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HYDROGEOLOGY AND DRAINAGE OF COPPER-COBALT MINES IN THE KOLWEZI AREA OF SHABA, REPUBLIC OF ZAIRE

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ABSTRACT

Hydrologic conditions have considerable impact on mine planning, development and operation in the Kolwezi area of Shaba, Republic of Zaire, where open pit and underground copper-cobalt mines have been developed.

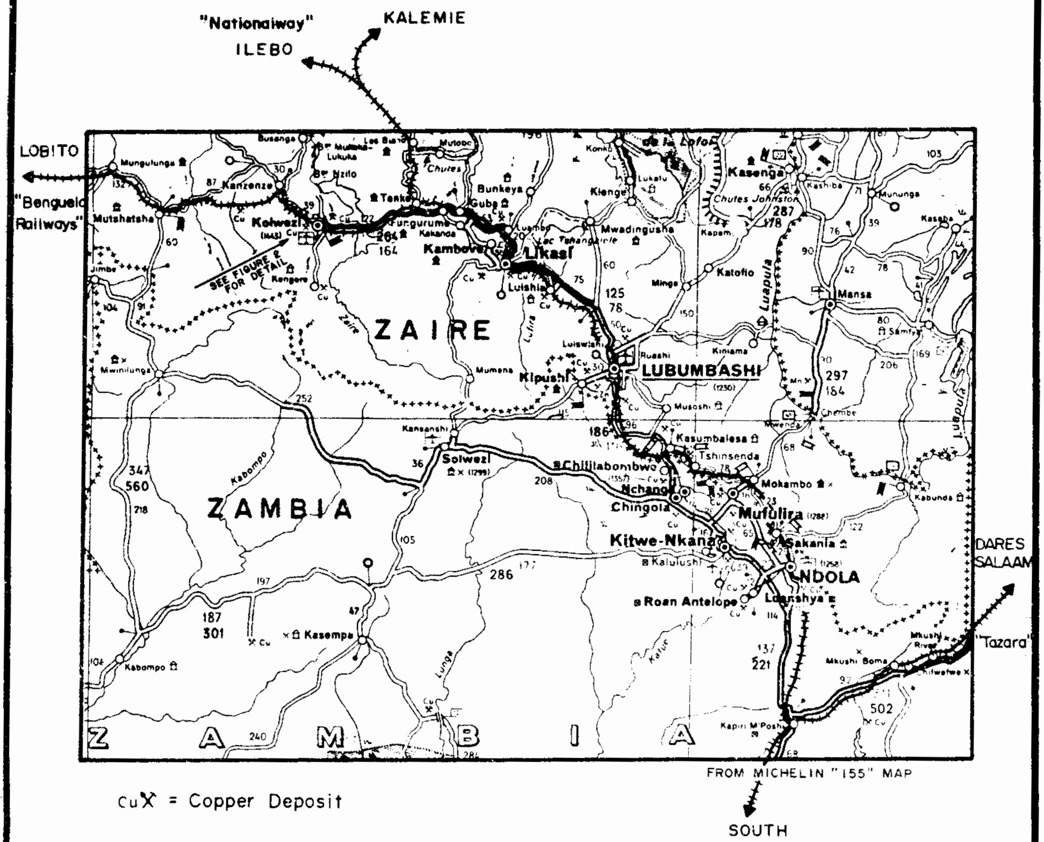
The mine operator, the Generale des Carrieres et des Mines (GECAMINES) retained Geomines, Inc., a mining consulting firm, of Tucson, Arizona, to assist in solving many mining, geotechnical and hydrological problems related to the open pit and underground mining in the Kolwezi area.

A comprehensive hydrologic study of the Kolwezi area included installation of many test and monitoring wells, performance of aquifer pumping tests and studies of local surface and ground water hydrology. Results of the hydrologic investigation were analyzed and recommendations for mine dewatering and water handling were presented. The selection of an optimal long term dewatering scheme for open pit mines was based on computer modeling with the use of a three dimensional finite-difference ground water flow model.

This paper presents general information about geology, hydrogeology and mining activities in the area. A second paper presented by the sames authors describes methods of analyses and results of computer modeling for a group of three open pit mines called Dikuluwe-Mashamba.

INTRODUCTION

The ore bearing strata, primarily copper with accompanying cobalt, are present in the province of Shaba (Precambrian A). The Kolwezi mining district is located in the western extremity of the Shaba copperbelt (see Figure 1). The copper-bearing arc of Shaba is a continuation of the Zambian copperbelt. However, the lithology and complex tectonics make the Shaba section of the copperbelt different from the Zambian section.



