

THE WATER PROBLEM IN RELATION TO MINING AT KONKOLA DIVISION, NCHANGA CONSOLIDATED COPPER MINES LIMITED

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ABSTRACT

Nchanga Consolidated Copper Mines Limited, Konkola Division (formerly Bancroft Mines Limited) is the wettest mine on the Zambian Copperbelt and probably the second wettest in the world. The stratigraphic position of the orebody, between the Hangingwall and Footwall Aquifers, results in large quantities of controllable and uncontrollable water flowing into the workings during mining operations. In 1970 an average of 340 000 cubic metres (75 million gallons) per day were pumped to surface, equivalent to 64 tonnes of water per tonne of ore hoisted. Sufficient pumping capacity has to be installed to lower the water table in the various aquifers in time to meet production commitments. The sustained capacity for 1972 will be in the region of 600 000 cubic metres (130 million gallons) per day. The mining method of sub-level open stoping requires dewatering of the Footwall Aquifer during development operations and dewatering of the Hangingwall Aquifers prior to stoping. Water is, therefore, a major consideration in mine planning. A clear understanding of the geological features of the Konkola mining area is essential to develop a successful and efficient dewatering scheme. Dewatering of the various aquifers is achieved by drilling boreholes and by driving mining headings into the aquifers. The problem of recharge is not yet solved and research in this field is in progress, including colour and infra red aerial photographic surveys, chemical and neutron activation analyses of waters, regional water balance studies, and age determinations of waters by natural isotope analysis.

INTRODUCTION

Nchanga Consolidated Copper Mines Limited,
Konkola Division, (formerly Bancroft Mines Limited)

¹⁾ Konkola Division N.C.C.M. Ltd.

is a copper producing company, situated in the north of the Zambian Copperbelt.

The average production is presently 150 000 tonnes of ore per month from two shafts. A labour force of 5 000 is employed. An average of 350 000 cubic metres of water is being pumped out of the mine every day, thus making Konkola Division the wettest mine on the Copperbelt, if not in the world. (There appears to exist one wetter mine near Kintau, U.S.S.R., Editor).

The total ore reserves are estimated at 94 000 000 tonnes at an average grade of 3.5% total copper.

Copper was first discovered in the Chililabombwe (Bancroft) area in 1924. After an extensive exploration programme, production started from the South Orebody (No. 1 Shaft) in 1957 and from the North Orebody (No. 3 Shaft) in 1963.

Konkola Division has continually experienced great difficulties in mining as a result of the large quantities of water encountered during development. The main pump stations at Konkola have presently a sustained capacity to surface of 460 000 cubic metres per day and future expansion of this capacity is expected with increase in production.

GEOLOGY

(1) *Geomorphology*

The Copperbelt's erosional surface is a mid-Tertiary peneplain, about 1300 metres above sea-level. The Kafue river and its major tributaries cut

shallow valleys in the peneplain. The surface generally has a flat and monotonous aspect. The Lubengele stream and its tributaries form the main drainage system in the Konkola area, feeding into the Kafue.

(2) *Stratigraphy*

The Basement Complex and Katanga system are of pre-Cambrian age and form the framework for the Konkola ore deposits. The Basement Complex consists of pre-Katanga rocks, namely the Lufubu System, the Muva System and granite (table 1).

System	Series	Group
Katanga	Kundelungu	Upper Middle Lower
	Mine	Mwashai Upper Roan Lower Roan
	Unconformity	
BASEMENT		COMPLEX

TABLE 1
General stratigraphic column.

The geological succession around the Konkola orebodies is shown in table 2, representing the Mine Series of table 1. The position of the main aquifers is indicated in order to show the position of the orebody relative to the Footwall and Hangingwall Aquifers, in which large quantities of water are encountered.

(3) *Structure*

Fig. 1 is a regional geological map of Konkola Division and shows the structural pattern formed by the Kirila Bomwe Anticline, Fitwaola Syncline, Kakosa Syncline and the Konkola Dome. The Kawumbe crossfold, possibly with east-west faulting, separates the Konkola Dome from the Kirila Bomwe Anticline. The North Orebody is situated over the nose and the South Orebody on the west limb of the Kirila Bomwe Anticline. The dip of the ore shales varies from 13° at the nose to between 40° and 70° on the north flank and west flank. The thickness of the ore shales varies between 4 metres and 10 metres.

