NSW GOVERNMENT

NSW Resources Regulator

LEADING PRACTICE TAILINGS MANAGEMENT FOR SUCCESSFUL CLOSURE

Questions and answers

JUNE 2020

Purpose of this document

A key component of the NSW Resources Regulator's compliance model is to educate and engage the regulated community. This includes helping to exchange information about leading practice tailings management.

As part of the April 2019 tailings management workshop, the Regulator engaged Professor David Williams (from the University of Queensland) to give a presentation on leading practice tailings management as well as key lifecycle tailings management risks.

Professor Williams, Director of the Geotechnical Engineering Centre within the School of Civil Engineering at the University of Queensland is an internationally recognised expert on tailings management and is a key contributor to other leading practice guidance material, including the Tailings Management, Leading Practice Sustainable Development Program for the Mining Industry (Department of Industry, September 2016).

Information provided by Professor Williams on consideration of leading practice and sustainable tailings management has been incorporated into this question and answer document. This may assist mine operators consider a range of issues associated with leading practice tailings management and closure of tailings storage facilities.

> The Regulator and Professor Williams do not endorse the tailings management practices described in this document as being the only examples of leading practice, or as being acceptable for broad-based implementation. Mine operators should review options based on the circumstances associated with their mining operation, life cycle stage and climatic, topographic, seismic and environmental settings. As part of this process, mine operators are required to undertake risk assessments and comply with applicable NSW legislation.

Q: What is leading practice for tailings storage management?

A: There is a move away from conventional slurried tailings storage facilities due to considerations of the best outcome overall, taking into account how the facility will be closed. This is resulting in the implementation of dewatered tailings management practices and a combination of dewatered tailings with waste rock - referred to as integrated waste disposal or co-disposal.

Q: What are examples of leading practice or innovative tailings storage management?

A: Integrated waste landform management practices are being developed that involve the combination and mixing of tailings and waste rock before disposal. Integrated waste landforms have the potential to produce combined waste of improved density and strength, resulting in a more robust storage facility. These practices can also have the advantage of encapsulating the waste rock to reduce the potential for acid and metalliferous drainage (AMD).

Integrated waste landforms have been proposed at some new magnetite iron ore mines, in Western Australia and South Australia. These projects generally involve the filtration of the tailings and crushing or screening of the waste rock to enable the two streams to be conveyed and stacked.

Integrated waste landforms are being developed and trialled for new or expanding overseas projects, including the use of patented processes such as GeoWaste, which uses a combination of filtered tailings and waste rock, and paste rock, which incorporates paste tailings and waste rock.

Q: What are key considerations for successful implementation of leading practice tailings management?

A: For these projects to become cost-effective, some challenges must be overcome including:

- limiting the extent of tailings filtering required
- limiting the need to crush or screen the waste rock
- deciding on an efficient transportation method
- effectively mixing the filtered tailings and sized waste rock
- minimising compaction requirements on placement to ensure stability.

Regarding integrated waste landforms, the best co-disposal is one that is well-mixed. However, achieving this may be prohibitively expensive. Effective mixing may not be ensured by truck or conveyor delivery, as the fine and coarse waste streams tend to remain segregated. Mixing can be achieved using various methods, including drop points along a transport conveyor.

Another issue is the concentration of fines in the mixture that may remain liquefiable. This may require compaction of at least the outer zone of the integrated waste landform.

Q: What are the key considerations for successful closure and sustainable final land uses of existing tailings storage facilities?

A: The key considerations are: consolidation/settlement of the tailings, capping design, and final landform design.

Q: What are the considerations for consolidation/settlement for successful closure?

A: Poorly consolidated tailings will take extended periods of time to develop a strength profile that will allow capping placement, adding considerable costs and delays to the closure of the facility. Hydraulic placement, the use of low bearing pressure equipment, and the placement of separating and reinforcing layers may be used to facilitate this process, but at considerable additional cost.

Once capped, differential consolidation settlement of tailings will likely disrupt any constructed surface drainage features, particularly if they are gently sloped (typically <1%). It will also result in surface ponding of rainfall runoff on the tailings, recharging and exacerbating seepage.

Slurry tailings placed at a rapid rate of rise, particularly in-pit (often underwater) may result in under-consolidation, which will take a long time to consolidate, if ever. This will translate to much less and much slower total and differential consolidation settlement than would be predicted by conventional laboratory consolidometer testing (taken to full consolidation) and analysis (based on full consolidation).

Q: What are the considerations for testing and modelling consolidation?

A: Estimates of settlement magnitude and rate can be overestimated where conventional consolidation testing is done on tailings samples of soil-like consistency, as this state may not be reached in a tailings deposit. This is particularly the case in situations involving clay mineral-rich tailings, a high rate of rise, and a continuous water cover associated with in-pit disposal. A slurry consolidometer test can be carried out on tailings from a slurry-state, and can simulate under-consolidation. Hence, it can provide a more realistic estimate of settlement magnitude and rate (hydraulic conductivity).

