The Mining Process: 5 Lifecycle Stages Explained

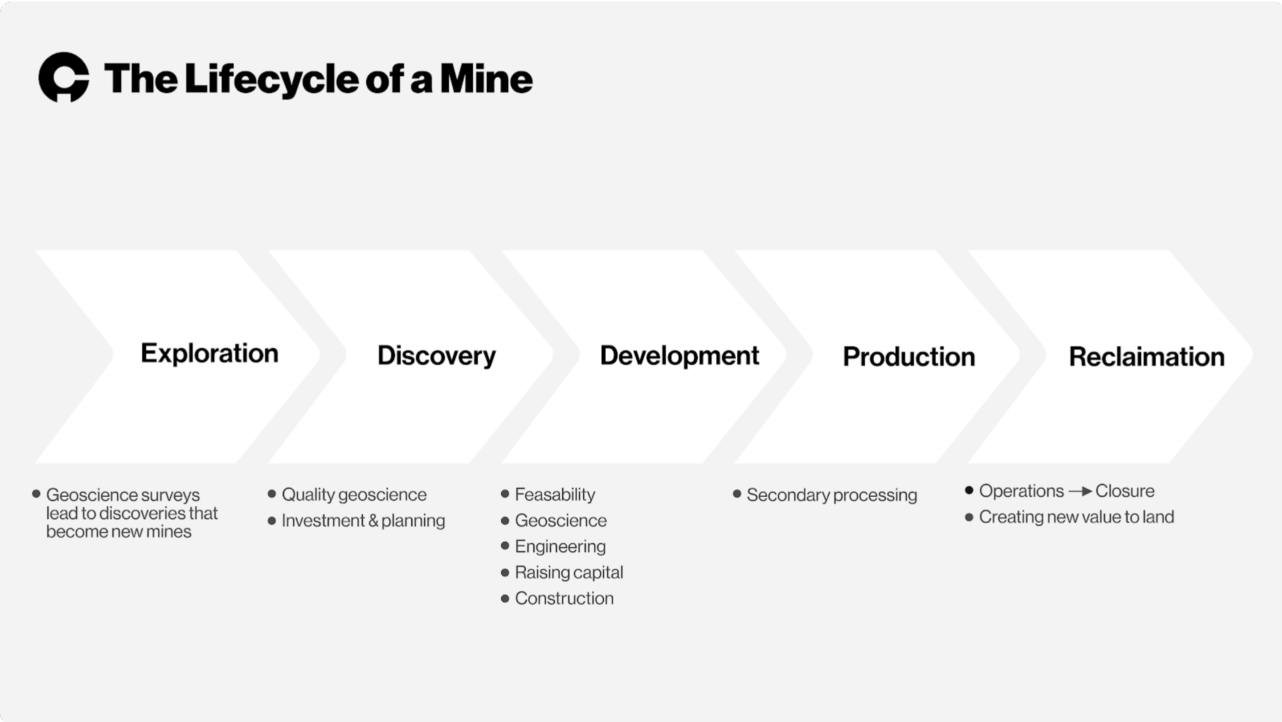
By CRUX Investor

When looking at mining stocks, it's easy to only focus on the finished product that you are investing your money in. Whether that's uranium, gold, silver, palladium or any other natural resource, it is necessary to understand the full extraction process in order to really appreciate the asset.

Just like no two diamonds are the same, neither are two mining projects.

Every billion-dollar project varies in some way (location, commodity, size) but there are 5 key stages that all miners follow that form the backbone of mine development.

The 5 Lifecycle Stages of Mining



1. Exploration & Prospecting Stage

This is the first and most essential step of the mining process: in order to open a mine, companies must first find an economically sufficient amount of the deposit (an amount of ore or mineral that makes exploitation worthwhile.)

Geologists are enlisted by the companies to understand the characteristics of the land to identify the presence of mineral deposits.

What is a geologist?

A geologist studies the solid, liquid, and gaseous matter of the Earth as well as the processes that shape them. A mining geologist is responsible for mapping out the locations of valuable minerals and will use aerial photographs, field maps, and geophysical surveys, to determine where valuable materials are and estimate how much of those materials are in that location.

Exploration geologists search for mineral resources and get involved in the planning and expansion of mining operations. They locate and evaluate potential deposits of precious metals, industrial minerals, gemstones, pigments, construction materials or other mineable commodities.

What mining techniques are used by geologists?

