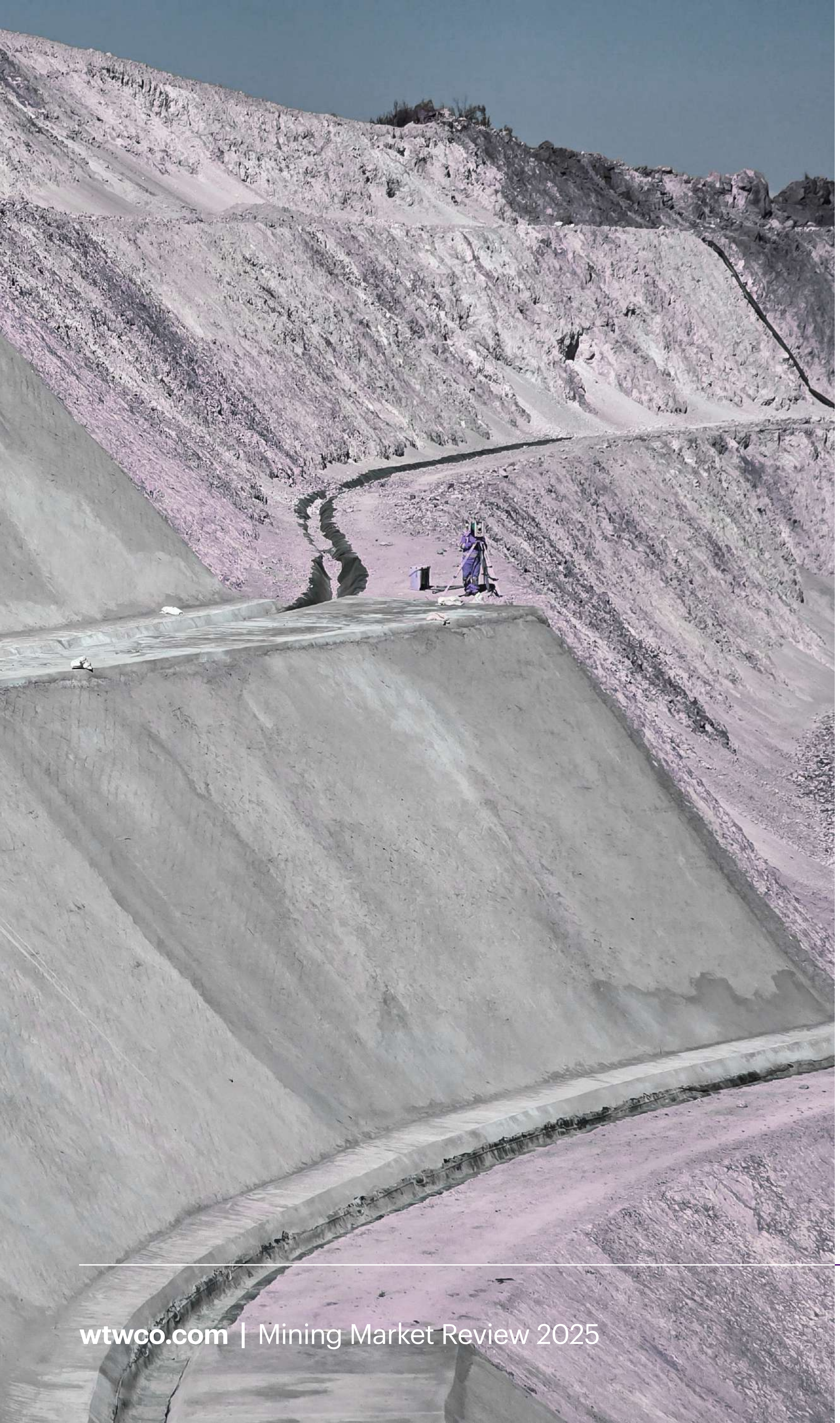


Before rock bottom: Why geotechnical engineering is an asset in mining risk managers' toolkits

Geotechnical exposures are impacting risk profiles as mining companies, suffering from reduced grades and increased strip ratios, are embarking upon projects in more remote locations and challenging jurisdictions.

Key takeaways:

- The mining and metals sector is going further and digging deeper. Risk profiles are changing
- Depending on location, geohazards impacting geotechnics can encompass seismic risks, mass movements, rainfall-induced flooding and geochemical risks, among others
- There are exposures that are outside risk managers' control, but seven key steps can help to keep mining businesses moving

The scope of geotechnical engineering adds value across the lifecycle of a mine, from exploration/feasibility studies through operations and closure. Designing underground workings, accessways, shafts, walls, slopes, waste dumps, tailings storage facilities (TSFs), stockpiles and backfill placements in underground operations all fall within a geotechnical engineers' purview.

