ZAMBIA CONSOLIDATED COPPER MINES LIMITED
NCHANGA DIVISION - GEOLOGY DEPARTMENT

DEWATERING SCENARIO AT NCHANGA MINE

ABSTRACT

The Nchanga Mine Licence Area comprises three major synclines of dolomitic, sandy and shaly sediments flanking a granite dome. The surface forms an undulating plateau with a regional slope to the north-northwest across strike of sedimentary rocks. The syncline contain highly porous dolomites and sandstones which bear large volume of water. the permeability of these rocks is variable, but relatively free circulation of water over large strike and dip lengths occur. The water bearing rocks within the synclines are interstratified with predominantly quartzitic and shaly units act as aquicludes or, if heavily fractured, jointed and faulted; acquitards. On this basis, generally, water is confined to a number of aquifers; each with its own hydrological characteristics. Five main aquifers are recognised and there are:

a Footwall aquifer
b Banded Sandstone aquifer
c Upper Banded aquifer
d Chingola Dolomite aquifer
e Upper Roan Dolomite aquifer

The two major aquifers, Banded Sandstone and Upper Banded Shale aquifers, overlie two important orebodies at Nchanga. To ensure dry and flood free extraction conditions of these orebodies, extensive dewatering is done ahead of production.

The dewatering of these aquifers is achieved mainly by diamond drilling. The Lower Orebody developments normally are sufficient to dewater the footwall aquifer.

The problem of water entering active production blocks, thereby rendering moving of ore difficult, has been recognised in some parts of the mine. Two sources are thought to be the main contributing factors and these are:

a perched water tables where the clayey, sticky Transition occurs which has permeability and high retention; and

b NOP sump water which seeps through Banded Sandstone and Upper Banded Shale. An effective way of minimising or total control of this water has not yet been found.

H SIBBENGA

1

1.0 INTRODUCTION

The Nchanga Mine Licence Area lies in the vicinity of latitude 13 degrees South and longitude 28 degrees East, and forms the northwest end of the Zambian Copperbelt.

The rocks present in the area range stratigraphically from the Basement Complex to the Lower Kundelungu. The stratiform copper deposits occur in the Lower Roan subdivision of the late Precambrian Katanga sequence consisting of the Roan, Mwanshia and Kundelungu groups.

Isotopic age determination indicate that the Katanga Sequence was deposited before 620 m-Yr, and that the Lower Roan is older that 840 m.Yr and younger than 1300 m.yr (Cahen 1970 in Binda and Mulgrew 1974). The existing stratigraphic nomenclature is largely related to mining and is not in agreement with modern stratigraphic practice. The stratigraphy and geology of the area are points for discussions in this paper.

The Nchanga Division is one of the world's leading copper and cobalt producers and contributes 52% of ZCCM's total copper production. The ore is mined both by open cast and underground methods.

The lower orebody underground is mined by continuous block caving. To allow mining to progress under flood free conditions the draw down of the water table in the aquifers must be such that the cave cracks caused by block caving mining do not intersect undewatered strata in the hangingwall.

The open pits situated above underground workings have been dewatered by underground diamond drilling to ensure that ground water does not hinder earthmoving and adversely affect slope stability.