Group	Formation	Aquifers
Mwashia	Mwashia Shale Basal Conglomerate	Upper Roan Dolomite Aquifer
Upper Roan	Upper Roan Dolomite	
Lower Roan	Shale with Grit	Includes Hanging-wall Aquifer
	Hangingwall Aquifer Zone	
	Hangingwall Quartzite ORE SHALES	
	Footwall Conglomerate) Footwall Sandstone) Porous Conglomerate)	Footwall Aquifer
	Argillaceous Sandstone Footwall Quartzite Basal Conglomerate	Aquaclude Water in joints Aquifer

TABLE 2
Stratigraphic succession at Konkola.

MINING METHOD

Figure 2 shows the mine workings relative to the geological strata.

Shafts, pump chambers and other ancillary development are mined in the strong Footwall Quartzite. Main crosscuts to lode and quartzite haulages parallel to the orebody are mined within the Footwall Quartzite formation. From here connecting crosscuts are mined at 300 metre intervals to the footwall haulage position. Footwall haulages are mined parallel to the orebody in the Footwall Sandstone formation in such a position that ore from the stopes gravitates into stope boxes in these haulages. In addition, drain drives are mined ahead of the footwall haulages, for piloting, dewatering and ventilation purposes (see fig. 3).

The general method of extraction is sub-level open stoping with longhole drilling. In the steep areas of the orebody, ore will gravitate down onto grizzlies where secondary blasting takes place. In the flat areas, ore is extracted by scraping down dip into drawpoints.

Most sub-level development take place in the orebody and the drives are piloted by following a specific lithological contact or marker band. Waste development is normally limited to grizzly drives and accesses at intermediate levels to rib-pillar posi-

