

# mining services

an overview of SRK's services to the global mining industry







## Mining Services

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**A** world of experience, technical knowledge, and understanding. That's what SRK brings to your project. Profitable mining demands an independent, experienced, long-term perspective that gives you real clarity. Whether it's advice on project feasibility, property acquisitions/disposals, financing, geotechnical stability, sustainability or mine closure, we have an extensive breadth of knowledge and depth of experience to ensure you get the right advice, where and when you need it most.

mining



## Multi-specialist services through project life cycle

SRK Consulting is an independent, international consulting group providing focused advice and solutions for your mining and exploration challenges. SRK's services cover the full life cycle of mineral industry projects. Our team includes leading experts in services ranging from exploration through resource estimation, mining, geotechnics, hydrology, tailings, processing and valuations to environmental planning, remediation and mine closure.

## Global expertise, local experience

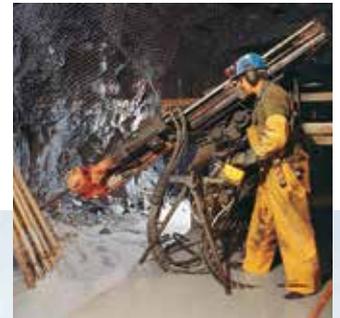
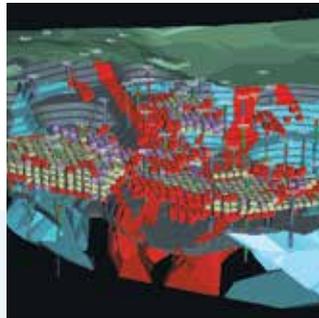
Established in 1974, the SRK group employs more than 1400 staff in over 45 offices on six continents. Over 150 internationally recognised associates complement our team. When appropriate, we partner with other consultants, EPCM companies and research organisations. We draw on our global industry specialists to match your project challenges with appropriate expertise and experience.

## Solid track record - most countries, most commodities

We have successfully completed a wide range of projects, large and small, in most areas of the world and across the full spectrum of mineral commodities. The industry background of many of our staff ensures that advice is not only technically sound but thoroughly practical. Our working relationships with the international banking/financing community and regulators reduce your risks with project financing and permitting.

## Clients large & small seek our advice

Among our multiple clients are most of the world's major, intermediate and junior mining and exploration companies. We also work with banks, EPCM and construction firms and public sector entities. We take pride in our independent opinions based on honest and appropriate analysis. We do not own equity in any projects or companies.



# Exploration Services

Finding the mines of tomorrow

## Approach

Successful exploration relies on efficiently managing exploration programs based on effective application and interpretation of geology, geochemistry and geophysics to generate and test exploration targets. Our core exploration services include exploration and drill planning, exploration management, QA/QC assessments and planning, audits on drilling, economic assessments, and project evaluations.

In addition to these core offerings, our specialised services include advanced structural interpretation skills, the ability to connect the minerals systems to the structural setting, systematic orebody targeting, and 3D modelling. We specialise in the development of process-driven, conceptual models to identify and improve the understanding of your mineral targets. Our in-house consultants have expert knowledge of the processes of ore body formation and distribution within a wide range of geological and tectonic settings.

In many geological terrains around the world, exploration is becoming much more focused on discovering deeper or “blind” orebodies, as the scope for targeting easily accessible areas is becoming more limited. In highly mineralised terrains, exploration for these orebodies is a major opportunity. Delivering exploration success in deep targeting requires a much more reliable understanding of the geometry of structures in the third dimension. This need is driving development and application of 3D modelling and 3D visualisation technologies (for example, GoCAD, Geomodeller and Leapfrog software), ensuring that mineralisation targets are defined by multiple exploration and mining parameters, and are directly focused on adding value to the project.

These new technologies are essential tools for effective 3D exploration. However, their use is not yet widespread because of the perceived cost and time required to develop expertise. We use these and other cutting-edge 3D geological and geophysical modelling methods, and are also undertaking research and development of our own. This gives us a distinct advantage in providing the best solutions for your projects.

## Services

- Exploration project management
- Exploration and drill planning, drill spacing studies, sampling protocol definition
- Property and project evaluations, assessments and audits
- Regional tectonic and metallogenic syntheses to provide context for province selection, property acquisition and project generation, including ranking of exploration targets for specific deposit styles or commodities
- Detailed structural analysis, from basin- to ore deposit-scale, emphasising 4D (3D+time) controls on mineralisation
- Advanced geophysical and geological interpretation of remote sensing data
- Deposit-scale structural evaluation to define geotechnical domains and hydrogeological controls
- Exploration risk evaluations
- Geophysical modelling/enhancement processing/data visualisation
- Tailored, onsite structural geology training courses with a focus on practical tools for exploration and mine geologists



Technical review of a coking coal project in Manchuria, NE China, conducted for Celadon Mining

#### Giralia Resources

**Project:** Earahedy Basin iron formation targeting, Western Australia.

**Scope:** The project area is part of a major undeveloped Mesoproterozoic Fe province in Western Australia. SRK was asked to interpret the structural setting, structural history and generate exploration targets.

**Outcome:** We identified the major factors that control Fe-enrichment in the Basin. These factors were mapped by combining the interpretation of geophysical data, geological mapping, drilling results. After assessing topographic and structural controls, and direct magnetic anomalism, a number of exploration targets, of both hypogene and supergene enrichment styles, were located.

#### Vale Inco

**Project:** Footwall PGE exploration, Sudbury Basin, Ontario, Canada.

**Scope:** Footwall PGE mineralisation in the Sudbury Basin is often hosted in Sudbury breccia zones and copper-rich chalcopyrite veins. We provided structural assistance and training to Vale Inco personnel on multiple projects, building the team's strengths in structural geology at the same time as helping to define potential PGE deposits and new targets.

**Outcome:** Using Vale Inco personnel's knowledge of Ni - Cu - PGE systems and our knowledge of structural controls the client was able to define new resources on multiple projects.

#### PT. Merge Energy Sources Development

**Project:** Coal exploration management, Barito Basin, Kalimantan, Indonesia.

**Scope:** Based on successful due diligence work on the Rantau Nangka coal project in southern Kalimantan, SRK provided JORC-compliant exploration management for the client.

**Outcome:** SRK refined coal exploration targets within the large tenement area primarily based on structural analysis of magnificent highwall exposures in a surrounding coal mine. Moreover, SRK inspected the local coal laboratory, and updated Standard Operating Procedures for the Rantau Nangka coal project based on site observations and findings.

#### Thani Dubai Mining Limited

**Project:** Medden gold, Republic of Yemen.

**Scope:** SRK conducted a technical audit of previous exploration and recommended a comprehensive set of standardised procedures for core logging and sampling and the creation of an electronic database. In addition SRK acted as technical consultants ensuring that the exploration met international best practice standards.

**Outcome:** SRK produced a Resource Statement based on all exploration to date, investigated a number of production scenarios and presented a business case study on this deposit. We will also be involved in an ongoing resource delineation drilling program.

# Resource Modelling and Estimation

Unlocking greater value with experience and innovation

## Approach

Our geologists have extensive experience in exploration, database management, resource estimation, grade control and conditional simulation. We can take your project from grassroots exploration through the feasibility study stage and into production.

Our approach to resource estimation combines our strengths in structural geology and ore deposit geology, our understanding of geostatistical theory and our extensive resource estimation and mining operational experience. While each resource estimate is tailored to each specific project, our general procedures typically include:

- An assessment of the quantity and quality of the data available including database management and verification
- The creation of 2D and/or 3D geological and mineralisation models for the deposit
- Statistical and geostatistical analyses of the data and the determination of the most appropriate grade and density interpolation methods
- Classification and reporting according to accepted internationally recognised codes

We have a large skills base and extensive experience in the use of all the major geological modelling and geostatistical packages. Notably, the original Gemcom software was developed within SRK while more recently the Leapfrog software has been developed under a joint venture agreement with Applied Research Associates of New Zealand. This gives SRK the flexibility to continue the use of the software that you are currently using or select the most appropriate software for new projects.

We have experience in developing and reviewing geological models and resource estimates for all commodities and deposit types. We also have a large base of competent/qualified persons as defined by the various internationally accepted resource reporting codes.

## Services

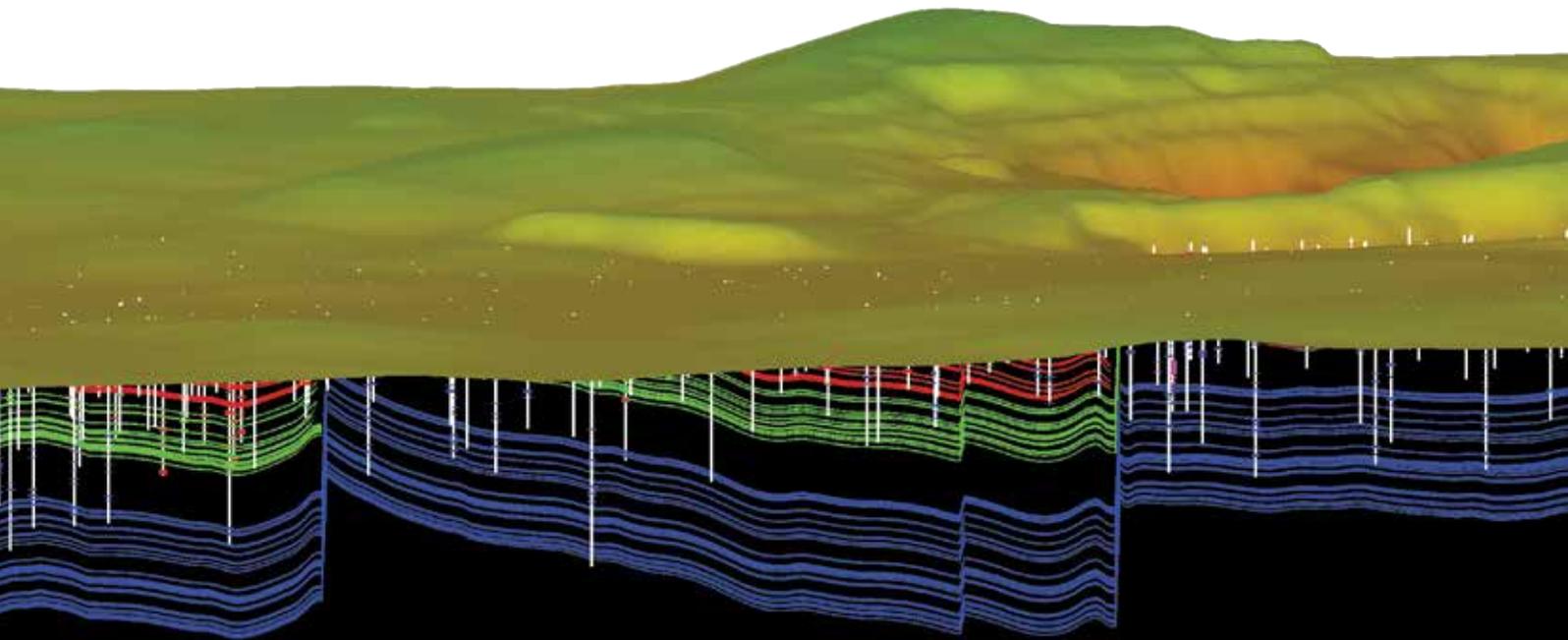
- Evaluations of exploration properties
- Reviews of exploration sampling results and QAQC procedures
- Optimisation of drillhole targeting for resource definition
- Exploration and database management
- Creation of 2D and 3D geological, structural and mineralisation models
- Statistical and geostatistical analyses
- Resource estimation, classification and reporting for all stages of projects from scoping studies through to feasibility studies and operating mines
- Due diligence reviews of geological interpretations and resource estimates
- Metal accounting and production reconciliations

### Sino Gold

**Project:** Jinfeng, China.

**Scope:** Resource estimation for a structurally controlled gold project requiring selective mining via open-pit and underground methods.

