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OPTIMISING DEWATERING COSTS ON A SOUTH AFRICAN GOLD MINE

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ABSTRACT

Many South African Gold Mines are geologically in proximity to the Transvaal Dolomites. This geological unit is karstic in many areas and is very extensive. Very large volumes of ground water can be found in the dolomites, and have given rise to major dewatering problems on the mines. Hitherto, the general philosophy on the mines has been to accept these large inflows into the mine, and then to pump out from underground at a suitably convenient level.

The dolomites constitute a ground water control area which means that Government permission is required to do anything with ground water within the dolomite. When the first major inflows occurred, the mines started dewatering the dolomites and in many areas induced sinkholes, with significant loss of life and buildings. The nett result is that mines have to pump large quantities of water out of the mine but recharge into the dolomite to maintain water levels. During the past 2 years a number of investigations have been carried out to reduce the very high costs of dewatering. On one mine the cost of removing 130 x 10^3 m^3/day is about 1 x 10^6 Rand/month.

The hydrogeologic model for the dolomites is now reasonably well understood. It shows that surface wells to a depth of up to 150 m can withdraw significant quantities of water and reduce the amount that has to be pumped from considerable depth with significant saving in pumping costs. Such a system has a number of additional advantages such as removing some of the large volume of water from the underground working environment and providing a system that can be used for controlled surface dewatering should it be required.

1 INTRODUCTION

The Gold Mines of the West Rand near Johannesburg, South Africa, mine gold bearing reefs from quartzites at depths of up to 4000m below ground surface. The gold bearing strata are overlain by Ventersdorp lava, and Transvaal dolomite. The dolomites are highly karstic in some areas and contain large volumes of water. They are divided into various compartments by a series of north south and east west dykes. When a dyke is intersected or when mining activities cause the 'protective' Ventersdorp lava to break, or when the protective layer of Ventersdorp lava is absent, large volumes of water can flow into the mines.

Lowering of the water table in the dolomites, due to mine dewatering, has resulted in major settlement and sinkhole problems.

This places the mines in a dilemma. If water levels are to be maintained, then pumping from underground must be compensated by artificial recharge. The constant recycling can result in flushing out of the fissures with resultant continuous increase in pumping rates and costs.

The other alternative is to dewater the compartment which can result in damage to existing structures and incur large costs. The latter is strictly controlled by Government to avoid such problems.

This paper discusses some of these problems with a suggestion for an alternative approach which could save significant costs.

2 GEOLOGICAL SETTING

Gold is mined extensively in conglomerates in the pre-Cambrian quartzites at the edge of the Witwatersrand basin on the West Rand. These sediments are unconformably overlain by andesite lava of the Ventersdorp supergroup. These are in turn overlain by up to 1200 metres of pre-Cambrian dolomite. Outliers of karoo sediments occupy depressions in the dolomite.

The dolomite is divided into ground water compartments by intrusive dykes and ground water spills from one compartment to the next through springs on the dyke contacts, although many springs have dried up due to mining impact on the ground water.

A locality plan is shown in Fig 1 and a general plan of the geology and ground water compartments is shown in Fig 2.

3 GEOHYDROLOGY

Mean Annual Precipitation (MAP) is about 750mm. Studies of recharge to ground water are currently being undertaken but estimates to date are generally about 10% of MAP. Until disturbance by mining became significant, most of the recharge was discharged naturally through various springs. Table 1 lists some spring discharges for some compartments.

TABLE 1

Compartment Eye	Elevation metres above mean sea level	Average yield megalitres/day
Gemsbokfontein	1 562	9,2
Venterspost	1 539	21,5
Bank	1 502	46,7
Oberholzer	1 471	55,9
Turfontein	1 417	18,7

Solution weathering in the dolomites is extensive in the area, to the point where major sink holes have resulted in loss of life and property.

