THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

ENVIRONMENTAL IMPACTS OF COAL MINING AT MAAMBA COLLIERIES LIMITED IN CHOMA, ZAMBIA.

BY

BUNDA BESA

Lusaka,

June, 2001

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A dissertation submitted to the University of Zambia in partial fulfillment of the requirements of the degree of Master of Mineral Sciences.

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Declaration

I, **Bunda Besa**, declare that this dissertation was written in accordance with the rules and regulations governing the award of Master of Mineral Sciences of the University of Zambia. I further declare that the dissertation has neither in part nor in whole been presented as a substance for award of any degree, either to this University or any other University.

Signature: ______________________________

Date: **18th June 2001**

Dedications

To my Lord and Saviour Jesus Christ. To my late mum, dad and brother. I also dedicate it to my wife, son and my family for their support and encouragement.

Approval

This dissertation of **Bunda Besa** is approved as partial fulfillment of the requirements for the award of degree of Master of Mineral Science by the University of Zambia.

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Abstract

Environmental impacts of coal mining and processing operations on land, water and air are identified, measured, evaluated, interpreted and discussed. The impacts of these operations are scarring most of the areas, land surface degradation, pollution of surface water bodies as well as air pollution.

This study is aimed at quantifying how much damage has been done to the environment as a result of open pit coal mining and processing operations. Estimates of rehabilitating and revegetating Kanzinze and Izuma pits have been established by the study. To achieve these objectives, assessment was done to quantify the total area disturbed by mining and waste dumping operations. This was done by detailed surveying of the pits and waste dumps using a GTS 701 Total Station. Results showed that 321 hectares of land and forest have been destroyed by the operations. Total volume of excavations in Kanzinze and Izuma pits amounts to 13.9 million m^3 occupying an area of 268 hectares. Waste dumping have also affected the environment quite extensively and to date, 6.61 million m^3 of overburden and discard material have been dumped and have occupied an area of 53 hectares. The types of costs estimated in the study include costs of backfilling excavations in mined out areas, dozing and grading of backfill material to required slope and revegetation in Kanzinze and Izuma pits. The costs of rehabilitating and revegetating past and present damages in Kanzinze and Izuma basins have been estimated at US$68,641,784.

Water samples were collected at various points along the Kanzinze River and along its tributary (Izuma River). Results showed that the pH of water in the Kanzinze River dropped drastically from 7.7 at Kanzinze upstream to 2.5 downstream. The decrease in the pH was due to oxidation of pyrite (after exposure to oxygen and water) resulting in the formation of acidic effluent, acid water that is eventually discharged into the Kanzinze River.

Effects of mining operations on air have also been assessed and discussed and results of the dust sampling indicate that the open pit and the Coal Preparation Plant (CPP) are the most affected in terms of coal and silica dust concentrations.

Environmental regulations (i.e. current environmental policies and the Environmental and Protection and Pollution Control Act No. 12 of 1990) and their impacts on the operations of the mine have been reviewed and discussed. Factors that contribute to non-compliance by Maamba Collieries Limited (MCL) have also been established and suggestions made on how best the existing regulations can be modified to allow Maamba Collieries Limited conform to or embark on redressing past environmental impacts as well as modifications to current mining practices for the betterment of the environment.

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All the staff at Maamba Collieries Limited for allowing me to carry out this research at their mine, and for allowing me to use their laboratory facilities for data analysis – In particular Mr. R. Mdala (Mine Manager), Mr. E. Ngwata (Superintendent - Technical), Mr. G. Munachonga (CPP – Superintendent), Mr. I. Chipaila (Chief Surveyor), Mr. N. Nyembe (Pit Superintendent) and all the people who assisted me with data collection.

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List of abbreviations

No.	Abbreviation		Description
1.	AMD	-	Acid Mine Drainage
2.	ANFO	-	Ammonium Nitrate Fuel Oil
3.	Ave.	-	Average
4.	BCM	-	Bank Cubic Meter
5.	Cat.	-	Caterpillar
6.	CDG	-	Carl Duisberg Gesellshaft
7.	Conc.	-	Concentration
8.	CPP	-	Coal Preparation Plant
9.	DC	-	Drive’s Cabin
10.	ECZ	-	Environmental Council of Zambia
11.	FEL	-	Front End Loader
12.	FJF	-	Fuel Job Factor
13.	GC	-	General Conditions
14.	GTS	-	Geodetic Total Station
15.	HCL	-	Hydrochloric Acid
16.	HMC	-	Heavy Media Cyclone
17.	K	-	Kwacha (Currency)
18.	MCL	-	Maamba Collieries Limited
19.	MENR	-	Ministry of Environment and Natural Resources
20.	PHB	-	Pohlig Hanchel and Bleichert
21.	ppcc	-	Parts per cubic centimeter
22.	RE	-	Relative Error
23.	ROM	-	Run-of-mine
24.	SANTREN	-	Southern African Network for Training on Research and Environment.
25.	SME	-	Society for Mining Engineers
26.	UDI	-	Unilateral Declaration of Independence

27. UNU/INRA– MRU - The United Nations University, Institute for Natural Resources in Africa – Mineral Resource Unit.

28. US$ - United States Dollars (Currency)

29. ZSIC - Zambia State Insurance Cooperation.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Study area

1.1.1 Location and access

Maamba Collieries Limited (MCL) is located in the Gwembe valley within the Gwembe Coal Formation. It is bounded by latitudes $17^0 20^1$ and $17^0 27^1$ S and longitude $27^0 10^1$ and $27^0 15^1$ E (Figure 1.1). Access to Maamba is by a road that extends southeast from the Great North Road that links Livingstone, Lusaka and Copperbelt. The mine is 88 km from Batoka.

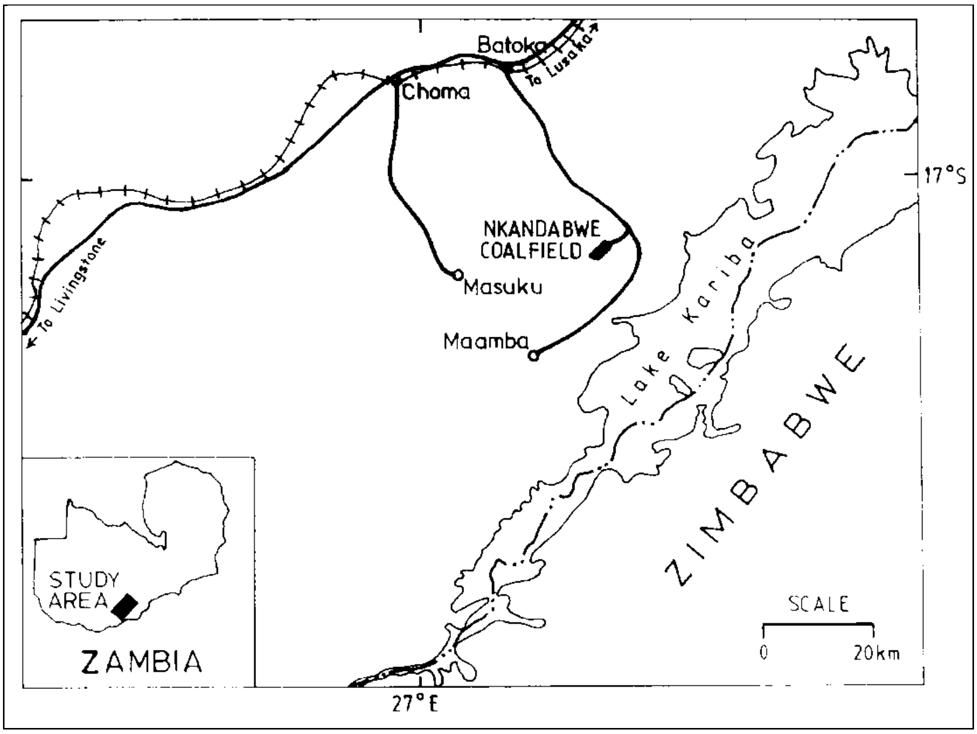

Figure 1.1: Location and access of Maamba Collieries Limited.

Alternative route to Maamba is a gravel road from Choma to Masuku and then a rough track down the escarpment to the valley floor or a track that follows the aerial ropeway from Masuku to Maamba. The track routes are often impassable during rainy season.

1.1.2 Topography

Maamba Collieries Limited is located in a low broad valley surrounded by relatively steep ridges. It is situated on the northwestern side of the valley, with Maamba Township approximately in the centre (Figure 1.2). The intervening terrain is rugged. Drainage is provided by the Kanzinze River, which used to transverse Maamba Collieries Limited in an east-southeasterly direction before turning northeast. The Kanzinze River was later diverted through the Kanzinze diversion canal to facilitate coal extraction in Kanzinze Basin. Major tributaries of the Kanzinze River are the Izuma, Jongwe and Siankondobo rivers. All streams are predominantly seasonal in flow. Izuma River was also diverted to allow open pit mining operations in Izuma basin. The Kanzinze River and its tributaries eventually flow into Lake Kariba, which is a man-made lake and serves as a water reservoir for the Kariba hydroelectric facility shared by Zambia and Zimbabwe.

Figure 1.2: Topographic map of Maamba area (Source; Survey Department)

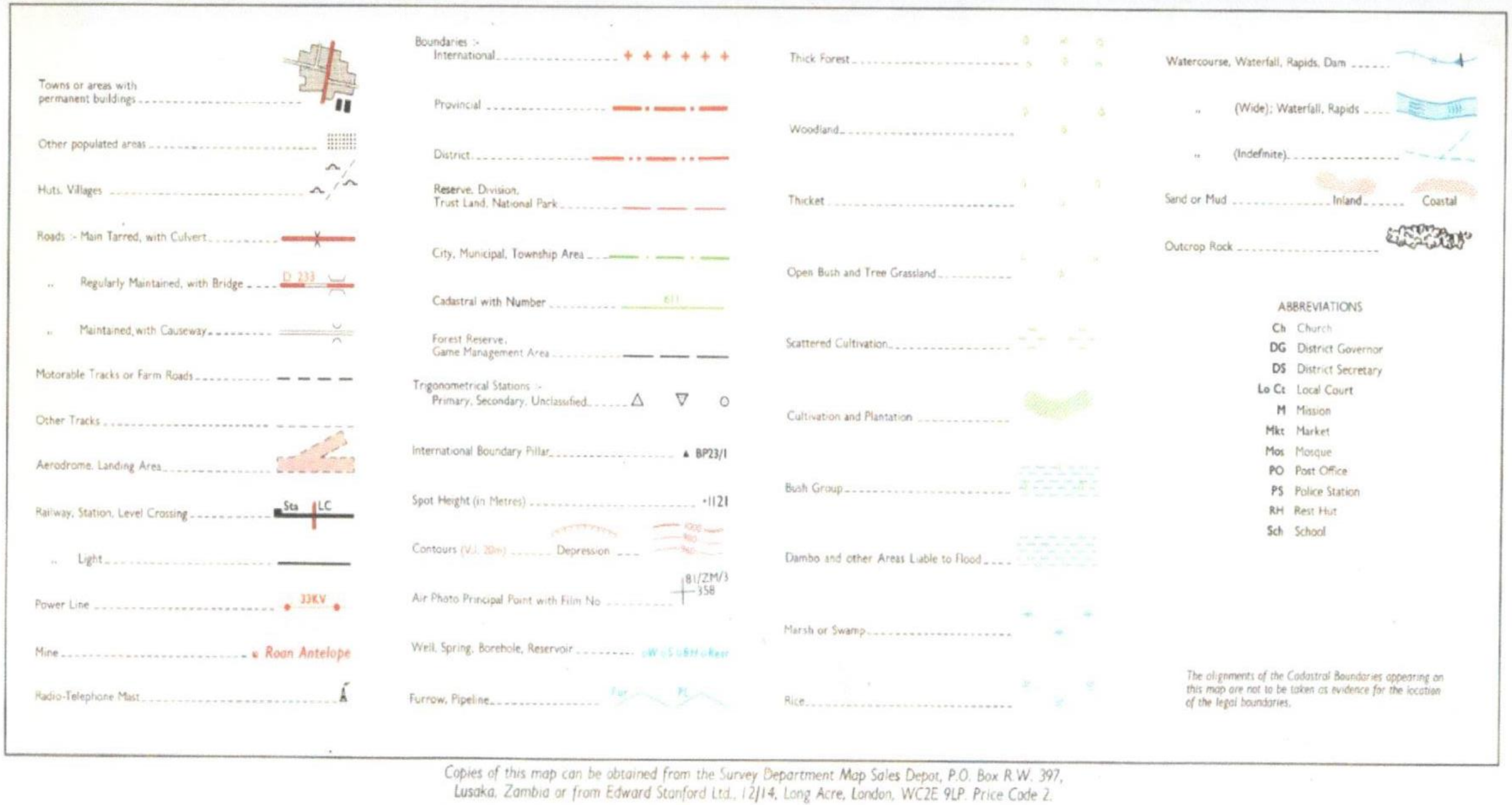

Figure 1.3: Legend of Topographic map of Maamba area (Source; Survey Department)

1.1.3 Geology

Maamba Collieries Limited is situated in the Gwembe Coal Formation, which is part of the Lower Karoo System (Figure 1.4). The Gwembe Coal Formation is subdivided into lower, middle and upper units (Matherson G.D (10)[1]). The lower unit is arenaceous and the middle and upper units, argillaceous and carbonaceous respectively. The middle unit comprises the main coal seam, and it overlies the carbonaceous and coaly mudstone. The main coal seam shows considerable variation in thickness and may grade laterally into coaly mudstone. In some regions, it is split by horizons of sandstone and siltstone. The overlying rocks are dark – grey to black, homogenous, massive silty mudstones or fine-grained siltstone. The thickness of the main coal seam ranges from a few centimeters to a maximum of 11 meters thick. The coal seams, which occur above the main seam, are usually only a few centimeters and rarely more that 1.5m thick.

[1] Number in brackets indicates reference number.

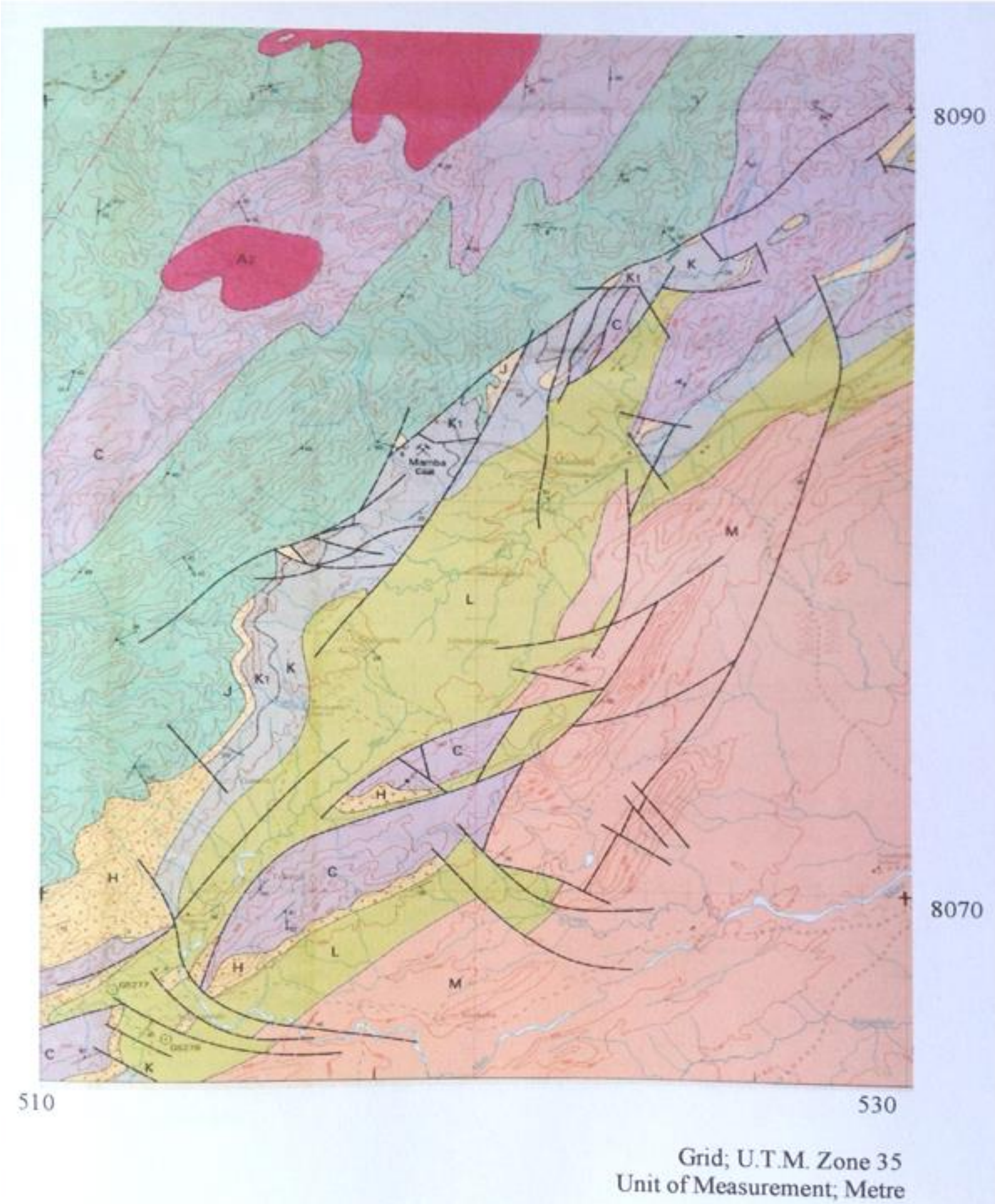

Figure 1.4: Geology and Tetonics of map of Maamba area (Source; Geological Survey Department, Report No. 37)

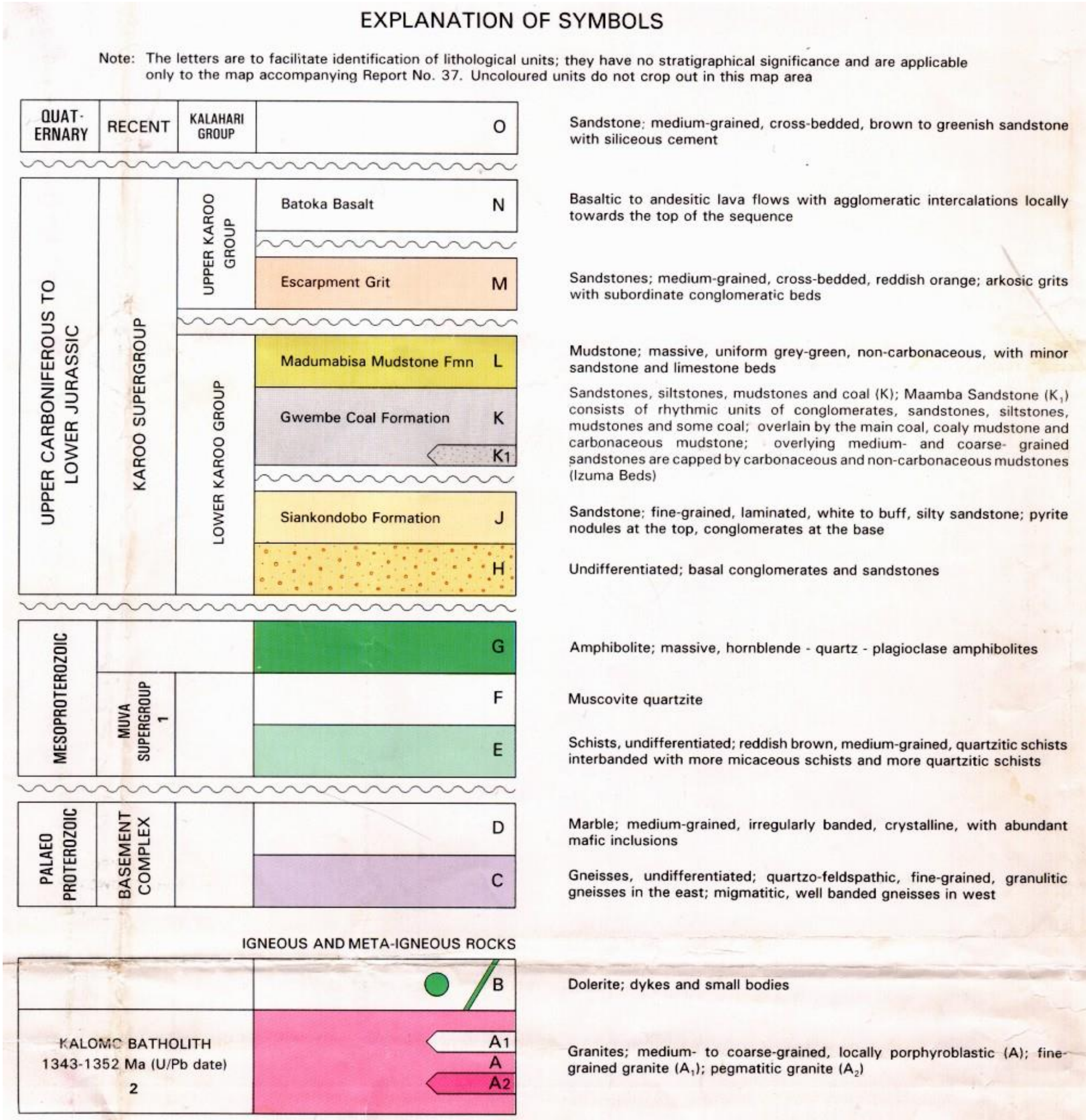

Figure 1.5: Legend of Geological map of Maamba area (Source; Geological Survey Department)

1.1.3.1Seam characteristics

The following are descriptions of seam horizons in descending order of stratigraphic occurrence (Figure 1.6):

Seam No. 5: - This is the highest stratigraphically occurring seam. It occurs as a single bed with average thickness of 0.84m.

Seam No. 4: -This seam lies approximately 23m below seam No. 5 and occurs as a multi-bedded seam generally containing two to four separate beds. The thickness of the individual bed is variable with a combined total thickness of 2.30m. The beds are separated by mudstones of varying thickness.

Seam No. 3: -It is situated approximately 3m below seam No. 4. This seam is also multi-bedded, consisting of two or three individual coal beds separated by varying thicknesses of mudstone and / or carbonaceous mudstone. The combined thickness of the coal beds averages 1.43m.

Seam No. 2: - It lies approximately 12m below seam No. 3 and it occurs as a single bed. The average thickness of this seam is 1.33m.

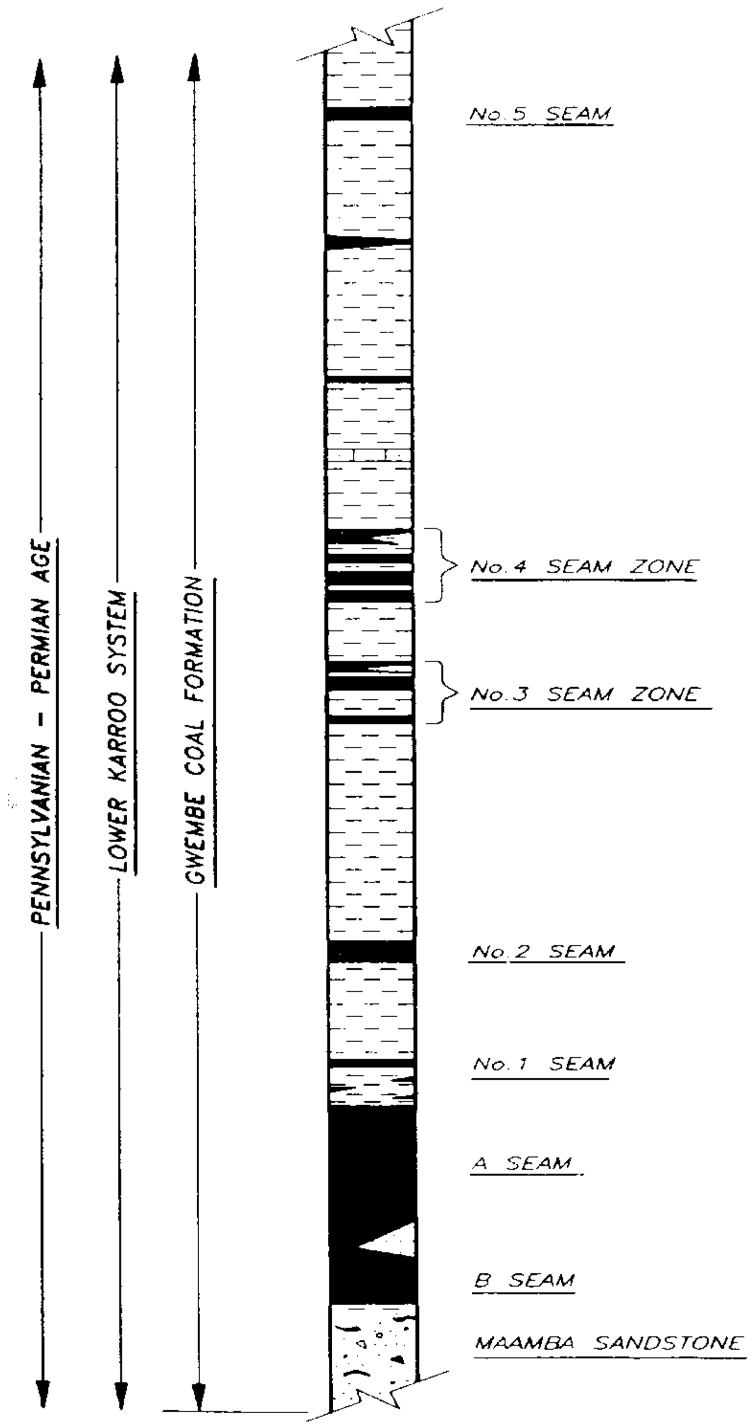

Figure 1.6: Generalised stratigraphic sections showing the relative position of major coal seams and zones of the Gwembe formation within MCL (Source: John T.B – 1993 (9))

Seam No. 1: -This lies approximately 5m below seam No. 2 and it also occurs as a single bed but is sometimes split into two benches. The seam averages 0.36 in thickness with a variable in-seam parting.

Seam A: -This is the thickest of the seams being mined at MCL and it lies approximately 2m below seam No 1. The average thickness of seam A is 6.25m with several small, variable in-seam partings. Separate splits of seam A occur both above and below the main seam. The ability to recover the lower split during mining is dependent on the thickness of the split and the amount of sandstone separating the split from the main seam.

Seam B: -This is the other major seam being mined at MCL and it occurs from 0 to 2m below seam A. The average thickness of seam B is 2 to 2.5m and occurs as a single bed. The immediate bottom strata vary from a thin layer of clay / mudstone to direct contact with the sandstone.

1.1.3.2 Coal reserves

The coal reserve base of MCL totals 78 million tonnes with Kanzinze and Izuma pits having a total of 21 million tonnes. The tonnages are expressed on an in-situ basis and are limited to seams A and B. The following are the in-situ coal reserve statements of MCL as at 31 st March 2000.

AREA		ESTIMATED RESERVES IN-SITU – METRIC TONNES
KANZINZE		
(i)	Open pit	7,440,000
(ii)	Underground	8,650,000
(iii)	Pillar	1,590,000
(iv)	Block X	2,730,000
	TOTAL	**20,410,00**
(i)	Kanzinze extension**	18,000,000
SUB-ECONOMIC RESERVES		
South fault 'D'		11,700,000
IZUMA BASIN		
(i)	Open - pit	13,890,000
(ii)	Underground	14,000,000
	TOTAL	**27,890,000**
Total Reserve of Maamba		
Proven		60,000,000
Probable		18,000,000

**Kanzinze extension reserves are classified as probable; all remaining areas are classified proven.

1.1.4 Population and agriculture

The area is fairly densely populated, mainly by Tonga speaking people. The Valley Tonga live in villages ranging in size from less than a dozen to more than a hundred families depending on the availability of water, fertile soils and distribution of Tse–tse flies. Flooding of Lake Kariba has had a tremendous impact on the social and cultural environment of the people, because they had to leave their fertile flood plains to resettle in the escarpment belt and the non-flooded valley floor.

Goats, cattle and poultry are kept in most villages. The staple food is corn (maize) which is grown with bulrush millet, together with groundnuts, pumpkins, cassava and drought resistant sorghum. Crops are grown for family consumption (subsistence farming), so agricultural methods are simple and include the use of hand hoes and cattle-drawn ploughs.

1.2 Objectives of the research

The objectives of the research were to: -

(i) assess and quantify the extent of past environmental degradation in terms of land, water and air, and propose possible measures to redress them;

(ii) review current environmental regulations/practices pertaining to such type of operations and suggest ways of how best they can be modified; and

(iii) suggest and estimate the costs of remedying / mitigating past and present damages to the environment in Kanzinze and Izuma basins.

1.3 Research methodology

Fieldwork involved detailed traverse survey on the disturbed surfaces of the open pits and on waste dumps. Traverse surveys were done with a GTS701 Total Station. Surveying of open-pits involved determining the coordinates and elevations of selected points within and along the Kanzinze and Izuma open pits. Coordinates and elevations measured were plotted in Surfer Mapping System to determine the volume of excavations that have been created by open-pit mining operations and to determine how much material would be required to backfill the mined-out areas of the two pits. Coordinates were also used to determine the total surface area degraded by open pits and waste dumping in the area. To determine the volume contained in waste dumps, traverse surveys were done around the top and bottom of the waste dumps. Coordinates and elevations of selected points around the top and bottom of waste dumps were determined and results plotted in Surfer Mapping System. The volume of the solid material above the lower surface of the dump indicated the volume of the dump. To determine the effects of open pit coal mining and processing on water quality, water samples were collected using one liter containers and the samples were taken to Environmental Engineering Laboratory at the University of Zambia for analysis. Dust sampling was also undertaken at various open-pit mining and coal processing operations and within Maamba Township using a Konimeter. This was done to determine the extent and magnitude of particulate emissions in the area.

1.4 Significance of the study

The results of the assessments have furnished information as to which measures/steps should be undertaken to remedy current and mitigate past negative impacts of mining operations on the environment at Maamba Collieries Limited. Costs to rehabilitate past environmental impacts in Kanzinze and Izuma basins have also been established in the study. Review of current environmental regulations, has come up with suggestions in which Maamba Collieries Limited could be made to embark on measures aimed at environmental remediation.

CHAPTER TWO

2.0 OPEN PIT MINING OPERATIONS

2.1 History on the progression of open cast mining at Maamba

Maamba Collieries Limited (MCL) has operated surface mining since its inception in 1967. Prior to the development of MCL, coal requirements of Zambia were covered by imports from Wankie mine located in Hwange, Zimbabwe. After the Unilateral Declaration of Independence (UDI) in 1965, the Zambian government became concerned over the reliability of Wankie coal supplies and by late 1966, Nkandabwe mine, located 23 km northeast of present MCL mine was opened. After producing approximately 1.0 million tonnes of coal, operations were abandoned because of complex geologic faulting, steep inclination of coal seams and inundation of the open pit by water (9). Open pit mining operations at MCL began in the Kanzinze basin at the outcrops of seams A and B along the present Kanzinze river diversion canal. However, after producing approximately 13 million tonnes of clean coal, production shifted to Izuma basin in 1985 as a stop gap measure while the dragline (the major stripping machine) was being repaired in the Kanzinze basin. Operations in Kanzinze basin resumed in 1986 after a major breakdown of the dragline. Production, however, did not last long before the dragline broke down again in 1991 and operations were again shifted to Izuma in the same year. Operations in Izuma basin allowed MCL to maintain coal production during the dragline repair. Currently, all coal mining operations have been shifted to Izuma basin.

2.2 Open cast mining operations in Kanzinze basin

Open-pit mining operations in the Kanzinze basin began in 1967 after execution of the Kanzinze River diversion canal. Mining operations began by bush clearing and loose soil removal ahead of mining using bulldozers. This operation was followed by prestripping[2] of loose soil material (Plate 2.1) done with 88BE and 110RB Rope Shovels.

Plate 2.1: Soft overburden material that is removed by shovels and dozers (Photo: Besa - 2000)

Prestripping of loose soil sediment material was done without blasting and material consisted of alluvium and oxidised (weathered) zones. Prestripping was

[2] This is the removal of top-most layer of loose soil and overburden material overlying the coal seam without exposing the seam.

followed by stripping[3] of competent overburden material overlying the coal seam with the aid of the Dragline, i.e. sidecasting. Material was drilled and blasted before the dragline could strip and expose the coal seam. Stripped material was sidecasted within the mined-out areas of the pit

2.2.1 Overburden drilling

Overburden drilling in Kanzinze basin was initially performed by Airtracs. However, because of the increasing stripping ratio[4] and need to increase production, this necessitated the purchase of the BE 50R drill, later replaced by BE 45R used on rotary blasthole drilling of competent overburden material. The drill rig is crawler mounted and drills 230mm diameter blastholes. Later, two drill rigs were purchased i.e. an Ingersoll-Rand DMM and Drill tech D25K to replace the BE 45R drill rig due to its poor performance and constant breakdowns. DMM drill rig drills 230mm diameter holes while D25K drills 170mm diameter holes. Both drills are electrically powered, crawler mounted, hydraulically levelled and have maximum drilling depth of 38.1m. During drilling operations, holes were drilled vertically on a pattern of 8 x 9m which was at times varied to ensure good fragmentation of the material being drilled.

2.2.2. Charging and blasting

[3] This is the removal of waste overburden material directly overlying the coal seam.

[4] Ratio expressing the amount of waste to be moved per unit of ore mined.

Blasting of drill holes utilised non-electric initiation system. This method was employed because of its safety (pressure of high voltage, 6.6kV pit machinery), gave less misfires and did not require blasting accessories such as cables, exploders etc. Drill holes were charged with Ammonium Nitrate Fuel Oil (ANFO) because the explosives offered the following advantages:

- it fills the hole and gives acceptable borehole loading;
- results in an acceptable level of performance during loosening of mudstone;
- is safe during handling; and
- is economical.