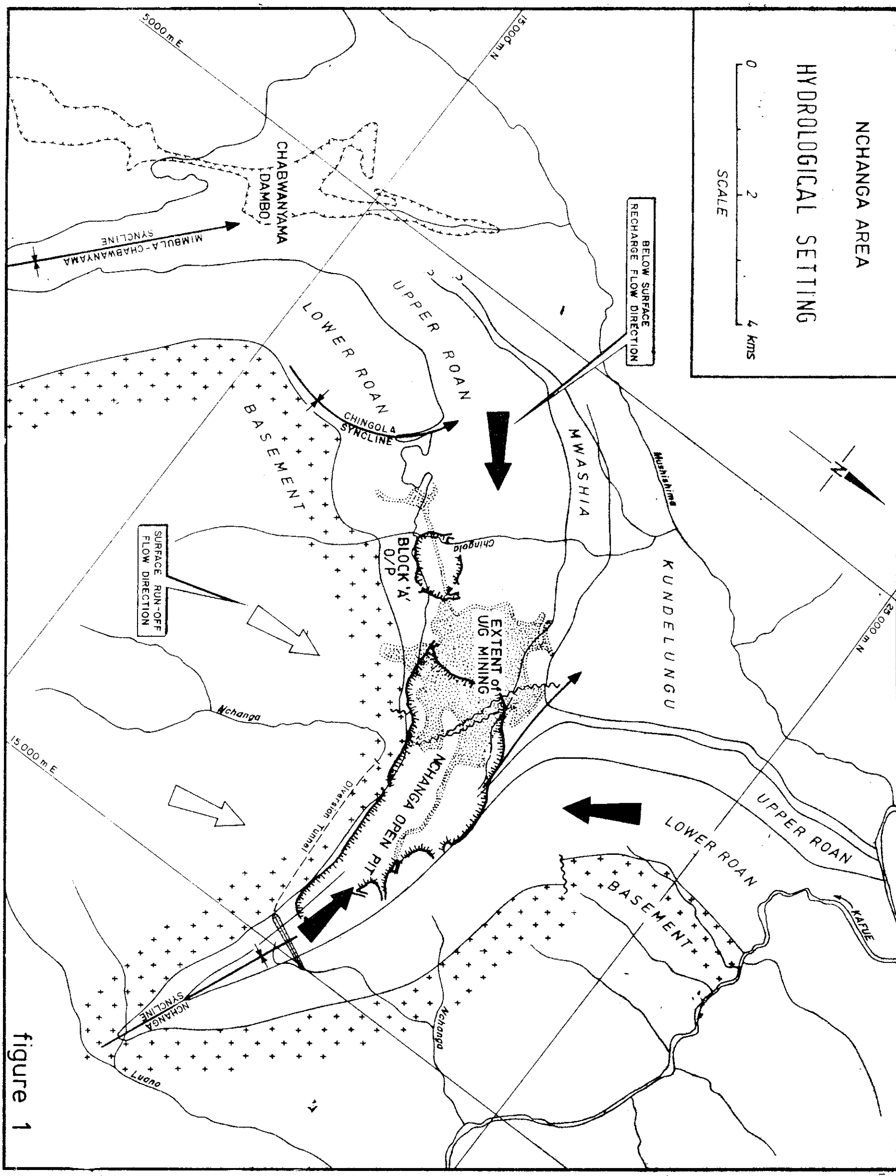

NCHANGA AREA
HYDROLOGICAL SETTING
0
2
4 kms
SCALE
BELOW SURFACE RECHARGE FLOW DIRECTION
SURFACE RUN-OFF FLOW DIRECTION
5000 m E
15 000 m N
15 000 m E
25 000 m N
N
CHABWANYAMA DAMBO
MIMBULA-CHABWANYAMA SYNCLINE
UPPER ROAN
LOWER ROAN
BASEMENT
CHINGOLA SYNCLINE
MWASHIA
KUNDELUNGU
Mushishima
Chingola
BLOCK 'A' O/P
EXTENT of U/G MINING
Nchanga
NCHANGA OPEN PIT
Diversion Tunnel
NCHANGA SYNCLINE
Luano
KAFUE

figure 1

2.0 HYDROLOGICAL SETTING - (FIG 1)

The Nchanga Mining Licence Area comprises three major synclines of dolomitic, shaly and sandy sediments flanking a granite dome. The surface forms an undulating plateau with a regional slope to the north and northwest across the strike of the meta-sedimentary rocks towards the Kafue River.

The Chabwanyama, Chingola, Nchanga and Luano streams flow perennially across the area. The underground workings lie within the catchment area of the Nchanga and Chingola streams. The areas extending north and northwest, bounded by the Kafue River and Chabwanyama dambo, are regarded as open conduits into the mine area from the main hydrological basin further northwest. The eastern extent of the Nchanga syncline itself consists of smaller, restricted, hydrological basin.

