Journal of Engineering and Applied Sciences 3 (9): 708-717, 2008
ISSN: 1816-949X

Assessment of Flood Control in an Open Pit Mine-Shagamu Experience

Afeni Thomas Busuyi
School of Mining Engineering, Faculty of Engineering and the Built Environment,
University of the Witwatersrand, Johannesburg, South Africa

Abstract: In the quest for economical mining operations, much emphasis should be placed on controlling flood in order to achieve reserve optimization, adequate crusher output, equipment mobility and effectiveness. This study therefore, focuses on flood control in a mine environment taking particular reference in Shagamu Limestone Quarry, Sagamu, Nigeria. The study sheds, more light into the geology of the deposit of the study area, the dewatering and drainage process, operating characteristics, performance and efficiency of pumps were discussed. The Shagamu limestone quarry daily pump record for four weeks were taken and subjected to statistical analysis. The result gotten indicated that their method of flood control is effective. However, it was noted that huge sum of money were expended on pump repairs especially, during rainy season, which is due to epileptic power supply in Nigeria. Additional recommendations were proffered to further enhance the effective and efficient control of flood on the quarry floor.

Key words: Flood control, limestone quarry, regional geology and pump

INTRODUCTION

Flooding in mine environment has in recent times been a menace that has struck most mining (especially, limestone) industries in different parts of the globe. Mining companies in the Middle Eastern, Southern American and Northern American parts of the world has made stringent efforts to mitigate the problems caused by flooding. So, many mines and quarries site has been abandoned due to the fact that there was no proper or adequate measures put in place to control the insurgence or influx of water in such mines.

A report extracted from Daily Newspaper, America on the 22nd May 2001 reported that over twenty lives and million dollars worth of properties were lost to the flooding that occurred in a mine in east China and the department of environment management suggests that the mine be abandoned to avert future occurrence.

Construction of sump, drainage, construction of dam and dewatering are methods utilized in controlling flood on the quarry site. Insufficient available water or too much water can present an operational challenge to a quarry manager. Some quarries are not only dry, but there is not adequate precipitation collected and held during the year to have a continuous water supply on hand. This can be problematic if washing of aggregates is necessary. A good, steady water supply is also needed to achieve effective airborne dust control at the crushing and processing plant and the haul roads. If water cannot be collected from a ground water inflow or the surface-water runoff, hopefully the quarry has permission to tap into a nearby stream. When all else fails, there is always the municipality's water supply, which cost money.

Shagamu quarry is equally faced with this problem of flooding like other mines in the rest of the world. Several attempts have been put in place by the management of the company to control flood on the quarry site. The limestone deposit formed within a sedimentary basin enriched with water would face such problem. Dewatering system has been designed by the management in such a way to rid the quarry of the influx of water, particularly when the case is worsened by natural precipitation during season. Dewatering of quarry is a well-established and essential part of the quarrying process (Ogunkoya, 2006).

The strategies for water management in open pit mines depend on a number of factors among, which are: the size of the operation, the geological conditions, the characteristics of the ore deposits being mined and especially the climate. For example, in arid regions, a primary consideration is the storage of rainwater for future operational use (e.g., dust control, production preparation). In contrast, in humid regions, where annual rainfall is in excess of 1.000 mm, the primary concern for water management is surface drainage control to prevent flooding in the pit or other adverse effects on mining operations (Meek, 1990).

In open pit mines, 2 kinds of water flow can concentrate in the lowest parts of the pit. One is the surface water, which rapidly flows over the ground during rainfall and the other is the groundwater, which slowly

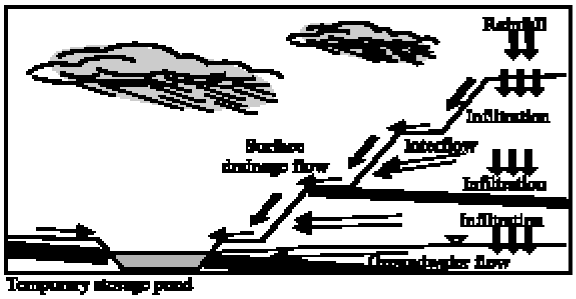

Fig. 1: Conceptual view of runoff phenomenon in open pit mine during rainfall

infiltrates vertically as well as moving towards the free face during and after rainfall. It can also take, the form of aquifers.

