drop-in productivity.

Pumping of water out of the pits is an integral part of the opencast operations such that it should be given a top priority because during rainy season, if the pumping process is not efficient, production is affected too badly. The rate of pumping has a direct relationship with productivity. An effective pumping system is one that has proper compliance with the relevant regulations and has less environmental impacts. This study revealed that pumps that are used at Khanyisa are not efficient and are not always reliable. The low availability of the pumps and the breakdowns frequency contributed greatly to the slow rate of pumping.

Khanyisa Colliery suffered production losses due to the summer rainfalls, even though drops were expected under planning production, the drops were more than the anticipated ones. Rainfall will always be there during the summer and the best way to achieve higher productivity is to make necessary preparations. This includes improving haul road conditions, water pumping facilities, and slope management such that operations can continue safely.

5.2 Recommendations

From this study, the following recommendations are drawn to improve the mining production at Wescoal Khanyisa Colliery during raining season.

- The mine should improve their method of measuring the amount of rainfall from using ordinary rain gauge to the modern smart rain intensity gauge. This would prevent error and inaccuracies and give the actual weather forecast.
- Services like UBIMET which gives weather predictions should be used instead of relying on the day to day public weather services. UBIMET services can also be used to detect lightning which will reduce lightning-related accidents.
- Khanyisa colliery should pay more attentions to the mine water management. The mine must ensure that the pumps are in good conditions and can be relied on to reduce the impact that rainfall has on production.
- The mine should spray the haul road with concrete and limestone to avoid washing away and limit the effect of muddiness.

Declarations

Conflict of Interest

The authors declare that there is no known conflict of interests that could have appeared to influence the work reported in this paper.

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Figures

Figure 1

Flooded pit after rainfall (Connelly & Middleton, 2018)

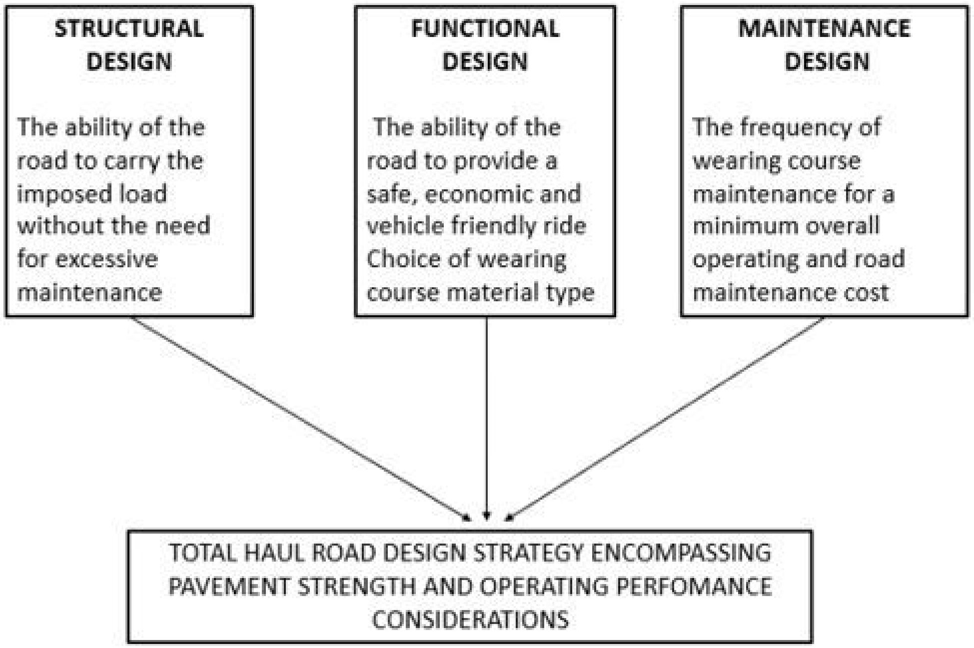

Figure 2

Components of haul road design strategy (Thompson & Visser, 2000).