Geological surface mapping and sampling

A Geologist will record all geological information from the rocks that outcrop at the surface and will look for boundaries between different rock types and structures, look for fault-lines and evidence of the rocks undergoing deformation. The geologist will look for ore minerals, evidence of metal-rich fluids passing through the rock, and recording mineralised veins and their distribution.

Mining companies need to target and prioritise their drilling activity so will use this data to target more specific areas where rock and mineral sampling might be appropriate. High-resolution geological mapping can also delineate areas of likely mineralisation which will lead to potential deposits.

Geophysical measurements

Geophysical measurements are taken for mineral exploration to collect information about the physical properties of rocks and sediments. Geophysical companies employ the use of magnetic, radiometric, electromagnetic and gravity surveys to detect responses which may indicate the presence of mineral deposits.

Exploration geophysics is used to detect the type of mineralisation, by measuring its physical properties. It is used to map the subsurface structure of a region, to understand the underlying structures, the spatial distribution of rock units, and to detect structures such as faults, folds and intrusive rocks.

Geochemical analysis

A chemical analysis that determines the proportion of metallic or non-metallic presence in a sample is called an assay. A wide variety of geological materials can be chemically analysed which include water, vegetation, soil, sediment and rock.

Assay labs can provide single and multi-element analyses by a variety of methods. Rock and soil samples are crushed, powdered, fused or digested in acid and then analysed using several different analytical methods and instruments.

Water, oil and soil tests

Most metallic ore deposits are formed through the interaction of an aqueous fluid and host rocks. Baseline samples are taken to determine hydrologic conditions and natural occurrences of potentially toxic elements in rocks, soils, and waters.

Surface geochemical analysis of soil, rock, water, vegetation, and vapour for trace amounts of metals or other elements that may indicate the presence of a buried ore deposit. Geochemical techniques have played a key role in the discovery of numerous mineral deposits, and they continue to be a standard method of exploration.

Rock, water, soil and vegetation samples collected by prospectors and geoscientists can either be tested on-site or in laboratories called assay labs.

Airborne or ground geophysical surveys

Through either ground or airborne methods, geophysical companies undertake magnetic, radiometric and electromagnetic surveys to detect a response which may indicate potential deposits of mineral resources.

Airborne geophysical surveys are used for mineral exploration for mapping exposed bedrock, geological structures, sub-surface conductors, paleochannels, mineral deposits and salinity. There are several airborne geophysical methods used for minerals exploration including aeromagnetics, radiometrics and VTEM. A digital elevation model (DEM) is also used as an addition to most airborne geophysical surveys. Gravity surveys can also be conducted from the air as well as from the ground.