**Outcome:** Uniform conditioning was applied to the open-pit material, allowing an estimation of the distribution of mineable economic grade material within the larger resource blocks. A conditional simulation approach was utilised for the underground mining, stope size blocks were directly estimated and the levels of risk in each evaluated.



## Integrated Buckingham geological model in Minex

### Various

**Project:** Resource estimation for nickel laterites.

**Scope:** Nickel laterites, in particular the saprolites, present difficult challenges for resource estimation. The geometry is complex due to the presence of low-grade or waste boulders and the bedrock contact is highly irregular at a scale which is much smaller than the typical drilling grid.

**Outcome:** SRK introduced an innovative estimation method based on uniform conditioning, extended to several variables, aimed at reproducing the real degree of mining selectivity likely to be achieved in practice.

### Hampton Mining

**Project:** Medium-sized copper porphyries and copper-gold veins, Chile and southern Peru.

**Scope:** Early to advanced stage copper projects at resource definition drilling stage, to mining scoping study to early pre-feasibility.

**Outcome:** Provided the client with tailored integrated services, beginning with early exploration resource definition, and including geotechnical, environmental and mining aspects of ongoing engineering and feasibility studies.

### Rainy River Resources

**Project:** Rainy River gold project, Ontario, Canada.

**Scope:** Produce a resource update to address deficiencies in an earlier study.

**Outcome:** Detailed structural analyses led to the construction of unique 3D geological/geostatistical domains which were further refined using Leapfrog software. Resources were reported at multiple cut-offs to reflect 'reasonable prospects of economic extraction'. The resulting resource estimate will allow the client to make technically-sound strategic decisions on the future of the resource.

### African Minerals

**Project:** Tonkolili, Sierra Leone.

**Scope:** Review the extensive data collected during a two-year drilling program, assist in the detailed logging of the overlying hematite cover and underlying magnetite itabirite, produce 3D geological models, and prepare the project's first resource estimate (which has since been updated).

**Outcome:** The most recent resource estimate produced by SRK exceeds 5Bt at a mean grade of 30% total iron, making it one of the largest magnetite iron ore projects in the world.

# Open Pit Mining

Digging deeper for value

## Approach

SRK professionals have strong operational and technical backgrounds and have gained substantial experience in mines across multiple commodities, methods, continents and countries. This ensures that our solutions and advice are not only practical and workable, but take account of appropriate geotechnical, hydrogeological, economic and environmental considerations.

SRK's services cover scoping, pre-feasibility and feasibility studies and economic evaluations, detailed mine design and layouts, production scheduling and equipment selection, operating cost estimation and capital expenditure estimation. We also have key people pro-actively reviewing improved mining methods outside traditional approaches.

We have in-house skills with all major software design, optimisation and scheduling packages. We have expert users for a range of software packages including Whittle, Gemcom, Vulcan, MineSight, Datamine, Surpac, Talpac, Xpac and Minemax.

We have developed an innovative and rigorous mine planning methodology that takes a mineral resource through to a comprehensive technical report inclusive of the life-of-mine plan and techno-economic model. The methodology first focuses on pit optimisation to determine the cut-off strategy, economic mining depth, size and scale of operation. We are dedicated to identifying the best option for project development and producing client-focused solutions to technical challenges.

With the growing need to bring projects into production more quickly and on budget, we can accelerate the process for mining companies by supplying consultants to supplement the client's own technical resources to achieve the desired outcomes within the project timeframe. Our personnel ensure appropriate decisions to guide project development are made at the earliest opportunity, and are committed to reviewing what aspects of project advancement can be done in parallel to minimise the risk of rework.

## Services

- The full range of studies from scoping to feasibility
- Mine planning reviews and technical audits
- Development and implementation of optimal mining strategies
- Operational assistance, reviews and improvements
- Financial evaluations
- Risk analysis
- Project reviews
- Due diligence
- Competent person reports
- Independent expert reports
- Stock market listing reports

European bulk commodity producer

**Project:** Located in Finland.

**Scope:** Feasibility studies assessing the viability of in-pit crushing and conveying (IPCC) for a long life-of-mine operation.

**Outcome:** A conceptual study considered the benefits and risks; operating and capital costs were estimated and reported. This determined the IPC locations and conveying options potentially adding significant project value. Further studies considered modifications to the mine plan to provide an updated mine production schedule, and staged and final mine designs to update both cost and revenue streams.



Norilsk's Thunderbox Pit (previously LionOre), Western Australia

#### Norsemont Mining Inc

**Project:** Constancia, Peru.

**Scope:** Scoping study which involved mineral resource evaluation, geotechnical, open pit mining, plant, tailings, environmental and infrastructure.

**Outcome:** Two production rates, 30 and 55ktpd, were evaluated for copper and molybdenum processing. The study included open pit optimisation and pit design, mining equipment selection, waste dump location analysis, operating and capital cost estimation, metallurgical parameters review, process and plant layout design based on sulphide flotation process, water supply, power supply, access roads, transport alternatives and economic evaluation.

#### Areva

**Project:** Trekkopje, desert region of Western Namibia.

**Scope:** Definitive feasibility study for an open pit uranium mine and heap leaching operations (36Mtpa ore).

**Outcome:** Mine planning included analysis for two potential ore types with variable processing costs and a deleterious material penalty formula. Project optimisation focused on strategic development of the open pit resources involving analysis of production rates, material handling options, permanent pad/on-off pad alternatives, and project layouts. Project planning assisted the client to negotiate sale of the junior mining company to a major company in the uranium industry.

#### Projeto Pedra de Ferro (PdF)

**Project:** Caetité, Bahia State, Brazil.

**Scope:** Feasibility study of an iron ore deposit done in conjunction with BAMIN, Construções e Comércio Camargo Corrêa S.A. and SRK, with contributions by other consultants.

**Outcome:** SRK assisted BAMIN on the pre-feasibility study (PFS), including open pit optimisation, analysing many pit planning scenarios and selection of a base case. After the delivery of the PFS, BAMIN requested SRK develop the geology and mining components of the definitive feasibility study.

#### Luna Gold Corporation

**Project:** Aurizona, Maranhão State, Northern Brazil.

**Scope:** Feasibility study (compliant with Canadian NI 43-101 for an open pit gold mine and milling operations (1.5Mtpa ore).

**Outcome:** Mine planning optimisation studies examined different operating costs and processing assumptions, and the optimum mine production schedule to extract mine reserves was developed. The ultimate pit design incorporated more than 10 design phases. The report was compiled within a period of weeks, filed with the regulatory authorities and used by the client to solicit project financing.

# Underground Mining

Ensuring technical viability and economic realism

## Approach

We have years of first-hand underground mining experience in most countries and across multiple commodities using all common mining methods. As a global group, we have specialist underground mining expertise to provide solutions for the unique features of each project.

Based on this extensive experience, we utilise an innovative and rigorous mining method selection and planning methodology that maximises the economic benefit of the project. The methodology first focuses on understanding the complete mining context or characteristics of the deposit. This is the fundamental information required to select the appropriate mining method and establish a robust mine plan. The design of stoping blocks using the appropriate cut-off grades and minimum mining widths is followed by optimised production and development scheduling. All mine design and schedule opportunities are left open until an optimised plan is defined.

We recognise the constant need to match changing commodity prices and capital costs with appropriate responses from mining operations: reduction in operating and/or capital costs when prices fall, and increasing capacity when prices rise. We also understand the socio-economic implications of mining operations and address these in our strategic planning.

We are focused on producing mine designs and schedules that make the most effective use of mine capital, in both short and longer term time frames. We can assist companies optimise the transition from open pit to underground mining by offering a thorough analysis of the appropriate cross-over depth as well as presenting highly mechanised and often automated solutions.

Whether optimising an existing operation or deciding how to extract a new deposit, SRK can help ensure appropriate solutions are understood and implemented.

## Services

- Mining context definition
- Mining methods selection
- Complete mine design
- Development and production scheduling including sequence optimisation
- Geotechnical characterisation
- Ground support system design
- Equipment selection
- Engineering studies (from scoping to feasibility studies)
- Drill and blast design
- Strategic planning: cut-off grade and production rate analysis
- Fragmentation analysis and draw control for caving operations
- Backfill system design
- Risk analysis and management
- Due diligence
- Ventilation system design
- Operational review and assistance



Since 1999 SRK has worked with BHP Billiton's team at the Ekati™ Diamond Mine in Canada to select and design appropriate underground mining methods for individual kimberlite pipes

#### Codelco Chile

**Project:** División El Teniente, Chile.

**Scope:** Carry out a peer review to check compliance with Codelco's standards for a pre-feasibility study, in order to advance to a feasibility study phase for the new mine level project.

**Outcome:** Analysed the location of the new undercut level for the panel caving exploitation at 140ktpd with the possibility to expand to 180ktpd.

#### Ivanhoe Mines Ltd

**Project:** Oyu Tolgoi, Mongolia.

**Scope:** Open pit and underground studies and ongoing technical assistance for development of the Oyu Tolgoi deposit.

**Outcome:** SRK was involved from the early stages of the project in various aspects of the mining studies. Utilising extensive knowledge of mass mining technology, SRK assisted the client to make the critical decision in terms of mining approach and selection of design parameters. SRK also helped to evaluate trade-off studies between mining methods and has been retained to provide technical support for one of the largest block caving projects currently being considered.

