Hilton Mine Dewatering—North West Queensland, Australia

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ABSTRACT

Hilton deposit comprises en-echelon silver-lead-zinc orebodies with reserves in excess of 50 million tonnes. The host rock to the ore is a dolomitic and pyritic shale/siltstone which dips steeply west. The shale/siltstone is deeply leached and porous, particularly over the Ore Zone where the depth of leaching continues down to 440 m below surface, and constitutes an extensive permeable aquifer system containing a large volume of saline acidic groundwater.

Initial production commenced at Hilton in 1987 well below the aquifer. A dedicated dewatering and monitoring programme is in place to ensure security of stoping operations and allow extraction of ore close to the leached zone in future years. Dewatering is undertaken from controlled bores from underground sites. Mine groundwater discharge is presently at the rate of 4000 kl/day with plans to increase to 8000 kl/day. An additional 2000 kl/day of fill and service water and water from secondary aquifers is also pumped from the mine daily. Although recharge rate to the aquifer is minimal, studies indicate that due to the size of the aquifer and future extensions to mine development, dewatering will be a life of mine activity.

The investigations which have been undertaken to determine optimum dewatering techniques and schedules are described. These include production bore tests, mine planning constraints and computer aquifer modelling. Gravity geophysical techniques have been successful in delineating the lateral and vertical disposition of the aquifer. The mine dewatering schedule, whose principal component is underground mine drainage, is also outlined.

INTRODUCTION

The Hilton Mine is situated 20 kilometres north of Mount Isa and the Isa Mine in North West Queensland, Australia. The deposit was

