Relieving the pressure

Jeremy Dowling and Geoff Beale of Water Management Consultants explain the core concepts and solutions in open-pit water control

MOST active open-pit mines encounter groundwater sooner or later. The extent to which operations are impacted by groundwater can vary considerably. In most situations, a properly planned and managed program of water control will provide added value to a mine project and contribute to safe operating conditions. In some cases, dewatering and slope depressurisation is essential to mine implementation, providing for workable conditions, improved slope performance and considerable annual operational cost savings.

A robust conceptual understanding of site hydrogeologic conditions and interactions with the mine plan is essential for implementation of appropriate pit dewatering measures.

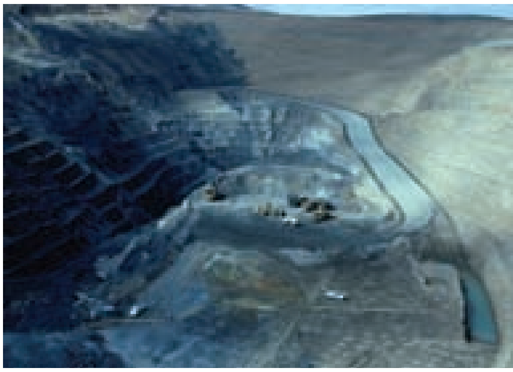
Understanding the dewatering requirements for a mine involves integrated assessment and quantification of geology, geologic structure, rock mass hydraulics, rock mechanics, surface hydrology and climate. The operating plan must then be placed in the site-specific hydrogeologic context, enabling dewatering issues to be identified, predicted and managed in advance of mining.

Depending on the setting, dewatering can involve several key components including,

- **In-pit groundwater storage removal:** Typically involving in-pit dewatering pumping wells to remove the groundwater occupying the pores or fractures in the rock mass within and surrounding the mine shell. Wells are installed and operated to lower groundwater levels ahead of the active benches. Wells that are within the mining footprint are at risk from mining activity, and this is planned for, with replacements installed as required to maintain dewatering production.
- **Interception and removal of lateral groundwater inflow:** From the regional hydrogeologic system surrounding the mine, typically requiring operation of pit perimeter dewatering or interceptor wells. These are positioned to remove groundwater that is flowing toward the pit from the surrounding system and to lower the groundwater table behind the pit slopes.

Understanding of the broader-scale groundwater flow system and interaction with the local pit area is important to guide appropriate placement of interceptor wells on the primary groundwater flow paths. In many cases these are controlled by geologic structure. In some cases, it may be possible to achieve considerable cost savings by intercepting groundwater flow toward the workings at shallow levels.

- **Pit slope depressurisation:** In some settings, pit slope rock mass is inadequately permeable to support pumping from wells. Elevated pore pressures can develop in the slope because the rock is unable to adequately drain as mining advances. Depressurisation may then become necessary. Common approaches involve horizontal or vertical drains installed directly into the slope sectors of concern. In some of the larger pits, cost-benefit analysis may support the installation of a depressurisation tunnel driven behind major push-backs and expansions. Detailed interaction with slope-scale structural and geomechanical programs is typically required so that depressurisation measures are planned and focused in areas where benefit is most needed and provides most value to the overall mining operation.
- **Management of local recharge on the pit crest:** Many open-pit operations include process facilities located close to the pit crest. These can create artificial recharge to the pit slope, contributing to in-pit flows and pore pressure in the pit slope wall rocks. Controlling such flows can be a challenge because sources and flow paths can be difficult to identify. Diligent operation of process facilities and infrastructure is often important for minimising recharge at the crest of the pit wall.
- **Control and removal of surface water runoff:** Generated by incident precipitation falling on the pit slopes or other contributing drainage areas. This can be of considerable importance and, in some cases, is the major challenge for operations, particularly in tropical or monsoonal environments where highly intense rains occur. The pit floor is a concentration point for runoff generated from the pit slopes, so that reserves and infrastructure in the pit-floor can be vulnerable to surface water inflow. Pit floor sump pumping and adequate booster facilities to remove surface water inflow and other water accumulation in a timely manner is often an essential requirement, depending on the specific mine setting.