#### Minera Hierro Pajoso

**Project:** Iron ore deposit, Chile.

**Scope:** Complete a scoping study which considered open pit (at 100ktpd) and underground (at 20, 25 and 30ktpd) options for ore extraction. High-level consultant for hydrology and hydrogeology issues, process and plant design, ore transportation, environmental, and port facilities review.

**Outcome:** Technical and economic evaluation was carried out to define the best mining extraction method. Underground option was selected due to limited time for ore production. Dry magnetic concentration was selected for the ore process. Further work recommended for the next stages.

#### Northgate Minerals Corp

**Project:** Young-Davidson, northern Ontario, Canada.

**Scope:** Preparation of a conceptual underground mine design and economic assessment. The client was assessing the possible reopening of a historic gold mine that had two shafts and extensive underground workings, and involved high tonnage bulk mining employing open stoping.

**Outcome:** Completed conceptual mine design and indicative economic assessment, which justified additional work to advance the project. After further studies and investigation, Northgate has completed a pre-feasibility study and has started a full feasibility.

# Feasibility Studies

Eliminating fatal flaws; finalising and detailing options

## Approach

Our goal is to give you the highest confidence in the underlying value of your project, by providing appropriate analyses and interpretations to support your key project decisions and development strategies. We know what works, and which issues constitute opportunities and risks. Our focus is on getting specific project concepts correct at the front end, where it matters.

Most of our team of experienced mining personnel have spent many years on operating mines prior to consulting. This experience helps us offer practical expertise in a wide range of technical services from geology and resources, to tailings and heap leach engineering, through permitting and mine closure. This blend of know-how, together with the innovative application of advanced mining technologies, has led to the wide acceptance of our engineering studies by the mining, banking and investment community internationally.

Our teams are assembled to meet the unique needs of each project. We typically partner with an EPCM company which provides process and infrastructure skills. Our strong relationships with several of these companies enable us to form the partnership best suited to your project's challenges. SRK's services consist of the preparation of scoping studies, pre-feasibility and feasibility studies for both underground and open pit projects.

Being part of the SRK worldwide group means we have access to many global specialists. We can supplement and complement local expertise with the geological, geotechnical, hydrogeological, mining, metallurgical, mine closure and environmental and social skills of consultants required to match the specific challenges of your project.

## Services

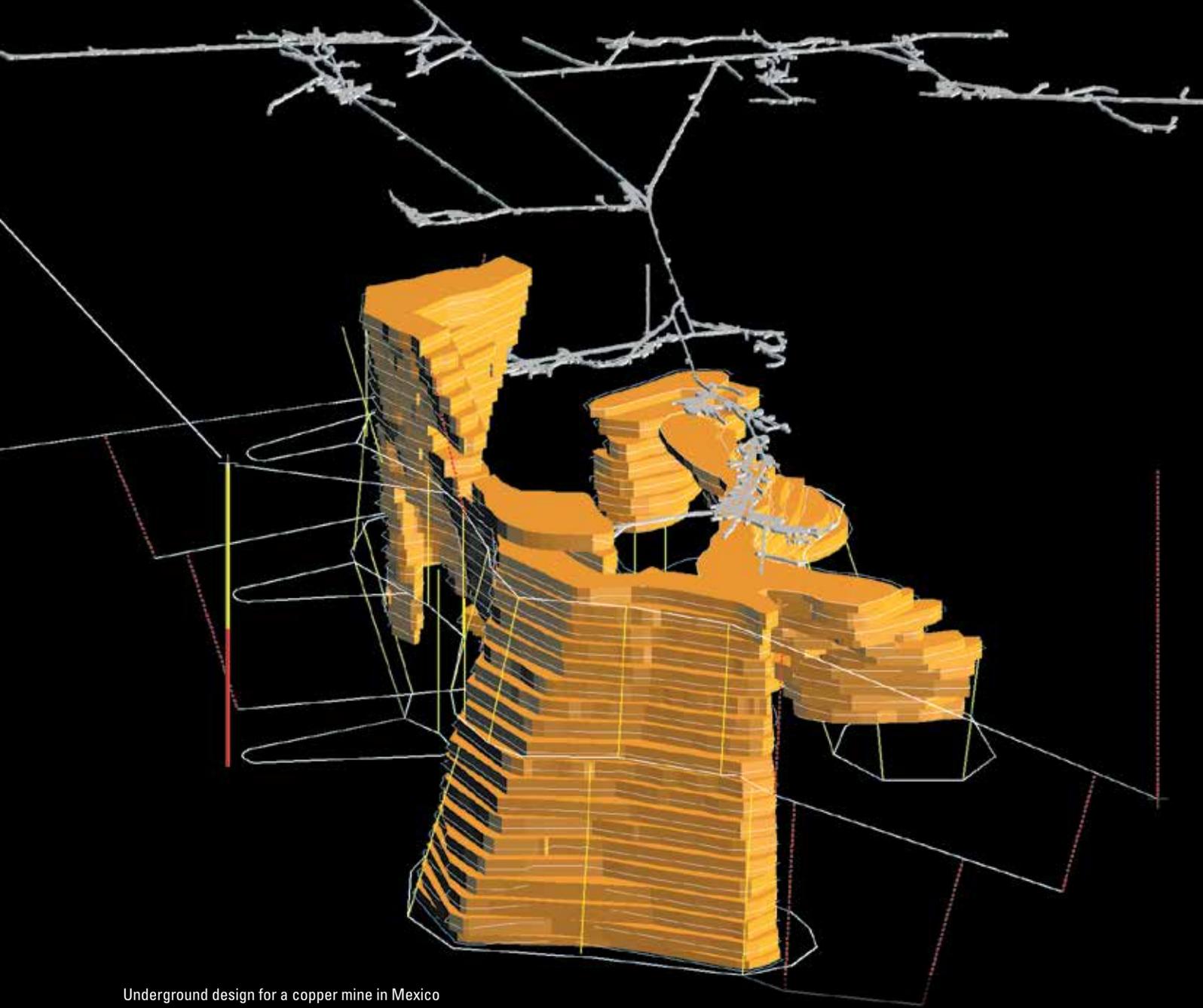
- Scoping, pre-feasibility and feasibility studies
- Legal tenure assessment
- Mining method analysis and selection
- Production capability assessment
- Production and development scheduling
- Capital and operating cost estimation
- Equipment selection
- Logistics capability assessments
- Engineering and infrastructure design
- Estimation of manpower and management requirements
- Implementation schedule
- Financial analysis modelling and valuation

### Sinosteel Midwest Corporation (SMC)

**Project:** Weld Range, Western Australia.

**Scope:** Detailed pre-feasibility study (PFS) and bankable feasibility study (BFS).

**Outcome:** SRK's contribution to both studies included project management, geology, resource estimation, geotechnical engineering, geochemistry, groundwater, mine planning, mine closure and risk assessment. The mine planning aspects of the studies included pre-strip, production ramp-up, mining fleet selection, blending and dilution and ore loss aspects. Several option studies evaluating adjacent deposits were planned.



Underground design for a copper mine in Mexico

#### Minera Tayahua

**Project:** Scoping study, Mexico.

**Scope:** Completion of a feasibility study covering aspects such as mining, geology, estimation of resources and geotechnical model, as well as environmental issues and hydrogeology in order to select the mining method and underground operation design (10,000tpd).

**Outcome:** Selected an underground mine design with a high productivity and extraction rate at a preliminary level for the demonstrated and potential geological resources of the skarn-type deposit. The project's business potential was identified, giving the client a strong technical base on which to base future decisions.

#### A-Cap Resources

**Project:** Letlhakane uranium project, Botswana.

**Scope:** Scoping study of the Letlhakane project located in east-central Botswana.

**Outcome:** The scope of work for the study included mining optimisation, evaluating the mineralogy and metallurgy, evaluation of water supply potential, the project environmental requirement, and then selecting a process option. Capital and operating cost estimates were developed for four scenarios.

#### Confidential Client

**Project:** Gold project, eastern Senegal.

**Scope:** Pre-feasibility study (PFS) of a multiple deposit gold project involving a team of SRK and subconsultants. Conduct the studies and oversee all technical aspects of the project from exploration targeting through to mine closure.

**Outcome:** Conducted a PFS within a very restrictive timeline. Managed data collection to get the most data possible from each part of the exploration program and kept multiple elements of the project progressing at the same time. The solutions met the needs of the client and local community.

#### Katanga Mining Limited

**Project:** Kolwezi, Democratic Republic of Congo.

**Scope:** To complete a feasibility study and independent technical report (ITR) on the material assets, which included four open pit and one underground copper/cobalt mine, two existing processing plants and the development of a new SX/EW refinery and plant.

**Outcome:** Both studies were published in April 2009.

# Rock Engineering and Slope Stability

Ensuring a safe environment and profitable mining

## Approach

We have the knowledge and experience to work on a range of studies from scoping to feasibility and operational improvement across all major resource types, for open pit and underground operations, and for operational support. Our consultants, many with industry backgrounds, have worked on deposits on all continents bringing a broad international perspective and experience to your projects.

Our team of professionals includes individuals with highly developed numerical modelling capabilities. We offer a mix of analytical and empirical analysis complemented by sound operational experience to give solutions that are innovative and practical and design parameters that are optimised for the conditions and mining strategy. We focus on the application and interpretation of the analytical results by reducing the data to create geotechnical domain models, representing sectors of the project that are expected to have similar geotechnical characteristics. Our deliverables are useful geotechnical models and design parameters to ensure that you get practical, focused results that add value to your projects.

We work hard to stay at the forefront of industry and technological developments: our experts have participated on the Large Open Pit Study group coordinated by CSIRO, the Weak Rock Support group coordinated by ITASCA and the industry sponsored Mass Mining Technology Study (formerly International Caving Study). We use techniques such as Sirovision or 3DM Analyst and we are developing data collection improvements for rock mass classification.

We are able to provide experts in the key areas to assist you to deliver successful projects and are happy to work closely with your teams to strengthen in-house capacity by transferring our understanding and skills.

## Services

- Training of client personnel
- Geotechnical field investigation, mapping, logging, and databasing
- Structural interpretation and analysis
- Rock mass characterisation and domain modelling
- Mining method selection and excavation sequencing optimisation
- Assessment of impact of groundwater on open pit and underground design
- Mine infrastructure and capital development excavation design
- Pit slope and underground stability analysis, 2D and 3D modelling and design
- Dilution, fragmentation and caving analysis
- Design of underground and slope support systems
- Design, implementation and management of monitoring systems

### Rio Tinto

**Project:** Simandou iron ore project, Guinea.

**Scope:** Geotechnical feasibility studies, characterisation of itabirite and waste, pit slope and waste dumps design, and operational criteria.