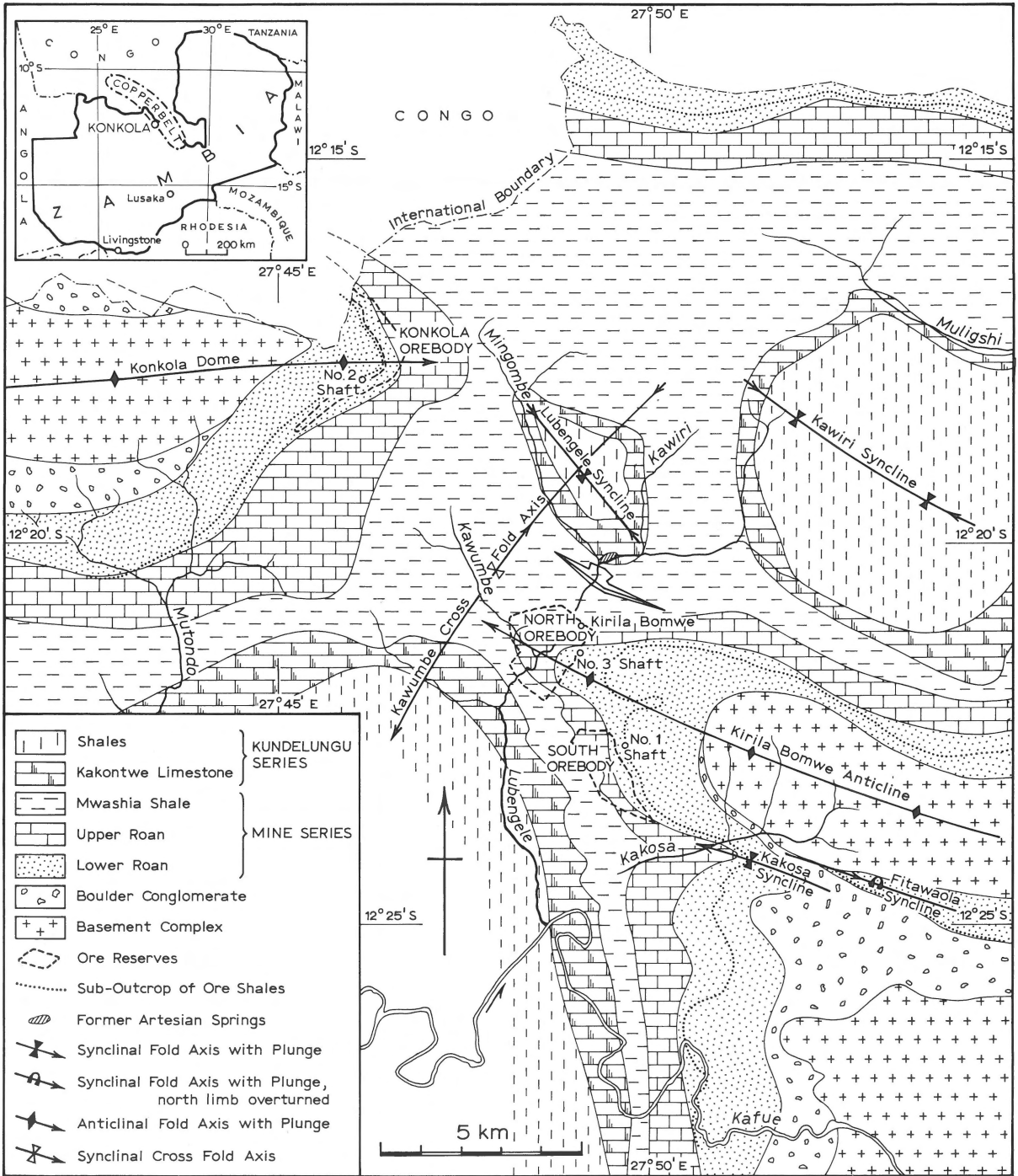


Fig. 1
N.C.C.M. Ltd., Konkola Division, Regional Geological Map.

