Demystifying WATER MANAGEMENT STRATEGIES

Canadian Rockies as seen looking west from within the Teck Greenhills operation's tailings facility. Photo: SRK

North American Mining *speaks to experts from Ausenco, Black & Veatch, SRK, and Stantec about the complex yet essential task of developing an effective water management plan.*

by Jonathan Rowland

There is tension at the heart of any discussion about mine water management; rising demand for commodities is driving ever-larger mining projects. These projects carry greater impacts and risks related to water consumption and tailings management systems. We are also seeing "increased demands from stakeholders, such as local communities and regulators, to reduce those impacts and risks, which must be carefully weighed when developing and extracting a mineral resource," explained Javier E. Torrealva, project technical lead for Mine Water Management at Stantec. Set alongside this, "shareholders expect consistent revenue and adherence to schedules" for new mining projects, whether greenfield or brownfield, the Stantec consultant concluded.

This complex web of needs and expectations means that "early and comprehensive mine water management planning is a key part of resilient, cost-effective, and sustainable mine plans that address water challenges during mine construction, operation, and closure," Torrealva continued. Such a plan will include strategies to supply water for processing, meet water quality discharge objectives and other watershed-specific requirements (often determined by stakeholders), and minimize the amount of contact water. It begins, added Jim Oliver, Industrial Water technical director at Black & Veatch, with "a robust water balance model, understanding the system's inflows, outflows and storage requirements."

According to Jonathan Cooper, Water Resources team lead at Ausenco, key questions in this process include determining the amount of water required by the operation over the mine's lifetime and identifying environmental constraints, such as water restrictions and areas that cannot be developed. Site location and meteorology play a critical role here. For example, in areas of high precipitation, non-contact upstream diversions or reducing the amount of water that needs active management are key considerations. In contrast, plans for arid areas and regions with extreme seasonality will need to incorporate water stockpiling or explore options to recycle process water. Runoff, tailings decant water, and pit or underground dewatering need to be considered to "provide a holistic view of the water quantity to be managed – and its variability," added the Ausenco engineer.

Once all potential inflows and outflows have been quantified, it is time to evaluate storage and attenuation options, including ponds, water transportation methods (such as gravity channels or pumping), and surplus water discharge locations. Any planning will also account for water quality and effluent treatment requirements and options, such as a treatment plant or settling ponds. "Once a conceptual water management strategy is selected and developed, the various components can be further refined and engineered," Cooper concluded.

Throughout the process of compiling and refining a properly integrated water management strategy, there must be communication between all departments on water-related objectives to assess how individual needs impact the broader picture, said Samantha Barnes, Principal Hydrotechnical Engineer at SRK.

For example, the grinding and tailings groups often collaborate to ensure sufficient water for ore production; however, they also need to communicate with the environmental group, whose focus will be on reducing a project's risk profile by discharging excess water off-site. Meanwhile, the operations team will be concerned about the sufficiency of the water management infrastructure in satisfying everyone's expectations.

The pitfalls of missing the wider picture can be significant, as Stantec's Torrealva described. "I remember a project when the design team focused everything on ensuring there would be enough water for the process plant start-up and the initial ramp-up phase. Very conservative values were used in the absence of limited ore moisture uptake data for a heap leach operation. The water system was then designed with those assumptions. Because the team did not consider the possibility of lower ore moisture uptake, as occurred when the mine started operations, instead of a potential deficit, the team had a surplus scenario. This ultimately led to the early implementation of the water treatment system."

"Developing a site-wide strategy aims to satisfy all aspects of a project, lowering the overall risk profile, and ensuring collective success," Barnes added. "This strategy will be documented in a water management plan that summarizes water management objectives, describes the water management infrastructure, and explains how this system is operated for a range of mine planning, climatic, and geochemical scenarios to meet the site water management objectives."

Today's mine is not tomorrow's mine

As we noted earlier, mining projects are a compromise of competing interests, objectives, and timelines, which makes any form of planning a challenge. Adding to this complex picture, mines are also inherently dynamic; mine plans change over time for a host of technical, social, political, and economic reasons.

For example, new deposits may be identified, extending the mine's life, footprint, and water catchment beyond what had been envisaged when the original water management planning occurred. Such expansion leads to a larger area being disturbed by mining operations. This can degrade water quality and limit the space for storage or attenuation options, while increasing the volume of contact water, thereby complicating compliance with permit conditions, noted both Ausenco's Cooper and SRK's Barnes.

Increasing water recycling and recovery is another instance of change that could disrupt a water management system.

Although this can "reduce dependency on perpetual auxiliary sources, it may necessitate more water discharge offsite, potentially requiring water treatment to meet environmental standards," added Barne's colleague and fellow principal hydrotechnical engineer at SRK, Brandon Smith.

