Proceedings of the 21st Annual British Columbia Mine Reclamation Symposium in Cranbrook, BC, 1997.
The Technical and Research Committee on Reclamation

CLOSURE PLANNING PRACTICE AND LANDSCAPE PERFORMANCE AT 57 CANADIAN AND U.S. MINES

Gord McKenna PEng, PGeol[1]
Richard Dawson PhD, PEng, PGeol[2]

[1] Syncrude Canada Ltd, PO Bag 4009 MD X302, Fort McMurray, AB T9H 3L1
[2]Norwest Mine Services, #400-205 9th Avenue SE, Calgary, AB T2G 0R3

ABSTRACT

A large number of operating, dormant, and abandoned minesites in Canada and the U.S. were visited in 1996 to gather information on closure planning practice and to observe the performance of reclaimed landscapes. Information was compiled from mine tours and through on-site interviews with reclamation and environmental personnel.

Most Canadian mines are on the closure path and have completed their first conceptual closure plan, usually in response to new government regulations. However, there is considerable uncertainty regarding several key closure issues including certification, abandonment, long-term residual liability, financial assurance, and numerous technical issues.

Most mining landforms are showing good performance in terms of physical stability and revegetation. However, there is some uncertainty regarding the long-term reliability and performance of some landforms, most notably constructed rivers, end-pit lake filling, and tailings slopes. Difficulty in prediction of the long-term performance of closure landscapes has, in part, lead to a certification barrier. Very few mines have requested or achieved certification of reclaimed land, despite the fact that certification is usually the stated objective of reclamation activity.

Although most mine reclamation focuses on certification, a more strategic focus is required. The ultimate objective for mine reclamation should be custodial transfer of the land (to the crown or a third party), with certification being one step on the closure path. Due to the concerns about long-term liability for reclaimed sites, a transfership barrier exists and very little reclaimed mine land has been transferred to new owners.

Landscape engineering (setting goals, designing for closure, using landforms and vegetation that have sustainable and reliable long-term performance) is perhaps the next major step in mine reclamation practice. Aspects of this approach have already been adopted by several mines and research is ongoing.

INTRODUCTION

In 1996, the authors visited 57 minesites in Canada and the U.S. to learn about closure planning practices and make visual observations of the reclaimed landscapes. Most of the sites were in Alberta and British Columbia. The work was carried out to help Syncrude Canada Ltd, an operating oil sands mine in northeastern Alberta, to gain an industry-wide ajppreciation for mine closure practices. The program's goals were to allow Syncrude to:

- benchmark the current state of practice for mine closure planning
- share experiences with mines about closure planning
- learn about the physical performance of various types of mining landforms

A variety of mines was visited in numerous geographic regions. The selection of mines was biased towards those with closure planning experience and similarities to Syncrude, especially climate. The sites ranged from small abandoned mines to large producing operations. While the sample was neither complete nor statistical, it was suitable to achieve the program's goals. During the visits, which averaged about four hours each, numerous photos were taken. A checklist of questions and observations was used to gather similar data from most mines. Back in the office, this data was entered into a spreadsheet for qualitative analysis and trip reports were generated. Figure 1 shows the location of the mines visited and Figure 2 shows the approximate areas of disturbed and reclaimed land for each mine.

This paper provides a summary of the major learnings. These learnings are divided into regulatory issues, closure experience, reclaimed landscape performance, and trends.

REGULATORY ISSUES

Uncertainty about certification

There is a formal regulatory signoff process for reclaimed land that usually involves certification and return of the land to a permanent custodian. Certification for small sites (such as oil wells or industrial sites) is routine, but certification of reclaimed mine land appears to be rare and transfer back to the crown extremely rare. There seem to be several reasons for this:

- As a result of rapid evolution of formal reclamation and closure regulations, there is a lot of uncertainty about how the certification process works
- Mines are exposed when they bring land to the certification process as they:
  - don't want to be turned down
  - don't want to give up future access to the land
  - risk a far-reaching reclamation order
- Regulators are reluctant to make final certification commitments (due to uncertainty about future performance and future changes to regulations)
- Where certification is coincident with transfer of land to a new custodian, the mine is exposed to liability for poor management of the land by future custodians.