CuX = Copper Deposit

0 50 100 150 200 250 km

SCALE

FIGURE 1

LOCATION MAP

ZAIRE AND ZAMBIA COPPERBELT

Zaire / Zambia — BORDER

ROADS

RAILWAYS

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The Kolwezi mining district is on a high plateau called Manika with an average elevation ranging between 1,400 and 1,450 meters above sea level. The area has an annual dry and rainy season, and a savanna type of vegetation. The average annual precipitation is 1,200 mm, with the duration of the rainy season of 210 to 240 days, between September and April.

Mining activites in the Kolwezi area date back to 1903 (Ruwe-Mutoshi mined for gold then for copper). Since that time, a dozen open pit mines and one underground mine were developed in an area of approximately 20 by 10 km.

The Dikuluwe-Mashamba (DIMA) mining area, which is the subject of this paper, is located in the southwestern portion of the Kolwezi mining district. This district consists of three open pit mines in various stages of mining activities (Figures 2 and 3).

The hydrologic study of the Dikuluwe-Mashamba area was prompted by a need for comprehensive knowledge of the area hydrology that would aid in water handling for future mine development. The purpose of the study was to analyze the general hydrologic characteristics of the area and to recommend an optimal dewatering system suited to the planned mine development.

Geology

The ore bearing strata in the Kolwezi area are part of the Katanga system (Precambrian). The stratigraphy is divided into the Roan and Kundelungu Series. The Roan series and its "Serie des Mines" (where the stratiform copper deposits are formed) are a succession of dolomites and dolomitic sandstones (Figure 4). Ore bearing strata (Series des Mines) are present in the DIMA area in the form of several interconnected anticline/syncline blocks. These structures trend southeast - northwest. The main anticlinal structures dip moderately toward the east and dip steeply toward the northwest.

The structural system of the DIMA area contains three ore deposits. These are mined separately in open pits designated Dikuluwe, Mashamba West and Mashamba East (Figures 5 and 6).

The geologic character of the strata and local hydrologic conditions caused deep alteration of the synclinal/anticlinal structures. Most of the overburden is altered and only small parts remain dolomitic. The combination of synclinal structures and deep alteration created surface morphology consisting of wide sandy or argilaceous solution depressions with some sinkholes. These areas are the source of ground water recharge and are sensitive geotechnical areas within the open pits.