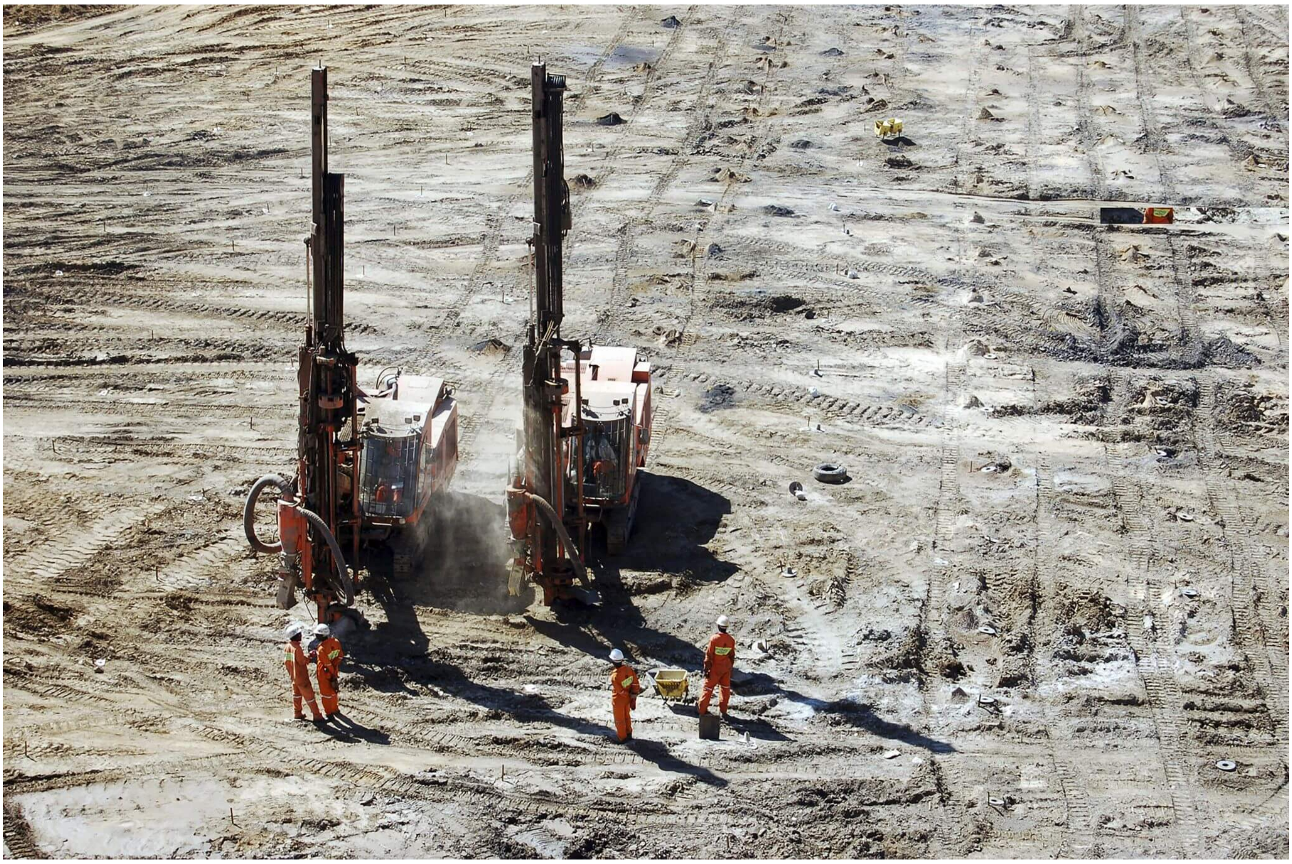
Ground-based geophysical surveys are implemented once mining companies have identified potential deposits at a regional scale and are performed from the soil surface, through boreholes, excavations or in a combination of placing sources and detectors.

Drilling

Mineral exploration involves drilling to probe the contents of known ore deposits and potential sites to produce rock chips and samples of the core.

Drilling is used in areas that have been identified as targets with potential deposits based on geological, geophysical and geochemical surveys which have led to the design of the drilling programme. The aim is to obtain detailed information about rock types, mineral content, rock fabric, and the relationship between the rock layers close to the surface and at depth.

Samples taken from the orebody are taken to the lab and geologists can analyse the core by chemical assay and conduct petrologic, structural, and mineralogical studies of the rock.



Sampling

Exploration objectives are to find the ore and the drilling and sampling will provide the information upon which to base estimates of its quantity and grade.

Estimates of ore grade are based on the assays of samples obtained from drill holes into the ore. The accuracy of the estimates will depend on the care taken in procuring the samples and the judgment used in deciding on sample interval required, the accuracy in assaying, and the proper weighting of the individual assays in combining them for determining average grades of individual ore blocks, especially the treatment of erratic high values.

Valuable minerals are distributed unevenly and are present in varying degrees of purity throughout the material so that assays of individual samples may vary widely throughout sampling.

Socio-economic factors

Companies must also take into account the socio-economic effects that the presence of a new mine could have on the area and surrounding communities.

Mining activities, including prospecting, exploration, construction, operation, maintenance, expansion, abandonment, decommissioning and repurposing of a mine can impact social and environmental systems in a range of positive and negative ways. Mining companies need to integrate environmental and social impact assessments into mining projects.

These assessments are the process of determining, analysing and evaluating the potential environmental and social impacts of a mining project, and designing appropriate implementation and management plans for the mining life cycle.

Orebody models

At the end of the exploration stage, miners are able to draw up a preliminary outline of the potential size of the deposits found using 2D or 3D models of the geological ore. An orebody model serves as the geological basis of all resource estimation and starts with a review of existing drill hole and surface or underground sample data as well as maps and plans with current geological interpretation.

2. Discovery Stage

Mine-site Design & Planning

Once the miners are sufficiently confident that there is a financially viable amount of deposit, the project can progress to the planning stage.

Companies will create multiple plans with different variables (time-span, amount of ore mined) to evaluate which fulfils the most criteria.

Planning criteria & permit considerations:

Safety

From exploration to mining of mineral resources, it is vital to ensure that critical safety and operational risks are considered in designing a mine. The mine plan should allow the miners to work in the safest way possible.