Runoff phenomenon during rainfall: During rainfall, surface drainage flows down to the bottom of the pit through benches, bench slopes and ramp ways and then accumulates in artificially constructed temporary storage ponds before being pumped to settling chambers outside the pit. During the wet (or rain) season, the storage capacity may be insufficient for the fast inflow from surface water, leading to flooding in the lower working area of the mine. In addition, groundwater flows will also, contribute to the rise in water level in the temporary storage pond, although this is more consistent due to the time taken for the water to pass through the bedrock geology. The steep gradient of the batters in open pit mines can significantly accelerate the velocity of surface drainage flow; valleys/rills can be created on the bench slopes due to these concentrated fast flows. Rapid gully erosion processes at the rear of the benches allows infiltration into existing discontinuities, creating enhanced pore pressures, widening of the discontinuities and eventually slope failures, which endanger the safety of the mining operations. Therefore, control of the concentrated surface drainage flows and protection of the bench slopes vulnerable to gully erosion is critical in open pit mines (Choi *et al*., 2008). Figure 1 shows the conceptual view of runoff phenomenon in open pit mine during rainfall.

Aquifers: An aquifer is a stratum of formation of permeable rock that yields groundwater in an appreciable quantity. It is a water bearing formation from, which water can be freely and economically extracted. An aquitard is an underground geologic formation that stores groundwater but poorly transmits water. An aquiclude is an underground geologic formation that stores water but hardly transmit water, but it is confined. The rock layer or

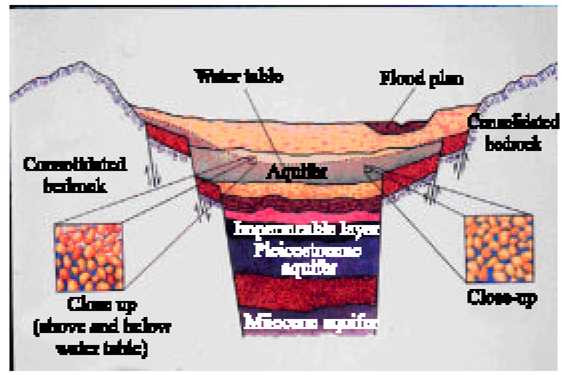

Fig. 2: Picture showing an aquifer

stratum contains many pore spaces, which when connected from a matrix allows movement of water through the rock. Sometimes aquifers can be found only few meters from the ground surface, while in other places it is necessary to bore a well hundreds of meters down in order to reach water. Water permeating such rock can be released as spring or tapped in wells when the movement of the water is towards the water table. Common aquifers are sandstone and limestone. Figure 2 shows a picture of an aquifer. At Shagamu limestone quarry, water gets into the quarry as aquifer in the Lagos-end and Mogaji-end of the quarry.

Water circulation cycle at Shagamu limestone quarry: Water circulation cycle of Shagamu limestone quarry follows a simple sequence or chain of flow. Water circulation is a vital cycle in a quarry especially in Shagamu cement factory, it shows the ways and manner in which water extracted or pumped are distributed, utilized and disposed. Water from different sources discussed above find their ways into the quarry floor most, especially to the Shagamu-end of the quarry and flows under gravity through, a horizontal drain (1 m width and 2 m length) to the main sump located at the lowest point of a mine into, which water drained in order to be pumped out. Water in the sump is pumped out with the aid of pumps to reduce the water level in the sump to an appreciable height. The water is pumped in 2 ways either to the perimeter drainage ditch or to the processing plant. The unused water from the processing plant cum domestic usage flows back to the perimeter drainage ditch that runs the entire quarry face and all flows to Odan River as shown in Fig. 3.

Drainage methods adopted at Shagamu limestone quarry: Flood control is one of the major aspects in any quarry operations. To control flood in any quarry, a dewatering system is used and it can simply be defined as a technique of removing water from the surface, subsurface and to decrease water pressure. Dewatering can be done on a temporary measure to permit construction such as basement of a building or as a permanent measure to protect a structure and allow continuous operation as in the case of Shagamu works. Shagamu quarry combines the horizontal drains, vertical (trenching) drains and well point (Sump) to achieve the said objective. A horizontal trench is constructed along the quarry faces from Shagamu-end of the quarry to the Lagos-end where the AWC (Artificial Water Collection) is created for pumping water into the perimeter drainage. Water in the drains flow under gravity to the sump and pumped by means of pump out of the quarry in order to keep the quarry floor dry.

Another method of drainage in Shagamu quarry is FDM (Fresh Drain Method). When water is present in the floor of the about to be excavated bench of the limestone and it poses inhibition to quarry operation this method is adopted in order to rid the quarry floor of the water. Drills holes are made of about 4 m depth from the toe of the bench and it follows in decreasing order along a straight line to the main drain (Sump), the first drill hole is then charged with one explosive, after denotation it creates