During charging, one 5 Kg case of gelignite wrapped with cordtex was used as a primer (Figure 2.1) and was pushed down with a wooden tamping pole to ensure placement of ANFO explosive column on top.

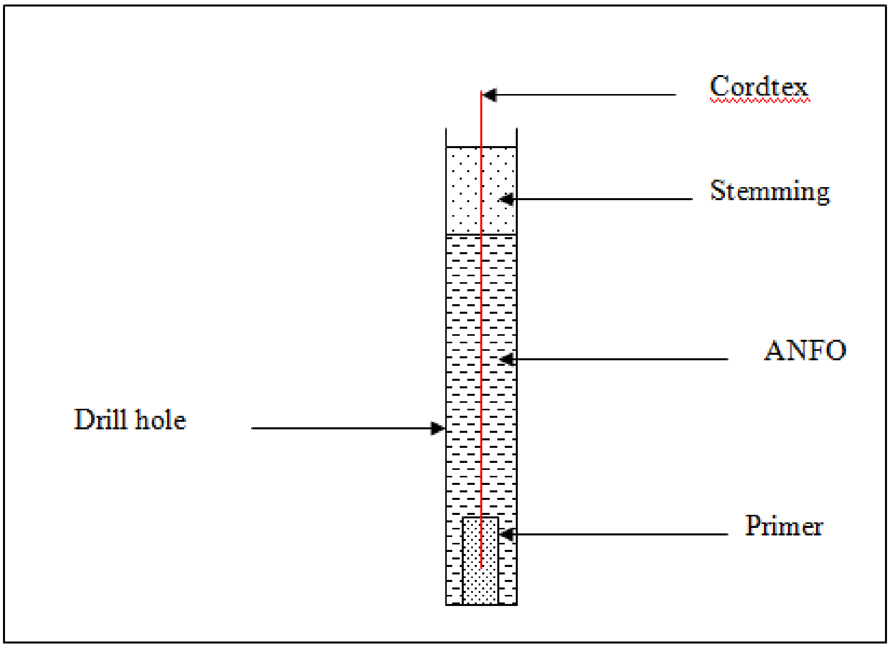

Figure 2.1: Single - hole explosive arrangement.

Approximately 2m of stemming (drill cuttings) were shoveled into the hole (to reduce blowouts) leaving a length of cordtex exposed for tying. All holes were tied together with cordtex after loading. Rows were doubly connected with relays effectively allowing 24 millisecond delay. Front raw (free face) holes were initiated first. The powder factor[5] on overburden blasting averaged 0.30 Kg/Bank Cubic Meter (BCM).

2.2.3 Overburden removal (stripping)

Figure 2.2 shows a simplified dragline operation during overburden stripping. Stripping begins with the dragline at position 1, cutting a trench referred to as a keycut, along the newly formed highwall (2). The distance from the previous keycut position to the new position is referred to as the digout length. The keycut is made to maintain the strip width[6] and uniform highwall. Without a keycut, the panel width would narrow with each subsequent digout, because the dragline could not control the bucket digging against an open face. The dragline deposits the keycut material in the bottom of the mined out pit off the coal and against the previous spoil pile. When the keycut has been completed, the dragline is moved to position 2 to complete excavation of the digout. The material from the digout is cast on top of the keycut spoil. When the digout has been completed the dragline is moved to position 3, the beginning of the next stripping cycle (next digout).

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[5] Ratio of the weight of explosives consumed for blasting a unit volume of material

[6] Width of the cut taken by the dragline as it progresses from digout to digout, along the highwall from one end of the pit to the other.

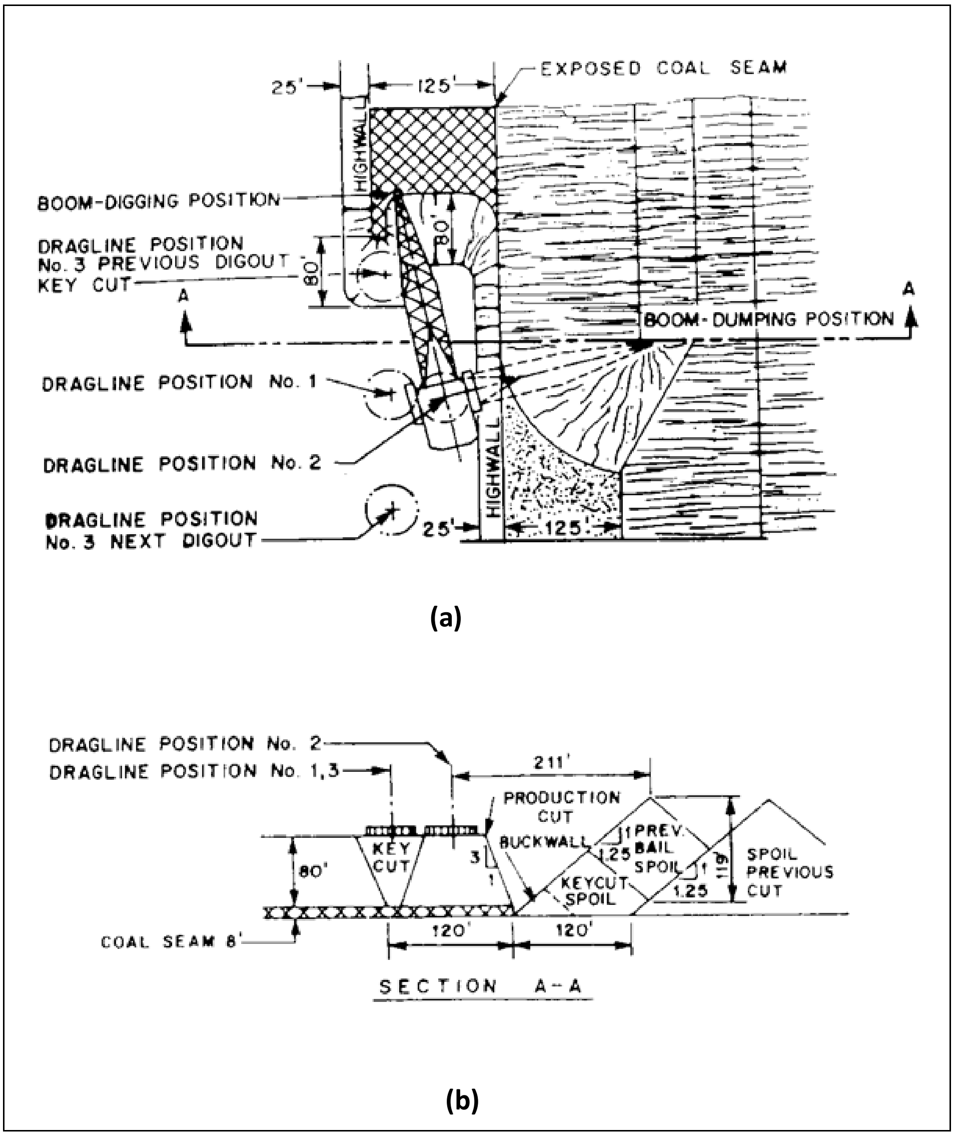


Figure 2.2: Simplified (plan (a) and section (b)) dragline operation sequence during overburden removal (Source; Sengupta. M – 1995 (11))

2.2.4 Coal drilling and blasting

Upon completion of stripping competent overburden material overlying seam A, the top of the coal seam was determined by raw coal analysis of highwall samples from previously mined cut. The geological section of the Technical Service Department was responsible for taking samples while the laboratory section of the same department was responsible for raw coal analysis. After determining the coal roof, the top of the coal seam was cleaned with a rubber tyred dozer prior to drilling. Pit cleanings were loaded into trucks and discarded in waste dumps. The top of the coal seam was then drilled on 5 x 5m pattern with an Airtrac. The depth of each drill hole varied and was dependent on the thickness of the coal seam down to the interburden between seam A and B. Charging and blasting of drill holes was performed utilizing the same procedure of blasting overburden material described in section 2.2.2.

2.2.5 Coal Extraction (Seam A)

Loading of run-of-mine (ROM) coal into trucks was performed by front-end loaders (FEL) or rope shovels. ROM was loaded in 45 tonne haulpaks or 76 tonne rock trucks for transportation to a receiving hopper of the CPP for processing.

2.2.6 Interburden removal

The interval between seam A and B is separated predominantly by sandstone. The interburden varies in thickness from 0 to 2m and its removal was accomplished by ripping when the interburden thickness was less than 1.0m and by drilling and blasting when the interburden thickness was more than 1.0m. When interburden removal was by ripping, a dozer equipped with a ripper was used to break the material. The broken material was either loaded into trucks by front-end loaders for disposal within the mined out areas of the pit or simply dozed off towards the mined out strip. When interburden thickness was more than 1.0m, the sandstone was drilled with an Airtrac on a 5 x 5m pattern. The depth of drill holes also varied depending on the thickness of the interburden. Blastholes were charged and blasted as described in section 2.2.2. Blasted material was loaded into trucks by front-end loaders and was dumped in waste dumps or material cast in mined out areas of the pit by the dragline.

2.2.7 Coal extraction (Seam B)

After determining the roof of seam B by raw coal analysis, the seam roof was cleaned and drilled on a 5x5m pattern using Airtracs. Charging and blasting seam B was identical to seam A. Blasted seam B was loaded into trucks by front-end loaders and transported to the grizzly of the coal preparation plant for processing or dumped at the run-of mine (ROM) coal stockpile near the coal preparation plant.

2.3 Open cast mining operations in Izuma basin

Mining operations in Izuma basin began in 1985 when the dragline was undergoing major repairs in Kanzinze basin. Open-pit operations started at the outcrops of seam A and B and allowed MCL to maintain coal production when the dragline was on breakdown. Trucks, shovels and front-end loaders units were used during open-pit mining operations. Open pit operations in Izuma are similar to Kanzinze except that:

(1) Stripping operations in Izuma pit were done with rope-shovels while in Kanzinze a dragline was used for the same purpose; and

(2) Stripped overburden material in Izuma was dumped in Izuma dump unlike in Kanzinze basin where material was sidecasted within the mined-out areas of the pit.

2.3.1 Overburden drilling

Drilling of competent overburden material in Izuma was done in a similar way overburden drilling in Kanzinze basin was done (see section 2.2.1). Holes were drilled vertically on pattern of 8 x 9m though additional holes were drilled where extra explosive force was required.

2.3.2 Charging and blasting

Charging of blastholes was similar to Kanzinze Basin (see section 2.2.2 for details)

2.3.3 Overburden removal (stripping)

Stripping of blasted competent overburden material in Izuma basin was done using rope-shoves and front-end loaders (Plate 2.2), unlike in Kanzinze basin where the BE 1260W Dragline was utilized for the same purpose.

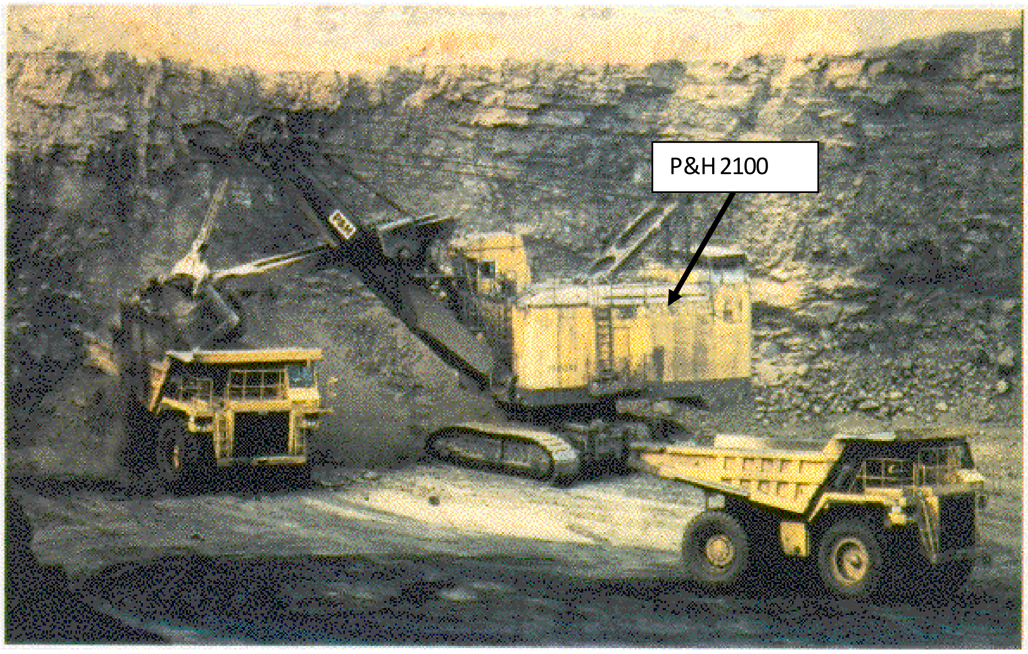


Plate 2.2: Overburden stripping using P&H 2100 Rope Shovel and Cat 777 Dump trucks in Izuma pit (Photo: Besa - 2000)

Since blasted material was retained in the highwall area as fragmented structure, the overburden material was scooped up and discharged into trucks with relative ease. Stripped overburden material was transported and dumped in Izuma dump or within the mined out areas of the pit.

2.3.4 Coal extraction (Seam A)

Coal removal in the Izuma pit is accomplished by means of shovel/ front-end loaders /truck unit operations (Plate 2.3). After stripping the competent overburden material above the coal seam, the top of the seam was determined by raw coal analysis of highwall samples from the previous cut.

Plate 2.3: Coal loading using Cat. front-end loaders in conjunction with Cat 773 Dump trucks in Izuma pit (Source: John T.B – 1993 (9))

The top of coal is then drilled and blasted as discussed in section 2.2.1 and 2.2.2. Blasted coal was loaded into trucks by shovels and the ROM coal transported by trucks to the grizzly or ROM stockpiled for subsequent coal preparation plant processing.

2.3.5 Interburden removal

Since the two coal seams are separated by an interval of sandstone with thickness ranging from 0 to 2m, the sandstone was also removed as discussed in section 2.2.6.

2.3.6 Coal extraction (Seam B)

Seam B was also extracted as discussed in section 2.2.7.

CHAPTER THREE

3.0 PREPARATION AND HANDLING OF COAL

3.1 Coal Preparation Plant

The coal preparation plant, was constructed by Vernot Plc of France and began operations in 1970. Run-of-mine coal from the Kanzinze and Izuma pits is transported using 45 and/or 76 tonne haul trucks to the coal preparation plant for processing. At the coal preparation plant, incoming coal trucks dump the ROM coal into the receiving hopper for onward processing. However, ROM coal is sometimes stockpiled in the area when there is planned maintenance in the pit or on the major equipment e.g. the dragline. Stockpiling allows continuous production of coal in the coal preparation plant when there are no operations in the pit. Coal stockpiling is expensive because of the rehandling costs involved and it promotes formation of Acid Mine Drainage (AMD) (7) and should therefore be minimized. At the receiving hopper, large lumps (approximately +500mm) that cannot pass through the grizzley are broken up manually using hand-held hammers. A reciprocating feeder (Figure 3.1) discharges coal from the hopper onto the belt conveyor, which conveys ROM to the scalping screen that separates the ROM coal at +150mm size. The +150mm material reports to a picking belt where rocks are removed manually. ROM coal on the picking belt reports to the jaw crusher which reduces the raw coal to -150mm before discharging to the silo storage conveyor, where it combines with the -150mm size fraction from the scalping screen. A 780 tonne capacity concrete silo, equipped with two vibratory feeders, is used to store the raw coal before being processed.

Coal processing begins with a primary raw coal vibratory screen, which separates the rounds (+40mm to -150mm) from the -40mm size fraction. The +40mm to -150mm ROM coal reports to the round drewboy washer (Section 3.1.1) for processing. The -40mm size is separated on two secondary raw coal vibratory screens at +10mm separation with the –40mm to +10mm size reporting to the medium drewboy washer for cleaning. Rounds (+40mm to +150mm) and medium (+10 to -40mm) clean coal and reject products are dewatered on vibratory drain and rinse screen to remove magnetite before reporting to their respective belt conveyors. Following are typical operations of a drewboy washer.

3.1.1 Drewboy washer

Drewboy washers (Figure 3.2) are used to wash coal of size +10 to -40mm (mediums) and +40 to -150 mm (rounds). These types of washers are used because of their high float capacity and the lighter nature of coal (density = 1.56t/m^3). Approximately 76% by weight of ROM coal is processed through the drewboy washer vessels.

The raw coal is fed into the separator at one end and the floats (clean coal) are discharged from the opposite end by a star-wheel with suspended rubber, while the sinks (coarse discard material) are lifted out from the bottom of the bath by a radial-vaned wheel mounted on an inclined shaft. The medium (magnetite in fluid form) is fed into the bath at two points i.e. at the bottom of the vessel, and together with the raw coal, the proportion being controlled by valves. Clean coal and coarse discard reject material from the drewboy washer is dewatered and rinsed to recover the magnetite using magnetic separators.

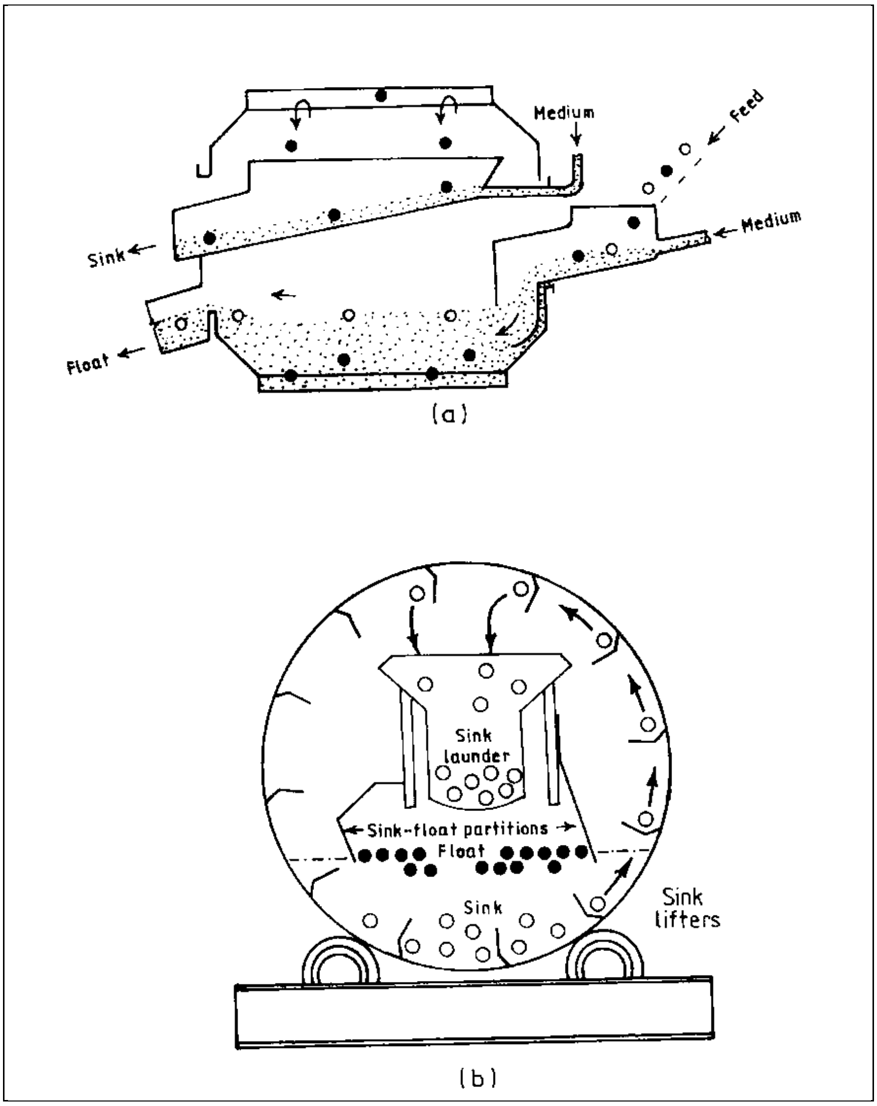


Figure 3.2: Construction of a drewboy washer (Source; Wills B.A – 1988)

3.1.2 Jig bath

Fines (-10mm) from the two secondary raw coal screens were initially washed in the jig bath. Jigs work on a principle of gravity concentration to separate coal fines from coarse waste material (Figure 3.3).

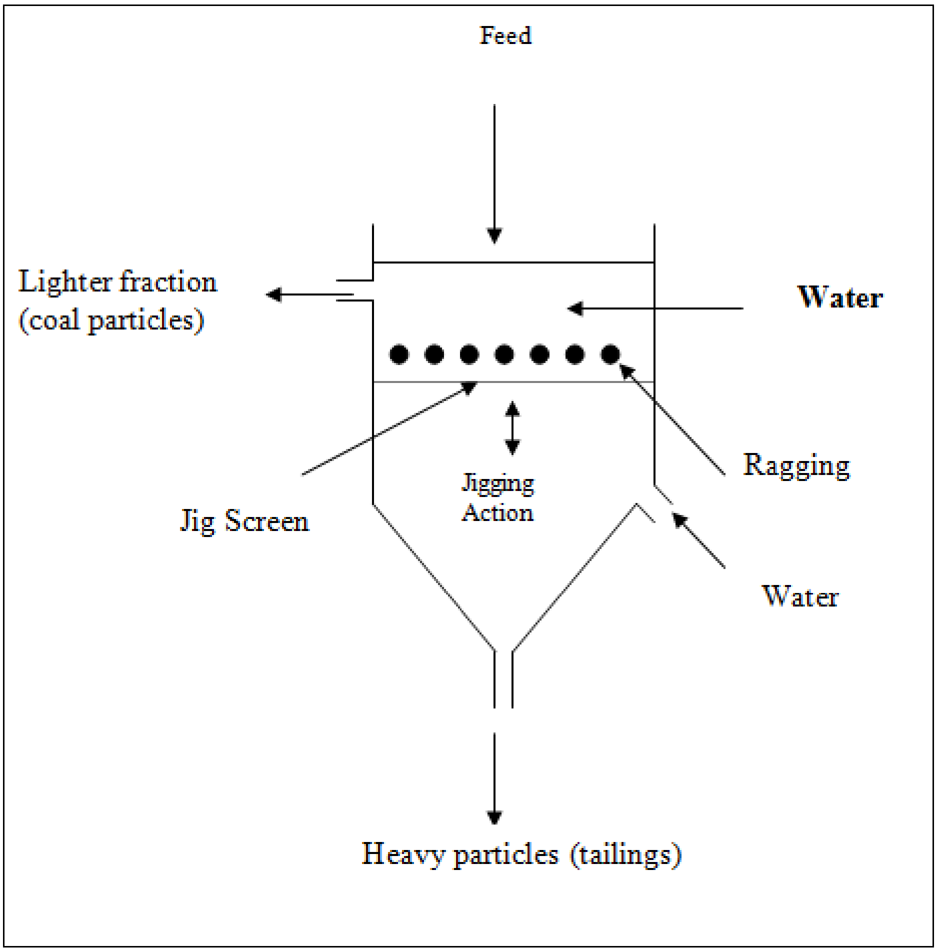


Figure 3.3: Basic construction of a Jig bath

In the jig bath, the separation of minerals of different specific gravity is accomplished in a bed which is rendered fluid by a pulsating current of water so as to produce stratification (14). Particles of different specific gravity arrange themselves according to sizes and specific gravity during the pulsating movement of the jig.

Heavy particles (discard materials) sink and form the bottom layer while the lighter coal particles float and form the top layer and are recovered. Later, jig baths were replaced by the cyclones which used to treat fines more efficiently than the jig bath thus increasing coal production.

3.1.3 Cyclones

Cyclones are continuously operating classifying devices that utilize centrifugal force to accelerate the settling rate of particles (14). These were used to treat coal fines of size +0.5 to -10mm more efficiently than the jig bath. A typical cyclone (Figure 3.4) consists of a cone shaped vessel, open at its apex or underflow, joined to a cylindrical section, which has a tangential feed inlet.

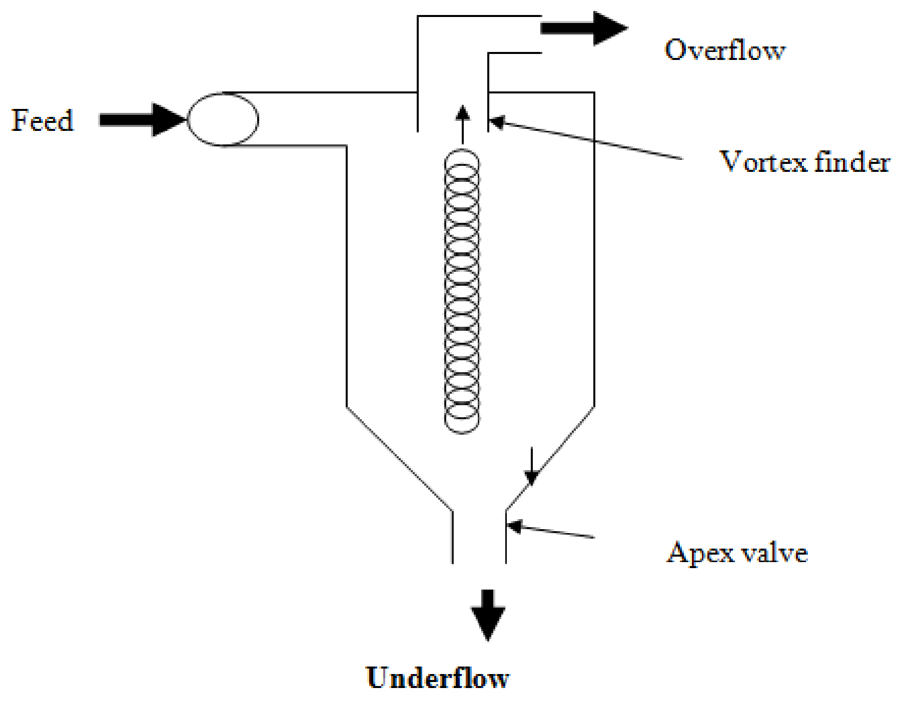


Figure 3.4: Basic construction of a cyclone

The top of the cylindrical section is closed with a plate through which passes an axially mounted overflow pipe. The pipe is extended into the body of the cyclone by a short removable section known as the vortex finder, which prevents short-circuiting of feed directly into the overflow.

The feed is introduced under pressure through the tangential entry, which imparts a swirling motion to the pulp. This generates a vortex in the cyclone, with a low-pressure zone along the vertical axis. The classical theory of cyclone action is that particles within the flow pattern are subjected to two opposing forces i.e. an outward centrifugal force and an inwardly acting drag (14). The centrifugal force developed accelerates the settling rate of the particles, thereby separating particles according to size and specific gravity. Faster settling particles (coarse material) moves to the wall of the cyclone where the velocity is lowest and migrate to the apex opening as reject material. Due to the action of the drag force, the slower-settling particles (coal fines) move towards the zones of low pressure along the axis and are carried upward through the vortex finder to the overflow. Later in 1985, the CPP was upgraded (to increase production) by addition of heavy media cyclones (HMC) which replaced the already existing cyclones.

3.1.4 Heavy Media Cyclones

Fine coal (+0.5 to -10mm) is cleaned using heavy media cyclones. Heavy media cyclones provide a high centrifugal force and a low viscosity in the medium enabling much finer separations to be achieved (14). In the coal preparation plant, 20% of ROM is washed in the heavy media cyclones. Feed to the heavy media cyclones is deslimed at about 0.5mm to avoid contamination of the medium with slimes, and to minimize medium consumption. The fine coal is suspended in a very fine medium of magnetite and is introduced tangentially to the cyclone under pressure. The sinks (-0.5mm) which are the tailings, leave the cyclone in the apex while the float products (fine clean coal) are discharged via the central vortex finder. Both sinks and floats are then washed, dewatered and rinsed to recover the magnetite by magnetic separation.

3.2 Processed coal handling

Initially when mining operations commenced at MCL, all coal was transported by road to Batoka loadout area. Coal from Batoka was loaded in rail wagons for onward transportation to consumers. However, because of the expensive nature of road haulage, bad state of the road from Maamba to Batoka and the rugged terrain (because of the escarpment) between Maamba and Masuku (which did not favour construction of rail or conveyor belt) a decision was reached to construct the aerial ropeway from Maamba to Masuku. The aerial ropeway was commissioned in 1971 to transport clean coal to Masuku Screening Plant. Clean coal from Masuku is transported by rail to consumers.

3.2.1 Road haulage

Currently, due to expensive nature of road haulage, less than 5% of coal is transported by road. Distance to markets and the quality of the existing road infrastructure and the large number of trucks which must be employed to deliver any significant tonnage of coal makes road haulage expensive. The road from Batoka to Maamba descends the face of the escarpment traversing relatively rugged terrain making road haulage costly. The above constraints have lead to most of the coal from MCL being transported by the aerial ropeway.

3.2.2 Aerial ropeway

The aerial ropeway was constructed by Pohlig Hanchel and Bleichert (PHB) in 1971 to transport washed coal from Maamba to Masuku. The ropeway (Plate 3.1) is approximately 11.8km in length and traverses difficult terrain having a 680m rise in elevation between the coal preparation plant and Masuku.

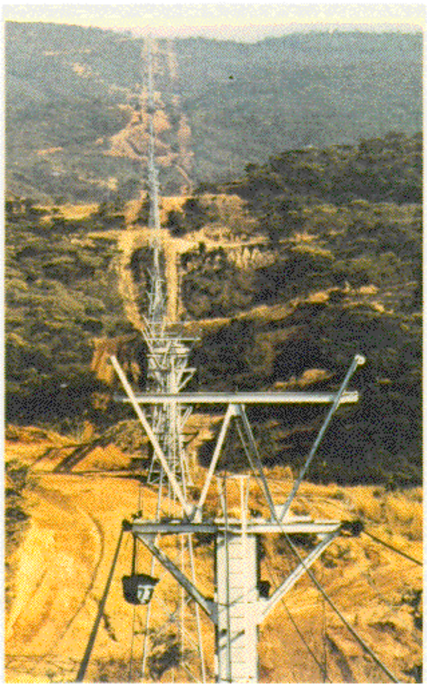


Plate 3.1: Aerial ropeway (Source: John T.B – 1993 (9))

It has a design capacity of 272 tonnes / hour with 365 carriers. Currently, an average of, 119 carriers exist on the ropeway system. Clean coal from the coal preparation plant is received at the ropeway by conveyor discharging into a revolving distributor feeding the carriers. From MCL, coal is transported by ropeway to Masuku where the carriers are unloaded. At Masuku coal from the carriers is reclaimed from the receiving hopper by vibratory feeder and transported by belt conveyor to the screening station and rail loadout.

3.3 Coal Screening at Masuku

The aerial ropeway discharges coal to a receiving hopper which directs the coal to either the 'crushing and screening' facility or to ground storage area. Coal is reclaimed from ground storage by FEL which dumps coal into the hopper mounted over the ground reclaims belt. Coal reclaimed from storage reports to one of the two rail loadout bins. Coal is then sized to –80mm by two roll crushers and conveyed to the screening plant. The screening plant utilizes two inclined vibratory screens to create the following products (Table 3.1).

Table 3.1: Product size fractions at Masuku Screening Plant

No.	Product	Minimum size (mm)	Maximum size (mm)
1	Cobbles	30	80
2	Nuts	20	30
3	Peas	10	20
4	Mediums	0.5	40
5	Fines	0.5	10

These product sizes are discharged from the elevated screen to concrete bunkers. A front-end loader is used to recover the coal from storage area and load the railcars. The capacity of the screening facility is rated at 180 to 200 tonnes/ hour.

CHAPTER FOUR

4.0 APPRAISAL OF ENVIRONMENTAL IMPACTS OF MINING

Although Maamba Collieries Limited has had positive socioeconomic impacts on the local and regional culture in the southeastern part of southern province in Zambia, these have been offset by negative environmental impacts of the mining activities in the area. The impacts include land degradation, pollution of surface water bodies and air pollution (particulate dust and gaseous emissions).

Environmental issues at Maamba Collieries Limited have remained unaddressed because of not having compelling environmental regulations when mining started. Also, in light of the parastatal status and relationships of Maamba Collieries Limited vis-à-vis other government bodies/agencies and economic pressures in the past, relaxed approach had been applied relative to the interpretation and enforcement of governing environmental regulations. It is only recently that there has been an increased global awareness of environmental concerns. The following are the environmental impacts engendered by open pit mining operations in Kanzinze and Izuma Basins of Maamba Collieries Limited.

4.1 Environmental impacts in the Kanzinze Basin

4.1.1 Vegetation removal (Bush clearing)

Surface coal mining at Maamba Collieries Limited has profound effects on the environment. During initial development of the mine, vegetation at mine site is cleared using dozers. As a result of vegetation removal, indigenous species of plant have been destroyed leaving the area bare. Destruction of these plant species may in future end up with extinction.

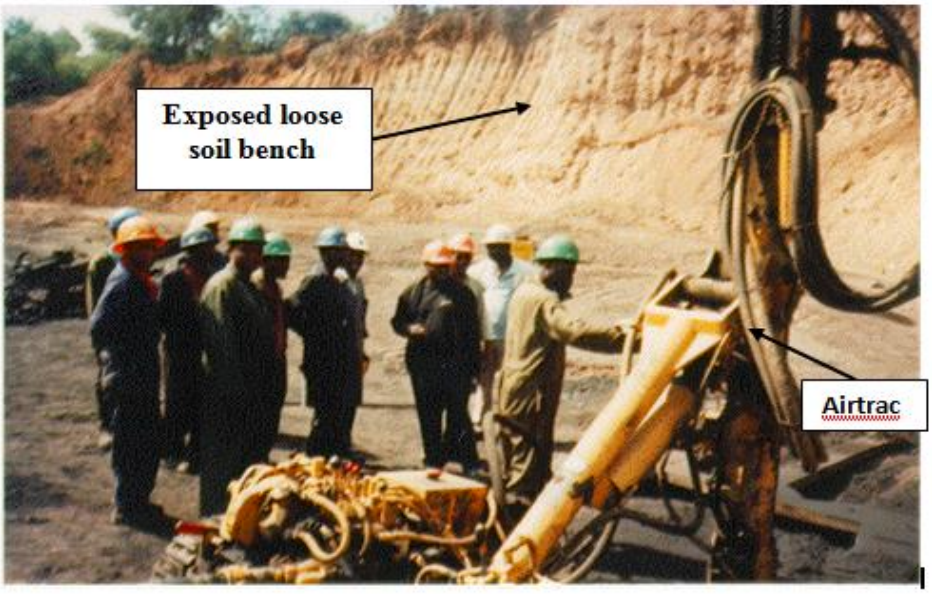
The bare soil resulting from vegetation removal is vulnerable to various agents of erosions e.g. wind, surface runoff etc. The newly exposed soil is also subjected to new weathering, compaction and transport mechanism. Since Maamba coal and overburden material are associated with pyrite, the newly exposed soil material promotes formation of acid mine drainage that eventually joins the stream. Surface runoff from these areas carries with them sediments that have silted and clogged the Kanzinze River.

