

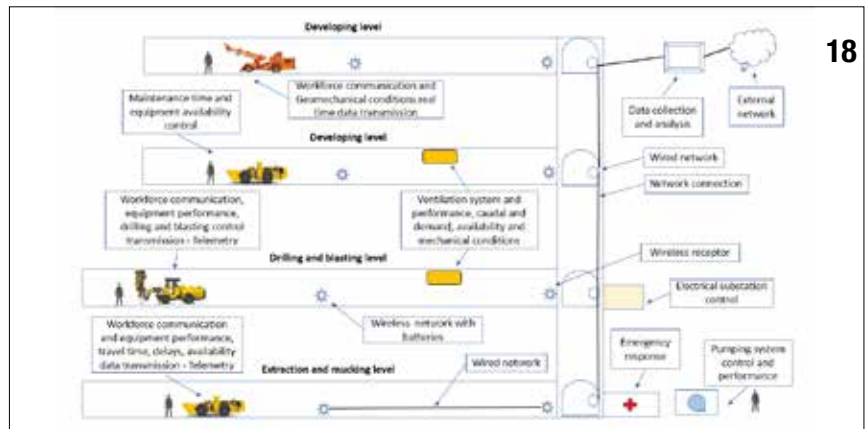
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# Mining engineering®



**Performance optimization in underground mining**  
**Dump planning optimization**  
**Regulatory training-needs assessment**



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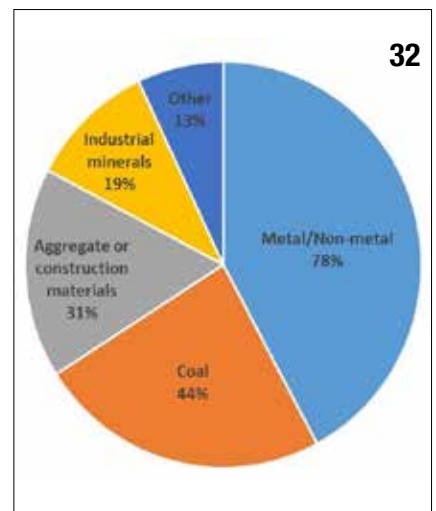
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# Dump planning optimization with environmental constraints

by J. Dufayard, R.E. Vivas and C. Goldsmith

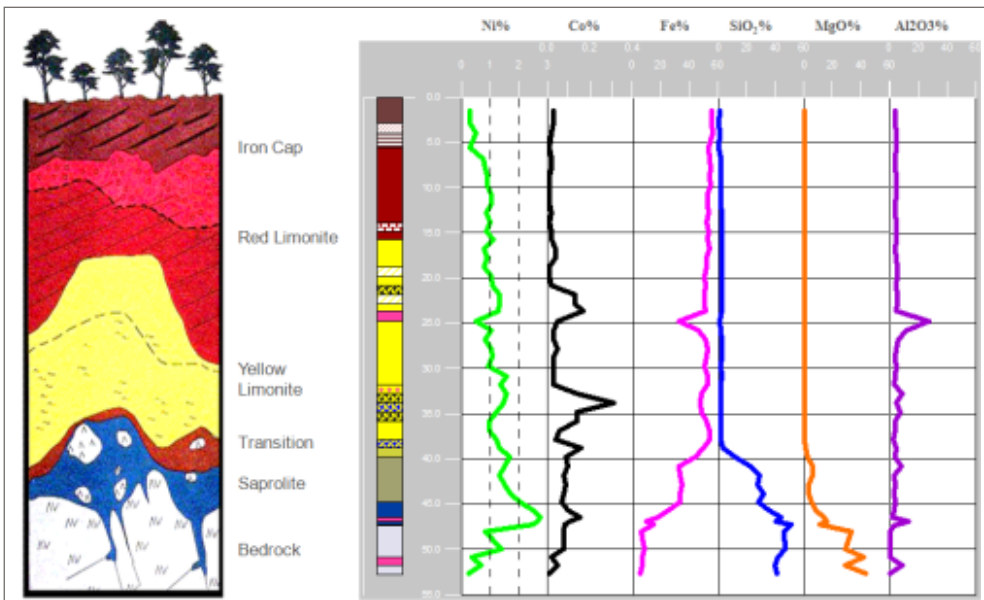
A significant amount of the world's nickel production comes from New Caledonia, a French island located in the South Pacific Ocean. New Caledonia is on of the top five producers in the world, with more than 90 percent of the island's exports being metallurgical goods. There are several mines and mining companies operating in this region. The mining industry in New Caledonia

preservation of the rich marine ecosystem.