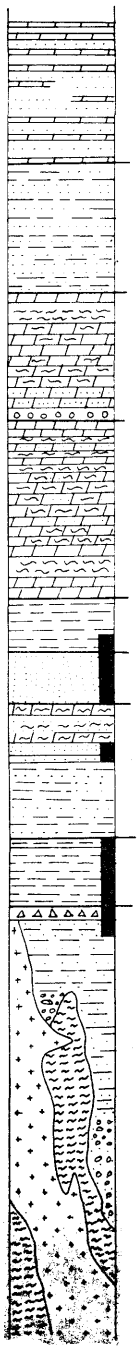
The Nchanga Syncline contains highly porous dolomites and sandstones which bear large volumes of water. The permeability of these rocks varies, but relatively free circulation of water over large strike and dip occur. The water bearing rocks within the syncline are interstratified with predominantly quartzitic and shaly units which act as aquicludes or if heavily jointed, acquitards; water is therefore generally confined to a number of aquifers, each with its own hydrological characteristics (Fig 2). On this basis five main aquifers have been recognised and these are starting from the base (i) Footwall (ii) Banded Sandstone (iii) Upper Banded Shale (iv) Chingola Dolomite and (v) Upper Roan Dolomites aquifers. The two major aquifers the Banded Sandstone and Upper Banded Shale contribute 68% and 23% respectively to water made underground from boreholes. The Footwall aquifer contributes 7% and the Chingola Dolomite aquifer only 2%. The Upper Roan Dolomites is correctly not being dewatered.

3.0 AQUIFERS AND THEIR CHARACTERISTICS

3.1 Footwall Aquifer

The Footwall aquifer comprises Transition member. The Transition beds are generally highly permeable and water is readily transferred to the underlying Arkose and Granite through joints, faults and localised leached zones. In the 1W and 2W parts of the mine the sticky, soft Transition which is largely composed of montmorillonite permeability is very poor. The Arkose becomes porous towards the top, especially above the 'Natural Footwall', where localised

OREBODIES AND AQUIFER RELATIONSHIPS



UPPER ROAN DOLOMITES AQUIFER

SHALE WITH GRIT: Gritty, sandy argillies and siltstones with thickness

CHINGOLA DOLOMITE AQUIFER: High yield, fissured crystalline schistose

DOLOMITIC SCHIST: Interbedded micaceous dolomites, mica schist and argillites

UPPER BANDED SHALE AQUIFER: Isolated and interconnected weathered porous zones.

THE FELDSPATHIC QUARTZITE: Medium to coarse grained feldspathic to glassy quartzite

BANDED SANDSTONE AQUIFER: Comprising Banded sandstone lower, pink quartzite, shale marker and banded sandstone upper.

CHAR: Barely coherent

CHERT MARKER AND LOWER BANDED SHALE

FOOTWALL AQUIFER: Composed of transition member, Arkose and Granite formation

CHARACTERISTIC: Incoherent, transition, jointed and faulted Arkose and granite.

leaching frequently occurs. Normal footwall mining development together with the standard pattern of Lower Orebody evaluation drilling is sufficient to dewater this aquifer.

The shales and siltones of the overlying Lower Banded Shale were originally considered to be impervious. Water pressures measured in several boreholes stopped in the shale have indicated Banded Sandstone aquifer water table elevations. This indicated that the shale is interconnected to the overlying Banded Sandstone aquifer through joints, fissures and localised decomposed, permeable zones and is now considered as an aquitard.

3.2 Banded Sandstone Aquifer

The barely coherent mica siltones and sandstones of the Banded Sandstone Lower are separated from the more dolomitic mica schist of the Banded Sandstone Upper by the highly jointed Shale Marker and Pink Quartzite members, in certain localities they are absent, which permit interconnection between the two. The aquifer consists of somewhat well defined lenses and strata of higher permeability in a porous formation of lower permeability. In depth the Banded Sandstone Aquifer becomes more dolomitic, the dolomite horizons acting as barriers to downdip and lateral permeability. This was evidenced on 3020 4.5W Section, where six boreholes drilled intersected solid Banded Sandstone with lower permeability as compared to the adjacent boreholes. The aquifer is drained only by diamond drilling where boreholes have to intersect the whole formation to be effective. Owing to the generally low permeability of the formation, 2 x 10^-3 cm/sec, a lot of drilling is done. The Banded Sandstone Aquifer is overlain by the Feldspathic quartzites of the Upper Orebody and the which are relatively impervious. These rock units act as aquicludes, although isolated cases where the Banded Sandstone Aquifer appeared to have interconnection with the Upper Banded Shale Aquifer, have been noticed.