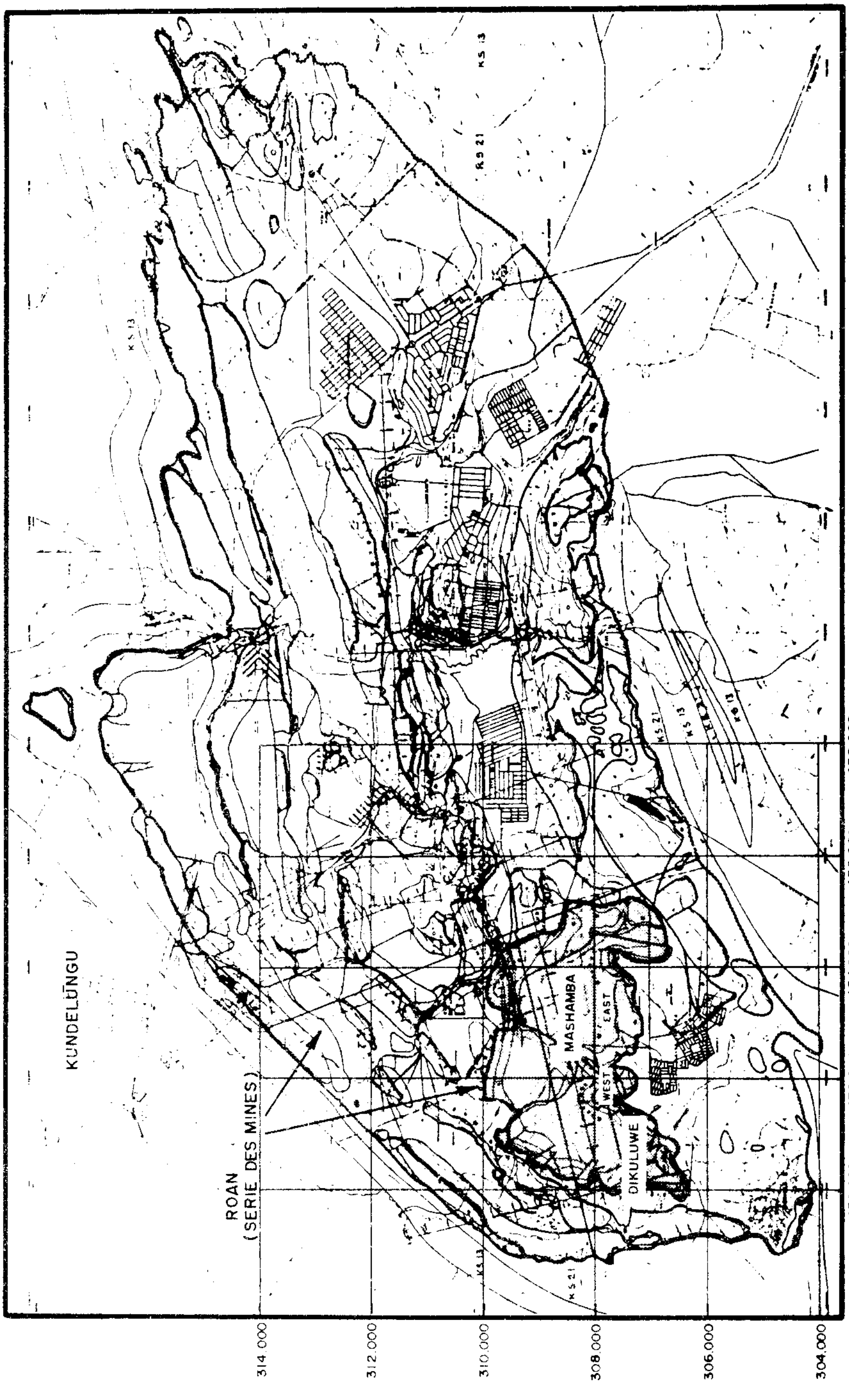

FIGURE 2

KOLWEZI
LOCATION OF DIKULUWE - MASHAMBA (DIMA).

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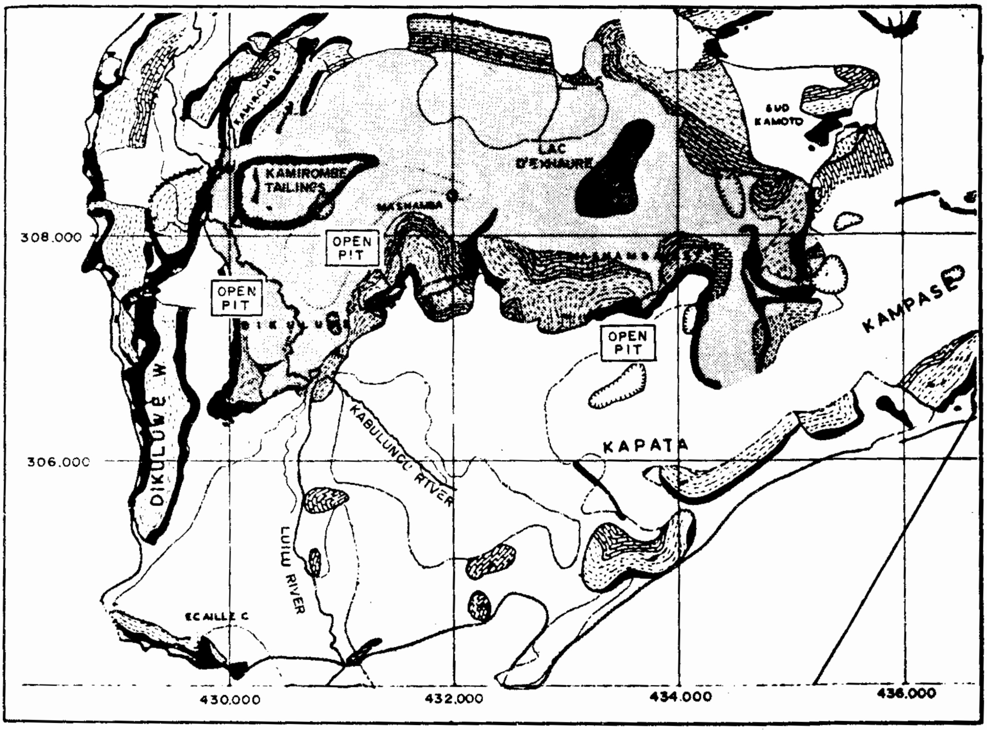
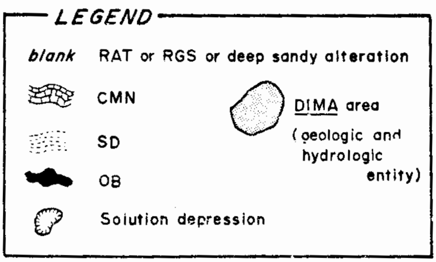


