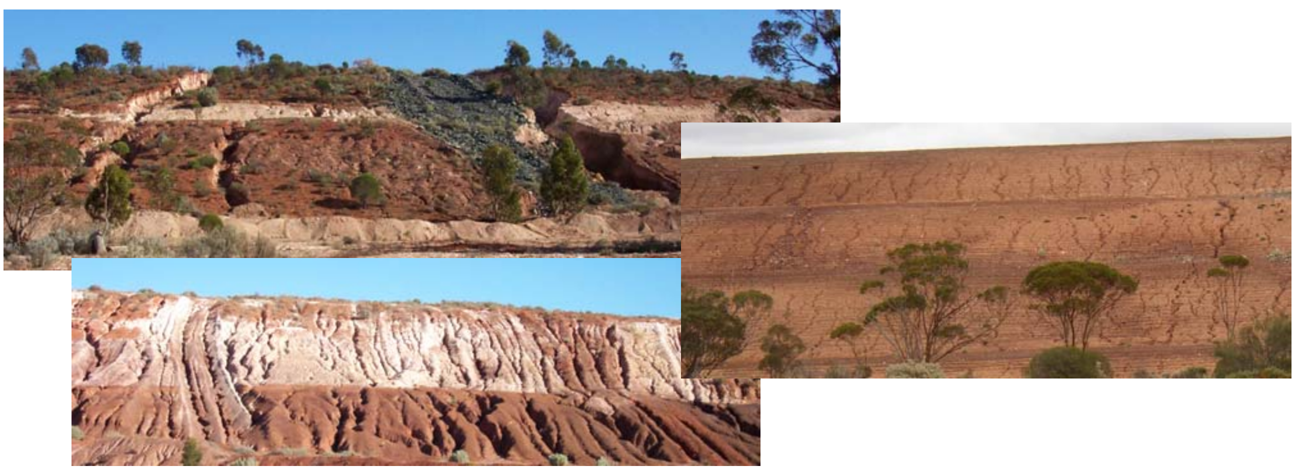
Designing stable constructed landforms for minesites

This article documents Landloch's observations of constructed landforms, and outlines the range of approaches we use to provide the foundation of successful landform design and construction.

Over the last 9 years, Landloch staff have inspected a large number of constructed landforms on minesites across Australia, Papua New Guinea, and Africa. Some have been stable, but the large majority are subject to high rates of erosion. Some simply do not support vegetation. Unsuccessful rehabilitation is highly undesirable, as the potential for companies to relinquish leases and have bonds returned depends strongly on the perceived long-term stability and sustainability of those landforms. The concerns are even greater if erosion has potential to expose or release particularly undesirable materials to the surrounding environment.

Why does it appear to be so difficult to create stable post-mining landforms?

In the absence of a representative national survey (which would be REALLY helpful), the proportion of landforms that are failing is not known accurately. Nonetheless, the proportion of unstable landforms is obviously much higher than the mining industry would prefer, as they represent an on-going cost for repair and management. It was telling that speakers at the 2004 Goldfields Environmental Management Group Workshop in Kalgoorlie were unanimous in commenting that existing waste dump design guidelines are "not working".



From our observations, the main reasons for landform "failure" include:

- construction of landforms from highly unsuitable or unstable materials;
- adoption of inappropriate landform designs;
- inaccuracies in construction; and
- lack of understanding of the prevailing climate and its impacts on water balances and pathways for water movement.

Underlying all of these causes of failure is a tendency to believe that some generic landform guideline can be applied to **all** minesites irrespective of material properties, climate, or vegetation. At best ……. that **is** irrational.

Reducing risk of failure

Although it is seldom possible to reduce risk to zero, it is possible to reduce it enormously, by:

(a) characterising the materials likely to be used in landform construction, and investigating the prevailing climate and vegetation;

(b) using that information to identify risks to the landform (salinity, acidity, erosion, etc.); and

(c) planning landform design and construction that will not only achieve goals developed for the landform, but also minimise the risks identified.