3.3 Upper Banded Shale Aquifer

The Upper Banded Shale Aquifer consists of isolated and interconnected weathered, porous zones; after dolomite, in a formation of laminated, micaceous shales. Diamond drilled holes which are cased in the Banded Sandstone, are used to dewater this aquifer. The Aquifer yields its water quickly due to its relatively higher permeability of 1.7 x 10^-2 cm/sec.

The Upper Banded Shale Aquifer is separated from the Chingola Dolomite Aquifer by a sequence of mica schists, dolomites and shales of the dolomitic Schist. This slightly weathered dolomite with low porosity contain only limited amounts of water and do not cause a problem to mining.

3.4 Chingola Dolomite Aquifer

The Chingola Dolomite Aquifer is a high yield, fissured crystalline to schistose dolomite. The fissures are strata bound in the form of a network of connected lenticular openings. There are two principal fissure systems that occur and these are

a fissures that contain mud and

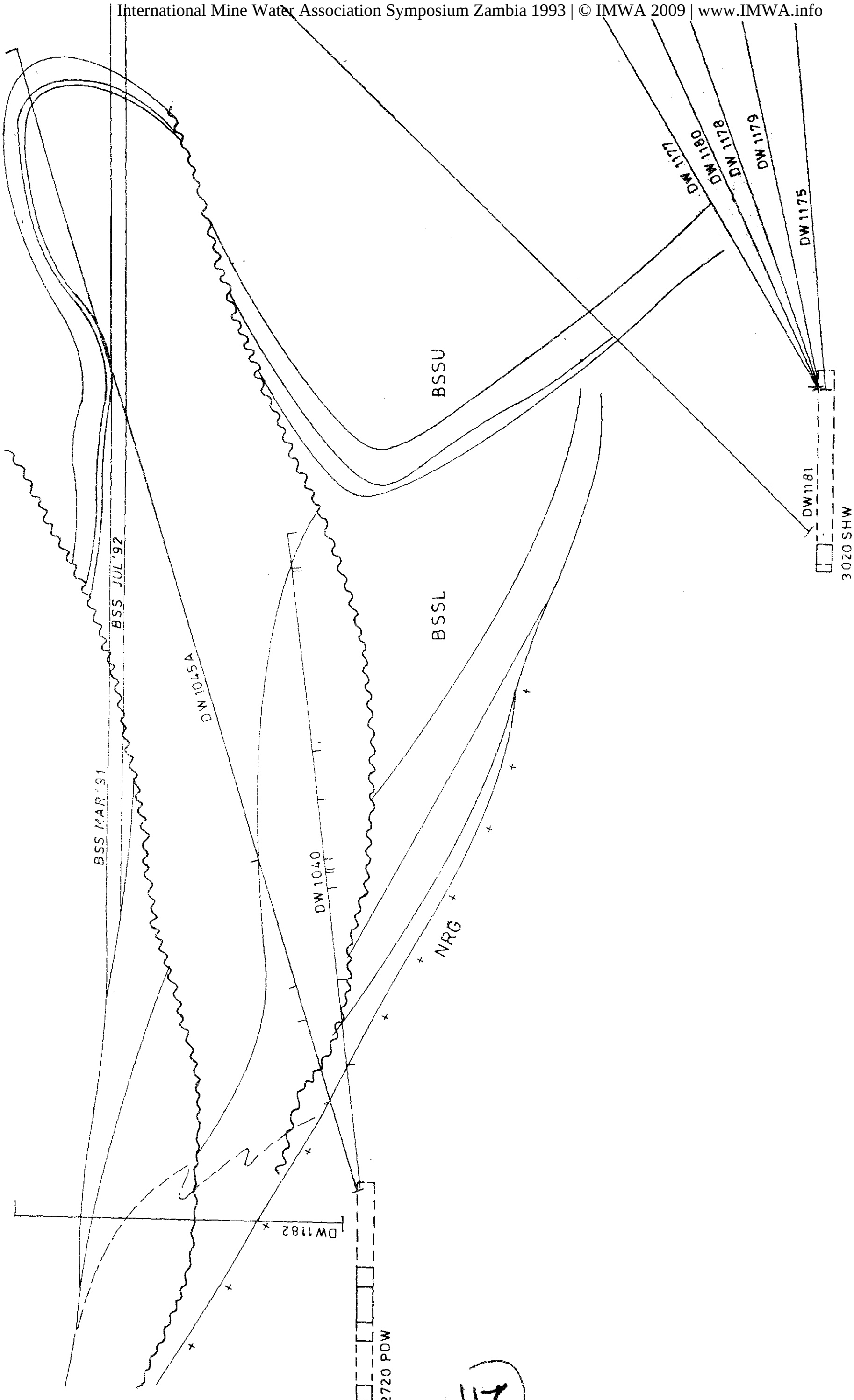
b water filled cavities capable of releasing large volumes of water.