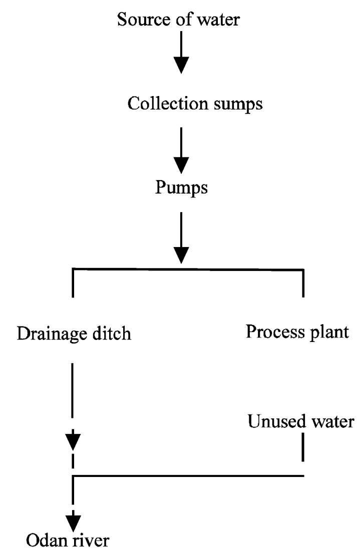

Fig 3: Flow chat of water circulation cycle at Shagamu limestone quarry

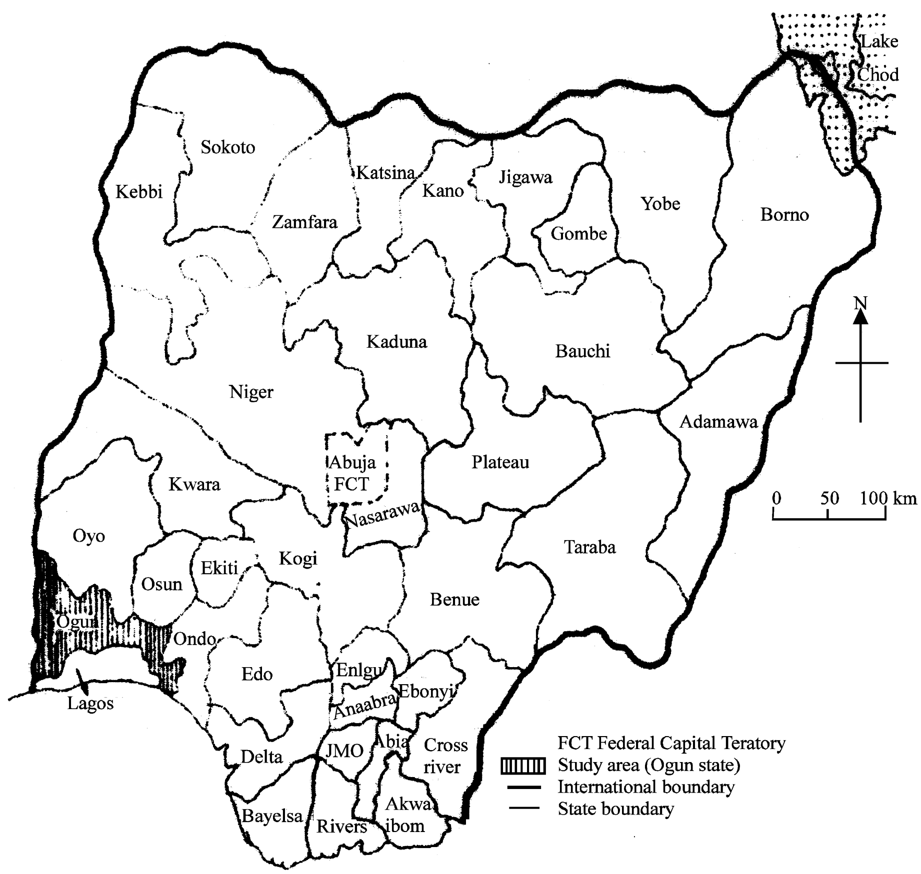

Fig. 4: Map of Nigeria showing Ogun State

a crack along the straight line and from there water finds its way or flows from there to the main drain.

Regional geology: The study area is Shagamu limestone quarry in Ogun State, which is located within the Dahomey basin in Southwestern Nigeria (Fig. 4 shows the map of Nigeria showing location of Ogun State, while Fig. 5 shows the map of Ogun State showing Shagamu, respectively). The Dahomey basin is an extensive sedimentary basin, which extends from Southeastern Ghana in the west to the western flank of the Niger Delta. It is bounded to the north by the Precambrian basement complex and the Gulf of Guinea to the south. Structurally, the basin is bounded on the west by fault and other tectonic structures associated with landward extension of fracture zone. Eastward it is bounded by the Okitipupa ridge a paleographic height and Benin hinge line a major regional fault structure (Murat, 1970), which is probably a landward extension of the chain fracture zone (Omotsola and Adegoke, 1981).

Jones and Hockey (1964) and Agagu (1985) revealed that the sedimentary succession dip gently southwest at 30°. This implies that the basin record only very little post-depositional tectonism. Therefore, the diastrophisms that result in the formation of hoist and grabens were probably pre-depositional. The coastal is mounted on a voluminous through localized sedimentary protrusion the Gulf of Guinea is the oceanic basin that comprises 10 km thick pile of cretaceous to tertiary sediment close to the syntaz of the two boundaries (Allen, 1964). This contains about 300 m of sediments and thickens offshore (Ejedawe and Coker, 1984). The sedimentary formations outcrop in an arculatebelt, roughly parallel to the ancient coastline. The continental sediments were deposited in a series of rapidly subsidizing fault-controlled depression on the basement complex. Finer detrital sandstones, siltstones and shale's of a transitional nature progressively overlie them. The younger cretaceous strata are marginal to fully marine sand shale of Mastrichitian age.