Loss of vegetation cover due to open pit mining operations has greatly contributed to the loss of wildlife in Maamba area. Vegetation removal has interfered with normal existence of flora and fauna leading to migration of wildlife from the affected areas to quieter and less disturbed habitats.

4.1.2 Loose soil removal

Removal of loose soil (Plate 5.1 (a) and (b)) has resulted in extensive effects on the environment at Maamba Collieries Limited. The newly exposed surfaces are prone to agents of erosion and runoff from these areas, which carry with them sediments, end up in Kanzinze River affecting the water quality in the stream.

(a)



(b)

Plate 4.1: (a): Stripping of soft overburden material with shovels (b) Stripped soft overburden material in the background (Photo: (a) Besa, (b) Sinkolongo – 2000)

4.1.3 Competent overburden (mudstone) removal

Stripping of competent overburden material overlying seam A in Kanzinze basin is accomplished through drilling and blasting to loosen the material and sidecasting of material within the pit by the dragline. Sidecasting of overburden material has created undulating spoil ridges in Kanzinze basin making the area visually unattractive. This has resulted in rugged terrain emanating from excavations that have been created in the area. The excavations act as effluent and leachate impoundment (Plate 4.2).

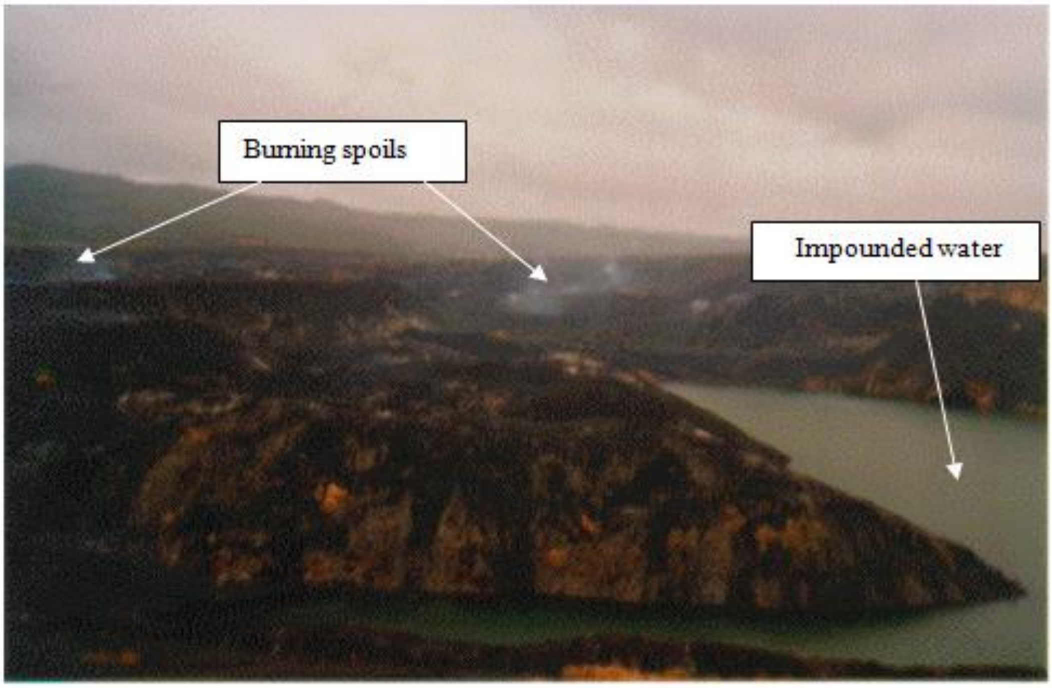


Plate 4.2: Land disturbance and water pollution in the Kanzinze pit. (Photo: Besa - 2000)

Overburden removal has also led to spontaneous combustion of sidecasted sulphidic material (Plate 4.3). During combustion, gaseous fumes such as sulphur dioxide, nitrous fumes and at times carbon monoxide are emitted polluting the air not only in the mine area but also in the Maamba Township and nearby villages. Since overburden material occurs with pyrite, reactions between water, air and the overburden results in the formation of sulphuric acid that finds its way in Kanzinze River. The acid lowers the pH of water, leading to the destruction of aquatic life in the stream (see stages and mechanism of acid formation below).

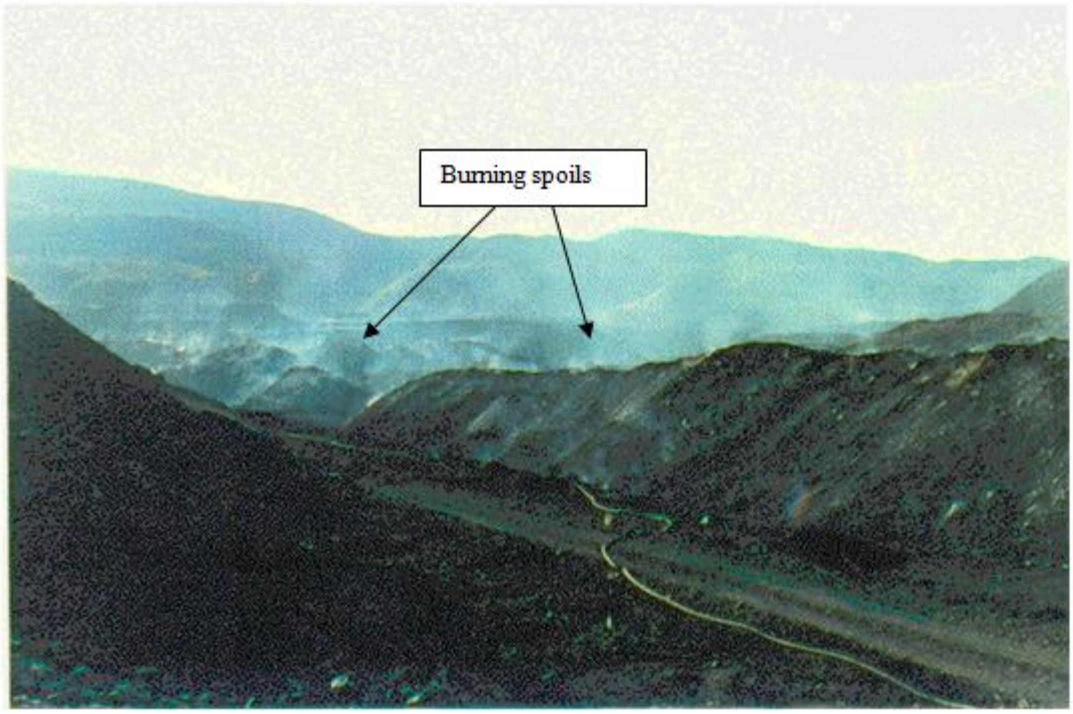


Plate 4.3: Burning spoils in the Kanzinze pit (Source: John T.B - 1993 (9))

Stage 1

This stage is a relatively slow chemical or biological oxidation of pyrite and other sulphide minerals near neutral pH, producing ferrous iron and acid (equation 1). The step may be catalysed by the bacteria Thiobacillus Ferroxidans through direct contact with sulphide mineral.

$$FeS_2 + 7/2O_2 + H_2O \longrightarrow Fe^{2+} + 2SO_4^{2+} + 2H^+ \quad \text{.............................. (1)}$$

Stage 2

In this stage and in the presence of oxygen, ferrous iron is oxidised into ferric iron which precipitates as ferric hydroxide and release more acidity (equation 2). As the pH falls even further, below 3.5, ferric iron remains in solution and oxidises the pyrite directly (equation 3).

$$Fe^{2+} + 1/4O_2 + H^+ \longrightarrow Fe^{3+} + H_2O \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

$$Fe^{3+} + 3H_2O \longrightarrow Fe\,(OH)_3 + 3H^+ \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Stage 3

At this stage, the bacteria rapidly catalyses the process by oxidising ferrous iron into ferric iron and the overall rate acidity production is increased by several orders of magnitude (equation 4)

$$FeS_2 + 14Fe^{3+} + 8H_2O \longrightarrow 15Fe^{2+} + 2SO_4^{2+} + 16H^+ \quad \ldots\ldots\ldots\ldots \text{(4)}$$

4.2 Environmental impacts in Izuma basin

Environmental impacts in terms of land degradation in Izuma basin are relatively not as severe as in Kanzinze basin. This is because the Izuma pit is new as compared to Kanzinze. However, the following environmental impacts are observable in Izuma basin:

4.2.1 Vegetation removal (bush clearing)

Open pit mining operations in Izuma basin have led to loss of vegetation as a result of bush clearing ahead of mining operations. This has resulted in destruction of the indigenous plant species in the area. As in Kanzinze basin, vegetation removal has also resulted in migration of wildlife from the area to quieter and less disturbed areas. Erosion during the rainy season is accelerated on the newly exposed surface leading to increase in sediments in the Izuma stream, thereby silting and clogging the stream.

4.2.2 Removal of loose soil

The removal of loose soil in Izuma basin has created varying impacts on the environment which include:

1. Destruction of soil by altering its chemical characteristics, which limits its use for agricultural purposes;
2. Accelerated erosion on newly exposed surfaces; and
3. Changing the landscape thus creating negative visual impacts.

4.2.3. Competent overburden (mudstone) removal

Stripping of competent overburden material in Izuma basin is carried out using rope shovels in conjunction with trucks while lately the dragline is used for prestripping purposes. Like in Kanzinze basin, competent overburden material (mudstone) is first drilled and blasted before stripping (see section 2.2.1 and 2.2.2 for details). Stripped material was initially dumped in the Izuma dump across the Izuma river diversion canal. Currently, the overburden material is dumped within the mined out areas of the pit close to the coal face to reduce haul distance. Environmental impacts of mudstone removal observed in Izuma basin are outlined below:

- Dumped material in Izuma pit is not graded affecting the area visually as well as changing the landscape of the area;
- Dumped overburden material is also prone to erosion and it increases sediment loads in the Izuma River;
- The pyrite found in overburden material reacts with water and air (oxygen) forming sulphuric acid. The acid is washed in Izuma River lowering the pH of the water in the stream; and
- Overburden material in Izuma basin has led to spontaneous combustion which has resulted in gaseous fumes e.g. CO_2, SO_2, NO_X, and CO to be emitted in the air.

4.2.4 Waste dumping

Exposure of coal in Izuma basin is done by rope shovels in conjunction with trucks. Unlike in Kanzinze pit, stripped overburden material from Izuma pit is not sidecasted but material is transported using dump trucks and dumped in Izuma waste dump across the Izuma diversion canal. Environmental impacts of waste dumping at Izuma are the following:

- Waste has taken up large areas (6.4 hectares) of land destroying vegetation and soil suitable for agricultural purposes. Destruction of vegetation might also lead to extinction of indigenous plant species in the area.
- Dumped overburden material has resulted in artificial hills creating negative visual impact in the area.

- Runoff from dumped overburden material (Plate 4.4) carries with them sediments that silt and clog the Izuma stream.
- Since wildlife depends very much on dense vegetation cover, destruction of vegetation at dumpsites leads to migration of wildlife to denser quieter areas.

Plate 4.4: Erosion from Izuma waste dump (Photo: Besa - 2000)

4.3 Environmental impacts of rejects from CPP

Coal Preparation Plant produces two solid waste streams i.e. fine tailings and coarse waste (Figure 4.1). The latter constitutes the +5mm material and is transported by trucks to disposal areas. Fines constitute the –0.5mm and are discharged into slurry ponds through flexible pipes for disposal (Plate 4.5).

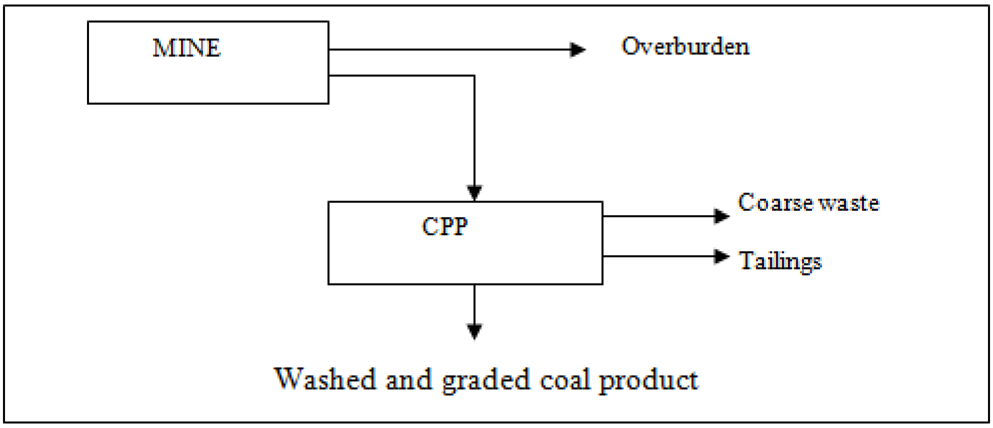


Figure 4.1: Products from the CPP

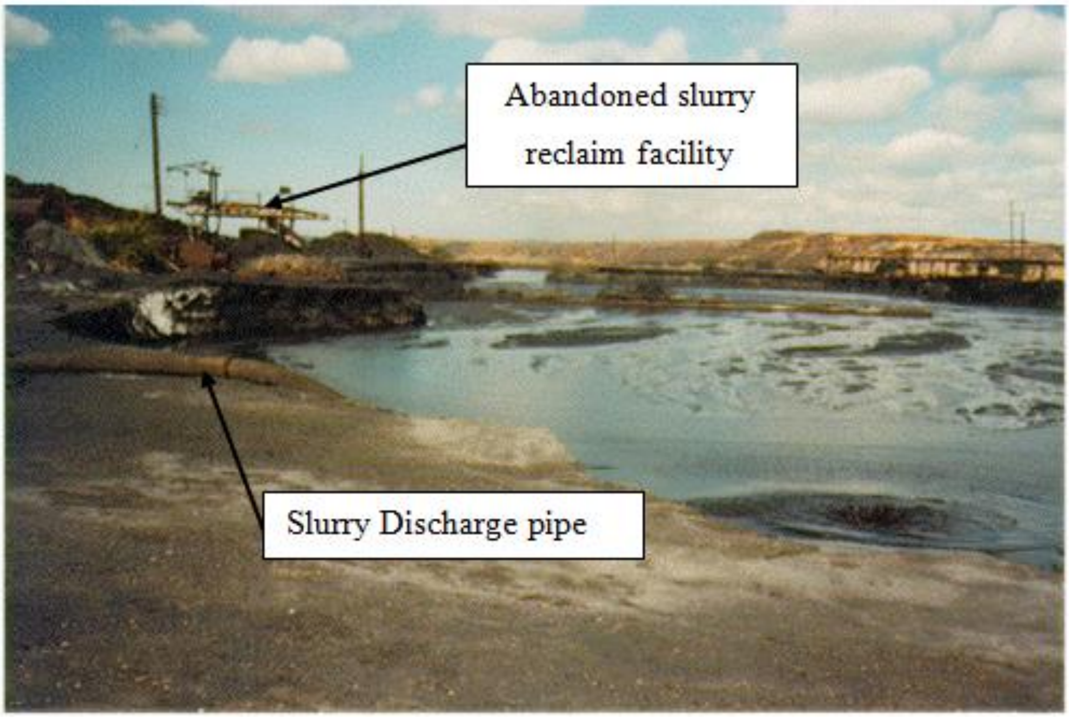


Plate 4.5: Slurry material from CPP allowed to settle by gravity (Photo: Besa – 2000)

4.3.1 Environmental impacts of discarded material

Marketable coal, coarse discard material and slurry are produced from the coal preparation plant. Coarse discard material consists mainly of poor quality coal and carbonaceous shales from the drewboy washer and the heavy media cyclones. After washing coal, coarse discard material from the drewboy washer combines with coarse discard material from the heavy media cyclones and the combined material discharged on the coarse reject conveyor that discharges into a truck bin for disposal using dump trucks.

Initially, discard materials were disposed of in mined-out areas of the Kanzinze pit. However, because of long distance from the coal preparation plant, which resulted in high operating costs, disposal of discard material shifted to the area along the Kanzinze river diversion canal (Plate 4.6) where the distance is relatively short.

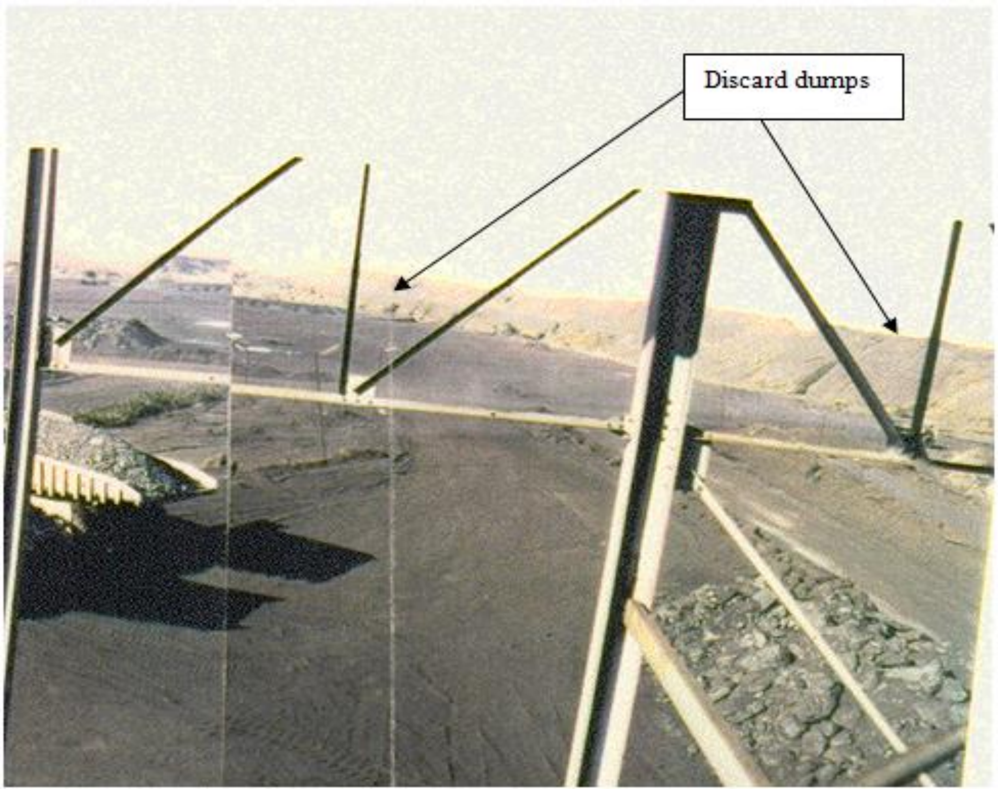


Plate 4.6: Discard material dumped along Kanzinze river diversion canal (Photo: Besa -2000).

As a result of dumping discarded material in this area, the following impacts have been created in the area.

1 Discard dumps have disturbed large area of land and vegetation. A total of 28 hectares of land and vegetation have been destroyed by the dumping operations. Good fertile soils, which can be used for agricultural purposes, have been destroyed by these operations;

2 Artificial hills have been created in the area resulting in negative visual impacts. During rainy season, silt and fine coal particles from these hills are transported by water into Kanzinze and Izuma rivers;

3 Dumped discard material have spawn in spontaneous combustion in the area resulting in the production of gaseous fumes in the area. When the gaseous fumes which are mostly SO_x and NO_x comes in contact with rain water, they form sulphuric acid and nitric acid (see Chapter 5 for details of acid formation) that eventually affect the vegetation, water bodies as well as the soil; and

4 There is also a danger of contaminating ground water resources as a result of seepage of acid water from the dumps. During rainy season, the pyrite found in dumped material reacts with air and water resulting sulphuric acid formation. The acid seeps / leak during heavy rains and contaminates the ground water system and the nearby streams.

4.3.2 Environmental impacts of slurry discharge

Slurry material (-0.5mm) from the two desliming screens was initially discharged in the thickener for process water recovery/recirculation and the thickened slurry pumped at 500m^3/hr to an impoundment area. Initial slurry impoundment area consisted of a pond No.1 with three compartments (Figure 4.2). Each compartment had a capacity of 20,000m^3 and was 5 m deep.

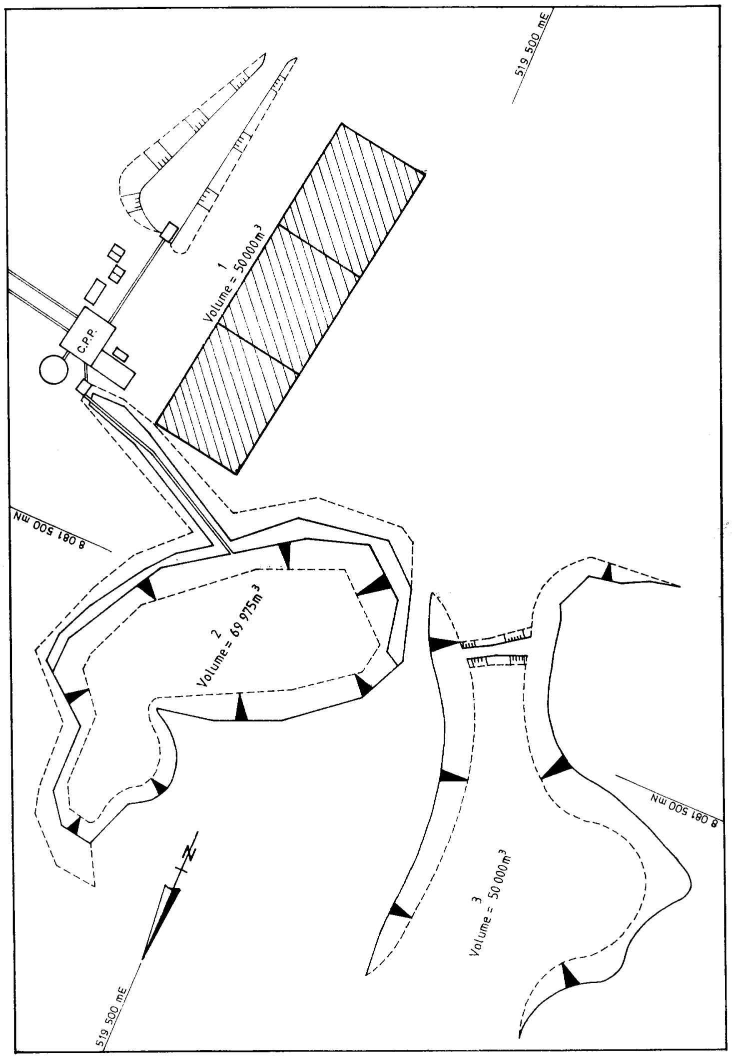


Figure 4.2: Location of slurry ponds

The initial concept of constructing the slurry pond in this manner was that, as slurry was being discharged from the thickener, when the first compartment is filled up, discharge of slurry was supposed to continue in the second compartment and then third compartment.

By the time the third compartment was becoming full, the first should have dried up and dried material being removed by front-end loaders into trucks for further handling. After emptying compartment 1, discharge of slurry was supposed to start in compartment 1 while material in compartment 2 was being excavated and disposed off. After filling compartment 1, compartment 2 was supposed to be ready for filling and by the time compartment 2 was becoming full, compartment 3 was supposed to be ready for filling. This cycle was supposed to be replaced over and over. However, the arrangement failed because of the following reasons:

- The pond was constructed too deep to allow sunheat to penetrate lower strata to dry up within anticipated time. Therefore, it was difficult to scoop wet material as the material got stuck in the bucket.
- Percolation of water from slurry material was not possible because the location and construction of the pond base was in impervious (mudstone) formation.
- The surface area occupied by the pond was not adequate and this made slurry material to be confined thus reducing the drying rate.

After the failure of this arrangement, and when all the compartments of the slurry pond were filled up, slurry material was then dumped in nearby valleys (Pond No. 2 and 3) surrounding MCL using 20.3mm diameter flexible pipes. This method is currently being used to discard slurry material from the CPP. The disadvantage of this method is that it has created extensive negative environmental impact in the area. As a result of dumping slurry material in nearby valleys, extensive impacts on the environment have been created which include:

- taking up considerable area of land, which has resulted in land degradation in the area. A total of three slurry ponds exists (Figure 4.2) degrading an area of over 6.4 hectares of land. Also two tailings disposal areas have been constructed adjacent to the slurry ponds to allow reclaimed tailings from the slurry ponds to be disposed of in the same area in drier state. These disposal areas have degraded over 2 hectares of land.
- Overflow water (Plate 4.7) from the slurry ponds, which carry with them sediments, being discharged directly into the Kanzinze stream decreasing the water quality in the stream.
- Formation of AMD, (due to presence of pyrite in slurry material, its exposure to oxygen and water) which is washed in the Kanzinze River.

Plate 4.7: Discharge of effluent from the coal preparation plant into the Kanzinze River (Photo: Besa - 2000).

4.3.3 Environmental impacts of process water and effluent discharge

Water used for cleaning coal is pumped into industrial tanks from Lake Kariba pump station. Water for washing coal is pumped into the CPP at $300m^3$/hour from industrial tanks. After washing coal, water is collected together with slurry material in the thickener for process water recovery. Water recovered from the thickener is pumped back into the CPP at $300m^3$/hr and is recycled within the CPP. Recycled water is first neutralized with lime so as to avoid corrosion of pipes as a result of acid water from the CPP. Although recycled water is neutralized with lime, it is not done so often because of the costs involved in acquiring lime. Currently, all the process water from the CPP is not recycled, neutralized and is discharged with slurry material into the slurry pond in preference for fresh water from Lake Kariba.

From the ponds, solids are allowed to settle by gravity while the overflow water and seepage from an embankment (Plate 4.7) are discharged into the Kanzinze stream without treatment. Results of direct discharge of untreated water into Kanzinze River are:

- lowering the pH of the water in the Kanzinze stream because the process water from the coal preparation plant is acidic i.e. average pH is 4.5 (although it also depends on the geology of the area). As a result of the low pH values of water, dissolution of heavy metals like Zn, Cu, Pb, Cd, As etc. takes place;

- Process water also acts as the transport medium of suspended and dissolved material from the CPP. Suspended materials are normally the fine coal elements and other carbonaceous shales in ROM, while dissolved material are the heavy metals dissolved in the acid water. Suspended particles reduce light from reaching photosynthetic organisms in the stream, hence the reduction in oxygen production (13). Existence of dissolved heavy metals in water in high concentrations affects the water quality and may lead to the death of aquatic life (7)

4.4 Environmental impacts of run-off-mine (ROM) and washed coal stockpiling

When there is planned maintenance on the pit or on the major equipment, ROM coal is stockpiled in the CPP area (Plate 4.8) to allow continuous coal production in the CPP. Stockpiling of ROM coal has environmental impacts associated with it which include the following:

- Since ROM and washed coal contains pyrite, the stockpiled ROM and washed coal is made to react with air and water resulting in the formation of sulphuric acid. The acid which is formed is washed in the Kanzinze stream, lowering the pH of the water in the stream thereby affecting the aquatic life. The iron oxide forms a coating on the bottom of the stream and further limits the ability of aquatic life to survive in this stream.
- During rainy season, storm water runoff transports suspended solids from the stockpile area into the Kanzinze River.

- Stockpile areas occupy large surface area at MCL. Results of this study (Chapter 5) show that about 1.2 hectares of land have been disturbed only by ROM coal stockpiling.

Plate 4.8: Stockpiled coal at coal preparation plant which leads to acid mine drainage (Source: John T.B – 1993 (9))

CHAPTER FIVE

5.0 QUANTIFICATION AND EVALUATION OF ENVIRONMENTAL IMPACTS

5.1 Land degradation

Mining operations at Maamba have been going on for three decades since its inception and has been done through opencast mining. During the process of mining, substantial amounts of material were moved out as coal and as overburden, leaving excavations of varying depths and sizes in mined-out areas of the Kanzinze and Izuma basins. The excavations and dumped overburden and spoil material have created a rugged terrain, extensively changing the landscape of the area. Therefore, in assessing the redevelopment potential of surface mining and processing at MCL, the magnitude and geometry of the disturbed land was quantified.

5.1.1 Survey area

Environmental impacts of mining operations on land were evaluated in the following areas.

(a) Kanzinze basin

(i) Kanzinze pit

(ii) Kanzinze discard dumps

(iii) Slurry ponds and the dry fine solid dump area; and

(iv) Raw coal stockpile areas

(b) Izuma basin

(i) Izuma pit; and

(ii) Izuma waste dump

The study areas were chosen on the basis of them being the most affected in terms of land degradation and were the major sources of water and air pollution in the area.

5.1.2 Method of estimating surface areas

Total surface area disturbed by mining and coarse rejects from coal processing in the study areas was computed using the method of coordinate (1). A traverse survey was conducted in each study area using a GTS 701 Total Station. Coordinates (x, y) of selected points around each area were determined (Appendix A, B and C). From the survey measurements data for each study area was plotted (as illustrated in Figure 5.1) and surface area determined using formula 1 (See Table 5.1 for results).

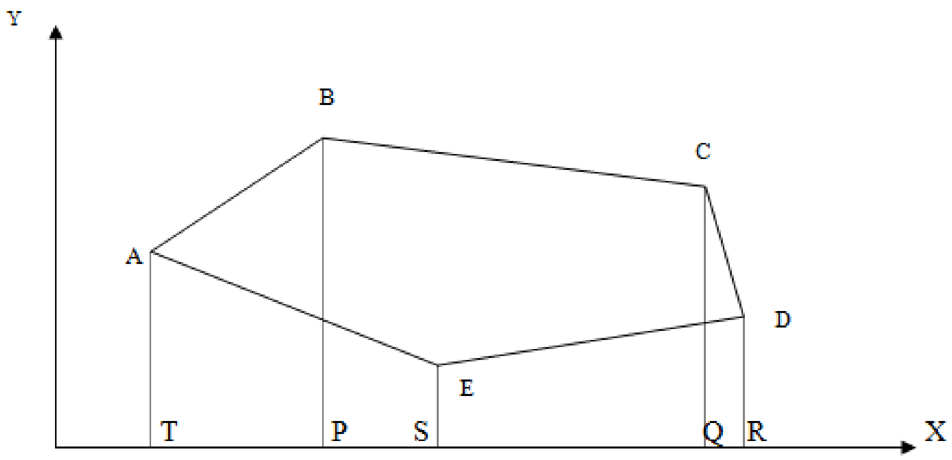


Figure 5.1: Illustration of plotted survey points

Consider ABCDEA as a closed traverse around the study area, whose stations have coordinates E_A, N_A; E_B, N_B; E_C, N_C; E_D, N_D and E_E, N_E relative to the two axes.

The area ABCDEA is calculated as follows:

= [Area (ABPT) + Area (BCQP) + Area (CDRQ) – Area (AEST) – Area (EDRS)]

Which simplifies to:

$$1/2\left[\sum_{i=1}^{n} N_i(E_{i+1} - E_{i-1})\right] \quad \text{...}(5)$$

Where;

N_i = Northing at **i** th station

E_{i+1} = Easting at **i** +**1** th station

E_{i-1} = Easting at **i - 1** th station

5.1.2.1 Results and discussion

Results of the study are given in Table 5.1

Table 5.1: Surface areas disturbed in study areas

No.	Study area	Surface area (m^2)
1	Kanzinze pit	2165578.737
2	Izuma pit	509764.692
	Total Pit area	**2675343.429**
3	Izuma dump	59429.237
4	Kanzinze discard dumps	
	Kanzinze discard dump 1	78284.084
	Kanzinze discard dump 2	122685.790
	Kanzinze discard dump 3	79608.447
	Total dumping area	**340007.558**
5	Slurry ponds	
	Pond No.1	12270.828
	Pond No.2	27771.617
	Pond No.3	24686.887
	Total area occupied by slurry ponds	**64729.332**
6	Stockpile area	
	Area No.1	99196.203
	Area No.2	10256.540
	Total ROM stockpile area	**109452.743**
7	Slurry dump area	
	Slurry dump No. 1	10172.896
	Slurry dump No.1	10284.342
	OVERALL SURFACE AREA DISTURBED	**3209990**

Results of the study show that approximately 321hectares of land have been destroyed by mining and waste dumping operations in the area. Since MCL have been in operation for 3 decades now, it means therefore, that an average of 10 hectares of land is destroyed annually. With the current production at Maamba, the mine has a life of over 47 years, which means that over 470 hectares of additional land will be disturbed before cessation of mining operations.

5.1.3 Method of estimating volumes of excavations and waste dumps

(a) Excavations

Computations of volumes of open excavations were done in Surfer Mapping System, version 5.01. Coordinates (x, y) and elevations (z) of selected points around and within the Kanzinze and Izuma pits were measured with a GTS 701 Total Station. Three methods (i.e. Trapezoidal, Simpson and Simpson'3/8 rules) where used to compute the volume of cuts and fills and the net volume was reported as the average of the three values. Cuts represent the volume of material above the horizontal surface (to be defined) while fills represent the volume of excavations below the horizontal surface (Figure 5.2).