But critically, geotechnical engineers are a valuable asset to risk managers beyond designing safe pits and mine workings —to identify ways to build efficiencies, control costs and expand revenue margins.

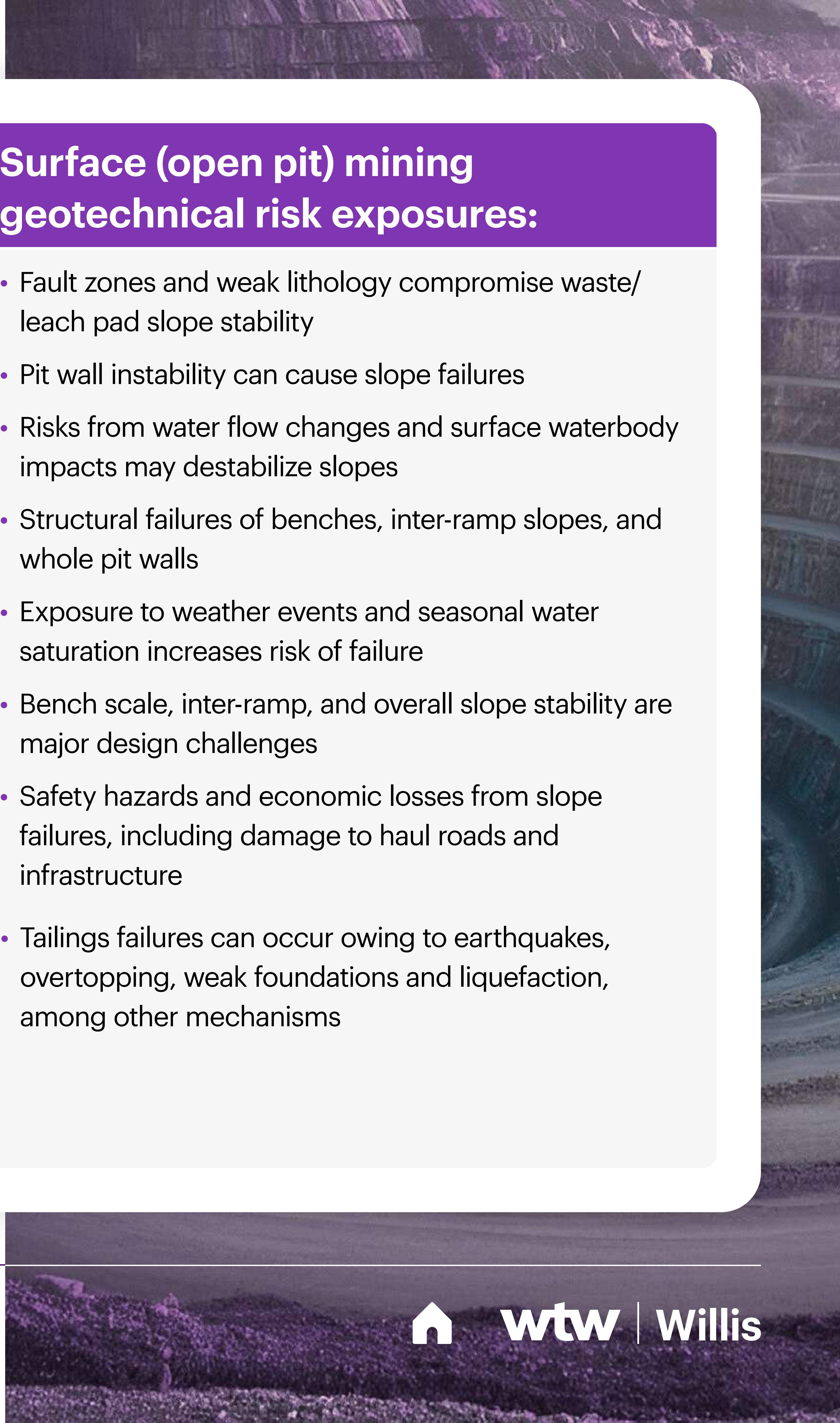
As demand for the majority of minerals accelerates due to population growth and the energy transition, the mining and metals sector is going further and digging deeper. Risk profiles are changing.

