

## Mine and facility closure trends

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The field has changed a lot since SRK's last newsletter with a closure theme, which we issued in July 2000. The above photograph illustrates one example of the current state of the practice. The graphs on the next page show how some of those changes are really part of long-term trends.

Let's start with the graphs. In a recent knowledge mapping project, SRK found over 4000 publications related to mine closure, and analyzed them using the latest bibliometric and text analytic methods. The lower graph shows how the number of closure-related publications started increasing in the 1970s, and plateaued in the last decade. That tracks well with the beginnings of mine closure consulting practices in the early 1980s, expansion and growth for two decades, and today's mature expertise.

The upper graph illustrates another trend in the mine closure literature. In the 1960s and early 1970s, the emphasis was on physical reclamation

of pits and waste dumps. But through the 1980s and 1990s, other mine components began to receive more attention. The closure of waste rock and tailings now dominates the literature.

A simple word count shows a related shift. Since 2005, the terms "reclamation," "closure" and "remediation" have been appearing in publications in roughly equal numbers. The term reclamation has been in use since the 1960s. But the more holistic closure only began to appear in the mid-70s. And remediation, with its connotations of fixing geochemical problems, first appeared only in the mid-80s.

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# Mine and facility closure trends (continued)

A number of other trends became evident in our study, but the broad movement from physical remediation of pits and waste to holistic closure and remediation of geochemically challenged components is the most

evident. And it also relates to this newsletter's theme of "facility" closure. Perhaps it is just the current day commodity market, but SRK's project lists show a distinct trend away from full mine closures and towards closure of selected minesite facilities. There are still many worthy challenges in the permanent mine closure world, and several articles here describe them. But the new challenges of interim closure, partial closure, and closing selected facilities, while continuing to operate a mine around them, also get some attention.

## DARYL HOCKLEY

Daryl Hockley is a Practice Leader in the GeoEnvironmental Engineering Division of SRK Canada. He provides senior review of multi-disciplinary mining and environmental projects, as well as specialist consulting in mine closure, tailings and waste management. Daryl also leads some of SRK's efforts at internal knowledge management. In that regard, text mining of assembled literature is his latest hobby. Text is proving to be less profitable than other "ores", but the closure costs are minimal, and it doesn't require geological interpretation!



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Back to the photograph. It shows Baker Creek, a stream flowing through the abandoned Giant Mine in Canada's Northwest Territories. Environmental assessment and permitting of a closure plan for the site as a whole is in progress, but concerns about immediate risks led to this particular reach of the stream requiring early remediation. SRK completed engineering designs and construction oversight for that work, and regulators, local citizens and several dozen spawning fish have since indicated their approval of this particular facility closure.

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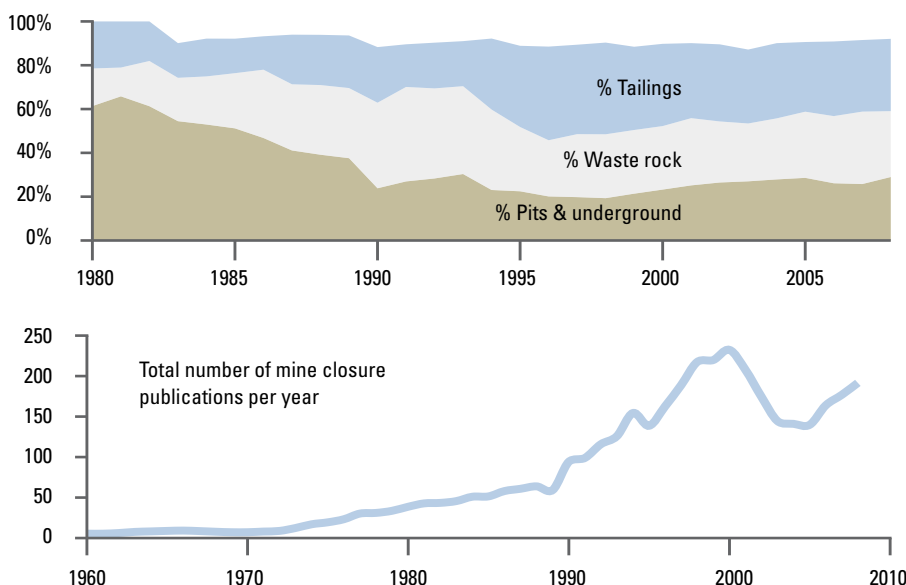


The sanded in concentrator and surge bin ready for demolition. A black topped gravel surface surrounds the plant

In 2007 when Richards Bay Minerals (RBM) decided to close their Mining Pond B, SRK was appointed to manage the project. Prior to removing the pond and rehabilitating the pond area, the dredger had to be docked for transfer to another mining pond and the floating concentrator had to be demolished. The possibility of relocating the concentrator was also considered, but an SRK study showed that this was not cost effective.

Working with the RBM operating personnel, the team excavated a docking area by creating a slot in the end of the pond, using the dredger. The neck of the slot was then closed by bulldozing sand in from each side to form a sand wall between the pond and the docking area. The water in the dock was then pumped back to the main pond and the docking area was kept dry by pumping from sumps and a well point system, which had been installed in the sand wall.

The floor of the dock area was strengthened by placing a half-meter-



## Closure of Mining Pond B at Richards Bay Minerals, South Africa



thick layer of crushed stone enclosed in geofabric, half a meter below the sand surface of the floor. Concrete strip foundations were then cast to accommodate a structural steel cradle, on which the dredger would be placed. Once the cradle had been assembled, pond water was pumped back into the dock until the water in the pond and the dock were the same level. Breaching the sand wall between the dock and the pond without adjusting the water levels would have caused a rush of slimes from the bottom of the pond into the docking area. The dredger then cut through the sand wall and positioned itself above the submerged cradle using a laser positioning system. The sand wall was re-installed and the dock once again pumped dry, with the dredger settling on to the cradle.

After docking the dredger, the plant, comprised of the concentrator and surge bin, sanded itself in and a platform was built around the plant using black topped gravel as a

surface layer to support cranes and demolition equipment. Pumps and other electrical and mechanical items that could be re-used were carefully removed before the main demolition started. The sheeting was then removed before the demolition, using cutting torches and cranes, starting at one end of the plant. Once the superstructure had been removed, the supporting pontoons which were about 3.5m deep were dragged out of the sand and cut up. The scrap value of the plant covered the cost of the demolition.

The dunes around the pond and the pond area were then reshaped using bulldozers, front-end loaders and articulated dump trucks before re-vegetating the site, following RBM's tried and tested methods. The project was completed successfully within budget due to the close teamwork between RBM, SRK and the demolition contractor.

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### PETER LABRUM

Peter Labrum, Pr Eng, C Eng, a Principal Engineer with SRK (SA) has over 30 years of experience. With a background of structural engineering and project management, he has been involved in mine closure work in Southern Africa for 20 years. He specialises in the project management, demolition and costing aspects of closure.



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## LUKE ESPREY

Luke is a Hydrologist with 15 years' experience. His diverse skills set covers water resource studies and water allocation planning, catchment modelling, flood studies, plantation growth, yield modelling, and mine closure and rehabilitation. Luke's experience in mine closure and rehabilitation includes research in post-mining rehabilitation and consulting projects in both South Africa and Australia. Most recently, he has applied the SRCE Model on Australia-based mine closure projects.



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## DANIELLE KYAN

Danielle has over 9 years' experience working as a GIS/Geology consultant; she specialises in closure cost estimations using the Standardised Reclamation Cost Estimate (SRCE) Model, GIS compilation, data management and data interrogation across a range of commodities. Her experience in closure cost modelling includes state bond and Life of Mine estimations and closure costs estimates for Annual Asset Retirement Obligations (FASB143). Danielle has managed closure cost estimations in Australia and Papua New Guinea including management of budgets, ARO cost estimations and work with site environmental professionals annually since 2006 and worked alongside external consultants as part of a number of feasibility studies.



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## What goes up...