**Outcome:** Completed geotechnical, logging and material testing programs over a 14km strike of the proposed mine. Site supervision and logging teams collected data for over one year. Deeply weathered footwall influenced stripping costs and waste volumes. A robust geotechnical model, defined slope angles and a mining strategy to reduce the geotechnical risk were developed. The recommendations had the potential to substantially reduce stripping costs.



### Well engineered slopes: Essential in major open pits

#### Alamos Gold Inc

**Project:** Mulatos Mine, Sonora Mexico.

**Scope:** Design level pit slope evaluations for four open pits at Mulatos.

**Outcome:** SRK conducted a probability-based evaluation that allowed pit slopes to be modelled using probability distribution functions of rock strength test results. This Monte Carlo analysis approach prevented overly conservative pit slope angle recommendations by avoiding using simple average, or low-end, rock strength values. The Estrella pit is currently being excavated, and performance indicates that the pit slope angle was effectively maximised.

#### De Beers Canada

**Project:** Victor Mine, Ontario, Canada.

**Scope:** Geotechnical, structural and hydrogeological investigation and open pit slope design and technical assistance to the mine.

**Outcome:** SRK was part of a multidisciplinary technical team which assisted De Beers Canada to formulate and develop a mining approach from the advanced exploration stage to feasibility study for the first diamond mine in Eastern Canada. SRK's specific responsibility covered geotechnical investigation of soils and rocks and ongoing geotechnical support to the mining operation to assist De Beers achieve its goal of a safe and profitable operation in James Bay Lowlands.

#### Compania Minera Antamina S.A.

**Project:** Antamina Mine, Ancash, Peru.

**Scope:** Conducted structural review of the polymetallic skarn deposit to define key structures that may influence rock stability. Included detailed field mapping within the open pit, review of exploration and production drillcore, 3D modelling, and structural geology training for Antamina staff.

**Outcome:** Identification of 59 fault structures forming seven different fault generations with associated kinematics and cross-cutting relationships. Created the mine's first structural 3D model, which was integrated with ongoing slope stability engineering and used to form a structural framework for prospective exploration areas.

#### Hindustan Zinc Limited

**Project:** Rajpura Dariba lead-zinc Mine, India.

**Scope:** Underground rock mechanics studies and numerical modelling for development of mining method and sequencing for stoping in an area which was prone to premature hangingwall collapse due to the presence of a shear zone.

**Outcome:** SRK identified longitudinal sub-level open stoping with cemented backfill for the poor ground areas. Stable stope dimensions, stope support, backfill requirements and a sequence of mining that minimised exposure of the poor rock hangingwall shear was developed. The recommended mining method was trialled with good stability results and reasonable productivity.

# Tailings and Mine Waste Engineering

Ensuring practical operations; successful closure

## Approach

We have been extensively involved in the permitting, design, operation and closure of mine tailings, mine waste and associated water disposal/management facilities since 1974. Our expertise includes a wide range of tailings and mine waste products and hands-on knowledge of proven management techniques under a broad range of climatic conditions. We also have in-depth experience in understanding the long-term evolution of solids and porewaters in tailings storage facilities, allowing robust assessment of the adequacy of management and closure plans.

To achieve real cost benefits for tailings disposal, it is necessary to integrate the design of the process plant with the tailings disposal system, while giving consideration to all design aspects from site selection to impoundment closure. Our philosophy towards tailings and water management is heavily based on our worldwide operational experience. We aim to provide solutions that appropriately cater to each project's needs, providing stable facilities that can be practically operated and successfully closed.

Recognising the growing need for the provision of mine waste management systems with increased water efficiency, we have invested in expanding our tailings and waste management capability. Also, with the greater emphasis on water conservation and social conscience in the mining industry, we have improved our knowledge of thickened tailings technology. This emerging technology is attractive to mines operating under strict water restrictions or those that have limited water resources available, enabling them to attain a competitive advantage in terms of water use. It also reduces the potential for contamination of soil and water sources, allowing these scarce resources to be available to other users.

## Services

- Short- and long-term strategic planning for tailings and water management
- Risk and hazard assessment
- Failure evaluations
- Feasibility studies and financial evaluations
- Emergency response plans
- Site evaluation and selection
- Water balance development and utilisation
- Emissions testing and evaluation
- Geotechnical, hydrogeological, rheological and geochemical characterisation
- Geotechnical, hydrologic and rheological evaluation and design (conceptual through to detailed)
- Life cycle trade-off studies
- Design to accommodate low strength, low density materials
- Paste and thickened tailings schemes
- Pilot scale test work and material characterisation
- Design of tailings facilities (conceptual through to detailed)
- Assistance with government permit acquisition and compliance
- Assistance with construction management and quality assurance
- Assistance with operational monitoring and management
- Decommissioning, closure and landform restoration



Construction of flotation tailings storage embankment at Jinfeng, China

#### Antofagasta Minerals

**Project:** Esperanza, Chile.

**Scope:** Conceptual design for tailings disposal, including evaluation of conventional cyclone and thickened tailings disposal (TTD).

**Outcome:** The TTD option was recommended and pilot testing was undertaken to establish the likely beach angles, seismic properties and seepage rates from the TTD. Trade-off studies were undertaken to further evaluate the impacts and costs of dewatering to a dry product. A BFS and detail design for permit submittal to the Chilean authorities were completed. The permit was issued in 2008 and the facility is due for construction in early 2010.

#### Ferrexpo Poltava GOK (Poltava Mining)

**Project:** Yeristovskoe Mine, Ukraine.

**Scope:** Design of two waste dumps to store large quantities of soft overburden and waste rock materials. Optimisation of storage capacity to match the geotechnical constraints and earth moving strategy.

**Outcome:** SRK's work involved multidisciplinary cooperation with the mine planners, hydrologists, local institutes and potential earthmoving specialists. A risk-based approach to dump design was deemed to be appropriate and allow optimisation of the slope angles to meet local authorities' regulations and practical considerations for storage of soft overburden waste.

#### Ma'aden

**Project:** Al Jalamid, Saudi Arabia.

**Scope:** Detail design of the thickened tailings phosphate disposal facility and pit diversion structure.

**Outcome:** The scope of services included the detailed design of earthworks and water diversion structures, construction drawings, development of technical specifications and schedules of quantities, the development of an operations manual, an operational risk assessment and statement of environmental impacts. The project is to be constructed in 2009.

#### Anglo Platinum

**Project:** Mogalakwena Mine, South Africa.

**Scope:** Establishment, commissioning and operation of a pilot scale thickener and evaporation paddocks. Characterise the tailings paste material in terms of rheology and geotechnical properties and calculate water consumption of the tailings material at different slurry densities.

**Outcome:** The pilot plant was constructed on site along with the evaporation paddocks. On-site testing included thickener optimisation and rheology testing along with evaporative drying tests. Off-site testing included determination of thickener sizing and operating parameters along with geotechnical testing.

# Heap Leach Engineering

Reducing risks; increasing production

## Approach

Our approach to heap leach engineering follows the traditional custom of initially defining project criteria, and then focusing on the most efficient manner to develop conceptual and ultimately detailed engineering design drawings, specifications and quality assurance programs that meet the project criteria. Project criteria typically include:

- Regulatory criteria including prescriptive requirements for protection of site environmental resources such as surface water, groundwater, air quality, flora, fauna and soils
- Corporate criteria including risk management, health, safety, environmental and community criteria, operational scheduling deadlines, and cash flow constraints
- Engineering design criteria for conceptual through detailed design based on state-of-the-art engineering practice incorporating all relevant regulatory and corporate criteria for all phases of the heap leach life cycle, including construction, operational, decommissioning and closure phases

Experience in both base and precious metal leaching projects has shown that the successful accomplishment of our design mission requires both a sound understanding of regulatory and permitting issues, and proficiency in a wide range of technical disciplines including but not limited to civil and geotechnical engineering, hydrology and hydrogeology, regulatory permitting, metallurgical engineering and geochemistry.

In striving to maximise leached product recovery, we have developed and implemented innovative solutions including utilisation of artificially created negative pore pressures in heap ore to optimise leachate flowpath and product metallurgical recovery. In addition, and based on our experience with heap and process pond closure design and implementation, we have developed an approach to closure design that focuses on appropriately reducing (if not eliminating), post-closure effluent flows and associated water management risks and treatment costs.

## Services

- Site selection
- Geotechnical investigation
- Conceptual through final level design and studies
- Detailed engineering
- Construction quality assurance
- Operational monitoring and management
- Permitting and regulatory compliance
- Decommissioning and closure
- Risk and hazard assessment

### Areva

Project: Somair Mine, Niger.

Scope: Leach pad engineering for the feasibility and detail design of a 17Mt dedicated uranium leach pad and associated ponds at the Somair mine.

Outcome: Interfaced with Technip on the stacker and process solution application systems, and designed the containment and solution collection system, performed stability analysis, designed the solution conveyance and solution pond system, and prepared a detailed schedule of quantities, drawings and specifications. Completed the construction QA/QC oversight of the leach pad earthworks and geosynthetics.



The heap leach facility at Alamos Gold's Mulatos Mine in the Sierra Madre Occidental mountain range, Sonora, Mexico

#### Jipangu

Project: Standard Gold Mine, Nevada, USA.

Scope: Geotechnical site investigation and engineering design for a 25Mt run-of-mine (ROM) gold heap leach facility and associated process solution ponds. The 25,000tpd operation is anticipated to produce heap with net ore height of about 300 feet on ground up to 13% slope angle.

Outcome: Design optimised heap and proposed ore stacking sequence, evaluated containment requirements, and static and seismic stability. Specific, sub-grade and overliner versus smooth and textured HDPE liners were analysed. A water balance was completed, and solution ponds and solution management systems designed.

#### Aura Minerals Inc

Project: San Andres Mine, Honduras.

Scope: Design of three phases of heap leach expansion.

Outcome: SRK designed the Phase IIB, Phase III, and Phase IV heap leach pad expansions. The primary challenge was to create stable heaps in excess of 100m in height, with clay-rich foundation material. SRK developed grading plans that met stability requirements. SRK's Phase IIB work included design and construction management of a cement-amended soil foundation that has provided additional stability for the heap.

#### Alamos Gold Inc

Project: Mulatos Mine, Sonora, Mexico.