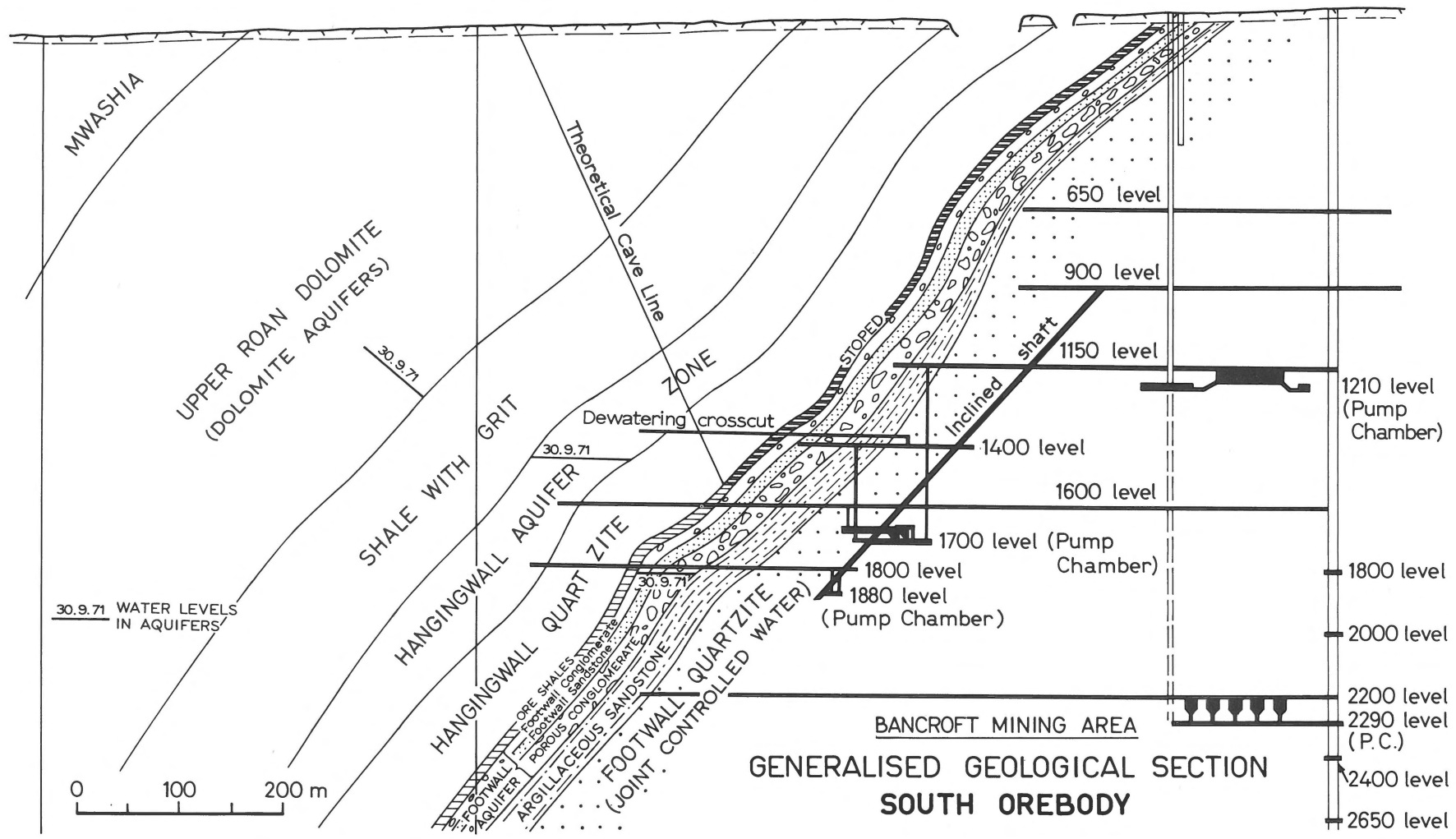
Surface borehole

Surface borehole

Caved Area

Ventilation shafts

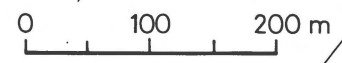
No.1 SHAFT



BANCROFT MINING AREA
GENERALISED GEOLOGICAL SECTION
SOUTH OREBODY

- 650 level
- 900 level
- 1150 level
- 1210 level (Pump Chamber)
- 1400 level
- 1600 level
- 1700 level (Pump Chamber)
- 1800 level
- 1880 level (Pump Chamber)
- 2000 level
- 2200 level
- 2290 level (P.C.)
- 2400 level
- 2650 level

30.9.71 WATER LEVELS
 IN AQUIFERS



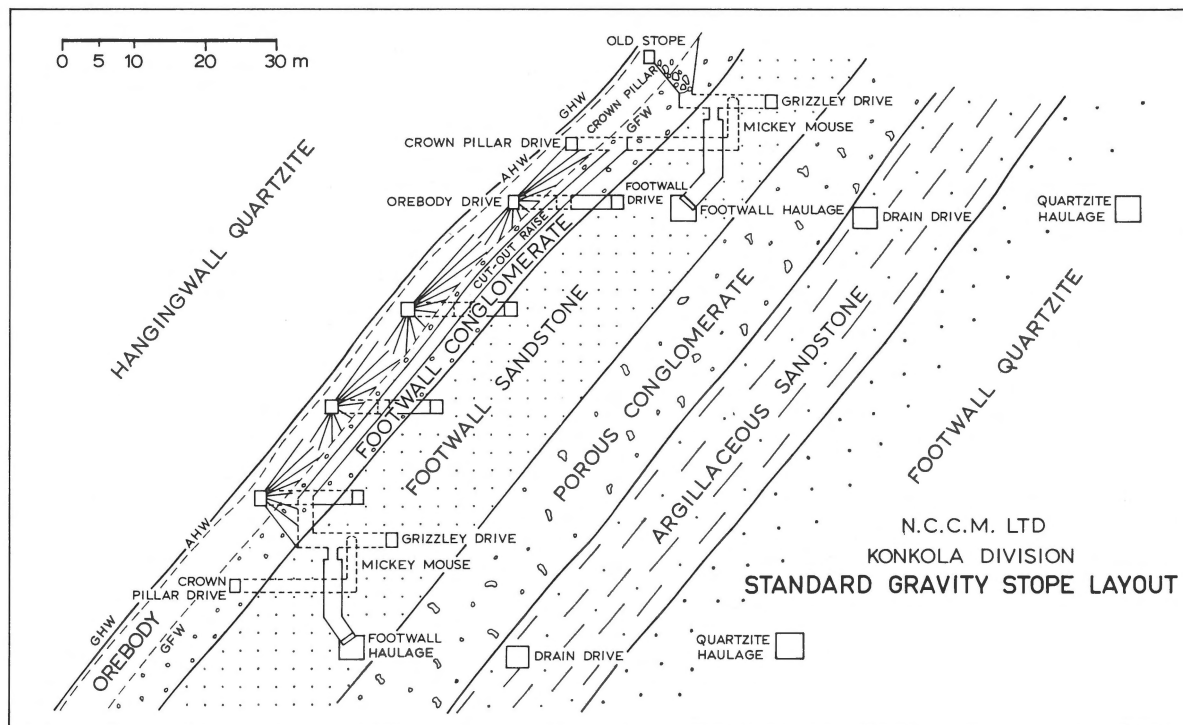


Fig. 3
N.C.C.M. Ltd., Konkola Division, Standard gravity stope layout.