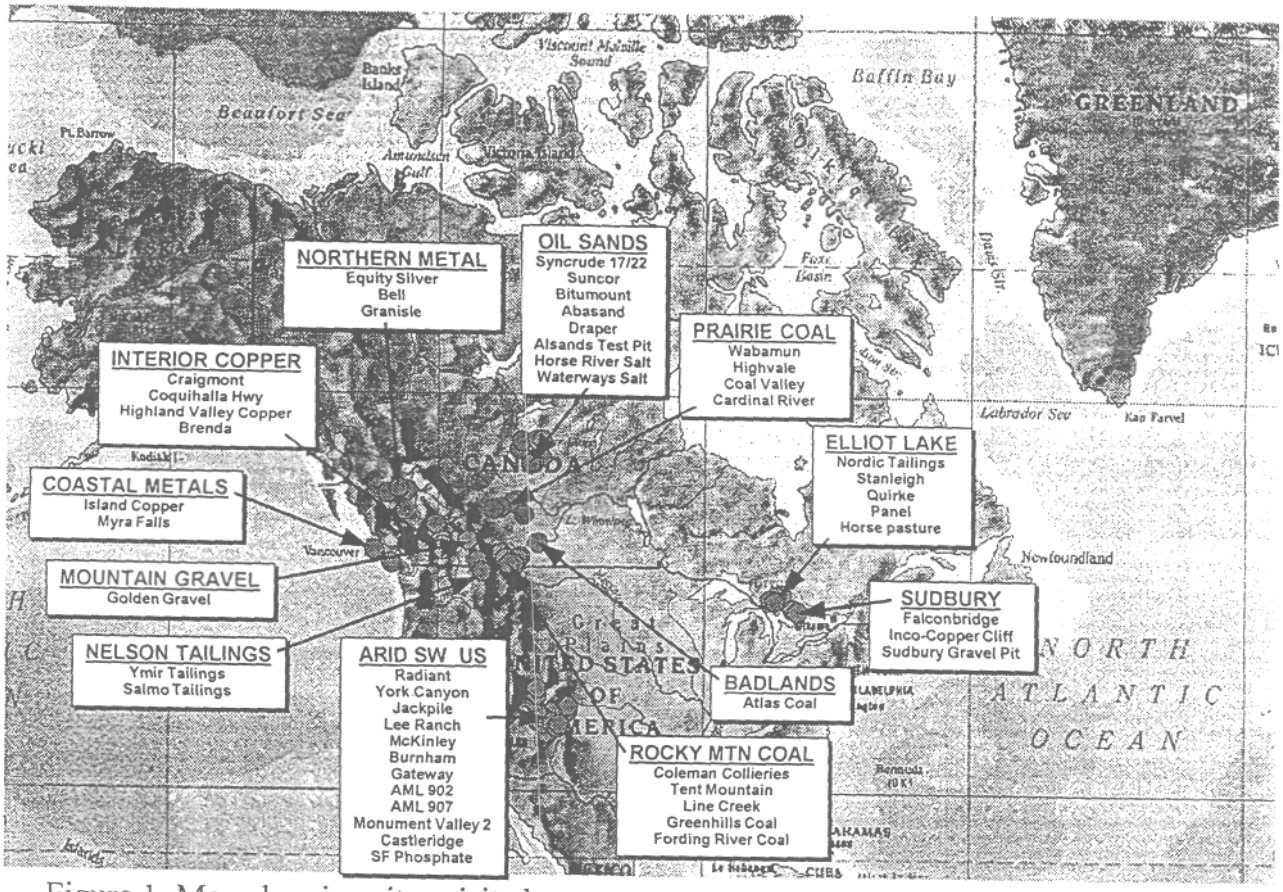


Figure 1. Map showing sites visited

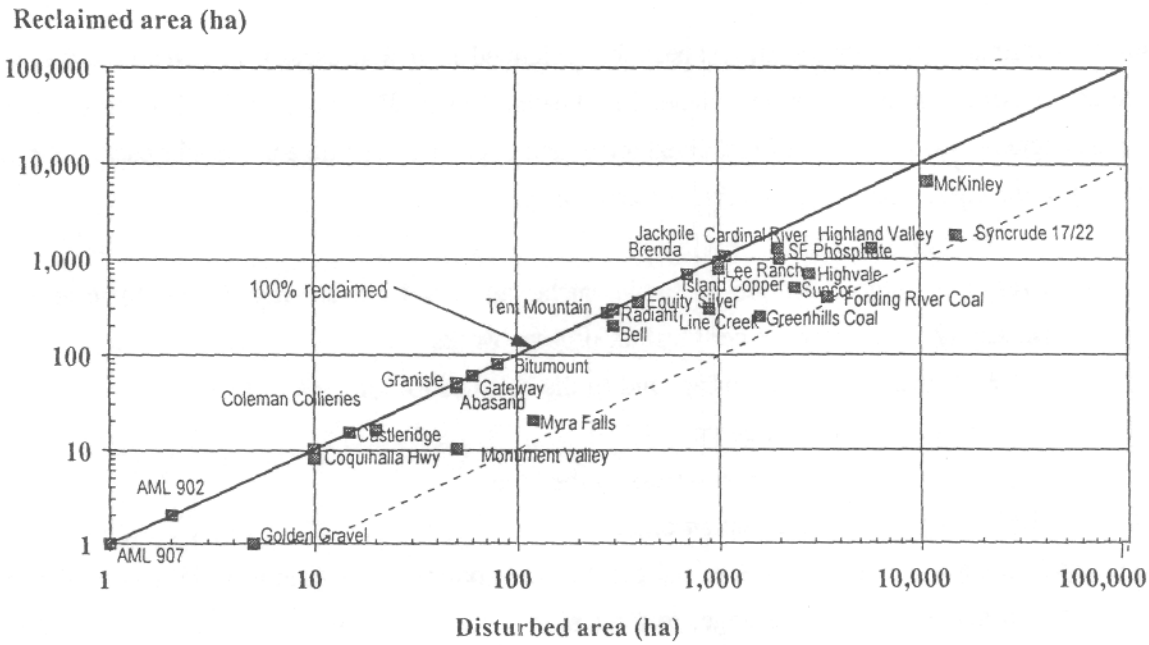


Figure 2. Disturbed vs reclaimed areas (log-log scale)

Some mines are considering going through certification (or mock-certification) of a parcel of reclaimed land to provide experience for both the mine and the regulators and to start setting precedence.

Closure goals and end land uses poorly defined

A common theme for most mines is that landscape performance goals are poorly defined. They are usually a few broad policies which are not specific enough to provide enough direction, and there are numerous undeclared goals. In the absence of clearly defined goals, it is difficult to determine whether the closure landscape will be successful and to what degree. Similarly, end land uses are usually poorly defined. In some cases, multiple end land uses are envisioned, but it is usually unclear whether all are achievable and which ones take precedence. There is much work to be done in the area of setting end land use and closure performance goals and few easy answers.

One of the greatest uncertainties is the timeframe for which the landscape is to show good performance. Suggested timeframes range from 10 to 10,000 years but is usually undeclared. There seems to be some consensus forming that landscapes should provide good performance for 200 years with a broad consideration for timeframes to 1000 years. This has originated from regulations for closure of uranium mines and mill sites in the U.S.

A potentially powerful strategy is to return the land's performance to that of the surrounding natural environment, with maintenance levels similar to those being applied today to natural crown-owned land. While this strategy can likely be employed for most of the landscape, most sites will have a small area that requires greater maintenance and fuller consideration of timeframes for performance. In addition, once the land has been mined, it may be better suited to another use. This amounts to capitalizing the next economy through the creation of brownfields sites — a concept gaining favour in some regions.

Prescriptive versus performance approaches

Mine reclamation and closure practice is greatly influenced by the regulatory environment. There are two essentially different regulatory philosophies:

• Prescriptive approach

The prescriptive approach requires compliance to specific criteria. This is meant to make reclamation easier, more accountable, and less susceptible to political influence. Sometimes prescriptive regulations are transported from one region to the next. In this case, they may not make sense and can be counter-

productive, with biological stability often being the goal that suffers the most. As a result, certification may be difficult to achieve. This approach also results in a stifling of creativity and innovation. The resulting landscapes are usually not self-sustaining even though they may meet most of the prescribed criteria. There is a near lack of certified land in regions visited where prescriptive approaches are in force. This approach has been common in the U.S., especially for federally regulated uranium and coal mine producers. The mining industry needs to resist this type of legislation.