Laboratory slurry consolidometer testing (the University of Queensland has the only such apparatus in Australia) can simulate the actual rate of rise and under-consolidation of slurry tailings and provide more reliable input parameters for analysis. All commercially available consolidation models are driven by input data from conventional consolidation testing, and hence cannot simulate under-consolidation. This leads to an over-estimate of the actual settlement, since the tailings will continue to take load via fluid pressure, with this dissipating very slowly, and an under-estimate of the time this would take.

Cone penetration testing (CPTu – incorporating pore pressure) has become the most common and useful in situ method of investigating tailings deposits, providing estimates of their shear strength, compressibility and permeability (via pore water pressure dissipation).

Q: What are the key considerations for capping design?

A: Appropriate consideration of capping performance and design at an early stage is critical. Unfortunately, capping has been prone to geotechnical, erosional and geochemical failure, primarily due to its limited thickness. Shedding (wet climate) covers tend to fail due to erosion, particularly on slopes, requiring good vegetation and/or rock cover. Store and release (dry climate) top covers tend to fail due to a combination of unsuitable materials, poor design and construction, lack of a sealing layer to hold up rainfall infiltration, and inadequate vegetation to extract the stored wet season rainfall.

For chemically unstable tailings, capping design and performance must aim to limit net percolation into the tailings. In a humid climate, excluding oxygen may be possible by maintaining saturation. Chemically unstable tailings could be located below a water cover (best from the start of deposition or at least before the tailings have had time to oxidise), or below a soil cover maintained saturated. Composite covers (geomembrane combined with an underlying clay layer to reduce the hydraulic gradient) is also a consideration. Perpetual water treatment is an undesirable last resort.

In a dry climate, excluding oxygen is challenging, and limiting net percolation (and the transport of contaminants) is more feasible. A store and release cover with an underlying sealing layer can limit net percolation into underlying chemically unstable tailings. The sloping beach of the underlying tailings can promote clean runoff and seepage through the cover towards a low point, where it could be diverted, avoiding the ponding of excessive rainfall infiltration above low points.

Consideration of vegetation growth on the capping needs to be incorporated into the design. Tree death (when tree roots reach the tailings) and/or blow-down (of shallow-rooted trees, due to roots progressing laterally across a compacted layer or contaminating tailings) can threaten the integrity of a cover over contaminating tailings. However, excluding tree growth is not a sustainable alternative option. The cover should be designed for inevitable revegetation and sustainability.

Q: What are the key considerations for final landform design?

A: Long-term geotechnical, erosional and geochemical stability is the key consideration. The Australian National Committee on Large Dams - ANCOLD (2012) have adopted 1000 to 10,000 years (depending on the failure consequence category) as a notional post-closure life for the purposes of focusing design and operational considerations. This requires consideration of annual exceedance probability (AEP) for rainfall and seismic events of up to 1:10,000 years (effectively in perpetuity) for closure. This translates to the probable maximum flood and an earthquake magnitude equivalent to about a 1:100 year event for San Francisco (requiring projection of less than 150 years of low seismicity data for Australia to 10,000 years).

Tailings storage facilities designed for 1:100 or 1:1000 years during their operation may not be able to readily be retrofitted to accommodate 1:10,000 years post-closure (e.g., due to being constructed close to the lease boundary or existing infrastructure preventing the flattening of tailings dam slopes). If the tailings undergo a net drain down post-closure, the tailings dam will become more stable and may satisfy the recommended closure factor of safety. However, in wet climates, the tailings will be seasonally recharged.

Q: How is surface water management considered as part of the final landform design?

A: Long-term geotechnical stability is assessed based on traditional slope stability calculations, typically using two-dimensional limit equilibrium methods. There is a trend to undertake three-dimensional numerical modelling, which has shown value in back-analysing tailings dam failures. *SIBERIA*, *CAESAR* and other long-term models are used to project long-term erosion. However, the results obtained should be considered as indicative of the form of erosion gullying, with high error bars (100% or greater).

Closure spillway requirements are assessed using ANCOLD (2012), coupled with hydrological projections. In regions with extreme rainfall events, such as Australia, a spillway should be provided both during operations and post-closure, to avoid the risk of the tailings dam overtopping, which can lead to failure of the dam.

Post-closure, a spillway also limits the storage of rainfall runoff on the tailings, which would reduce dam stability and increase seepage. The spillway should ideally be constructed through natural rock, requiring that the tailings dam be constructed against a hill or valley, since it is more difficult to reinforce a spillway taken through the tailings dam.

Q: What guidance and training is available for consideration of tailings management?

- ANCOLD (2012) is the leading and accepted *Guideline for the Design, Construction, Operation and Closure of Tailings Dams*. ANCOLD offers periodic training presentations
- Chapter 6 of the Global Acid Rock Drainage - GARD Guide (2009) is the recognised authority on mine waste covers.
- The Australian Centre for Geomechanics, and The University of Queensland offer periodic training in Tailings Dams and Tailings Management
- Tailings management consultants offer periodic training in Tailings Dams and Tailings Management, including for operators.

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