The safety and wellbeing of employees, contractors and local communities is a big concern for responsible mining companies and a mine plan will look at any aspect of mine operations that could have a direct impact on the wellbeing of workers, contractors and communities.

Environmental impact

The mine plan needs to be designed to keep the damage to the environment to a minimum using strategies that can reduce environmental impact. Lower impact mining techniques will reduce interference at the mining site. Mining waste such as tailings, rocks and wastewater can be reused on or off-site.

Eco-friendly equipment such as electric engines which will result in big carbon savings and longer lasting equipment will cut down on waste over time.

Many former mine-sites are left unusable by landowners once the mine life has come to an end. Mine companies can employ land rehabilitation techniques such as topsoil replenishment and reforestation schemes to make the land productive again and speed up the land's natural recovery process.

Illegal mining is a significant issue for the industry so preventing illegal or unregulated mining operations will help ensure that all mining is bound by the same environmental standards and ensure accountability.

Economical viability

Mine development starts when a deposit is discovered and continues through to the start of construction. The technical feasibility and the economic viability of each project are determined during the phases of mine development, with more detailed engineering data required at each stage.

- *The Preliminary Economic Assessment (PEA)* is an early level study and the preliminary evaluation of the mining project. A PEA is useful to determine if subsequent exploration activities and engineering studies are warranted. However, it is not valid for economic decision making or for reserve reporting.
- *The Pre-Feasibility Study (PFS)* is an intermediate step in the engineering process to evaluate the technical and economic viability of a mining project. The pre-feasibility study is a critical step for project development as it represents the minimum prerequisite for conversion of a geologic resource into a reportable reserve.
- *A Feasibility Study (FS)* represents the next and most detailed step in the engineering process for evaluating a mining project and is a comprehensive technical and economic study of the development.
- *A Bankable Feasibility Study (BFS)* also known as a definitive feasibility study (DFS) is the final piece of the financing puzzle. The results of the study serve as the basis for a final decision whether to proceed with the mine plans. It would be unusual for a company to get finance in place without one.

Corporate social responsibility

Social responsibility is very important in the world of mining and companies are finding it beneficial to strengthen their corporate social responsibility (CSR) efforts and find ways to give back to the surrounding community.

Mines often employ a large percentage of the local residents as their workforce and some companies get involved by financing local suppliers and so promoting local trade and growing the local economy. They also fund shared infrastructure in power distribution, roads, and water treatment and distribution.

Other companies become involved in local communities by supporting climate change programmes and environmental stewardship and wildlife projects, contributing to local and regional programmes including sponsorship of educational and sporting events, local medical facilities and the funding of local children's schemes and arts festivals.

Companies aim to employ local labour and trades people wherever possible and focus on educational, health and infrastructure improvements that will have the greatest impact on the quality of life.

3. Development Stage

Once the plan has been confirmed, the real work can begin. This is the longest stage of the process so far, and can take anywhere from 10-20 years before the mine is ready for production, depending on the site size.

Does a mines size affect the amount of ore produced?

Measuring mine productivity can be difficult given how unique each operation is.

Mines set their production goals but productivity at some mines is restricted by location. Mines are trying to minimise operating expenditure while continuing to increase productivity.

What does construction involve?

Building roads

The construction of roads, rail, air-strips or ports to access the mine plus the services such as water, sewage and power is similar to the work required for establishing other types of industries except that this construction could be in remote areas with added logistical challenges.

Mining roads are a critical component of mining infrastructure and the performance of these roads has a direct impact on operational efficiency, costs and safety. A significant proportion of a mine's cost is associated with material haulage and well-designed and managed roads contribute directly to reductions in cycle times, fuel burn, tyre costs and overall cost per tonne hauled and critically, underpin a safe transport system.

Processing facilities

Development of the mine itself is different for an open pit to an underground mine and will require different experience and equipment. Porphyry deposits are often large and many of the deposits are near the surface and mined as open pits with large mining equipment; however, at depth some may have suitable characteristics to convert to large underground block caving mines. Vein type deposits are often narrow, can go to depth and are mined by underground methods with smaller equipment.

Once the mineral is extracted from a mine, it is processed and the processing operation depends on which material is excavated. The crushing and processing facility is constructed based on the testing, flow sheet and design determined in the FS. Processing of the ore starts with understanding the mineralogy and the metallurgical testing for crushing, grinding and recovery of the metals and treatment/management of the tailings.