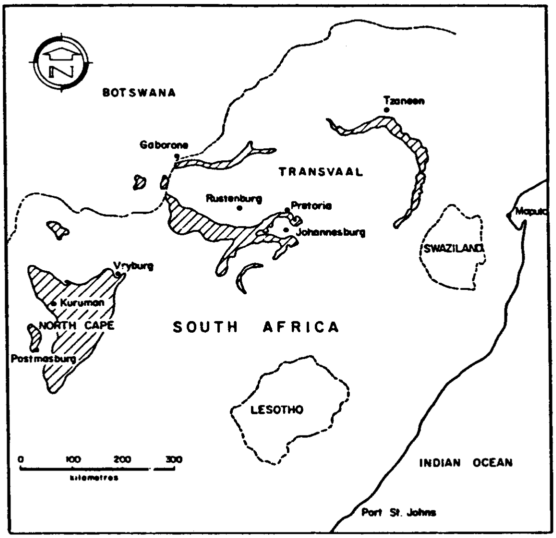


FIGURE 1 SKETCH PLAN TO SHOW DISTRIBUTION OF THE DOLOMITES

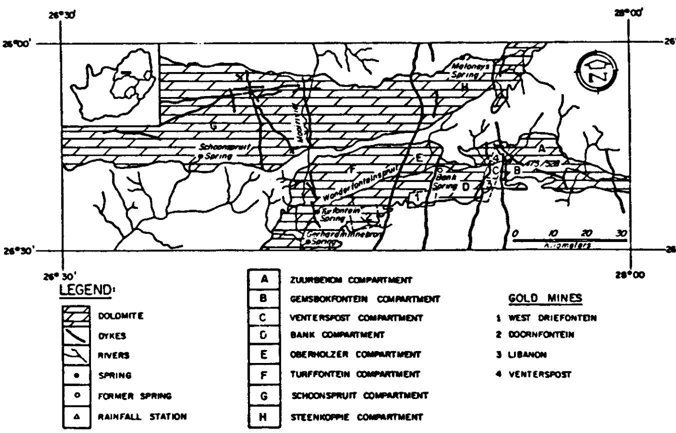


FIGURE 2 LOCALITY OF MAIN SPRINGS AND DOLOMITE COMPARTMENTS WEST RAND DOLOMITES

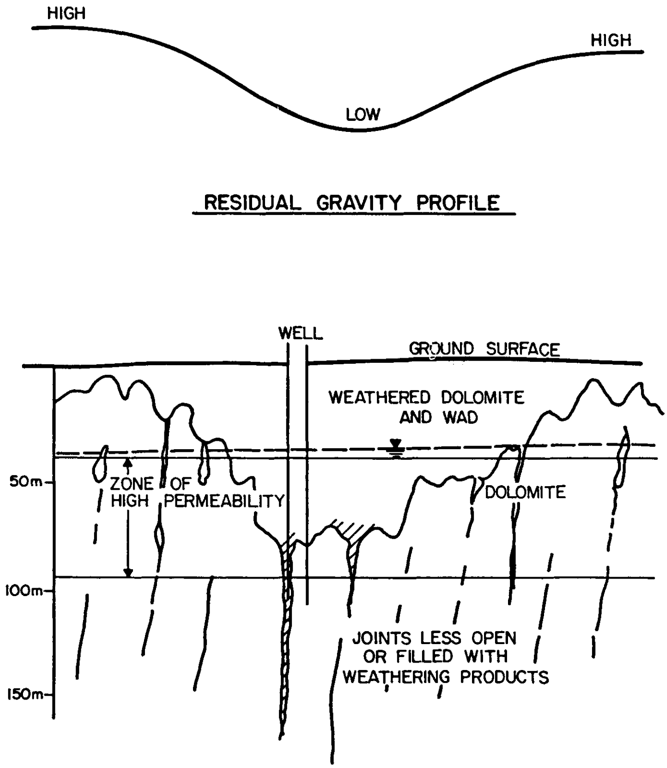


FIG. 3 HYDROGEOLOGIC REPRESENTATION OF A GRAVITY LOW

For this reason, dewatering of the dolomites has become a sensitive issue.

The volumes of water in storage in the dolomites, are very large. Schwartz and Midgley (1975) estimated 2,2 x 10^6 Ml in storage in the bank compartment prior to dewatering.

The main water bearing features are tensional features, generally parallel to the dykes. These features are often zones of closely spaced fractures, rather than single features. Solution weathering has widened these features, though they are often filled with weathering products.

Fig 3 shows a cross-section of the general concept of weathering in the dolomite. Most of the ground water storage in the dolomite is in a fairly relatively thin zone of about 10 to 20 metres.