FIGURE 3 **DIMA - SURFACE GEOLOGY**



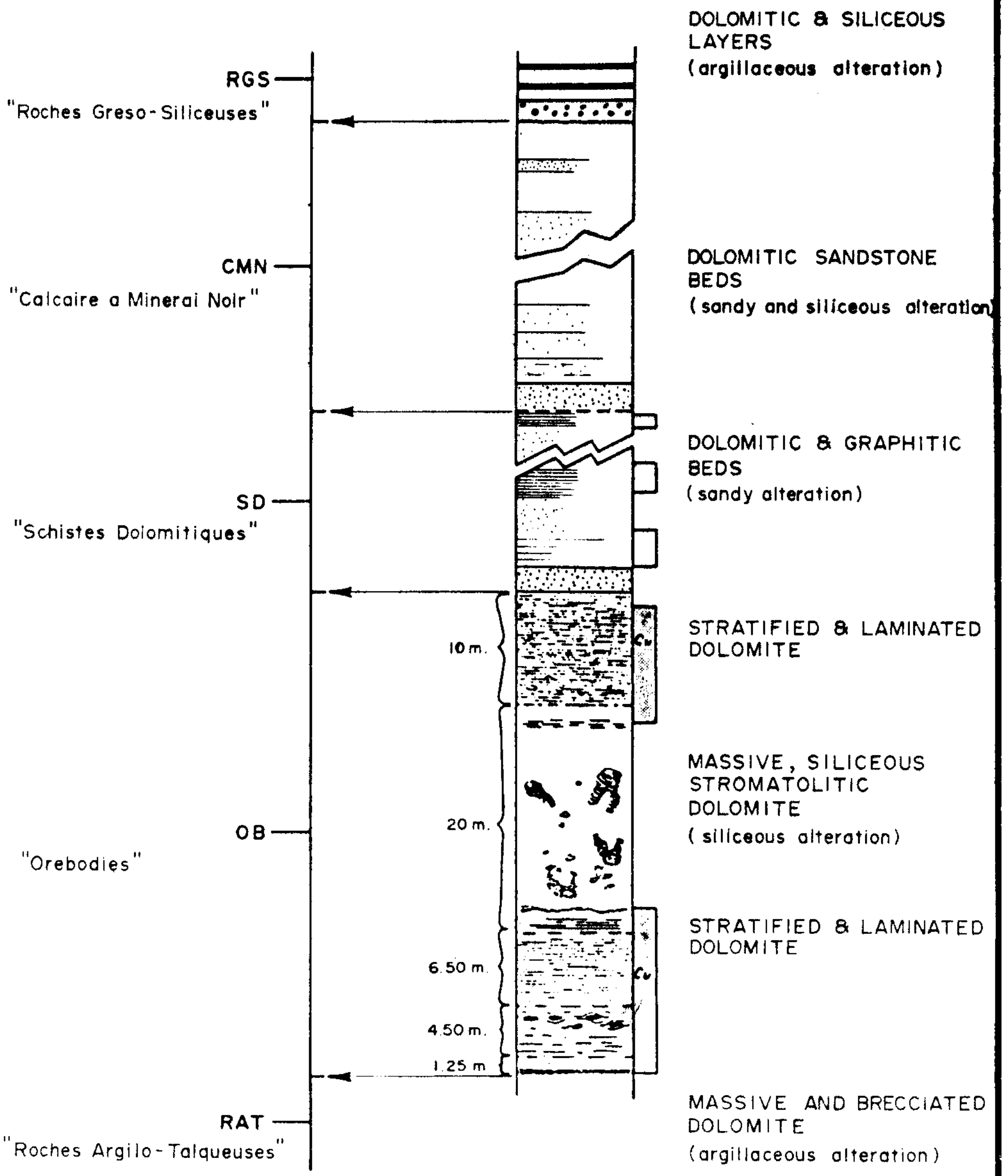


FIGURE 4 DIMA -"SERIE DES MINES" STRATIGRAPHY & PETROGRAPHY

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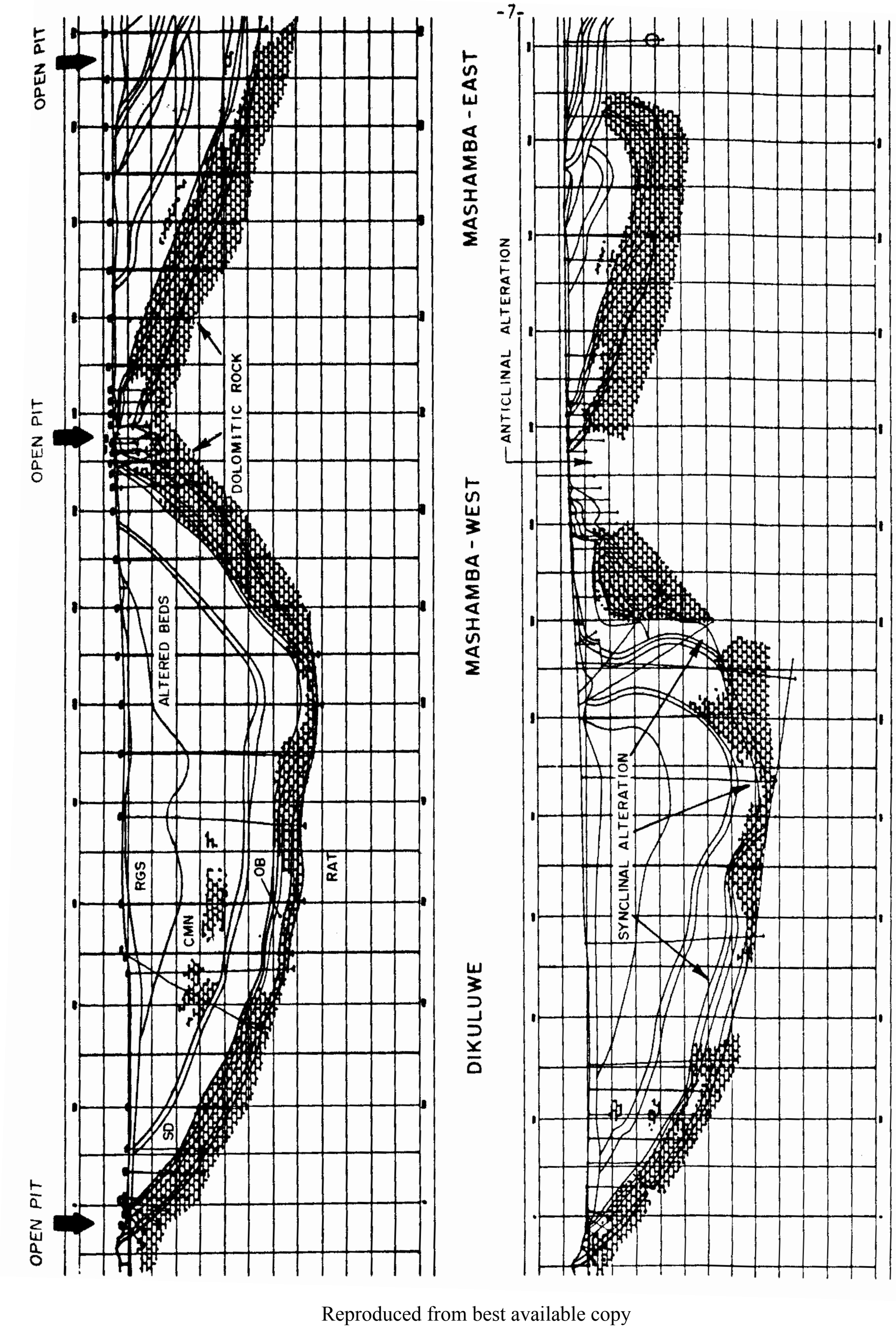