Environmental management systems

Environmental aspects are included on the FS which has determined the current environmental habitat and the long-term impact of building the mine. The FS will also have determined the quantity and quality of all ore and waste to be mined plus tailings, the potential to generate acid and other deleterious metals plus how to treat these issues while operating and at closure.

Also included in the FS is the amount and quantity of water that will be used during operation and whether the water will need long-term treatment. Some countries require the FS as the basis for submitting plans for required mining permits.

An Environmental Management System (EMS) is part of the management system and includes organisational procedures, environmental responsibilities, and processes and will help the mining company comply with environmental regulations, identify technical and economic benefits, and ensure that corporate environmental policies are adopted and followed.

Mining companies with economical and technological flexibility have implemented comprehensive EMSs at current sites but these require input from governments, international environmental organisations, educational facilities, and the companies themselves.

Employee housing

Mine planning includes decisions on workforce accommodation which will affect not only employee quality of life but also the impacts and relationships with existing local communities. Workforce accommodation are usually community-based (either as purpose-built company towns or integrated within existing local communities) or commuter (fly-in, fly-out) mine camps which will depend on the location of the mine and how remote it is.

The quality of accommodation underpins the fulfilment, morale and motivation of employees. This is not only relevant to productivity and safety, but also to recruitment and retention, particularly with the significant human resources crisis. If communities exist close to a proposed mine then the accommodation strategy can influence the value-adding potential for the sustainable development of such communities.

Where mine locations are isolated in remote areas and/or face significant economic, social and political adversity, the decisions on employee housing are more challenging. The mine company will need to understand the complexity of local planning issues and consider environmental, social, economic and political implications, together with the proposed accommodation strategy.

Other facilities

- Maintenance facilities - location for service and repair of mine equipment to reduce downtime and ensure that production capacity and safety objectives are met.
- Management offices, workshops, storage, refuelling, and power generation facilities. In some cases, a control tower may also be constructed to offer a complete view of processing operations.
- Transportation for mine personnel - Miners, contractors, and supervisors need to move between work areas which may be spread across a wide area.

4. Production Stage

Now the mine is finally ready to begin producing.

What are the two common methods of mining?

Surface mining

Surface mining is a broad category of mining in which the soil and rock overlying the mineral deposit is removed. It has been estimated that more than two-thirds of the world's yearly mineral production is extracted by surface mining.

Surface mining is the preference for mining companies because removing the terrain surface to access the mineral beneath is often more cost-effective than digging tunnels and shafts to access mineral resources underground.

Surface mining methods:

- Strip Mining involves stripping the surface away from the mineral that's being excavated (usually coal). Soil, rock, and vegetation over the mineral seam is removed with huge machines, including bucket-wheel excavators.

- Open-Pit Mining is a technique of extracting rock or minerals from the earth by their removal from an open-air pit. Open-pits are sometimes called 'quarries' when they produce building materials and dimension stone.
- Mountaintop Removal Mining for retrieving minerals from mountain peaks and involves blasting the overburden with explosives above the mineral seam to be mined. The broken mountaintop is then shifted into valleys and fills below.
- Dredging is the more sophisticated version of panning for gold where a scoop lifts material up on a conveyor belt, and the mineral is removed, then the unwanted material is put back into the water.
- Highwall mining collects ores from a "highwall" with overburden and exposed minerals and ores.

Underground mining

Underground mining is used to access ores and valuable minerals in the ground by digging into the ground to extract them. There are several underground mining techniques used to excavate hard minerals, usually those containing metals such as ore containing gold, silver, iron, copper, zinc, nickel, tin and lead, but also for excavating ores of gems such as diamonds and rubies.

Underground mining methods:

- Ore is natural rock that contains valuable minerals, typically metals and is extracted from the earth through mining and extracting the valuable metals or minerals. The grade of ore refers to the concentration of the valuable material it contains.
- Subsurface mining involves digging tunnels or shafts into the earth to reach buried ore deposits. Ore and waste rock are brought to the surface through the tunnels and shafts.
- The recovered minerals are processed using large crushers, mills, reactors, roasters and other equipment to consolidate the mineral-rich material and extract the desired compounds and metals from the ore.
- Ore is separated from the waste rock, the rocks are crushed and the minerals are separated from the ore by:
    - Heap Leaching - addition of chemicals such as cyanide or acid to remove the ore. This is often done at very high temperatures.
    - Flotation - addition of a compound that attaches to the valuable mineral and floats.
- Smelting facilities - roasting rock at a temperature greater than 900oC. This causes it to segregate into layers. The valuable minerals are then extracted.
- Once the mineral is extracted, it is often processed to extract the valuable metal from its ore through chemical or mechanical means which will depend on the mineral resource present.
- The ore is then poured into moulds to create bars of bullion (metal formed into bars or ingots) ready for sale.