Available stratigraphic evidence indicated that rift generated basement subsidence during the lower cretaceous (Neucomian) resulted in the deposition of a very thick sequence of continental grits and pebbly sand over the entire immediate post drift arenaceous deposits were preserved in Afowo-1, Ojo-1, Ise-1 and Ise-2, boreholes drilled near the coast. During the early late cretaceous, probably santonian there was another episode of the major tectonic activity probably associated with the closure and folding of the Benue trough. The granite gneisses and associated pegmatite as well as the sediments in the Dahomey basin were tilted and block faulted forming series of hoists and gradens. Table 1 shows the stratigraphic unit of the Eastern Dahomey Basin as described by five authors.

Exposed lithology at the quarry: Six different lithologic units were exposed at the Ewekoro quarry site (Adegoke, 1977) but the Shagamu quarry is divided into three sections namely; Lagos end, Main phase and Shagamu end. The 3 section mentioned above further subdivided into benches as a result of phase changes, we have the First bench, this is immediately after the

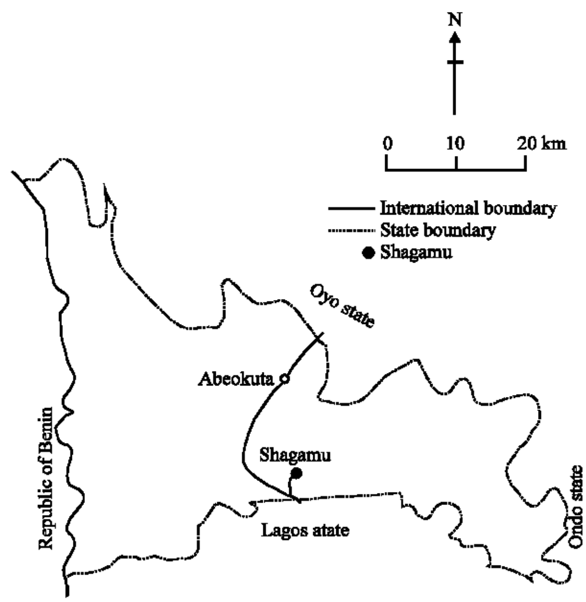

Fig. 5: Map of Ogun State showing Shagamu

Table 1: Stratigraphic unit of the Eastern Dahomey Basin

	Jones and Hockey (1964)		Omatsola and Adegoke (1981)		Agagu (1985)	
ERA	Age	Formation	Age	Formation	Age	Formation
Quaternary	Recent	Alluvium				
Tertiary	Pleistocene-Oligocene	Coastal plain	Pleistocene-Oligocene	Coastal plain	Pleistocene-Oligocene	Coastal plain
	Eocene	Ilaro	Eocene	Ilaro Oshosun	Eocene	Ilaro Oshosun
	Paleocene	Ewekoro	Paleocene	Akinbo Ewekoro	Paleocene	Akinbo Ewekoro
Late cretaceous	Late Senonian	Abeokuta	Mastrichitian Neocomian	Araromi Afowo Ise	Mastrichitian	Araromi member
					Neocomian	Afowo member
						Ise member

Precambrian crystalline basement rocks, Source: Jones and Hockey (1964), Omatsola and Adegoke (1981), Agagu (1985)

Table 2: Geologic section of strata exposed in Shagamu Quarry, Southwestern Nigeria (Source: Shagamu works)

Height (M)	Geologic section	Lithology	Height (M)	Geologic section	Lithology	Height (M)	Geologic section	Lithology
0.9		Top soil	0.8		Top soil	0.8		Top soil
2.3		Dark grey laminated shale	2.4		Dark grey laminated shale	2.4		Dark grey laminated shale
3.5		Brownish grey fossilferous limestone	3.5		Brownish grey fossilferous limestone	3.7		Brownish grey fossilferous limestone
1.8		Greyish white fossiliferous limestone	2.5		Greyish white fossiliferous limestone	2.0		Greyish white fossiliferous limestone
1.0		Dark white fossiliferous limestone	1.5		Dark white fossiliferous limestone	1.5		Dark white fossiliferous limestone

overburden, that is the shale, the Second bench, this is overlain by the first bench and the Third bench or bottom bench as it is called, which is greyish or whitish in some part, while in some part brownish-grey and consist of fossils. They are medium to dark grey in colour shown in Table 2.