Due to open fissure connections water is more readily transmitted along strike and dip.

Dewatering of this Aquifer was done from strike drives mined within the dolomite itself with a combination of bar machine holes or diamond drilling from upper orebody, development. Currently there is no need to dewater this aquifer as it is very far from underground workings. The lowest of an extensive sequence of discrete Upper Roan dolomites Aquifer is separated from the Chingola Dolomite by 120 m of relatively dry Shale With Grit. very limited amounts of water are encountered.

3.5 Upper Roan Dolomites Aquifers

The Upper Roan Dolomite consists of well defined zones of very porous, limonitic, talcose chert residue; formed by weathering of quartz talc dolomites. The zones separated by aquicludes of micaceous siltstones. No systematic dewatering ever done.



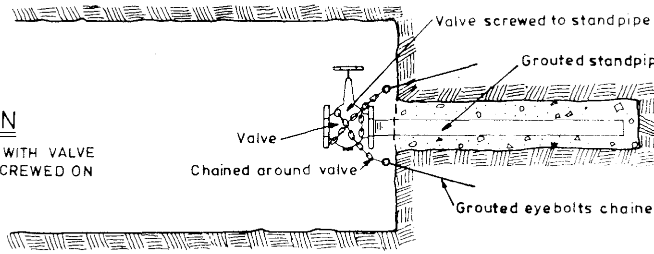
DEWATERING CROSSCUT
4½W 1:1000

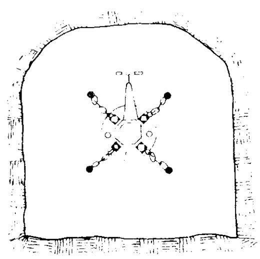
FIG. 3

STANDPIPE INSTALLATION

SECTION

STANDPIPE WITH VALVE DIRECTLY SCREWED ON





ELEVATION

1. Drill standpipe hole and eyebolt holes.
2. Fill holes with cement grout and insert standpipe and bolts,
3. Bolt on valve and chains.
4 Allow 1 to 2 days for cement to dry.
5 Drill hole through standpipe and open valve