5. Reclamation Stage

Before the company can be issued a permit to build the mine, they must first prove that they have the funds and plans to close the mine in a safe and structured way.

Mining is a temporary activity, once the deposit is gone it's time to relocate to a new site. But before they can do this, they must first close and rehabilitate the mine.

What needs to happen before a mine can close?

The final step in mining operations is closure and reclamation. Mine companies have to think about a mine closure plan before they start to build as governments need assurances that operators have a plan and the required funds to close the mine before they are willing to issue permits.

Detailed environmental studies form a big part of the mine closure plan on how the mine site will be closed and rehabilitated. A comprehensive mine rehab programme will also include:

Ensuring public health and safety

There are many dangers with abandoned mines, many of which are not visible from the outside, including horizontal openings, vertical shafts, explosives and toxic chemicals, dangerous gases, deep water, spoils piles, abandoned unsafe buildings and high walls. Mine companies need to ensure mines are fully closed and sealed to make them safe for the public.

Removing waste and hazardous material

There is a high-volume of waste material that originates from the processes of excavation, dressing and further physical and chemical processing of metalliferous and non-metalliferous minerals and mine companies need to remove waste and hazardous material from the site both during operation and at closure of the mine.

Establishing new landforms and vegetation

Reclamation of mined areas involves the re-establishment of viable soils and vegetation at a mine site. For example, a simple approach could add lime or other materials that will neutralise acidity plus a cover of topsoil to promote vegetation growth. Modifying slopes and planting vegetation will stabilise the soil and prevent erosion.

Minimising environmental effects

A landscape affected by mining can take a long time to rehabilitate and mine companies need to minimise environmental effects during mine life and mitigate the impacts of mining from from the discovery phase through to closure:

Preserving water quality

The initial closure plan usually focuses on water quality and where the water will go after closure and the quantity of water which will either discharge or migrate into the groundwater system after flooding.

Mine companies must find ways of protecting groundwater and surface water resources and to understand the risks related to water quantity and quality and to develop appropriate engineering controls and reclamation measures.

Stabilising land to protect against erosion

Reduction of slopes by land infill and reclamation, growing plants and trees on mined areas will stabilise the soil and reduce erosion by binding the soil and protecting the ground. Good erosion control will help keep valuable soils on the land and allow natural growth and regeneration.

Mine closure plans can aim to renovate the site to varying degrees:

1. Remediation

Cleaning up the contaminated area, removing all mine wastes including water and the treatment of water. Isolating contaminated material.

2. Reclamation

Stabilising the terrain, infill, landscaping and topsoil replacement to make the land useful once again.

3. Restoration

Rebuilding any part of the ecosystem that was disturbed as a result of the mine such as flora and fauna. The planting of trees and vegetation native to the area to allow regeneration.

4. Rehabilitation

Rehabilitating the site to a stable and self-rejuvenating state, either as it was before the mine was built or as a new equivalent ecosystem to take local environmental conditions into account. Mines can be repurposed for other uses such as for agriculture, solar panel farms, biofuel production or even recreational and tourist use.

Mine closure process:

1. Shut-down:

Production stops and workers are reduced. Some skilled workers are retained to permanently shut down the mine. Re-training or early retirement options are sometimes provided.

2. Decommissioning

The mine is decommissioned by workers or contractors who take apart the mining processing facilities and equipment which is cleaned to be stored or sold. Buildings are repurposed or demolished, warehouse materials are recovered, and waste is disposed of.

3. Remediation/Reclamation:

The land and watercourses are reclaimed to a good standard to ensure any landforms and structures are stable, and watercourses are of acceptable water quality. Hazardous materials are removed and land is reshaped and restored by adding topsoil and planting native grasses, trees, or ground cover.

4. Post-closure:

It is important to assess the reclamation programme post closure and to identify any further actions required. Mines may require long-term care and maintenance after mine closure such as ongoing treatment of mine discharge water, periodic monitoring and maintenance of tailings containment structures, and monitoring any ongoing remediation technologies used such as constructed wetlands.

What happens to a mine once it's closed?

Post-mining land use is an important issue in mine lifecycle planning and there are many extraordinary examples of how mine sites can be repurposed, from underground bike parks to luxury hotels.