Wall failure at pit void

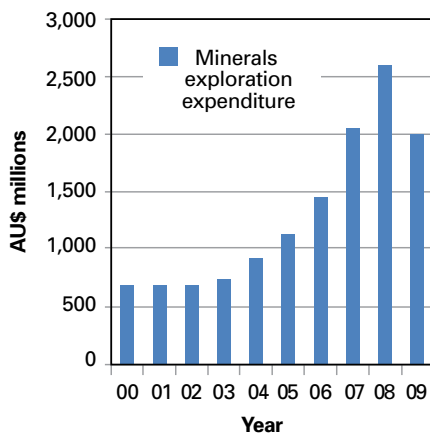
**T**he Australian mining industry is booming again! Despite the global financial downturn of 2009, mining investment continues to rise, with strong export growth in the iron ore, gold and coal sectors in 2010 and 2011. So, is it prudence or terminal pessimism that has motivated the Western Australian Department of Mines and Petroleum (DMP) to revise the Mining Act 1978 to impose more stringent mine closure obligations on mining operators and proponents?

A new set of guidelines to be issued jointly by the DMP and the Environmental Protection Authority, describes the new standards that will apply to both existing and new mining operations in the future. Among the key changes is a requirement to include estimates of mine closure costs in the Mine Closure and Rehabilitation Plan that must be submitted to the government as part of the project approvals process, or for existing operations, in mandatory 3-year reviews. The closure cost predictions

must be supported by information on the costing method, assumptions and financial processes used to estimate costs.

SRK Australasia has been using the Standardised Reclamation Cost Estimator (SRCE) model since 2006. The SRCE model was developed by SRK and the Nevada mining and regulatory community to improve accuracy, completeness and consistency in mine closure and reclamation cost estimates. It is essentially a specialised cost estimating tool that standardises user input requirements, productivity calculations, volume and area calculations, while allowing enough flexibility to incorporate site-specific conditions. This model is also a useful "what if" scenario tool, for instance, to answer questions such as "how do rehabilitation costs vary as a function of changing cover, growth media and revegetation equipment?" or "what are the cost implications associated with different regrade systems used on waste rock dumps"?

## From abandoned site to community asset



The demand for closure and reclamation estimates is increasing and SRK has established a solid client base, which continues to grow as mining companies understand the potential of the SRCE model and how it can be tailored to site-specific needs. SRK is currently working alongside several clients in Western Australia and Queensland, using the SRCE model to estimate mine closure and rehabilitation costs.

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The Yankee Girl site is an abandoned tailings area located on the shore of a river in the small community of Ymir, British Columbia, Canada. Tailings periodically eroded into the river and oxidation resulted in the release of contaminants, including cadmium, lead and zinc, into a high-value fish habitat. After extensive consultation, the BC Crown Contaminated Sites Branch and the local office of SNC-Lavalin arrived at a remediation objective that would turn the area into a park-like setting for use by the local community.

In 2007, SRK was awarded a design-and-build project in partnership with Quantum Remediation, a well-respected BC contractor specialising in contaminated site remediation. SRK's design centered around the relocation of low-lying tailings from the river floodplain into an engineered containment system constructed on an upper tailings bench.

During the relocation, lime was added to neutralise acidity and precipitate soluble contaminants. The engineered containment system included a bentonite-amended soil cover to minimise the infiltration of water. A passive treatment system, constructed using organic wastes from a nearby pulp mill, was incorporated to remove any residual contaminants from the underlying groundwater.

The design-build partnership provided an opportunity to create a number of

construction efficiencies in the design while delivering a quality product. Innovative QA/QC methods were developed to control the addition of lime to the tailings and the mixing of bentonite with the lower layer of the soil cover.

The project incorporated several features selected by the local community, including an amphitheatre and parking area for concerts, natural topography and vegetation, and provision for a disk-golf course. The construction was completed on schedule and within budget, and transformed an unproductive and hazardous site into a high-value recreational area for the local community.

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### PETER MIKES

Peter Mikes, M.Eng., P.Eng. is a Senior Consultant who has been with SRK's Vancouver office for 8 years. Most of his experience is in mine closure projects throughout western and northern Canada. He was SRK's project lead in the Yankee Girl project described here and a similar project located near Kaslo, BC. Both sites are close to home for Peter, who was raised in nearby Rossland, BC. He's not sure if he likes the added pressure of having project stakeholders in the family, but he did appreciate the home cooking!



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View of construction of the Upper Tailings Repository

## Closure north of 66°

It's another bitterly cold morning. Mine reclamation work has continued with the use of mobile light towers since the sun set for the season. A call comes in over the radio; the boom on an excavator has cracked. Minus 52°C has won the battle. The soil remediation activities will cease until spring. Closing a mine in the Arctic is no less a challenge than building one.

Permafrost engineering and the traditional knowledge of northern residents will benefit the remediation effort. Permafrost can be used to control the migration of contaminated groundwater. Berms of fine-grained material constructed down gradient of an impacted site build up the level of the permafrost below the berms and thus create a subsurface barrier that inhibits the water's migration. In the high Arctic, permafrost can also be used to encapsulate contaminated soil within mine workings, even under the warmest climate change scenarios.

To direct the day-to-day excavation of contaminated soil, soil samples need to be tested but the cost and time of

shipping samples from remote sites can be prohibitive. Field screening tools, such as gas detectors and portable analysers, must be relied upon along with professional judgment. A portable X-Ray Fluorescence (XRF) analyzer is a valuable tool for assessing metal concentrations. Depending on the grain size and heterogeneity of the soil, the samples may need to be screened to -2mm to get results that are comparable to those of a laboratory. A program to examine the relationship between the field results using various sample preparation techniques and laboratory results must be completed before using the XRF to guide soil remediation. An XRF analyzer, coupled with a GIS database to manage and communicate the sample results, was utilised during the successful reclamation of both the Polaris Mine (75°N latitude) and Nanisivik Mine (73°N latitude).

North of 66°, SRK's expertise can help clients manage their mine closures.

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Spring time excavation of contaminated soils during mine remediation in the Arctic



Land rehabilitation for pasture use after alluvial gold mining

Russian legislative requirements on closure and rehabilitation are contained in federal laws and related regulations, under titles law "About subsoil", Land Code, law "About environmental protection", "Instruction about the work order on liquidation and temporary closing-down of dangerous industrial projects related to the subsoil use". A few state standards (GOSTs) also determine topsoil protection, conservation and use, and the rehabilitation of disturbed land. In general, Russian legislation says that disturbed land should be rehabilitated and a mine operation should be liquidated (the Russian term for closed) following the designed and approved rehabilitation plan.

In practice, initial closure requirements can be included within a mining licence. A conceptual plan is usually part of the OVOS report (the Russian version of ESIA), but at this stage the plan is formal and is unlikely to be developed further. There are no requirements or



# Land rehabilitation requirements and practices in Russia



practices to estimate closure costs at the design stage. A detailed closure and rehabilitation plan is prepared about one year before closure, but with no clear legislative deadline, the local authorities may require the detailed closure plan at the design stage.

There are few specific technical requirements for closure and rehabilitation in general, and for mine closure in particular; most are related to topsoil, as follows:

- The topsoil may be removed and stored as practical. The thickness of the topsoil layer is determined by soil fertility. In the forest, topsoil less than 10cm thick need not be removed
- If topsoil is kept for more than 2 years, it should be stored for sowing or replanting

Rock stability should be taken into account in determining the height of dumps and the angle of slopes.

According to the GOSTs, rehabilitation consists of two stages – technical and biological. Technical may include dumps, resloping, construction of a drainage system, closing of the dams and ponds, erosion prevention, covering the area with soil. The biological stage includes sowing or planting, depending on the final planned land use.

The legal “Instruction” covers mine closure – banking open pits or pit slope profiling; dumps and tailings facilities, long-term stability – and states the closure plan should be designed by an organisation licensed by the mining and safety supervision authority, Gosgortekhnadzor.

There are no requirements for demolishing buildings or structures. In practice, they are left on mine sites, supposedly for future use.

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## EKATERINA VERSHININA

Ekaterina started working with SRK in 2004 as an associate and joined the UK office in 2005. Previously, she worked for the Russian environmental authority and then for an international mining company, which had assets in Siberia and Kamchatka in Russia. Now, as Principal Environmental Specialist in SRK’s Moscow office, Ekaterina is working on numerous mining projects throughout Russia, C.I.S and other countries. She is currently engaged in preparing an ESIA for an existing mining client.