Climates and vegetation: The wet and dry seasons are the 2 prevalent seasons that are of importance in the State where this research was carried out. The wet season starts in March and lasts till September with short break in August and dry season starts in November and ends in March. The average annual rainfall is about 1300 mm. There is marked variation in sunshine hours, with the month of January to April having a mean sunshine of 3.3 h, while increasing cloud cover causes decreasing sunshine hours between June and October. The annual and diurnal temperature ranges between 35°C during the dry season and 20°C during the wet season.

MATERIALS AND METHODS

The research methodology adopted for this project is known as ex-post fasto design method .i.e. the researcher has no control over variables (cannot manipulated) but can only report what has happened or seen in the course of the study. For effective monitoring of the drainage system and flood control measures put into practice at Shagamu quarry and equally to determine the efficiency of the pumps utilized for the drainage process, a month monitoring of flood control at Shagamu Limestone Quarry was carried out, splitted into 2 weeks for the month of March 2006, when we have little or no rainfall and two weeks for the month of July 2006 when we have abundant rainfall in the quarry. The readings were recorded on the pumps log sheet and data gotten were subjected statistical analysis. The results gotten were presented.

RESULTS AND DISCUSSION

Appendix 1 and 2 show the samples Shagamu limestone quarry daily pump log sheet for 1st March and 1st July 2006, respectively, out of several log sheet gotten from monitoring dewatering at Shagamu quarry pit for 2 weeks each in the month of March and July 2006. The summary of these log sheet were presented in Table 3 and 4.

Table 3: Summary of Shagamu limestone quarry's daily pump log sheet for two weeks in March 2006

Date	Number of pump used	Water level (m)	Rainfall measured (mm)	Types of faults in pumps (Electrical and Mechanical Faults)
01-03-06	4	2.06	-	Pump 4 and 5 have electrical fault
02-03-06	4	2.02	-	Pump 4 and 5 have electrical fault
03-03-06	4	2.08	-	Pump 4 and 5 have electrical fault
04-03-06	3	2.41	20.00	Pump 2, 4 and 5 have electrical fault
05-03-06	3	2.23	-	Pump 2, 4 and 5 have electrical fault
06-03-06	3	2.39	-	Pump 2, 4 and 5 have electrical fault
07-03-06	4	1.80	-	Pump 4 and 5 have electrical fault
22-03-06	4	2.02	-	Pump 4 and 5 have electrical fault
23-03-06	3	2.40	23.20	Pump 2, 4 and 5 have electrical fault
24-03-06	3	3.10	-	Pump 2, 4 and 5 have electrical fault
25-03-06	4	1.98	-	Pump 4 and 5 have electrical fault
26-03-06	4	1.98	-	Pump 4 and 5 have electrical fault
27-03-06	3	2.23	-	Pump 4,5 and 6 have electrical fault
28-03-06	3	2.26	-	Pump 4 and 5 have electrical fault.

Source: Field Survey, 2006

Table 4: Summary of Shagamu limestone quarry's daily pump log sheet for two weeks in July 2006

Date	Number of pump used	Water level (m)	Rainfall measured (mm)	Types of faults in pumps (Electrical and Mechanical Faults)
01-07-06	6	3.16	26.76	-
02-07-06	6	3.02	-	-
03-07-06	5	3.20	34.55	Pump 5 has electrical fault
04-07-06	5	3.24	30.22	Pump 5 has electrical fault
05-07-06	6	3.10	27.10	-
06-07-06	6	2.99	-	-
07-07-06	5	3.17	-	Pump 5 has electrical fault
21-07-06	5	3.24	27.60	Pump 5 has electrical fault
22-07-06	5	3.09	-	Pump 5 has electrical fault
23-07-06	6	3.15	25.00	-
24-07-06	6	3.12	29.15	-
25-07-06	6	3.03	-	-
26-07-06	6	3.02	-	-
27-07-06	5	3.22	32.00	Pump 4 has electrical fault

Source: Field Survey, 2006

Table 3 shows the summary of all the log sheets prepared for the 2 weeks in the month of March when rainfall is scanty. The water at the quarry pit resulted from the little rainfall and infiltration from water table underground. In this month only 4 pumps were put on to dewatering the pit water. The rainfall measured were 20 and 23 mm on the 4th and 23rd of March, respectively. The water level at sump ranges between 1.80 and 2.41 m, with the high level of water recorded on those 2 days that rain fell. Pump 4 and 5 were not switched on because they had electrical faults. Out of the 4 pumps that were switched on, pump 2 had electrical fault on 4-6th of March, repaired on 7th of March and later breakdown on 23rd-24th of March. From this observation, it is clear that the pump usually break down when it rains due to excess work and the common fault is electrical fault, which resulted from epileptic power supply by National Electric Power Authority (NEPA) now called Power Holding Company of Nigeria (PHCN).