Some jurisdictions allow prescriptive regulations to be overruled by the director of mines in negotiation with an individual mine. This allows much more flexibility than purely prescriptive approaches.

• Performance approach

The performance approach relies on demonstrated capability. This involves establishing acceptable standards of practice that rely on proven performance. Research and monitoring are integral components of this approach. Alberta is perhaps leading the way by providing for a demonstrated-capability approach. Instead of requiring specific productivity levels, as is often prescribed elsewhere, Alberta has taken the approach that mines can provide reclaimed! landscapes that meet land capability requirements through demonstrating this capability on a reasonable (but relatively small) scale. For example, certain thicknesses and compositions of soils (combined with other features such as drainage and aspect) are capable of producing forests to various classes, so growth measurements on a hectare by hectare basis should not be required. This leaves the mine a lot more flexibility and room for innovation and ultimately a better landscape.

Financial assurance

Most reclamation and mine closure regulations require financial assurance which can take many forms including corporate assurance, letters of credit, and bonds. Many mines have a bond that is based on the number of hectares disturbed. Some mines must be bonded for the instantaneous cost of closure. A few mines have been asked to post bonds to cover perpetual maintenance, especially for treatment of acid mine drainage. There is some discussion about insurance for damage due to extreme events or latent defects.

Perhaps the greatest uncertainty facing mines is the changing standards to which they must reclaim the land. The cost of closure is growing and there: appears to be unlimited retroactive liability for reclaimed sites. Some suggest that permit areas should be: grandfathered and subject only to requirements negotiated at the time of initial permitting. Governments would be liable for the cost of future regulatory changes of this grandfathered land, which would factor into the cost of implementing new or harsher regulation.

CLOSURE EXPERIENCE

Closure plan development

Almost all mines visited in Canada have closure plans, mainly due to legislative requirements. British Columbia, Saskatchewan, Yukon Territories, Ontario and Quebec all require closure plans from mines, and it would seem that the remaining jurisdictions are likely to follow. Some foreign countries and some U.S. states also require closure plans. Alberta does not require formal closure plans, but both the Syncrude and Suncor oil sand mines have recently developed closure plans to meet internal needs.

Closure planning is a relatively new activity for most mines. In compliance with new legislation, most Canadian mines have developed their first conceptual closure plan in the last few years. Consultants are often used to assist in various aspects of closure planning and provide some sharing of closure planning techniques. The legislation in developing closure plans leaves room for innovation and while each of the plans is different in form, they all follow similar styles.

Closure plans are typically about 150-200 pages long, as a rule of thumb cost about $1000 per page to develop, and are backed by various pre-existing reports and studies. Plans are typically in the public domain and are filed with the government. They usually take nine to eighteen months to prepare. Although normally a regulatory requirement, most mines have found the closure planning process to be useful and productive. New closure plans may be required by the government on a five-year basis.

A key challenge in developing closure plans is balancing the amount and type of information and effort. While they must be detailed enough to be complete and useful, they cannot be too detailed as they will evolve and change over time. In general, closure plans will become more detailed as the mine goes through its lifecycle. The final closure plan is a detailed decommissioning plan.

Influence of the closure leader

Closure plans are usually developed by a closure leader, usually the supervisor of the environmental department who is often a biologist. The closure leader has a very strong influence over the closure plan and the final appearance of the reclaimed site. As shown in Table 1, the closure leader's background has a significant influence on the major focus of the closure plan, and subsequently, the final landscape.