Scope: Design of a interlift liner system and stacking plan for a vertical expansion of the 14,000tpd heap leach facility. An assessment of the slope stability of the interliner system was conducted to assure stability of the heap, with the addition of lower shear strength liner surfaces.

Outcome: Ore recovery has increased 30% with the addition of the first interlift liner and other factors that have improved recovery.

#### Areva

Project: Trekkopje, Namibia.

Scope: Feasibility design for a new 30 million tonne on-off uranium heap leach pad and associated process solution ponds. SRK designed the 2.5Msq.m pad to optimise the grading requirements, designed the containment and solution collection system, performed geotechnical site investigations, stability analysis and water balance, and designed the solution conveyance and solution pond system.

Outcome: SRK is currently developing the detailed design, including bid document support such as developing schedule of quantities, drawings and specifications.

# Environmental and Social Services

Facilitating decisions: permitting, risk management and social license

## Approach

Whether planning a mine, staying on course, suspending operations or closing a facility, mining companies need to satisfy numerous and often complex regulatory requirements while simultaneously addressing community expectations. The complexity can be compounded by a need to prove to investors that risks are handled appropriately. We can assist you in achieving your ultimate goals, whether they are an environmental permit, an investment decision, a “social license” to operate or a closure certificate.

Our practical experience with a wide range of mining projects assures the identification of environmental and social issues critical to a venture’s success. To this end, we work with mining companies to overcome any challenges; with financial institutions to identify and manage risk; and with environmental regulators to provide relevant assurances and solutions.

Environmental and social studies often require a multi-specialist approach. Technical knowledge combined with project management expertise ensures the appropriate level of study is undertaken. Our professionals have the skills and experience to reduce your risks whilst meeting project objectives in a cost and time-efficient manner.

We can assist you with monitoring programs, audits and reviews to evaluate the effectiveness of existing management systems, and identify weaknesses and risk areas in terms of potential environmental failures and community grievances. Audits also provide a forum for the exchange of technical knowledge and identification of cost reductions.

Our environmental and social data management skills can turn your data into information, enabling you to make decisions in real time. Combining appropriate technical skills and experience with available computer technologies enables the processing and integration of large and varied spatial data sets of environmental, socio-economic, mining, hydrological and geotechnical information. Outputs can be analysed and compared, allowing for multi-disciplinary decision support and implementation of unique and cost-effective solutions.

## Services

- Site characterisation
- Baseline environmental and social studies
- Permitting for mining and associated operations
- Environmental and social impact assessment
- Environmental and social management
- Environmental liability assessments and financial assurance
- Stakeholder involvement and consultation
- Resettlement planning and implementation
- Environmental and social monitoring
- Audits and reviews
- Risk assessment
- GIS mapping and information management



Conducting ecological studies at Suriname, South America

#### Oriel Resources

**Project:** Voskhod chrome project, Kazakhstan.

**Scope:** Undertook an environmental and social assessment process, including baseline studies, stakeholder engagement, impact modelling and reporting. Working with our mining and geology colleagues who conducted the feasibility study, the challenges were to bring international standards to an area where historical and current mining has resulted in significant environmental disturbance, and to capacitate the community to participate in the consultation process.

**Outcome:** Integration of local regulatory and IFC performance standards: the requirements to satisfy lenders and obtain regulatory approval and stakeholder support.

#### NV Bhp Billiton Maatschappij Suriname

**Project:** Bakhuis bauxite project, Suriname, South America.

**Scope:** Coordinated a multinational team to assess impacts in a remote rainforest location to IFC performance standards. In addition to considering mining and waste disposal activities, the study evaluated impacts of ore transport to the refinery and dredging of transport watercourses.

**Outcome:** Innovative approaches were adopted to compile a baseline for a pristine and previously unstudied region and to work with indigenous people and their US and Canadian advisors, including the establishment of a communication forum ensuring a successful partnership with client and stakeholders.

#### Nunavut Government Canada

**Project:** Government inspector exploration checklist, Canada.

**Scope:** SRK was asked to develop a checklist for use by environmental inspectors (regulators) with high staff turnover and increased exploration activity in the region.

**Outcome:** A succinct checklist for inspectors with varying backgrounds and experience to use as a roadmap for environmental inspections of grassroots exploration programs. The exploration companies knew what they needed to do to maintain compliance with regulations and were assured these requirements would be consistent across the entire territory.

#### Standard Bank

**Project:** First Quantum Mineral Limited assets in Zambia, Mauritania and Democratic Republic of Congo.

**Scope:** SRK initially evaluated the environmental and social performance of FQML's assets with respect to the Equator Principles and IFC performance standards on behalf of a lender syndicate group. Over the next three years and in accordance with the loan conditions, SRK provided regular review and advice to FQML on how to achieve compliance within an agreed timeframe.

**Outcome:** Assisted FQML in making significant progress towards Equator Principles compliance.

# Environmental Geochemistry and ARD

Predicting, controlling and managing mine drainage chemistry

## Approach

Managing mine drainage water quality is a critical concern for all mining operations because discharges must typically meet stringent water quality standards set by local, regional and national governments. Acidic drainage remains the most significant issue due to high concentrations of metals, and costs of treatment to achieve acceptable levels. However, in the past decade or so, awareness of leaching under non-acidic conditions has greatly increased.

Accurate prediction of leaching effects, and design of practical and proven control measures, is often critical to the feasibility of your projects. These issues are encountered during permitting of new mines, optimisation of existing operations, development of closure plans and remediation of abandoned mines.

The cornerstone of our approach is that the release of ARD (acid rock drainage) is controlled by geological conditions. We therefore work with your geologists to understand how the geology of your property affects drainage chemistry, and how it can be used to limit potential impacts and engineering costs.

ARD potential is also affected by local climatic conditions. We have experience in the full range of global climates including permafrost in the high arctic, temperate regions, and both wet and dry regions of the tropics.

Our global team of experienced professionals will assist you to develop cost-effective solutions to mine drainage issues ranging from severe acidity to dealing with unusual trace elements. Our experience includes addressing drainage chemistry at all stages of the mining cycle.

## Services

- Waste characterisation
- Evaluation of potential for acid rock drainage
- Field assessments and monitoring
- Waste rock dump and tailings instrumentation for poregas and porewater monitoring
- Water quality modelling for input into waste management planning and effects assessment
- Site-wide contaminant load balances
- Evaluation of waste management measures
- Water treatment evaluations
- Cyanide geochemistry and waste treatment
- Integration of geochemical characterisation into mine planning
- Assessment of mine closure requirements
- Workshops and short courses
- Expert witness

### Western Canadian Coal Corporation

**Project:** Brule coal mine, British Columbia, Canada.

**Scope:** Estimation of water quality for environmental assessment and design of a new coal mine.

**Outcome:** Water quality estimates for waste rock and coal processing wastes were used as part of waste and water management planning to result in an open pit mine design that was subject to rigorous government review. The wastes were not expected to produce acid but selenium leaching was a particular concern. The project received all approvals and permits needed to begin operation, and is now producing coal.



Faro pit, Yukon Territory

#### Quadra Mining Ltd

**Project:** Malmbjerg project, Greenland.

**Scope:** Geochemical characterisation of a porphyry molybdenum deposit including field sampling, characterisation, mineralogy, acid base accounting, total and leachable metal content, groundwater chemistry, kinetic weathering tests and numerical predictions using the code PHREEQC to predict seepage and runoff chemistry from waste rock, lean ore stockpiles and tailings, and subsequent mixing with surface water. Critical issues included protection of arctic marine and wildlife habitat, potential interaction of ML/ARD from waste rock disposal and long-term passive attenuation of ML/ARD release.

**Outcome:** Feasibility study finalised and included ML/ARD mitigation.

#### Ministry of Agriculture & Lands (MAL)

**Project:** Britannia Mine, British Columbia, Canada.

**Scope:** During 1904-74, the mine produced about 800,000 t of copper. After the mine shut down, 5Mcu.m of contaminated mine water continued to flow into Howe Sound each year. In 2005, MAL commissioned an HDS water treatment plant (WTP). Surface water diversions were also constructed to reduce the volume of clean water passing through the plant.

**Outcome:** Surface water diversions redirect 300,000cu.m of clean water away from the mine workings annually, reducing the annual operating cost of the WTP.

#### BHP Billiton

**Project:** Olympic Dam expansion, South Australia.

**Scope:** SRK developed a conceptual model of the geochemistry of the tailings storage facility. Field and laboratory investigations furnished data to describe processes taking place within and beneath the facility. Current porewater within the facility is acidic and a focus of the investigation was predicting the long-term evolution of the seepage below the facility. The mobility of metals and radionuclides was examined to better understand attenuation mechanisms that exist in the system.

**Outcome:** The work supported preparation of EIS documentation submitted to the South Australian, Northern Territory and Federal governments in May 2009.

#### South Deeps JV

**Project:** South Deeps mine waste evaluation, South Africa.

**Scope:** Environmental and economic evaluation of historic mine waste piles and tailings via drilling of waste piles followed by geochemical characterisation for environmental geochemistry and geometallurgical assessment of residual value of waste for gold, uranium and sulphuric acid (pyrite). Numerical predictions assessed impact of metal leaching, sulphate release and acid generation on adjacent river.

**Outcome:** Waste piles were reprocessed to recover value and mitigate potential impacts. Non-economic material was covered and a passive treatment system was implemented to alleviate drainage impacts.

# Mine Reclamation and Closure

Protecting the environment & transitioning properties to new land uses

## Approach

The combination of our internationally recognised experience in all aspects of mining with our knowledge of local requirements makes us the partner of choice for many clients embarking on mine closure projects.

We recognised the increasing importance of mine closure to the industry in the early 1990s. We made it a central focus and have since worked closely with industry and governments to develop the current state-of-the-art practices that meet today's necessary requirements and standards.

Mine closure planning is necessary at all stages of a mining operation. Current best practice dictates that all mines should be 'designed for closure'. Closure plans and related financial securities are also required for permitting in many jurisdictions. Recent changes to standards for accounting of "asset retirement obligations" have created an additional need for mine closure planning and cost estimation. We routinely develop appropriate mine closure plans to meet these and your needs.

Implementation of closure plans begins with the engineering studies, testing and monitoring that translate plans into construction drawings. Our experience in these stages includes detailed closure designs for mines throughout the world. Implementation then continues through procurement and construction. Our knowledge here ranges from assistance with tendering and construction QA/QC, to delivery of complete design-build packages.

The importance of mine closure to our business has led to a high awareness of closure requirements by all of our technical specialists. Reclamation and closure planning is routinely incorporated into feasibility studies, operating plans, due diligence assessments and many other areas of our work.