FIG. 4

4.0 METHODS OF DEWATERING

4.1 Diamond Drilling

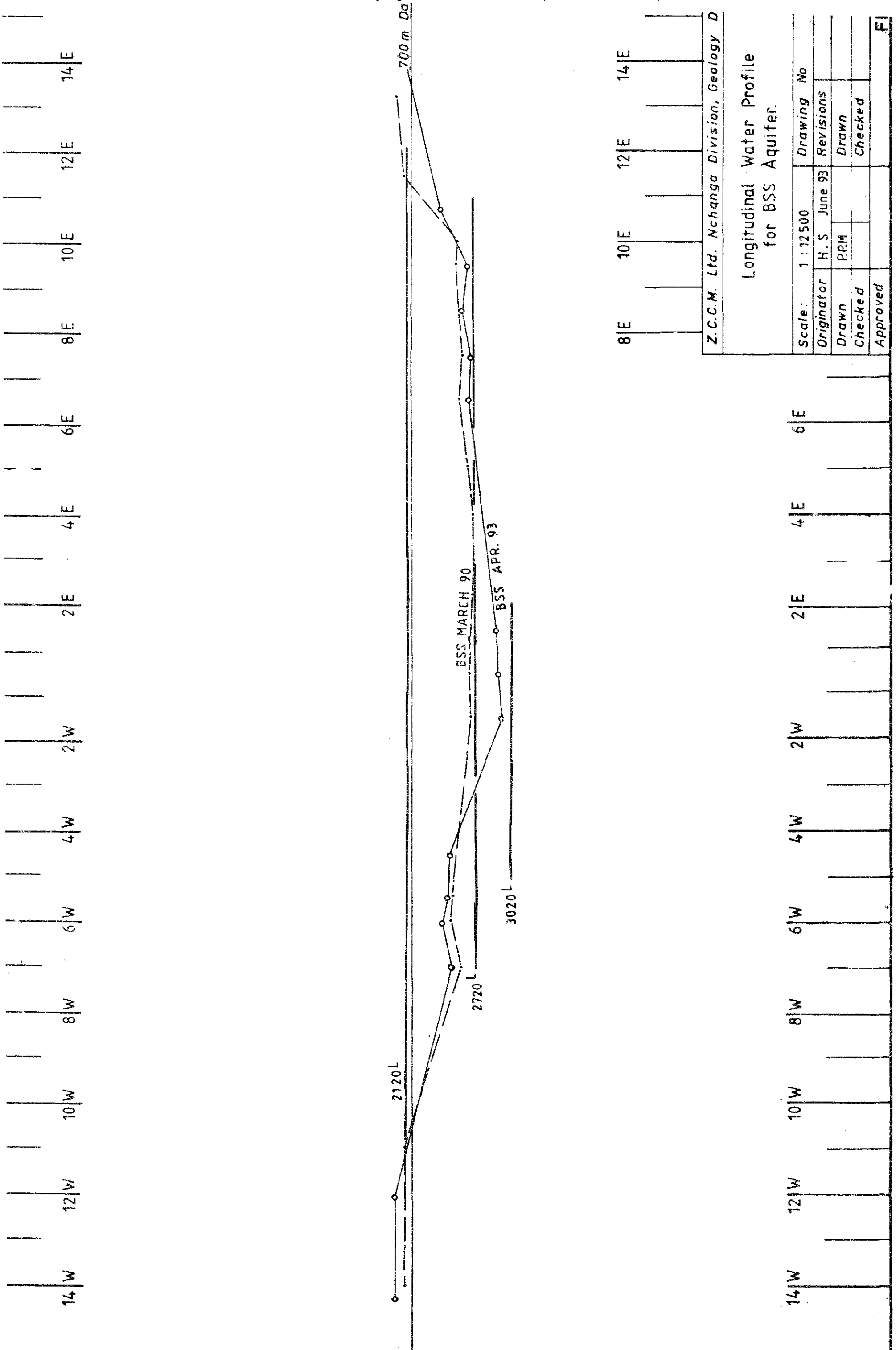
Underground diamond drilling is the most extensively used method. The dewatering boreholes are drilled on predetermined levels so that a sufficient head is achieved from one dewatering level to the next. It was found out that to achieve an effective dewatering programme dewatering levels have to be three mine levels apart or approximately 186 m. On the dewatering level, crosscuts are mined at every section line position, ie 120 m.

These crosscuts are advanced as close as possible to the footwall of orebody formations (Fig 2). Dewatering boreholes are drilled from these dewatering crosscuts with inclinations ranging between 0-35 degrees. It is very important to collar dewatering boreholes in solid ground so that no leaks occur around the borehole. Boreholes normally start with UV(173.7 mm) or SF(145.4 mm) in order to achieve a satisfactory hole diameter when penetrating the stratigraphically higher aquifers. Drilling conditions are hard due to high pressures encountered at times (up to 30 bars) and the alternation of hard and incoherent soft strata. This condition gives rise to blockage problems. To overcome this problem drilling additives are used, though sparingly, because the water made underground is used for domestic and ore treatment purposes. A complete set up of dewatering boreholes is shown in (Fig 4).

Due to the corrosive nature of the Banded Sandstone and Footwall water mild steel stand pipes and casings are rapidly corroded, causing major leaks thereby reducing water controllability. The use of stainless steel stand pipes is an effective way but expensive. Currently, heavy duty pvc stand pipes are being used with stainless steel flanges and perforated plastic casings.

3.2 Mine Development and Boreholes

The mine developments which take place in the footwall in conjunction with prospecting boreholes and bar machine holes adequately drain the Footwall Aquifer.