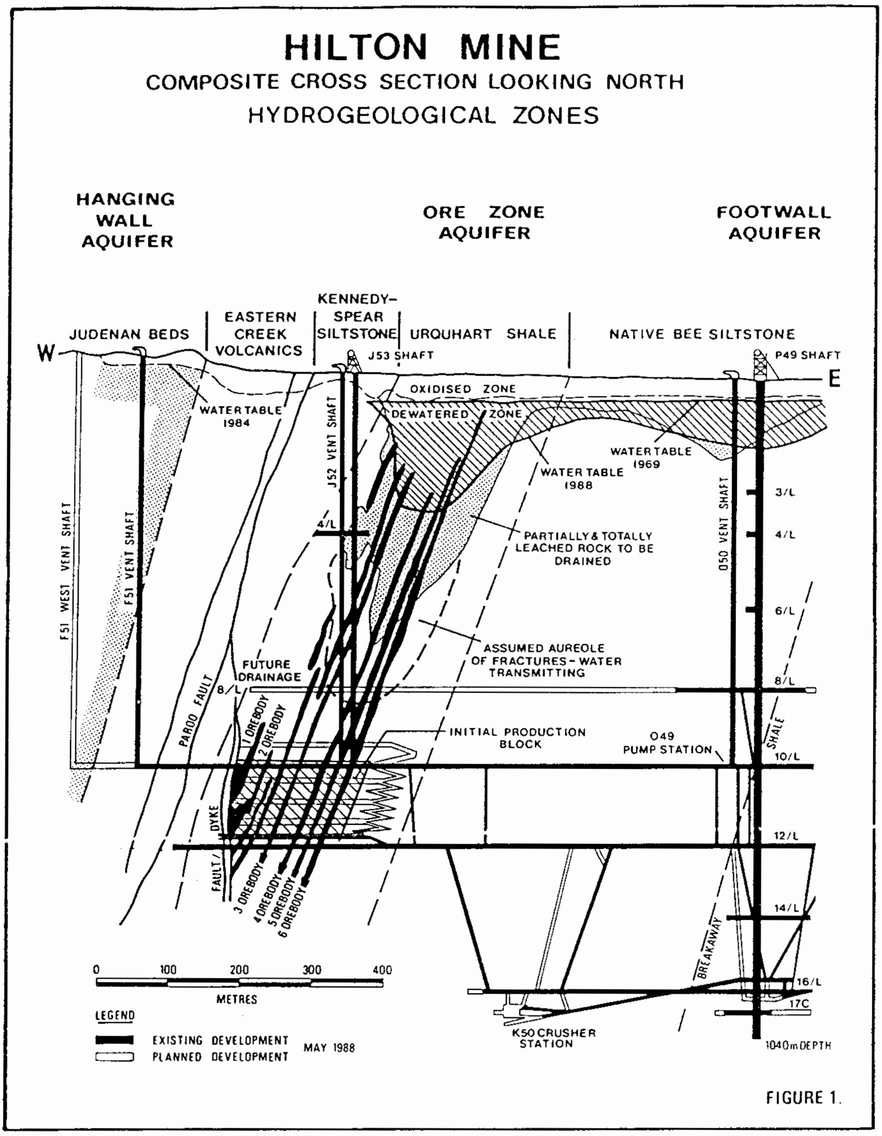


FIGURE 1.

characterised by a complex of strike shears and transverse faults with associated strong jointing. Deformation associated with this faulting has influenced ore continuity and grade distribution, as well as groundwater movement and leaching.

GROUNDWATER OCCURRENCE AND DISTRIBUTION

Three distinct aquifers have been recognised. (Figure 1)

- Ore Zone Aquifer (Urquhart Shale)
- Footwall Aquifer (Native Bee Siltstone)
- Hangingwall Aquifer (Judenan Beds)

All three aquifers contribute to total mine water discharge, however the Ore Zone Aquifer is the largest and most important and will subsequently have the greatest effect on future production areas.

Gravity Survey Delineation

An accurate three dimensional definition of the Ore Zone and Footwall Aquifers became available from the successful application of a ground gravity geophysical survey. Gravity surveying, which can measure the density contrast between weathered/leached rock and fresh rock, particularly ore bearing fresh rock, was therefore available to map the leached zone regionally well beyond the control of drilling and underground development.

The overall precision[3] in the resultant anomalies using a reduction density of 2.67 t/m^3, was of the order of 0.25 mGal, which gave a possible depth deviation of 10%. The altered rock mass possesses a typical density of 2.0-2.1 t/m^3 with a gross range of 1.7-2.3 t/m^3 zonally. Values less than 1.8 t/m^3 are implied for the zone of complete surface oxidation and weathering which is usually about 50 m thick. Bulk densities of 3.1 and 2.1 t/m^3 for the mineralised and altered material respectively were determined.

The final model revealed a deep leached zone associated with the Urquhart Shale extending in excess of 5 kilometres north and south of the existing mine development. Regional trend changes due to major lineaments or faults were also discernible.

This information, combined with data from specifically located monitoring bores and metered mine discharge provided an essential breakthrough in determining the overall aquifer response and evaluation of mine dewatering strategies for the future of Hilton Mine.

The Aquifers

The two main aquifers relevant to mine dewatering are the Ore Zone Aquifer which lies within the Urquhart Shale, and the Footwall Aquifer which lies in the Native Bee Siltstone, (Figure 2) The shale in the Ore Zone Aquifer has been leached extensively with the major leached zone being centred over the footwall orebodies. The leaching is most pronounced in the uppermost sections, honeycombing both the ore and adjacent shales to form a vughy brittle and crumbly mass of high porosity. The intensity of leaching decreases with depth and outwards from the main leached zone. In this partially leached zone, bedding plane partings, shear zones and other structural features are the main conduits for groundwater flow. The maximum depth of leaching over the main ore zone is 440 m below the surface, rising to within 200 to 300 m below the surface along strike. An aureole of 100 m has been assumed around the leached aquifer in which there is the potential for transmission of groundwater via structural conduits.

The Footwall Aquifer is less leached because of the lower sulphide content. It is discontinous along strike and has a broader and shallower zone of leaching.

