We identified three techniques to reduce water wastage and the subsequent water consumption of deep-level mines. These include leak management, stope isolation control and supply water pressure control. The outcome of the evaluation at mine 1 led to the implementation of all three water reduction techniques. Leak management realised a total daily reduction of 7 Ml with an additional reduction of 1.6 Ml per day from stope isolation and pressure control. An average daily energy reduction of 92 MWh was achieved. This relates to an estimated cost saving of R5 617 000 per annum. Further investigations revealed that a combined daily energy reduction of 170 MWh can be achieved by implementing water reduction techniques on five other mines. This relates to an estimated financial saving of R13 120 000 per annum.

**Electricity consumption in mining**

Extracting minerals is an energy intensive process. Gold and platinum mining in South Africa is responsible for approximately 47% and 33% respectively of the total electricity consumed by the mining industry. South Africa has some of the world’s deepest mines, reaching depths greater than 3700 m below the surface. One of the major concerns when mining at these depths is the high ambient temperatures as virgin rock temperatures could exceed 60°C. Ventilation and cooling in deep-level mining are of paramount importance to ensure a safe working environment. The use of air ventilation alone becomes less effective as depth increases, partly due to the air being heated through auto-compression. This led to the use of water as a medium to extract heat from the mine. Refrigeration plants, underground chilled water supply and the underground dewatering system all form part of the complete water reticulation system. Fig. 1 shows the breakdown of the...
average electricity consumption of a typical deep-level mining processes. The data used to calculate this breakdown was obtained from two gold mining groups in South Africa.

The water reticulation system, associated with production (drilling and sweeping) and cooling (cooling cars etc.), is responsible for a large portion of the total electricity usage of the mine. A typical mine can, on average, pump between 15 Ml to 25 Ml water to the surface daily.

**Water supply and demand**

Water was initially used for dust suppression after blasting and during the drilling shifts, but is now used more widely in the mining industry. Cooling is one of the most vital roles of water in deep-level mining today due to the depths reached and the virgin rock temperature (VRT) present at these depths.

The VRT in South Africa increases by approximately 12°C per kilometre of vertical depth depending on the region in which the mine is located. Fig. 2 illustrates the increase of VRT at different regions in South Africa as the depth below surface increases.

With VRT reaching temperatures as high as 60°C, cooling becomes an engineering challenge. The water supply system of a deep mine consists of the refrigeration system; surface and underground chilled water storage dams; energy recovery systems and energy dissipating equipment.

Water is stored in chilled water storage dams on the surface. This is because of the varying water demand as a result of different mining activities. From the surface storage dam water is gravity-fed to the working areas via an intricate piping network. Chilled water is used as service water because of its cooling benefits. Some of the typical uses of water in the underground working areas are cooling cars and spot coolers, high-pressure water cannons, drilling and water spraying.

The used service water must be extracted from the mine along with other fissure water or groundwater. This is accomplished using the mine’s dewatering system. The dewatering system of a deep mine consists of settlers, hot water storage dams, dewatering pump stations and other free energy dewatering systems.

The power consumption data for 2009–2010 of several deep gold mines in South Africa was analysed. From this data it was concluded that, on average, the dewatering system accounts for approximately 15% of the total electricity consumption of the mine.

**Reducing water demand**

The South African mining industry offers significant potential for water supply optimisation. Large water consuming mines can be identified by establishing the functional relationship between water consumed and the combination of ore and rock hoisted. The combination of rock and ore is used as water consumption takes place in both production and development areas.

The water consumption and hoist data obtained from several deep-level gold mines were collected. From this data it could be concluded that, on average, the deep-level gold mining industries in South Africa require approximately 2,45 kl water to mine a ton of rock. The water consumed as a function of rock hoisted is shown in Fig. 3. It can be seen from this figure that mine B and mine E require more water to mine a ton of rock than the average.

The following three techniques have been identified to reduce the water consumption in deep-level mining:

- Leak management
- Stope isolation control
- Water pressure control system
To simplify the management and implementation of leakage repairs, a data-capturing unit can be used on which the identified leak can be stored. The leak type, size and location are required to simplify the repair process. With accurate data, the leaks can be repaired quickly and effectively.