Once a suitable design has been developed, construction to specification is essential. Also important is post-construction management and monitoring.

Characterisation

The level of characterisation adopted can vary enormously, but can include:

- salinity – with highly saline materials being unsuitable for plant growth;
- sodicity – with sodic materials representing a risk of dispersion & tunnel erosion;
- susceptibility to tunnel erosion – with not all materials susceptible to tunnel erosion being sodic and dispersive;
- water holding capacity – affecting potential plant growth, water balance, and seepage to depth;
- erodibility – with parameters derived varying enormously depending on the erosion model to be used; and
- chemical fertility – including pH and macro and micro nutrients.

Challenges for characterisation include ensuring that appropriate methods of measurement are used, properly interpreting interactions between various results, and accurately interpreting the data. Landloch has extensive experience with these issues.

Landloch is currently the only supplier in Australia of erodibility measurements for a range of runoff/erosion models. (There are groups able to provide information for one or two models in some situations.)

Interpretation/Risk assessment

Risk assessment is not always simple. Issues considered by Landloch include the way in which soil profiles "work" – water balances (runoff, water available for plants), potential for seepage and tunnelling, and the likely performance of various pathways for runoff to leave the landform.

The soil profiles created may have interactions between the various layers and the local climate such that a spoil that would be stable in one situation may be quite unstable in another. There may be potential long-term changes in soil/spoil that need to be avoided or accentuated. Interactions with vegetation also need to be considered.

Planning and Design

Planning and design are often underpinned by computer simulations that quantitatively compare a range of design alternatives. As part of this process, Landloch uses a range of water balance and runoff/erosion models. One advantage of modelling is that the designs produced can be closely adapted to site climate and soil and spoils.

Thinking long-term

For a landform to be sustainable implies that it will be stable for long periods – up to a thousand years if encapsulated material is of concern. This requires a different mind-set, as some "traditional" erosion control practices tend to be effective only in the short term, or only if they are maintained in perpetuity. (The latter **should** concern mining companies. Why adopt a rehabilitation strategy that guarantees long-term liability?)

What practices tend to work in the short term only?

Simply – things that are susceptible to highly undesirable changes.

One very common example is the loss of capacity or effectiveness of structures such as cross-slope rip lines or berms. In the short term, water storage in rip lines can aid plant establishment, but rip lines can also concentrate flow across considerable widths of slope and create instant gullies when they overtop. Similarly, sediment deposition in berms can reduce their capacity and lead to overtopping and gullying.

Sediment deposition in a berm 12 months after completion of rehabilitation, and flow already overtopping the berm

Because erosion on batter slopes is inevitable, it is equally inevitable that berms between the batters will gradually fill with sediment, lose capacity, and overtop to form gullies, except in situations where erosion is extremely low, or overtopping does not cause damage. Both situations require extremely high surface roughness from rock or vegetation. However, as these are not commonly available, gully erosion is a common consequence of berms on constructed landforms.

In some situations, chemical changes in soil or spoil can be disastrous. One example is the interaction between salinity and clay dispersion, with leaching of salt sometimes triggering dispersion and tunnel erosion.

Development of tunnel erosion in a level berm due to ponding of water, leaching of salt, and increase in clay dispersion. Ponding is a strong driver of tunnelling, even on some non-dispersive spoils.

Some structures, such as rock drains, tend not to work even in the short term. Stable rock drains on minesite landforms are a rarity due to problems with design, construction, and site preparation. (The gully is usually **beside** the rock drain!)

Conclusions

Current success rates with constructed landforms are unnecessarily low. In most cases, the costs of repair and maintenance of unstable or unsatisfactory landforms for extended periods far exceed the costs of characterisation and design (getting it right the first time).

The successful design and construction of stable landforms involves a number of critical and interrelated processes. Achieving a successful outcome depends on **all** of those processes being carried out competently. Care and attention to detail are an essential part of the design and construction process.