tions for pillar drilling. However, the behaviour of the orebody drives, in certain areas of the mine, is such that falls of roof and side-walls occur if the drive is exposed for any period of time. The present solution is to develop drives in the footwall and only open up the orebody drives at the last possible moment before stoping. Guniting is now being considered to be another possible solution. Mechanised mining is being introduced and progress is being made with the use of the Robbins raise borer and Wagner scoop trams.

Because of the relatively narrow width of the tabular orebody, waste dilution in stoping is a problem, and every effort has to be made to prevent peeling of the waste hangingwall. This, however, is a minor issue compared to the water problem.

THE WATER PROBLEM

(1) General

The crux of the problem lies in the stratigraphic position of the orebody between Footwall and Hangingwall Aquifers. Large quantities of water enter the workings from four main sources: the Footwall Quartzite, the Footwall Aquifer, the Hangingwall Aquifer and the Upper Roan Dolomite (see fig. 2). During 1970, an average of 340 000 m³/d of water was pumped to surface, equivalent to 64 tonnes of water per tonne of ore hoisted.

Extreme care has to be taken in advancing development headings in water-bearing strata and stoping can only take place after the hangingwall strata above the stoping area have been dewatered.

◀ Fig. 2
Bancroft Mining Area, Generalised Geological Section South orebody.

(2) *Aquifers*

(a) *Footwall Quartzite*. — The Footwall Quartzite formation consists of three members. The Basal Conglomerate, the Footwall Quartzite (*sensu stricto*) and the overlying Argillaceous Sandstone. The latter is an aquaclude, whilst water in the crossbedded quartzites is generally joint controlled. The conglomeratic member at the base may form stratiform aquifers.

(b) *Footwall Aquifer*. — This aquifer consists of three members. The Porous Conglomerate, the Footwall Sandstone and the Footwall Conglomerate. Above the Footwall Aquifer occur the Ore Shales which, together with the Hangingwall Quartzite, form an aquaclude. Therefore, water in the Footwall Aquifer is stratigraphically bounded and is encountered throughout the strike length of the orebody.

(c) *Hangingwall Aquifer*. — The Hangingwall Aquifer Zone lies stratigraphically 50 to 100 metres above the orebody. Water in this zone generally occurs in decomposed dolomitic bands which may yield either clear water or a mixture of water, mud, sand, pebbles and cherty rubble.

(d) *Upper Roan Dolomite*. — This formation comprises impure dolomites and argillite. It has an extensive surface distribution, weathers deeply, and is a known bedded aquifer or series of aquifers. Because of this there is obvious potential for this formation to act as a collecting “tray” for surface waters and as a storage reservoir, but recent work suggests that it is limited in these respects.

(3) *Dewatering*

(a) *Footwall Quartzite Dewatering*. — Most capital development — shafts, pump chambers, ventilation systems and all quartzite haulage development — is mined in the Footwall Quartzite formation.

As mentioned before, the Argillaceous Sandstone can be considered as an aquaclude; there is virtually no transfer of water between the Footwall Quartzite and the other aquifers. The Footwall Quartzite is, therefore, not deliberately dewatered but when water is encountered in precautionary pilot cover drilling, it is sealed off by cementation. The operation is not

totally successful and approximately one fifth of the water pumped from the mine derives from this formation.

(b) *Footwall Aquifer Dewatering*. — All footwall haulages, stope box raises, grizzley drives and crosscuts and footwall sub-level development are mined in the Footwall Aquifer and, therefore, dewatering of it is inevitable and necessary. Dewatering of the aquifer is generally achieved by normal haulage development. The porous nature of the conglomerates and the jointing in the Footwall Sandstone result in effective drainage. The water is removed via drain drives, mined parallel to the footwall haulage and at a slightly lower elevation in the drier Argillaceous Sandstone. It is fed into a system of settlers and sumps near the pump chamber.

The yield per advancing haulage face varies considerably. A combination of two ends (footwall haulage and accompanying drain drive) can yield up to 18 000 m³/d but a normal yield is between 9 000 — 13 000 m³/d. Transfer of water to the Footwall Aquifer from the Hangingwall Aquifer definitely occurred on the upper levels of the North Orebody, but, at the South Orebody, there is only a poor connection.