Leak reports should be distributed weekly and feedback provided from the person responsible for the specific operational area. The water leak management and reporting system will simplify the maintenance of the water reticulation system. This system can also be used to track the progress and cost savings of the identified leak repairs.

Leak management

The water reticulation system on a mine consists of many kilometres of pipe columns supplying water from the surface to the deepest and furthest mining and development areas. Leaking pipes are a common problem in the mining industry. This is due to the extremely rough conditions these pipes are exposed to. Many leaks are caused by faulty gaskets and ruptured piping. In some cases the valves of the water hoses are left open and the water is allowed to run out freely.

The fluid flow rate through a hole is expressed as a function of hole size (see Fig. 4). There are various techniques to identify leaks in fluid systems. Visual inspection of the column sections are by far the simplest and most cost-efficient method for detecting water leaks. A responsible person is assigned to each level and each section in the mining industry. It is this person’s responsibility to ensure that the columns are in a good and acceptable operating condition. This can be accomplished by appointing a dedicated team whose priority must be to identify safety hazards and wastage. Identified leaks should be reported to the section foremen and mine managers.

Leak reports should be distributed weekly and feedback provided from the person responsible for the specific operational area. The water leak management and reporting system will simplify the maintenance of the water reticulation system. This system can also be used to track the progress and cost savings of the identified leak repairs.

The installation of flow meters will also assist in identifying leaks by comparing actual water flow measurements with historic flows.

Stope isolation control

Stopes are areas where the actual mining, drilling, blasting and scraping or sweeping of the reef takes place. The stope is accessed via the crosscut which is a branch of the main travel way. The water columns are usually situated along the travel ways with taps or valves at each crosscut to supply the stope area with water.

Water is used primarily for cooling, drilling and sweeping purposes. Drilling and sweeping require manual intervention. Water wastage can easily occur at these stations if a worker forgets to close off the water supply after usage. A good practice would be to isolate the water supply automatically when no water consuming mining activities are taking place.

With the stope-isolation system, significant water consumption reduction can be accomplished. The mine should usually be cleared by approximately 18h00 for blasting, after which the sweeping shift starts at approximately 22h00. If a flow rate of 2 l/s enters the stope area, then a water reduction of more than 28 kl per day can be achieved for the four hours of the blasting shift.

Pressure set-point control

Tests were conducted by on a deep-level gold mine. At a typical mining level the pressure was reduced and the flow rate logged to determine the relation between the flow and pressure. The result of this test is shown in Fig. 5, which shows that the water flow increases significantly with an increase in water pressure. The gradient and magnitude of the graph may vary from

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**Fig. 6:** Mine A water consumption baseline flow.

**Fig. 7:** Electrical demand profile of the dewatering system.

**Fig. 8:** Bypass control valve assembly.
one level to another, depending on the conditions of the downstream piping and mining equipment installed (such as cooling cars).

For pressure control, a pressure schedule for each mining level will be predetermined according to the mine shift schedule and pressure requirements. The valves will be controlled to the specified downstream pressure using a programmable logic controller (PLC), and feedback instrumentation. Each level will be controlled separately according to the level-specific requirements.

During production shifts the water pressure will be controlled at a sufficient pressure so as not to interfere with the mine’s production capabilities negatively. During the afternoon shift, where minimal water is required, the pressure can be reduced to a value that will allow only sufficient flow to the BACs, cooling cars, and to the working areas where water may be required.

Water leakages were present on the column supplying water to all the stopes. Therefore, pressure control valves on each individual level will be installed as close to the main supply column as possible. This will reduce water wastage on the entire level and not only in the stope areas, as is the case with stope isolation.

In some cases the water supply to a particular level can be terminated completely during the blasting shift using the control valve. The valve should not be closed too quickly as this could lead to water hammer which would result in serious damage and even rupturing of the pipes and associated loss in production.

Case study

Mine A was selected as a case study. The mine comprises twin vertical and twin sub-vertical shafts reaching a depth of 3.6 km below the surface. Chilled water is gravity-fed to the various cascading storage dams through a single supply column. The water consumption of the mine and the electrical power consumption of the dewatering system were logged during a three-month baseline period. This mine consumes an average of 24 Ml chilled water per day. The total water consumption flow profile is shown in Fig. 6.