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## ARLENE LAUDRUM

Arlene Laudrum, P.Geol. is based in SRK’s Yellowknife, NWT office and has 25 years of experience in mining, mineral exploration and the environmental management of mining and exploration projects. She has assessed environmental impacts and the environmental liability of mine sites, and provided technical and strategic permitting advice for industry, government and regulatory clients. Arlene has prepared closure and reclamation plans and supervised mine remediation for projects across Canada, including the Polaris Mine at 75°N latitude and the Nanisivik Mine at 73°N latitude.



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## Using ecological risk assessment to establish closure criteria

### MARK WILLOW

Mark Willow, an Environmental Scientist with SRK for over 14 years, is a Principal Consultant in the U.S., with degrees in fisheries and wildlife management, and environmental science and engineering. He is certified by Nevada to manage hazardous materials, investigate the potential release of hazardous substances, and respond to the cleanup and remediation of contaminated soil or water. Mark focuses primarily on environmental permitting and impact assessment, analyzing ecological mining-related risks to produce due diligence and competent person evaluations.



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Reclaimed dump surface at the Manhattan Mine, Nevada

**D**oes an open pit lake represent a toxic threat to wildlife after closure? If a former process pond is converted into an evapo-transpiration (ET) basin to manage heap leach and tailings drainage, does it create soil conditions that are hazardous to vegetation and soil organisms? These questions are increasingly being asked during the feasibility and permitting stages of mining projects, and the answers are guiding water management and closure strategies for mines around the world, to the benefit of the environment.

For nearly 20 years, the U.S. Environmental Protection Agency (EPA) focused on assessing potential human health risks at industrial waste sites including abandoned mine sites. However, in the last decade, equal consideration is being given to livestock, wildlife, and vegetation at risk of exposure to residual chemical compounds. Understanding the risks from exposure to metals and developing appropriate mitigation measures are key to extending corporate stewardship of the environment beyond mere regrading

of heaps and backfilling of ponds, and fosters the guiding principles of sustainable development.

Decision-makers at all levels rely on predictive modelling of future site conditions in determining the profitability and potential liability of mining projects. While these models have limitations, assessing environmental risk is complicated by variability in the natural occurrence of metals in soils and water, and the fundamental requirement for metals in every biological organism. Background concentrations and sometimes the speciation or valence state of metals must also be considered before properly assessing a hazard, and the evaluation must include the uncertainties associated with natural biological variability.

Both the EPA's "Guidance for Ecological Risk Assessment" (1998) and the International Council on Mining & Metals, "Metals Environmental Risk Assessment Guidance" (2007), provide environmental professionals an extensive set of risk assessment tools to quantify the potential threat to the



# Rehabilitation and construction issues for Silvermines, Ireland



ecosystem from mining. During project development, these tools are used to factor potential future liabilities, including mitigation measures, in costing projects. New, authoritative studies on the toxicity of inorganic compounds add evidence to wildlife Toxicity Reference Values, the cornerstone of ecological risk assessment. Moreover, exposure factors measuring wildlife food consumption are constantly being refined, increasing their validity.

SRK Consulting (U.S.) continues to apply these techniques in assessing ecological risks at mining sites throughout Nevada, including at a gold and copper mine where the potential for elevated ecological risks was a factor in designing the long-term, post-closure, fluid management system, which needed to exclude wildlife from exposure to proposed evaporation cells. More recently, evaluation requests have come from projects in Pakistan, Australia, and Tanzania, demonstrating the expanding use of ecological risk as an essential tool for effective closure management.

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The Silvermines area in County Tipperary, Ireland comprises an area of around 5km<sup>2</sup> plus a 74ha tailings facility. A number of abandoned open pits and underground mines were worked there, mainly from the 17th to 20th century, for lead, zinc, copper and barites with some silver. There is a legacy of health and safety issues, as well as potential mining heritage, with tourism and educational interest.

The challenge is not only to remove or minimise health and safety risks, and achieve Water Framework Directive requirements, but to optimise the expenditure while considering what should be conserved or protected in consultation with a wide range of stakeholders.

Progressively, over a number of years, a rehabilitation project has been carried out and is now in the final design and construction stage.

A key issue of dust from tailings has been resolved by capping and vegetation. Targeted sources of contaminated water have been addressed by evaluating the water balance, assessing contributing contaminant loads, and identifying the key sources of contamination for removal. Various small mine waste dumps will be consolidated into a single constructed hazardous waste storage facility using a passive water treatment system to collect and treat mine water.

SRK has been involved in developing concepts for closure over a ten-year period, carrying out site investigations and negotiating with all stakeholders to determine the best solutions for rehabilitating the Silvermines abandoned mine sites. SRK developed the preliminary designs, prepared relevant planning applications and is currently contributing its expertise in the final phases of design and contract management.

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## RICHARD CONNELLY

Richard Connelly, MSc, C Eng, C Geol, is an Associate Consultant with SRK (UK) and has 42 years' experience in mining hydrogeology and engineering geological aspects of groundwater. He specialises in integrated water management for open pit and underground mines and quarries. A key focus of his work is demonstrating the value of collecting water and geotechnical data during exploration and mine development to minimise risk of uncertainty and minimise the costs of subsequent specialist investigations.



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Capillary break and seeded soil cover construction on tailings

# A risk-based approach to tailings facility closure

**SRK** recently undertook the closure design and implementation for the tailings facility at a defunct operation in central Nevada, USA. The facility stored gold cyanide tailings in three individual cells of differing heights and construction.

Initially, SRK needed to access and review all the as-built records and the facility's annual operational report as there was limited knowledge of cell design and condition. The operation had been defunct for a number of years and portions had been designed by three different engineering consulting companies.

Following this review and limited site visits, and in accordance with state

reclamation requirements, the strategy adopted for developing the closure design was to define the potential failure modes and then develop engineering solutions to mitigate them. In essence, SRK used a risk-based approach to the closure design.

The identified modes of failure included overtopping, slope failure, failure to manage the draindown of entrained tailings water, and the failure of the decant inlet and pipe systems.

This risk-based approach also led SRK to design measures for the long-term management of stormwater infiltration and runoff, as well as runoff from surrounding catchments during closure.

Published papers and statistics related to tailings failures, as well as SRK and client experience with numerous other closure designs were important components of the approach.

The closure was successfully implemented and included installing closure spillways to the various cells, sealing the decant pipes and capping the exposed tailings. The draindown seepage was managed passively via evapo-transpiration cells constructed in the water ponds.

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## DAVE LUPPNOW

David Luppnow has over 18 years of experience in site investigations, site selection, design, construction, reclamation and project management of engineered structures for mine waste disposal, including tailings dams, heap leach pads and mine waste rock dumps. He has managed multi-disciplinary studies for related projects. His specific projects in South Africa, USA, Papua New Guinea, Argentina and Chile involve mine tailings and leach pads for copper, gold and uranium. Recently, David completed the feasibility design of a 90,000 tonnes-per-day copper paste tailings facility in Chile.



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San Manuel mill demolition

The San Manuel property is a former integrated mining, milling and smelting operation located in central Arizona, USA. Large-scale mining activities started with underground block cave operations in the 1950s. In the mid-1980s, mining was expanded to include a surface heap-leach facility and an in-situ leach operation within the active cave area. Seven miles to the south, the mill, smelter and refinery processed ores from the San Manuel mine. Ultimately, the mining operation encompassed over 300 acres, the plant site operation covered approximately 400 acres, and the tailing storage facilities over 3,000 acres.

In June 1998, BHP Billiton suspended operations at San Manuel. By 2004, BHP elected to permanently close the mine and plant sites. Given the scale of the combined operations, this decision triggered one of the largest,

Volunteer vegetation on re-sloped tailing dam



## San Manuel, Arizona: from mining to reclamation



owner-funded, mine and plant closure programs in the world.

Beginning in 2000, SRK staff worked closely with the BHP Billiton project team during the critical decision phases of the project. After the public announcement of closure of the mine site in 2002, SRK continued to provide technical support for conceptual closure planning, site investigation, and assessment of value recovery. This support included evaluating short-term and long-term closure strategies, from cost estimating to preliminary designs. We provided technical assessments of closure requirements, long-term predictions of changes in site conditions, navigating the regulatory framework, as well as contributing to stakeholder consultation with local and regional organisations.