## Services

- Assessment of closure requirements
- Management of closure planning
- Assistance with public consultation
- Development of closure concepts
- Waste characterisation and geochemical assessment
- Hydrologic assessments
- Seismic assessments
- Water quality predictions
- Environment assessment
- Earthworks stability assessments
- Earthworks design
- Soil cover design
- Reclamation design
- Landform engineering
- Water treatment system design
- Water diversion design
- Construction QA and QC
- Construction contract management
- Construction environmental management
- Design-build packages
- Preliminary and detailed cost estimates
- Development of cost estimation models



Cover construction over tailings, Colomac Mine, Northwest Territories

U.S. Army Corps of Engineers and Bureau of Land Management

**Project:** Elder Creek Mine, Nevada, USA.

**Scope:** The USACE identified the Elder Creek mine in Nevada as a site requiring extra funding for additional assessment prior to reclamation.

**Outcome:** The USACE and BLM proposed to stabilise and reclaim portions of the waste rock dumps, spent heap, ponds, and other disturbance. SRK evaluated the potential environmental impacts, prepared the engineering designs, and oversaw the construction efforts. We prioritised the reclamation efforts to use available funding to reclaim components that presented the greatest risk of degrading the environment.

BHP Billiton

**Project:** San Manuel mine and plant sites, Arizona, USA.

**Scope:** Development and implementation of closure plans for the former underground block cave copper mine, surface and in-situ leach operations and milling and smelting facility.

**Outcome:** Developed strategic closure strategies for the 10,000-acre facility, which included 4,000 acres of tailing impoundments, 400 acres of industrial area and 300 acres of mining area. Prepared the various environmental permit applications and obtained the necessary approvals for closure. Completed the engineering design for the final closure plan and monitored implementation.

Deloitte & Touche and Yukon Government

**Project:** Faro mine complex, Yukon Territory, Canada.

**Scope:** Development of a closure and remediation plan for the mine complex.

**Outcome:** The Faro mine was the largest operation in the Yukon and its closure plan required the agreement of two governments and three First Nations. We led the assessment of closure options, and helped to find a plan that was endorsed by all parties. During the multi-year assessment process, we also provided engineering for ongoing care, maintenance and remediation projects.

Department of Indian & Northern Affairs

**Project:** Giant Mine, Northwest Territories, Canada.

**Scope:** Processing of arsenopyrite ore generated 230,000 tonnes of arsenic dust that was stored underground when the mine was abandoned in 1999.

**Outcome:** SRK assembled a team that was selected as the lead technical advisor. We led the review of options and the development of a final remediation plan for the arsenic dust, and were then asked to develop a closure plan for the entire site. We are currently leading a full scale demonstration of the innovative ground freezing technology that was selected for stabilising the arsenic dust.

# Risk Management

Managing the risk, reaping the rewards

## Approach

The term “risk” has many meanings in the mining world. The current draft ISO guideline uses the broad definition of risk as “the effect of uncertainty on objectives”, and similarly broad definitions for “risk analysis”, “risk management” and “risk tolerance”. At SRK we are aware of the broader perspective, but also of the fact that many areas of our practice require expertise with specific risk management tools.

Our technical specialists apply state-of-the-art risk management tools related to their discipline. These tools vary widely. For example, our geotechnical engineers might use a reliability analysis to estimate the likelihood of a slope failure, and our environmental scientists might use an ecological risk assessment to characterise the significance of effects on the environment.

Our ability to apply complex risk tools is modulated by experience and judgment. Our specialists are aware of the weaknesses of overly quantitative risk tools, and work with you to find the simplest approach.

One of our particular strengths is the ability to integrate the methods used by our technical specialists into analyses of overall risks. Our processes help to take the numbers generated by technical specialists and relate them to your broader financial, environmental, community, and health and safety objectives.

Our goal in all cases is to help our clients achieve “risk efficiency”, i.e. a state in which all of the technical and non-technical issues facing an enterprise have been identified, analysed and mitigated to acceptable levels.

## Services

- Fault-tree analysis of engineered systems
- Event-tree analysis
- Reliability analysis of earth structures
- Dam safety risk assessments
- Human health and ecological risk assessment
- Failure mode and effect analysis
- Failure mode, effect and criticality analysis
- Technical-economic model risk analysis
- Enterprise risk assessment and management
- Facilitation of risk assessment workshops

### Ok Tedi Mining Ltd

**Project:** Fubilan underground mine pre-feasibility study (PFS), Papua New Guinea.

**Scope:** Risk management of PFS technical and commercial investigation for the conversion of an open pit operation to an underground mine.

**Outcome:** A risk investigation was conducted for each PFS element and the 13 sets of results collated into a draft aggregate risk register for the PFS. A risk workshop was held at the end of the PFS to agree on final risk evaluations. The risk register was included in the PFS report; risk knowledge applied in project approval process; and risk controls were identified for the next phase of development.



Freshwater supply dam decommissioned to mitigate failure risks, Faro Mine, Yukon. The project included engineered features (i.e. meanders, pools, riffles) specifically designed to create fish habitat within and upstream of the dam breach

#### Codelco Chuquicamata

**Project:** Chuquicamata Mine, Chile.

**Scope:** Investigated the possibility of increasing pit slope angles as the pit approached its planned closure. The slope steepening was understood to raise the net present value of the mine, but also an increase in the likelihood of slope failures.

**Outcome:** Completed quantitative evaluation to define the risks in terms of safety and economics, quantifying risk levels for different slope configurations and comparing results against industry norms. The study provided management with the appropriate basis for decisions about slope steepening.

#### STX Corporation

**Project:** Surat Basin coal asset due diligence, Queensland, Australia.

**Scope:** SRK, in conjunction with PricewaterhouseCoopers performed technical and commercial due diligence on a defined set of Surat Basin coal assets for a proposed purchase.

**Outcome:** A risk investigation was performed on each technical and commercial element of the due diligence study for which SRK had responsibility. The results were collated into an aggregated risk register and included in the report.

#### Indian & Northern Affairs Canada

**Project:** Development of enterprise risk system for closed mines.

**Scope:** Indian & Northern Affairs Canada manages dozens of closed mines in the Canadian north. We helped the Contaminated Sites Program develop an enterprise risk assessment process, including risk matrices, consequence-severity tables and action requirements.

**Outcome:** The risk assessment system is now an integral part of INAC's project management process, with annually updated risk registers being used to prioritise cost control as well as environmental, social, and health and safety improvements.

#### Riversdale Mining

**Project:** Benga Mine, Tete, Mozambique.

**Scope:** Risk management of a bankable feasibility study (BFS) technical and commercial investigation into the greenfield establishment of a 5Mtpa open-pit mine and associated infrastructure.

**Outcome:** A draft aggregate risk register was collated using the results from a risk investigation which was completed for each BFS element. The resultant risk register is to be included in the BFS report by the client, and the risk knowledge applied in the project approval process. Identified risk controls are to be included in the next phase of project development.

# Mine Water Management

Minimising contamination, optimising consumption, improving performance

## Approach

Efficient water management is essential to nearly all mining and mineral processing activities and must be dutifully considered during each development and operational cycle – from preliminary approvals, production, de-commissioning and closure – and its practices must adhere to stringent environmental and socially responsible policies, with due consideration of all stakeholders.

We promote an integrated approach to mine water management, combining specialist expertise in hydrology, hydraulics, hydrogeology and water quality with geotechnical, environmental and mining skills. Our extensive experience in wet, arid, hot and cold climates enables us to provide cost-effective, practical solutions for your project, and identify methods for more efficient utilisation of water in mining and mineral processing.

Finding a balance between meeting regulatory compliance and cost savings involves innovative thinking. This includes the conjunctive use of surface, groundwater and recycled water; collecting baseline surface and groundwater data from early in an exploration project, including borehole water levels, surface flows and water quality data; and integrating each water component with the total mine water system.

SRK recognises that the key to effective mine water management is a sound understanding of the process and tailings circuits, and integrating this with climatic data, and recycling opportunities to form an interactive range of water balances, responsive to process, seasonal and climatic variations pertinent to the mine at any time. This provides the basis for minimising water make-up, the use of the right water quality for each operation, and incorporation of contaminated streams into less demanding activities, saving pumping and treatment costs.

We are widely experienced with managing the potential, and occurrence, of acid drainage through production and closure, and anticipating likely engineering problems. And we are also proficient in modelling pit dewatering, identifying contamination risks and designing the most suitable water control system for your project.

## Services

- Baseline environmental studies
- Hydrological and hydraulic studies linked to flood prediction
- Integrated environmental planning
- Water balance modelling
- Waste characterisation and management
- Water supply
- Mine dewatering
- Seepage control and contamination assessment
- Quantitative contaminant fate modelling
- ARD, water quality and geochemistry
- Diversion structures, stormwater controls and spillways
- Water treatment
- Engineering design and procurement
- Contract management and QA/QC
- Permitting and licensing



Continuous flow measurement of seepage from rock pile, Questa Mine, New Mexico

#### Deloitte & Touche Inc

**Project:** Faro Mine, Faro, Yukon Territory, Canada.

**Scope:** A fresh water supply dam about 20.5m high and 410m long was no longer needed, and presented a risk to the downstream receiving environment. A decision was taken to breach the dam. SRK, with support from several other consulting firms, led the design, planning, permitting and decommissioning of the dam.

**Outcome:** The project was completed on time and budget. Some minor post construction modifications were required in relation to material placement in winter, but the breach and related works have been performing as designed.

#### Ma'aden

**Project:** Umm Wu'al phosphate mine, Saudi Arabia.

**Scope:** Locate and assess groundwater resources and design a well field to supply the proposed mine.

**Outcome:** A preliminary field investigation and desk study were conducted to select the best well field site and aquifer for further drilling investigations. Supervision of drilling and construction of three boreholes up to 900m deep in the Tawil Sandstone aquifer was followed by hydraulic testing. Detailed conceptual and numerical groundwater models were then used to assess the aquifer's long-term sustainable yield and potential impacts on other groundwater users.

#### Indian and Northern Affairs Canada

**Project:** Creek relocation, Giant Mine, NWT, Canada.

**Scope:** Baker Creek was relocated away from an open pit through areas with 30% ground ice in clay soils, so settlement was a concern. The creek bed design allowed for flooding and natural movement of bedding material.

**Outcome:** The channel has performed as designed, with minor settling filled in by the mobile bed load. Fish surveys three years after completion indicate high returns. DFO (federal fisheries regulator) has brought department engineers from across Canada to see this successful case study.