Underground mining geotechnical risk exposures:

- Limited lifespan of mine structures such as shafts, declines and pump stations
- Poor or unknown rock mass conditions impacting excavation stability
- High in situ rock stress, especially deeper underground, can lead to rock bursts, spalling, and seismic events
- Mining-induced stress concentrations can cause local failures in stopes and drives, particularly for block caves
- Risks from water or mud ingress affect ground stability
- There are challenges with ground support design, pillar dimensions, and control of mine subsidence
- Stress redistribution and rock fracturing can cause seismicity
- Backfill operations e.g. cemented rock fill (CRF)/paste fill must consider various geotechnical factors
- Operational impacts such as subsidence, tunnel collapse, and infrastructure damage endure

Surface (open pit) mining geotechnical risk exposures:

- Fault zones and weak lithology compromise waste/leach pad slope stability
- Pit wall instability can cause slope failures
- Risks from water flow changes and surface waterbody impacts may destabilize slopes
- Structural failures of benches, inter-ramp slopes, and whole pit walls
- Exposure to weather events and seasonal water saturation increases risk of failure
- Bench scale, inter-ramp, and overall slope stability are major design challenges
- Safety hazards and economic losses from slope failures, including damage to haul roads and infrastructure
- Tailings failures can occur owing to earthquakes, overtopping, weak foundations and liquefaction, among other mechanisms



Not investing in ground control can increase short-term cashflow and profitability, but at the risk of a later failure which can create longtail financial exposures, or even mine closures.

The cost of poor ground support far outweighs the financial outlay of getting it right first time. Costs associated with recovery/rehabilitation and business interruption are compounded by potential loss of life, reputational damage and regulatory penalties.

Hot beds of activity are compounding risks

The production and processing of critical minerals is highly concentrated geographically, which drives exposure. Susceptibility to extreme weather, such as flooding from rainwater ingress and regional tectonics are key vulnerability points that can cause major bottlenecks in critical mineral delivery. “Currently, the Democratic Republic of Congo supplies 70% of cobalt, China 60% of rare earth elements (REEs), Indonesia 40% of nickel, and Australia lithium mining respectively”. The mining operations in these countries are located on or close to tectonic plate boundaries and faults capable of producing large magnitude earthquakes, with some also containing mountainous terrain that could be prone to resulting landslides.

Coastal locations around the Americas, Asia and Oceania are also prone to tropical windstorms and climate-driven extreme rainfall events have become increasingly prevalent in temperate regions across the globe.

Depending on location, geohazards impacting geotechnics can encompass:

1. Seismic risks:

Many valuable deposits are found along or near fault zones, with high concentrations in countries such as Chile at high risk of large magnitude ‘megathrust’ earthquakes. These fault zones can act as conduits for mineral-rich fluids, leading to a higher concentration of ore deposits in these areas. In these stressed areas, mining operations promote local stress changes, compounding the risk of a seismic event.

2. Mass movements:

Mass movements are usually considered to be ‘secondary’ hazards, triggered by another event such as earthquakes or from weather events such as cyclones and extreme rainfall.

Climate change is increasing the intensity and frequency of weather events. Although TSFs present less risk in seismically stable and flat areas such as those found in Australia and South Africa, areas of central Asia and the southern Caucuses are more at risk: TSFs are located on or close to active faults and above population centers. The upstream raising method – already having been banned in Chile after strong earthquakes between 1960 - 1965 which caused failure of El Cobre dam – was also banned in Brazil in 2019 following the Fundao and Dam B1 failures.

> Unfortunately, geology is fixed. The only way to mitigate seismic risks is through rigorous geotechnical design at all levels of operation. Best practice will always invite independent third-party review and ongoing assessments as part of normal operations.

Joe Carr, Mining Risk Engineering Leader, Willis Natural Resources

Failures are a reminder of how poor geotechnical design and data may lead to unsuitable foundation and drainage channel design, putting facilities and finances on shaky ground.

3. Rainfall-induced flooding:

In addition to triggering landslides, extreme rainfall can also lead to subsurface mine flooding if geotechnical design and surface water management aren't able to withstand these events. An example of this was seen in the Capricorn Copper mine in Queensland, Australia in March 2023 where 370mm of rainfall fell in seven days. This rainfall led to pooling in surface depressions created due to mining activities, ingress through resultant cracks, with the subsequent flooding leading to a loss of mine access and multi-million dollar insured losses. While previously, geotechnical design would have considered a 1:1,000-year event as suitable, a 1:10,000-year model is emerging as a new minimum standard weather-related volatility.

4. Geochemical risks:

The geochemistry of the rockmass is often overlooked.

The interaction between rock, its minerals and the ground control systems can have huge consequences should the perfect storm of conditions be met. For example, an acid forming rockmass, which is highly saturated may degrade rockbolts faster than anticipated, especially if there is galvanic corrosion. In these conditions, the rockbolt reacts with the rockmass via an electolyte (the mineral rich water present). This creates an electrical potential. In these scenarios the rockbolt essentially becomes an anode and corrodes at an accelerated rate. This rate is far beyond design expectations and because the bolt is hidden within the rock, the corrosion is often undetected.