Before volume computations, the horizontal and lower surface between which the volume is calculated is defined. In this study, constant (horizontal) elevation was used and allowed specification of horizontal surface. Constant horizontal surface was used because surface elevations (which were going to be used as the top surface) were not determined before commencement of mining operations at Maamba.

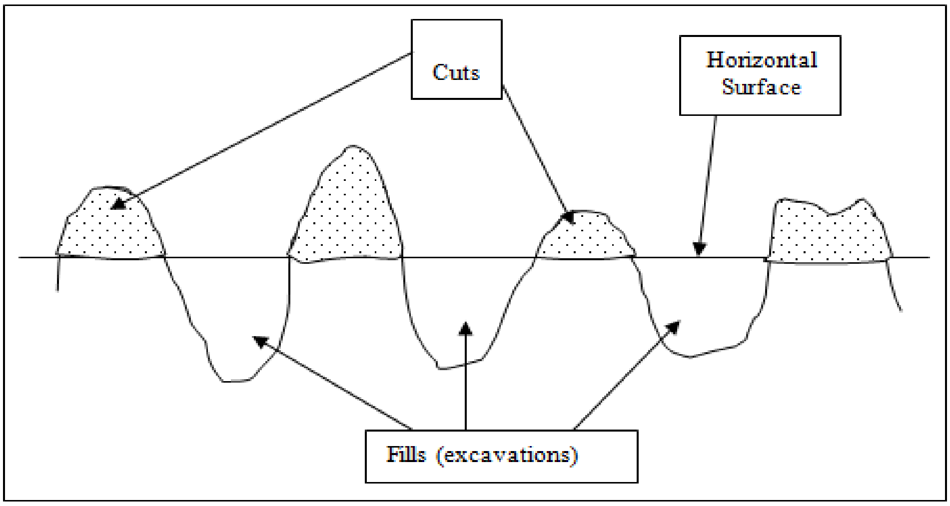


Figure 5.2: Illustration of cuts and fills

(b) Waste / discard dumps

Volume of material contained in waste and discard dumps were also estimated using Surfer Mapping System. Coordinates (x, y) and elevations (z) of selected points around the lower and upper surfaces of the dumps were measured with a Total Station. Volume computations for waste dumps were performed on a solid above the lower surface. Before calculations were done, the upper and lower surface between which the volume is calculated was defined. After defining the upper and lower surface, the volume was calculated using the volume command and results displayed in a volume computation report (Appendix J).

5.1.3.1Results and Discussion

(a) Excavations

Results of the study (Table 5.2) show that a total of 13.8 x 10^6 m^3 of excavations have been created by mining operations in the Kanzinze and Izuma basins.

Table 5.2: Volume of excavations created by open cast mining at Kanzinze and Izuma basins.

No.	Study area	Volume of Excavations x 10^6 (m^3)	Additional Volume required x 10^6 (m^3)
1	Kanzinze pit	8.1	55.0
2	Izuma pit	5.8	1.8
	Total	**13.9**	**56.8**

Of this volume, 8.1 million m^3 of excavations have been created in Kanzinze while 5.8 million m^3 is in Izuma. Results also indicate that 56.8 million m^3 of additional material is required to backfill these excavations (i.e. after dozing the volume of material contained in cuts into these excavations). Volume computations from plotted coordinates of Kanzinze and Izuma pits (Figure 5.3 (a) and (b)) reviews that over 55 million m^3 of additional material is required to backfill the excavations in Kanzinze basin while 1.8 million is required in Izuma basin. The backfill material required in Kanzinze basin accounts for over 96% of the total volume of backfill material required at MCL. Since mining in Kanzinze basin has been going on for over 28 years, it means, therefore, that an average of 290,000 m^3 of volume of excavation is created annually while 390,000 m^3 is created in Izuma basin over the same period.

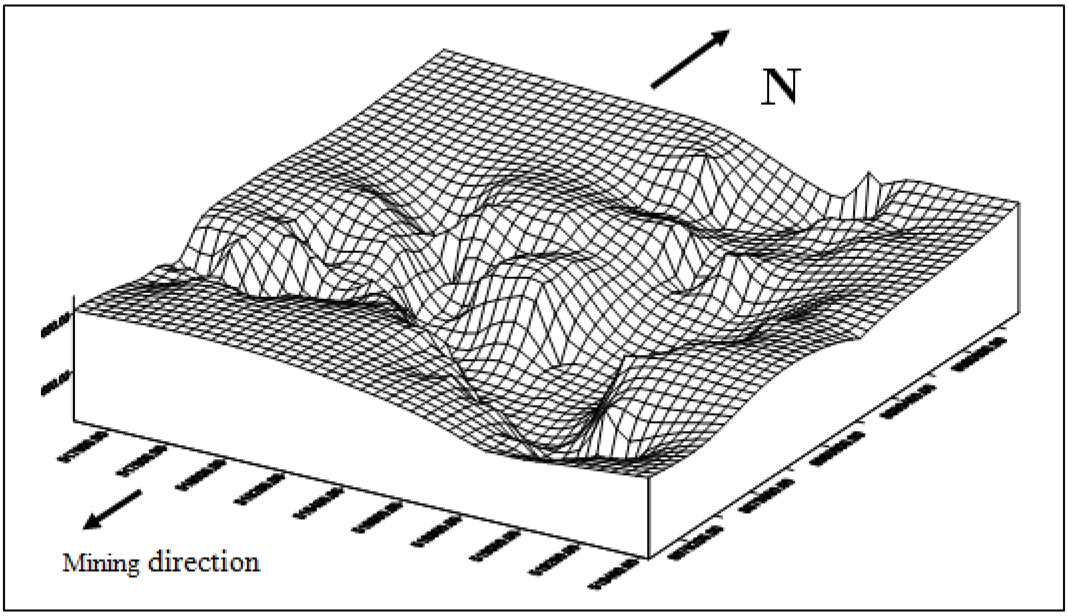


Figure 5.3 (a): Plotted coordinates of Kanzinze pit showing excavations created after mining operations.

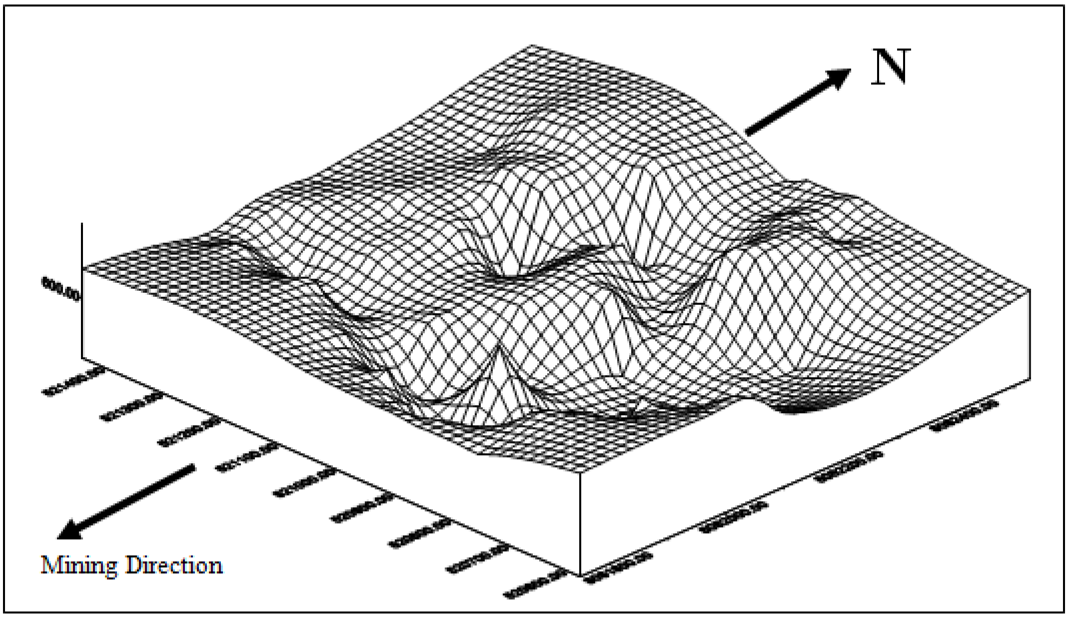


Figure 5.3 (b): Plotted coordinates of Izuma pit showing excavations created after mining operations.

(b) Waste dumps

Results of the volume computations are shown in Table 5.3.

Table 5.3: Volume of material contained in waste and discard dumps.

No.	Study area	Volume x 10^6 (m^3)
1	Kanzinze discard dumps	
	• Kanzinze discard dump 1	0.9644
	• Kanzinze discard dump 2	2.078
	• Kanzinze discard dump 3	1.029
2	Izuma dump	2.348
	TOTAL	**6.4194**

Results of the studies (Figure 5.4 and 5.5) show that over 6.4 million m^3 of overburden and discard material have been dumped in waste dumps at MCL. Kanzinze discard dumps account for 63% of the total volume while the rest is from Izuma dump.

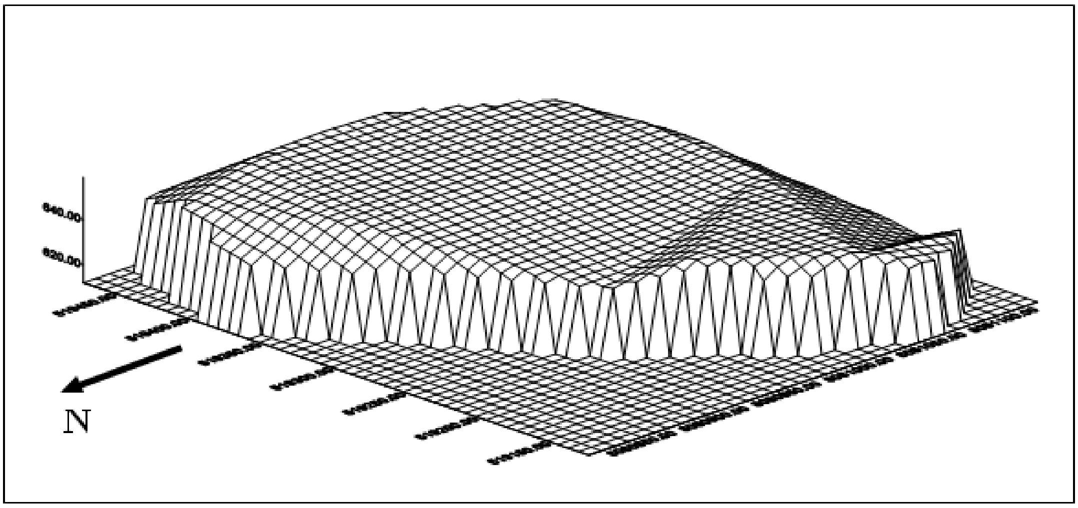


Figure 5.4 (a): Plotted coordinates of Kanzinze discard dump 1

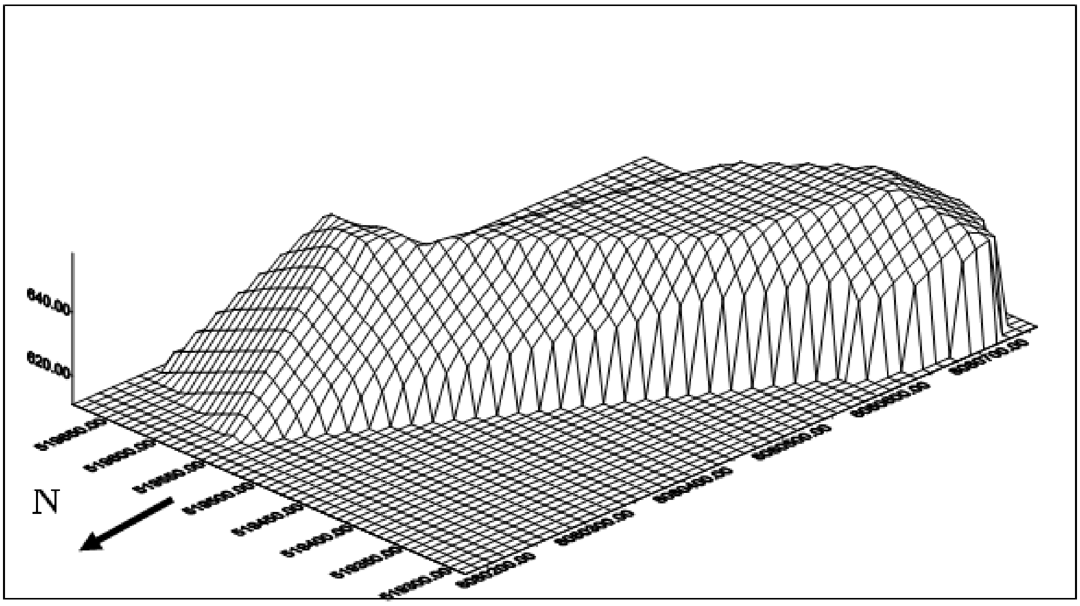


Figure 5.4 (b): Plotted coordinates of Kanzinze discard dump 2

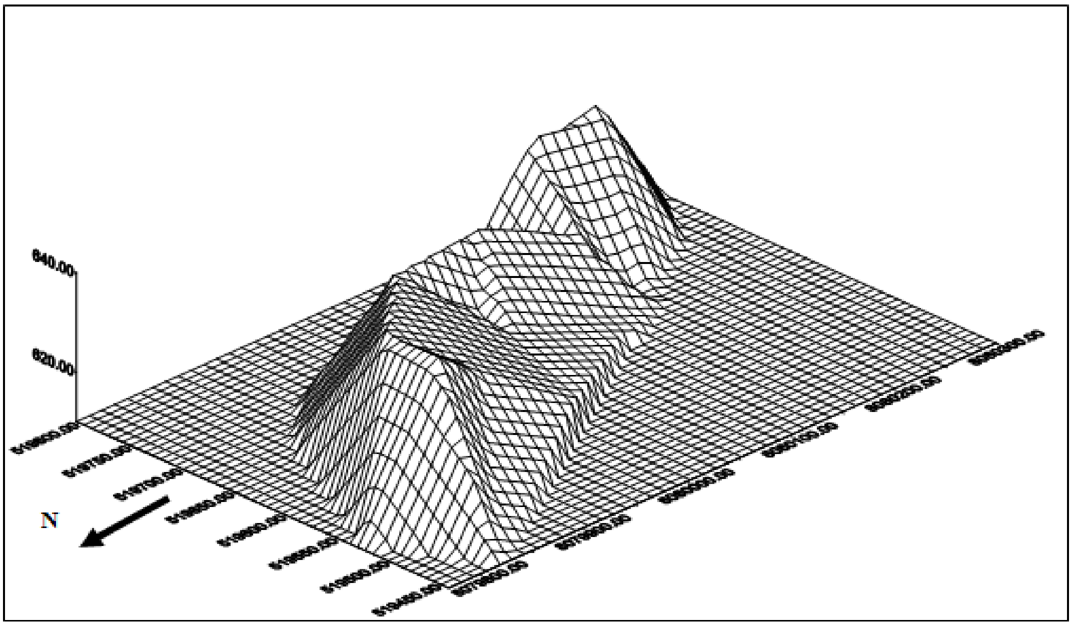


Figure 5.4 (c): Plotted coordinates of Kanzinze discard dump 3

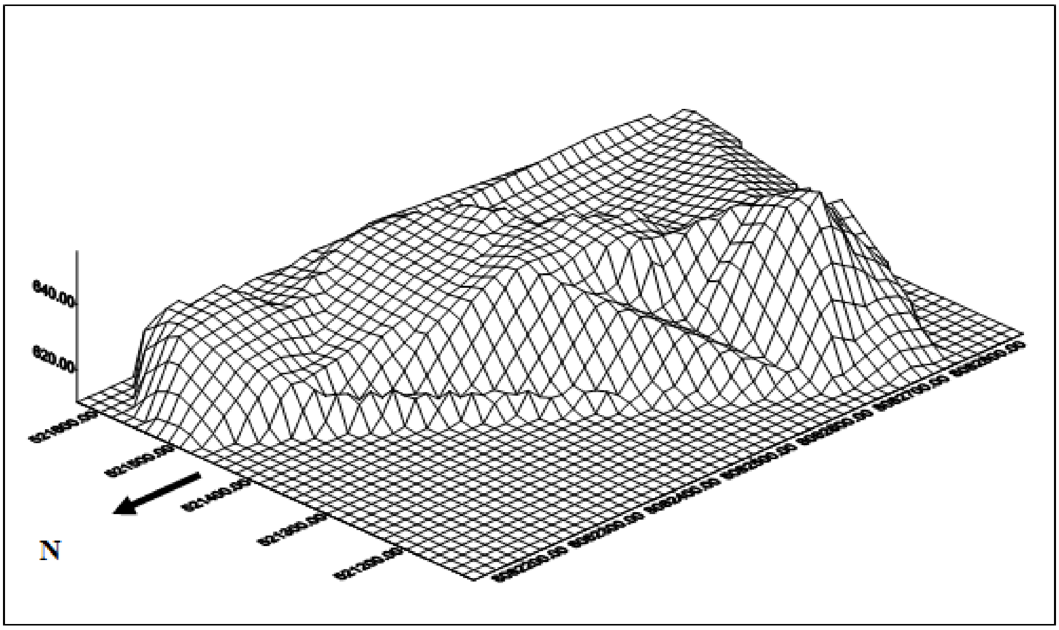


Figure 5.5: Plotted coordinates of Izuma dump

Since inception of mining operations, results show that over 4 million m^3 of discard material have been dumped in the area. Currently, 20% of the coal preparation plant output from drewboy washer and the cyclones are discharged as discard material in Kanzinze dumps. An average of 110,000 tonnes of discard material from drewboy washer and 40,000 tonnes from the cyclones are discharged annually from the coal preparation plant. This means, therefore, that over 150,000 tonnes (20%) of plant input is discharged as coarse material into the Kanzinze basin annually. Disposal of slurry material from the thickener has also contributed to the decline of environmental conditions in the area. Discharged slurry materials in nearby valleys have created negative visual impacts in the area. Results of this study show that a total volume of 145,000m^3 (Table 5.4) have been dumped in these ponds since inception of the CPP.

Table 5.4: Volume of material dumped in slurry ponds

No.	Study area	Volume (m^3)
1	Slurry pond No.1	25,767
2	Slurry pond No.2	69,975
3	Slurry pond No.3	50,000
	Total	**145,742**

When fine material in slurry ponds dries up, the ponds are emptied by front-end loader / truck operations and material dumped in slurry dump area along the Kanzinze River. A total volume of 47,052 m^3 has been dumped in this area. An average of 23,000 m^3 of slurry material is discharged annually from the CPP.

5.1.3.2 Relative Error (RE) on volume computations

Three methods were used to determine the volume i.e., Trapezoidal rule, Simpson's rule and Simpson's 3/8 rule. The difference in the volume calculations by the three different methods gave the quantitative measure of the accuracy of the volume calculations. If the three volume calculations are reasonably close together, the true volume is close to these values. The net volume was reported as the average of the three values.

The relative error for the volume results was estimated by comparing the results of the three methods and was given as a percentage of the average volume. It was estimated using formula 2.

$$RE = \left[(LR - SR) / AVER \right] * 100 \qquad \text{... (6)}$$

Where; RE = Relative Error

LR = Largest results from the three methods

SR = Smallest results from the three methods

AVER = Average of the three method

Relative error was less than 0.5% in all volume computations (Table 5.5) which indicated that the volume estimates were accurate and close to the true values.

Table 5.5: Relative errors on volume computations

Study Area	Volume x 10^6 (m^3)			Average	Relative Error (%)
	Trapezoidal	Simpson	Simpson 3/8		
Kanzinze pit	55.0134	55.0045	54.8819	54.9666	0.24
Izuma pit	1.77381	1.77566	1.77474	1.77475	0.10
Izuma dump	2.34887	2.34845	2.34468	2.34733	0.18
Kanzinze discard dump 1	0.964117	0.963652	0.965642	0.964470	0.20
Kanzinze discard dump 2	2.078	2.07811	2.07806	2.078056	0.005
Kanzinze discard dump 3	1.02884	1.02843	1.02841	1.02856	0.04

5.2 Water Pollution

5.2.1 Choice and location of sampling points

To determine the effects of mining operations and coal processing on the environment, water samples were collected from different sampling points (Figure 5.6), along the Kanzinze River and along its tributaries. Sampling points were chosen on the basis of the following;

- Kanzinze (P7) and Izuma (P3) upstream were selected on the basis that they were going to give us the quality of the water before being polluted or before the streams pass through mining and coal processing areas.
- The Kanzinze (P2) and Izuma (P4) downstream were selected to determine the amount of pollutants that were introduced in the streams as a result of mining and processing operations.
- Effluents from the coal preparation plant (P6) were also sampled so as to determine the amount of pollution from the processing operations that join the stream.
- Izuma sump water (P5) was sampled to determine the quality of water discharged into the water system from the Izuma central Sump.
- Samples were also taken within the Maamba Township (P1) to determine the effects of mining operations on the water within the township.

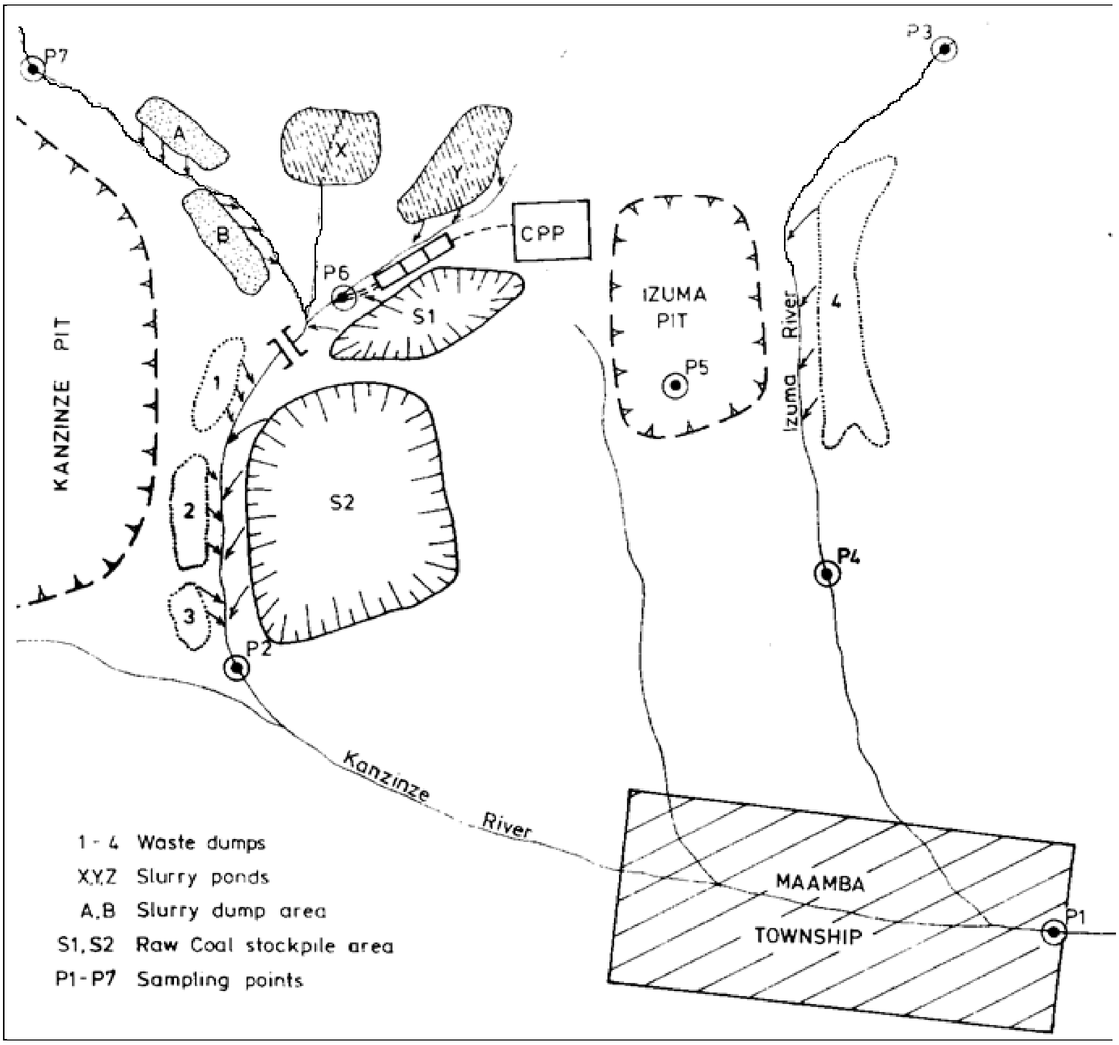


Figure 5.6: Schematic diagram showing location of water sampling points

5.2.2 Water sampling

Sampling was performed at river crossings where the river was safely accessible. Water samples were collected using 1-liter plastic bottles and stored in cool boxes containing ice cubes. At all times, samples were drawn as much as possible from the middle section of the stream where much turbulence was usually observed (to avoid sampling stagnant water). Samples were taken to Environmental Engineering Laboratory at the University of Zambia for analysis. All samples were transported in cool boxes containing ice cubes to Environmental Engineering Laboratory for analysis.

5.2.3 Results and discussion

Water sampling results are indicated in Table 5.6.

Table 5.6: Water sampling results.

PARAMETER	SAMPLING POINTS						
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**
p H	4.9	2.5	8.4	7.9	6.6	4.5	7.7
Turbidity (NTU)	63.2	109	2.4	2.81	198	586	3.51
Total Dissolved solids (mg/l)	532	1090	144	170	648	702	210
Total Suspended Solids (mg/l)	140	294	90	166	256	894	108
Magnesium hardness (as mg $CaCO_3$/l)	220	268	132	96	72	140	28
Total Hardness	524	608	180	144	392	600	108
Iron (mg/l)	145.6	299.5	20.8	20	47.7	103	39.5

P1 = Maamba township
P2 = Kanzinze Downstream
P3 = Izuma Upstream
P4 = Izuma downstream
P5 = Izuma central sump
P6 = Effluents from CPP
P7 = Kanzinze upstream

(a) p H (Acidity)

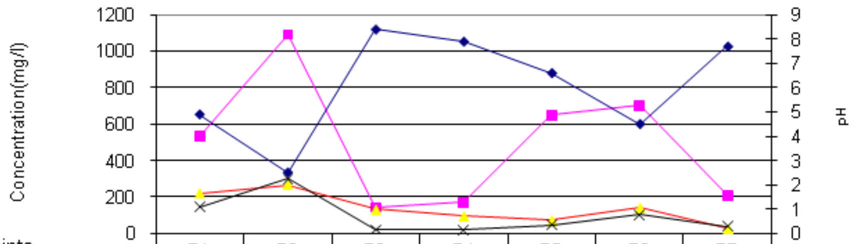
The pH values for water samples in the Kanzinze and Izuma upstream showed alkaline condition i.e. pH was 7.7 and 8.4 due to the fact that the streams do not pass through pyrite bearing rocks making acid formation not possible. However, as the water flow past the Kanzinze pit and the CPP, the pH dropped drastically to 2.5 as monitored at Kanzinze downstream (P2). The pH values of water at Izuma downstream and central sump was alkaline and acidic i.e. 7.9 and 6.6 respectively.

As mining progresses and unreclaimed spoils accumulate, oxidation of pyrite will further increase the pH of the central sump. Drastic reduction in the pH values at downstream of Kanzinze can be attributed to the following: -

- Disposal of dry slurry material, from the slurry ponds, along the Kanzinze stream. The dry slurry material contains pyrite, which is allowed to react with oxygen and water forming sulphuric which is washed in the Kanzinze River.
- Runoff from stockpiled coal and the stockpile area into the Kanzinze River diversion canal has also resulted in low pH. This is also because of the pyrite contained in coal that is allowed to react with oxygen and water forming sulphuric acid (see mechanism and stages of acid formation in section 4.1.3) that eventually finds its way in the Kanzinze river diversion canal.
- Direct discharge of acidic effluent from the coal preparation plant (P6), which showed a pH of 4.5.
- Discard dumps are all located along the Kanzinze river diversion canal. Therefore, the pyrite in discard material reacts with the water (surface runoff) and oxygen resulting in AMD, which would be responsible for lowering the pH of the water in Kanzinze River.

(b) Dissolved solids

Low pH values observed in the Kanzinze River have resulted in dissolution of heavy metals. From the sampling results, Table 5.6 and Figure 5.7, the dissolved iron and magnesium in the Kanzinze River were high at low pH values. This also indicates that even other heavy metals e.g. Zn, Cu, Pb, Cd, As etc. might have dissolved in this water. Results also show that sources of dissolved solids are the coal preparation plant and Izuma central sump.



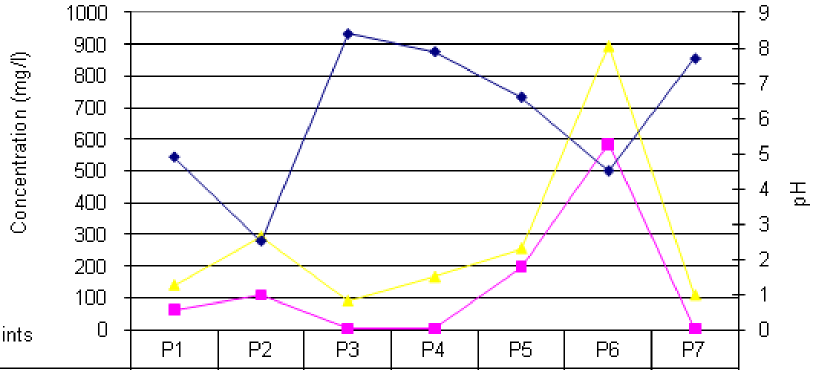
Sampling points	P1	P2	P3	P4	P5	P6	P7
Total Dissolved Solids (mg/l)	532	1090	144	170	648	702	210
Magnesium hardness (as Mg, CaCO3/l)	220	268	132	96	72	140	28
Dissolved Iron (mg/l)	145.6	299.5	20.8	20	47.7	103	39.5
p H	4.9	2.5	8.4	7.9	6.6	4.5	7.7

Figure 5.7: Variation of dissolved solid, Magnesium, Iron and pH at different sampling points.

(c) Suspended solids / Turbidity

Suspended solids, like turbidity are the undissolved materials suspended in water (13). Although seemingly insignificant pollutants, suspended solids have caused pollution in Kanzinze River by;

- inhibiting light from reaching photosynthetic organisms thereby reducing oxygen production (13); and
- Having deleterious effects to aquatic organisms.



	P1	P2	P3	P4	P5	P6	P7
Turbidity (NTU)	63.2	109	2.4	2.81	198	586	3.51
Total Suspended Solids (mg/l)	140	294	90	166	256	894	108
p H	4.9	2.5	8.4	7.9	6.6	4.5	7.7

Figure 5.8: Variation of Turbidity, Total Suspended Solids and pH at different sampling points.

From the water sampling results Table 5.6 and Figure 5.8, coal preparation plant and the Izuma central sump are the main sources of suspended solids and turbidity. As the stream passes the coal preparation plant, the concentration of suspended solids increased exceeding the maximum allowable concentration of 100mg/l (Zambian standards for effluent and waste water).

5.3 Air pollution

5.3.1 Sampling points

Dust samples were collected in the following areas:

(i) Izuma open pit i.e. during stripping, loading and coal drilling operations.

(ii) Coal preparation plant i.e. at grizzly, in the basement, screening and crushing operations and the general conditions within the coal preparation plant.

(iii) Township i.e. Secondary school, Hospital, Market, Montrev, Golf club and Button Mess (Figure 5.9)

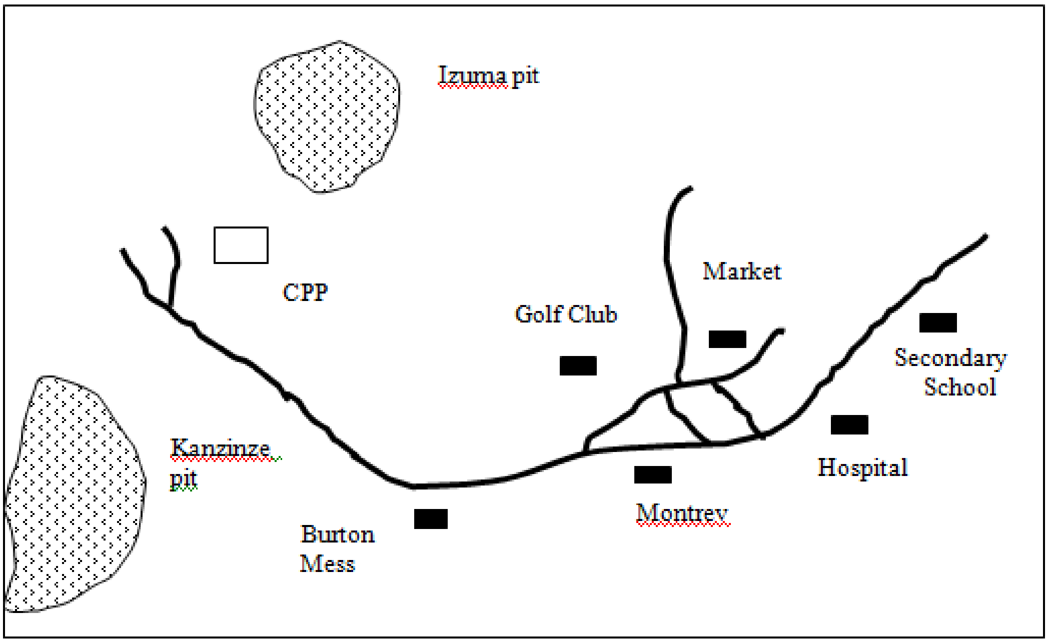


Figure 5.9: Schematic diagram showing location of dust sampling points

5.3.2 Method of data collection

The prepared slide coated with xylol solution was inserted into the Konimeter. The release of a spring-loaded plunger draws a 5ml sample into the instrument through a narrow jet discharging at right angles. Particles in the air samples are collected by impact on the slide in the form of a "spot" and after each sample the glass slide was rotated a few degrees to bring a clear space on the slide opposite the jet. At each sampling point two samples were taken. After completion of measuring process, the slide was removed from the Konimeter and taken to the laboratory for analysis (counting).

