RECLAIMED CLOSURE LANDSCAPES: THE IMPORTANCE AND BENEFITS OF OPERATIONS MAINTENANCE AND MONITORING

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ABSTRACT

The process of landform design of closure landscapes and watersheds can be divided into a seven step process; conceptual closure planning design, individual landform design, individual landform construction, final closure plan design, final closure plan construction, monitoring and operation, and closure.

As part of recent work on landform design and construction for open pit mines, several constructed projects have progressed into the monitoring and operations phase. This phase is important for assessing the performance of the landform to compare to the proposed landform design goals and objectives, for preparation for final closure, and potentially for closure certification. This paper presents a call to action for undertaking this phase of the landform design process with skill, creativity, and effective organization. We provide some useful tools and some lessons learned which highlight where this aspect of landform design is being undertaken successfully and where it could be improved upon.

There are three separate components to the monitoring and operation step of landform design; operation, maintenance, and monitoring. The scope of each of these will depend on the individual landform design and what purpose it is designed for. For example, for an instrumented research watershed the level of effort will be high with respect to managing water levels, maintaining access, fixing outlets, and undertaking research monitoring to assess performance. At the other end of the scale, for a small opportunistic wetland or a small waste dump, operation and maintenance may be negligible and monitoring may be limited to an annual inspection.

As part of this paper we provide a table of important operation, maintenance, and monitoring activities as well as roles and schedules for both an upland and a lowland setting which can be used as a tool for this phase of design. We also discuss the intricacies involved in some typical monitoring and operating activities such as outlet operation, water balances, post construction landscape fixes, and methods to simplify the entire process.

KEY WORDS: Closure, Operation, monitoring, maintenance, OMM Manual, certification, early planning

INTRODUCTION

Design of mine closure landscapes and their landforms and watersheds involves numerous steps: conceptual closure planning design, individual landform design, individual landform construction, final closure plan design, final closure plan construction, operation, maintenance and monitoring, and final closure (McKenna and Cullen, 2008; CEMA in prep). As part of recent work on landform design and construction for open pit mines, several projects the authors have worked on have progressed into the
operations, maintenance, and monitoring (OMM) phase. This phase is important for assessing the performance of the landform to compare to the original landform design goals and objectives. It is also important for preparation for final closure, and potentially for closure certification / bond release, yet this phase is often overlooked. There are opportunities to enhance this aspect of mine reclamation. This paper describes the current state of practice of planning for this OMM phase, proposes a new way forward, provides some example of success, and lists a few lessons learned thus far, mainly from recent experience in oil sands reclamation and from examples elsewhere from the past two decades.

CURRENT STATE OF PRACTICE

Most mines begin with an overarching goal that mine reclamation will allow a “walk away” / self-sustaining landscape at closure or soon after (McKenna 2002) and will be entitled to release of financial assurance obligations. Much of the early reclamation may involve re-sloping, cover soiling, and planting of upland terrestrial vegetation and any required post reclamation maintenance and monitoring is done in an informal / ad hoc way. Issues related to more challenging reclamation (e.g. stabilizing dykes for abandonment, dealing with acid rock drainage, creation of wetlands) often arise much closer to closure. Dealing with these issues highlights the need for higher levels of maintenance and monitoring during the operational phase.

In reality, most mines find that they will need to monitor and maintain much of the reclaimed landscape for a considerable period after reclamation, through closure, and in many cases, in perpetuity (e.g. Goldcorp 2006). A typical goal is to conduct the minimum levels of OMM to protect the reclamation investment and develop enough information for successful relinquishment (Cowen et al 2013). Thus the overall challenge is to design and carry out an optimal level of OMM activities, in an organized fashion, with an eye to steering each landform (and the entire reclaimed mine landscape) towards meeting regulations, achieving declared goals, and ultimately leading to timely relinquishment to a willing custodian (usually the Crown).

Reclamation specialists do monitor their reclaimed land, keeping an informal eye on the growth of vegetation, ingress of volunteer species, land use by wildlife, evidence of erosion or deposition, zones of seepage, etc. But documentation is sparse, budgets for fix-ups difficult to justify, and monitoring is generally done in the absence of a plan or schedule. Lacking a repository for observations or data collection, knowledge of the land is usually lost when the specialist moves to another job or retires. Given that the time between reclamation and relinquishment may span decades, such losses are common.