Open-pit mines that plan and implement a program of advanced dewatering will typically gain benefit in the form of:

- **Reduced blasting costs:** Wet blast holes require more costly emulsion explosives. Lowering and maintaining groundwater levels beneath the active benches results in reductions to wet blast hole frequency and reduced blasting costs.
- **Lower haulage costs:** Dry ore and waste rock weigh less than wet material, so removing groundwater from the benches being mined presents a haulage cost saving.
- **Improved working conditions:** Including traffic and diggability; particularly where significant groundwater would otherwise lead to reduced muck cohesion or where excessively wet haulage areas would create unstable traffic conditions.
- **Improved slope performance:** Dry and depressurised slopes always perform better than wet slopes and, in circumstances where slope design or factor of safety is 'pore pressure sensitive', considerable added value can be achieved by reducing pore pressure to a point where design angles are attained or improved, and the factor of safety is increased. Most importantly, pore pressure control is integral to slope management and safe operating conditions.

The overall cost-benefit of a dewatering program needs to be assessed to ensure that it can add maximum value to the mine operation. The preferred approach is to develop an interpretation of site conditions and then progressively ramp-up the dewatering and slope depressurisation system. Constant monitoring of system performance can then be undertaken and the experience gained from initial dewatering used to help optimise the longer range plan. It is important to identify and address areas of uncertainty in the dewatering system. This will enable future changes to the mine plan or to the hydrologic interpretation to be pro-actively incorporated into the system design. As with many aspects of the overall mining operation, if the dewatering system is flexible and adaptable to change, it will produce greater efficiency and greater cost savings in the long run.

Dewatering flow is pumped from the pit and utilised for mine process supply

Working against the flow

The static groundwater level at Morenci was about eight benches above the pit floor, depicted by brown staining of the rock

Jeremy Dowling of Water Management Consultants and Todd Ashinhurst of Freeport McMoRan Copper and Gold outline two practical examples of open-pit dewatering

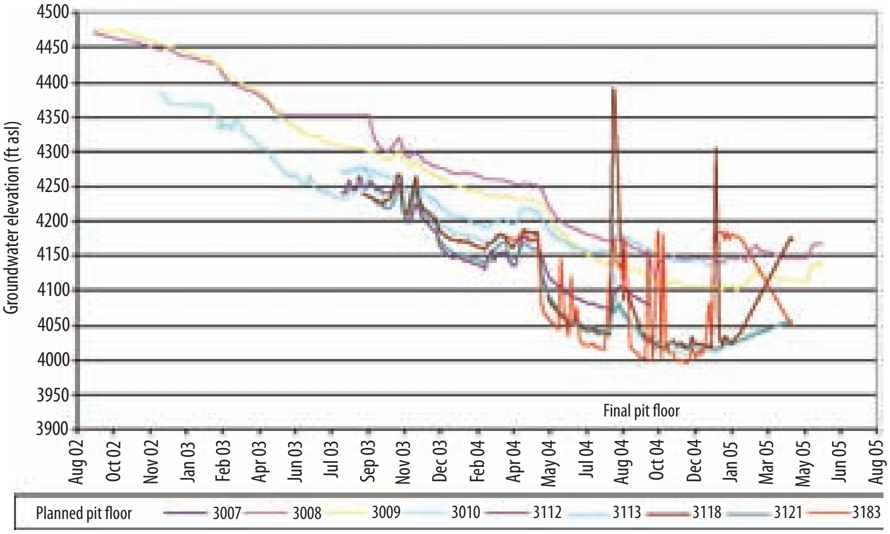
THIS article presents two open-pit dewatering case histories. In each case, applied hydrogeology was combined with the implementation of practical dewatering measures to provide added value to mining operations.

The first example is from the Morenci copper mine complex in Arizona, where a series of strategically placed in-pit dewatering wells were installed and operated to reduce groundwater inflow to the advancing Metcalf pit, resulting in improved operating costs and conditions. The second example is from Chino copper mine in New Mexico, where a series of horizontal drains were installed to reduce pore pressure and the movement of a slope sector, allowing the mine plan to be implemented.

MORENCI, ARIZONA

Morenci copper mine is located in east Arizona on the lower slopes of the White Mountains. The complex includes multiple open-pit mining of oxide and sulphide ores. Mineralisation is classic copper porphyry, hosted in regional sedimentary and intrusive bedrock. In 2003, mining of the Phase 2 Metcalf pit commenced. The mine plan called for a relatively fast expansion and deepening of the Phase 1 pit over a period of three years.