(c) *Hangingwall Aquifer Dewatering*. — Prior to stoping, it is essential to dewater the wedge of rock above the stope, formed by the plane of the orebody and the plane of the anticipated cave cracks. Cave cracks are assumed to extend at a 65° angle through the succession of strata to surface. (see fig. 2).

There are, in principle, two ways of dewatering the Hangingwall Aquifer:

(i) Mining of dewatering crosscuts through the orebody and the Hangingwall Quartzite into the base of the Hangingwall Aquifer Zone. A water-tight door is installed in the crosscut as security against water breakthrough and the crosscuts are carefully mined under pilot cover drilling. The pilot holes are collared from drill-bays in the crosscut and eventually define the position of the main water bearing zone. Strike development in the Hangingwall Aquifer may be mined about 20 metres below the water bearing ground, and under tight geological control. Dewatering is then achieved by drilling short boreholes to tap the overlying water. It is policy to extend the

dewatering along strike, and to establish as many points of attack as possible to prevent the build-up of steep dewatering cones.

- (ii) If dewatering by boreholes cannot successfully be achieved, crosscuts are mined directly into the aquifer in order to achieve controlled water breakthroughs.

The procedure is to mine a dewatering crosscut under pilot cover to within a safe distance of the fissure. The heading is stopped and a 90 cm diameter steel puddle pipe is installed in a reinforced concrete plug, about 20 metres back from the face. The final rounds are mined into the aquifer with the blasts detonated electrically from outside the plug.

This method is not always successful because the heading can become choked with mud and rubble. However, successful dewatering points of this type yield up to 13 000 m³/d.

The rate of recharge in the Hangingwall Aquifer is considerable and high yields of water are sustained over long periods. The present yield from this aquifer in the South Orebody is about 113 000 m³/d. It is necessary to maintain the high rate of dewatering development on successively lower levels to ensure continuity in lowering the water levels.

(d) *Dolomite Dewatering.* — At shallow depths, water from the Upper Roan Dolomite may be freely transferred to the Hangingwall Aquifer, but the degree of weathering, and therefore the rate of transfer, decreases with increasing depth. As stoping proceeds down-dip, an increasing wedge of Dolomite falls within the cave crack area. This can be seen in figure 2. It has therefore become necessary to commence dewatering of the Upper Roan Dolomite directly. Several methods of dewatering were considered and two have been successfully applied:

- (i) Drilling of long boreholes from dewatering crosscuts. This method has only been successful where the Hangingwall Aquifer contained a minimum of water, mud and rubble which could be cased off without severely reducing the hole size.
- (ii) Mining of crosscuts through the Hangingwall Aquifer and establishing drill-bays in the Shale with Grit formation. From here, boreholes are drilled into the Upper Roan Dolomites. This has

been successful in one attempted crosscut so far and a yield of 30 000 m³/d has been achieved. The method proved expensive and difficult due to the extensive support required in the crosscut as it passed through the aquifer.

(4) *Recharge*

Considering the total volume of water pumped from the mine since it opened in 1957, the cone of dewatering created in the near surface groundwater table is small. The lateral extent of the dewatering cone created within the aquifers is difficult to determine but it may extend for several miles beyond the orebody limits.

To determine the source or sources of any recharge by surface waters into either the aquifers or the cone of dewatering, a major hydrological research programme has been mounted over the past seven years. Infiltration investigations over the Lubengele basin and measurements of the flow of the major Kafue river have so far failed to indicate major single sources of recharging or recirculation of pumped water. The potentially vast reservoir of the Upper Roan Dolomite formation has been tapped by underground boreholes and the rapidity and extent of the resulting draw-down tends to negate suggestions that this may be a major recharge source close to the mine.

Age determinations by tritium analyses of water entering the workings have indicated that the water is not recent rainfall and that the major recharge sources may be more distant than has previously been suspected. Current investigations comprise more extensive water balance studies, river measurements, colour and infra red aerial photographic surveys, chemical and neutron activation analyses of waters, the establishment of a comprehensive network of water measuring boreholes from surface and from underground, and further studies of the age of circulating groundwaters by analysis of the natural isotopes ¹⁴C and tritium.