#### Molycorp Questa

**Project:** Questa Mine, New Mexico, USA.

**Scope:** Evaluation and remote monitoring of underground mine inflows to characterise sources of inflow; develop a water and chemical load balance; tracer tests to evaluate flow pathways in the overlying rock; and develop a management plan for operational and storm water inflows.

**Outcome:** Using a digital flow monitoring system, SRK identified the sources, quantities and chemistries of various source waters, and distinguished those source waters from surface water captured by a subsidence zone and conveyed to the underground.

# Metallurgy and Mineral Processing

Unlocking mineral wealth

## Approach

Our experienced team of metallurgists and process specialists primarily focus on metallurgical studies, due diligence and project review, and have played key roles in early stage engineering studies, process operations optimisation and technical support. We typically team with EPCM companies for the processing aspects of feasibility studies and for detailed engineering, plant commissioning and performance trials.

Our team's experience includes most aspects of extractive metallurgy and mineral processing of base and precious metals; industrial and energy minerals; diamonds and rare earth elements, including test work, engineering and operations. We have a strong background in the operation of crushing, grinding, leaching (tank and heap), concentration, pressure and bio-oxidation, SXEW, smelting and roasting processes.

Our specialists have strong operations backgrounds, having advanced many greenfields projects from metallurgical sample identification, test work program development, data analysis, process flowsheet design, trade-offs and engineering studies through detailed engineering, construction, commissioning and operations support.

We work to provide value-added economic-sensitive recommendations and results to clients, and have the tools and experience to maximise economic return to your project. With the increased demand for experienced technical operating personnel, we can fill the role of senior technical advisors to provide support and mentoring as needed to your operations and personnel.

With continuing changes to regulatory and financial requirements relating to disclosure and development of mineral projects, our extensive project review and due diligence experience is vital to meet your project evaluation requirements. Our specialists are also up to date with modern sustainable technologies.

## Services

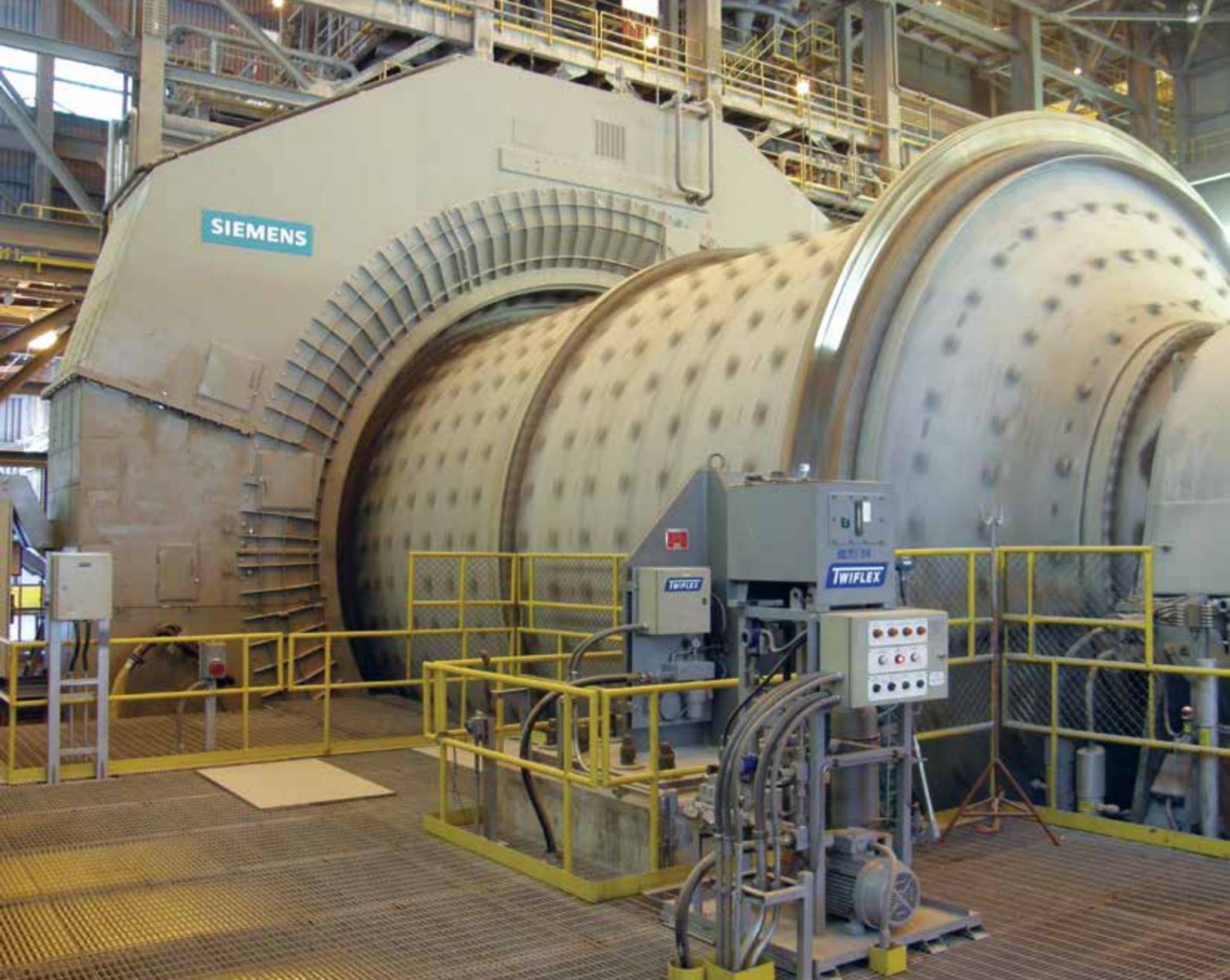
- Development and supervision of bench and pilot plant testing programs
- Development of robust and economic processing solutions
- Metallurgical plant design
- Process and metallurgical plant trouble shooting and optimisation
- Operational reviews and plant/equipment audits
- Technical advice and training
- Project review
- Due diligence

### Capstone Mining Corp

**Project:** Cozamin Mine, Mexico.

**Scope:** Metallurgical review and plant audit of the copper, lead and zinc mine to assure the viability of current and proposed plant capacities and metal recoveries pertaining to the NI 43-101 level technical report, and to support a new resource estimate.

**Outcome:** Performed required metallurgical review and prepared relevant sections of the technical report. While on-site, recommendations were made to operations personnel for process and operations improvements to assist with increases in production rate, metal recoveries and concentrate grades.



One of two grinding mills at the San Cristobal Mine in Bolivia. SRK performed an independent engineering review of the site operations, particularly for the mining, processing and project turnaround program

#### Talvivaara Mining Company

**Project:** Talvivaara Mine, Finland.

**Scope:** Preparation of a mineral expert report (MER) for listing on the LSE and a technical audit report of the feasibility study for debt finance. We were also acting as the independent engineer for the lending banks.

**Outcome:** The metallurgical review of the project was incorporated into the MER and audit reports. These reports were used for a successful listing of Talvivaara on the LSE and for a \$US300 million debt finance facility.

#### Confidential Client

**Project:** Metallurgical study for a copper/gold/magnetite concentrator, Russia.

**Scope:** Preparation of the metallurgical study including evaluation of laboratory and pilot scale metallurgical testing performed in Russia, supervision of comminution testwork to prepare a technical report outlining the sizing of SAG and ball mills based on JKTech parameters.

**Outcome:** A metallurgical study report was prepared for the concentrator. A grinding circuit was specified to cater for a wide range of ore hardness parameters.

#### Confidential Client

**Project:** Review of a novel process to treat a low-grade tin ore in Kazakhstan.

**Scope:** The client has developed a novel process to recover tin from low-grade materials and required an independent review of the testwork and process design as part of the ongoing commercialisation of the process.

**Outcome:** Preparation of a report, including a review of available testwork, the process chemistry, the proposed flow sheet and equipment selection, client's capital and operating costs together with SRK recommendations for further work.

#### Aura Minerals Inc

**Project:** Metallurgical due diligence of operating properties.

**Scope:** Assist the Aura Minerals due diligence team in review of several operating projects proposed for purchase and make recommendations for process improvements.

**Outcome:** Due diligence review assisted in the assessment of three operating gold properties which Aura Minerals is in the process of acquiring.

# Geotechnics for Infrastructure

## Getting projects onto sound footings

### Approach

Geotechnical challenges that could influence the development of your site can include geological environment, ground and groundwater conditions, and seismicity. Additional challenges may originate from your particular equipment and infrastructure, eg. vibrating mill foundations, machinery with limited tolerance for settlement and other design constraints for structural and operational purposes.

Our teams of geotechnical specialists combine extensive knowledge and experience with sophisticated numerical modelling capabilities to develop appropriate, cost-effective solutions for your project. Our services include detailed site evaluation for development, foundation design, preparation of designs and contract management. We also investigate and present specialist and expert opinions for technical or legal disputes. Examples include investigation and geotechnical design for buildings, roads, pipelines, bridges, plant site foundations, wharf and docking facilities, dams and other water retaining structures, shallow undermining and mine closure, as well as for embankments, excavations and tunnels.

For projects in remote parts of the world, our regional experts ensure that local challenges are understood. These may include collapsible, expansive or dispersive soils and karst conditions. Our experts in soil-structure interaction can assist you with the design of tunnel linings, foundations for volume change soils, lateral support of excavations and optimisation of construction procedures. Our cold climate geotechnical experts provide specialist input to infrastructure and foundation designs in permafrost conditions. With our widespread geographical footprint, we can provide the appropriate expertise to resolve the challenges on your particular project.

### Services

- Geotechnical investigation
- Foundation design
- Lateral support and retaining wall design
- Borrow material investigation
- Dam design and safety inspection
- Excavations and embankments
- Erosion control
- Geological hazard assessment
- Terrain stability analysis
- Tunnel geotechnics and design
- Monitoring and instrumentation
- Land reclamation

#### Anglo American Exploration Division

**Project:** Túnel Sur, Los Bronces Mine, Chile.

**Scope:** Technical site supervision involving the control of operational, geological and topographic advance aspects of conceptual to detail engineering design for a tunnel boring machine (TBM) for 8km x 4.5m tunnel.

**Outcome:** First stage of the works included excavation with traditional drill and blasting method of the surface portal and the TBM assembly chamber has been finalised. Assembly of the TBM machine has begun.



The beginning – surface layout of lateral support and load bearing piles, Konkola, Zambia

#### MLP

**Project:** El Mauro tailings dam, Chile.

**Scope:** Detail engineering for three tunnels.

**Outcome:** Developed the detail engineering for three tunnels as part of the El Mauro tailings dam project. Tunnels of 2.4, 2.5 and 3.5km long and 4.5 x 4.9m section were considered. For the tunnels, portals and waste dumps, SRK did the complete design, technical specifications, bid documents, assessment during bidding process and site visit during construction. Tunnels are constructed and in operation.