5.3.3 Counting

The slide was placed under the microscope (x150) and spots were identified and counted (Plate 5.1).

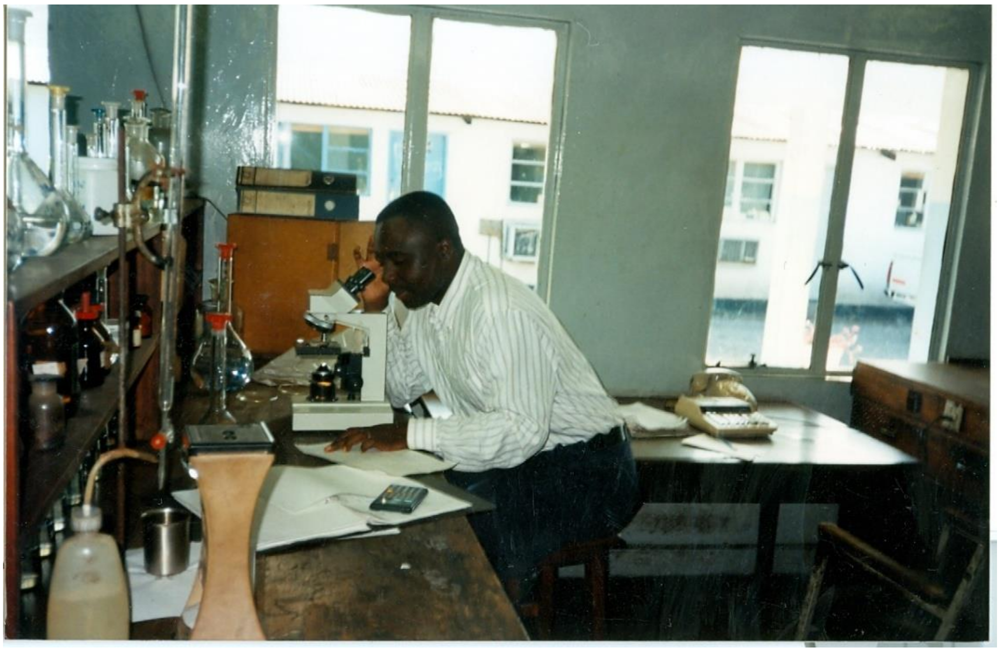


Plate 5.1: Counting of dust and coal duct

A graticule was positioned over one spot at a time for counting purposes. Black spots, which appeared under the microscope, were of coal dust and were counted in parts per cubic centimeters (ppcc). After counting the coal dust, the glass slide was removed from the Microscope and treated with Hydrochloric acid (HCL) to remove carbonaceous matter and soluble salts from the slide leaving silica dust stuck on the slide. The slide was treated as follows:

(i) The slide was first placed in the oven at a temperature of 550^{o}C to burn out the coal (carbonaceous shales);

(ii) The slide was then immersed in 50% HCL to remove the soluble salts and wash away the burnt coal.

The remaining silica dust on the slide was then counted under the microscope as it was done with coal dust.

5.3.4 Results and discussion

Results of coal and silica dust concentrations are indicated in Appendix L.

(a) Coal dust

Sources of particulate coal dust during open pit mining operations were during overburden and coal drilling, blasting operations, overburden and coal removal, and also during loading operations (Figure 5.10). Coal dust is also emitted during coal handling and processing within the CPP and partly in Maamba Township.

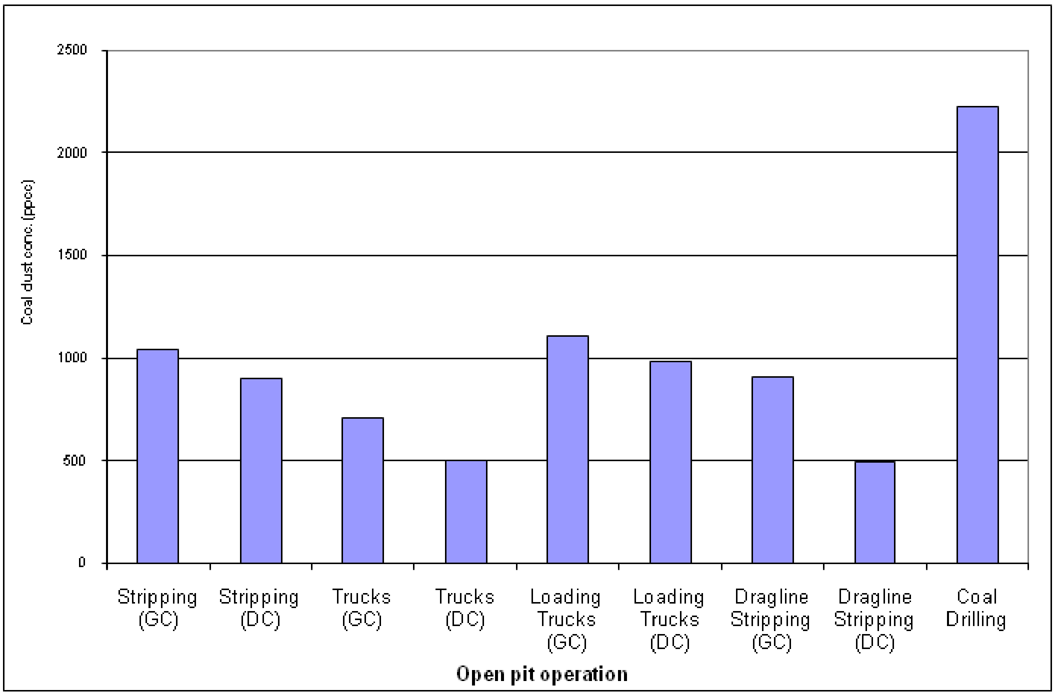


Figure 5.10: Variation of coal dust concentrations at different open pit operations.

From the dust sampling results, the general external conditions during coal drilling with an Airtrac had the highest coal dust concentration of up to 2225 ppcc. However, minimum coal dust concentrations were recorded within the driver's cabin during dragline operations. i.e., concentration was 491 ppcc. Generally, during open-pit operations, coal dust was higher as compared to the maximum allowable concentration of 900 ppcc (Environmental Council of Zambia (ECZ) standards). Higher concentration of coal dust during open-pit operations can be attributed to the following:

- During drilling operations of both coal and overburden material, large quantities of rock are pulverized to form dust resulting in coal dust emission in the area.
- Blasting operations also produce coal dust, which also contribute to high concentrations.
- During stripping of coal and overburden material, high dust levels are encountered which also contributed to high coal dust concentration.
- Loading of coal and overburden material also produces high coal dust concentration within the pit.

Within the coal preparation plant, coal dust is produced in coal handling areas i.e. grizzly, basement, screens, picking belt, crushers and on transfer points. From the dust sampling results, the picking belt and the basement had the highest coal dust concentrations i.e. 990 ppcc and 980 ppcc respectively (Figure 5.11) as compared to the maximum allowable concentrated of 900 ppcc. The high coal dust concentrations in the basement and picking belt was due to non-functioning of the exhaust ventilation system (connected to cyclone collector) which was responsible for sucking dust from the basement. Since coal is handled dry at transfer points, this produces high dust levels, which affects the workers as well as the surrounding environment. Vibrating screens that are used near the picking belt produced large amounts of coal dust. Since the material is screened in dry form, this causes high concentration of coal dust at screening and picking belt. Coal dust is also produced at crusher points within the coal preparation plant. The crusher within the coal preparation plant is not supplied with the exhaust ventilation and dust from coal crushing has not only affected the workers, but also the general condition within the coal preparation plant.

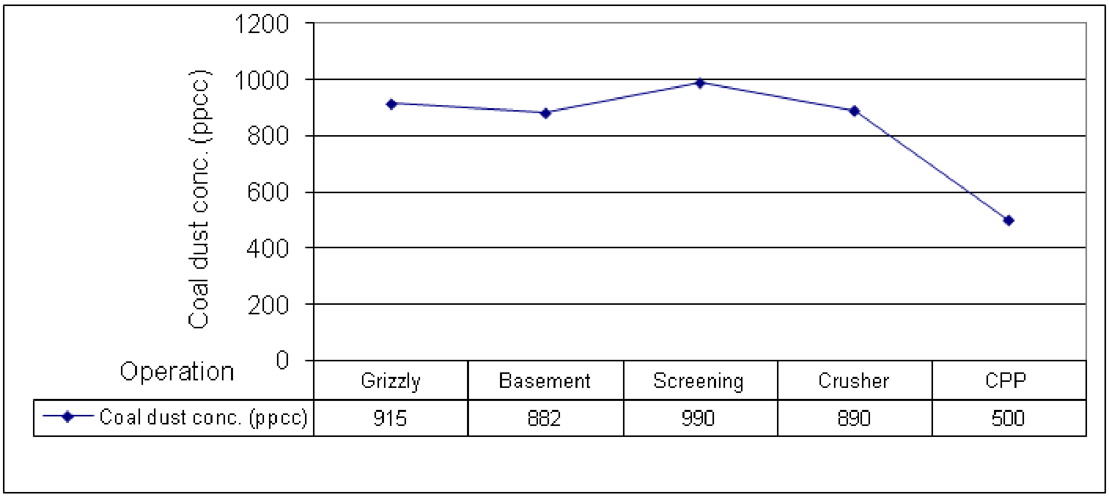


Figure 5.11: Variation of coal dust concentrations in the coal preparation plant

Within the Maamba Township, coal dust concentration was not as high as it was within the mining and processing areas. From the dust sampling results, coal dust concentration decreased gradually with increase in distance from the mining and processing areas (Figure 5. 12).

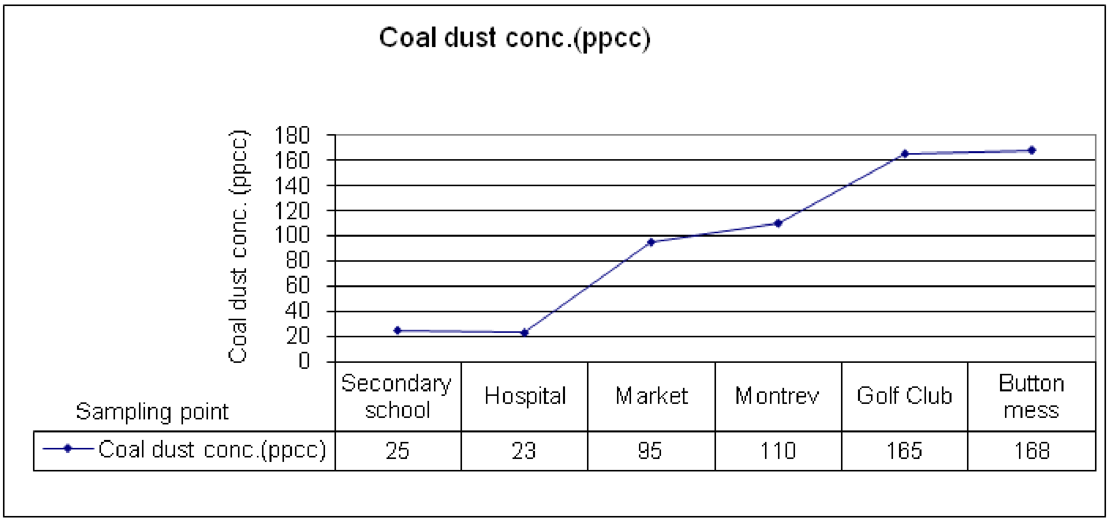


Figure 5.12: Variation in coal dust concentration within Maamba Township

Figure 5.12, shows that maximum concentration of coal dust within the township was highest at Button mess which was nearest to the active mining and processing areas. Golf club which was not as close as Button Mess, to the open-pit and coal preparation plant, was next with average coal dust concentration of 165 ppcc. Secondary School and the hospital which are furthest from coal mining and processing areas had the least coal dust concentration of 25 and 23 ppcc respectively. The coal dust concentration observed at the market, secondary school and the hospital was due to spillage from coal trucks which transport coal from Maamba to consumers.

(b) Silica dust

Apart from coal dust, silica dust is also emitted during open-pit and CPP operations. During open-pit operations, highest concentration of silica dust was recorded during loading of soft overburden material into trucks i.e. concentration outside the truck was 508 ppcc while in the truck driver's cabin, it was 406 ppcc

(Figure 5.13). These concentrations were high if compared to the maximum allowable concentration of 350 ppcc (ECZ standards). Stripping of soft material also produced silica dust of higher concentration than the maximum allowable concentration. High silica content in the pit can be attributed to the fact that most material (coal and overburden) are handled in dry state which results in high emission of silica particles in the air.

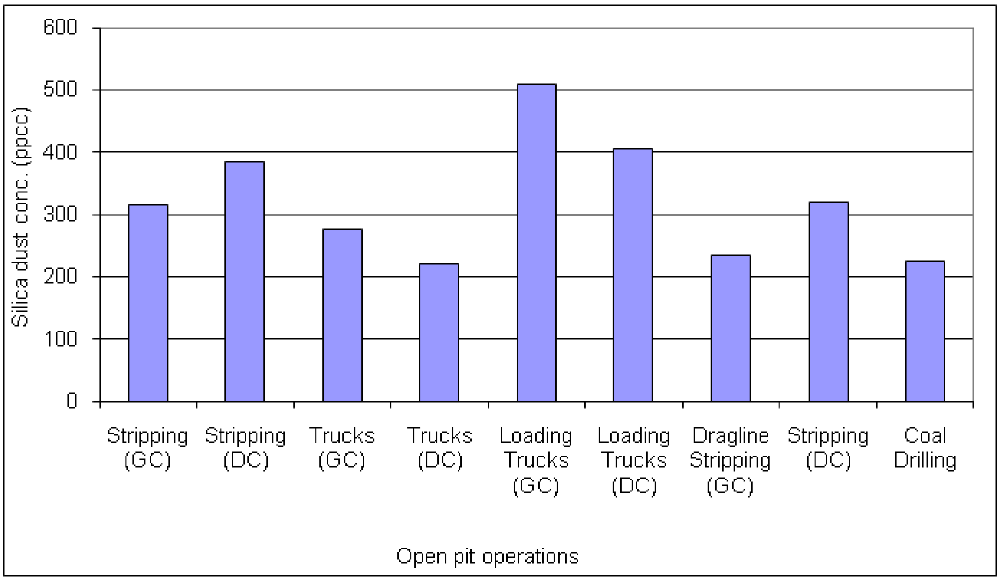


Figure 5.13: Variation of silica dust concentrations at different open pit operations.

Within the CPP, the grizzly, basement, picking belt and the crushers, high silica concentrations were recorded (Figure 5.14).

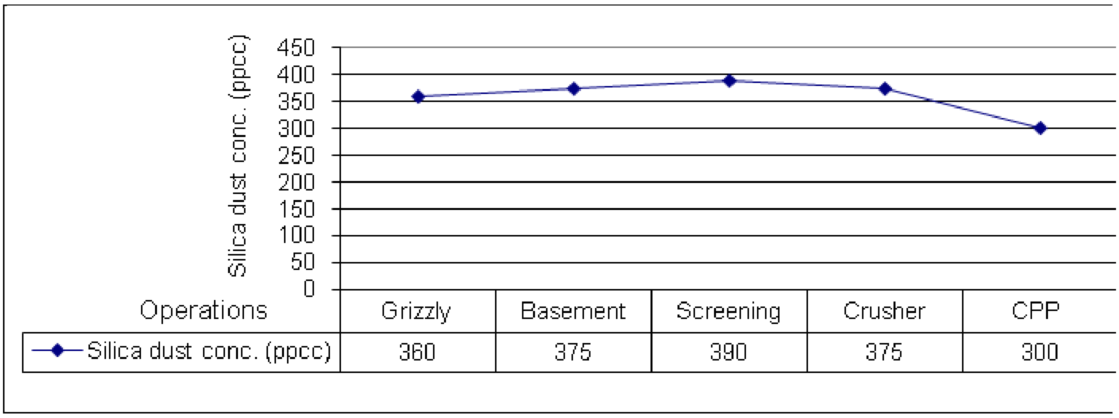


Figure 5.14: Variation of silica dust within in the coal preparation plant.

In the basement and grizzly, the high silica concentration was attributed to the non-functioning of cyclone type dust collector. Handling of the ROM coal in dry state also contributed to the high silica dust concentration levels. At the picking belt, high levels of silica concentration were as a result of the vibratory screens where the ROM coal is screened in dry state. Since no exhaust ventilation is provided at crusher point, the area had higher silica concentration because the ROM coal is disintegrated emitting silica dust around the crusher and also within the CPP.

In Maamba Township, concentration of silica dust was minimal when compared to the maximum allowable concentration. From the dust sampling results (Figure 5.15), taken during the period April and May, it can be shown that concentration of dust decreased with increase in distance from the mining and coal processing areas. Golf club and Button mess which were closest to the mine had high concentration of silica dust while the hospital and the secondary school which were furthest from the mine had very low silica concentration. The market recorded high silica values because of the presence of people who, when moving, cause silica dust to be emitted from the ground.

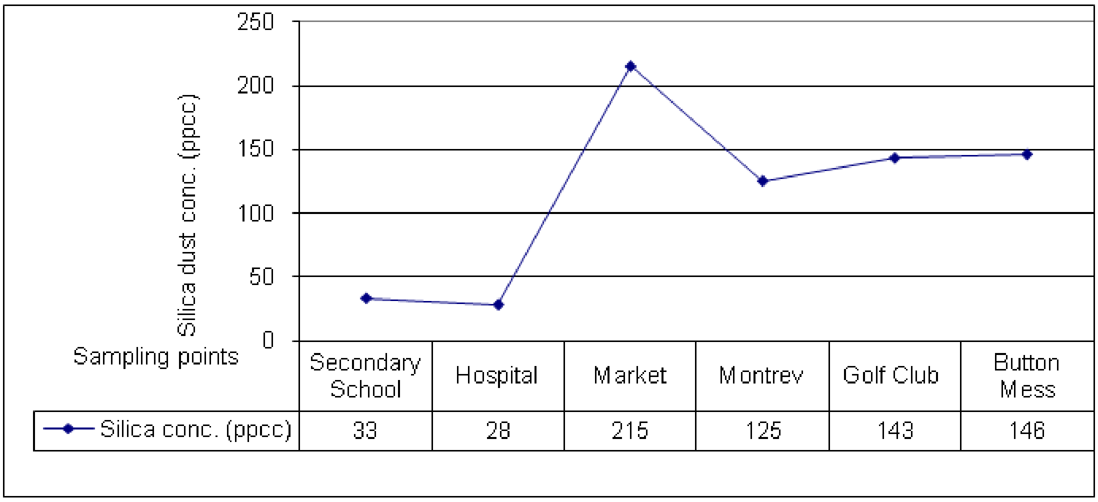


Figure 5.15: Variation in silica dust concentration within Maamba Township

CHAPTER SIX

6.0 REMEDIATION AND MITIGATION OF OBSERVED AND QUANTIFIED ENVIRONMENTAL IMPACTS

Mining and processing of coal have considerable adverse impacts on land, water and air and can initiate social impacts because of the need to displace settlements and increased social amenities in the mining area. Despite the positive socioeconomic impacts of mining operations and regional culture e.g. schools, hospitals, housing, social amenities etc., these have been offset by negative environmental impacts. Therefore, the negative impacts must be held to a minimum. The following control measures have been suggested to reduce negative environmental impacts in the area.

6.1 Land degradation

Coal mining operations at MCL have disturbed quite extensive land (321 hectares) through direct removal of material in open-cast areas, changing the topography and landscape of the area, and by waste dumping. These operations have created severe aesthetic land degradation. Following mitigation measures have been suggested to minimize the impacts of opencast mining operations on land.

6.1.1 Management of loose vegetative soil during pre-stripping

The existing topsoil around Kanzinze and Izuma basins is an important resource and there should be provision for their stockpiling so that the soils will be available for future rehabilitation. Soil resources within the pit limit should be identified, described properly and assessed. Soil resources comprise all existing topsoil, subsoil and potential soils forming materials. Where possible, soils should not be stockpiled but transferred and restored directly on regraded spoils (14). Where stockpiling is unavoidable, various soil types should be stripped and stored separately in low heaps of not more than 3m high (14). Soil heaps should be seeded with indigenous grasses to prevent erosion. Plans showing the location of all soil heaps should be maintained.

Segregation of topsoil in the removal stage is of prime importance and they should be replaced in mined out areas as it originally existed. To achieve this requires that each layer be carefully excavated and placed in the area where relatively easy recovery can be made. This is followed by leveling, placement of topsoil cover and revegetation of the area with indigenous plant / grass.

6.1.2 Reclamation, backfilling and slope engineering

Mining is a temporary activity, which should be integrated with or followed by other forms of landuse. Rehabilitation of mines should be aimed at clearly defined future landuse for the area. In this study, the aim of rehabilitating the Kanzinze and Izuma pits areas is to construct a stable landform and establish self-sustaining native ecosystem compatible with final landuse. From the results of the survey measurements, the total surface area (that occupied by open excavations) to be rehabilitated is 216.6 hectares in Kanzinze basin and 50.9 hectares in Izuma basin. Rehabilitation of the pits should start with Kanzinze basin where more extensive land damage has been done due to opencast mining with the Dragline. Since relatively less land disturbance has been done in Izuma basin, environmental control measures should be put in place on current mining operations so as not to allow more damage to be created in the area. Rehabilitation work should be divided into two:

(a) Landform design and reconstruction; and

(b) Revegetation of the reconstructed land.

6.1.3 Landform design and reconstruction

During landform design and reconstruction of stable land surface programme of activities is divided in five phases.

Phase One

In Kanzinze pit, immediate action should begin by first pumping water that has accumulated in the pit.

Phase Two

Earthmoving should follow and be concentrated on the spoils adjacent to the Kanzinze river diversion canal. Earthmoving activities should begin by dozing cone shaped spoil material into the excavations within the Kanzinze pit towards the mining area. Other material to fill the excavations within the pit should be taken from discard dumps along the Kanzinze river diversion. Battering of pit walls will also assist in filling the excavations within the pit and they will also ensure stable slopes at the site. All scrap metals and rocks around the Kanzinze pit should be pushed into the excavations also to assist in filling the pits. Many areas in Kanzinze pit were left ungraded and unfilled, protecting roadway which are no longer needed. These areas should also be filled with spoil material.

Phase Three

After filling the excavations, spoil peaks should be graded to a less steep angle, to approximately pre-mining contour. This will promote stability and reduce the velocity of water inflow and its subsequent erosive effects. Normally slopes will be stable if they have similar gradient to natural slopes.

Phase Four

Spreading of rehabilitated areas with fertile topsoil of at least 0.5m thick will then follow. The topsoil should be replaced along the contour where possible to help in erosion control by reducing water flow downslope and increasing water storage. Where possible, the topsoil should be immediately placed on an area where the landform reconstruction is complete. Topsoil should be taken from areas ahead of active mining.

Phase Five

After completing the rehabilitation earthworks, the rehabilitated area will be compacted as a result of the constant passage of trucks and other mobile plant. Therefore, at the end of earthmoving, the area should be ripped in order to loosen the surface and provide improved conditions for seed germination. During this operation, some oversize rocks will be brought to the surface and these should be collected into piles and spread randomly across the site to provide refuge for small animals and reptiles that would be anticipated to recolonise in the site.

6.1.4 Kanzinze and Izuma pits reclamation cost estimates

Reclamation of Kanzinze and Izuma pits would involve backfilling of excavations in mined out areas, dozing and grading of backfill material to the required slope and revegetating the reclaimed area with suitable plant species. Reclamation exercise will start in Kanzinze basin (approximately 5km from active mining areas of Izuma pit) where more land damage has been done. Backfill material will be transported from Izuma active mining area to Kanzinze pit area with dump trucks. After reclaiming the Kanzinze pit, reclamation of Izuma would follow involving in-pit dumping, dozing and grading of the dumped material to the required slope. Loading of backfill material will be done with a Rope Shovel in conjunction with dump trucks while dozing and grading will be done with dozers and graders respectively. Following are computations of cost estimates for reclaiming Kanzinze and Izuma pits i.e. for loading, haulage, dozing and grading operations.

6.1.4.1 Rope shovel cost estimates (Loading)

At MCL, two rope shovels are in operation on stripping overburden i.e. P&H 1900 and P&H 2100. In this exercise, P&H1900 was used for calculations because it has smaller capacity than P&H2100 i.e. P&H 2100 with larger capacity is left for production. Material to be loaded will vary from loose topsoil to well fragmented overburden. The following are cost estimates of loading operations using a P&H1900 Rope shovel.

(a) Shovel Performance

Machine type:	P&H 1900
Bucket capacity:	$10m^3$
Average cycle time:	40seconds
Bucket fill factor:	0.95
Availability:	95%
Utilisation:	95%
Production per cycle:	10 * 0.95 = 9.5 m^3 / cycle
Number of cycles per hour:	(3600*0.95*0.95)/40
	= 81 Cycles / hour

Shovel Production per hour = 9.5 * 81

= **769.5 m^3 / hour**

(b) Ownership and operating cost estimation

(i) Ownership costs

Purchase price:	US$4,000,000
Economic life (hours):	81,000
Economic life (years):	15 years
Operating hours:	5400 hours
Utilization:	100%

Depreciation (US$/ hour): 4,000,000 / 81000 = US$49.38 / hour

Interest rate (r): 10% (Source: Zambia state Insurance Cooperation Limited (ZSIC))

Insurance rate (i): 2.5% (Source: ZSIC)

Interest (US$/hour): = $\left[P(r + i)(N+1) \right] / (200NH)$ ……………………(7)

=(4,000,000(0.1+0.025)(15+1))/ 200*15*5400
= US$0.49/hour

Total ownership costs (US$/hour) = 49.38 + 0.49
= US$49.87 /hour

(ii) Operating costs

- Electricity consumption

Average electricity consumption by P&H 1900 Rope shovel at MCL is US$37,500 per year (Source: MCL annual reports)

Electricity costs per hour = 37,000/5400
= US$6.94 /hour

- Preventive maintenance (repair, Lubrication, grease, fluids, etc.

= 15 – 20% of energy costs - (Source: (2))
= 15 % * 6.94
= US$1.04 / hour

- Operator costs

Internationally, annual shovel operator costs average US$25,000. However, considering production performance of MCL and the economic situation in Zambia, the amount is relatively high. Therefore, a lower figure of US$10,000 per year is ideal (will suit the Zambian conditions) and is used in the calculations.

Operator costs (US$/hour) = 10,000/5400
= US$1.85 /hour

Total operating costs = 6.94 + 1.04 + 1.85
= US$9.83/hour

Total ownership and operating costs (US$/hour)
= 49.87 + 9.83
= US$59.7 / hour

Shovel production costs (US$/$m^3$) = 59.7/769.5
= US$0.078 / m^3

6.1.4.2Material Haulage cost estimates

At MCL, 11 Dump trucks (777 (x7) and 773 (x4)) are available at MCL although only 6 are in operation i.e. 777 (x4) and 773 (x2). In this exercise, a Dump truck of Cat 777 specification was used in the computations as the smaller Cat 773 are deployed on coal haulage with FEL. Cost estimates of material haulage with a 777B dump truck were computed as follows.

(a) Truck performance

Machine type: Cat 777B
Capacity: 51.3 m^3
Number of passes to fill: 51.3/9.5 = 5
Loading time: (40*5) = 200 seconds (3.3 minutes)

Dumping time: 0.2 minutes
Haul distance (maximum): 5km
Speed (loaded): 33km/hour (Manufacturer specification)
Speed (empty): 42km/hour (Manufacturer specification)

Travel time (loaded): = 5/33 *60 =9.1 minutes
Travel time (empty): = 5/42 *60 = 7.1 minutes

Spotting time at shovel
and dumps = 0.25minutes

Truck cycle time: = 3.3 + 9.1 + 0.2 + 7.1 + 0.25
= 19.95 minutes
Availability: = 95%
Utilisation: = 95%

Truck production (m^3/ hour) = ((0.95*0.95*60/19.95) * 9.5 * 5)
= **128.93 m^3 / hour**

Number of Trucks required = 769.5/ 128.93
= **6 Dump Trucks**

(b) Ownership and operating costs

(i) Ownership costs

Purchase price: US$550,000
Economic life (hour): 43,200 hours

Economic life (years): 8 years
Operating hours per year: 5400 hours
Depreciation (US$/hour): = 550,000/43,200
= US$12.73 / hour
Interest (r) rate: = 10%
Insurance rate (i): = 2.5%

Interest (US$/hour) = 550,000 (0.1 + 0.025) (8+1)/ 200*8*5400
= US$0.072 / hour

Total ownership costs = 12.73 + 0.072
= US$12.8 / hour

(ii) Operating costs (US$/hour)

- Fuel costs (U$/hour)

=Engine (kW)*0.3(L/h/kW) *FJF *Unit costs of fuel (US$/L) ………………………………………………………………………………. (8)

FJF = Fuel Job Factor (The consumption rate of fuel is dependent on age / condition of the engine, duty cycle, idling time, operator skill and area condition. These are reflected by the Fuel Job Factor (FJF) and the factor varies between 0.3 and 0.6. Since the machine is nearing the end of its economic life, its performance is low with high fuel consumption. Therefore, a FJF of 0.6 was used in the calculations.

Engine (kW) = 649 kW
Unit cost of fuel = US$ 0.800/L
Fuel costs = 649 * 0.3*0.6*0.800
= US$93.46/hour

- Preventive Maintenance (Repair, lubrication, grease, etc.)

= 15/100 *93.46
= **US$14.02 / hour**

- Operator costs

Average annual truck operator costs, internationally, range from US$15,000 – US$23,000 (Source: (2)). However, US$6500 would be more applicable to Zambian conditions and was used in the calculations.

Operator costs (US$/hour) = 6500/5400
= US**$1.20/hour**

Total operating costs	= 93.46 + 14.02 + 1.20
	= **US$108.68 / hour**

Total ownership and operating costs

	= 12.8 + 108.68
	= US$121.48 / hour
Truck Unit haulage costs	= 121.48 / 128.93
	= US$0.94/m^3

6.1.4.3 Dozing cost estimations

Dozing of backfill material will be done with a D7G dozer. Two dozer units are available at MCL i.e. D8L and D7G. D7G was used in the calculations because the D8L has a high power rating than D7G and will be left for production (i.e. for coal face clearing, vegetation clearing ahead of mining areas and Ropeway jobs). Estimates of dozing operations costs are computed as follows:

(a) Dozer performance

Machine type:	Cat D7G
Swell factor:	1.65
Dozing distance (maximum)	23m
Dozing speed:	2km/hour (Dozer transporting load in first gear – Manufacturer specification)
Cutting speed:	0.45min
Spread time:	0.12min
Return speed:	6km/hour (Maximum return speed of the dozer is 8km/hour. However, because of the conditions and performance of the dozer, a speed of 6km/hour was used in the calculations)
Dozing time:	0.023/2 = 0.69min

Return time: 0.023/6 = 0.23min

Dozer cycle time: 0.45 + 0.12 + 0.69 + 0.23 = **1.49min**

Blade loading 11.7m^3(From manufacturer specifications)
Availability: = 95%
Utilisation: = 95%

Dozer production (m^3/hour) =

= ((60*Blade loading * Swell factor)/ Dozer cycle time)) ………………………………………………………………………… (9)

= (0.95*0.95*60*11.7*1.65)/1.49
= **701.59 m^3/ hour**

(b) Ownership and operating costs

(i) Ownership and operating costs

Purchase price: US$200,000
Economic life (hours): 43,200 hours
Economic life (years): 8 years
Operating hours per year: 5400 hours
Depreciation (US$/hour) = 200,000/43,200
= US$4.63 /hour
Interest rate (r): =10%
Insurance rate (i): =2.5%
Interest (US$/hour):

= (200,000(0.1 + 0.025) (8+1))/(200*8*5400)
= **US$0.026/hour**

Total ownership costs = 4.63 + 0.026
= US$4.66/hour

(ii) Operating costs

- Fuel costs
  Engine (kW): 149 kW
  Fuel costs (US$/hour) = 149 * 0.3 * 0.6 * 0.800
  = **US$21.46/hour**
- Preventive maintenance
  = 15/100 * 21.46
  = US$3.22/hour
- Operator costs

Dozer operator annual income range from US$15,000 to US$20,000 internationally. For Zambian conditions, US$6000 is ideal and is used in all calculations.

Operator costs (US$/hour) = 6000/5400
= **US$1.11 /hour**

Total operating costs = 21.46 + 3.22 + 1.11
= US$25.79/hour

Total ownership and operating costs
= 4.66 + 25.79
= US$30.45 / hour

Dozer production (US$/$m^3$) = 30.45/701.59
= US$0.043/$m^3$

6.1.4.4Grading cost estimates

Currently, MCL has one operating grader i.e. 16G/1. This type of grader was used during estimating costs of grading operations. The following are computations of grading costs.

(a) Grader performance

Machine type:	Cat 16G
Speed (Forward and Reverse)	7.2km/hour (Manufacturer Specification- driving in gear 3)
Distance (maximum)	50m
Grading (Forward) time:	0.050/7.2 = 0.42min
Reverse time:	0.42min
Turning time:	0.10min
Swell factor:	1.65
Blade load:	3.1m^3 (Manufacturer specifications)
Grader cycle time:	= 0.42 + 0.42 + 0.1
	= 0.94min
Availability:	= 95%
Utilisation:	= 95%
Grader production	= (0.95*0.95*60*3.1*1.65)/0.94
	= 294.66 m^3/hour

(b) Ownership and operating costs

(i) Ownership costs

Purchase price = US$385,000
Economic life (hours) = 43,200
Economic life (years)(N) = 8 years
Operating hours per year (H) = 5400 hours
Depreciation = 385,000/43,200
= US$8.91/hour
Interest rate (r): = 10%
Insurance rate (i): = 2.5%
Interest (US$/hour)
= (385,000(0.1 + 0.025) (8+1))/(200*8*5400)
= US$0.05/hour

Total ownership costs = 8.91 + 0.05
= US$8.96/hour

(ii) Operating costs

- Fuel consumption
  Engine (kW) = 186kW
  Unit cost of fuel = US$0.800/L
  Fuel costs = 186 * 0.3 * 0.6 * 0.800
  = US$26.78/hour
- Preventive maintenance
  = 15/100 * 26.78
  = US$4.02 /hour
- Operator costs
  Internationally, grader operator's annually income range from US$15,000 to US$20,000. For Zambian conditions, US$6000 per year would be ideal and is used in the calculations.