In 2008, UNESCO added the Lagoons of New Caledonia to the World Heritage Site list. The reef systems in the area are among the three largest in the world and rival the Great Barrier Reef in coral and fish species diversity. There are serious conservation efforts in place to maintain their condition, and all fishing and mining activities are strictly watched in order to minimize their impact.

**Figure 1**

Geologic cross section.



### Project overview

The nickel/cobalt mines in New Caledonia consist of mostly openpit, truck and shovel operations. This type of mining is favorable as nickel laterite deposits are massive and typically located close to the surface. The deposition sequence includes iron oxides (laterites) near the surface and magnesium silicates (saprolites) beneath. The top layer primarily consists of low-grade material, while the high-grade ore is found at the bottom of the saprolites. Figure 1 shows an example cross section and the associated mineralization.

provides a large number of jobs to the local population both directly at the mine and indirectly through administrative positions and mining contractors.

The mining companies also provide to the community, investing in both sustainability and local cultures. There

are preservation efforts for the indigenous languages in New Caledonia, to both teach interested students and ensure that the languages are documented and kept. Numerous conservation groups, local tribes and government organizations ensure the

saprolite ores are extracted using hydraulic excavators and bulldozers, and the haulage is carried by a fleet of dump trucks. The climate on the island is tropical and the hot season (December to March) is humid and rainy. The top soil layers often become slick mud, which can impair the road conditions, making average driving speeds slower. In addition to the rain interfering with the driving conditions, mine sites constantly deal with water management and erosion control. The mine site needs appropriate drainage in place, and the waste impoundments need to be monitored, with appropriate dewatering measures. All these efforts require constant maintenance from the mine, as the working areas change.

**J. Dufayard, R.E. Vivas and C. Goldsmith** are geology & mine planning manager, Vale NC, New Caledonia, France and principal mine planning specialist and mine planning specialist (SME members), Hexagon Mining in Tucson, AZ, respectively. Email [ernesto.vivas@hexagon.com](mailto:ernesto.vivas@hexagon.com).

**Table 1**

Cobalt usage by year.

Usage industry	2006	2016	2020 (est.)
Lithium-ion batteries	20 percent	51 percent	62 percent
Super alloys	24 percent	20 percent	16 percent
Hard metals	12 percent	8 percent	6 percent
Ceramics & pigments	10 percent	8 percent	6 percent
Other	34 percent	13 percent	10 percent

Once the ore is mined from the pit, the material is sent to the high-pressure acid leach (HPAL) for recovery of nickel. HPAL is a process in which nickel and cobalt are extracted using elevated temperatures and pressures in order to separate the metals from their ore. This process is beneficial because of its ability to process ore quickly and efficiently. In our current industrial setting, both nickel and cobalt are sought after and heavily used.

Nickel is resistant to corrosion even at high temperature and is used to plate other metals to protect them. The primary industrial use is for alloys, specifically in the creation of stainless steel. Nickel alloys are also used in desalination plants, and boat/turbine propellers. Outside of alloys, nickel is also used in nickel-cadmium and nickel-metal hybrid batteries, as well as coins and currency pieces. Cobalt is a major component of lithium-ion batteries, which is a developing industry due to the rise of the electric car industry. Other industries include superalloys, material strengtheners, and the ceramics and pigments industry. Table 1 details predictions of cobalt usage by industry.

In addition to using cobalt in these batteries, newer lithium-ion batteries are using nickel manganese in their production. With electric cars, and lithium batteries becoming more common, these metals will only become more sought after. The New Caledonian mines are contributing to the production of green technologies.

## Dump planning optimization

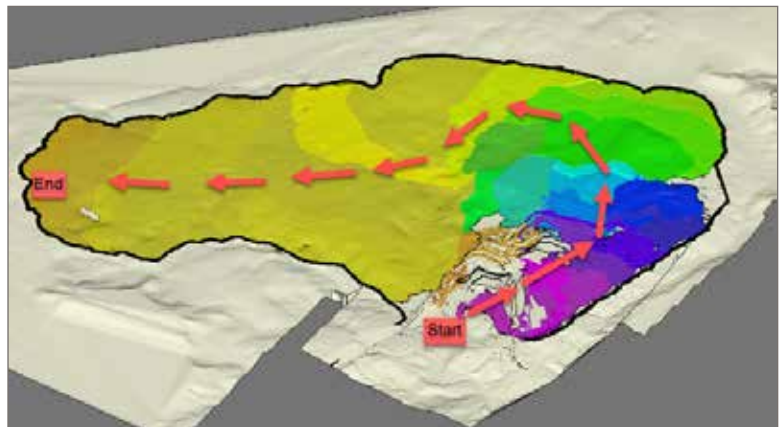
The mines of New Caledonia are subject to the highest environmental standards and regulations. One example is the restriction of disturbance limits. The disturbance area is restricted to the ultimate pit limits, and all mining activity must stay in this confined area. This imposes a series of limitations and challenges, including a limitation on the space available for waste dumps. So, throughout these projects it may be necessary to backfill the pit with waste material. However, opening the space on the pit floor to accommodate the waste can be tricky. In addition to the opening of the pit floor, the blending of grades is important, which makes planning of the mine pushbacks and of the dump sequencing a difficult task. These deposits contain both manganese and magnesium, which need to be controlled to meet the plant technical requirements. This poses a significant challenge in mine planning as the excavation requires precise removal of material types in