Table 4 shows the summary of daily pump log sheet for two weeks in July, 2006. The rainfall measured is between 2.50 mm and 34.44 mm, while the water level of the sump is between 2.99 and 3.24 m. Also, observed from this table is that pump 5 had electrical fault for 5 days (on 3rd, 4th, 7th, 2st and 22nd, respectively), while pump 4 developed electrical fault on 27th of July. In summary the more the numbers of pumps at work, the lower the water level in the sump.

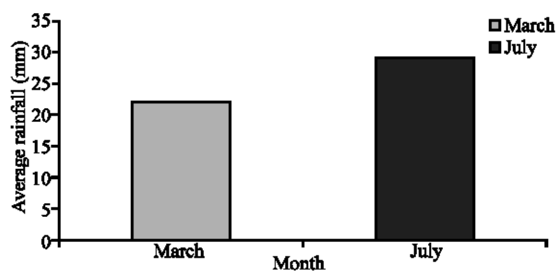

Fig. 6: Chart showing average rainfall for March and July 2006

Further critical analyses of Table 3 and 4 show the average rainfall measured for the periods of two weeks each for the month of March and July 2006 to be 21.60 mm and 29.0 mm (which is correspond to 42.69 and 57.31%), respectively, as shown in Table 5 show and graphically represented in Fig. 6.

Table 5: Showing average rainfalls measured for the month of March and July 2006

Month	Average rainfall (mm)	Percentage
March	21.60	42.69
July	29.00	57.31
Total	50.60	100.00

Table 6: The water level to pumps used in March 2006

No of pumps used	Average water level (m)	Percentage
3	2.29	53.52
4	1.99	46.50
Total	4.28	100.00

Table 7: The water level to number of pumps used in July 2006

No of pumps used	Average water level (m)	Percentage
5	3.18	50.72
6	3.09	49.28
Total	6.27	100.00

Table 6 and 7 show the water level to the number of pumps used in the month of March and July, respectively. In Table 6, when 3 pumps were used, the water level is 2.29 and 1.99 m when 4 pumps were used. The table revealed that the more the number of pumps used the lower the water level in the sump. Table 7 has similar pattern with Table 5 and 6 pumps were used as against 3 and 4 pumps used in March due to more rainfall in the month of July. The water level is 3.18 and 3.09 m. The graphical representation of Table 6 and 7 were presented in Fig. 7 and 8.

Analysis of the daily pump log sheet above revealed that by comparing the water level during the period of 2 weeks each in the month of March 2006 and July 2006 shows that the height of water in the main sump is higher in July 2006 when there is abundant rainfall than March when there is little or no rainfall. This is due to the fact that the sources of water to the quarry floor via rainfall, aquifer and filtration are increased during rainy season.

During the month of March 2006 when there is little rainfall 3 pumps to 4 pumps are utilized out of the 6 pumps expected to be in operation for pumping water out of the main sump. The reason for this is based on the fact that when these numbers of pumps are used during dry season it will reduce the cost of maintenance and also prolong the working life span of the pumps. It could be deduced that when 3 pumps are utilized the water level in the main sump is higher than when 4 pumps are utilized.

Analysis revealed that during the month of July 2006, when there is abundant rainfall the water level in the sump becomes higher, that usage of 3-4 pumps becomes ineffective for controlling the pumping of water therefore all the pumps available, which are 6 in number are utilized. Breakdown of the pumps due to mechanical fault or electrical fault causes the number of pumps used to vary between 5 and 6 pumps. The water level in the main sump when 5 pumps are used is higher than when 6 pumps are utilized.

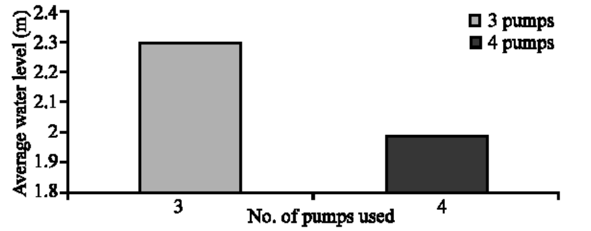

Fig. 7: Chart showing water level against number of pumps used in March

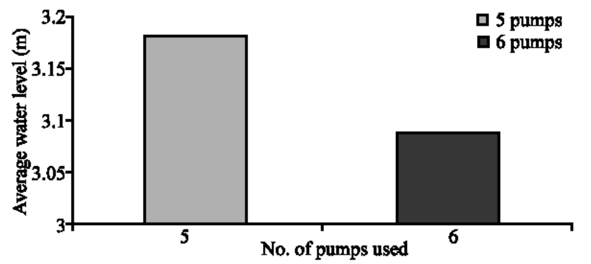

Fig. 8: Chart showing water level against number of pumps used in July

CONCLUSION

The analysis above revealed that the more the number of pumps used the lower the water level in the main sump, which is tantamount to reduction of flooding on the quarry floor. Nevertheless, the cost of purchasing spare part of worn out part must also be put into consideration when determine the type of pump to be used. The drainage and dewatering system adopted at Sagamu quarry is environmental friendly and poses less health hazard to indigenes and workers of the company but there are still some amendments that should be made to bring about more effective and efficient control of flooding in the quarry.