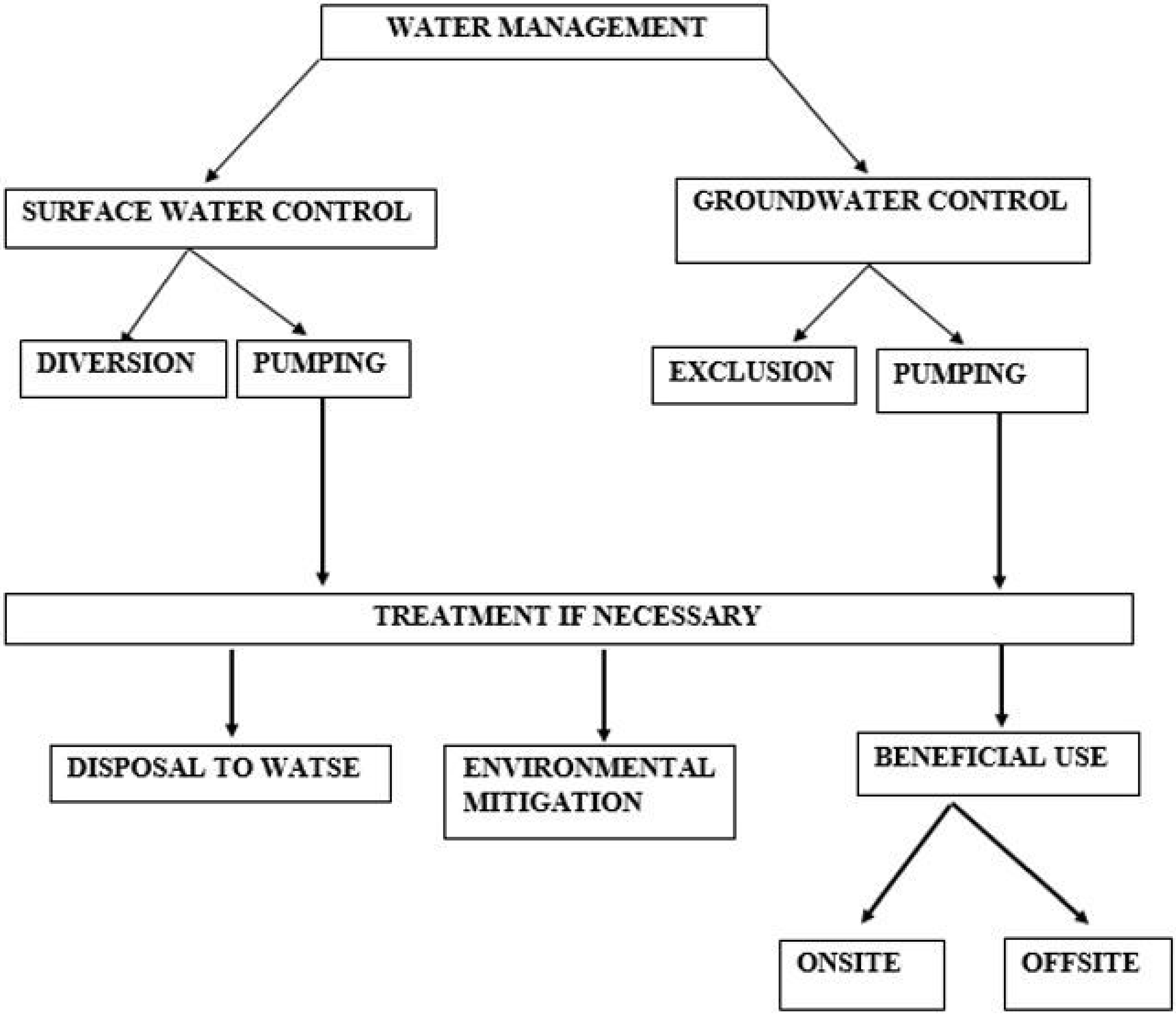

Figure 3

Diagram showing groundwater control in the context of mine water management (Preene, M., 2015).