Z.C.C.M. Ltd. Nchanga Division, Geology D
Longitudinal Water Profile
for BSS Aquifer.
Drawing No
Scale: 1:12500
Originator H.S June 93
Drawn P.P.M
Checked
Approved
Revisions
Drawn
Checked
700 m Da
BSS MARCH 90
BSS APR. 93
2120L
2720L
3020L
14E
12E
10E
8E
6E
4E
2E
2W
4W
6W
8W
10W
12W
14W

5.0 RATE OF DRAWDOWN AND WATER CONTROLLABILITY

Every three months direct measurement of hydrostatic pressures and uncontrollable water from underground boreholes are carried out. Water control is very critical to maintain the mine dry. As of now water controllability stands at 84%, though this is improved to 94% in the dry season.

The water elevations measured are plotted on dewatering sections and longitudinal profile (Fig 5), which provide a quick and useful reference to planning and production. This also allows direct comparison of rate of aquifer drawdown between two measuring times. It has been established that the water drawdown falls on exponential curve and asymptotically approaches a stabilisation level. This condition is achieved when the water being removed by dewatering boreholes equals the ground water recharge to aquifers. The only way to achieve drawdown when such a situation arises is by establishing another dewatering level or spread further along the cone of dewatering.

6.0 PUMPING FACILITIES

Water from underground to the surface is pumped from two pump chambers, namely 2800 and 1600. The 2800 Pump Chamber is equipped with nine pumps with an installed capacity of 145 800 m3/d though it is restricted by available water columns. This Pump Chamber handles water from below 1500 level to 3020 level. The 1600 pump chamber has four pumps which handle water arising from 1500 and the levels above. The water pumped to the surface from underground workings since April 1992 to March 1993 averaged 76962m3/d.

7.0 ANOMALOUS WATER

Anomalous water is classified as that water which is: (a) continuously being experienced in areas where the water table is well below caved areas and (b) the seasonal water that enters underground working in the rain season.

a Persistent flows, which are relatively small, continue to occur well above the elevations of the water table. This water combined with the effects of caving is sufficient to remobilise the incoherent Banded Sandstone in the hangingwall resulting in the danger of mudrushes and the difficulties of handling wet ore. This situation prevails in the central and the far eastern parts of the mine and average about 100m3/d and 30m3/d respectively.

Sources of this water are thought to be from:

i Perched water tables in the central parts of the mine where the sticky soft Transition occurs which is predominantly composed of a swelling clay mineral, montmorillonite. Boreholes were planned to punch the Transition to facilitate drainage of this water. However, due to the characteristics of the Transition the holes failed to penetrate the member.

ii The three parallel Upper Banded Shale synclines plunging northwest from the Nchanga Open get direct recharge. The boreholes that intersected these structures initially made water but dried out later, without solving this problem entirely.

iii Recharge from updip developments. R J Chifwaila (1989) observed that the high water yielded in 2720 1W (251m3/d) A Block was due to the shale with Grit crosscut on the upper levels. There is a dewatering programme to see if the prevailing situation on the central sections is due to such developments.

b The Nchanga Mine underground has a unique problem of having open pits directly above. At the moment there are two active open pits; Block A and Nchanga Open Pits. Block A pit sump water has never been as serious as the water from the Nchanga open pit sump. Nevertheless, flows of up 100m3/d were experienced underground attributed to infiltration from the sump.

The successive Nchanga Open Pit designs for the previous two years positioned in partly Arkose and Lower Banded Shale formations. The Lower Banded Shale underlies the Banded Sandstone Aquifer. A ten year rainfall average of 1333 mm of rain is received by the large catchment area of the open pit, 3.8 km^2. Assuming 50% runoff, half of this water reports to the Open Pit sump. Some of this water is pumped into underground workings at 1500 level through boreholes and the rest finds its way through seepage into underground works and direct recharge of the Banded Sandstone Aquifer. The previous season it was found out that the water entering underground workings uncontrolled equalled that which was being pumped. The uncontrolled water caused abandonment of production blocks in the east side of the mine. and since it was riddled with silt it clogged pumps causing failure. The only likely solution to this problem is to position the sump in the Arkose.

ACKNOWLEDGEMENTS

The author wishes to thank R J Chifwaila and Victor Simposya for assitance rendered and C Lukonde Mulembo for typing this paper

REFERENCES:

Mendelsohn F (Ed) Geology of the Northern Rhodesian Copperbelt, MacDonald, London

Stalker, T W & Schianini, P C Mine and Open Pit Dewatering at Chingola.