order to maintain the balance and meet the blend for the final product. The first step in this process is restraining the amount of material that is allowed into the mineral processing plant. This can be done through application of constraints and restrictions that allow for a reasonable processing of all the desired ore. Sequential planning of the waste dumps and how they connect into the haulage plan is very important in the life-of-mine plan.

**Pushback and slope design — with constraints for mill.** Over the course of their lives, these mines may have different pushbacks and extraction points used to excavate the area and produce the resources. A detailed plan is required in order to meet all the constraints, both production and environmental. The initial design of these pushbacks and associated dumping locations is what drives and limits the production schedule as the pit is excavated and backfilled. There may have to be several designs created and manipulated in order to meet the variety of restrictions that are in place. Even once an initial plan is developed, it will have to be revisited and altered as the mine develops in order to clearly understand the future workings to proceed.

**Figure 2**

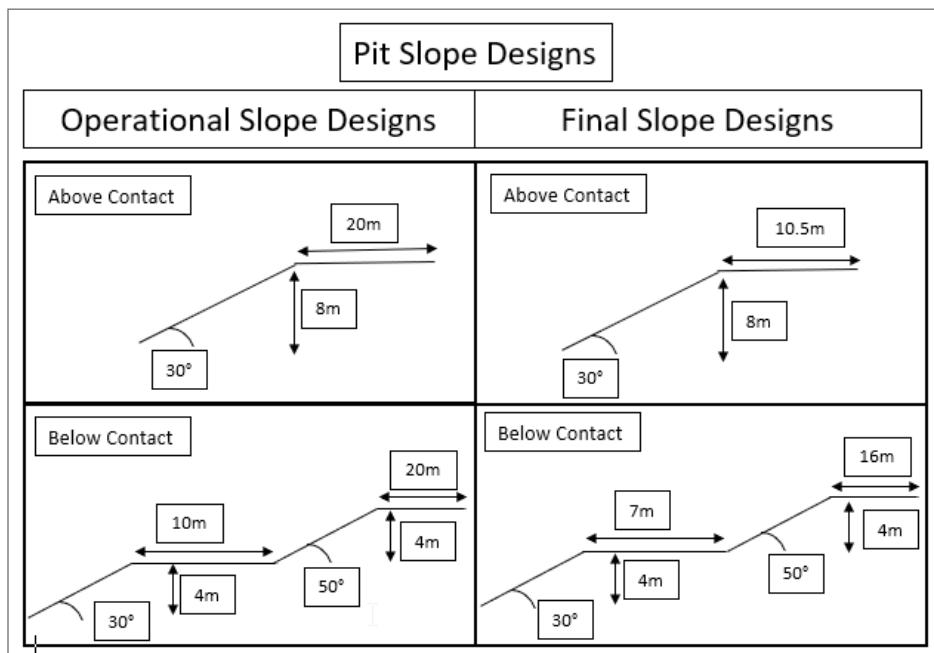
Pit with highlighted mining direction.



# Dump Planning Optimization

**Figure 3**

Pit design parameters.



environmentally or from a production standpoint. Taking all of this into consideration creates a difficult task when designing the excavation sequencing, furthering the need for attention to detail. In addition to the material constraints and slope designs, the pit boundary limits and dump design heavily impact the design process.

**Backfilling and dump sequencing — following pushback design and pit availability.** While structure and blending are prevalent design problems, the handling and designation of waste material is another planning issue. The first workings of the

The slopes of the pit walls need to be designed to withstand the heavy amounts of water that are present. Combined with the changing geology this poses an interesting problem when designing pit slopes. In some mines, the final design includes multiple geotech slope zones. For example, there may be specific design parameters that vary according to the geotechnical recommendations.

Since there will be workings in both areas of the geological zones, different slope designs need to be in place. Maintaining these two slope designs is of utmost importance to stay on top of the structural integrity of the areas. This means that there needs to be a consistent effort by the planning and operations staff to ensure that the working and completed areas are safe and stable.