(5) *Surface Drainage*

An artificial surface drainage system has been developed to improve the natural drainage system of rivers and streams in the vicinity of the mine workings. The additional drainage schemes have been

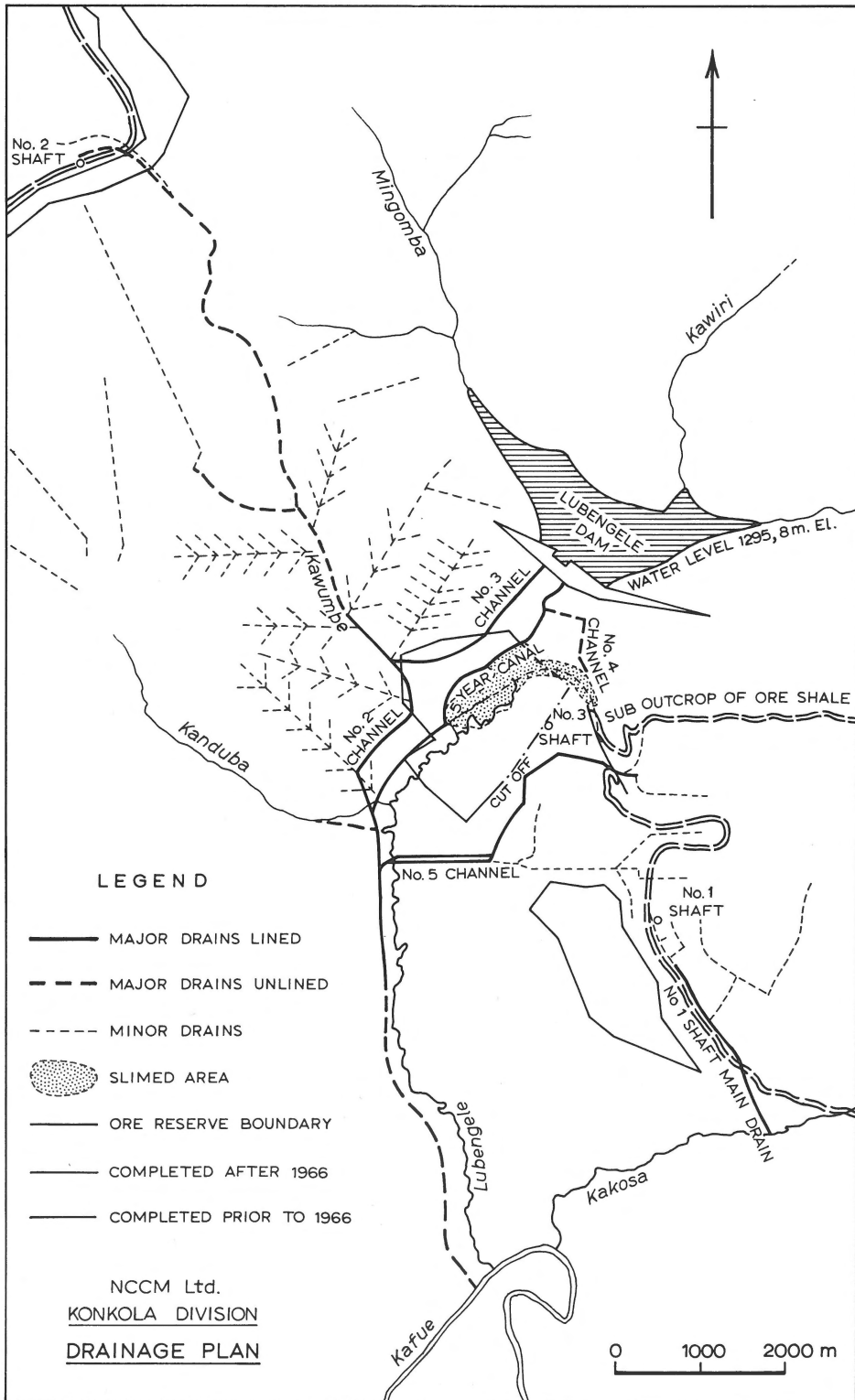


Fig. 4
 N.C.C.M., Ltd., Konkola Division, Drainage Plan.

designed to decrease the amount of water available for recharge and to avoid surface water losses over dewatered and mined out areas. (see fig. 4).