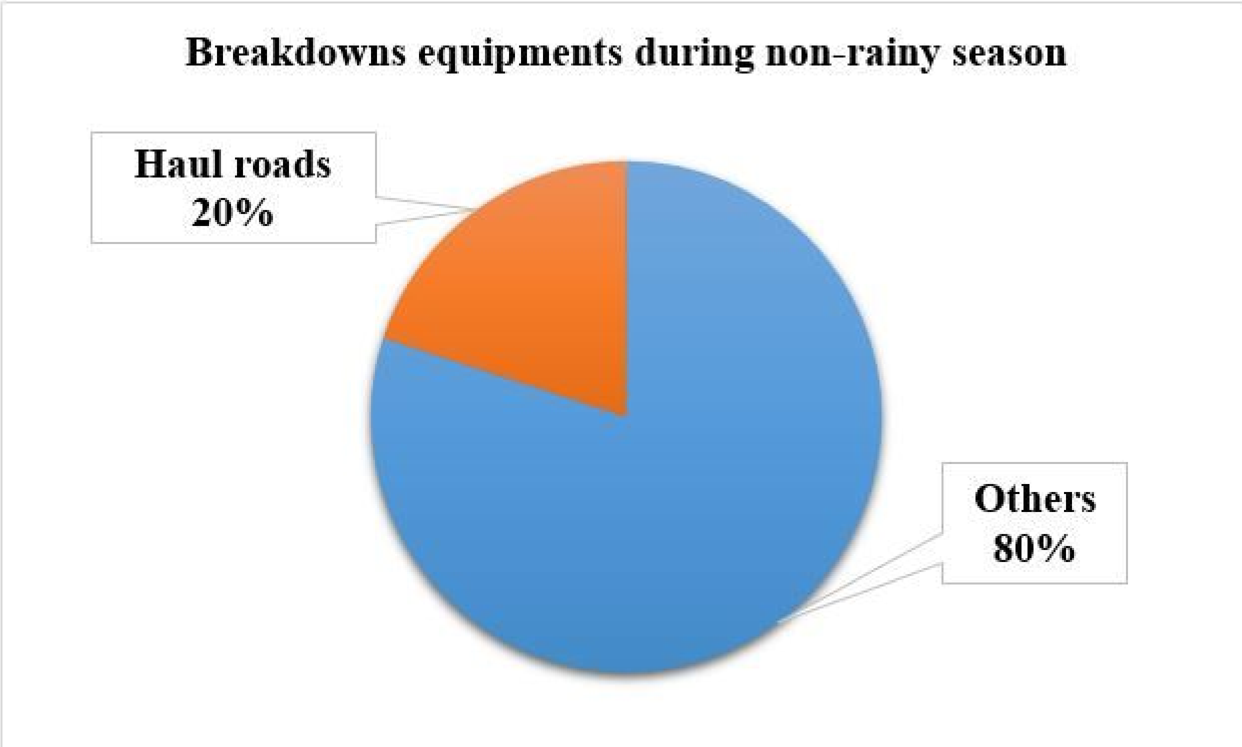

Figure 4

Breakdown analysis of equipments at Wescoal during non-rainy season.