Changes to the ore grade and type, water-use processes, and water quality will also impact the water management strategy. And these are just some potential operational changes, without considering the influence of events beyond the mine fence. Long-term climate change, for example, is likely to result in more frequent and intense extreme events, such as flooding and droughts. These will not only impact mining operations but also local communities, potentially straining that relationship and, thus, a mining operation's social license to operate.

Ultimately, it is "difficult to predict how a mine will change," concluded Ausenco's Cooper, "especially at inception when much of the water management planning is undertaken." Ideally, the mine water management plan will be future-proofed, ensuring that infrastructure, including channels, ponds, and treatment capacity, can expand to accommodate these changes; however, "there is a fine line between permitting too much and not enough."

Getting the baseline right

This inherent complexity makes understanding the water baseline paramount. This begins with data – and lots of it, according to our experts. As a "general rule of thumb," said Black & Veatch's Oliver, "the timeframe for historical data should reflect the anticipated life of the mine." Thus, an evaluation of a 20-year mine life would look back at the previous two decades to understand trends in the system.

Although baseline studies need to be "balanced with the project budget, timelines, and what is reasonably necessary to satisfy deliverables," Cooper continued, "undersizing the study area is one of the most common shortfalls, especially early in the project before the ultimate footprint or infrastructure locations are known." This is unsurprising, as baseline studies are usually the first step in permitting, preceding advanced engineering. As this work progresses, the location of infrastructure, pits, and waste rock facilities often changes and can end up sitting beyond the initial study area.

Another pitfall to avoid when working out the water baseline is performing water quality sampling under static conditions. "It is not uncommon for water quality to change as bedrock fractures are dewatered or inflows are drawn in from surrounding areas, such as geothermal water," explained Oliver.

When it comes to best practices, it is essential to be familiar with regulatory requirements and expectations before embarking on a baseline study, said SRK's Smith, who also noted the importance of community engagement, as "stakeholder concerns may not be apparent otherwise." Several industry experts also highlighted the constructive role that conceptual site modeling (CSM) can play in baseline studies. Such models identify potential contamination sources, pathways, and receptors, helping to define the scope

Superficial water sampling at Lobo Marte, Atacama, Chile. Photo: SRK

of the baseline study and ensuring that critical areas are understood.

Additionally, a CSM can assist in assessing waste management alternatives, which ideally occurs before the baseline study. Lastly, conceptual models are helpful when developing monitoring systems that are responsive to system changes during mine operation and to potential threats to supply posed by other local water users. This could include "gaining or losing streams, recharge boundaries, other water users, such as agriculture, and spring flows," Black & Veatch's Oliver said.

Water balance models: accounting for change

Baselines help us understand the current state of water resources in a potential mining area; however, as has been noted, mining operations and their surrounding environments are dynamic. The primary role of water balance models is to provide insight into how these changing conditions might affect a proposed water management system over time. These models form the basis of the water management system, enabling it to be stress-tested to identify pinch points or flaws in advance.

Water balance models "outline the quantity and seasonality of natural inflows, such as rain and snow, and internal sources and uses of water onsite," explained Ausenco's Cooper. This allows sensitivity assessments to be performed on the water balance, identifying a water management system's susceptibility to upset conditions or non-typical environmental conditions, such as wet or dry years and storms.

The water balance is, thus, an "essential starting point for understanding how the water management system will perform under various conditions and helps identify operational risks," continued Cooper. "Often, the water balance is the backbone of a predictive water quality assessment, used for both permitting and mitigation designs."

Modern modeling tools enable users to integrate a range of variables and uncertainties, including time-dependent inputs such as variable mine throughputs or increasing mine footprint, natural variability like dry or wet hydrological cycles, and actual uncertainties like material characterization values. For these cases, modeling tools "allow inputs to be expressed as a time series and probability functions," explained Stantec's Torrealva. "The results can also be expressed as a probabilistic time series to inform better decision making when dealing with inherent uncertainty and variability."

Working with other disciplines is crucial when developing these models, noted both Ausenco's Cooper and SRK's Smith, who highlighted obtaining accurate time-series data as a challenge that multi-disciplinary collaboration can help overcome. "All assumptions should be presented transparently for ongoing relevance," Smith continued. "Sensitivity analysis also requires team buy-in to ensure the management system remains robust under a range of operational scenarios."

For Cooper, working with other disciplines enables the model to "account for the influence of operational variability." Illustrating his point, the Ausenco engineer described a hypothetical discussion with the mechanical team regarding pipeline and pump requirements, leading to the use of pond storage to reduce pumping needs, overall costs, and operational complexity. Another example would be a discussion with the tailings management team to understand the timing and volume of return water, as well as the properties of the tailings, as these can influence how water is managed and modeled.