RECOMMENDATION

For the purpose of this study, some recommendations are proffered below, which if put into practice would enhance the control of water on the quarry floor:

- Construction of additional sumps and the enlargement of existing ones both in depth and width in order to accommodate more water flowing on the quarry floor.
- Construction of fishponds by damming the main sump because of the calcium-rich nature of water present in the sump (limestone deposit).
- Proper maintenance of the existing pumps and the purchase of new pumps to increase the rate at which water is pumped out.

- The multinational company that owns the Shagamu limestone quarry should be more forthcoming with relevant data to researchers to enable the researcher carry out researches, which may be of advantage to them.
- They should set up a water treatment plant in order to supply water to people living in and around the environs of the company as part of their community development programme.
- The company should endeavour to employ the services of Mining Engineer to man the dewatering section of the quarry.
- Nigeria government should try to revive the power sector of the economy to help reduce the burden of manufacturing companies in the country, which large chunk of their profit are being wasted on diesel oil and generator due to epileptic power supply by Power Holding Company of Nigeria (PHCN).

ACKNOWLEDGEMENT

The author wish to thank Mr. Ogunkoya (2006) for his contribution in the area of field data for this report.

Appendix 1: The west africa portland cement PLC

	No. 1			No. 2			No. 3			
	AMPS	Chek DSHG end	Chek DSHG end	AMPS	Chek DSHG end	Chek DSHG end	AMPS	Chek DSHG end	Chek DSHG end	Remark
07:00AM	120	C	C	120	C	C	120	C	C	4 pumps running
08:00AM	120	C	C	120	C	C	120	C	C	4 pumps running
09:00AM	120	C	C	120	C	C	120	C	C	4 pumps running
10:00AM	120	C	C	120	C	C	120	C	C	4 pumps running
11:00AM	120	C	C	120	C	C	120	C	C	4 pumps running
12:00Noon	120	C	C	120	C	C	120	C	C	4 pumps running
01:00PM	120	C	C	120	C	C	120	C	C	4 pumps running
02:00PM	120	C	C	120	C	C	120	C	C	4 pumps running
03:00PM	120	C	C	120	C	C	120	C	C	4 pumps running
04:00PM	120	C	C	120	C	C	120	C	C	4 pumps running
05:00PM	120	C	C	120	C	C	120	C	C	4 pumps running
06:00PM	120	C	C	120	C	C	120	C	C	4 pumps running
07:00PM	120	C	C	120	C	C	120	C	C	4 pumps running
08:00PM	120	C	C	120	C	C	120	C	C	4 pumps running
09:00PM	120	C	C	120	C	C	120	C	C	4 pumps running
10:00PM	120	C	C	120	C	C	120	C	C	4 pumps running
11:00PM	120	C	C	120	C	C	120	C	C	4 pumps running
12:00M\N	120	C	C	120	C	C	120	C	C	4 pumps running
01:00AM	120	C	C	120	C	C	120	C	C	4 pumps running
02:00AM	120	C	C	120	C	C	120	C	C	4 pumps running
03:00AM	120	C	C	120	C	C	120	C	C	4 pumps running
04:00AM	120	C	C	120	C	C	120	C	C	4 pumps running
05:00AM	120	C	C	120	C	C	120	C	C	4 pumps running
06:00AM	120	C	C	120	C	C	120	C	C	4 pumps running
07:00AM	120	C	C	120	C	C	120	C	C	4 pumps running

Appendix 1: Continued

	No. 4			No. 5			No. 6			
	AMPS	Chek DSHG end	Chek DSHG end	AMPS	Chek DSHG end	Chek DSHG end	AMPS	Chek DSHG end	Chek DSHG end	Remark
07:00AM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
08:00AM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
09:00AM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
10:00AM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
11:00AM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
12:00Noon	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
01:00PM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
02:00PM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
03:00PM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
04:00PM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
05:00PM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
06:00PM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
07:00PM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
08:00PM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
09:00PM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running

Appendix 1: Continued

	No. 4			No. 5			No. 6			
	AMPS	Chek DSHG end	Chek DSHG end	AMPS	Chek DSHG end	Chek DSHG end	AMPS	Chek DSHG end	Chek DSHG end	Remark
10:00PM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
11:00PM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
12:00M\N	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
01:00AM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
02:00AM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
03:00AM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
04:00AM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
05:00AM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
06:00AM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running
07:00AM	E\F	X	X	E\F	X	X	120	C	C	4 pumps running