#### Miramar Hope Bay Limited

**Project:** Doris North Mine, Nunavut, Canada.

**Scope:** Design of mine surface infrastructure to support a small high-grade gold mine in the high arctic, as well as geotechnical fieldwork, including offshore drilling. This included a permanent barge off-loading facility, 5km of all-weather roads, all-weather airstrip, camp and mill foundation pads, laydown areas, bridge, 5ML fuel tank farm, explosives storage facilities, and a precedent-setting frozen core tailings dam.

**Outcome:** The barge offloading facility, road and airstrip were subsequently constructed according to SRK design and are currently in use, allowing greater logistical flexibility.

#### Konkola Copper Mines/ Vedanta – Grinaker-LTA Mining Contractors

**Project:** Konkola No 4 Shaft, Zambia.

**Scope:** Design of shaft collar, winder house foundations and underground support for shaft stations, ore silos and crusher chambers.

**Outcome:** A double ring of piles was designed where the inner ring was used as initial lateral support and outer piles used to support the headgear (1000t per leg). The unique design aspect involved undermining the piles at 25m depth using segmental adits and an underground “spread footing” to transfer loads to the rock head.

#### Lebalelo Water Users Association

**Project:** Lebalelo water supply scheme for several platinum mines, South Africa.

**Scope:** Feasibility study, design of overall scheme, environmental and social study, geotechnical investigations and site monitoring. Includes a low-level weir with sluicing flume and low-level pump station; de-silting structure and off-channel storage dam of 570,000m<sup>3</sup>; high-level pump station and booster pump station each with three pump sets; 20 mega-litre concrete reservoir for scheme management and balancing storage, and five end-user storage dams; and power substation, housing and administration.

**Outcome:** The scheme is operating successfully and to be incorporated into a larger regional system.

# Independent Project Review

Finding fatal flaws; confirming forecasts

## Approach

We can assist you with acquisitions, equity and project financing, and IPOs, and can provide the intimate knowledge that you need to produce balanced and focused independent reviews and reports.

Each project has its own characteristics and unique risk areas, which requires the attention of experienced study managers to efficiently allocate and coordinate resources to produce balanced and focused independent reviews and reports.

As an independently owned company with no equity in any project, our impartial advice is widely accepted by the international banking and investment community and a wide range of mining clients. Our experienced consultants are often requested by finance institutions to conduct due diligence audits of ore reserves, mining assessments and environmental considerations for inclusion into prospectuses for stock exchange listings as well as for sale and purchase agreements, and valuations. We also act as expert witnesses on mining related litigation issues.

We have been involved with some of the largest mining transactions in the world, including the Katanga mining restructuring, the Harmony/Gold Fields takeover bid, the Kumba Exxaro split, the due diligence of Noranda/Falconbridge assets, the IPOs of Fresnillo PLC and Fujian Zijin Gold, and the dual listing of Sino Gold on the HKEx.

Because of our size and geographic spread, we can organise and deploy the required multi-disciplinary teams at multiple sites around the world concurrently and at short notice. This not only reduces costs for the client, but also enables rapid progress on several fronts which is often crucial to meet transaction timelines.

We know what it takes for an independent project review to provide assurance, highlight the areas of risk, and provide clients with the necessary real, defensible project information to meet the standards of the investment community.

## Services

- Independent technical reports for public disclosure, compliance and IPOs
- Technical reviews for mining finance projects
- Privatisation studies
- Technical reviews for mergers and acquisitions
- Risk assessments
- Technical assessments and valuations
- Due diligence studies
- Litigation work as expert witnesses
- Technical audits
- Competent/qualified person reports

### Aluminium Corporation of China (Chalco)

**Project:** IPO report for listing on Hong Kong and New York stock exchanges. The mining projects were located throughout China.

**Scope:** We were commissioned to prepare an independent expert report in a format which complied with the listing rules of both stock exchanges. This involved review of data, site visits and reporting on a number of mining projects in China.

**Outcome:** Our report was accepted by the client, their bankers and other advisers and the stock exchanges. Chalco was successfully listed on both HK and NY stock exchanges.



SRK has extensive experience with due diligence studies worldwide, including this small underground coal mine in Guizhou, south China

#### Lihir Gold Limited

**Project:** Lihir Gold Mine, Lihir Island, Papua New Guinea.

**Scope:** We were the independent engineer for the banking syndicate to the Lihir Gold project. This involved annual inspections and reports on the development and progress of the project.

**Outcome:** We were retained for more than four years by Lihir Gold and the bank syndicate. During that time, we completed independent technical evaluations of the technical, social and environmental strengths and weaknesses of the gold project.

#### Sino Gold Mining Limited

**Project:** Secondary listing of Sino Gold Limited on the HKEx.

**Scope:** Sino Gold had an existing primary listing on the Australian Securities Exchange (ASX) and requested SRK to complete a technical review and independent expert report of its mining and exploration projects in China. The report needed to comply with the requirements of both the ASX and HKEx.

**Outcome:** The SRK report was accepted by the HKEx and included in the listing documents in both English and Mandarin. Sino Gold was successful in completing its secondary listing on HKEx. First dual ASX/HKEx listed mining company.

#### Fresnillo PLC

**Project:** Initial Public Offering (London Stock Exchange (LSE) listing).

**Scope:** Technical advice and preparation of a mineral expert's report for the proposed listing of the company's precious metals assets on the LSE, including the Fresnillo and La Cienega underground mines; La Herradura open pit mine; and rights to the silver production (the Silverstream asset) from the Sabinas underground polymetallic mine. Assets were put in a new vehicle and name changed to Fresnillo PLC.

**Outcome:** Successful listing raised \$US1.787 billion for 23% of the company. First-ever LSE listing of a Mexican company.

#### Konkola Copper Mines Plc

**Project:** Restructure of KCM assets, Zambia.

**Scope:** Technical advisor to attract another strategic investor after the exit of Anglo American. Included technical audit of existing assets, turnaround strategy and identification of short-term opportunities to cut costs and generate cash, selection of new senior management team, and development of a new life-of-mine business plan and techno-economic model used as basis of financial advisor's valuations.

**Outcome:** Memoranda distributed to interested bidders, assistance with sales process through road shows, support of data room process, consultation and adjudication of bids, and negotiations with preferred bidder.

# Research and Development

Advancing our methodologies and services

We actively seek to participate in applied research projects in mining related fields. Examples of recent involvement include:

- PCSLC – joint development with Gemcom International of mine planning and scheduling tool for sub-level cave mines.
- LOP – large open pit design research project spearheaded by CSIRO in Australia.
- Weak Rock Support – internationally industry sponsored project spearheaded by the Itasca Consulting Group, which addresses problems related to underground development in weak rock masses.
- MMT – Mass Mining Technology, formerly known as International Caving Study, is an internationally sponsored project addressing the issues associated mainly with cave mining.
- PETT (Paste and thickened tailings) – pilot schemes to assess thickened and depositional characteristics of thickened and paste tailings.
- MEND (Mine Environment Neutral Drainage) research program – review of design and construction methods for mine waste covers in cold regions, identifying both current deficiencies and opportunities to better exploit cold regions phenomena.
- Collaboration and support of research programs at Université Laval (geotechnical characterisation, ground freezing), Queen's University (arsenic leaching from tailings) and INRS (heat and gas flow in waste rock piles).
- 3D modelling of geology through development of Leapfrog™ software and integration with other advanced 3D geological modelling packages.
- Centre of Excellence in Geochemical Engineering – in partnership with Cardiff University's School of Engineering. Research will include:
  - Extraction of metals and production of sulphuric acid from complex precious and base metal mine and metallurgical waste. Two patent processes have already resulted from this program
  - Geometallurgy of uranium deposits
  - Assessment of ML/ARD through field and laboratory prediction methods and geochemical testwork
  - Mitigation of ML/ARD, particularly through passive treatment schemes.
  - Coal bed gasification technology
  - A successful eight-year research partnership has produced more than 30 publications.
- SIMRAC, MHSC (Safety In Mines Research Advisory Committee, Mine Health and Safety Council), South Africa – our research projects include shotcrete monitoring and design, static and dynamic support testing for underground mines and calculating rockfall risk and the cost of rockfalls.
- Selenium task force – development of a selenium leaching model for five large coal mines in the drainage basin of Elk Valley.

# SRK Offices



## Country Website Addresses

**Argentina: [www.latam.srk.com](http://www.latam.srk.com)**

Buenos Aires, Mendoza, Salta

**Australia: [www.asia-pacific.srk.com](http://www.asia-pacific.srk.com)**

Brisbane, Melbourne, Newcastle, Perth and Sydney

**Brazil: [www.latam.srk.com](http://www.latam.srk.com)**

Belo Horizonte

**Canada: [www.na.srk.com](http://www.na.srk.com)**

Saskatoon, Sudbury, Toronto, Vancouver and Yellowknife

**Chile: [www.latam.srk.com](http://www.latam.srk.com)**

Santiago

**China: [www.asia-pacific.srk.com](http://www.asia-pacific.srk.com)**

Beijing and Nanchang

**Hong Kong: [www.asia-pacific.srk.com](http://www.asia-pacific.srk.com)**

**India: [www.asia-pacific.srk.com](http://www.asia-pacific.srk.com)**

Kolkata

**Kazakhstan: [www.srk.kz](http://www.srk.kz)**

Almaty

**Peru: [www.latam.srk.com](http://www.latam.srk.com)**

Lima

**Russia: [www.srk.ru.com](http://www.srk.ru.com)**

Moscow

**South Africa: [www.srk.co.za](http://www.srk.co.za)**

Cape Town, Durban, East London, Johannesburg, Kimberley, Pietermaritzburg, Port Elizabeth, Pretoria, Rustenburg

**Sweden/Finland: [www.srknordic.com](http://www.srknordic.com)**

Skellefteå/Rovaniemi

**Turkey: [www.srkturkiye.com](http://www.srkturkiye.com)**

Ankara

**United Kingdom: [www.srk.co.uk](http://www.srk.co.uk)**

Cardiff

**U.S.A.: [www.na.srk.com](http://www.na.srk.com)**

Anchorage, Clovis, Denver, Elko, Fort Collins, Reno and Tucson

**SRK Exploration Services: [www.srkexploration.com](http://www.srkexploration.com)**

Cardiff

**General Enquiries: [enquiries@srk.com](mailto:enquiries@srk.com)**



Every type of mining project in all environments everywhere in the world.

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

 **srk**.com