However, models are not infallible; there are critical limitations that should be acknowledged. One potential source of error is simply failing to account for the residual impact of previous events on long-running simulations, noted Black & Veatch's Oliver. "A simple example of this is in the design of evaporation ponds. In many circumstances, the pond is not empty at the end of the year, especially when precipitation is high and evaporation rates are low. This residual water needs to be carried over year to year to ensure that the storage volume properly accounts for the amount of water in the system."

Meteorological conditions – and the accuracy of weather forecasting – pose a critical point of uncertainty when developing water balance models. According to Ausenco's Cooper, water balance modellers typically rely on historical data sets to assess meteorological conditions, considering sensitivity ranges. "For instance, the average monthly precipitation is used to produce a baseline model, but data from a wet or dry month could be used to provide a range of conditions that could occur. The sensitivities will vary depending on the site, water management strategy, and the risk tolerance of the project."

Of course, mine sites are "developed where there is ore, not necessarily where there is good meteorological data," said Stantec's Torrealva. "Extending record series always involves some level of uncertainty, especially for extreme conditions."

"Regional data can be adjusted to develop a representative synthetic dataset for the site," continued Cooper, although its accuracy will "depend on the overlap between site and regional data." Models can also be "refined as more overlapping data become available," the Ausenco engineer added, "reevaluating the potential range of conditions and reviewing the overall design strategy to ensure it still meets the design intent and to determine if optimizations can be made."

Other limitations include uncertainty regarding the hydraulic and geochemical properties of mined materials, particularly in the early planning stages, when sampling may be limited. There is also the human or equipment factor. "Operating rules embedded in the modeling should be as simple or straightforward as possible to be easily replicable at full-scale operations," said Torrealva.

Despite their inherent limitation and uncertainties, especially at the early planning phases, the Stantec engineer concluded with several specific items that a water balance model allows, including:

- Assessing the practicality of water reuse and recycling.
- Considering the use of different technologies.
- Evaluating system reliability, flexibility, and redundancy.
- Testing facility safety, such as storage volumes and freeboard requirements (i.e., the vertical distance between the maximum surface elevation and the top of a structure, such as a dam).
- Supporting trade-off analysis, such as flow segregation based on origin or expected chemistry and treatment technologies.
- Developing operating rules and proactive management of site operations and equipment in anticipation of water deficit or surplus.

"There is always some uncertainty around whether the assumptions in the conceptual model are accurate or whether the components will act in a way that we do not expect," added SRK's Smith, who emphasized the need for calibration data to verify that model assumptions and mechanisms are appropriate. When calibration data are unavailable, "we rely on the modeler's expertise, informed by their knowledge from other similar sites. Ultimately, however, without a water balance model, making effective water management decisions becomes significantly more challenging, especially as planning looks further ahead."

The impact of climate change

Climate change is perhaps the most significant contributor to uncertainty around water management in the mining industry, with high temperatures, more frequent and extreme weather events, and thawing permafrost threatening infrastructure and operations, according to Ausenco's Cooper. This makes it critical to incorporate climate change into long-term planning.

Approaches to this may vary; however, they should begin by understanding what potential climate change might look like. Several government organizations, academic institutions, and industry associations have developed tools to aid in this process. Once these scenarios are assessed, the next step is to apply these changes to the existing water management system or strategy to understand how the system might respond. This provides a starting point for future-proofing the system. Ideally, this information is used at the early planning or development stages of the mine.

According to Tom Sharp, an SRK principal hydrotechnical engineer, mining companies may then opt to design for worst-case climate scenarios, providing "conservatism and flexibility, though at a slightly higher cost." Alternatively, operators may design for more moderate projects and stress-test under extreme conditions. "Results from these scenarios help gauge system robustness and develop contingency and recovery plans to operate in unplanned or more extreme situations," Sharp continued, concluding that "each operator should select and routinely re-evaluate a set of climate assumptions matching their risk profile."

Learning the lessons of the past

Mine water management strategies have undergone significant improvements over the past few decades. This follows a "growing recognition that poor planning poses unnecessary risk, including increased costs, delays, or unscheduled shutdowns," explained SRK's Sharp. "While water management may have been overlooked previously, many clients now see its importance and are improving their plans for greater resiliency."

Specific improvements have been made in determining the quantity of water that needs to be managed and how it is utilized in operations, with an emphasis also placed on water quality and contamination mechanisms, discharge locations, and the impacts on the surrounding environment, including fisheries, aquatic life, and release rates. Predictive water quality modeling is "now being integrated into most mine developments and continues into mining operations, alongside water management strategies and water balances," concluded Cooper, "providing valuable insights to achieve operational efficiencies and inform long-term planning of mining operations."

Stantec's Torrealva offered a positive summary of the situation to conclude the discussion, noting: "From modeling and design tools used in the early stages of planning, adoption of advanced water treatment and water reuse technologies, to monitoring and adaptive management during operations, the industry has made a lot of progress."