When dolomite water drains down into the mines, it must be through occasional individual tension features which penetrate the full thickness of the dolomite.

It is well known that some of the mines are 'wet' and others are 'dry'. Doornfontein and Libanon mine have not experienced major water problems, yet they are heavily faulted. It is apparent that the faults in these cases are gouge filled and cannot transmit water easily. Adjacent mines can have very significant problems. West Driefontein and Blyvooruitzicht pumped 170 megalitres per day (Ml/day) from the Oberholzer compartment in 1963. In 1968 a major sudden inrush of 16 Ml/hour nearly closed West Driefontein mine. Venterspost has had large water problems and Western areas GM has pumped steadily increasing quantities up about 130 Ml/day in 1984.

Wolmarans and Guise-Brown (1978) described an investigation into one of the major tensional faults at East Driefontein and showed the following features:-

1 Cavities are limited to the vadose zone and that part in the phreatic zone where hydraulic forces are operative. The pH of the dolomite water below this level varies between 7,3 and 7,9 and dissolution rather than solution is a feature.

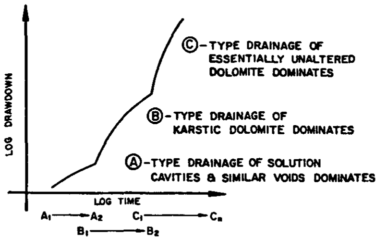
2 The fault zone was filled with weathered dolomite and decomposition products to a width of 35 metres at a depth of 150m below surface. There are records of gouge filled fractures at depths of up to 600m.

Many of the recorded major inflows appear to be associated with failure of the hanging wall in areas where the protective cover of lava has thinned out or has been faulted out. Once the flow path has been created, then the individual fissures can be gradually flushed out, resulting in progressively increasing flows. If the compartments could be dewatered, then the inflow would progressively decrease with lowering water table until inflow matched natural recharge.

Schwartz and Midgley (1975) analysed the rate of drawdown in the Bank compartment after the West Driefontein flooding in 1968. The essential features of this assessment showed a stepped nature of the time drawdown curve as shown in Fig 4.

A generalised statement can be made that for ground within 2 metres of the original ground water table the Transmissivity is greater than 1000 m^3/day/m (values of several thousand are recorded). The range is between 100 and 1000 m^3/day/m for greater than 12m. Similarly values for storage in the region close to the water table range from 1 to 10% but are well below 1% at depths greater than 10 metres.

Recent investigation into ground water resources in the Zuurbekom department have confirmed the above general relationships within the deeper weathered zones which correspond to the major jointed zones. Laterally away from these zones, it appears that Transmissivity and Storage Coefficients also reduce rapidly.



FIG·4 POSSIBLE MODE OF DEWATERING IN DOLOMITE

4 MINE DEWATERING

All of the gold mines on the West Rand have pump stations in the working levels usually at least 1000 m below ground level. Most water extracted has its origin in the dolomite. Of those mines which have had or still have major inflow problems, there are two main scenarios:

1 Where the compartment is dewatered then inflow is probably close to the natural recharge to the compartment.

2 In cases where dewatering has not been permitted, then water extracted underground must be recharged to maintain water levels, resulting in much higher pumping rates than the natural recharge.

The hydrogeologic model has been illustrated and the following paragraphs will illustrate how this understanding may be used to reduce dewatering costs.

The studies in question were developed for one particular mine, but actual details cannot be revealed. Assuming 100 Ml/day are pumped to surface from a depth of about 1600 metres, the operating costs are close to 1 x 10^6 Rand/month. Of the 100 Ml/day approximately 90% is directly recharged back to the aquifer. Thus 90 Ml/day are being recycled through specific features through a head of 1600 metres.

Most of the major inflows to the mines are very localised. Once the flow has developed it is very difficult to seal off due to the volumes and flow velocities involved. An approach not previously used on the mines has been considered. This involves the use of surface wells to pick up water in the high transmissivity zone near surface. Such wells will:

- reduce the pumping head, so that even if the total quantity were not reduced, the reduction in pumping head will reduce costs

- reduce the quantity of water pumped by collecting it at source in the weathered zone aquifer

- reduce and control the possibility of surface settlements by utilizing wells placed in specific areas. Recycling may be required in some areas, but would be less than the present recycling due to lower hydraulic conductivities, in the undisturbed dolomite

- reduce pollution which typically occurs in the mining area. The ground water would gradually clean up due to limited recycling and exposure to the mining area.