FIGURE 5 STRUCTURE OF DIKULUWE - MASHAMBA

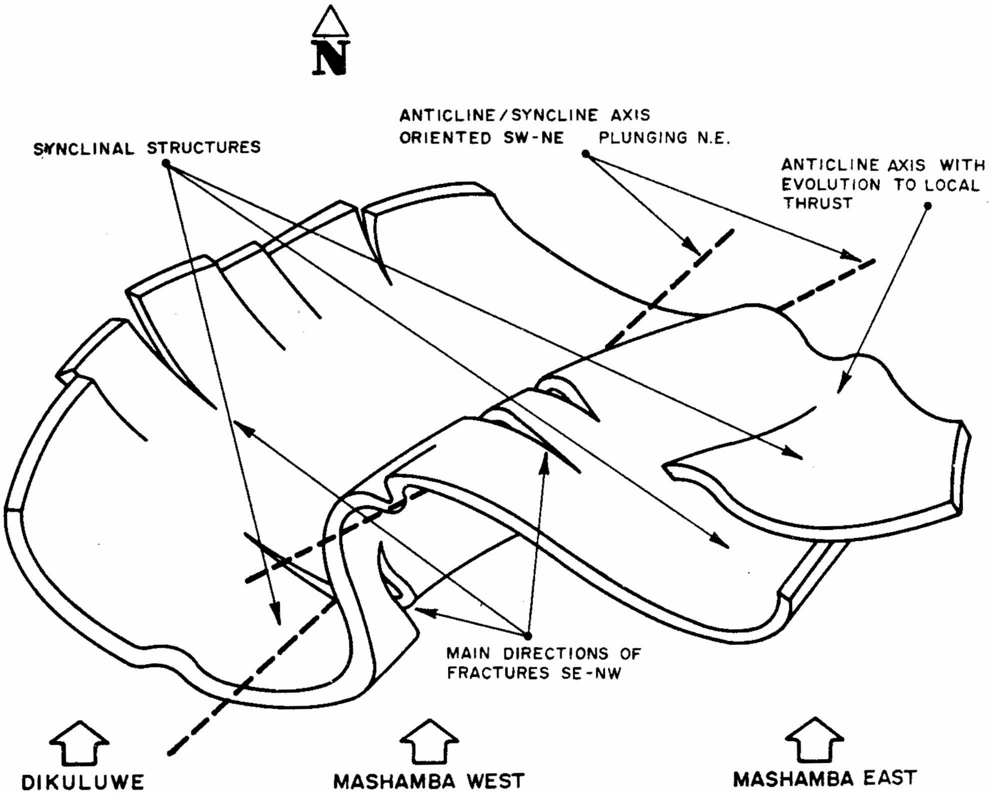

FIGURE 6

DIMA

MAIN STRUCTURAL FACTS

· NO SCALE ·

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Hydrogeology

Hydrogeologic conditions in the Dikuluwe-Mashamba (DIMA) mining district are very complex. The presence of the Luilu River crossing the Dikuluwe pit area from south to north, the existence of the Kamirombe tailings pond and the existence of the Lac D'Exhaure (discharge from Kamoto underground mine which is in another geologic unit, northeast of DIMA) have a substantial impact on the local ground water regime. In addition to surface water bodies, there are, within the study area, several karst phenomena, sink-holes or dolinas. These do not contain impounded water year-round. However, during the rainy season they collect local runoff and contribute significantly to ground water recharge (Figure 3).

The main water bearing strata in the DIMA area are the CMN, SD and OB altered strata. Typically, these units are enveloped or covered by RAT or RGS strata which are less permeable. Geologic characteristics of single stratum are highly variable due to different degrees of alteration. Therefore, the hydraulic characteristics can be highly variable within the same geologic unit. The permeability in the altered strata is mostly primary (intergranular). In the dolomitic parts, the permeability is secondary (fracture controlled).

The hydrogeologic interpretation of the DIMA area indicates that two distinct aquifers are present: one in the RGS strata; one in the CMN, SD and OB strata.

The main aquifer in the CMN,SD and OB strata is of unconfined (water table) character, where these strata are outcropping. In areas where the main water bearing strata are covered with RGS and overburden strata, confined or semi-confined conditions exist.

Aquifer characteristics were obtained from pumping tests performed in four wells. Typically, during the pumping tests, one test well and 2 to 3 observation wells were available. The results of testing are presented in the following table:

TABLE 1

HYDROLOGIC PARAMETERS OF THE PRINCIPAL AQUIFER

WELL NO.	HYDRAULIC CONDUCTIVITY (K in M/DAY)	TRANSMISSIVITY (T in M^2/DAY)	STORAGE COEFFICIENT (S)
P-6	6.1	2,218.3	5.0×10^{-2}
P-10	0.7	367.2	2.3×10^{-1}
P-22	2.0	444.3	6.0×10^{-4}
DIK P-1	20.8	3,958.4	9.7×10^{-2}

Three of the test wells are located in the Dikuluwe area and only one test was performed in the entire Mashamba area. Therefore, and as reflected in the computer modeling, good data were available for the Dikuluwe pit area and less information was available for the Mashamba area. In such an area of highly variable hydrogeologic conditions, it would have been desirable to have several additional pumping tests performed.

Ground Water Regime

The original water table in the DIMA area was not documented at the time of the initiation of mining. However, there are some indications that the water table was very near the ground surface.

The original, pre-pumping water table or potentiometric surface in the principal aquifer for the DIMA area was generated by computer modeling using the existing data on the depth to the water table, the local topography, drainage patterns and surface geology. This information is averaged for each of the 3 open pits in Table 2.

TABLE 2

ORIGINAL, PRE-MINING WATER TABLE ELEVATIONS

Pit Area	Average Elevation of Water Table (1974)
Dikuluwe	1390 m
Mashamba West	1405 m
Mashamba East	1415 m

The natural flow direction prior to mining was probably from southeast to northwest, following the general topography and local drainage patterns. The natural recharge of the aquifer from precipitation and infiltration from the surface streams is increased in the DIMA area by the presence of karst phenomena, sinkholes or dolinas, as shown on Figure 3.