Table 1. Leadership influence on closure planning

Closure planning leader	Major focus
Biologist	Revegetation, wildlife, natural systems, aesthetics, biological stability
Geoscientist or geotechnical engineer	Physical stability, hydrology
Mining engineer	Schedule and costs, physical repairs
Mill supervisor	Water treatment and chemical neutralization, chemical stability
Mine manager	Cost control, meeting regulations, questioning regulations

Suggestions from mines for closure planning

Mines were asked for general closure planning advice. The responses included:

- Obtain senior management buy-in before beginning
- Get good (digital) topography of natural and disturbed areas for base maps
- Identify all issues for waste materials
- Have a rough plan in mind before approaching stakeholders and regulators
- Capitalize and amortize closure expenses and include them in the budget
- Negotiate with stakeholders and government well before closure
- Plan for a maintenance-free landscape as much as possible
- Establish regular environmental audits
- Understand there will be ongoing long-term liability
- Understand that a truly maintenance-free landscape is likely unobtainable
- Have a better handle on the baseline data (mainly biological and water quality) than the government and stakeholders so concerns can be addressed immediately and with confidence
- Work closely with university and government consultants to develop defensible scientific research
- Work closely with stakeholders to develop end land use and to develop a clearer definition of closure goals
- Establish good public relations on reclamation and closure issues including public tours and open houses to show off both production and the reclaimed areas

Difficulties observed in closure plan implementation

Experience from the mines that were visited indicates some of the difficulties that have been encountered with the closure planning process. Most of these issues have not shown up until just before implementation of the closure plan. Some of the difficulties are as follows:

- Identification of post-closure monitoring activities
- Over-reliance on modelling (biological, ecological, chemical, physical, risk)
- Poor appreciation for long-term erosion and other long-term landscape changes
- Closure-information gap (information and data is often lost at closure)
- Incomplete historical performance databases
- Difficulties in resolving short-term dïscount-cash-flow economics with long-term closure costs

Dormancy versus temporary use of the land

Several sites that were visited are dormant sites still under the care and maintenance of the mining operators. At these sites, reclamation is mostly complete, but there is no indication that there will be return of the land back to the crown or another custodian in the near future. In some cases, this is due to future prospects for additional mining, but in other cases, ore reserves are exhausted and there is little chance that mining will resume. There seems to be several other reasons for maintaining a dormant site:

- The company is busy reclaiming and closing other sites and wishes to postpone closure
- The company hopes to avoid having to reclaim the site altogether
- The company hopes to postpone final decommissioning costs for the site to take advantage of discount cash flow economics or future technologies
- The original owner has informally indicated it doesn't want to take the site back in its present condition
- The mine is unwilling to hand the site back to the original owner for fear of incurring additional liability for the site. Given this liability trap, mines prefer to hold onto the sites indefinitely. Some dormant sites have had extensive reclamation and monitoring to ensure the mining company continues to meet environmenlal regulation during the dormancy period.

The last reason was a common theme for many dormant sites. The mining industry has strongly promoted mining as a "temporary use of the land." It is unfortunate that, in almost all cases, mines are unwilling (because of the liability trap) to give back the land for future land uses. Thus there is a certification barrier where neither mines nor regulators are attempting to certify land and a transfership barrier where the mines

don't want to give up the land and the original owner (usually the crown) doesn't want the land back. Until these two barriers can be overcome by all levels of government working with the mines, the notion of temporary use of the land is not being fulfilled as intended. The cause of these barriers is the lack of predictability and reliability of both the long-term landscape performance and future regulatory changes — which ultimately boils down to the liability for changes to the land. The solution likely involves the government accepting the land back with a bond from the mine, in return for which the mine needs to be absolved of all liability, provincial and federal.

RECLAIMED LANDSCAPE PERFORMANCE

For a reclaimed landscape to fulfil its design intent, it must satisfy declared performance goals (including biological, chemical and physical stability) while also satisfying land use goals. Usually performance and land use goals are coincident, but are sometimes at odds. Observations made at the various mine sites reveal that, in general, most landscapes an: performing well. Some indicators of good performance that were observed during the site visited are as follows:

- Acceptable off-site impacts
- Minor and decreasing surface erosion and deposition (both by wind and water)
- Successful establishment of drainage courses
- Geotechnical mass stability
- An apparently healthy, self-sustaining vegetative cover
- Presence of volunteer flora and fauna
- Minimal areas of inactive, unreclaimed land
- Performance indicators that follow predicted trends
- Fulfilment of reclamation/construction promises
- Visual appearance (aesthetics) coincident with expectations
- Acceptance by regulators
- Achievement of goals set by the mine
- Satisfaction of stakeholders
- Having received awards for reclamation
- Successful re-introduction of big-game or game-fish species

Almost all active and recently decommissioned mines visited are exhibiting most of the performance indicators listed above. Based on our observations, mine reclamation practices (especially revegetation) are well in hand with a few exceptions.