The greatest development of the cavernous and highly Transmissive zone is within the zone of fluctuation of the original water table. This is illustrated in Fig 3. Below this zone, the dolomite is still jointed, but the joints are tighter. Where major joints and faults occur, the solution weathering can occur to great depths, but these features are usually filled with weathering products. If these weathering products are not disturbed, then hydraulic conductivity should remain relatively low.

It seems reasonable therefore, that provided boreholes can be sited outside the zone of strong vertical flow which has flushed out weathering products to depth, then shallow wells should be able to collect a significant proportion of the ground water.

The existing systems of recycling 90 Ml/day through a head of 1600 M could be replaced by a system of shallow wells pumping about 45 Ml/day through a head of about 150 m and a residual amount of about 15 Ml/day from the 1600 m level. The two scenarios are illustrated in Figs 5 & 6.

5 GENERALISED DEWATERING COSTS

The unit cost of pumping from the deep levels is about R250 per megalitre/day. For a total of 100 Ml/day this is R25 000/day.

Using the shallow well concept and the figures illustrated in Fig 6 the costs are summarised as follows:-

Deep pumping	15 Ml/day @ R250/Ml	=	R3 750,00
Shallow pumping	45 Ml/day @ R 40/Ml	=	1 800,00
	Total		R5 550,00/day