Surface water is carried in lined canals over outcrops of aquifers and in unlined channels over impervious rocks. A thin layer of tailings has been pumped over some of the old river beds to achieve sealing and promote run-off during the wet season. A tailings dam has been built diverting part of the Lubengele stream which would otherwise flow directly over the North Orebody workings.

PLANNING OF MINING OPERATIONS

The large quantities of water experienced and expected during mining are a major consideration in mine planning for Konkola Division.

(1) *Planning Criteria*

In order to dewater adequately, current production and development schedules have been based upon the following assumptions:

- (a) Sub-level development must start one year ahead of stoping.
- (b) Footwall haulage development must commence one year ahead of sub-level development.
- (c) Crosscuts to lode through the water-bearing strata of the Footwall Aquifer must start six months prior to footwall haulage development.

This allows for one and a half years dewatering prior to commencement of sub-level development and two and a half years of dewatering prior to stoping. It is considered that this allows adequate time to lower the water table in readiness for production.

(2) *Water Predictions*

It is necessary to calculate anticipated water inflows in order to plan and install sufficient sustained pumping capacity. Water predictions are based upon the 5-year mining schedules and 15-year mining activity programmes. The present average yield per specific heading is taken as a measure to calculate future estimated water inflows. It has to be noted that quartzite and footwall water is often

uncontrollable whilst water tapped from boreholes, e.g. hangingwall water, is controllable.

(3) *Dewatering Progress Checks*

It is necessary, for production planning purposes, to have regular observations of water levels carried out in order to determine the rate of draw-down. Comparison with previous results serves to detect critical areas and highlight possible future problems.

The progress of dewatering is monitored by regular pressure readings of underground boreholes and by measuring the water levels in specially drilled and equipped surface measuring boreholes.

PUMPING

(1) *Pumping Capacity*

The present sustained pumping capacity to surface at No. 1 Shaft is 368 000 m³/d and this will increase to 491 000 m³/d in early 1972. The sustained capacity to surface at No. 3 Shaft is 91 000 m³/d. Water can be transferred if necessary from No. 3 Shaft to No. 1 Shaft via a drain drive connecting the workings. Total sustained capacity to surface for Konkola Division in 1972 will be in the region of 600 000 m³/d. The total installed capacity will be considerably more than 600 000 m³/d, allowing for stage pumping, stand by and maintenance.

(2) *Pumps*

Basically, two types of pumps are used underground:

- (a) *Submersible Pumps*. — Flyght and Pleuger. Flyght pumps are mainly used as a temporary arrangement in the shaft bottom and for initial development ex sub-incline systems. Pleuger pumps are installed in semi-permanent pump stations. An advantage of submersible pump stations is the saving in the amount of capital development required. Research into the future applications of submersible pumps is in progress. The latest Pleuger pump used is a 1250 hp N167 — 2X4 having a capacity of 18 000 m³/d at 330 m head.

(b) *Conventional Centrifugal Pumps*. — a wide range of this type of pump is used e.g. Sulzer, Mather and Platt, Harland and Pulsometer. Capacities have a wide range. The capacity of a 3250 hp Sulzer 8-stage high-lift pump, for instance, is 20 000 m³/d at a head of about 700 m. Denver equipment is used for pumping slurry.

(3) *Pump Stations*

Underground pump stations vary in size and capacity. In principle, dirty water emerges from the drain drives and is cleared in settlers. The overflow runs into clear water sumps and is thence pumped to surface. Settlers are cleaned at regular intervals and their precipitate pumped to surface as slurry. The complete installation of a 230 000 m³/d pump station — which includes mining of the excavations for settlers, sumps and pump chamber, the civil construction and the installation of mechanical and electrical equipment — takes three to five years to complete, at a cost of approximately 3 to 4 million Kwacha.

CONCLUSIONS

It has become apparent that a clear understanding of the geological features of the Konkola mining area is essential to develop an efficient and successful dewatering scheme. Dewatering of Hangingwall and Footwall Aquifers is essential to meet production and development commitments and sufficient pumping capacity is required to secure dewatering at the required rate. Dewatering progress checks are necessary to follow the rate of draw-down and to establish the position of the dewatering cone and water levels in the various aquifers. It is important to be able to assess the effectiveness of the present dewatering policy. Recharge has been recognised as a major problem and a research programme, directed at establishing the sources of recharge, is in progress.

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