The Luilu River originally flowed through the Dikuluwe pit area from south to north. Prior to mining in the Dikuluwe pit, the Luilu River and its eastern tributary, the Kabulungu River, were dammed just south of the Dikuluwe pit and the impounded water was diverted via pipelines and a diversion ditch. Although the surface flow from these two drainages was prevented in the pit area, the underflow through the alluvial sediments still exists (Figure 7).

The Kamirombe tailings ponds existed prior to the Dikuluwe pit. Although the tailings pond bottom consists of very fine particles, the hydraulic head over a great area induces considerable seepage out of the pond. The seepage from the tailings pond is facilitated by the presence of a sinkhole in the southern part of the tailings disposal area. It is very difficult to estimate the quantity of seepage from the tailings pond. However, using a typical permeability for tailings (3×10^{-6} cm/sec) and an average head of 5m and an area of 720,000 m^2, it is estimated that the seepage could amount to 400 m^3/h. Existence of the seepage from the tailings pond seems to be confirmed by a steep hydraulic gradient between the tailings pond area and the Dikuluwe pit.

The Lac D'Exhaure is located in the north central part of the DIMA area. The sinkhole has been used for discharge from the Kamoto underground mine and concentrator for many years prior to development of the Dikuluwe pit. The Kamoto underground mine was opened in 1957 and production began in 1968. The average dewatering rate from this mine is around 2,600 m^3/hour of which 840 m^3/hour is discharged to this lake. The overflow is drained to the Luilu River (Figure 7). The Lac D'Exhaure is considered to be a source of significant recharge to the principal DIMA aquifers and the seepage to the aquifer can contribute up to 350 m^3/hour. This fact is confirmed by high water level elevations in piezometers located south and southeast of the lake.

The original discharge of ground water from the DIMA basins was downstream along the Luilu River which is topographically the lowest point of the study area. This original ground water flow direction was altered after the initiation of mine dewatering.

HISTORY OF MINING AND DEWATERING IN THE DIMA AREA

Dewatering effort

The Dikuluwe pit was the first open pit mine in the DIMA area and excavation in this pit began in 1975. Very limited documentation is available regarding the first years of the dewatering effort. According to the existing documentation four dewatering wells were operational in the latter part of 1974.

The history of dewatering was interpreted from the available data. A listing of a number of operating wells and of the total average pumping rate for a particular year (as used for the computer model) is presented in Table 3.