  Operator costs = 6000/5400
  = **US$1.11/hour**

  Total operator costs = 26.78 + 4.02 + 1.11
  = US$31.91/hour

  Total Ownership and operating costs
  = 8.96 + 31.91
  = US$40.86/hour

  Grader Production cost (US$/ m^3) = 40.86/294.66
  = US$0.138/ m^3

Table 6.1: Total unit costs of loading, hauling, dozing and grading operations

No.	Operation	Machine type	Ownership/ operating costs (US$/hour)	Production costs (m^3/hour)	Production costs (US$/ m^3)
1	Loading	Rope shovel	59.7	769.5	0.078
2	Haulage	Dump Truck	121.48	128.93	0.94
3	Dozing	Dozer	30.45	701.59	0.043
4	Grading	Grader	40.86	294.66	0.138
TOTAL					**1.198**

Therefore, to load, transport, doze and grade a cubic meter of overburden material would cost US$1.198 (Table 6.1). Rehabilitation of Kanzinze and Izuma pits requires 55.8 x10^6 of backfill material and approximately 1.34 x 10^6 m^3 of topsoil material (to least 0.5m thick layer). Total volume of backfill material required to fill the pits would be;

= 55.8 x10^6 m^3 + 1.34 x 10^6 m^3
= 57.14 x10^6 m^3

Total cost of rehabilitating Kanzinze and Izuma pit (268 hectares of land) would be:

= 1.198 * 57.14 x10^6 m^3
= US$68,568,000
= US$68,568,000.00

Computations show that a total of US$68,568,000.00 is required to rehabilitate the Kanzinze and Izuma pit areas. MCL alone cannot afford this amount without government assistance. Therefore, the government, through the MENR should provide incentives (e.g. giving subsidies to importation of rehabilitation equipment, tax holidays, provision of loan for rehabilitation exercise, etc.) that will encourage MCL embark on rehabilitation exercise. Rehabilitation work in Kanzinze and Izuma pits should be an ongoing program until cessation of mining operations. Progressive rehabilitation significantly reduces the amount and cost of rehabilitation required at cessation of mining operations. Critical shortage of equipment has hindered MCL embark on rehabilitation exercise. From the study, approximately six (06) dump trucks are needed for material haulage during rehabilitation and from the current production MCL cannot afford to purchase the required equipment. Therefore, the government through the MENR should put incentives that will encourage or enable MCL acquire reclamation equipment cheaply from outside the country. Since MCL has a high reserve base of 27.87 million tonnes of coal with economic life of over 47 years, these can be used as collateral to access loans from lending institutions (e.g. Banks) to purchase rehabilitation equipment.

Because MCL should remain in business and continue with its production, more damages will be done to the environment if control measures are not instituted on current operations. Results of this study show that an average of 10 hectares of land is destroyed annually by mining operations. Therefore, with economic life of over 47 years, a total of 470 hectares of additional land and forest will be destroyed before cessation of mining operations. At MCL, over 67% of the total land disturbance was done before regulations were enacted and as such mining operations were conducted without regard for environmental protection. This means that, MCL cannot be punished for the damages created before environmental regulations were enacted. However, after 1992, when the regulations were put in place, MCL is responsible and answerable for all the damages although lack of resources will hinder rehabilitation exercise. Therefore, a compromise between MCL and the government should be reached on how best rehabilitation can be done. Rehabilitation should also not interfere with normal production operations and it should take place at times of little or no production and staggered over mine e.g. at weekends as well as during slack periods of coal production demand.

Due to continued production of coal at MCL, more land will be disturbed and there is need to put control measures on current operations so that damage to the land and forest is kept to the minimum. The following control measures have been suggested to reduce the impacts of current mining operations on land:

- Utilisation of overburden spoils and discards from the CPP for backfilling excavation;
- Dry material from slurry ponds should be dumped within the pit to assist in backfilling;
- Backfilling should be followed by dozing, grading and revegetating graded areas; and
- Environmental control officers should conduct regular monitoring to ensure that rehabilitation is being carried out according to laid down procedures and at the rate specified.

6.1.5 Revegetation of the reconstructed land

The benefits of a vegetative cover on land disturbed by mining are well known – erosion will be controlled thereby lessening stream sedimentation; beauty will be restored to the landscape; and the land will become productive again (6). As soon as the mining operations cease a natural process begins that, if left alone, eventually will culminate in the establishment of a vegetative community in harmony with climatic and other environmental forces acting upon that particular site. This process, usually, is too slow for today's society. Emphasis is therefore, placed on the rapid establishment of a vegetative cover composed of desirable species. Desirable species are those that can best achieve the goals of revegetation, both in the long term as well as in the short-term.

6.1.5.1Species selection

The species selected for establishment will depend on anticipated / projected future landuse of the area, soil conditions and climate. Some indigenous species may not thrive in areas where soil conditions are substantially different after mining. If this is the case, and the objective is to re-establish vegetation, which fulfills the functions of the original native vegetation, then some species from outside the mining area will have to be introduced. Species which have similar growth forms to the original vegetation, and thrive in areas with comparable soil types, drainage status, aspects and climate to the rehabilitated area, are the most appropriate. Care must also be taken to avoid introducing species, which could become unacceptable, invade surrounding areas of native vegetation or become a weed for the local agricultural areas. Table 6.2 shows the unit cost of some plant species, which can be used for revegetation. These species were selected on the basis of the following:

- ♦ All the plants / species are naturally found in Zambia and there is no need of importing them from other countries;

- The soil type in Maamba region favours the growth of these plant species;
- The plant species are also not difficult to grow i.e. can grow on their own without much care;
- Most of the species are eatable e.g. Fan palm, Bush oranges and Masuku and these will provide food for the people in the area;
- Plants like Fan Palm will provide good scenery in the area once planted; and
- Most of them are drought resistant.

Table 6.2: Cost of plant species (Source: University of Zambia, Biology Department)

No.	**Genus & Species name**	**Common name**	**Planting Space**	**Unit Costs (US$)**	
				Per seedling	**Seeds (kg)**
1	Vigna unguiculata	Cow pea	0.9 x 0.3m	1.26	
2	*Borassus aethiopum*	Fan Palm	Varies	5.26	
3	*Ficus sycomorus*	Umukunyu	Varies	5.26	
4	*Ximenia americana*	Wild Plum	2m x 2m	5.26	
5	*Strychnos cocculoides*	Bush Orange (Kasongole)	2 x 2m and also varies	5.26	
6	*Uapaca kirkiana*	Wild Loquat (Musuku)	Varies	5.26	
7	*Pericopsis angolensis*	Mubanga	Varies	5.26	
8	*Acacia sieberianu*	Paperbark Thorn	2 x 2m	5.26	0.11

6.1.5.2 Establishment

Plant species can be established on rehabilitated area from: -

1. Propagules (seeds, lignotubers, corns, bulbs, rhizomes and roots) stored in the topsoil;
2. Sowing seed;
3. Spreading harvested plants with bradysporous (seed retained on the plant in persistent woody capsules) onto areas being rehabilitated;
4. Planting nursery – raised seedlings;
5. Transplants of individuals from natural areas; and
6. Habitat transfer – the transfer of substantial amount (around $1m^2$ or more in area and 200-300 mm depth) of relatively undisturbed soil with its vegetation intact from natural areas.

6.1.5.3 Seedbed preparation

The preparation of a suitable seedbed is an important factor in the successful establishment of plants from seeds (6). The objective in creating a seed bed is to place the seed in a suitable place for germination. The seed must be in good contact with the soil to ensure it can take up water easily and the soil must be well aerated. The soil around the seed must be loose enough for the seedling to grow up through the soil and allow root growth. The seed bed should be free of weeds. Care should also be taken not to over prepare the soil, as a rough surface provides more niches for the seeds and encourages infiltration of rain. Soil should be cultivated when moisture levels are adequate to avoid powdering, but not so wet that compaction and loss of structure becomes a problem.

6.1.5.4Weed control

Controlling the introduction and spread of weeds is an important consideration in rehabilitation. Weed infestations on rehabilitated areas can be very difficult to control and so the emphasis should be on prevention rather than cure. Weeds in areas adjacent to the disturbed areas should be controlled to reduce the potential seed load. Care must be taken that weeds are not introduced to the area in manure or as contaminants in seed of the desirable species. Fertilizers and manures should always be used carefully as they can stimulate weed growth, seed set and growth. Cultivation, hand weeding, burning and herbicides can all be used in attempts to control weed infestations.

6.1.5.5Revegetation cost estimates

The species that are considered for the revegetation exercise are indicated in Table 6.2. For the calculations below: -

(i) Each zone is assumed to be a rectangle of length Lm and breadth Bm and is divided into rectangular (or square) plots (**x** by **y**) as shown in Figure 6.1.

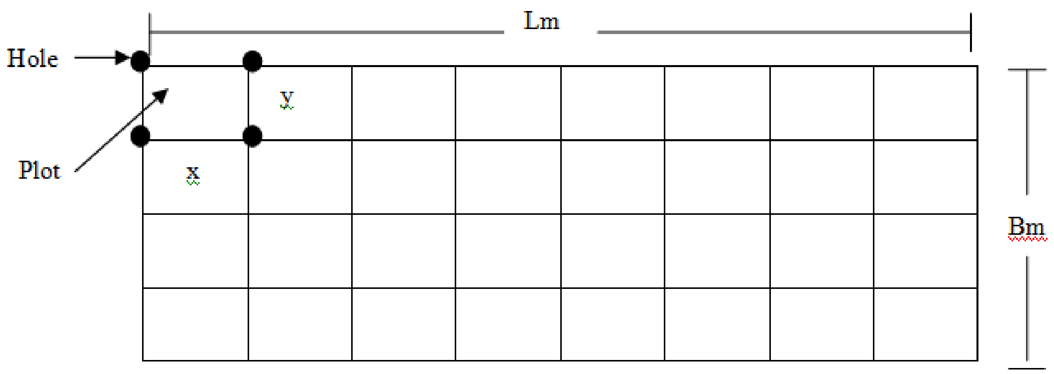


Figure 6.1: Revegetation cost estimates

Each plot is bounded by four (4) holes.

A	=	Area of the zone to be revegetated (268ha)
Npl	=	Number of plots along L
Npb	=	Number of plots along B
Hn	=	Total number of holes
Sh	=	Number of seedlings per hole
Qs	=	Quantity of seedling required
Us	=	Unit cost of seedlings
Tcs	=	Total cost of seedlings required.
Hn	=	(L/x + 1) (B/y + 1)

Where:

(L/x + 1) = number of holes along L

(B/y + 1) = number of holes along B

Qs = Hn x Sh

Tcs = Qs x Ups

Revegetation cost of Kanzinze pit with surface area of 268ha using a plant spacing of 2 x 2m at 1 seedling per hole (e.g. Acacia) is calculated as follows:

Assume L = B = √ 2680000 = 1637m

Npl = 1637/2 = 818 plots

Npb = 1637/2 = 818 plots

Hn = (818 + 1) (818 + 1) = 670761 holes

Qs = 670761 x 1 = 670761 seedlings

Tcs = Qs x Ups = 670761 x 0.11 (see Table 6.2 for seedling costs)

= **US$73784**

6.1.6 Erosion control in rehabilitated areas

Control of erosion is important both during mining and in the rehabilitation program. The major objective of rehabilitation in Kanzinze basin is to establish adequate cover of vegetation to stabilize the site and prevent or control erosion. Until an adequate cover of vegetation has been established, it is imperative that provision be made to control erosion from disturbed and rehabilitated areas. Soil particles in rehabilitated areas can be lost in two ways, i.e. they can be blown away or they can be washed away (8). Therefore, before a vegetation cover is established in the rehabilitated area, erosion can be controlled by the following methods.

6.1.6.1 Wind erosion

Wind erosion in rehabilitated areas can be controlled by the following methods: -

1. Protecting the soil surface with mulch of natural or manufactured material.
2. Maintaining the soil in an erosion resistant condition i.e. moist or with a compacted surface crust.
3. Reducing wind velocity across the disturbed areas by establishing wind breaks.

6.1.6.2 Water erosion

Erosion by water involves two stages: - first, large soil aggregates are broken up into finer particles and second, these finer particles are transported down slope. The loss of soil through water erosion is a function of the erosivity or intensity of the rainfall, the erodibility of the soil, the area of catchment, the length and gradient of the slope, the amount of vegetation cover and the erosion control measures undertaken (8). Measures to protect the soil from water erosion should be carried out on a catchment basis. Drainage from external catchment must be controlled by diversion channels or holding structures such as banks, drains or dams. Water leaving site or diverted around the site must also be controlled. It is necessary to discharge this water so that it does not cause erosion or carry sediment downstream. Sediment dams are the most common means of controlling sediment levels in runoff.

On disturbed (rehabilitated) areas, control of water erosion is achieved by: -

- Slowing the water flow across the soil surface.
- Reducing the impact of raindrops on the soil surface
- Maintaining the soil in an erosion resistant condition

Water flow across the soil surface can be reduced by encouraging infiltration and building drainage control structures to channel water off the site. Infiltration can be encouraged by ripping and cultivation on contour and constructing contour banks. Water can be channeled off-site by drains, graded banks and stabilized waterways.

Ripping encourages infiltration, relieves soil compaction, increases the volume of soil readily accessible to plant roots and binds the topsoil to the subsoil. Ripping should always be along the contour. Areas can be ripped after the topsoil has been returned or before topsoiling, in which case, the area will normally need to be cultivated before revegetation. When ripping after topsoil return, care must be taken to avoid burying significant quantities of the topsoil and therefore losing its benefit. Mulches can be used to protect the soil from raindrop impact. Examples of suitable materials are bush matting, stubble mulch, hay mulch, sawmill waste, bitumen, and other chemical stabilizers.

6.1.7 Management of waste (spoil) and discard material

Solid materials from the open-pits (spoil material) and from the CPP (discard) are dispersed into the environment in discrete dumps within the Kanzinze and Izuma areas. Normally, wastes should not be disposed of by indiscriminate or haphazard tipping over land, but in properly constructed dumps. Waste dumps should be engineered and constructed to ensure long-term stability and at the same time enabling an appropriate after use. Areas of waste dumps should be minimized as far as practicable. Tip or dump design and construction should be done under the supervision of a suitably qualified engineer and should be inspected periodically. Waste dumps should be rehabilitated as soon as possible in a proper manner.

The following techniques suggested should be used for waste and discard disposal:

1. Utilization of the overburden and discard material by backfilling the pits to help in reclamation and rehabilitation of the terrain without affecting the drainage and water regimes.

2. Dumping overburden and discards in the available low lying areas (as long as they do not affect the nearby environment) accompanied by leveling and providing spill-over to utilize the land profitable.
3. The dump must be properly graded and terraced with contour drainage as necessary.
4. Terracing of dumps must be accompanied by stabilizing of the slopes.

6.1.7.1 Waste disposal site requirements

When viewing a site for the disposal of mine waste rocks, planners must consider the percent rejection from the pits and also from the CPP. Adequate area for waste disposal is an important factor and should be identified at the planning stage. The aesthetics and possible pollution, which might be created by the disposal site, are the other considerations, which should be taken into account. Other factors of crucial importance in selecting a site for mine waste rocks are: -

1. The site should always be located on a secure and impervious base so as not to allow infiltration of pollutants into the groundwater bodies.
2. The site should be as far away as possible from the natural watercourses, shallow aquifers etc.

6.1.7.2 Control of erosion from waste dumps

Soil erosion by water from waste dumps is a major threat degrading both land and the surrounding environment into which it erodes such as water courses along Kanzinze and Izuma rivers. The design and management of site operations should incorporate measures to minimize surface runoff. Normally slopes of waste dumps require particular attention to prevent erosion by surface runoff, especially the discard dumps in Kanzinze basin.

The best protection against all forms of erosion is a dense cover of vegetation. Therefore, discard dumps and waste dump in Kanzinze and Izuma should be vegetated to protect the soil surface against wind and erosion from surface runoff. Surface litter and plant roots help to bind soil particles together and promote water infiltration reducing the volume of surface flow. During early stages of rehabilitation work on the dumps, it is inevitable that the newly formed surface will be exposed and very susceptible to erosion. Therefore, failure to provide adequate erosion control, will not only increase the need for water treatment to remove suspended solids, but also the loss of replaced top soil can make the job of revegetation significantly more difficult and delay the return of land to a self-sustaining condition, all of which add to costs.

6.2 Water pollution control

6.2.1 Acid mine drainage control

Acid mine drainage control can be achieved by eliminating one or more of the components that promote acid-generation processes or by controlling environmental factors at the source in order to retard the rate of acid generation (7). This control can be achieved in one of the following ways: -

(a) sulphide removal or isolation

(b) exclusion of water using impermeable barriers

(c) exclusion of oxygen to prevent oxidation of sulphides

(d) pH control by maintaining it within the alkaline range to inhibit acid generation

(e) Control of bacteria action by using organic acids and food preservatives.

At Maamba Collieries, the following measures have been suggested to reduce acid generation.

6.2.1.1Water quality management strategy

Mine drainage and particularly mine process water from the CPP, runoff from row coal stockpile area and dumped material from slurry pond is contaminated by acid mine drainage. Water, which accumulates in mine pit, has AMD. Therefore, control of AMD from these areas should involve capturing all the water from the mentioned areas into the central collection pond.

To capture runoff from the raw and washed coal stockpile areas, should involve contouring the area around the raw and washed coal stockpile area properly so as to allow collection of runoff from these areas into the central collection pond. Contouring the land properly will also lower the speed of overland flows during rain season, thereby reducing erosion and sediment problems.

From the central collection pond water should be treated with an alkali reagent such as the following until the water quality conforms to the required Zambian standards (Appendix K).

1. Limestone (calcium carbonates)
2. Hydrated lime (calcium hydroxide)

3. Quick lime (calcium oxide)

4. Caustic soda (sodium hydroxide)

5. Caustic magnesia (magnesium oxide)

Treatment stage should be followed by a settlement stage to recover the fine metal precipitants (hydroxides). After treatment, the water is then reticulated back to the mine where it will be available for use in the CPP and for dust suppression at the mine. The water management system will reduce the requirements for raw water from Lake Kariba and it will also reduce the need to release water from the mine area into local water resources. Therefore, downstream water users will not be put at risk. Currently, this water management system is being used at Gregory Open Cut Coal Mine BHP Australia Coal (7).

6.2.1.2Bacterial inhibition

The rate of sulphide oxidation and acid generation is enhanced by microbiologic activity, particularly that of Thiobacillus Ferrooxidans (12). This bacteria is known to increase greatly the rate of acid production from pyritic materials. Therefore, Bactericides have been developed which inhibit the growth of these micro-organisms. Their primary effect is minimising the catalytic role played by the bacteria in converting ferrous iron to ferric iron under acid conditions.

This method is suggested so that the Bactericide is applied frequently to temporary coal stockpiles or to waste/discard material to delay the onset of acid conditions or reduce the secondary treatment cost such as lime dosing of drainage/runoff water. The most popular bactericides for acid-generating material include benzoate compounds, sorbate compounds, anionic surfactants such as sodium lauryl sulphate and phosphate compounds (12). Laboratory and field experiments indicate that bactericides reduce the rate of acid generation as well as concentrations of certain metals generally by a factor of five (12). Because this method is a short-term solution and only partly effective, bactericides need to be part of an integrated system approach to managing sulphide waste. To date this technology has largely been used for rehabilitation in the US coal industry to assist establishment of an active vegetation cover prior to the onset of significant acid generation.

6.2.1.3 Control of acid production from surfaces of existing dumps

Coal waste and discard dumps contain varying levels of sulphides, mainly in form of pyrite. The rehabilitation strategy for the dumps must therefore be designed to minimise the potential for AMD. The rehabilitation strategy for the dumps is the construction of a sealing layer over the bulk waste to:

1. reduce infiltration to very low levels
2. prevent convective transport to oxygen and
3. have the potential to reduce diffusive transport of oxygen

All dump surfaces should be sampled to ascertain the chemical nature of their external layers and, where acid-producing material has been identified, the surface should be encased with non-reactive material. In future, new dumps should be constructed with the aim of preventing acid drainage occurring. This is achieved by ensuring that all highly reactive overburden is buried in the core of dumps, away from a fluctuating water table and oxygen.

6.2.2 Control of suspended solids

Suspended solids result from non- settleable particulate matter in water. Sources of dissolved solids are the effluents from the CPP and the water from the central Izuma sump. Other sources are the runoff from the raw and washed coals stockpile area and from the aerial ropeway. Control of suspended solids in water should also involve construction of sediment catch basins down gradient of a mine i.e. central collection pond. The central collection pond will give suspended material enough time to settle, thereby controlling the amount of suspended solids entering the stream. Controlling suspended material will also reduce the turbidity of the water in the area.

6.2.3 Control of dissolved solids

Dissolved solids result when the pH of the water decreases and acidity increases. This is because most minerals are dissolved as a result of the presence of acids. Effluents from the coal preparation plant and Kanzinze exit (Kanzinze downstream), where the pH of the water was low, showed high concentrations of dissolved solids. Control of dissolved solids involves reducing the pH of the water entering the stream. This should be achieved by treating all the water and effluents joining the stream with an alkali such as those outlined in section 6.2.1.1.

6.3 Air pollution control

The gaseous pollutants are controlled by removing / minimizing them from source points and dispersed areas to either liquid or solid surface, where they are retained or where they react to form a non-polluted species that is more readily removed than the original contaminant. In more general terms, control of dust air pollutants involves passing the gas, stream containing the particles through a chamber and permitting a force to act on the dust particles which takes them out of the gas stream. The following methods of controlling dust within the open pit and CPP are suggested:

6.3.1 Air quality management in open pits

Dust within the open-pit is generated by mining activities that disturb topsoil, overburden or coal causing dust to be emitted into the air. During vegetation removal, operations of dozers and other heavy equipment also produce dust into the air. These dust emissions can be controlled by restricting the area of disturbance and by spraying water on disturbed areas to prevent dust conditions. The following dust control measures are suggested to reduce dust concentrations in dust producing areas: -

6.3.1.1Topsoil stripping

At Maamba Collieries Limited, shovels are used to strip topsoil and during this operation considerable dust is generated. Dust generation during this operation can be reduced by spraying, minimizing the length of time that stripped areas are exposed to wind erosion and by limiting the total area stripped.

6.3.1.2 Drilling

Blasthole drilling, whether in overburden or coal, generates dust. Dust from drilling can be controlled by shielding the drilling area to prevent dust from being carried by the wind. During drilling operations, dust at the top of the drill hole can be collected by a shroud or skirt and vented through a mechanical dust collector e.g. cyclones.

6.3.1.3 Blasting

Blasting operation is also one of the sources of dust in open pit operation. Because blasting occurs infrequently, it does not generate as much dust over a period of time as more continuous fugitive dust sources such as stripping, drilling, loading etc. Dust from blasting can be minimized by avoidance of overcharging and introduction of millisecond delay in the detonation sequence.

6.3.1.4 Overburden and coal stripping

Several different pieces of equipment are used for material removal - dragline, shovels, dozers and front-end loaders and each is a significant source of fugitive dust. Dust is generated by shovels and draglines when material is scooped into the dipper or bucket, and again when the material is dropped into the spoil site. Dust is also created in scooping and dropping material onto trucks. In either case, dust can be controlled by minimizing the drop distance that material falls onto spoil piles or trucks.

6.3.1.5Materials haulage

Haul trucks are the predominant source of fugitive dust. The magnitude of dust emissions from haul trucks increases with truck speed and truck weight. Fugitive dust on haul roads can be reduced by treating the road surface to minimize dust. This can be accomplished by routine spraying, by removal of loose debris on roadways and by application of dust suppression chemical. Although spraying is done at MCL, it is only restricted to the open-pit haul roads and therefore, watering should also be extended to all roads leading to coal preparation plant. Application of chemicals to haul roads would inhibit dust by forming a hard, relatively smooth surface. Chemicals that can be used are the following:

1. Petroleum resin;
2. Emulsified asphalt;
3. Calcium lignosulfunatet;
4. Magnesium chloride; and
5. Molasses from Mazabuka Sugar Factory.

6.3.2 Control of dust in the CPP

6.3.2.1Dust control at grizzly and raw coal bunker basement

Control of dust from the grizzly and the basement should involve construction of the dust extraction plant, which should be equipped with the exhaust ventilation connected to the cyclone (see Figure 6.2 for arrangement). The exhaust fan will remove (suck) dust air from the basement and grizzly into the cyclone where dust is collected.

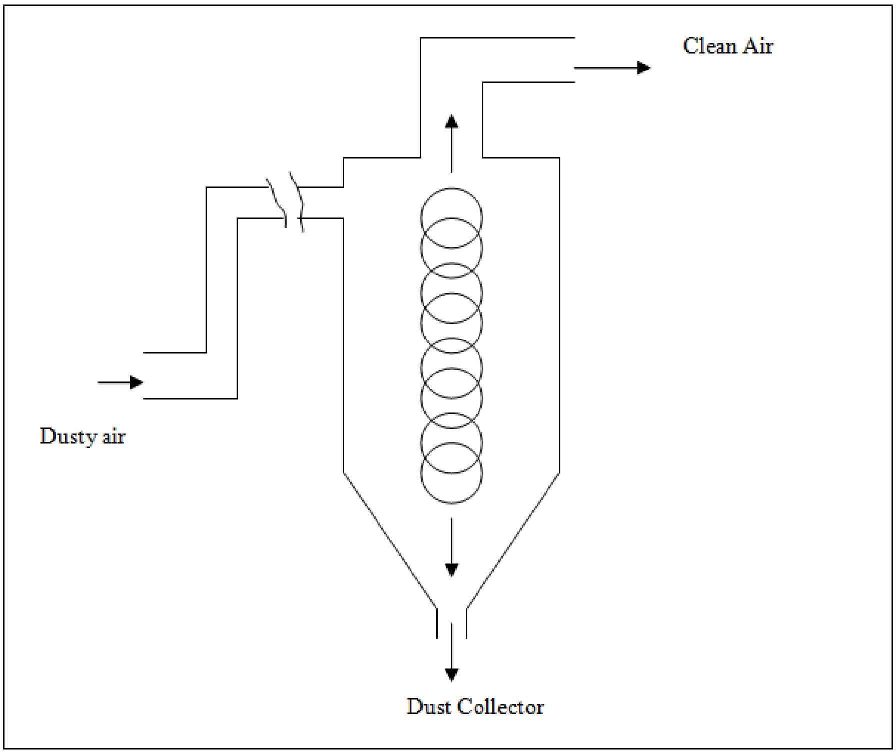


Figure 6.2: Arrangement of a dust control cyclone

6.3.2.2 Control of dust at transfer points

Transfer points in the CPP are the high-drop points of the conveyor belts. The handling of dry material invariably produces dust levels which must be controlled. Control of dust at these points should involve enclosing these points (see Figure 6.3) and provide them with exhaust ventilation connected to the cyclone.

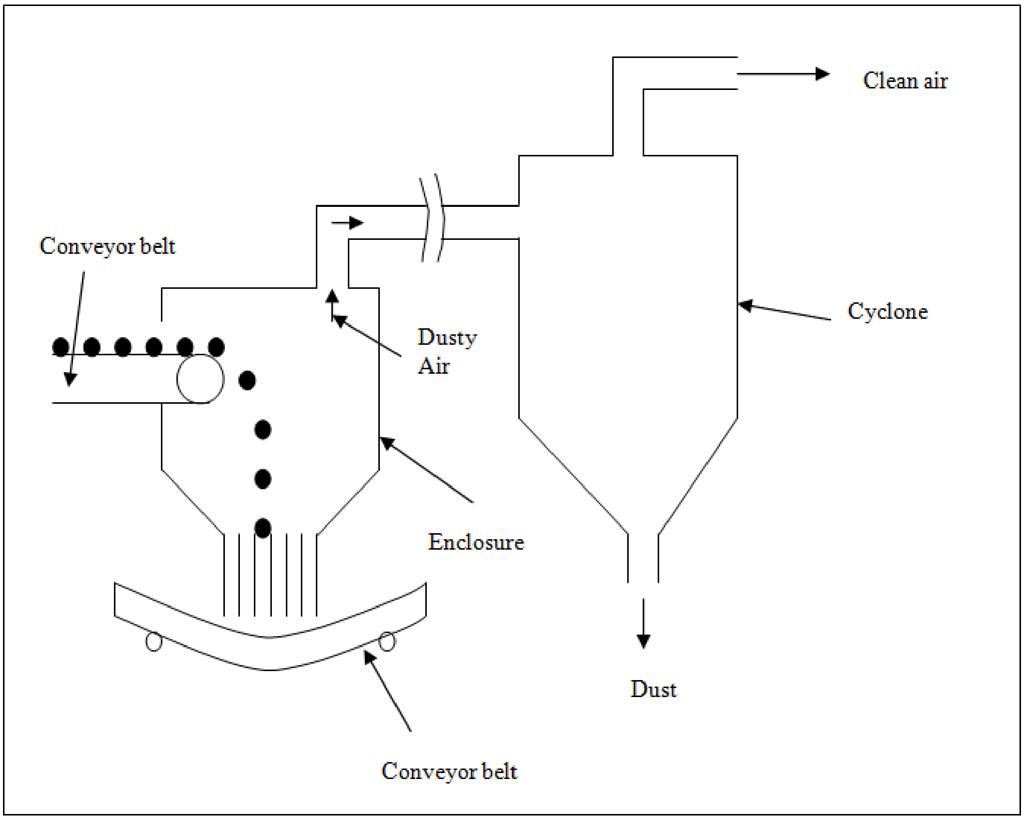


Figure 6.3: Arrangement of dust control apparatus at transfer points

6.3.2.3 Control of dust from screening operations

Vibratory screens are used for size classification of the ROM ore. Large amounts of dust are released since the material is handled in dry form. Control of dust in these areas would involve using water sprays (3) on the screens for dust suppression or enclosing screens and place them under negative air pressure. Other alternatives would include installing exhaust hood near the screen and connect it to the cyclone.

6.3.2.4 Control of dust at crusher point

ROM ore is crushed and this process produces high dust levels, which affect the workers as well as the general environment in the coal preparation plant. Such dust emissions must be controlled as near as possible to the point at which the dust is produced and before being dispersed into the atmosphere. To control dust from crushers, the crusher should be totally enclosed and wet scrubber used to suppress dust. Wet scrubbers will prevent contamination of the atmosphere by dust particles from the crusher.

6.4 Environmental regulations

6.4.1 Environmental Policies

Mining and its associated activities have always been in conflict with the environment (4). Although coal mining at MCL contributes revenue to the national economy, provides employment as well as infrastructure, it is a cause of environmental damage if not well controlled by comprehensive environmental policies. Mining under proper environmental policies should therefore:

(i) Help nature to tolerate or regenerate without undue harm,

(ii) Provide optimum income and revenue; and

(iii) Provide development to the local community in and around the mining area.

Sustainable development in the mining operations at MCL therefore requires a good balance between the protection of the environment and the economic growth. Before commencement of mining operations at MCL, there were no compelling environmental regulations or guidelines to sustain the environment. It is only recently that there is increased global awareness of environmental concern. As a result, land, water, air pollution, habitat destruction, health and safety risks have been major drawbacks of coal mining operations at MCL. It is therefore, imperative for the government to set policies, among other things, to safeguard social and economic security, safety and worker's health as well as the environment. In order to achieve these goals, "The Environmental Protection And Pollution Control Act, 1990" was commissioned in 1992. Under this Act, the Environmental Council, which falls under the Ministry of Environment and Natural Resources (MENR) was defined and is responsible for the following:

(i) Ensuring rational use of the natural resource environment and prevention and elimination of environmental pollution and damage to the ecosystem, so as to create clean and favourable living and working environment for the people; and
(ii) To provide fundamental guidelines, principles requiring supervision, management and punishment on the activities of environmental protection.

Therefore, it is important that mining is conducted within an environmental regulation framework that allows for protection of the environmental quality standards that have to be met by the producer.

6.4.2 Environmental Protection and Pollution Control Act No. 12 of 1990

The Environmental Protection And Pollution Control Act No. 12 of 1990 was enacted by the parliament of Zambia to:

(i) Provide the protection of the environment and the control of pollution;

(ii) Establish the environmental council and to prescribe the functions and powers of the council; and

(iii) Provide for the matter connected with or incidental to the foregoing.

(a) Natural Resources Conservation Act (Part X of "The Environmental Protection and Pollution Control Act No. 12 of 1990")

In order to conserve the natural resources from mining and other destructive operations, the government has put up the Natural Resource Conservation Act. Under this Act, the environmental Council is empowered to:

(i) Monitor dereliction of land and where derelict land exists, assess the nature of rehabilitation works required;

(ii) Monitor land contamination and where such contamination exists, assess the nature of any rehabilitation works required; and

(iii) Carry out campaigns to increase public awareness about natural resource conservation.

In section 77 (01) of the Act, the council is empowered to direct any person responsible for land dereliction or contamination to carry out rehabilitation works, within reasonable specified time. To ensure that the regulation is followed, penalties have been put in place. In Section 77 (03) the regulations states that "any person who fails to comply with the regulation in Section 77 (01): -

(i) Shall be guilty of an offence; and

(ii) A court, in addition to any other penalty which it may impose, may make an order requiring that person to comply with the regulation within a specified reasonable time".

(b) Waste Management Act (Part VI of "The Environmental Protection and Pollution Control Act No. 12 of 1990")

This regulation (Section 50(03)) prohibits disposal of waste in areas where they will cause pollution to the environment. It also prohibits persons from transporting waste to any dumping place other than in accordance with a licence or to a disposal site established in accordance with the licence.