Groundwater drawdown was tracked in piezometers located in and around the Metcalf Phase 2 pit



Existing site monitoring data revealed groundwater levels very close to the bottom of the Phase 1 pit. The planned, ultimate pit floor was about 550 ft below static, groundwater levels.

A dewatering programme was pursued with the overall aim of reducing the impact of groundwater on the mine and, in particular, to achieve:

- Fewer wet blast holes, lowering blasting costs and increasing blast efficiency.
- The removal of moisture from the ore and waste, resulting in reduced haulage costs.
- Reduction of pit-slope pore pressure to increase slope performance.
- Improved in-pit transport and operating conditions.

A pre-existing hydrogeologic assessment of the pit area indicated low hydraulic-conductivity rock mass and, consequently, only minor inflows during mining were predicted. However, a re-evaluation of the hydrogeology of the pit area was conducted, concentrating on structural geology interpretation. This suggested that, while much of the rock mass would produce minimal water during mining, as originally predicted, more significant inflows could occur in discrete, structurally-controlled fracture zones.

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A new in-pit dewatering well at Morenci produces groundwater as it is being constructed

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A series of 6-in diameter pilot holes were drilled in the pit using the reverse-circulation air-rotary method. The purpose of these holes was firstly to investigate and test the occurrence of groundwater in the structural system and, secondly, to confirm the productive locations for the installation of dewatering holes.

A key aim was to intercept yielding fractures low in the deposit, beneath the planned, ultimate pit floor, thereby facilitating dewatering to full depth.

A major challenge was to establish drilling locations that met structural and hydrogeologic criteria, but could also be maintained as infrastructure within the mine plan.

Hydraulic tests were performed in each pilot hole as it was drilled and included extensive airlift testing, well-head injection tests and groundwater-recovery monitoring through the drill string. The data was interpreted to assess the extent and potential productivity of the fracture systems intercepted by each hole. The most prospective pilot holes were subsequently reamed to a larger diameter and converted to dewatering production wells.

The depths of the wells ranged from 400-700 ft, and each one was completed with 8-in schedule 80 PVC casing and screen.

Electricity links were brought to each well from the main mine power loop. Surface-discharge lines were installed, conveying water from each well to a staging tank and booster in order to transfer dewatering flow out of the pit. An initial system of five wells was installed with a combined yield of 400 gallons per minute (gpm). The remaining pilot holes were converted to piezometers, which were used to monitor the drawdown of the groundwater system in the pit area.

Pit area groundwater-level targets and rates of drawdown were established, based on the mine plan, while the piezometer-monitoring data was continually tracked and compared to the targets.

After an initial period of pumping experience and interactive monitoring, it was determined that a second round of production-well installations would be needed to maintain dewatering progress. Additional in-pit wells were constructed to increase output to 900 gpm at peak production. During the final stages of mining, access to some of the wells became an issue and the ability to maintain pumped, dewatering flow was compromised. However, the dewatering system enabled full implementation of the mine plan without water-related disruption.

Tracking of blast-hole loading was completed throughout the operation. The dewatering efforts significantly reduced the number of holes requiring emulsified explosive. It was predicted that 90-100% of holes would required emulsion in the absence of dewatering.

Yet, as mining progressed, only 30-70% of holes required emulsion, with the higher values due to seasonal pit-area surface-water inflow and recharge from the intense, monsoonal rain. The lower values were achieved by continuing to pump from the wells, thereby removing recharge and storage throughout the drier parts of the year.

At the end of mining, all-inclusive dewatering cost-savings to the operation were reconciled and were estimated to have added about US$4 million of value to the mining project, as well as helping to optimise safety and working conditions.

CHINO, NEW MEXICO

The Chino mine is located in western New Mexico within the historic Silver City mining district. Like Morenci, the mine is centered on a classic copper porphyry and includes the Santa Rita open-pit plus a series of historic underground workings.

The open pit has been worked since around 1930 and is developed to about 1,100 ft below pre-mine static-groundwater levels. Historic groundwater inflows during mining were very minor, indicative of low hydraulic-conductivity rock mass.

During 2004, a new series of push-backs were brought into the mine plan. One area of planned mining involved a short-term cut into high-grade material close to the base of a historic slide. Historic movement of the slide area dates back to the mid-1980s. In June 2005, the slope reactivated, involving a total of 18 mining benches and a strike length of 1,000 ft along the toe of the slope. The mechanism of failure was defined as reverse toppling.