Both aquifers are elongated north-south along strike and are flanked by impermeable formations. The permeability is enhanced parallel to the strike of the host formations. There is a hydraulic connection between the two aquifers which is controlled by the shallow depth of leaching at the formation contact, thereby creating a low permeability barrier between the deeper sections of the two aquifers.

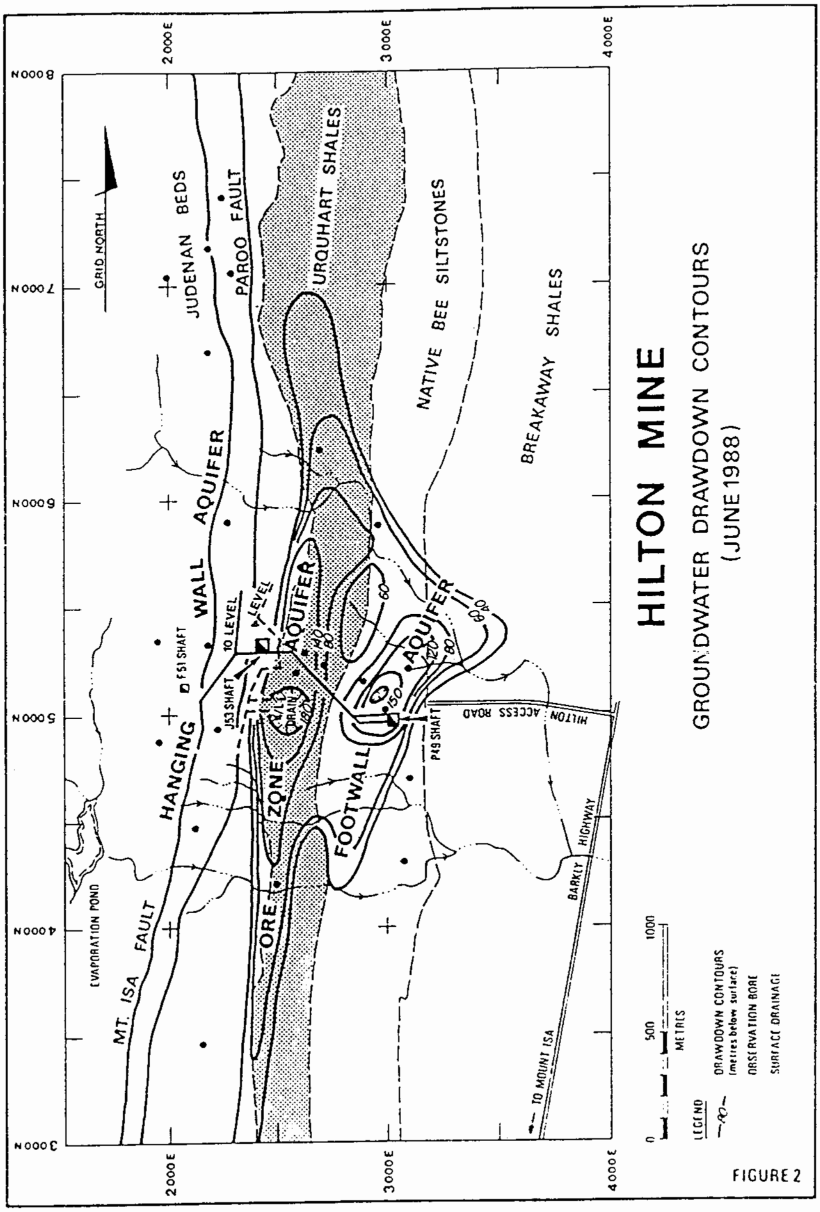


FIGURE 2

GROUNDWATER QUALITY

At the initiation of dewatering in 1969 the groundwater was very acidic and high in heavy metals, particularly iron and zinc. The quality has since improved as groundwater has been released from storage to the north and south, from areas with less sulphide mineralisation.