FIGURE 7

DIKULUWE - MASHAMBA
SURFACE HYDROLOGIC FACTORS

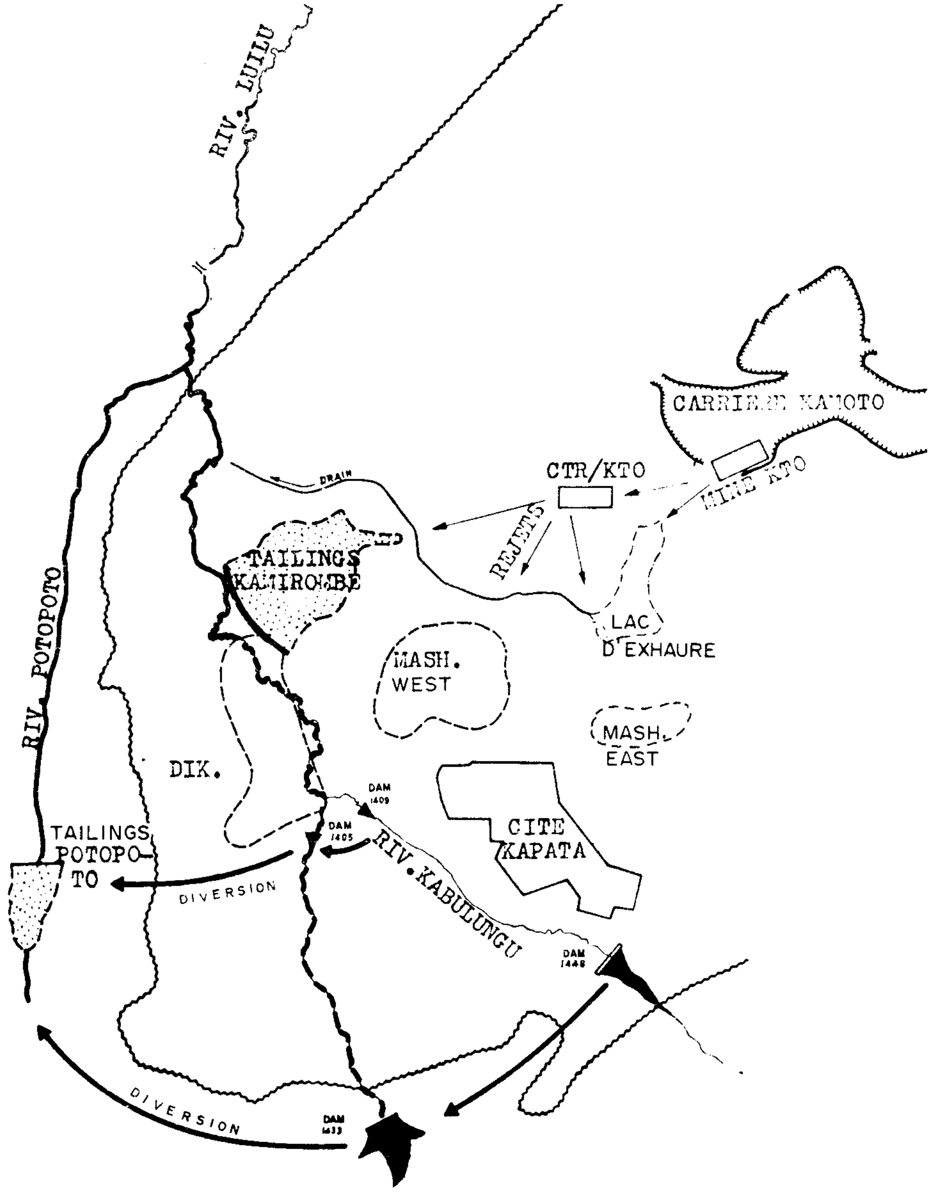

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TABLE 3

HISTORY OF DIMA DEWATERING

YEAR	OPERATING WELLS	AVERAGE TOTAL PUMPING RATE (M3/HOUR)	TOTAL PUMPED PER YEAR (MILLION M3)	TOTAL PUMPED CUMMULATIVE (MILLION M3)
1974	4	690	5.96	5.96
1975	5	1,126	9.73	15.69
1976	6	1,237	10.69	26.38
1977	6	1,372	11.85	38.23
1978	8	1,531	13.23	51.46
1979	10	1,470	12.70	64.16
1980	10	1,580	13.65	77.81
1981	12	1,786	15.43	93.24
1982	11	1,737	15.00	108.24
1983	13	1,776	15.34	123.58
1984	12	1,803	15.58	139.16

From the dewatering history of the DIMA area, it is obvious that most of the effort was concentrated in the Dikuluwe pit area, where the excavation was advancing toward the saturated zone. Dewatering in the Dikuluwe pit sump through the use of a radial pump began during the year 1978.

Dewatering in the other parts of DIMA was initiated much later, and even at this time, it is very limited. In the Mashamba area, only one well was operating for several years to supply water for the city of Kapata. In 1983, pumping in another well located north of the Mashamba West began. One well located in the Mashamba West area operated between 1978 and 1983.

Dewatering in the area of Mashamba East has not yet begun. Due to a lack of pumping and the proximity of this pit to the recharge area, the water level decline over the years was minimal.

Almost ten years of extensive dewatering in the Dikuluwe pit area caused a substantial lowering of the potentiometric surface. From the original level at an elevation of approximately 1,390 meters in 1974, the water level dropped to an elevation of 1,310 meters by the end of 1983. The most drawdown has occured near the lowest part of the pit where the gradient is very steep in all directions except east. The higher permeability of geologic formations to the east produced gradient along the axes of the Dikuluwe-Mashamba mining district much flatter.

A brief history of water level lowering in the DIMA area is expressed in Table 4.

TABLE 4

HISTORY OF WATER LEVEL LOWERING

OPEN PIT AREA	WATER LEVEL ELEVATIONS (m) 1974	1978	1979	1980	1981	1982	1983	1984	TOTAL DRAW DOWN (m)
Dikuluwe	1390	1356	1350	1345	1342	1330	1320	1310	80
Mash. West	1405	1380	1376	1372	1369	1366	1362	1360	45
Mash. East	1415	1414	1412	1410	1406	1402	1400	1398	17

CONCLUSIONS

The excavation in three open pit mines in the DIMA area proceeds at an average rate of 20 m per year. Mining progress at this rate would encounter highly water saturated strata in the near future. Therefore, a study for an increased dewatering effort was undertaken. The selection of an optimal dewatering system for the Dikuluwe, Mashamba West and Mashamba East open pit mines was based on computer modeling. The computer model used in the study, the calibration procedures and the results of modeling are discussed in a second paper entitled "Application of Computer Modeling for the Design of Open Pit Mine Dewatering" presented at this Congress by the same authors.

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