Once the closure strategy was defined, SRK proceeded with detailed

permitting and engineering support. During this process in 2004, BHP Billiton announced that the plant site would also be closed. The SRK team built on the success of the mine site program and applied this experience to closing the plant site, including a 750M ton tailings facility.

In 2005, permitting and design work advanced to the point that construction was possible. SRK provided field engineering and construction oversight throughout the 2-year construction period. The estimated cost of the combined closure program totaled more than US\$200 million. Over a 6 year-period, SRK helped BHP Billiton move from a strategic evaluation of closure alternatives to the successful, full-scale implementation of the preferred closure design.

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### TERRY BRAUN

Terry Braun, P.E., is a Principal Engineer with SRK with over 20 years of experience in the mining industry. His projects often require negotiating with regulatory agencies and other stakeholders to achieve client objectives. After several years consulting directly with U.S.-based mining operations on environmental compliance issues, his practice has expanded to include larger-scale projects that integrate environmental, geology, metallurgy and mining planning specialists. He considers his involvement in the closure of the San Manuel mine, as well as a recent, successful Initial Public Offering for a new mining company, to be indicative of the changing demands of the industry.



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### ROB BOWELL

Rob Bowell, PhD C.Chem., C.Geol., Eur Geol, is Principal Geochemist with 20 years' experience. Rob specialises in the application of geochemistry and mineralogy to a wide range of mining and engineering problems. His main field of expertise is mineral processing and geochemical treatment of arsenic-rich waste, mine waste and water (including metal, radioactive, cyanide solutions, acid rock drainage and saline water). He is a certified auditor under the ICMI cyanide code. Rob's background is in mining and academic research in process chemistry, environmental geochemistry, environmental engineering and mineralogy.



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## Mine closure planning in the Chinese mining industry

### PETER SMITH

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management for the mining and mineral processing industries. This experience has been gained mainly from within Australia and China. Peter has also undertaken environmental due diligence reviews for projects in Mongolia, Uruguay and Serbia. He has been involved in exploration, mining and processing and has particular expertise in environmental due diligence reviews, environmental auditing, environmental impact assessment, project approvals and permitting, environmental management systems, rehabilitation and mine closure planning, and environmental risk assessment.

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Erich Heymann and the client taking measurements during the site visit, at a Mongolian mine

**SRK** stands at the forefront of mine closure planning in the Chinese Mining Industry. SRK China has completed numerous Independent Technical Reviews (ITRs), covering stock exchange listing, acquisition and/or financing for both domestic and internationally based mining projects. Through this due diligence process, the Chinese Mining Industry is adopting international standards and management practices, incorporating mine closure planning.

The Chinese National requirements for mine closure focus on the management and approval of site decommissioning and rehabilitation. A Site Decommissioning and Closure Report is submitted and must be approved before closure can proceed. Currently, mine closure planning is not a Chinese National requirement.

If a domestic Chinese mining project is put forward for international listing and/or finance, it must develop and implement a mine closure planning process. A Chinese mining company that intends to invest or acquire projects internationally, will also face this requirement.

In a recent example, a Chinese mining company operating in Mongolia, seeking to list its operations on an international stock exchange, needed to develop a mine closure plan that met international industry standards.

The company commissioned SRK to complete this work. The process began with an in-depth study of Mongolian and Chinese Statutory requirements, and Australian and international industry guidelines. After a site visit SRK developed the mine closure plan.

## Mine closure regulation in Turkey



As the operation is still in its early stages of development, with a remaining mine life of greater than 15 years, SRK produced a post-closure vision, closure principles, objectives and performance criteria. Stages for moving from the conceptual closure plan to actual execution were included, SRK took the current environmental liabilities into account and proposed measures for all current and planned future disturbances. These will be updated and refined as the operation moves through its life-cycle. Post-closure monitoring and maintenance requirements were also included. Finally, SRK used the Standardised Reclamation Cost Estimator (SRCE) to estimate the life-of-mine closure cost and current asset retirement obligations.

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The “Regulation on Reclamation of Lands Disturbed by Mining Activities,” published in December 2007 and amended in January 2010, is a milestone toward establishing requirements for mine closure planning in Turkey. It requires that reclamation plans for mining projects be appended to the Environmental Impact Assessment (EIA) reports.

The regulation provisions do pose general mitigating actions, such as post-mining safety of the land and acid rock drainage prevention and mitigation, but the process is still in its infancy and shows some limitations. First, as evidenced in its title, the concept of “reclamation” is rendered in Turkish as “restoring to nature.” In general, the approach addresses the impacts of the earth-moving aspect of mining, rather than those arising from recognising the need to explore after-use opportunities. Perhaps understandably, at this stage, there is little encouragement for considering alternatives in post-mining land use that add value to post-industrial landscapes, whether through governmental guidance or community consultation and regular closure planning. However, there are mentions, in passing, of the creation of recreational ponds being governed by the relevant regulations, and the utilisation of infrastructure after the mining activity, even though they appear in the regulation’s appendix. Secondly, as the regulation focuses on mining activities only, there have been examples of EIA processes allowing tailings dam expansions to operations or otherwise benefiting from “grandfather provisions” to the EIA regulation or where stand-alone mineral processing facilities have been exempt from the official requirement for closure planning.

Reclamation plans are currently submitted to the authorities on a once-only basis without a requirement to update, include cost estimates and post bonds, or conduct community consultation about post-mining land use expectations. And the published views of some chambers to the regulation’s draft amendment sanction the impression that interested parties view its purpose as parallel to that of an EIA. Nonetheless, we must not lose sight of the landmark status of the regulation. Potentially, a broader understanding of closure could develop through Turkey’s efforts toward accession to the European Union and the transposition of the Mine Wastes Directive and Environmental Liability Directive to eventually converge with internationally accepted best practice.

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### FILIZ TOPRAK

Filiz Toprak has a degree in mining engineering and pursued her interest in mine reclamation in graduate studies. She has been based in SRK’s Turkish office



since 2007. Filiz has participated in various environmental impact assessment and mine closure and reclamation studies in Turkey. She is currently engaged in preparing mine closure plans and cost estimates for gold mines in the Middle East.

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# Demolition costing

An integral part of any facility closure is estimating the cost of removing the mine infrastructure that cannot be used for other purposes. This cost, while considerable, usually forms a smaller portion of the total closure liability.

The approach taken in assessing demolition costs depends on the level of information available. New

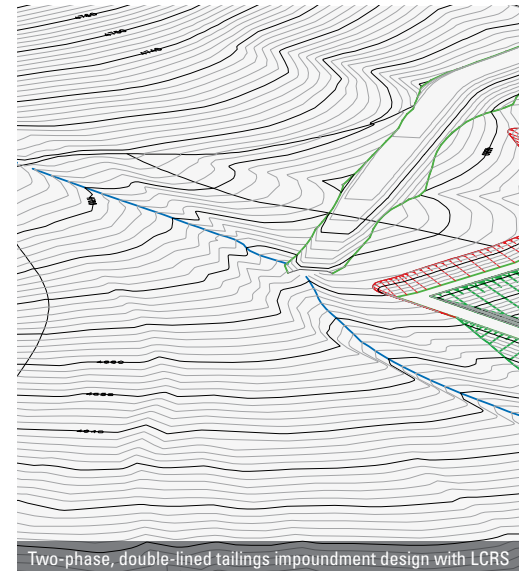
mines can usually provide drawings and schedules of quantities for the infrastructure, whereas older mines, at best, only retain surface layout plans. The less information available, the longer the time required to quantify the extent and type of infrastructure at the mine.

SRK has developed an estimating tool that uses typical contractor labor and plant rates to assess the demolition liability, and to update this cost by inserting the latest rates applicable at any later date.

The actual demolition cost will obviously be sensitive to the resale value of the plant and the value of the scrap material at that particular time. As this is uncertain, any benefit from this source is normally excluded from the cost estimate; however, the estimating system can provide a scrap recovery cost, based on current scrap prices.

It is possible to link the demolition costs to a client's asset register and to a GIS information system, if available, that shows the costs associated with closing a particular aspect of a mine.