Shagamu works, Quarry pumps log-sheet, Rainfall measured, Water level: 2.06 m C = Checked, X = Not checked, E\F = Elect. Fault, M\F = Mech, Fault

Appendix 2: The west africa portland cement PLC

	No. 1			No. 2			No. 3			
	AMPS	Chek DSHG end	Chek DSHG end	AMPS	Chek DSHG end	Chek DSHG end	AMPS	Chek DSHG end	Chek DSHG end	Remark
07:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
08:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
09:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
10:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
11:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
12:00Noon	120	C	C	120	C	C	120	C	C	6 pumps running
01:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
02:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
03:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
04:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
05:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
06:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
07:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
08:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
09:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
10:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
11:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
12:00M\N	120	C	C	120	C	C	120	C	C	6 pumps running
01:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
02:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
03:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
04:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
05:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
06:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
07:00AM	120	C	C	120	C	C	120	C	C	6 pumps running

Appendix 2: Continued

	No. 4			No. 5			No. 6			
	AMPS	Chek DSHG end	Chek DSHG end	AMPS	Chek DSHG end	Chek DSHG end	AMPS	Chek DSHG end	Chek DSHG end	Remark
07:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
08:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
09:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
10:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
11:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
12:00Noon	120	C	C	120	C	C	120	C	C	6 pumps running
01:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
02:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
03:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
04:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
05:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
06:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
07:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
08:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
09:00PM	120	C	C	120	C	C	120	C	C	6 pumps running

Appendix 2: Continued

	No. 4			No. 5			No. 6			
	AMPS	Chek DSHG end	Chek DSHG end	AMPS	Chek DSHG end	Chek DSHG end	AMPS	Chek DSHG end	Chek DSHG end	Remark
10:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
11:00PM	120	C	C	120	C	C	120	C	C	6 pumps running
12:00M\N	120	C	C	120	C	C	120	C	C	6 pumps running
01:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
02:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
03:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
04:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
05:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
06:00AM	120	C	C	120	C	C	120	C	C	6 pumps running
07:00AM	120	C	C	120	C	C	120	C	C	6 pumps running

Shagamu works, Quarry pumps log-sheet, Rainfall measured, Water level: 3.16 m C = Checked, X = Not checked, E\F = Elect. Fault, M\F = Mech, Fault

REFERENCES

Adegoke, O.S., 1977. Stratigraphy and Paleontology of the Ewekoro formation (Paleocene) of Southwestern Nigeria. Bull. Am. Paleontol., 71 (295): 1-37.

Agagu, O.K., 1985. A Geological Guide to Bituminous Sediment of South-western Nigeria Unpublished Report on Nigerian Bitumen Deposit, Department of Geology, University of Ibadan, Nigeria, pp: 16.

Allen, J.R.L., 1964. The Nigerian Continental Margin: Bottom Sediments, Submarine Morphology and Geological Evolution. Marine Geol., 1: 289-332.

Choi, Y., H.D. Park and C. Sunwoo, 2008. Flood and Gully Erosion Problems at the Pasir Open Pit Coal Mine, Indonesia: A case study of the hydrology using G.I.S. Bull. Eng. Geol. Environ., 67 (2): 251-258. htt:/www.springerlink.com/content/th76475t72272488/.

Ejedawe, J.E. and S.J.L. Coker, 1984. Dynamic Interpretation of Organic-Matter Maturation and Evolution of Oil-Generative Window. American Association of Petroleum Geologist (AAPG) Bul., 68 (8): 1024-1028. http://aapgbull.geoscienceworld.org/cgi/content/fulltext/68/8/1024.

Jones, H.A. and R.D. Hockey, 1964. The Geology of part of Southwestern Nigeria, Bull. Geological Survey of Nigeria (GSN), 31: 101-112.

Meek, F.A., 1990. Water and Air Management. In: Kennedy, B.A. (Ed.). Surface Mining. Society for Mining, Metallurgy and Exploration, Littleton, pp: 819-840.

Murat, R.C., 1970. Stratigraphy and Palaeogeography of Cretaceous and Lower Tertiary in Southern Nigeria. In: African Geology, T.F.C. Dessauvagie and A.J. Whiteman (Eds.). Ibadan University Press. Ibadan, Nigeria, pp: 251-266.

Ogunkoya, P.O., 2006. Flood Control in a Mine Environment (a case study of WAPCO Plc. Shagamu). Federal University of Technology Akure, Nigeria, unpublished B.Eng Final year project, pp: 76.

Omatsola, M.E. and O.S. Adegoke, 1981. Tectonic Evolution and Cretaceous Stratigraphy of the Dahomey Basin. Nig. J. Mining and Geol., 10 (1): 130-137.