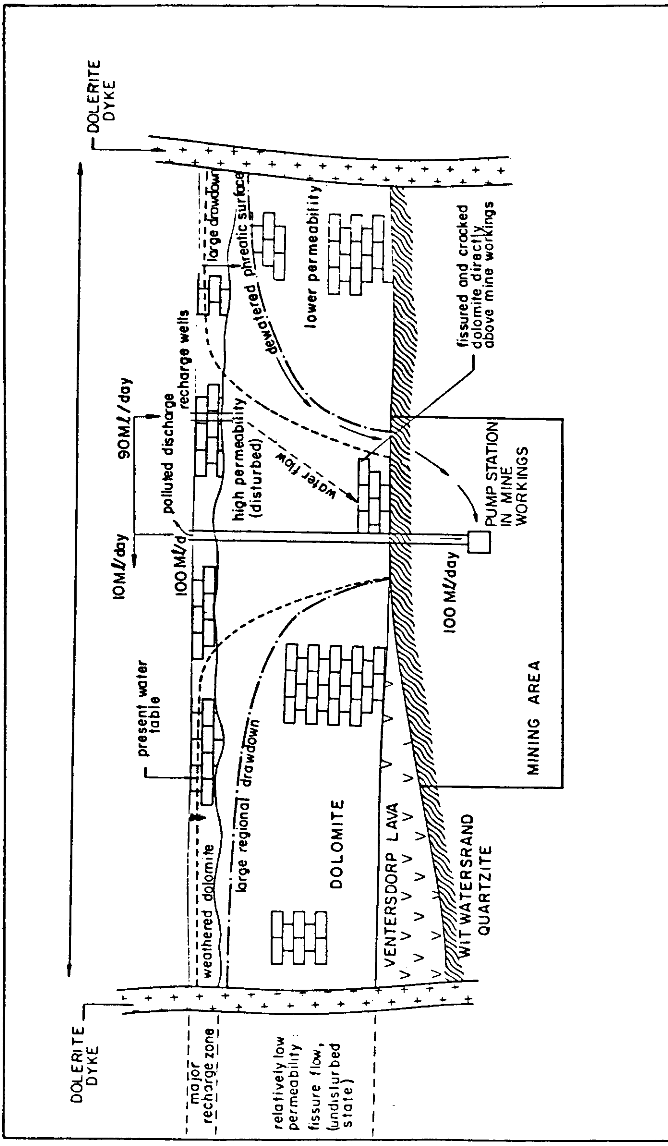


FIG. 5 WEST RAND GOLD MINES : DEWATERING FROM UNDERGROUND

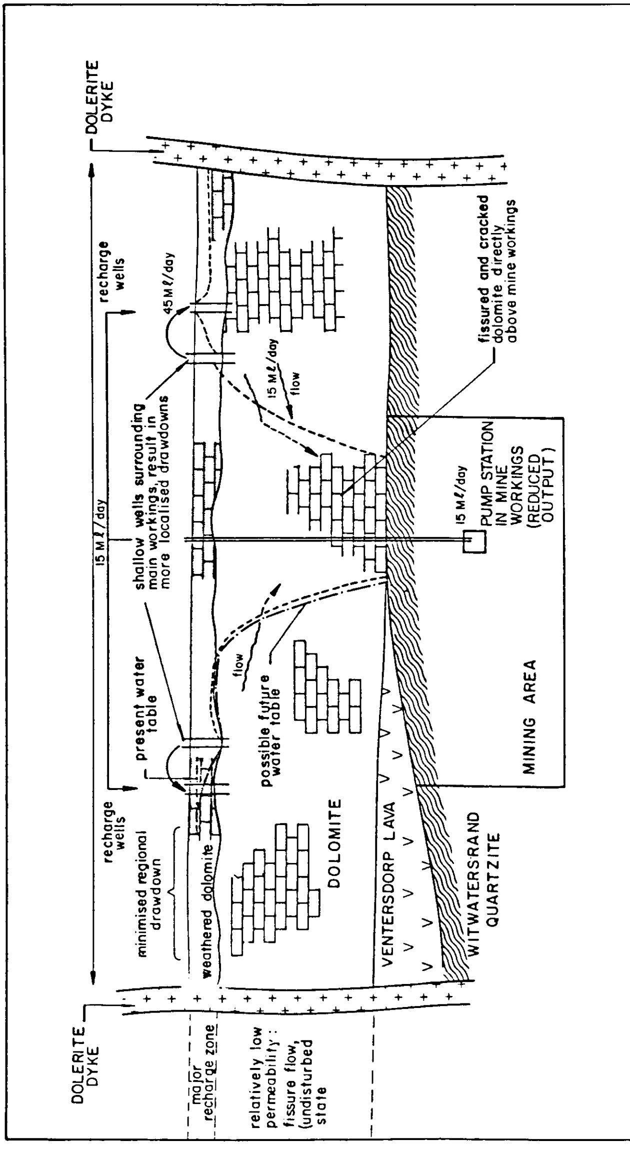


FIG 6 WEST RAND GOLD MINES : DEWATERING USING SHALLOW WELLS

A total of 14 production wells, and 14 recharge wells would be required. To achieve this, it is assumed that a total of 43 wells would have to be drilled (to allow for failures) at a cost of about 2,0 x 10^6 Rand including equipping of 14 wells. A larger number of wells could theoritically extract a larger amount of water from the surface wells but computer simulation of flow into the workings suggested that the lower extraction by surface wells was probably more realistic.

The figures are summarised in Table 1 and show the considerable potential savings in operating costs.

TABLE 1 : GENERALISED POTENTIAL COSTS

TOTAL MINE		PROPOSED SYSTEM			PUMPING QTY ml/day			
PRESENT DISCHARGE ml/day	OPERATING COSTS R/MONTH	TOTAL NO OF HOLES	PUMPING WELLS	CAPITAL COST (RANDS)	FROM UNDER GROUND	WELLS	OPERATING R/MONTH	SAVING R/MONTH
127	966 468,00	43	14	1 500 000,00	87	30	697 810,00	268 658,00
		78	26	2 500 000,00	46	55	412 012,00	554 455,00

6 CONCLUSIONS

The water inflow problem on the West Rand Gold Mines is a major cost item on many mines. The problem has usually been addressed by trying to treat the effects rather than the cause. The dolomites are certainly now treated with respect and mine planning usually takes into account the potential effects of breaking through the hanging wall where the distance to the base of the dolomite is thin. The conclusions of this paper are based on mathematical and computer modelling results and no specific field trials have been made. A number of conclusions can however be drawn:

- Recent investigations have provided reasonable confidence in the generalised hydrogeologic model as shown in Fig 3.

- The system would depend on successful location of the main water bearing features and successful siting of boreholes. Recent investigations for water supplies in the region, show that this can be done.

- The shallow well dewatering option appears to have significant cost saving benefits even if only some of the water is prevented from penetrating to the mine workings.

- Such a system would give greater flexibility in controlling water levels and water quality.

- The system would reduce the danger underground and reduce interference to mining activities.

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