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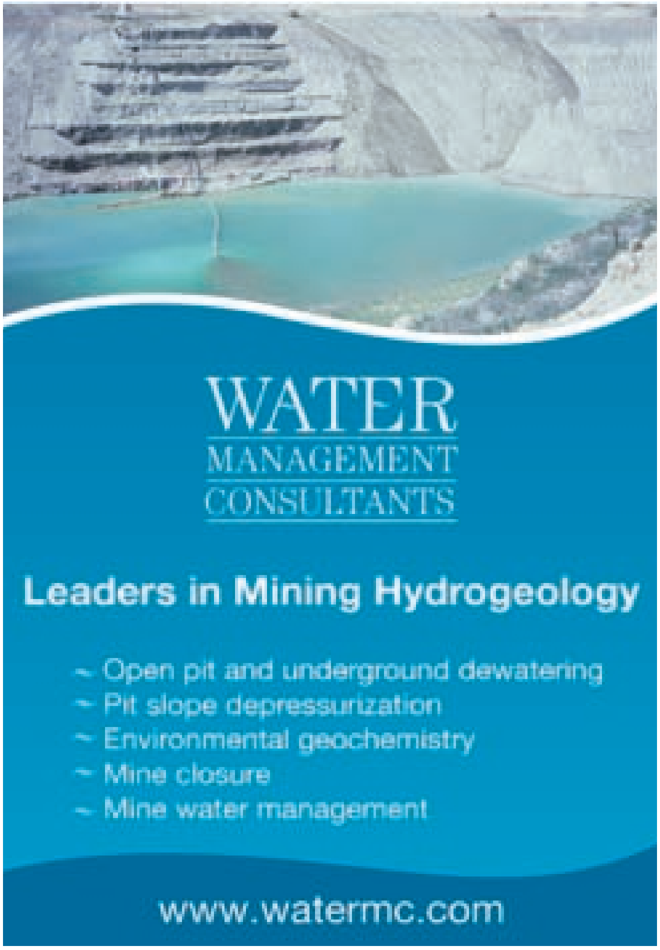
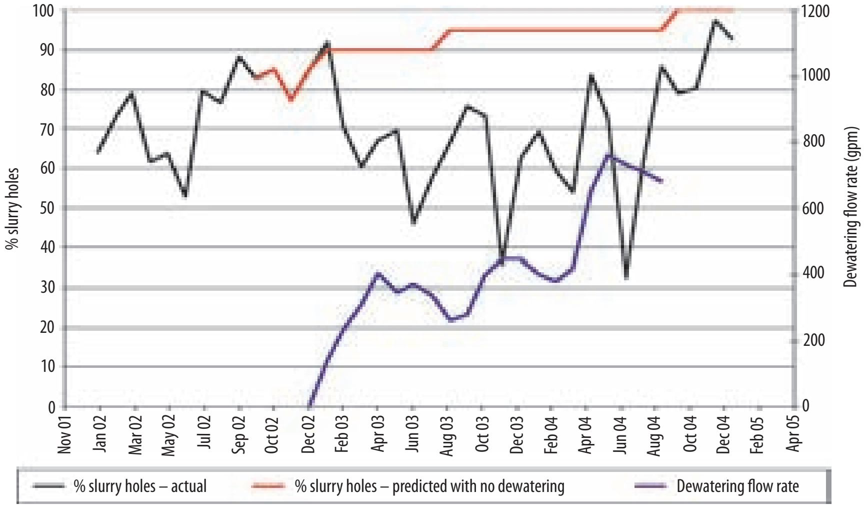


Morenci: a significant reduction in emulsified explosive usage was attained due to dewatering



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Hydrogeologic assessment of the slide area was undertaken. This involved structural interpretation of bedrock, plus drilling and testing of several reverse-circulation pilot holes, placed near the slide toe and in the regional system behind the pit crest. The investigations indicated:

- Rock mass with low hydraulic conductivity.
- High pore pressure close to the toe.
- A relatively high regional water table fed groundwater towards the toe area, maintaining the significant pore pressure.
- Strong groundwater compartmentalisation due to a number of steep structures, oriented sub-parallel to the pit slope.