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**SRK Reno** recently designed and permitted a flotation tailings disposal impoundment in Nevada. The conceptual engineering design envisioned traditional grading, embankment construction, and a single synthetic liner overlain by a drainage system with a gravity outfall passing through the synthetic liner into a lined collection pond. In addition, the conceptual design required incorporating a diversion channel for upstream stormwater to accommodate 1-in-100-year, 24-hour peak flows for the regulated minimum design criteria. Closure measures for this design incorporated a 3-foot-thick store-and-release soil cover and semi-passive management of long-term recharge and draindown effluent flows.

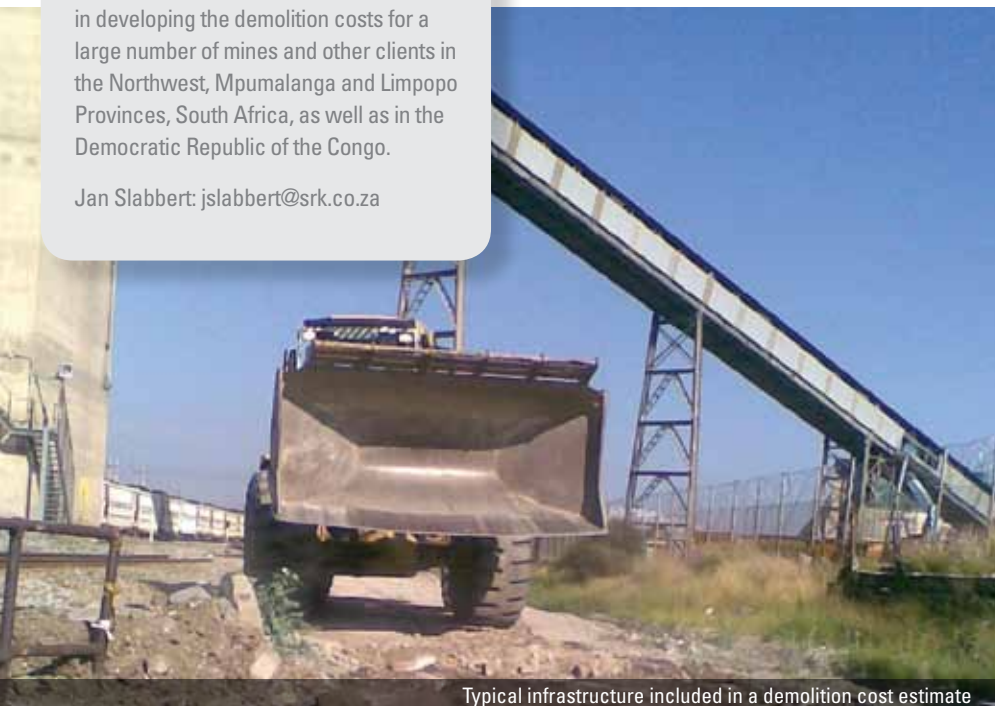
The estimated closure costs for the conceptual design were similar to the project's capital costs, mainly due to the costs of constructing stabilisation earthworks, the semi-

## JAN SLABBERT

Jan Slabbert graduated as a Civil Engineer and is a registered Professional Engineer and Construction Project Manager. He has 30 years' experience in Project Management and Contract Administration for large diameter pipelines, large reinforced concrete and structural steel structures, pump stations, water reticulation systems and general building projects. After working as a contractor for SRK in 2001, he joined the permanent staff in 2002 to head the newly established office in Rustenburg. In 2003, he was introduced to mine closure and has since been involved in developing the demolition costs for a large number of mines and other clients in the Northwest, Mpumalanga and Limpopo Provinces, South Africa, as well as in the Democratic Republic of the Congo.



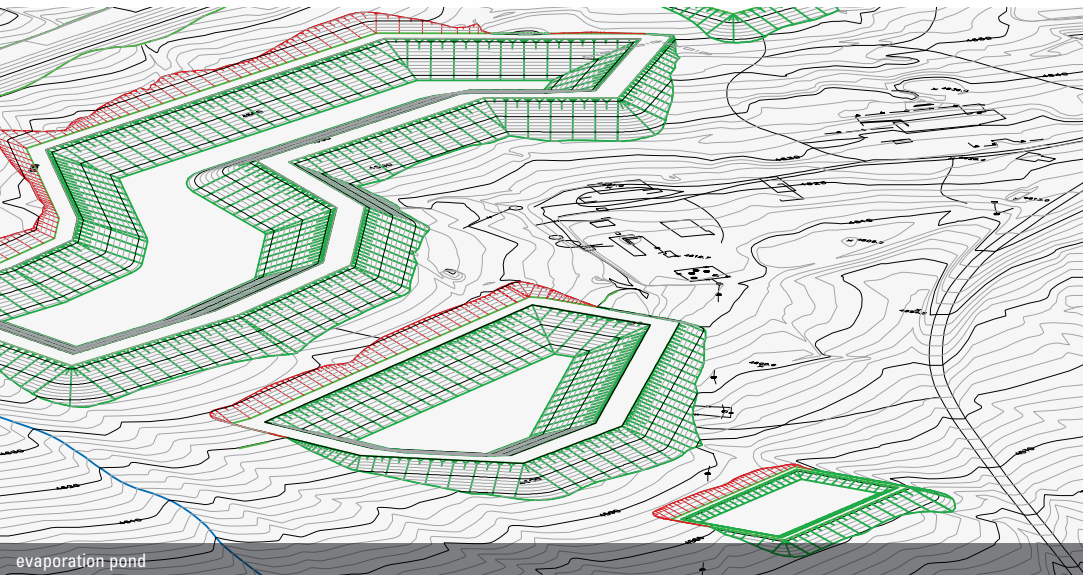
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Typical infrastructure included in a demolition cost estimate



## Capital expenditure to reduce long term closure liability



active management of post-closure draindown, and the anticipated requirement to pay the reclamation bond in cash. To reduce long-term closure liability and therefore upfront cash bonding requirements, the design was modified as follows:

- The single synthetic liner was replaced with a double-synthetic liner, sandwiching a leakage collection and recovery system (LCRS)
- The site grading design limits the rates of rise of the tailings surface to generally less than 10 feet per annum, and provides 3 feet of closure cover material for the tailings area
- Material from the grading operation was used to construct an upstream diversion berm, which includes all material for closure cover installation
- The drainage system was reconfigured to flow to an internal sump with the water either discharged back onto the tailings surface or recycled to the plant

- If operations suddenly cease, water balance scenarios all show a net negative water balance within the first one to two closure years, under average climatic conditions.

The capital design allows for constructing a designed penetration of the secondary liner to gravitate leakage into a double-lined evaporation pond that can easily manage the maximum permitted LCRS flow of 150 gallons per day.

With these modifications, capital costs increased by about 20 percent, but reclamation costs decreased by about 70 percent, resulting in an estimated 25 percent reduction in short-term capital outlay for construction and reclamation bond payment for the tailings impoundment.

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### DAVE BENTEL

Dave Bentel has over 30 years of experience providing engineering and environmental permitting services, and financial estimating services for mining facilities. He specialises in cost-benefit evaluations using risk-based assessments of water and waste management facilities, and planning, design and implementation for closure and reclamation of mine infrastructure, processing plants, tailings impoundments, heap leach facilities, open pits and waste rock facilities.



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### BREESE BURNLEY

Breese Burnley of SRK's Reno office has 18 years of experience in engineering consulting. His expertise includes mine and waste disposal site engineering, permitting, stormwater, slope stability, design specifications, cost estimation, bid adjudication, and construction oversight. Breese's work has taken him to numerous industrial, mining, and landfill properties throughout the western United States and South and Central America.



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# Reducing economic impacts from interim closure



A well-planned interim closure will position the mine for a smooth start

## VALERIE SAWYER

Valerie, based in SRK's Elko office, has a degree in Metallurgical Engineering and over 30 years of experience in mine environmental permitting and compliance, and metallurgical engineering. She has worked on a broad range of projects throughout the western United States. Her environmental experience includes the management and preparation of National Environmental Policy Act (NEPA) documents, the permitting of precious metals mines, and environmental compliance. Valerie has managed closure planning under various regulatory requirements and has overseen multi-discipline studies for the collection of environmental baseline information that supports environmental impact statements.