Present groundwater quality can be summarised as follows:

- brackish to saline with total dissolved salts in the range 5000 to 10 000 mg/l.
- acidic with average pH 5.5.
- high in concentrations of heavy metals, notably iron (up to 20 mg/l), zinc (up to 4 mg/l) and lead (up to 0.4 mg/l).
- hardness in the range 2500 to 4000 mg/l as calcium carbonate.

The discharge water is pumped to surface and passes through a disposal system which has been optimised[4] by both natural and assisted means. Oxidation/aeration, biological and other processes render the water suitable for milling process water and for use in underground hydraulic and cemented fill.

DEWATERING STUDIES

Background

Seven exploratory shafts were sunk at Hilton between 1950 and 1957, four being terminated prematurely due to heavy water inflows at the base of oxidisation at 40 to 50 m depth. A groundwater problem in terms of volume of flow and poor quality (saline and acidic) was therefore recognised at an early stage of exploration.

Underground development recommenced in 1969 with the sinking and lining of two deep shafts, the J53 Shaft to 620 m depth and the P49 Shaft to 1040 m depth[5]. (Figure 1) Dewatering was required at both shafts to facilitate their construction, and over the period 1969 to 1972, the first preliminary data on aquifer characteristics was obtained. From 1973 to 1975 most activity was directed toward reducing water inflows through the concrete linings of the two shafts by placement of underground grout holes, water rings, and surface dewatering bores.

In 1975 the magnitude of the problem was further emphasised when underground development on 4 Level, 240 m below surface commenced. Large groundwater inflows were encountered from the first horizontal diamond drill hole near the J53 Shaft. The proposed crosscut development to link with the P49 Shaft had to be abandoned. Drives were completed over a strike length of 680 m and diamond drilling recommenced. By December 1975 the inflow from diamond drill holes peaked at about 10 000 kl/day causing the drilling programme to be curtailed to avoid further inflows which would have exceeded the pumping capacity at J53 Shaft. These drill holes were then grouted, and inflow reduced to about 1520 kl/day. Development was redirected to 10 Level, 620 m below surface, and well below the aquifer zone.

In 1980, a total of 13 specially designed and strategically sited monitoring bores were installed into the Footwall and Ore Zone Aquifers. A regular water table monitoring programme was initiated on these bores and on 25 pre-existing diamond drill holes. Weirs were also installed to monitor mine water discharges. This work represented a major advance in the understanding of aquifer response to mine water discharge.

In early 1984, Mount Isa Mines Limited and Groundwater Resource Consultants commenced a study to examine and resolve the preferred dewatering strategy for the Hilton Mine, taking into account mine development schedules, disposal or recycling of the discharged waters, security of stopes and the preferred location and capacity of underground pumping stations.

The development of the 050 Exhaust Shaft by raiseboring through the Footwall Aquifer at this time required the installation of a series of surface dewatering bores and also underground drainage bores from the P49 Shaft to permit its successful completion. These bores afforded the opportunity of conducting long term pumping tests, and further refinement of aquifer parameters.

By the end of 1984, approximately 12.5 million kl of groundwater had been pumped from the Ore Zone and Footwall Aquifers.

Aquifer Parameters

Analysis of all pumpage and water level data from 1970 through to 1984, including the results of controlled pump tests, provided the following estimates of aquifer parameters.

Ore Zone Aquifer	. Transmissivity	(north - south)	250 m^2/day
		(east - west)	80 m^2/day
	. Effective Porosity		3 percent
Footwall Aquifer	. Transmissivity	(north - south)	100 m^2/day
		(east - west)	30 m^2/day
	. Effective Porosity		2.5 percent

These values have been used in a computer model of the Aquifers and introduce a degree of conservatism to dewatering estimates if it is accepted that both transmissivities and porosities probably decrease with depth and degree of dewatering in the aquifers.