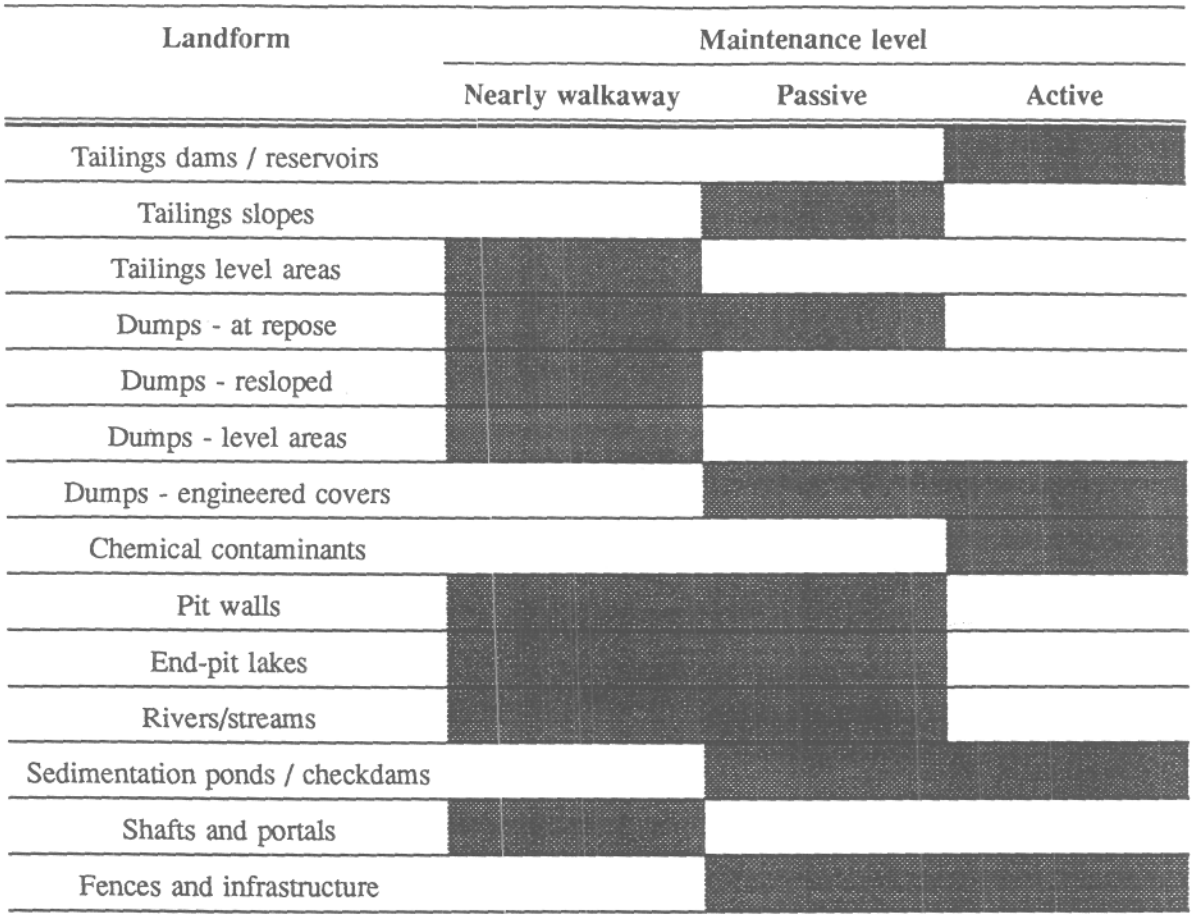
In areas where drainage courses are re-established after mining, the design and / or construction is sometimes inadequate. Streams that are built to be erosion-free for 100- to 200-year design storms have few provisions for excedence of design flows. Most streams are not designed but merely field fit, others having been designed, but the size of the channel and the armouring are built below design specs to reduce construction costs. Beaver dams, log jams, landslide dams, ice jams / icing, and numerous other blockages are not considered. Mines need to learn how to design channels to pass very large flows with significant but acceptable erosion and be able to withstand the effects of blockages.