One such structure was interpreted to be the slide-release plane. It was concluded, with the aid of geotechnical back-analysis, that the presence of groundwater and elevated toe-pore pressure were strong contributing factors to slope movement. It was determined that a programme of short-term slope depressurisation would provide considerable benefit to maintaining the slope.

Slope depressurisation was approached with a series of deep, horizontal drains, located close to the toe area of the slide. Horizontal drains were selected because they provided the best short-term means to cross-penetrate the multiple compartments stacked behind the slope. In addition, they directly penetrated the areas of elevated pore pressure in the

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THE LISHEEN MINE

Mine Planning Engineer

The Position
Reporting directly to the Technical Services Manager, the Mine Planning Engineer will have responsibility for the following:-

∞ Prepare conceptual, preliminary and final stope designs using Vulcan and other software as appropriate.
∞ Prepare associated stope access, development and services.
∞ Communicate all aspects of designs through written reports to all stakeholders.
∞ Back analysis of designs/stopes upon completion of stope.
∞ Specify, in conjunction with the Geotechnical Engineer, stope fill requirements.
∞ Conduct investigations and initiatives that may improve safety, cost effectiveness or productivity.
∞ Identify appropriate mining methods, designs and mining sequences for the mining process.
∞ Short, medium and long term scheduling of the mine.
∞ Assist in Ore Reserves progress for the mine.
∞ Undertake and supervise miscellaneous projects as required.

The Qualifications
Applicants should possess a recognised Qualification in Mine Engineering coupled with a minimum of three years of underground trackless mine experience. Knowledge of Vulcan software, the computer based mine design package is desirable but not essential. The successful candidate will possess good communications skills, be a team player and capable of working in a results orientated environment

If you are interested in this position and feel you meet the requirements of the job; please send your C.V. to:

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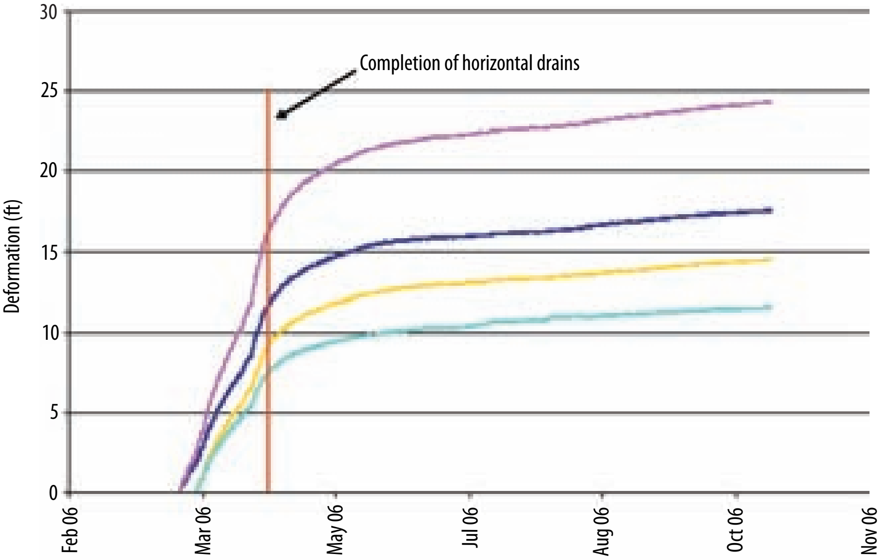
Chino: a depressurisation drain being installed in the pit slope

Prism data was used to manage the slope and demonstrated the benefit of the slope drains



toe of the slide. Each drain was carefully planned, with their length and orientation selected to maximise penetration and the cross-connection of the hydrogeologic compartments.

A total of 17 drains were drilled in early 2006. Typically, each drain produced 20-30 gpm when initially drilled, with the flow rate rapidly decreasing to less than 5 gpm in a matter of days. The flow characteristics reflected the strong structural control and compartmentalisation behind the slope.

Due to access issues, it was difficult to install piezometers in the slope, directly behind the slide, to monitor local groundwater-level reduction. However, continually gathered slope prism data recorded a very distinct reduction in slope movement, which coincided with drain installation. The prism data was used to monitor and manage the slope, while nearby mining was completed at an accelerated rate of one bench per month. The slope-velocity reductions achieved due to horizontal drain drilling and slope depressurisation were integral to the successful implementation of the mine plan.

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