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**Interim or temporary closure** can be defined as the cessation of the operation of a mine, or a mining or processing activity, as a result of a planned or unplanned activity. Cessation of operations can be precipitated by a number of factors such as a drop in commodity price, seasonal closures, unforeseen weather events, a failure in a major processing plant component, labor disputes, agency shutdowns, or litigation.

Planned or unplanned temporary closure does not release an operator from their compliance obligations. Temporary closure planning has to consider:

- Removing blasting materials, fuels, and reagents from the site
- Maintaining public safety
- Maintaining wildlife protection measures

- Maintaining stormwater runoff and runoff controls
- Managing process fluids
- Continuing environmental monitoring
- Stabilising excavations and workings
- Controlling toxic or deleterious materials
- Dewatering

An unplanned interim closure has the potential to cause major economic losses through loss of key staff, environmental compliance issues, improperly stored equipment and consumables, lack of security, leading to theft and vandalism, restocking fees, and re-negotiation of contracts.

A successful interim closure will be well-planned prior to the occurrence and should involve the different areas of the operation, including the mine (operations and maintenance), mill/process (operations, maintenance,

## Soil covers for cold region mine closures

**S**oil covers are widely used in the closure of tailings and waste rock. However, current soil cover practices are based on experience from temperate regions, and on the theoretical basis provided by agricultural soil physics, which is also derived largely from studies in temperate zones.

Two recent research projects led by SRK's Vancouver office identified several dozen "cold region" processes with the potential to significantly affect soil covers in high latitude or high altitude locations. Natural cold region soils are subject to ground freezing and ground ice formation, ground thawing and thaw settlement, and seasonal freeze-thaw cycling. But more exotic processes like cryoturbation, solifluction, gelifluction and convective cooling can also occur. These processes result in a range of exotic terrain features, such as ice wedges, pingos, thermokarst, patterned ground, boulder fields, mounds, hummocks, and mudboils. The rates at which these processes occur can be slow enough that they would not be obvious in current observations of soil covers, but fast enough that they might have significant effects over a cover's design life.

The research surveyed over 100 examples of soil covers either proposed for or constructed on mine wastes in cold regions. Very few of the constructed or proposed covers have been reviewed from a cold region perspective. But several large-scale cover trials in cold

regions were identified, and SRK made recommendations for ensuring that those projects make the most of opportunities to advance the state of the art.

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### MARITZ RYKAART

**M**aritz Rykaart, P.Eng., Ph.D. is a Principal Geotechnical Engineer in the Vancouver Office. He has 19 years' experience in mine waste management



and applied research. Maritz specialises in mine waste management, with special interest in design and construction of soil covers for waste rock piles, tailings impoundments and heap leach pads. Maritz has been directly involved in the design of over fifty cover systems on five continents in all climate zones including arid, tropical and arctic. His involvement in cover design spans the full spectrum from material characterisation, modelling, construction, performance monitoring, senior peer review and teaching short courses on the topic.

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dewatering), the environmental department, the safety department, and administration (purchasing, human resources, and accounting). The kickoff meeting will define the anticipated parameters, including environmental and safety compliance and monitoring, security, mobile and stationary equipment storage, handling of stored fuels, oils, blasting materials, and reagents, whether dewatering can be curtailed or set at a maintenance level, and staffing levels.

SRK professionals can help with the different facets of interim closure planning to reduce the potential economic impacts and position the mine for a smooth start. In addition to our expertise in interim closure planning, SRK provides final closure planning services throughout the world.

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Example of the effect that "cold region" processes imposed on a cover constructed in the Canadian Arctic



# How did the International Cyanide Code get started?

In response to public concern about environmental impacts from gold mining operations, the mining industry set up a stakeholder group under the United Nations Environmental Program to address prevention planning. The group developed a certification program to demonstrate responsible management of cyanide, protection of human health and prevention of environmental impacts. Companies comply with a set of nine principles related to cyanide handling and use, and must pass periodic audits. As of October 2009, 21 gold mining companies, 12 cyanide producers and 23 cyanide transporters were Signatories.

Part of the Code's strength is its public transparency. Audits are conducted by an independent company with demonstrated expertise that is able to show no conflict of interest with the audited company. Browse [www.cyanidecode.org](http://www.cyanidecode.org) to learn more.

SRK assists mining operations internationally to comply with the requirements of the International Cyanide Code. Our services include engineering designs; monitoring plans, closure plans and other documentation; and pre-audits/audits.

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About 10 years ago, a multi-stakeholder group created a system that demonstrates a company's voluntary commitment to environmental standards under the International Cyanide Code. Companies certified under the Code (referred to as Signatories) have publically committed to comply with its requirements and have demonstrated that their business is environmentally responsible. Principle 5 of the Code concerns decommissioning and addresses the issue of closure, which was often overlooked or underfunded by the mining industry in the past. The Code focuses exclusively on cyanide-related activities, and excludes some other typical closure activities, such as physical stabilisation and reclamation.

The Code objective regarding closure states: *"Protect communities and the environment from cyanide through development and implementation of decommissioning plans for cyanide facilities."* There are two Standards of Practice associated with the

## Closure planning to comply with the International Cyanide Code



decommissioning principle. The first states that Signatory companies must *“Plan and implement procedures for effective decommissioning of cyanide facilities to protect human health, wildlife and livestock.”* The second states that Signatory companies must *“Establish an assurance mechanism capable of fully funding cyanide related decommissioning activities.”* The Code places the burden on the company to demonstrate compliance with broad objectives and goals, but does not address technical methods to achieve compliance.

The Code requires a written decommissioning plan that includes three key parts: (1) the methodology to be used to decommission at each cyanide-related facility; (2) a schedule of closure activities; and (3) a cost estimate. The closure methodology should address decontaminating equipment and facilities, such as rinsing equipment, removing residual cyanide reagents, and neutralising

heap leach pads. The schedule need not be based on calendar dates; a better method is sequencing the tasks involved. The company must establish a financial assurance mechanism based upon the cost of a third-party contractor implementing the decommissioning activities.

The Code does not specify when the closure plan should be updated, but if changes occur, the closure plan will need to be current and up-to-date to pass periodic audits required to maintain certification.

By complying with the closure requirements, companies show their stockholders, lending institutions, the public and other stakeholders that their operations are environmentally responsible. Long-term benefits include better support from stakeholders; lower risk operations; reduced liabilities; and easier financial funding.

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### DAWN GARCIA

Dawn Garcia is based in SRK's Tucson office and has over 20 years of experience in groundwater characterisation studies,



environmental compliance and project management. Her experience includes diverse project sites, such as smelters, active mining facilities, aerospace facilities, oil refineries, steel foundries, crude oil production land, manufacturing facilities, and gas stations. She has taught a course on mine closure at the University of Guanajuato, Mexico and has been an invited speaker at mine closure workshops. Her current project work includes support of multiple gold mining operations to obtain certification under the International Cyanide Code. She is licensed as a professional geologist in many US states and certified under AIPG. She meets the definition for a qualified person under the Canadian NI 43-101.

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## PETER HEALEY

Peter Healey has a degree in Civil Engineering and has over 25 years of experience in mine waste and water management, mine reclamation and closure, environmental assessments and mine permitting. His broad project experience throughout Canada, the US and Mexico includes the design and construction of tailings and waste rock management facilities including water management. His multidisciplinary projects focus on providing technical advice and support to the mining industry.



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## ANDREW BARNES

Andrew Barnes, C.Geol, FGS, MSc, PhD, is a Senior Consultant in geochemistry. He has specialised in aquatic and environmental geochemistry and has attained British



Geological Society charterhip in environmental geochemistry. Andrew's areas of expertise include characterising mine wastes to assess Acid Rock Drainage and Metal Leaching (ARDML); field and laboratory based analytical geochemistry, geochemical modelling and data analysis. He has worked on over 20 mine waste characterisation projects in base and precious metals, and numerous geochemical modelling projects. Andrew has extensive ARDML project management experience in Africa, Asia and Europe.