During the early years of dewatering when discharge rates were relatively low, a large proportion of groundwater withdrawals at the mine were derived from the shallower section of the Footwall Aquifer and strike extensions of the Ore Zone Aquifer to north and south. The concept of a "basin yield factor" has been introduced to account for these groundwater inflows from outside the immediate dewatered zone of the mine area. Over the period 1972 to 1974 for example, when water table levels stabilised, the total pumpage from the P49 and J53 Shafts amounted to 785 kl/day, which can be attributed to regional inflow. In 1983/84 when a pronounced cone of depletion was created at the mine, this regional inflow had increased to about 2000 kl/day.

These inflows have distorted the apparent effective porosities in the early years of dewatering. To account for the anomalously high apparent porosities of 15%, the term basin yield factor is used, encompassing both regional inflow and dewatering of voids in the aquifer.

Aquifer Model

Groundwater modelling was undertaken by Groundwater Resource Consultants, using a version of the Prickett and Lonquist model[6]. Sub-routines simulating free drainage wells and sub-surface drainage were added to make allowance for extensive variations in aquifer geometry and parameters. The geometry of the models was derived from the contours of base of leaching delineated by the gravity and geology studies. An interconnection between the Ore Zone and Footwall Aquifers was presumed only until the end of 1984.

The actual figures for mine water discharge measured over the period 1969 to 1984 were used and the model was then calibrated against observed water level drawdown in the Ore Zone Aquifer over the same period. Basin yield factors (effective porosities) ranged from 15% initially, reducing to 10% in 1977, 8.5% in 1982 and 3% in 1984. Computed water level drawdown (see Figure 3) closely follows the observed drawdown trend, giving confidence in the model parameters.

The model was then used to predict future drawdown levels, using a range of different dewatering schedules.

Dewatering Strategy

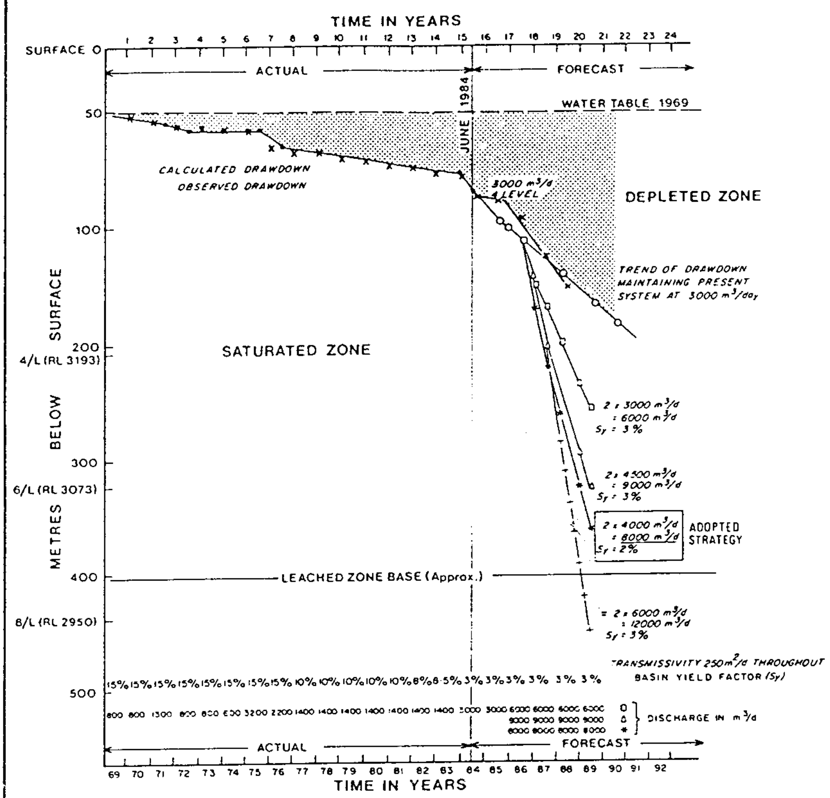
Formulation of a dewatering strategy took into account a number of hydrogeological, mine planning, environmental and engineering considerations and constraints. The preferred strategy derived from a series of simulations and scenarios was as follows:

. increase and maximise 4 Level discharge system via new diamond drilled drainage bores, using the existing pump station.