(c) Water Management Act (Part IV of "The Environmental Protection and Pollution Control Act No. 12 of 1990")

Under this regulation (Section 22), prohibition have been made to discharge or apply any poisonous, toxic, erotoxic, obnoxious or obstructing matter, radiation or other pollutant or permit any person to dump or discharge such matter or pollutant into the aquatic environment in contravention of water pollution control standards established (Zambian standards for effluent and waste water). In Section 28, regulations state that any person who discharges any effluent into the environment in contravention of the condition shall be guilty of an offence. In this regard, the council has been empowered to:

- (i) Establish water quality and pollution control standards;
- (ii) Determine conditions for the discharge of effluents into the aquatic environment; and
- (iii) Enforce the regulations.

(d) Air quality Management Act (Part V of "The Environmental Protection and Pollution Control Act No. 12 of 1990")

In order to ensure air pollution free environment, Section 39 of the regulations was enacted to prohibit all persons emitting any pollutant which cause air pollution in contravention of emission standards established or prescribed by the council. The act also empowers the council to:

(i) Establish air ambient quality and emission standards and guidelines; and

(ii) Enforce the regulations.

In general, Section 90(01) of the Act states that "a person who pollutes the environment or contravenes any provision of the act for which no penalty is provided shall be guilty of an offence and liable upon conviction to a fine not exceeding One Hundred Thousand Kwacha (K100, 000.00) or imprisonment for a term not exceeding three (03) years or both." And for continued violation, Section 91(02) reviews that a court may order a daily fine not exceeding Fifty Thousand Kwacha (K50, 000.00).

6.4.3 Factors contributing to non-compliance

Despite the existence of environmental regulations, environmental impacts at MCL have remained unaddressed because of the following factors:

1 Absence of Environmental Regulations at inception of mining until as recent as 1992. Therefore, all operations at inception of mining were conducted without regard for environmental protection;

2 Lack of resources to embark on rehabilitation works. MCL is continuously faced with a critical shortage of equipment. Although very few equipment exists e.g. Dump trucks, Dozers, shovels etc., these are not sufficient to operate at production as well as at reclamation operations. These equipments have also exceeded their maximum life and cannot work efficiently in reclamation exercise.

3 Lack of law enforcement by environmental officers; Despite having environmental regulations in place, these are not enforced by law enforcement officers due to lack of resources (e.g. transport to visit the affected areas) by officers. From the interviews conducted with the employees, no environmental officer has ever visited the area to enforce these regulations or to determine the extent of the damage. As a result, relaxed approach has been adopted by MCL employees in as far as environmental compliance is concerned.

4 Lack of government incentives for environmental compliance; The government through the ECZ does not provide incentives that will encourage MCL embark on operations aimed at environmental protection. Fines for infringing standards (K100, 000.00) do not provide sufficient incentive to start operations aimed at environmental protection.

6.4.4 Strategies to encourage environmental compliance

In raising environmental awareness and encouraging MCL to start efforts aimed at environmental remediation, the main emphasis will be placed on voluntary approach i.e. a collective initiative of individuals and government. However, some environmental problems cannot be resolved only with the cooperation of individuals and thus calls for government actions through the use of policies like fines and taxation. Therefore, to ensure sustainable environmental management at MCL, the following strategies have been suggested:

(i) Establishing effective monitoring and enforcement of system. Fines for infringing standards (K100, 000.00) do not provide sufficient incentive to invest in pollution control measures. Therefore, a higher figure of US$10,000 is suggested.

(ii) Improving environmental awareness campaigns through the media and holding round table discussions between the polluters (MCL) and those affected (local communities).

(iii) Preparing and distributing information booklets and handbooks on acceptable mining practices and spell out the environmental obligation and legal consequences of non-compliance.

(iv) Empowering enforcement officers to conduct regular monitoring through adequate funding and other inputs.

(v) Giving MCL incentives on operations aimed at environmental protection e.g. subsidies on imported rehabilitation equipment, tax holidays, royalties, etc.

(vi) Encouraging the application of economically sound technologies, which are environmentally friendly.

CHAPTER SEVEN

7.0 DISCUSSION OF FINDINGS

From this study, it has been shown that 321 hectares of land have been disturbed (Table 5.1) by mining and coal processing operations. Results have also indicated that if operations at MCL are not controlled a total 470 hectares of additional land will be destroyed before cessation of mining operations. To date 13.8 million m^3 of excavations have been created by mining operations in Kanzinze and Izuma pits. A total of 56.8 million m^3 of material is required to rehabilitate the two pits. Dumps of mine wastes have also degraded quite extensive area of land. Results have shown that 6.61 million m^3 of material have been dumped occupying a total surface area of 53 hectares of land. Kanzinze discard dumps accounts for 63% of the total material dumped at MCL. Estimate of rehabilitating and revegetating costs at Kanzinze and Izuma pits amounts to US$68,641,784.

Quantitative estimation of remedial costs for particulate, gaseous and other minor environmental impacts of mining were not determined since no baseline data was collected due to equipment and time constraints. However, methods have been suggested on how to minimize their effects. The amount is colossal and MCL cannot afford without government assistance. Therefore, the government, through the MENR should provide favourable conditions that will encourage MCL embark on rehabilitation exercise. The government should provide incentives e.g. access to loans, tax holidays, royalties and subsidies on imported rehabilitation equipment, as well as direct financial assistance to encourage MCL embark on rehabilitation exercise. Strategies outlined in section 6.4.4 should be implemented to encourage MCL comply with environmental regulations. Since the mine has a high reserve base, with economic life of over 47 years, these can be used as collateral to access loans.

Results of water sampling indicate that the water in the Kanzinze stream is generally polluted. It was found that the pH values for Kanzinze and Izuma upstreams were 7.7 and 8.4 respectively. However, the pH dropped drastically to 2.5 as monitored at Kanzinze downstream. The drastic reduction was as a result of oxidation of pyrite (contained in coal and overburden) after exposure to oxygen and water. The result of pyrite oxidation is the formation of sulphuric acid that is eventually washed in the Kanzinze. As a result of the presence of acids in stream water, this has led to dissolution of metals in this water. Water sampling results reveal that dissolved iron and magnesium in the Kanzinze River were high at low pH values. Kanzinze downstream had the highest concentration of dissolved iron and magnesium of 299.5mg/l and 268mg/l respectively. Studies have also shown that the CPP and the Izuma central sump are the major sources of dissolved solids in the area. Suspended solids and turbidity were also high in Kanzinze stream. Results show that suspended solids were highest in effluents from the coal preparation plant i.e. 894mg/l, which was above the maximum allowable concentration of 100mg/l.

Coal mining and processing have also engendered air pollution especially during open pit mining and coal preparation plant operations. Dust sampling results indicates that the open pit and the CPP are the most affected in terms of air pollution. During open pit mining operations, it was found that stripping and loading operations created high concentrations of coal and silica dust. High concentration of coal and silica dust i.e. 2225 ppcc was recorded during coal drilling with an Airtrac. CPP also had high concentration of coal and silica dust and the major sources were during screening and crushing operations. The most affected were the basement and the picking belt where a total of 882ppcc and 990ppcc were recorded respectively. High dust concentrations were as a result of non-functioning of the exhaust ventilation system within the basement as well as handling of ROM coal in drier state.

Screening and crushing operations were also not enclosed, thus emitting substantial amount of dust within the CPP. However, Maamba Township is not polluted as can be shown by the dust sampling results. The little coal and silica dust that was recorded was very much below the maximum allowable concentration and was because of spillage from coal trucks. Although environmental regulations have been enacted, most of the damages were done before these regulations were put in place and mining was conducted without regard for environmental protection. Despite these regulations, MCL cannot afford to or embark on reclamation exercise because of the following factors:

- Lack of resources to embark on rehabilitation exercise;

- No government incentives for environmental compliance; and
- Lack of law enforcement by environmental officers.

Therefore, strategies outlined in section 6.4.4 should be instituted to encourage environmental compliance by MCL.

CHAPTER EIGHT

8.0 CONCLUSION AND RECOMMENDATIONS

From the study, results have shown that open-pit coal mining and processing operations have created quite extensive environmental impacts at Maamba. Mining and waste dumping operations have also scarred the landscape of Kanzinze and Izuma basins. Assessment of dust and water samples from the mining areas also indicated that non-availability of control measures is responsible for the environmental pollution and the high values of dust samples and the parameters in the water samples.

At Maamba, studies have shown that a total of 321 hectares of land and forest at mining and waste dumping sites have been destroyed. Results have also indicated that 67% of the land disturbance is at Kanzinze and Izuma basins. The two open pits at Maamba have degraded a total of 268 hectares of land while waste dumps cover a total area of 55 hectares have a total of 6.4 million m^3 dumped waste. In Kanzinze basin, a sum US$68,568,000 is needed to rehabilitate the area while an extra US$73,784 is required to revegetate the rehabilitate the area. Cost estimates of particulate, gaseous and other minor environmental impacts of mining were not determined since no baseline data was collected due to equipment and time constraints. However, methods to minimize their effects on the environment have been suggested. Rehabilitation is an essential part of development mineral resources in accordance with the principle of ecologically sustainable development. Rehabilitation should be part of an integrated program of effective environmental management through all phases of resource development, from exploration, to construction, operation and closure. Planning for land reshaping will result in the optimal post mining land use. Planning post mining land use should start as early as possible in the life of the mine and should incorporate pre-mining investigations including legal requirements, climatic, topographic and soil factors. Landform reshaping includes visual requirements, drainage and slope angles and length. Planning can be enhanced by the use of computer aided design in conjunction with accurate collection of data relevant to each site.

The water quality of the Kanzinze River is generally polluted as shown by the low pH values, high dissolved solids and high suspended solids. From the studies, it is also evident that the CPP is the major source of water pollution in the area and if control measures suggested are put in place, less negative impacts will be recorded. Low pH values of water in Kanzinze River results from discharge of acidulated water from the coal preparation plant. Mine wastes have also been identified as the source of water pollution and their proper management will greatly reduce pollution in the area.

Conclusion can also be drawn from the study that acid mine drainage in the area can be controlled by appropriate management strategies as follows:

(a) Increase neutralisation at source through addition of lime to effluent;

(b) Minimize oxidation rate and isolate higher risk materials from exposure;

(c) Minimise potential for transport of oxidation products from source to receiving environment; and

(d) Contain and treat acid drainage to minimize risk of significant off site impacts.

Studies have also shown that the open pit and CPP are the most affected in terms of particulate dust emissions. Sources of coal dust, within the pit, are during coal drilling with Airtracs and during coal loading and stripping operations. Within the CPP, coal screening and crushing were identified as the major sources of coal dust. Therefore, control measures suggested should be implemented to control particulate coal dust at the above mentioned areas. Conclusion can also be drawn from the studies that concentrations of coal dust decreased with increase in distance from the mine area. The further away a place is from the mine area the less coal dust is experienced.

Silica dust within the pit was highest during overburden loading and stripping operations. Within the CPP, sources of silica dust are from the screening and crushing operations. Control of silica dust in the CPP (by enclosing transfer points, use of dust collectors as well as handling of wet material) will not only improve the health of the workers but will also improve the house keeping in plant area. However, in view of the high silica and coal dust contents in mining and coal processing areas it may be desirable to enforce provisions of dust control measures suggested to minimise particulate emissions. Simultaneously, it may also be desirable to set a standard for cumulative coal and silica dust dose. Government and law enforcing officers should also carry out environmental audits not only at MCL but other mining and processing industries in the country.

Actions based on environmental regulations may avoid, limit, control or offset many of these potential impacts, but mining will, to some degree always alter landscapes and environmental resources. Regulations suggested are intended to control and manage these alterations of the landscape in an acceptable way and should be put in place and continually be updated as new technologies are developed to improve mineral extraction, reclaim mine lands and to limit environmental impacts.

The soil, water, land and air resources cannot be sacrificed to achieve the production of coal. Fortunately, with the new technology available today and the application of environmental economics, coal can be produced while protecting and even enhancing the environment and returning the land to an equal or better use.

APPENDIX

APPENDIX A

Table 1: Coordinates and elevations of selected points within Kanzinze pit

NO.	NORTHING	EASTING	ELEVATION		NO.	NORTHING	EASTING	ELEVATION
1	8079124.378	519049.751	609.1		53	8079298.507	518805.970	604.5
2	8079027.363	518905.473	617.2		54	8079475.124	518597.015	601.6
3	8079087.065	518835.821	617.1		55	8079557.214	518482.587	602.1
4	8079136.816	518845.771	616.2		56	8079500.000	518562.189	599.5
5	8079328.358	518579.602	634.8		57	8079500.000	518539.801	601.6
6	8079332.090	518507.463	625.4		58	8079355.721	518710.199	599.9
7	8079345.771	518574.627	623.2		59	8079199.005	518900.498	604.6
8	8079278.607	518669.154	623.9		60	8079161.692	518955.224	608.9
9	8079139.303	518850.746	612.6		61	8079191.542	519007.463	567.5
10	8079082.090	518840.796	615.4		62	8079253.731	519027.363	566.3
11	8079034.826	518890.547	615.2		63	8079360.697	519134.328	567.6
12	8079131.841	519044.776	603.6		64	8079241.294	518940.298	565.4
13	8079238.806	519134.328	605.7		65	8079457.711	518701.493	563.1
14	8079390.547	519179.104	599.9		66	8079470.149	518679.104	563.2
15	8079186.567	519044.776	600.5		67	8079599.502	518559.702	567.8
16	8079158.537	519012.438	600.6		68	8079828.358	518651.741	565.8
17	8079186.567	518900.498	615.6		69	8080181.592	518644.279	583.5
18	8079315.820	518748.756	618.8		70	8080597.015	518619.403	633.6
19	8079500.000	518519.901	618.2		71	8080549.751	518584.577	634.4
20	8079584.577	518402.985	629.4		72	8080022.388	518601.990	577.6
21	8079462.687	518415.423	629.4		73	8079689.055	518487.562	571.8
22	8079532.338	518395.522	637.8		74	8079840.796	518559.702	565.8
23	8079649.254	518228.856	629.3		75	8079815.920	518611.940	565.9
24	8079542.289	518405.473	622.3		76	8079659.204	518572.139	563.5
25	8079601.990	518388.060	622.7		77	8079671.642	518514.925	565.0
26	8079524.876	518512.438	614.8		78	8079850.746	518597.015	570.8
27	8079592.040	518427.861	614.8		79	8079800.995	518624.378	568.9
28	8079624.378	518350.746	609.6		80	8079649.254	518579.602	567.3
29	8079609.453	518323.383	623.6		81	8079664.179	518509.950	567.8
30	8079694.030	518206.468	625.9		82	8079855.721	518554.726	571.5
31	8079696.517	518161.692	633.9		83	8079975.124	518171.642	585.2
32	8079741.294	518116.915	634.6		84	8079639.303	518522.388	565.5
33	8079703.980	518082.089	636.2		85	8079664.179	518405.473	565.2
34	8079679.104	518131.841	632.3		86	8079853.234	518206.468	575.1
35	8079696.517	518079.602	626.4		87	8079870.647	518151.741	577.0
36	8079743.781	518099.503	631.0		88	8079840.796	518141.791	574.8
37	8079746.269	518121.891	626.7		89	8080000.000	518131.841	585.2
38	8079699.005	518206.468	619.6		90	8080039.801	518134.328	582.4
39	8079619.403	518323.383	612.2		91	8079771.144	518124.378	623.1
40	8079636.816	518345.771	612.2		92	8079798.507	518069.652	627.2
41	8079587.065	518442.786	604.8		93	8079669.154	517985.075	624.7
42	8079703.980	518305.970	601.9		94	8079671.642	517965.174	622.8
43	8079798.507	518169.154	609.8		95	8079781.095	518057.214	627.2
44	8079838.308	518121.891	612.7		96	8079791.045	518027.363	637.1
45	8079853.234	518129.353	574.8		97	8079701.493	517955.224	601.5
46	8079748.756	518268.657	569.1		98	8079788.557	518136.816	614.8
47	8079522.388	518567.642	566.9		99	8079825.871	518067.164	614.9
48	8079226.368	518940.298	565.4		100	8079962.687	518072.139	586.0
49	8079196.517	518962.687	567.2		101	8079835.821	518029.851	615.4
50	8079129.353	518947.761	607.4		102	8079900.498	518027.363	613.9
51	8079139.303	518942.786	608.9		103	8079917.910	518047.264	616.0
52	8079194.030	518955.224	604.2		104	8079845.771	518059.702	604.4

APPENDIX A - Table 1 cont.

105	8079674.129	517883.085	601.5		147	8080380.597	518345.771	648.8
106	8079524.876	517751.244	603.2		148	8080509.950	518333.333	644.6
107	8079542.289	51756.164	607.2		149	8080686.567	517835.821	645.7
108	8079517.413	517480.100	641.6		150	8080895.522	518500.000	658.6
109	8079504.975	517537.813	641.6		151	8081114.428	518907.960	651.6
110	8079542.289	517567.164	641.6		152	8081069.652	518905.473	536.5
111	8079512.438	517761.194	633.7		153	8080870.647	518554.726	602.5
112	8079694.030	517922.886	622.8		154	8080751.244	518393.035	616.5
113	8079676.617	517962.687	622.8		155	8080370.647	518390.547	627.3
114	8079753.731	518027.363	622.8		156	8080184.080	518126.866	625.9
115	8079455.224	517485.075	640.2		157	8080370.647	518000.000	591.5
116	8079398.010	517512.438	639.2		158	8080196.517	518291.045	633.8
117	8079440.299	517574.626	638.6		159	8080067.164	518251.244	634.2
118	8079450.249	517716.417	637.4		160	8080032.338	518452.736	634.0
119	8079475.124	517791.045	633.8		161	8080226.368	518467.662	631.7
120	8079537.313	517853.234	628.9		162	8080206.468	518284.577	601.9
121	8079621.891	517950.249	628.1		163	8080009.950	518532.338	569.0
122	8079544.776	517902.985	639.1		164	8079955.224	518273.632	577.4
123	8079455.224	517753.731	652.9		165	8080082.090	518194.030	582.4
124	8079373.134	517664.179	650.2		166	8080920.398	518900.497	630.6
125	8079427.861	517699.005	650.2		167	8080522.388	518815.920	638.9
126	8079452.736	517741.294	650.2		168	8080614.428	518679.105	599.1
127	8079432.836	517666.667	651.1		169	8080532.338	518649.254	582.1
128	8079641.791	517656.716	664.5		170	8080462.687	518880.597	589.1
129	8079800.995	517793.532	658.3		171	8080800.995	518967.662	612.8
130	8079868.156	517691.542	658.4		172	8081047.264	519022.388	637.4
131	8079718.905	517534.826	661.7		173	8080917.910	519000.000	633.8
132	8079619.403	517559.702	607.2		174	8080778.607	519106.965	634.2
133	8079619.403	517721.393	603.2		175	8080363.184	519263.682	633.4
134	8079746.269	517833.333	604.6		176	8080194.030	519363.184	632.0
135	8079920.398	517761.194	604.6		177	8080500.000	518820.896	625.7
136	8079905.473	517656.716	649.5		178	8080223.881	519430.348	625.7
137	8079721.393	517512.438	657.5		179	8080950.249	519129.353	625.7
138	8079940.299	517726.368	651.8		180	8080126.866	519151.741	636.1
139	8080161.692	517810.945	659.1		181	8079845.771	519074.627	640.7
140	8080236.318	518034.826	640.9		182	8079669.154	518965.174	639.6
141	8080029.851	517972.637	642.0		183	8079415.423	519049.751	626.2
142	8080181.592	518072.139	591.5		184	8079305.970	519092.040	566.3
143	8080318.408	517992.537	591.5		185	8079373.134	518982.587	567.3
144	8080562.189	517721.393	645.8		186	8079592.040	518858.209	564.6
145	8080450.249	518047.264	648.0		187	8079870.647	518950.249	574.4
146	8080293.532	518094.527	656.5		188	8080119.403	519079.602	591.1

APPENDIX A

Table 2: Coordinates and elevations of selected points within Izuma pit.

No.	NORTHING	EASTING	ELEVATION		No.	NORTHING	EASTING	ELEVATION
1	8082064.677	520577.114	621.6		53	8082455.224	520845.771	615.0
2	8082029.851	520587.065	627.8		54	8081945.274	520910.448	622.8
3	8081992.537	520621.891	619.3		55	8082529.851	520970.149	623.4
4	8081875.622	520766.169	619.6		56	8082527.363	520915.423	624.6
5	8081793.532	520858.209	609.6		57	8082512.438	520875.622	628.1
6	8081758.706	520858.209	610.5		58	8082532.338	520912.935	622.3
7	8081753.731	520753.731	610.5		59	8082527.363	520992.537	616.5
8	8081786.070	521000.000	609.8		60	8082467.662	520945.274	616.5
9	8081798.507	521039.801	609.9		61	8082338.308	520940.299	599.5
10	8081830.846	521094.527	611.2		62	8082243.781	520917.910	586.5
11	8081828.358	521000.000	607.8		63	8082216.418	520830.846	581.3
12	8081786.070	520960.199	609.9		64	8082253.731	520808.458	582.0
13	8081778.607	520905.473	610.1		65	8082218.905	520766.169	583.1
14	8081878.109	520766.169	611.4		66	8082109.453	520776.119	576.3
15	8081917.910	520728.856	615.1		67	8081975.124	520838.308	564.1
16	8081980.100	520706.468	618.8		68	8081863.184	520930.348	567.4
17	8082054.726	520606.965	620.7		69	8081927.861	521067.164	577.5
18	8082092.040	520604.478	603.1		70	8081992.537	521355.721	599.7
19	8081982.587	520716.418	601.3		71	8081947.761	521425.373	605.6
20	8081950.249	520708.955	601.8		72	8081987.562	521440.299	605.6
21	8081885.572	520781.095	602.2		73	8082000.000	521313.433	591.5
22	8081830.846	520855.721	599.0		74	8081972.637	521223.881	593.0
23	8081788.557	520910.448	602.4		75	8081965.174	521208.955	592.5
24	8081796.020	520942.786	603.6		76	8081947.761	521064.677	571.7
25	8082089.552	520654.229	603.7		77	8081875.622	520927.861	567.4
26	8082007.463	520756.219	600.7		78	8081970.149	521191.542	592.5
27	8081990.050	520726.368	601.3		79	8081990.050	521089.552	599.8
28	8081927.861	520798.508	602.6		80	8082027.636	521114.428	599.8
29	8081820.896	520940.298	603.3		81	8082052.239	521104.478	603.7
30	8081838.308	521000.000	611.1		82	8082009.950	521084.577	604.0
31	8081870.647	521104.478	612.1		83	8082089.552	521014.925	609.3
32	8081905.473	521233.831	618.3		84	8082171.642	520940.298	616.2
33	8081930.348	521355.721	613.6		85	8082213.930	521022.388	616.8
34	8081945.274	521358.209	615.7		86	8082278.607	521037.313	615.9
35	8081927.861	521218.906	620.0		87	8082276.119	520980.099	587.0
36	8081890.547	521059.702	586.0		88	8082231.343	520945.274	587.0
37	8081848.259	520942.786	568.4		89	8082156.716	520912.935	572.6
38	8081835.821	520932.835	567.9		90	8082032.338	520975.124	574.1
39	8081910.448	520833.333	570.7		91	8081962.687	521029.851	569.4
40	8081947.761	520788.557	568.7		92	8082037.313	521313.433	607.2
41	8081972.637	520808.458	568.3		93	8082054.726	521238.806	610.7
42	8082042.289	520726.368	579.4		94	8082166.667	521196.517	618.9
43	8082087.065	520674.129	589.0		95	8082256.219	521233.831	624.6
44	8082189.055	520731.343	578.7		96	8082246.269	521328.358	617.9
45	8082298.507	520756.219	578.7		97	8082022.388	521300.995	602.3
46	8082395.522	520788.557	627.9		98	8082037.313	521236.318	603.0
47	8082320.896	520845.771	630.3		99	8082121.891	521191.542	609.1
48	8082298.507	520883.085	628.3		100	8082258.706	521223.881	634.5
49	8082437.811	520898.010	627.8		101	8082268.657	521161.692	632.6
50	8082425.373	520835.821	629.7		102	8082370.647	521077.114	639.2
51	8082412.935	520793.532	627.2		103	8082507.463	521159.204	642.6
52	8082427.861	520833.333	625.4		104	8082375.622	521273.632	639.5

Appendix A: Table 2: Cont…

No.	NORTHING	EASTING	ELEVATION		No.	NORTHING	EASTING	ELEVATION
105	8082365.672	521208.955	641.1		114	8082059.701	521390.547	615.4
106	8082390.547	521166.667	636.5		115	8082146.766	521291.045	620.0
107	8082343.284	521213.930	631.9		116	8082179.104	521300.995	621.4
108	8082333.333	521313.433	617.3		117	8082146.766	521427.861	611.4
109	8082293.532	521340.796	617.3		118	8082186.567	521325.871	619.3
110	8082320.896	521221.393	631.3		119	8082194.030	521286.070	620.1
111	8082323.383	521062.189	573.7		120	8082134.328	521278.607	612.5
112	8082213.930	521159.204	573.7		121	8082072.139	521368.159	616.3
113	8082022.388	521400.498	613.0		122	8082032.338	521378.110	606.5

APPENDIX B

Table 1: Coordinates of the top traverse on Izuma dump

No.	NORTHING	EASTING	ELEVATION
1	8082233.327	5201457.695	624.424
2	8082245.682	5201440.546	622.818
3	8082301.594	5201446.422	624.965
4	8082416.629	5201412.448	635.301
5	8082516.465	5201364.243	642.589
6	8082575.592	5201343.557	645.762
7	8082601.390	5201331.478	642.881
8	8082601.543	5201383.265	645.461
9	8082555.352	5201413.492	644.696
10	8082537.635	5201458.361	643.717
11	8082518.198	5201514.936	642.757
12	8082481.169	5201562.782	638.449
13	8082417.829	5201562.782	638.499
14	8082860.135	5201548.225	635.378
15	8082298.018	5201578.807	635.737
16	8082232.373	5201604.060	632.939
17	8082197.674	5201556.685	632.051
18	8082251.469	5201553.732	634.125
19	8082302.546	5201513.401	631.622
20	8082305.943	5201481.160	623.991
21	8082465.174	521375.622	644.100
22	8082582.090	521320.896	645.100
23	8082679.104	521243.781	652.600
24	8082711.443	521223.881	656.800
25	8082723.881	521251.244	654.700
26	8082691.542	521286.070	651.300
27	8082718.905	521310.945	640.900
28	80821761.194	521281.094	639.200
29	8082747.756	521189.055	626.900
30	8082781.095	521213.930	629.900
31	8082803.483	521288.557	639.200
32	8082611.940	521380.597	647.100
33	8082557.214	521412.935	646.700
34	8082534.826	521470.149	647.100

Table 2: Coordinates of the bottom traverse on Izuma dump

No.	NORTHING	EASTING	ELEVATION
1	8082144.279	521537.801	608.500
2	8082146.766	521490.050	610.500
3	8082286.070	521432.836	615.600
4	8082592.040	521286.070	622.400
5	8082651.741	521144.279	610.200
6	8082718.905	521106.965	609.200
7	8082776.119	521129.353	610.800
8	8082803.483	521228.856	625.500
9	8082818.408	521291.045	628.700
10	8082674.129	521358.209	634.000
11	8082574.627	521440.298	625.600
12	8082522.388	521544.776	631.200
13	8082410.448	521572.139	633.900
14	8082308.458	521580.099	627.900
15	8082211.443	521626.866	622.500

APPENDIX C

Table 1: Coordinates of the bottom traverse on Kanzinze dump 1

No.	NORTHING	EASTING	ELEVATION
1	8080855.721	519472.637	640.760
2	8080823.383	519373.134	640.760
3	8080925.373	519218.906	640.620
4	8081000.000	519151.741	644.030
5	8081062.189	519124.378	642.590
6	8081114.428	519156.716	641.150
7	8081129.353	519199.005	625.350
8	8081131.841	519445.274	625.350
9	8081000.000	519467.662	610.830

Table 2: Coordinates of the top traverse on Kanzinze dump 1

No.	NORTHING	EASTING	ELEVATION
1	8081083.594	519267.707	648.307
2	8081089.369	519331.469	651.410
3	8081070.799	519403.078	654.644
4	8080955.387	519437.987	658.533
5	8080900.250	519434.045	659.360
6	8080836.583	519424.202	652.606
7	8080997.979	519438.223	657.418
8	8080874.683	519347.193	653.791
9	8080959.134	519195.772	651.513
10	8081030.500	519147.716	650.000

Table 3: Coordinates of the bottom traverse on Kanzinze dump 2

No.	NORTHING	EASTING	ELEVATION
1	8080216.42	519562.189	610.960
2	8080318.41	519514.925	628.190
3	8080490.050	519393.035	632.390
4	8080631.84	519305.970	634.560
5	8080723.88	519286.070	640.760
6	8080758.706	519345.771	640.760
7	8080728.86	519504.975	610.830
8	8080599.5	519639.304	610.830
9	8080450.25	519666.667	610.830
10	8080263.682	519684.080	610.960
11	8080176.62	519616.915	610.960

Table 4: Coordinates of the top traverse on Kanzinze dump 2

No.	NORTHING	EASTING	ELEVATION
1	8080691.343	519361.586	657.644
2	8080670.945	519340.072	658.996
3	8080535.871	519392.802	654.559
4	8080393.215	519531.280	654.433
5	8080349.709	519582.530	655.594
6	8080354.822	519564.502	655.367
7	8080696.278	519382.420	657.602
8	8080656.458	519439.302	656.397
9	8080633.831	519472.837	655.001
10	8080370.583	519616.397	655.391

Table 5: Coordinates of the bottom traverse on Kanzinze dump 3

No.	NORTHING	EASTING	ELEVATION
1	8079818.408	519442.786	610.440
2	8080000.000	519546.020	616.090
3	8080171.642	519644.279	610.960
4	8080191.542	519666.667	610.960
5	8080256.22	519701.493	610.960
6	8080301.244	519766.169	610.090
7	8080281.095	519803.483	610.090
8	8080054.726	519738.806	610.090
9	8079900.498	519716.418	610.830
10	8079848.259	519671.642	610.830
11	8079773.632	519527.363	610.830

Table 6: Coordinates of the top traverse on Kanzinze dump 3

No.	NORTHING	EASTING	ELEVATION
1	8079848.259	519582.090	640.850
2	8079930.348	519654.229	639.200
3	8080042.289	519686.567	634.710
4	8080144.279	519736.318	638.350
5	8080216.418	519743.781	638.380
6	8080136.816	519684.080	624.810
7	8080000.000	519641.791	623.150
8	8080194.030	519664.179	610.960
9	8080171.642	519669.154	610.960
10	8080007.463	519621.891	623.150
11	8079917.910	519559.702	629.010
12	8079850.746	519534.826	640.850

APPENDIX D

Table 1: Calculations of surface area of Kanzinze pit

No.	NORTHING	EASTING	ELEVATION	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8079121.891	519047.264	609.813	8079121.891	518069.652	519440.298	-1370.65	-5536808052
2	8079798.507	518069.652	627.200	8079798.507	517761.194	519047.264	-1286.07	-5195593233
3	8079512.438	517761.194	633.680	8079512.438	517567.164	518069.652	-502.488	-2029929023
4	8079542.289	517567.164	641.580	8079542.289	517400.498	517761.194	-360.696	-1457129293
5	8079606.965	517400.498	661.500	8079606.965	518074.627	517567.164	507.463	2050050795
6	8080470.149	518074.627	648.000	8080470.149	518437.811	517400.498	1037.313	4190988366
7	8080925.373	518437.811	659.650	8080925.373	518572.139	518074.627	497.512	2010178672
8	8081019.900	518572.139	661.920	8081019.900	518977.612	518437.811	539.801	2181071312
9	8081106.905	518977.612	638.230	8081106.905	519106.965	518572.139	534.826	2160993041
10	8080952.736	519106.965	644.600	8080952.736	519380.597	518977.612	402.985	1628251369
11	8080477.612	519380.597	632.390	8080477.612	519440.298	519106.965	333.333	1346744922
12	8079927.861	519440.298	610.440	8079927.861	519047.264	519380.597	-333.333	-1346653297
TOTAL SURFACE AREA (m2)								**2165578.737**

Table 2: Calculations of surface area of Izuma pit

No.	NORTHING	EASTING	ELEVATION	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8082014.925	520579.602	628.200	8082014.925	520594.527	520870.647	-276.12	-1115802980.545
2	8082176.617	520594.527	638.300	8082176.617	520636.816	520579.602	57.214	231206826.482
3	8082286.070	520636.816	627.900	8082286.070	520855.721	520594.527	261.194	1055522313.884
4	8082500.000	520855.721	623.160	8082500.000	520977.612	520636.816	340.796	1377241835.000
5	8082604.478	520977.612	620.600	8082604.478	521236.318	520855.721	380.597	1538107508.257
6	8082562.189	521236.318	621.100	8082562.189	521353.234	520977.612	375.622	1517994087.278
7	8082350.746	521353.234	616.000	8082350.746	521390.547	521236.318	154.229	623266436.602
8	8082199.005	521390.547	614.300	8082199.005	521472.637	521353.234	119.403	482519403.897
9	8082094.527	521472.637	616.710	8082094.527	521425.373	521390.547	34.826	140733511.999
10	8081947.761	521425.373	616.600	8081947.761	520870.647	521472.637	-601.99	-2432625866.322
11	8081746.269	520870.647	614.900	8081746.269	520579.602	521425.373	-845.771	-3417653311.839
TOTAL SURFACE AREA (m2)								**509764.692**