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# Engineering solution to save Pacific salmon in the Tsolum River



Subgrade preparation and liner deployment at Mount Washington, BC

In partnership with local communities, the BC provincial government and local industry, SRK developed a long-term solution to control copper-bearing drainage that has been contaminating the headwaters of the Tsolum River for decades. The objective of the project was to improve water quality, return salmon, steelhead and cutthroat trout to local waters, and support the goal of sustainable BC fisheries.

After briefly operating from 1964 to 1966, the Mount Washington copper mine has been a major source of acid rock drainage (ARD) entering the Tsolum River near Courtenay, BC. Previous remediation projects have been only partially successful at controlling the problem and treating the copper bearing discharge from the mine site.

Beginning in 1987, federal and provincial agencies funded studies, monitoring and on-site works to address the ARD problem. Between 1988 and 1992, the B.C. Ministry of Energy, Mines and Petroleum

Resources (MEMPR) spent \$1.5 million on site remediation, hiring Steffen Robertson and Kirsten (Canada) Ltd. (SRK) to design and install a till cover, the primary focus of the remediation work. The cover was placed over waste rock in the East Dump located below the North Pit, to prevent oxygen and water from contact with the waste rock. Other smaller scale Ministry activities included testing an experimental asphalt emulsion/geotextile cover, and applying calcium hydroxide to the pit walls and floor to attempt to raise the pH and reduce metal loading. Since SRK's initial work in 1988 and 1989, the site has been the subject of numerous government, consultant and academic reports and assessments.

Water monitoring results from 1993 to 1996 revealed there had been little reduction in copper levels. However, since 1998, water quality monitoring has shown sustained reductions of approximately 50%, which is believed to result from the onsite works.



# Using abandoned mines as field laboratories



In 2003, industry, government and the local community formed a unique partnership to seek long-term solutions. In 2003, the partnership asked SRK to develop a long-term remediation plan for the site.

In 2008, three BC Ministries announced funding for the project. Quantum Environmental, SRK and Stantec were hired to place a low infiltration cover on the North Pit of the mine. Work on the project started in 2009 and included constructing an underdrain system, installing a bituminous liner, and placing and revegetating a soil cover.

Early results have been encouraging; average copper loadings leaving the site dropped 77%. The project is expected to be completed in summer 2011, with post-construction monitoring carried out by the Tsolum River Restoration Society and the Ministry of Environment.

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**SRK** Cardiff and Cardiff School of Engineering are collaborating to characterise the impacts associated with mine waste at historical sites in central Wales, stretching back over 800 years. Our study will systematically collect representative mine waste samples from historic mine dumps. Working with industrial archaeologists, the dumps will be dated. Samples will be subjected to a range of diagnostic leaching and characterisation tests and compared to fresh, unweathered wall rock from underground. The results will be compared with reported levels of environmental impact at the site to determine the most effective test procedures.

Typically, efforts to deal with pollution from abandoned metal mines have been made by local, national and regional agencies. Most projects involve major upheaval to the site during civil engineering works that are designed to control leaching and dust generation from spoil heaps, often because of concerns over human health.

In some instances, such as at Bwlch and Cwmsymlog lead mines in mid-Wales, pollution impacts on the water have not been improved, spoil was disturbed and contamination released. There is also a common problem of unlicensed removal of spoils for use as aggregates. It is clear that any earth works on these

sites can cause or aggravate impacts and concomitantly impact their archaeological and historical value.

The issue to be considered is which scientific methods should be used to quantify the impact potential of mine spoils so that the effect of disturbances can be predicted and mitigated. This is not a straightforward question; a plethora of experimental procedures are available. Applying the wrong type of test can, and often does, lead to a gross misinterpretation of the impact potential.

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## MATT DEY

Matt Dey has over 12 years' experience in the geoenvironmental field. With expertise in mineral processing and the geochemical treatment of mine wastes and waters, he applies his skills to mining and engineering problems. Matt has a Ph.D. on The Origins and Control of Acid Mine Drainage; he does academic research in process engineering and chemistry, environmental geochemistry and environmental engineering.



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Preparation of soil closure cover

# The Environmental Management Plan and closure planning

During 2009, SRK Johannesburg completed a number of environmental compliance audits as part of due-diligence exercises. These reviews showed that closure planning is frequently limited to strategies presented in an Environmental Management Plan (EMP). These EMPs are generally prepared during authorisation, years before mining and decades before closure. Once developed, these plans are seldom revisited for appropriateness. In SRK's experience, closure requirements tend to focus on returning the site to some land capability that existed before mining. This strategy tends to mitigate most environmental impacts; however, very costly remedial measures are often required to achieve the objective.

As a result, mining operations that must make provisions for closure to the authorities annually, sequester capital until closure that could be used for other environmental or social purposes. Conversely, if the EMP is inadequate or outdated, significant unaddressed liabilities could arise.

If closure considerations were integrated into the process, and some closure activities undertaken during the operation, the liabilities deferred to the end of the operation could be reduced substantially and significant cost savings realised, for instance, by identifying alternative land use and land capability options and planning for them accordingly. While the post mining land capability may not be the same as the option envisioned pre-mining, it may still reduce impacts to an acceptable level.

Involving communities in closure planning is important to this process. Affected communities, left with the legacy of the mining operations, may miss potential land use that offers some economic return and is likely to be more sustainable. Planning closure early in the mine's life cycle and revisiting it regularly can potentially reduce social dependencies on mining, while economic realities, properly assessed and analysed, may not have been adequately addressed or even understood when the EMP was being developed.

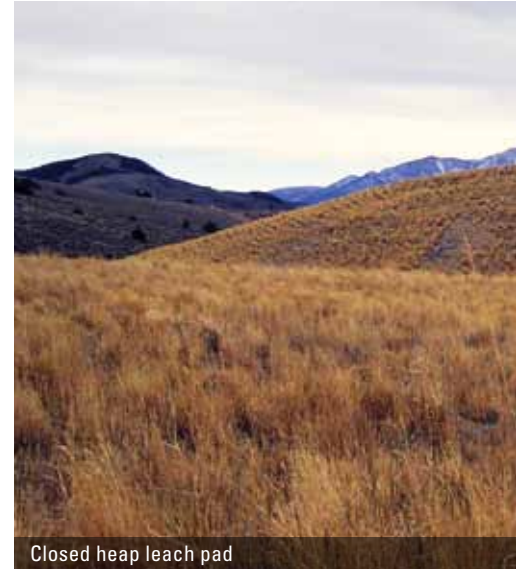
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## JAMES LAKE

James Lake is a Principal Scientist with 12 years' experience. Trained as a geochemist, he developed broad experience in general environmental management working on a colliery in South Africa and on various consulting projects. Over the last five years, James specialised in preparing closure liability assessments in South Africa's platinum industry, but also in the Copperbelt of Zambia and the Democratic Republic of Congo. He contributed to Environmental and Social Impact Assessments within the Equator Principles II framework. James helped audit compliance within these Principles on copper, nickel and uranium mining operations.



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Closed heap leach pad

The last two decades have seen a significant evolution in both the methods and purposes for estimating closure costs. As part of this evolution, changes in how closure cost estimates are used have resulted in coincident changes in the scope, methods employed, and level of detail required.

Before regulatory requirements were developed, closure cost estimates were typically intended for the planning, design, and contracting of the actual closure, and were often developed late in the mine life cycle. These estimates became the basis for construction contract bidding and tracking purposes.

As mining laws changed and the need to provide financial surety for closure activities became a priority, the focus changed to estimating the liability of the government that would assume responsibility should the operator abandon the site prior to planned closure.