The design of end-pit lakes is problematic. Even through the rate of rise, the ultimate level, and the percentage of littoral zone area are often crucial to landscape performance, the prediction/modelling ability appears to be lacking. Numerous mines have encountered difficulty at closure due to these issues. Building landscapes with adequate hydrological performance is a significant area of reclamation that needs to be advanced. It is curios to note that almost all mines have an end-pit lake in the closure landscape. This common element would benefit from some multi-disciplinary research to aid the mines instead of treating every end-pit lake as a unique entity. In addition to the filling rate and ultimate lake level, geochemical issues (particularly stratification) associated with end-pit lakes are usually complicated and crucial to good performance of the final landscape. More work to increase reliability of end-pit lakes is required.

Significant surface erosion occurs where tailings dam slopes are subject to surface runoff where tailings sand is fine enough to limit infiltration. Virtually all slopes visited that are composed of fine sand or coarse silt show considerable rilling, gullying, and depositional fans — enough to limit vegetation on these slopes. The only technology being successfully employed on such slopes is ongoing active maintenance to keep the slopes under control. This is clearly another area requiring further research at the field scale.

Mining's goal to create a maintenance-free landscape with relatively low residual liability is likely not attainable in a traditional walk-away scenario. However, it is clear that the performance of different types of mining landforms and the residual liability can be improved through long-term maintenance. Table 2 provides an estimate of the type of maintenance requirements necessary for different landforms.

Table 2. Landscape performance observations



Many unreclaimed or abandoned sites are showing moderately good performance, some 20 to 60 years later. Volunteer grasses, shrubs, and trees cover most of these sites (although less densely than surrounding undisturbed ares) and erosion is generally small and decreasing. Most of these sites are relatively small compared to the sites presently being mined. However, they do show that if small areas of modern reclaimed land are in distress, they will self-reclaim to acceptable levels. In other words, the revegetation of reclaimed sites need not be perfect everywhere. Sometimes, allowing nature to self-design (allowing species to invade naturally) is preferable to traditional revegetation.

Innovative practices

Prescriptive regulations and conventional practices are continually being challenged. This often results in more sustainable closure landscapes at lower costs that may have value-added benefits. Table 3 compares some of the more conventional design perspectives with more innovative practices that are being considered at many sites.

Table 3. Conventional versus innovative mine closure practices

Conventional practice	Innovative practice
Design dumps to minimize the footprints	Larger footprints allow shallower slopes and less erosion
Flatter slopes reduce erosion	Steeper slopes may have less erosion because they have smaller catchment areas
Construct planar slopes to induce sheet flow and minimize concentrated flow	Construct ridges and swales to concentrate surface water flow into armoured swales (landform grading)
Dumps should be built with flat tops	Dumps should have undulating tops that are sloped away from crests
Capping of wastes is essential and desirable	Direct seeding of wastes may provide better performance
Subaqueous tailings and rock disposal is to be avoided	Subaqueous disposal of tailings and rock may be the best solution to guard against acid mine drainage
Attempt to contain contaminants forever	Release contaminants to the environment slowly and acceptable to minimize the contaminating lifespan
Plant lots of trees everywhere	Plant trees in islands or allow natural invasion
Plant trees for uniform coverage in straight lines	Plant trees in swales where there is more moisture
It is enough to plant grass and trees	Shrubs are also important as is importing insects and small animals
Reclamation is something started after mining	Reclamation should influence mine and dump design *before* mining
Reclamation species should be chosen on the basis of end land use	May be preferable to create the right conditions and allow nature to self-design the species mix (self design through natural invasion)
It doesn't matter what is planted, the site will move to natural climax species	Growing recognition that pseudo-climaxes of agricultural plants may persist for centuries
A few good years of baseline data is sufficient	Base line data must be collected continually. There are changes and cycles that persist for decades and centuries that may invalidate the idea of base-line data and hydrologic prediction
Only native species are acceptable	Achievement of physical stability goals may benefit from non-native (exotic) species

