SOFT TAILINGS
LANDFORM DESIGN

Gord McKenna, PhD, PEng, PGeol
Geotechnical Engineer, Landform Designer

A keynote address at
Tailings and Mine Waste Conference 2017
Banff, Alberta, Canada

Here is an outline of the keynote address presented by Gord McKenna at the Tailings and Mine Waste Conference in Banff, Alberta, Canada on December 7, 2017. Please contact the author at gord@mckennageotechnical.com for additional information, comments, or questions. Useful references are listed at the end.
Q: How to manage soft tailings?

Key concepts

- **Soft tailings** are those that due to their low density and strength are difficult to stabilize, cap, and reclaim to provide acceptable long-term landscape performance.

- Most of the **important decisions** regarding soft tailings are already made before mining starts. Managing soft tailings involves decisions related to mining, extraction milling, tailings, reclamation, and water treatment. Soft tailings aren’t something to leave until the end of mining – their management throughout the mining lifecycle is critical to success.

- **Landform design** sets goals, objectives, and criteria for design, construction, reclamation, and long-term performance of mining landforms, and uses a practical multidisciplinary approach to achieve those goals throughout the mine life and beyond. It offers a way of controlling costs and achieving better environmental outcomes.

- **Designing the contents** of the tailings facility is as important as designing the containment. But we need to start before mining begins, selecting mill and tailings technologies to absolutely minimize the generation of soft tailings. The soft tailings need to be designed such that mining landforms, including tailings ponds, are easy to reclaim.

- We can redefine **sustainable mining** as the emergent outcome of doing seven things very well: engage communities and earning trust; exercising planning, decision making, and design with flair; executing promises operationally; empowering employees; efficiently managing resources; exceeding shareholder expectations; and enhancing the environment. Much of the keynote focusses on the second element – exercising planning, decision making, and design with flair.
The ongoing risk of a dam breach resulting in a catastrophic outflow of water and tailings.

Trafficability (or lack thereof) poses the risk of mining equipment, people, animals, or other users / equipment becoming mired (with a risk to life and limb).

Excessive post-reclamation settlement causing flooding, changes to land use, changes to water quality, and risk to dam structures. With respect to long-term water quality, settlement of saturated tailings also results in the release of large quantities of contaminated water.

The high cost of stabilization, capping, reclamation, monitoring and maintenance. The cost of such work may exceed the tailings costs for the mine up to that point. Such costs can reach more than $1m per hectare for soft tailings.
Q: When are soft tailings a problem?

- Most **metal mines have a small area of soft tailings** at the distal end of each tailings pond that requires special effort to reclaim.

- The few **metal mines with clays in their orebody** can generate large areas and large volumes of soft tailings.

- **Coal mines with high-plastic clay** seams can generate large volumes of soft tailings.

- **Oil sands mines**, with the high-plastic clay seams associated with the orebodies, generate vast quantities of soft tailings that already cover more than 92 km$^2$ of the land in northeastern Alberta.
Soft tailings cannot be directly trafficked. Instead, amphibious equipment is needed. Typically, these can only provide access for site investigation. Where there is a water cap, barges and boats can be employed.

*Soft tailings trafficability needs to be assessed.* Soft tailings are often weakest near the surface, which controls trafficability for equipment. Measuring the vane strength of the tailings and employing Terzaghi bearing capacity theory can be used to estimate the bearing capacity of soft tailings. Measuring the bearing capacity of capped soft tailings is more involved. Small caps can allow access for small dozers. Thicker, stronger caps allow careful access with larger dozers and small haul trucks. Often geogrid is employed to increase stability and safety. All access needs to have safe work plans and standby equipment to rescue people and equipment should they become mired.

- Soft tailings **crusting** can allow foot traffic and in some cases small dozers.
- A **thick frost layer** can allow slightly larger dozers.
- A **sand cap** can allow dozers and small trucks, but sometimes trafficability is limited by the new sand cap, not just the soft tailings below.
- **Underdrainage** leading to unsaturation of the tailings is usually difficult to implement but can allow access to large haul trucks.
There are six common methods / technologies employed for soft tailings capping. Many deposits require several different methods depending upon the strength and density of the soft tailings.

- **Water capping** is a common technology and doesn’t rely on the strength or density of the soft tailings (except with respect to resuspension from the mudline).

- **Floating coke** covers are employed in the oil sands – petroleum coke (similar to coal) is an refinery byproduct with a bulk density less than that of some soft tailings – the cap can be placed to float on the soft tailings underneath.

- **Raining-in tailings** can be done by placing thin layers (as little as about 5cm) with computer controlled barges gently depositing sand slurry that sinks down to the mudline. This is a common technique in capping dredged sediments.

- **Beaching in tailings sand** is one of the cheapest methods to cap soft tailings, but requires soft tailings density and strength such that displacements by the cap are manageable.

- **Soft ground** techniques usually involve laying geogrid and placement of thin layers (<1m) of sand or waste rock using very small dozers supplied by very small trucks that keep away from the active face. The layers are built up sequentially until the desired trafficability is achieved. This is the most common method of soft tailings capping but is expensive for large areas.

- **Standard earthworks techniques** can be employed if the tailings strengths can be improved to become “firm to stiff” for a large depth. This typically corresponds to strengths of more than about 50 to 100 kPa and may require desaturation or cementing of the tailings.
Landform design involves setting out clear objectives, doing the engineering and multidiscipline work as a team of ‘ologists, site investigation, improvements, capping, reclamation, revegetation, and finally getting regulatory signoff against your clear objectives and design criteria.

Mines need to work with local Aboriginal communities, regulators, and stakeholders to develop a set of reasonable and achievable goals, design objectives, and design criteria for each mining landform (and each mining landscape) containing soft tailings.

Generally, some topographic relief is required for the final reclaimed landscape to manage surface water and groundwater.

Designs need to mitigate against potential environmental impacts and may involve groundwater control, controlling the timing and amount of settlement, water treatment, and managing the risk of the beach.

There are numerous examples of successful soft tailings stabilization, capping, and reclamation, but typically the costs are high, and sites require long-term monitoring and maintenance.

Landform design offers a useful approach to setting and achieving goals for soft tailings deposits. It is most effective where it is included before mining starts.
You are charged with going out into the world and start really designing for closure, before the mine even starts and throughout its life. When the commodities are all consumed, what you have left is landscape. Get the right people on the team, use effective closure planning (no hand waving), get the right experts and workers, choose, and produce firm to stiff tailings where you can to make reclamation easy.

But most of all, have a plan for all tailings, and execute it operationally together, sustainably, with flair.
Bibliography


McKenna G, Mann V, Fisseha B, Beier N, & Olmedo N. 2017. This tailings has the consistency of chocolate pudding: a formal comparison of the geotechnical vane shear strength of food and soft tailings. Geotechnical News.