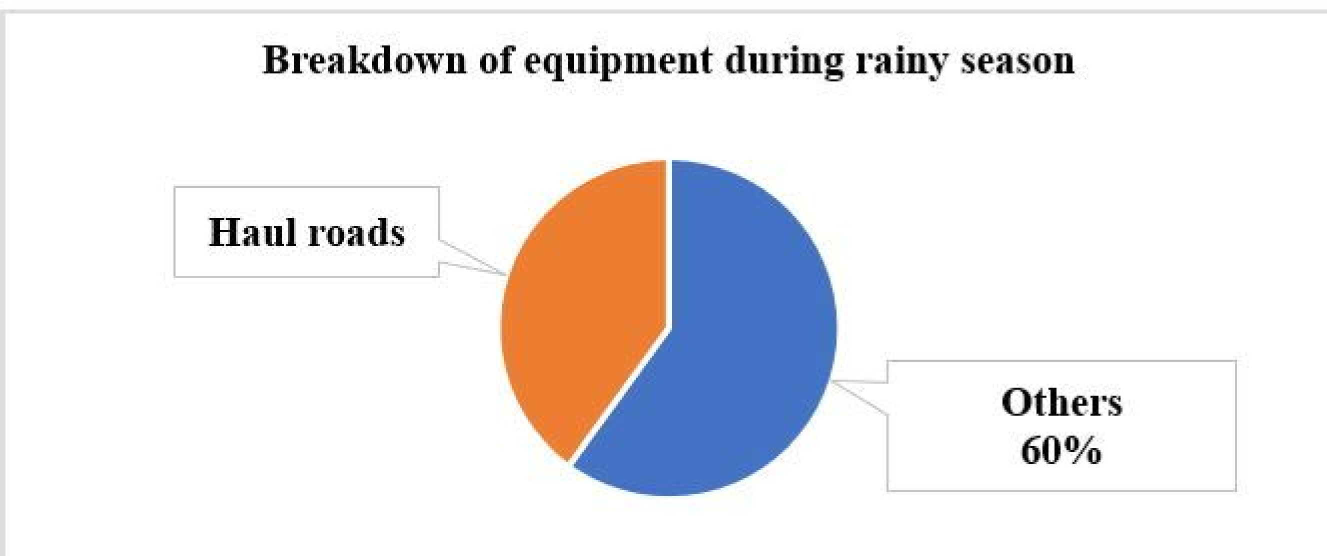

Figure 5

Breakdown of equipments at Wescoal during rainy season.