. install a large capacity underground pump station at P49 Shaft 10 Level.

. proceed with development of 8 Level and construct drainage bores into the base of the leached zone and increase total discharge, the development to also act as water cover above the 10 to 12 Level stopes.

. phase down 4 Level drainage system in line with progress of 8 Level development and drainage and direct 8 Level drainage to the new pump station on 10 Level at P49 Shaft.



HILTON MINE
PREDICTED DRAWDOWNS
ORE ZONE AQUIFER

FIGURE 3.

evaluate the increased mine water discharge for utilisation in milling and stope filling applications.

Based on this strategy, the aquifer model was then used to predict the probable duration and magnitude of dewatering required to achieve effective security against potential groundwater inflows to the 10 to 12 Level stopes. In effect, it was proposed to dewater a zone immediately above the initial production area, covering a 500 m strike length, over a 3 to 5 year period. The timing was based on scheduled increased production rates and rate of depletion of reserves. This indicated a dewatering requirement from the Ore Zone Aquifer via the 8 Level drainage system of 8 000 kl/day. (Figure 3)

CONCLUSIONS

In 1984 a dewatering strategy was formulated combining this hydrogeological knowledge with aquifer modelling, and taking account of schedules and constraints in mine planning, installation of pump stations and groundwater disposal.

Dewatering is closely following predicted trends although rescheduling of mine production rates and access development and drainage on 8 Level has meant that the dewatering strategy devised in 1984, hasn't been fully implemented.

A major pump station (049) has been constructed and commissioned on 10 Level comprising two Mitsubishi Mars H225 high pressure dirty water pumps. These 450 kW pumps each have a capacity of 38 l/s. It is now scheduled that controlled bores on 8 Level will be commissioned in early 1989 and the discharge rates from the Ore Zone Aquifer (including 4 Level) increased to at least 8000 kl/day to complete the dewatering programme.

Drainage from 4 Level has been increased through the addition of 2 production bores and the Ore Zone Aquifer discharge increased from 3000 to 4000 kl/day. Except for a short period during 1984/85 when the bores were closed to effect dewatering of a new exhaust shaft, F51, discharge from the Ore Zone Aquifer has been continuous and constant. This drainage has resulted in a further 85 m water level drop in the Ore Zone Aquifer to 195 m below surface.

The resultant drop in aquifer water level corresponds well with the predicted computer model drawdown and clearly demonstrates that the dewatering strategy will be achievable and manageable.

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REFERENCES

1. Black, B.N. and Mutton, B.K. (1986) The Development of Hilton Mine 1947-1985. 13th Congress CMMI., Singapore. pp 11-20.

2. Mathias, B.V., Morris, D., Clark, G.J., and Russell, R.E. (1973) The Hilton Deposit. Bull. Bur. Mineral Resources, Geol. and Geophysics. No. 144. pp 33-58.

3. Leaman, D. and Mutton, B.K. (in prep) (1988) Gravimetric Delineation of Aquiferous Alteration Zones, Hilton Mine, Queensland.

4. Chapman, B.M., Jones, D.R., Jung, R.F., Jones, C.J., Kadletz, O. and Teague, J.W.S. (1988) Treatment and Utilization of Hilton Mine Water. 3rd Int. Mine Water Congress Melb. Aust.

5. Salter, M. de G. (1976) The Sinking and Equipping of P49 Shaft, Mount Isa. 2nd Australian Tunnelling Conf. Melb. Aust. pp 203-211.

6. Prickett, T.A. and Lonquist, C.G. (1971) Selected digital computer techniques for groundwater resource evaluation. Illinois State Water Surv. Bull., 55.