The dewatering system of the mine pumped an average of 26 Ml water to the surface every normal working day. The difference in water consumed and the water extracted (2 Ml) by the mine can be ascribed to fissure water. Fig. 7 shows the electrical power demand of the dewatering system.

The implementation of leak management realised a reduction in water consumption of approximately 7 Ml per day, approximately 30% of the baseline water consumption. New leaks are still identified, logged and repaired on a daily basis.

The average water consumption per month is shown in Fig. 9. The daily production data for each month was obtained from the mine. The production data confirmed that the average daily
production did not decrease during the implementation period.
The savings achieved by this leak management strategy has resulted in a significant decrease in water flow rate. This, in turn, has reduced the expected impact of the pressure control valves.

Fig. 10 shows the predicted flow reduction due to pressure control and stope isolation. An additional reduction of 1,6 Ml per day is expected when the pressure control and stope isolation valves on the production levels are operational. Although this is 0,5 Ml less than originally expected, it does not pose a problem because the total savings have increased significantly due to leak management. A total water reduction of 8,6 Ml per day is expected to be achieved after implementation of the project.

Fig. 11 shows the baseline electrical demand profile, as well as the measured actual demand profile achieved through leak management, stope isolation and pressure control. The actual power profile also shows a significant improvement over the projected profile.
The shape of the power demand profile does not follow the optimised water demand profile. The reason for this is the lag in the system for cold water to reach the dewatering system.
The reduction in electrical energy consumption results in a financial saving of R34 700 per day during high demand season, and R16 800 per day during the low demand season. This results in an estimated annual saving of R5 617 000 using the dewatering system. This financial saving is calculated using 2009/2010 Eskom electricity tariffs, assuming 22 working weekdays per month.

With less water to be pumped, the mine should be able to shift the electrical load from the Eskom peak periods by utilising the storage dam capacities optimally. The optimised load profile is shown in Fig. 12.

If load shift can also be implemented on the mine dewatering system, additional financial savings will be achieved. This will increase the total savings to R9 153 000 per annum.

**Expanding the results to other mines**

Investigations were also conducted on various other deep level mines to determine the potential savings that can be achieved by optimising the water reticulation system. The conclusions drawn from these investigations resulted in DSM projects being implemented on these mines. The expected savings for each of these projects are shown in Table 1.

Successful implementation of these projects will result in a total energy reduction of 170,4 MWh per day. This will reduce the average electrical power demand on the national electricity supply grid by 7,1 MW and realise a saving to the clients of R13 120 000 per annum. This excludes the possibilities of additional savings due to load shifting.

**Conclusion**

In this case study, the biggest impact was achieved through repairing water leakages. Leak management results will depend on the existing condition of pipes in the mine as well as existing leak management programmes.

Stope isolation valves will always be a viable option if not already in place. This will, however, be more difficult to monitor and control than automated control valves.

High volumes of water flow on production levels will favour the installation of control valves on those levels.

Flow meters on mining levels are also essential for proper flow management, control and monitoring.

Improved management of mining water operations will result in huge savings and was not optimised in the majority of mines that were included in this study.

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**Table 1: Expected saving on other mines.**

<table>
<thead>
<tr>
<th>Mine name</th>
<th>Daily water consumption</th>
<th>Daily energy consumption</th>
<th>Expected daily impact</th>
<th>Annual saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A</td>
<td>33 Ml</td>
<td>480 MWh</td>
<td>39,6 MWh</td>
<td>R2 949 000</td>
</tr>
<tr>
<td>Mine B</td>
<td>34 Ml</td>
<td>633 MWh</td>
<td>45,6 MWh</td>
<td>R3 464 000</td>
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<tr>
<td>Mine C</td>
<td>25 Ml</td>
<td>330 MWh</td>
<td>39,6 MWh</td>
<td>R3 073 000</td>
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<tr>
<td>Mine D</td>
<td>70 Ml</td>
<td>377 MWh</td>
<td>36 MWh</td>
<td>R2 858 000</td>
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<tr>
<td>Mine E</td>
<td>15 Ml</td>
<td>264 MWh</td>
<td>9,6 MWh</td>
<td>R781 000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>R13 120 000</strong></td>
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