APPENDIX E

Table 1: Calculations of surface area of Izuma dump

No.	NORTHING	EASTING	ELEVATION	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8082144.279	521537.801	608.500	8082144.279	521490.050	521626.866	-136.816	-552883325.838
2	8082146.766	521490.050	610.500	8082146.766	521432.836	521537.801	-104.965	-424171267.646
3	8082286.070	521432.836	615.600	8082286.070	521286.070	521490.050	-203.980	-824312356.279
4	8082592.040	521286.070	622.400	8082592.040	521144.279	521432.836	-288.557	-1166144255.643
5	8082651.741	521144.279	610.200	8082651.741	521106.965	521286.070	-179.105	-723821670.036
6	8082718.905	521106.965	609.200	8082718.905	521129.353	521144.279	-14.926	-60321331.188
7	8082776.119	521129.353	610.800	8082776.119	521228.856	521106.965	121.891	492608831.961
8	8082803.483	521228.856	625.500	8082803.483	521291.045	521129.353	161.692	653462330.387
9	8082818.408	521291.045	628.700	8082818.408	521358.209	521228.856	129.353	522768404.765
10	8082674.129	521358.209	634.000	8082674.129	521440.298	521291.045	149.253	603181680.888
11	8082574.627	521440.298	625.600	8082574.627	521544.776	521358.209	186.567	753970850.218
12	8082522.388	521544.776	631.200	8082522.388	521572.139	521440.298	131.841	532803917.078
13	8082410.448	521572.139	633.900	8082410.448	521580.099	521544.776	35.323	142747492.127
14	8082308.458	521580.099	627.900	8082308.458	521626.866	521572.139	54.727	221160247.490
15	8082211.443	521626.866	622.500	8082211.443	521537.801	521580.099	-42.298	-170930689.808
TOTAL SURFACE AREA (m2)								**59429.237**

APPENDIX F

Table 1: Calculations of surface area of Kanzinze dump 1

No.	NORTHING	EASTING	ELEVATION	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8080855.721	519472.637	640.760	8080855.721	519373.134	519467.662	-94.528	-381933564.8
2	8080823.383	519373.134	640.760	8080823.383	519218.906	519472.637	-253.731	-1025177699
3	8080925.373	519218.906	640.620	8080925.373	519151.741	519373.134	-221.393	-894530155.6
4	8081000.000	519151.741	644.030	8081000.000	519124.378	519218.906	-94.528	-381940384
5	8081062.189	519124.378	642.590	8081062.189	519156.716	519151.741	4.975	20101642.2
6	8081114.428	519156.716	641.150	8081114.428	519199.005	519124.378	74.627	301534663.2
7	8081129.353	519199.005	625.350	8081129.353	519445.274	519156.716	288.558	1165937262
8	8081131.841	519445.274	625.350	8081131.841	519467.662	519199.005	268.657	1085526319
9	8081000.000	519467.662	610.830	8081000.000	519472.637	519445.274	27.363	110560201.5
TOTAL SURFACE AREA (m2)								**78284.08395**

Table 2: Calculations of surface area of Kanzinze dump 2

No.	NORTHING	EASTING	ELEVATION	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8080216.418	519562.189	610.960	8080216.418	519514.925	519616.915	-101.99	-412050636.2
2	8080318.408	519514.925	628.190	8080318.408	519393.035	519562.189	-169.154	-683409090
3	8080490.050	519393.035	632.390	8080490.050	519305.970	519514.925	-208.955	-844229399.2
4	8080631.841	519305.970	634.560	8080631.841	519286.070	519393.035	-106.965	-432172392.4
5	8080723.881	519286.070	640.760	8080723.881	519345.771	519305.970	39.801	160810445.6
6	8080758.706	519345.771	640.760	8080758.706	519504.975	519286.070	218.905	884459242.3
7	8080728.856	519504.975	610.830	8080728.856	519639.304	519345.771	293.533	1185980292
8	8080599.502	519639.304	610.830	8080599.502	519666.667	519504.975	161.692	653284147.3
9	8080450.249	519666.667	610.830	8080450.249	519684.080	519639.304	44.776	180905120.2
10	8080263.682	519684.080	610.960	8080263.682	519616.915	519666.667	-49.752	-201004639.4
11	8080176.617	519616.915	610.960	8080176.617	519562.189	519684.080	-121.891	-492450404
TOTAL SURFACE AREA (m2)								**122685.7904**

Table 3: Calculations of surface area of Kanzinze dump 3

No.	NORTHING	EASTING	ELEVATION	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8079818.408	519442.786	610.440	8079818.408	519546.020	519527.363	18.657	75372586.019
2	8080000.000	519546.020	616.090	8080000.000	519644.279	519442.786	201.493	814031720.000
3	8080171.642	519644.279	610.960	8080171.642	519666.667	519546.020	120.647	487424234.046
4	8080191.542	519666.667	610.960	8080191.542	519701.493	519644.279	57.214	231150039.442
5	8080256.219	519701.493	610.960	8080256.219	519766.169	519666.667	99.502	402000827.151
6	8080301.244	519766.169	610.090	8080301.244	519803.483	519701.493	101.990	412054961.938
7	8080281.095	519803.483	610.090	8080281.095	519738.806	519766.169	-27.363	-110550365.801
8	8080054.726	519738.806	610.090	8080054.726	519716.418	519803.483	-87.065	-351744982.360
9	8079900.498	519716.418	610.830	8079900.498	519671.642	519738.806	-67.164	-271339218.524
10	8079848.259	519671.642	610.830	8079848.259	519527.363	519716.418	-189.055	-763767856.303
11	8079773.632	519527.363	610.830	8079773.632	519442.786	519671.642	-228.856	-924552337.162
TOTAL SURFACE AREA (m2)								**79608.447**

APPENDIX G

Table 1: Calculations of surface area of Slurry pond 1

No.	NORTHING	EASTING	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8081203.980	519547.264	8081203.980	519569.652	519597.015	-27.363	-110562992.252
2	8081422.886	519569.652	8081422.886	519629.353	519547.264	82.089	331697961.644
3	8081415.423	519629.353	8081415.423	519597.015	519569.652	27.363	110565885.110
4	8081194.403	519597.015	8081194.403	519547.264	519629.353	-82.089	-331688583.674
TOTAL SURFACE AREA (m2)							**12270.828**

Table 2: Calculations of surface area of slurry pond 2

No.	NORTHING	EASTING	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8081487.562	519422.886	8081487.562	519437.81	519457.711	-19.900	-80410801.242
2	8081522.388	519437.81	8081522.388	519554.73	519422.886	131.840	532733955.817
3	8081579.602	519554.73	8081579.602	519559.7	519437.81	121.890	492531868.844
4	8081671.642	519559.7	8081671.642	519547.26	519554.73	-7.462	-30152716.896
5	8081699.005	519547.26	8081699.005	519574.63	519559.7	14.926	60313719.674
6	8081696.517	519574.63	8081696.517	519604.48	519547.26	57.214	231193092.262
7	8081611.940	519604.48	8081611.940	519639.303	519574.63	64.676	261343166.916
8	8081574.627	519639.303	8081574.627	519579.602	519604.48	-24.876	-100518625.211
9	8081467.662	519579.602	8081467.662	519679.105	519639.303	39.802	160829287.941
10	8081407.960	519679.105	8081407.960	519649.254	519579.602	69.652	281443113.615
11	8081407.960	519649.254	8081407.960	519559.702	519679.105	-119.403	-482472177.324
12	8081447.761	519559.702	8081447.761	519512.438	519649.254	-136.816	-552835678.434
13	8081440.299	519512.438	8081440.299	519457.711	519559.702	-101.991	-412117088.768
14	8081412.935	519457.711	8081412.935	519422.886	519512.438	-89.552	-361853345.578
TOTAL SURFACE AREA (m2)							**27771.617**

Table 3: Calculations of surface area of slurry pond 3

No.	NORTHING	EASTING	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8081676.617	519261.19	8081676.617	519368.16	519199.01	169.154	683523963.236
2	8081636.816	519368.16	8081636.816	519373.13	519261.19	111.940	452329212.592
3	8081542.289	519373.13	8081542.289	519401.74	519368.16	33.582	135697176.575
4	8081487.562	519401.74	8081487.562	519335.82	519373.13	-37.313	-150772272.701
5	8081452.736	519335.82	8081452.736	519305.970	519401.74	-95.771	-386984404.990
6	8081500.000	519305.970	8081500.000	519199.01	519335.82	-136.816	-552839252.000
7	8081549.751	519199.01	8081549.751	519261.19	519305.970	-44.776	-180929735.825
TOTAL SURFACE AREA (m2)							**24686.887**

APPENDIX H

Table 1: Calculations of surface area of Slurry dump area 1

No.	NORTHING	EASTING	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8081144.279	519417.910	8081144.279	519213.930	519417.910	-203.980	-824195905.015
2	8081144.279	519213.930	8081144.279	519139.304	519417.910	-278.606	-1125727641.497
3	8081156.716	519139.304	8081156.716	519144.279	519213.930	-69.651	-281430323.213
4	8081184.080	519144.279	8081184.080	519174.129	519139.304	34.825	140713617.793
5	8081199.005	519174.129	8081199.005	519417.910	519144.279	273.631	1105633282.469
6	8081164.179	519417.910	8081164.179	519417.910	519174.129	243.781	985017142.360
TOTAL SURFACE AREA (m2)							**10172.896**

Table 2: Calculations of surface area of Slurry dump area 2

No.	NORTHING	EASTING	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8081313.433	518838.308	8081313.433	518845.771	519023.632	-177.861	-718675244.253
2	8081330.846	518845.771	8081330.846	518890.547	518838.308	52.239	211080321.032
3	8081340.796	518890.547	8081340.796	518912.935	518845.771	67.164	271387586.611
4	8081358.209	518912.935	8081358.209	518960.199	518890.547	69.652	281441380.987
5	8081355.721	518960.199	8081355.721	519032.338	518912.935	119.403	482469058.577
6	8081313.433	519032.338	8081313.433	519023.632	518960.199	63.433	256310977.498
7	8081263.682	519023.632	8081263.682	518838.308	519032.338	-194.03	-784003796.109
TOTAL SURFACE AREA (m2)							**10284.342**

APPENDIX I

Table 1: Calculations of surface area of raw coal stockpile area 1

No.	NORTHING	EASTING	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8080733.831	519601.990	8080733.831	519592.040	519664.179	-72.139	-291468028.917
2	8080763.682	519592.040	8080763.682	519599.503	519601.990	-2.487	-10048429.638
3	8080828.358	519599.503	8080828.358	519554.726	519592.040	-37.314	-150764014.675
4	8081114.428	519554.726	8081114.428	519786.070	519599.503	186.567	753834637.744
5	8081154.229	519786.070	8081154.229	519835.821	519554.726	281.095	1135786024.000
6	8080868.159	519835.821	8080868.159	519863.184	519786.070	77.114	311574033.607
7	8080810.945	519863.184	8080810.945	519865.672	519835.821	29.851	120610143.760
8	8080781.095	519865.672	8080781.095	519843.284	519863.184	-19.900	-80403771.895
9	8080746.269	519843.284	8080746.269	519664.179	519865.672	-201.493	-814106903.990
10	8080718.905	519664.179	8080718.905	519601.990	519843.284	-241.294	-974914493.732
TOTAL SURFACE AREA (m2)							**99196.263**

Table 2: Calculations of surface area of raw coal stockpile area 2

No.	NORTHING	EASTING	Ni	Ei+1	Ei-1	(Ei+1 - Ei-1)	0.5*Ni(Ei+1 - Ei-1)
1	8081166.667	519696.517	8081166.667	519756.219	519805.970	-49.751	-201023061.425
2	8081288.557	519756.219	8081288.557	519858.209	519696.517	161.692	653339854.679
3	8081231.343	519858.209	8081231.343	519805.970	519756.219	49.751	201024670.273
4	8081181.592	519805.970	8081181.592	519696.517	519858.209	-161.692	-653331206.987
TOTAL SURFACE AREA (m2)							**10256.540**

APPENDIX J

Report 1: Volume computations of Izuma Pit

UPPER SURFACE

Level Surface defined by Z = 606.021

LOWER SURFACE

Grid File:	A:/IZUMA PIT.GRD
Rows:	0 to 32766
Cols:	0 to 32766
Grid size as read:	45 cols by 50 rows
Delta X:	17.7273
Delta Y:	17.6122
X-Range:	8.08175E+006 to 8.08253E+006
Y-Range:	520577 to 521440
Z-Range:	566.317 to 642.851

VOLUMES

Approximated Volume by	
Trapezoidal Rule:	-1.77381E+006
Simpson's Rule:	-1.77566E+006
Simpson's 3/8 Rule:	-1.77474E+006

CUT & FILL VOLUMES

Positive Volume [Cuts]:	4.03301E+006
Negative Volume [Fills]:	5.80621E+006
Cuts minus Fills:	-1.77321E+006

Report 2: Volume computations of Kanzinze Pit

UPPER SURFACE

Level Surface defined by Z = 612.144

LOWER SURFACE

Grid File:	A:/KANZINZE PIT.GRD
Rows:	0 to 32766
Cols:	0 to 32766
Grid size as read:	47 cols by 50 rows
Delta X:	42.3913
Delta Y:	42.6531
X-Range:	517480 to 519430
Y-Range:	8.07903E+006 to 8.08112E+006
Z-Range:	557.024 to 663.962

VOLUMES

Approximated Volume by	
Trapezoidal Rule:	-5.50134E+007
Simpson's Rule:	-5.50045E+007
Simpson's 3/8 Rule:	-5.48819E+007

CUT & FILL VOLUMES

Positive Volume [Cuts]:	2.57275E+007
Negative Volume [Fills]:	8.07389E+007
Cuts minus Fills:	-5.50115E+007

Report 3: Volume computations of Izuma dump.

UPPER SURFACE

Grid File:	A:/IZUMA DUMP.GRD
Rows:	0 to 32766
Cols:	0 to 32766
Grid size as read:	50 cols by 36 rows
Delta X:	14.6939
Delta Y:	14.8571
X-Range:	8.08214E+006 to 8.08286E+006
Y-Range:	521107 to 521627
Z-Range:	610.149 to 656.24

LOWER SURFACE

Level Surface defined by Z = 621.1

VOLUMES

Approximated Volume by	
Trapezoidal Rule:	2.34887E+006
Simpson's Rule:	2.34845E+006
Simpson's 3/8 Rule:	2.34468E+006

CUT & FILL VOLUMES

Positive Volume [Cuts]:	2.4844E+006
Negative Volume [Fills]:	135531
Cuts minus Fills:	2.34887E+006

Report 4: Volume computations of Kanzinze dump 1

UPPER SURFACE

Grid File:	A:/KNE1 DUMP.GRD
Rows:	0 to 32766
Cols:	0 to 32766
Grid size as read:	35 cols by 50 rows
Delta X:	9.11765
Delta Y:	7.12245
X-Range:	8.08082E+006 to 8.08113E+006
Y-Range:	519124 to 519473
Z-Range:	612.034 to 659.055

LOWER SURFACE

Level Surface defined by Z = 634.604

VOLUMES

Approximated Volume by

Trapezoidal Rule:	964117
Simpson's Rule:	963652
Simpson's 3/8 Rule:	965642

CUT & FILL VOLUMES

Positive Volume [Cuts]:	1.01253E+006
Negative Volume [Fills]:	48414
Cuts minus Fills:	964117

Report 5: Volume computations of Kanzinze Dump 2

UPPER SURFACE

Grid File:	A:/KNE 2 DUMP.GRD
Rows:	0 to 32766
Cols:	0 to 32766
Grid size as read:	44 cols by 50 rows
Delta X:	13.4884
Delta Y:	8.12245
X-Range:	8.08018E+006 to 8.08076E+006
Y-Range:	519286 to 519684
Z-Range:	610.946 to 658.802

LOWER SURFACE

Level Surface defined by Z = 622.003

VOLUMES

Approximated Volume by

Trapezoidal Rule:	2.078E+006
Simpson's Rule:	2.07811E+006
Simpson's 3/8 Rule:	2.07806E+006

CUT & FILL VOLUMES

Positive Volume [Cuts]:	2.21375E+006
Negative Volume [Fills]:	135744
Cuts minus Fills:	2.078E+006

Report 6: Volume computations of Kanzinze dump 3

UPPER SURFACE

Grid File:	A:/KNE3.GRD
Rows:	0 to 32766
Cols:	0 to 32766
Grid size as read:	44 cols by 50 rows
Delta X:	12.3256
Delta Y:	7.34694
X-Range:	8.07977E+006 to 8.0803E+006
Y-Range:	519443 to 519803
Z-Range:	610.097 to 640.357

LOWER SURFACE

Level Surface defined by Z = 611.106

VOLUMES

Approximated Volume by	
Trapezoidal Rule:	1.02884E+006
Simpson's Rule:	1.02843E+006
Simpson's 3/8 Rule:	1.02841E+006

CUT & FILL VOLUMES

Positive Volume [Cuts]:	1.03029E+006
Negative Volume [Fills]:	1448.73
Cuts minus Fills:	1.02884E+006

APPENDIX K

Table of Zambian standards (limits) for effluent and waste water

A. Physical

No.	Parameter	Limits for effluent and waste water
1.	Temperature (Thermometer)	$40^{o}C$ at the point of entry.
2.	Colour (Hazen units)	20 Hazen units
3.	Odour and taste	must not cause any deterioration in (Threshold Odour number) taste or odour as compared with the natural state.
4.	Turbidity (NTU sale)	15 Nephelometer turbidity
5.	Total suspended soilds	100mg/L. Must not cause formation (gravimetric method) of sludge or scum in receiving water.
6.	Settleable matter	0.5 mg/L in two hours. Must not (sedimentation in 2 hours, Imhoff funnel) cause formation of scum in receiving water.
7.	Total dissolved solids	3000mg/L. The TDS of the waste (evaporation at $105^{0}C$ and gravimetric method) water must not adversely affect water.
8.	Conductivity (electrometric method)	4300US/cm.

B. Bacteriological

No.	Parameter	Limits for effluent and waste water
9.	Total coliform/ 100ml (membrane filtration method)	25000
10.	Faecal coliforms /100ml (membrane filtration method)	5000
11.	Algae /100ml	1000 cells

C. Chemical

No.	Parameter	Limits for effluent and waste water
12.	pH (0 – 14 scale electrometric method)	6.0 - 9.0
13.	Dissolved oxygen mg O_2/l (modified Winkler method and membrane method)	5 mg/l after complete mixing oxygen content must not be less. Extreme temperature may result in lower values.

No.	Parameter	Limits for effluent and waste water
14.	Chemical oxygen demand (COD)	COD based on the limiting values for (Dichromat method) organic carbon 90 mg O_2/L average for 24 hours.
15.	Bichemical oxygen demand (BOD) (modified Winkler method and membrane electrode method)	50 mg O_2/L (mean value over 24 hours period). According to circumstances in relation to the self cleaning capacity of the waters.
16.	Nitrates (NO_3, as nitrogen) (spectrometric method and electrometric method)	The nitrate burden must be reduced as far as possible according to circumstances: watercourses 50 mg/L, lakes 20 mg/L.
17.	Nitrate (NO_3, as nitrogen/l) (spectrophotometric sulphanilamide)	2.0 mg NO2 as N/L.
18.	Organic nitrogen (N-Kjeldah)	5.0 mg/l mean* (* the % of nutrient elements for degradation of BOD should be 0.4 –1% for phosphorus, different for processes using algae)
19.	Ammonia and ammonium (total) (NH_3 as N/L) (Nesslerization method and electrometric)	The burden of ammonia salts must be reduced to 10 mg/L (depending upon temperature, pH and salinity) 0.2 mg/L.
20.	Cyanides (spectrophotometer)	0.2 mg/L
21.	Phosphorus, total (PO_4 as P/l) (colorimetric)	Treatment installation located in the catchment area of lakes: 1.0mg /L located outside catchment area: reduce the load of p as low as possible (PO_4 = 6mg/L).
22.	Sulphates (turbidimetric method)	the sulphate burden must be reduced to 1500 mg/L.
23.	Sulphite (iodometric method)	1.0 mg/L (presence of oxygen changes SO_3 to SO_4)
24	Sulphide (iodometric and electrometric Method)	0.1 mg/L (depending on temperature, pH and dissolved oxygen).
25.	Chlorides Cl/l (Silver nitrates and mercuric nitrates).	Chloride levels must be 800 mg/L
26.	Active chloride Cl_2/l (iodometric method)	0.5 mg/L.
27.	Active bromine (Br_2/l)	0.1 mg/L
28.	Fluorides F/l (electrometric and colorimetric method with distillation)	2.0 mg/L

D. Metals

No.	Parameter	Limits for effluent and waste water
29.	Aluminium compounds (atomic absorption method, AAM)	2.5 mg/L
30.	Antimony (AAM)	0.5 mg/L
31.	Arsenic compounds (AAM)	0.05 mg/L
32.	Barium compounds (water soluble concentration, AAM)	0.5 mg/L
33.	Beryllium salts and compounds (AAM)	0.5 mg/L
34.	Boron compounds (spectrophotometer method – curcumin method)	0.5 mg/L
35.	Cadmium compounds (AAM)	0.5 mg/L
36.	Chromium hexavalent, trivalent (AAM)	0.1 mg/L
37.	Cobalt compounds (AAM)	1.0 mg/L
38.	Copper compounds (AAM)	1.5 mg/L
39.	Iron compounds (AAM)	2.0 mg/L
40.	Lead compounds (AAM)	0.5 mg/L
41.	Magnesium (AAM and flame photometric method).	500 mg/L
42.	Manganese (AAM)	1.0 mg/L
43.	Mercury (AAM)	0.002 mg/L
44.	Molybdenum (AAM)	5.0 mg/L
45.	Nickel (AAM)	0.5 mg/ L
46.	Selenium (AAM)	0.02 mg/L
47.	Silver (AAM)	0.1 mg/L
48.	Thallium (AAM)	0.5 mg/L
49.	Tin compounds (AAM)	2.0 mg/L
50.	Vanadium compounds (AAM)	1.0 mg/L
51.	Zinc compounds (AAM)	10.0 mg/L

E. Organics

No.	Parameter	Limits for effluent and waste water
52.	Total hydrocarbons (chromatographic method)	10. 0 mg/L
53.	Oils (mineral and crude) (chromatographic and grvimetric method)	5.0 chromatographic
54.	Phenols, steam distillable non-steam distlled (colorimetric method)	0.2 mg/L
55.	Fats and saponifiable oils (gravimetric and chromatographic method)	0.05 mg/L
56.	Detergents (Atomic) (AAS)	20.0 mg/L
57.	Pestcides an PCB's (total) (chromatographic method)	2.0 mg/L (detergents should contain at least biodegradable compounds)
58.	Trihaloforms (chromatographic method)	0.5 mg/L

F. Radioactive

No.	Parameter	Limits for effluent and waste water
59.	Radioactive materials as specified by international atomic energy agency)	No discharge, not permitted / accepted

APPENDIX L

Table 1: Results of coal dust sampling in Izuma pit.

No.	Time	Area	Operation	No. of person	No. of samples	Coal Dust		
						A	B	Ave
1	15:50	P$H 2100	Stripping (GC)	2	2	1008	1080	1044
2	16:00	"	Stripping (DC)	2	2	882	924	903
3	16:10	"	Trucks (GC)	2	2	770	650	710
4	16:20	"	Trucks (DC)	2	2	500	504	502
5	16:30	"	Loading Trucks (GC)	2	2	1071	1140	1106
6	16:40	"	Loading Trucks (DC)	2	2	1008	950	979
7	11:00	Dragline	Dragline Stripping (GC)	2	2	850	960	905
8	11:05	"	Dragline Stripping (DC)	2	2	462	520	491
9	11:30	Air Trac	Coal Drilling	2	2	2100	2350	2225

Table 2: Results of silica dust sampling in Izuma pit.

No.	Time	Area	Operation	No. of person	No. of samples	Silica dust		
						A	B	Ave
1	15:50	P$H 2100	Stripping (GC)	2	2	320	310	315
2	16:00	"	Stripping (DC)	2	2	370	400	385
3	16:10	"	Trucks (GC)	2	2	300	250	275
4	16:20	"	Trucks (DC)	2	2	240	200	220
5	16:30	"	Loading Trucks (GC)	2	2	504	512	508
6	16:40	"	Loading Trucks (DC)	2	2	400	412	406
7	11:00	Dragline	Dragline Stripping (GC)	2	2	210	260	235
8	11:05	"	Stripping (DC)	2	2	290	350	320
9	11:30	Air Trac	Coal Drilling	2	2	250	200	225

Table 3: Results of coal dust sampling in the coal preparation plant.

No.	Time	Area	Operation	No. of person	No. of samples	Coal Dust		
						A	B	Ave
1	09:40	Grizzly	General Condition	4	2	950	880	915
2	09:50	Basement	General Condition	3	2	864	900	882
3	10:00	Screening	Screening	2	2	924	1056	990
4	10:10	Crusher	General Condition	2	2	880	900	890
5	10:20	CPP	General Condition	-	2	580	420	500

Table 4: Results of silica dust sampling in the coal preparation plant.

No.	Time	Area	Operation	No. of person	No. of samples	Silica dust		
						A	B	Ave
1	09:40	Grizzly	General Condition	4	2	400	320	360
2	09:50	Basement	General Condition	3	2	390	360	375
3	10:00	Screening	Screening	2	2	380	400	390
4	10:10	Crusher	General Condition	2	2	330	370	375
5	10:20	CPP	General Condition	-	2	270	330	300

Table 5: Results of coal dust sampling in Maamba Township

No.	Time	Area	Operation	No. of person	No. of samples	Coal Dust		
						A	B	Ave
1	14:30	Secondary School	General Condition	-	2	20	30	25
2	14:40	Hospital	General Condition	-	2	25	20	23
3	14:50	Market	General Condition	-	2	100	90	95
4	15:00	Montrev	General Condition	-	2	100	120	110
5	15:20	Golf Club	General Condition	-	2	150	180	165
6	15:30	Button Mess	General Condition	-	2	170	166	168

Table 6: Results of silica dust sampling in Maamba township

No.	Time	Area	Operation	No. of person	No. of samples	Silica dust		
						A	B	Ave
1	14:30	Secondary School	General Condition	-	2	35	30	33
2	14:40	Hospital	General Condition	-	2	25	30	28
3	14:50	Market	General Condition	-	2	250	180	215
4	15:00	Montrev	General Condition	-	2	130	120	125
5	15:20	Golf Club	General Condition	-	2	140	145	143
6	15:30	Button Mess	General Condition	-	2	150	142	146

REFERENCES

1 **Bannister A. and Raymond S., (1995)**: - Surveying, Fifth Edition, Patman Publishing Limited. pp 262 - 264

2 **Bruce A. K., (1992): -** Surface Mining, 2nd Edition. Society for Mining, Metallurgy and Exploration Inc. pp 592 – 595, 672 – 690.

3 **Burrows J., (1982):** - Environmental Engineering in South African Mines. The Mine Ventilation Society of South Africa. pp 389 – 393

4 **Crispin K., (1997): -** Environmental Aspects of Sand and Aggregate Quarrying in Tanzania. Case studies of Kilimanjaro Volcanic Rock and Coastal Sands and Limestone in Dar-es-salaam. Proceedings of an International Conference on Small-Scale Mining in African Countries – Prospects, Policy and Environmental Impacts. 29th Sept. - 1st Oct. 1997, Dar-es-Salaam, Tanzania. Publishers, Lars Landner (1997). pp 103 – 112.

5 **Cummins B. and Given I. A., (1973): -** SME, Mining Engineering Handbook, Vol. 1 The American Institute of Mining, Metallurgy and Petroleum Engineers, Inc. pp 8-16, 8-19

6 **Environmental Protection Agency, (1995): -** Rehabilitation and Revegetation. Australia Federal Environment Department Commonwealth of Australia. pp 11-14, 16 – 24.

7 **Environmental Protection Agency, (1997): -** Managing Sulphide Mine Waste and Acid Drainage. Australia Federal Environment Department, Commonwealth of Australia. pp 9, 11-13, 15, 18-65.

8 **Environmental Protection Agency, (1998):-** Landform design. Australia Federal Environment Department, Commonwealth of Australia. pp 19-28, 34-41, 46-49, 59-69.

9 **John T.B. (1993): -** Technical Report, Independent Assessment of Coal Mining Operations at Maamba Collieries Limited, Report 2324.2. Published by John T. Boyd and Company, Mining and Geological Engineers, Pittsburgh, Pennsylvania, United States of America – July 1993. pp 3-1 – 3-14, 6-1 – 6-21, 10-1 – 10-17.

10 **Matherson G. D., (1968).** The Geology of the Masuku – Kabanga area explanation of degree sheets 1726 SE quarter and 1727 NW and SW quarters. Ministry of Mines and Iindustry report of the Geological Survey No. 37. pp 35 – 37

11 **Mutakyahwa M. K., (1997): -** Environmental Impacts due to Mining of Industrial Minerals in Tanzania. Proceedings of an International Conference/Workshop on Small-Scale Mining in African Countries – Prospects, Policy and Environmental Impacts. 29th Sept. - 1st Oct. 1997, Dar-es-Salaam, Tanzania. Publishers, Lars Landner- 1997. pp 89 – 101.

11 **Sengupta M., (1995): -** Environmental Impacts of Mining-Monitoring, Restoration and Control. Lewis Publishers. pp 4 –18, 35 – 46, 103–119, 121-43.

12 **Tembo J.M. et al, (1997): -** Preliminary Research on the Ngwerere River Water Quality. Communications of the Department of Water Management, Environmental and Sanitary Engineering, Delft University of Technology. pp 4, 18-21

13 **Wills B.A., (1988): -** Mineral Production Technology. An Introduction to the Practical Aspects of Ore Treatment and Mineral Recovery, 4th Edition. Pergamon press. pp 353 – 357, 379 – 393, 425 – 429.

BIBLIOGRAPHY

1 **Dust Research and control (1964): -** The Effect of Ventilation on Air-borne Dust Concentration in Coal Mines in New South Wales. Report prepared by the Standard Committee on Dust Research and Control, Joint Coal Board, NSW, Australia.

2 **Environmental Protection Agency (1995): -** Mine Planning for Environmental Protection. Australia Federal Environment Department, Commonwealth of Australia.

3 **Environmental Protection Agency (1995): -** Environmental Impact Assessment. Australia Federal Division Department, Commonwealth of Australia.

4 **Environmental Protection Agency (1995): -** Environmental Management System. Australia Federal Environment Department, Commonwealth of Australia.

5 **Environmental Protection Agency (1995): -** Environmental Monitoring and Performance. Australia Federal Environment Department Commonwealth of Australia.

6 **Environmental Protection Agency (1995): -** Overview of Best Practice Environmental Management in Mining. Australian Federal Environmental Dept, Commonwealth of Australia.

7 **Environmental Protection Agency (1995):-** Tailings Containment. Australian Federal Environmental Department, Commonwealth of Australia.

8 **Geoff Ricks (1997): -** Environmental Considerations in Mine Closure Planning. Cardif, United Kingdom. Published by UNEP Industry and Environment, Oct. – Dec. 1997.

9 **Hough H., (1993): -** United Nations International Workshop on "Environmental Management at Mining Sites in Developing Countries. 6-10 Dec. 1993, Kitwe, Zambia.

10 **Howard L. H., (1992): -** SME Mining Engineering Handbook 2nd Edition Vol. 1 and 2.

11 **John, A.C., (1993): -** Mining and the Environmental Management at Mining Sites in Developing Countries: United Nations International Workshop 06-10 Dec 1993, Kitwe, Zambia.

12 **Krishna R. and Chanda M.W.:** - Environmental Issues of Mining, International Perspective.

13 **Lars Landner (1995): -** Environment and Mining in Eastern and Southern Africa. (Selected papers from an International Conference, 23-27th October 1995, Mwanza, Tanzania).

14 **Lars Landner (1997): -** Small-Scale Mining in African Countries - Prospects. Policy and Environmental Impacts; (Proceedings of an International Conference/Workshop 29th September - 1st October 1997) Dar-es-Salaam, Tanzania.

15 **Lima H.M. and Wathern P. (1999): -** Technical Paper; Mine Closure; a Conceptual Review. A publication of Mining Engineering Journal – November 1999.

16 **Mchaina D.M. (1985): -** Dust exposure and Pneumoconiosis in Mines. M.Min.Sc. Thesis University of Zambia.

17 **Nyambe I.A. (1993): -** Sedimentology, Tectonic Framework and Economic Potential of the Sinakumbe Group (? Ordovician to Devonian) and Karoo Supergroup (Permo-Carboniferous to Lower Jurassic) in the Mid-Zambezi Valley Basin, Southern Zambia. PhD Thesis.

18 **Priester M., Hentschel T., Benthin B. (1993): -** Tools for Mining, Techniques and Processes for Small-Scale Mining. Publishers, Deutsches Zeutrum fur Entwicklungstechnologien – GATE.

19 **Pullen A.W., (1993): -** Water Pollution and Control Technologies on Mine Sites, South African Experience.

20 **Raj K. S., (1995):** - Mine Planning and Equipment Selection `95, Proceedings of the fourth international symposium on mine planning and equipment Selection/Calgary/Canada, 31st October-3rd November 1995).

21 **Raj K. S., (1992): -** Environmental Issues and Management of waste in energy and Mineral Production, Volume 1.

22 **Robert S. (1983): -** Coal Mining Technology Theory and Practice. Published by Society for Mining Engineers of the American Institute of Mining, Metallurgy and Petroleum Engineers Inc, New York.

23 **Simukanga S. (1998): -** Training on Air Pollution and Monitoring Systems (TRAPMS) Reference Manual. CDG/SANTREN.

24 **UNEP/Tech. Report Series No. 5 (1991): -** Environmental Aspects of selected Non-Ferrous Metals. Ore Mining - a Technical guide 1991. (Cu, Ni, Pb, Zn, Au).

25 **Zou Z., (1992): -** The environmental impacts by mining and its countermeasures in China. Proceedings of the Second International Conference on Environmental Issues and Management of Waste in Energy and Mineral Production, Calgary/Alberta/ Canada 1-4 September 1992. Published by A.A. Balkema / Rotterdam / Brookfield – 1992.