While the material excavation aims to mine the best ore first, with high nickel and cobalt grades often come high magnesium and manganese as well. These two minerals need to be processed with a very specific balance to ensure that the processing proceeds as planned. The manganese and magnesium percentages must be within certain ranges as required by the plant. At these ranges the recovery rate for desired minerals can be optimized, while the acid and lime consumption are kept to a reasonable amount. This is critical for the processing plant, as exceeding these percentage amounts would cause the consumption rates of acid and lime to increase. Increasing the consumption rates means importing or creating more of these materials, which is not desirable

mine require a large in-pit dump that places the waste material further into the pit. This dump will be located near the excavation surface, and as close to the workings as possible, to minimize the rehandling distance.

After the first few pushbacks have been mined, the space will then be needed for waste material. The previous waste material will be rehandled, and the first backfilling dump will be constructed so all the ore-bearing material can be extracted. As the old waste material is being moved into first in-pit dump areas, the excavation group will have to manipulate the working faces so material will always be available for blending.

Multiple iterations of the dump designs may be required to ensure that different areas of the pit become available to mine. It is important to have multiple working faces, both for blending and for unexpected operational issues. Similarly, the inclusion of high cobalt grade in the design plan will change the footprint of the pit that further limits the space for dumping.

A balance will be struck between finding the appropriate blend, and simultaneously removing the material from the previous dump site, in order to relocate it to the newest in-pit dump site. The inner workings of the mine will consistently be changing, and operations will need to be in constant control of the next plan. As the last phases of the mines are excavated, the final layers will be added to the in-pit dumps. As the benches are not particularly tall, the material can be moved quickly, and the dumps will begin to expand

# Dump Planning Optimization

rapidly. This will aid in the reclamation efforts at the site, making the overall footprint of the mine smaller.

Over the life of the mine, the first working areas of the mine will be completely covered with the in-pit dumps. By the end of the mine's excavation, the working areas from the middle of the mine's life will also be covered. Reclamation efforts can ensure that these areas are consistent with the pre-mining environments. While optimizing profits and delivering the correct blend of material is important, meeting the environmental responsibilities and constraints are the main drivers of the schedules and dumping plans.

## Conclusions

In the coming years new developments and plans will continue to improve the quality of mining, and the recovery of desired minerals. It is important to minimize the impact of mining on local ecosystems and preserve the landscape that minerals are extracted from. By backfilling the waste material, the impact of the mine site on the local environment can be reduced and reclamation efforts can begin faster. Mine plans may have rigid restrictions that need to be met, but manipulating the constraints that are available allows for a plan that is both precise, and achievable. Finding the best location for backfilling the dump sequence can be an iterative problem as it depends on the space available as the pit opens up. The space available in the pit for backfilling may in turn be a function of the grade and blending requirements that dictate how the pit opens up and limits the space available for the in-pit dumps. ■

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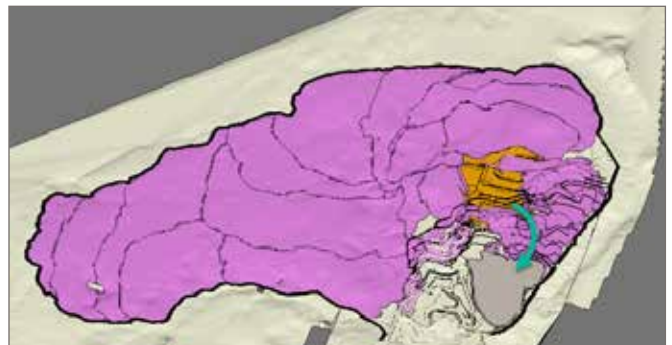
**Figure 4**

Allocating phase 1 waste material to an in-pit dump that will later be excavated.



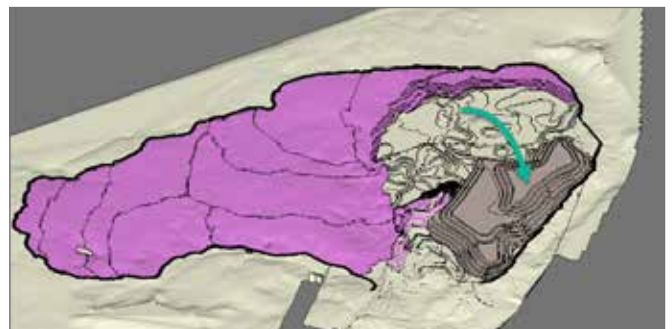
**Figure 5**

Relocating the in-pit dump.



**Figure 6**

Continuing the backfilling process.



**Figure 7**

Finalizing the backfill dumps.