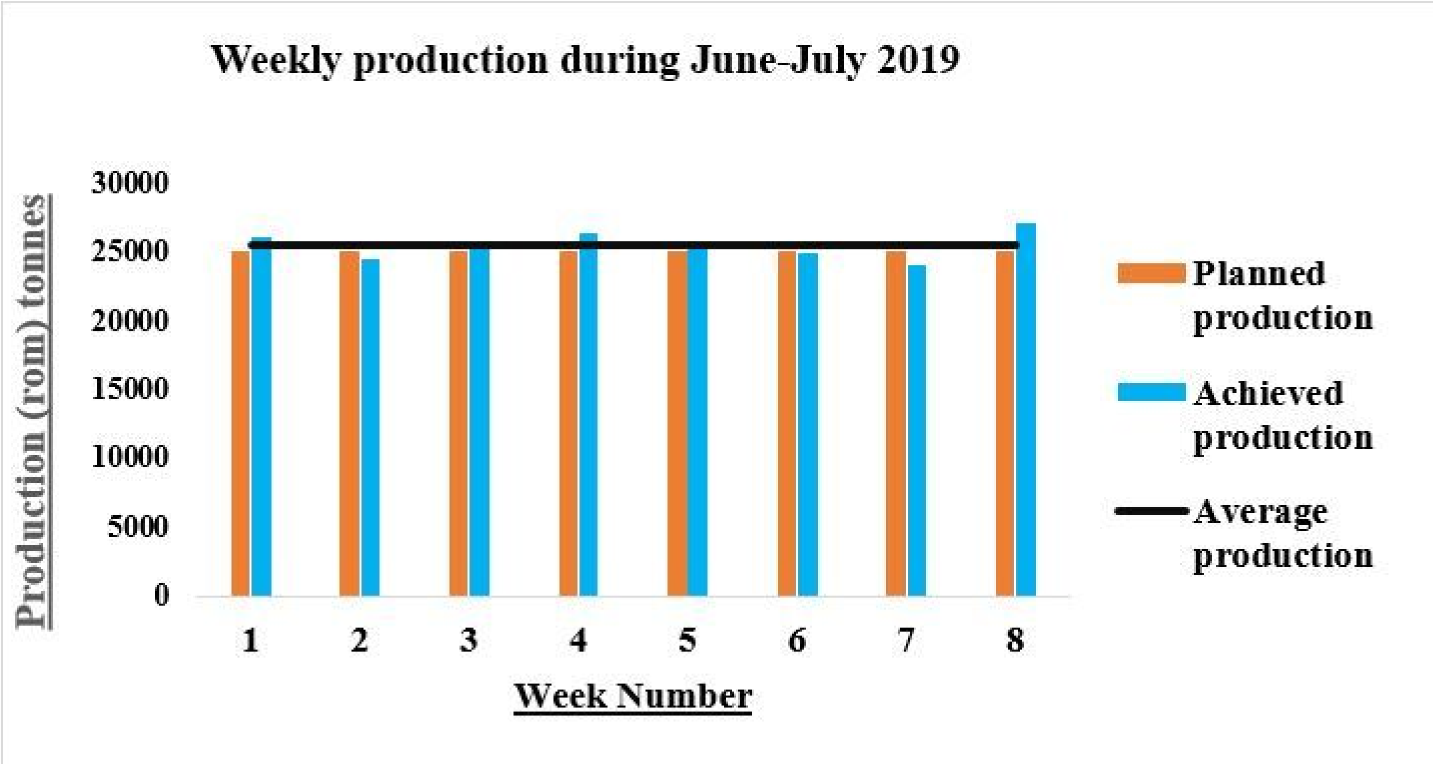

Figure 6

Weekly production during the non- rainy season

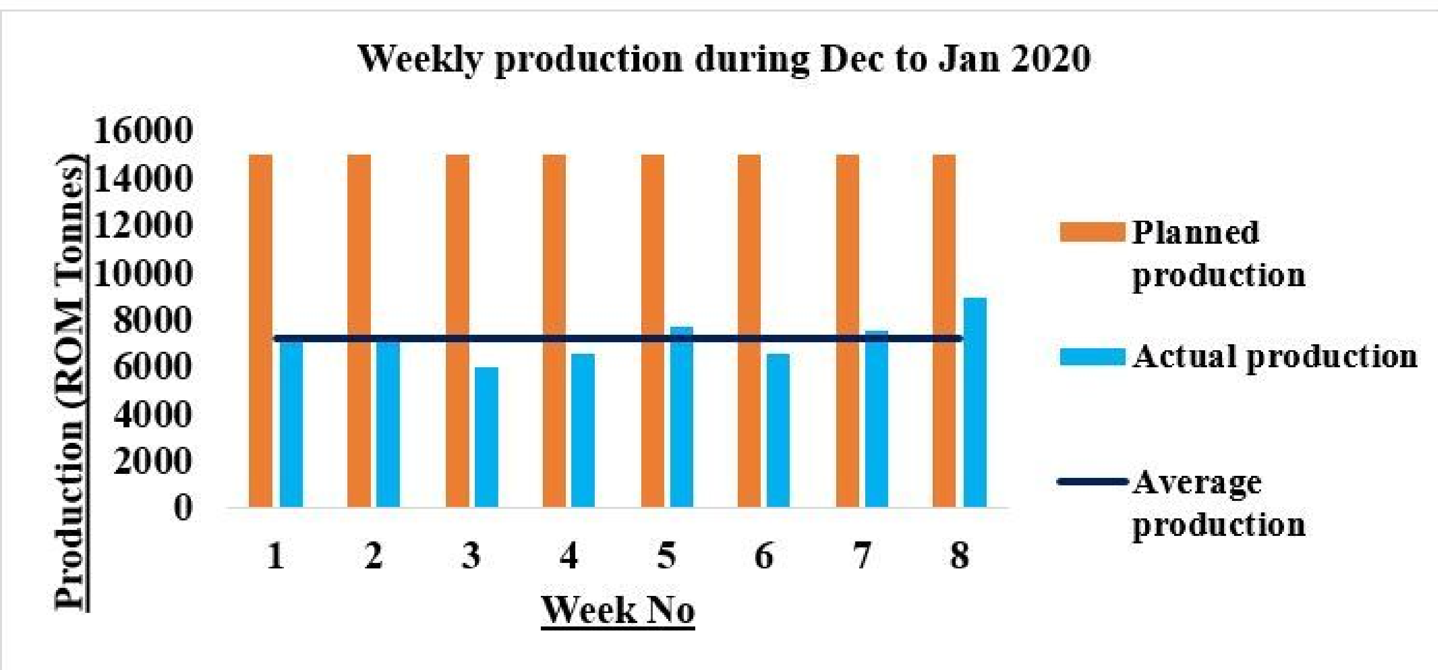

Figure 7

Weekly production during the rainy season