By better assessing these geological and geotechnical risks from the prospecting and planning stages through the mine's lifespan, owners and operators can add value for stakeholders and reduce the potential for losses and downtime.

> Traditional risk assessments track individual threats by identifying historical trends in the magnitude and frequency of single hazards; however, this approach does not capture the risk from interconnected and cascading hazards, which have the potential to amplify risks for a company's value chain. The resulting compound risks differ significantly from independent risks, often with distinct likelihoods and impacts.

James Dalziel,
Earth Risk Research Lead,
Willis Research Network

Top actions risk managers can take

Extracting value from geotechnical engineering

1. Know what good looks like

There is no global standard on geotechnical design. Many jurisdictions have their own systems, but there are shining examples of best practice standards which are widely used when there is no local standard to follow. Good examples include the Western Australian mining standards, Canadian standards and the Finnish/Swedish standards.

Mines should also consider the development of a ground control management plan (GCMP), which is a good idea example of how a regulatory framework can be applied to show what a robust approach can look like, even if the mine is out of this jurisdiction.

2. Get expert eyes on the geotechnical decisions

Geological surveys and geotechnical mapping should coexist. Examining the site and surrounding area for regional tectonics, host rock characteristics, groundwater and surface water drainage, creates a robust and detailed view of key hazards. These hazards must be constantly monitored during the lifecycle of a mine and cannot cease when it is decommissioned.

Mining and metals companies need to partner with experienced geotechnical engineers, including external specialists to test the rigor with an objective eye. Some structures such as TSFs require a more technical input from third parties such as engineers of record (EoR) as well as independent review boards (ITRB).

3. Look ahead through analytics

Scenario-based modelling can be used to predict changes in hazard susceptibility due to the presence of engineered infrastructure such as mine workings and TSFs, as well as accounting for potential climate change effects to weather intensification and the frequency of extremes over the course of a mine's lifespan.

4. Use risk engineering strategically

Risk engineering is a core component of a sophisticated risk strategy. For risks where the insurance markets have limited appetite, demonstrating a robust risk engineering protocol can make all the difference. Showcasing that geotechnical exposures have been identified, risk controls have been implemented and monitoring protocols are active will enable underwriters to fully understand the risks and the proactive measures taken. With these insights, underwriters can make informed decisions about coverage and pricing.

5. Build the optimal risk financing strategy

Geotechnical exposures exist in a network of emerging, complex and interconnected risks. A siloed approach to risk management is limiting. By assessing geotechnical risks as part of a complete risk profile, analytical tools can identify the most efficient balance of risk retention and transfer. This can help to free-up capital and keep costs down—value that is amplified when commodity prices are limiting already tight margins.

6. Lean on your broker

Sector-focused brokers are the connection point to local and international markets. Local markets can have a deeper understanding of local exposures, while international markets provide capacity and greater long-term stability. A global broker that's well connected in local hubs, is able to assess these trends and access insurance capacity where it is most competitive.

7. Maintain rigor

Real-time modelling is critical. By using monitoring equipment, mine operators can detect early indicators of instability. With warning, operators can implement emergency response plans to limit failures or cascading hazards. A robust response plan will help to ensure minimal damage, downtime, and both human and financial losses.

Sometimes, you can do everything right and failures still happen… on April 10, 2013, two massive landslides carried about 145 million tons of waste rock into the bottom of the open pit at Bingham Canyon, the largest copper mine in the U.S. These are the largest mining-induced landslides in history. Fortunately, a sophisticated network of geotechnical monitors was in place at the mine, which showed instability and increasing movement several days beforehand. All employees were evacuated from the mine and although operations suffered hundreds of millions of dollars of damage, there were zero fatalities.

…The company took every practical measure to identify and control risks through geotechnical engineering and monitoring, which helped to save the lives of the workforce. But an extreme event took the perils out of risk managers' hands. Insurance is an important partner in protecting your business, even if you're doing everything right.

Joe Carr, Mining Risk Engineering Leder, Willis Natural Resources

Keeping your business moving

There are exposures that are outside risk managers' control. But with the support of robust geotechnical risk engineering, mining and metals companies can make informed decisions from the outset. From design, to operations, emergency response and decommissioning, geotechnical engineering helps to reduce the potential for losses and downtime—a corner piece in the puzzle of keeping costs down where possible.

To find out how geotechnical engineering can help your business build resilience, contact:

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