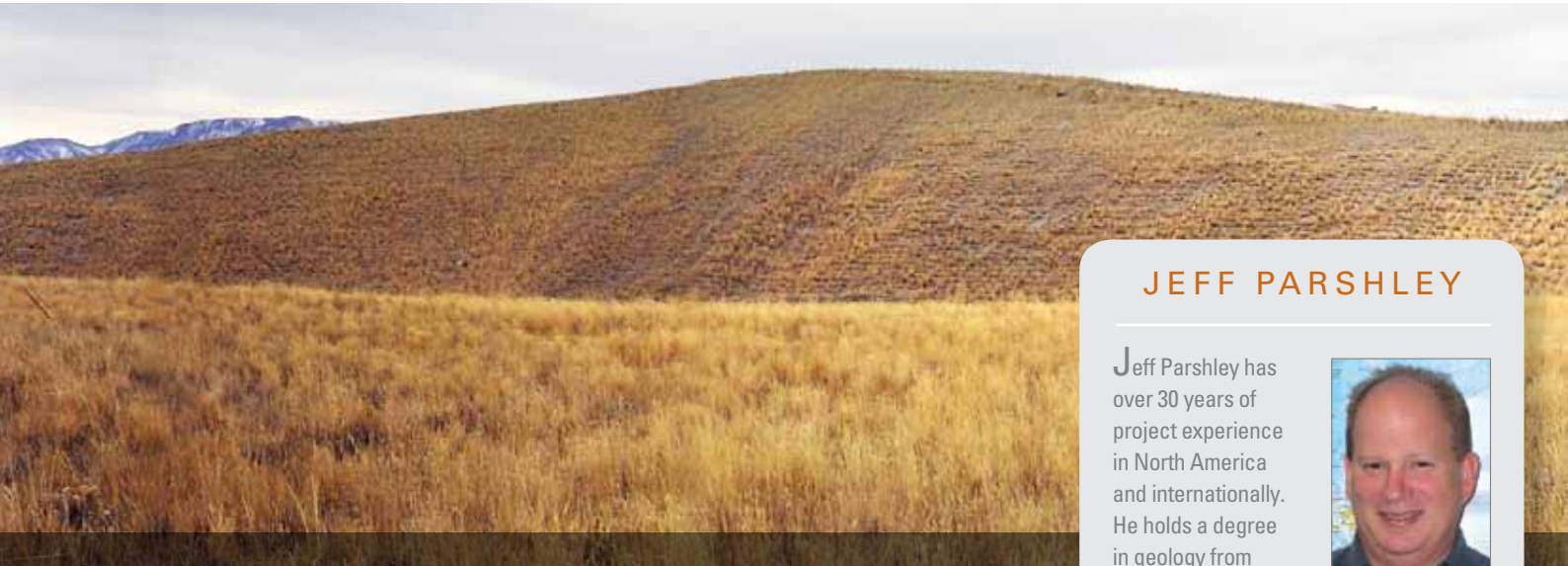
Most recently, techniques used in closure cost estimating have focused



Mine nursery where plants for remedial use are cultivated during operations



## Closure cost confusion



on accurate reporting of financial liabilities to shareholders and lending institutions, adding a new dimension to the scope and details of closure cost estimating.

To address these different uses, three types of cost estimates have been developed: financial assurance estimates, Life-of-Mine cost estimates, and Asset Retirement Obligation estimates. Each has specific requirements.

Financial assurance cost estimates define the cost that a government agency would incur to perform all of the actions documented in an approved closure plan should the company abandon the site without implementing closure. These estimates are usually based on the maximum liability that will be incurred during the current permit term. They typically require the use of third-party equipment and labor rates and may include significant government-mandated indirect costs.

A Life-of-Mine (LOM) cost estimate defines the cost that a mine operator

would incur to perform all of the actions required to fulfill the closure portion of their current mine plan. LOM cost estimates typically use operator rates, include all closure costs associated with the current mine plan, and are usually reported on a cash-flow basis. Common uses for LOM closure cost estimates include prefeasibility and feasibility studies, due diligence audits, accrual allocation, annual planning and budgeting, and cost tracking.

Asset Retirement Obligation (ARO) is the term used for financial reporting of mine closure liabilities by U.S. GAAP and IFRS compliant stock markets. ARO cost estimates are prepared each year as part of the annual financial reporting process to disclose the fair value (U.S. GAAP) or best estimate (IFRS) of the current liabilities associated with a mine or mineral processing operation. Each year they are adjusted to reflect any changes in the operations that occurred in the financial reporting year.

### JEFF PARSHLEY

Jeff Parshley has over 30 years of project experience in North America and internationally. He holds a degree in geology from Dartmouth College, Hanover, New



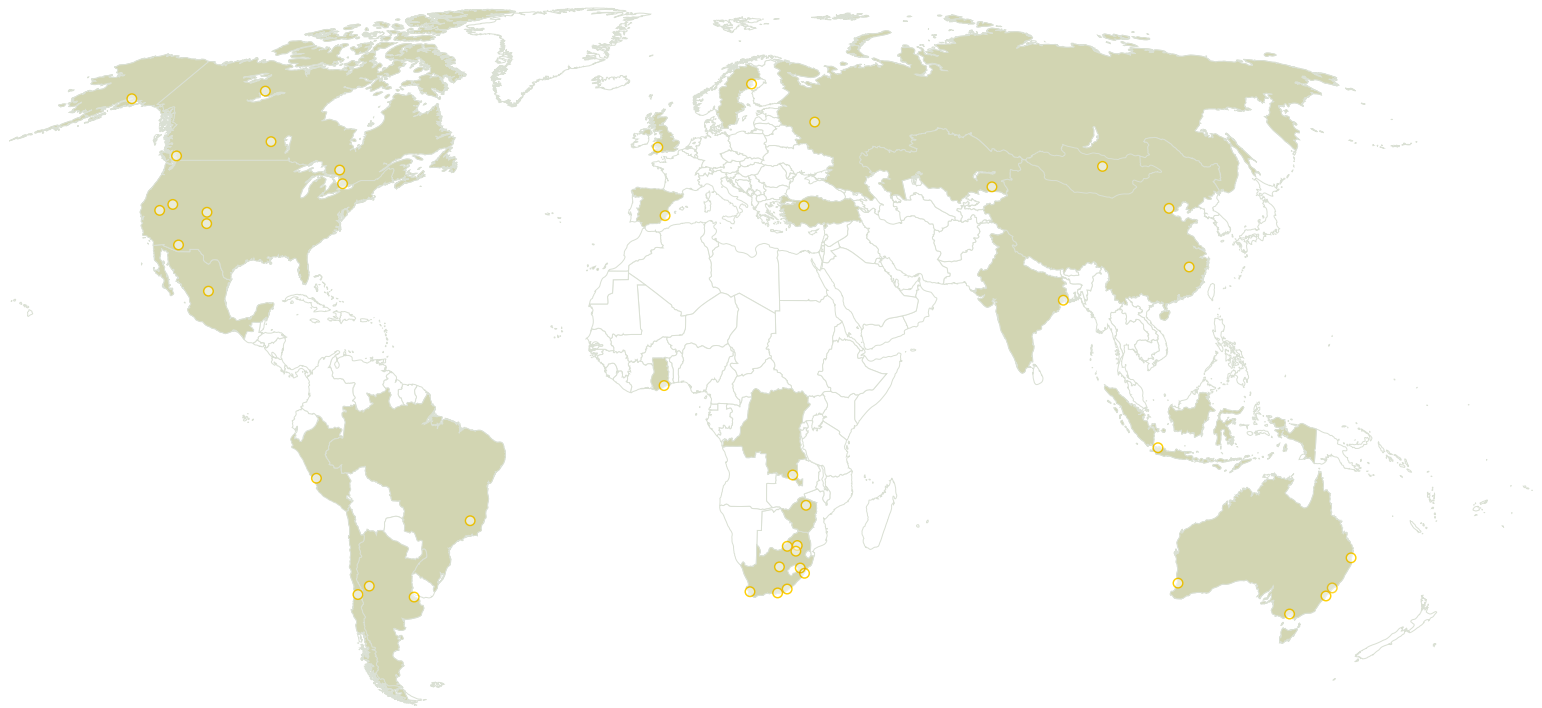
Hampshire. Jeff's expertise includes mine closure and remediation, mine environmental studies, mine permitting, and environmental geochemistry. In particular, he has specialised in closure cost estimating work including the development of the public domain Standardized Reclamation Cost Estimator (SRCE) model used by mining companies around the world to prepare closure cost estimates.

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Although it may appear that the differences between these types of closure cost estimates are subtle, the use, final product, and therefore approach will be different for each type of estimate. It is important to recognize the difference between these types and determine which type of estimate is required for each project and each purpose.

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Specialist advice for mining projects in all global environments and geotechnical consulting for other sectors.

To learn more about SRK and how we might help you with your next challenge, please visit:

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