TRENDS

Closure planning has become part of the mine development process and starts at the early stages of the mine-permitting process. Budgets and schedules are being used by government agencies to identify bonding levels for long-term post-closure maintenance and, in some cases, for the instantaneous cost of closure. High levels of bonding are affecting the bottom line of some mining companies, the viability of individual mines, and the efficiency of their mine plans by restricting the active mining area to what can

be afforded by bonding. Standardized means tests are being considered to determine the form of financial assurance to be posted by the mines. The mining industry may start to see mandatory insurance for liability of reclaimed sites. Accumulation of large numbers of dormant or closed sites begin to affect the financial performance of large mining companies. There may be a resurgence in single-mine companies whose liability is limited through shareholder limited liability.

Eventually changes to this spiralling burden must occur. Mines should become exempt from Polluter Pays legislation for mine wastes (Polluter pays; legislation is federal legislation that makes any active or previous owner of a site retroactive liability for future clean-up costs) and mine wastes should be considered differently from urban or other industrial wastes. Government will have to accept the cost burden of enacting stricter regulation and legislation on operating mines, using royalty money to pay for changes. Mining companies need to advance: closure design philosophies and technologies to increase the predictability and reliability of reclaimed mine sites. This will ensure the new owner has the confidence to accept the land back.

Traditional reclamation and revegetation are highly developed and very successful. However, as expectations for closure landscapes increase and the appreciation for the complexity of natural systems grows, there is a need to better integrate reclamation and revegetation with the mine planning process, right from the pre-feasibility stage. This is especially true for large sites, ones with complex chemical issues, or ones with difficult hydrologie conditions. Called design-for-closure, this concept has been around for about twenty years, but its application is only now starting to become widespread. Instead of designing our waste dumps and tailings dams to meet purely geotechnical and production economic constraints and leaving these structures for biologists and other reclamation specialists to green up, mines need to embark on a more interdisciplinary approach. Landscape engineering is an attempt to provide better direction and tools for this new approach to produce landscapes that meet clearly defined goals predictably and reliably with lower residual liability and at overall lower cost.

CONCLUSION

Findings from site visits at 57 Canadian and U.S. mines show that mine closure planning practices are now a regular part of mine development. Experienced gained from visiting this large number of sites suggest the following:

1. Mine réclamation is an important activity at all mines and the state of practice is well developed, particularly in the area of revegetation. At virtually all mines, it is very successful and is a source of pride for employees and owners.

2. Closure planning is a relatively new activity, still in its early stages of development. Most mines have a conceptual closure plan and are on the closure path.

3. Closure and reclamation requirements are becoming more onerous. Corporate requirements often exceed regulatory requirements. Recently, several mines have become the first to close under the new wave of closure requirements and are encountering and meeting significant technical challenges.

4. Almost no reclaimed mineland has received revegetation certification or other form of government recognition or approval. Almost no land has been returned to the crown or other original owner except as abandoned land where it has defaulted to the crown.

5. Mines are extremely hesitant to return land to the crown or another owner due to long-term liability concerns, particularly under federal "Polluter Pays" legislation. Upon reaching closure, most mines go into dormancy when one or two caretakers are assigned to the site, equipment and facilities are sold, reclamation is substantially reduced or halted, and there are no plans for return of the land.

6. Physical landscape performance is very good for most types of mining landforms but problematic for some types of landforms. In particular, re-establishment of surface-water hydrology is often problematic and stabilization of tailings slopes (especially where the tailings are fine-grained sand) is difficult.

ACKNOWLEDGEMENTS

This work would not be possible without the support of many people at numerous mines who shared their sites, philosophy and insights. This summary paper is an attempt to repay these individuals for their time and candid comments. Several consultants also provided valuable suggests and insights including Dave Devenny, Andy Robertson, John Gadsby, Les Sawatsky, and Ed McRoberts. John Errington and Tim Eaton are also thanked for their input, insight and suggestions. Support from the Syncrude Land Restoration Technical Advisory Panel, the Syncrude Closure Planning Team, and Syncrude Research is greatly appreciated.