Unfortunately, the current state of practice is not leading to timely relinquishment of mining properties – the mines are usually either abandoned, often partially reclaimed, or remain under long-term control of the mining company or subsequent owners (McKenna 2002, Cowen et al 2013). There are numerous reasons behind this situation, many of them routed in uncertainty of how well the reclaimed landscapes will perform into the future. Making the case for good long-term performance usually requires reliable performance data over years or decades. Typically such information is only available if a timely, formal monitoring program is designed and implemented at the mine.
In an ideal world, the landform design and OMM plan would be developed in tandem, and monitoring would start the start of mine operations. In practice planning for the OMM stage is generally overlooked until long after reclamation is complete. The OMM program and a manual are an afterthought, and the program can suffer from lack of budget, motivation, sometimes from lack of access to the site.

Thus, there is a major opportunity to develop and implement the OMM plan in a timely manner to help prove to the company, stakeholders, and regulators that the investment in reclamation is being protected, the reclaimed landscape is performing as intended, that reclamation technologies are working, and that the land is on a trajectory to successful relinquishment.

**A NEW WAY FORWARD**

As an initial attempt to solve this problem, we propose that writing the OMM manual in a conceptual form during the design stage could help with being more successful in the later OMM stage and ultimately achieving the landform goals, with the documentation to demonstrate it. Planning for OMM during the design stage will encourage the project team to think about how to fit in the final steps of landform design into the overall project. Developing the OMM plan concurrently with design will also boost the importance of these vital steps in the minds of the designers and operators.

There are some examples of mines that have adopted a take on this approach, and are having success with it. These mines are ahead on the road to relinquishment. Adopting some of their ideas and processes could help bring the industry forward to a place where the OMM steps are not left to the end of construction, could save time and money, and could streamline the relinquishment process.

Specifically, it is proposed that mines develop an OMM Manual as part of the landform design, prior to construction of each landform. The manual would be developed in consultation with regulators and stakeholders, and be updated periodically as new information becomes available. The monitoring is focused on helping to ensure that the reclaimed landscape is on a trajectory towards relinquishment. Care is taken to make the OMM program sustainable within the corporate environment: that it is useful, can be carried out efficiently, has corporate support, and is supported by a good data management program. Ideally the mining landforms and landscapes are designed to be easy to monitor and maintain, and that there is a process to take learnings from the OMM program and use them to adapt future landform design and reclamation activities on the site as part of an overall adaptive management program (e.g. Holling 1978; CEMA 2012).

**DEVELOPING DESIGN AND OMM PLANS IN TANDEM**

Ideally, landform designs are done prior to construction, and updated as needed through the construction, regrading, and reclamation process. Often, formal design waits until the landform is largely constructed. Either way, the design includes documentation of design goals and usually includes a description of potential failure modes as part of an engineering risk assessment. As part of engineering risk management, the monitoring plan is developed. The OMM provides the information to assess the landscape performance against these goals and indicates when and where any intervention is needed.
The level of required monitoring may vary considerably based on the goals. For example, a reclaimed landform built with the goal of obtaining research information (e.g. an instrumented watershed for reclamation research) will require significant data collection over a number of years and a high level of monitoring (e.g. Daly et al 2010). Similarly, wetland establishment on reclaimed land may initially require daily or weekly adjustment of water levels or ongoing short-term control of invasive plants (CEMA in preparation). At the other end of the scale, an upland area may only require minimal OMM – perhaps limited to a brief annual visual inspection and a final vegetation surveys.

Figure 1. Developing design and OMM plans in tandem

EXAMPLE OMM PLANNING FOR WETLANDS AND UPLANDS

There are a few notable examples of companies that are benefitting from OMM planning early in the landform design phase. Teams working on the constructed fens at Syncrude Canada and Suncor Energy oil sands operations both had OMM plans in mind from the beginning (Pollard et al. 2012). The main goal of both fens was to gain knowledge about construction and performance of reclaimed wetlands, so monitoring began early (even before reclamation), and the data were analyzed and used to make operational decisions at a later date. Water flow and chemistry data, weather data, records of construction and materials, photos, and satellite imagery collected during construction were invaluable in understanding the functioning of the landform and informing the future construction of fens. These fens had the goal of operating as research landforms and were therefore operated, maintained, and monitored at a much higher level of effort than a run-of-the mill reclamation landform could be. However, a lot of knowledge can be taken from these two fens and applied as needed to design, construction and operation of commercial scale reclamation landforms in the future (Pollard et al. 2012). Ultimately data from the
OMM will be used in support of an application for reclamation certification to the Alberta Government, a key step in relinquishment of reclaimed mine lands.

As part of our work in post closure and studying mines that have started to adopt parts of the early OMM development, we, with guidance from CEMA’s 2005 Landscape Design Checklist, have identified the following common areas to consider for operations and monitoring of a post closure landscape:

- Access and security
- Geotechnical stability
- Groundwater / seepage
- Surface water control – quality and quantity
- Erosion
- Vegetation
- Wildlife
- Dust / air quality
- Safety – public and on-site.

A worked example of an OMM table which can be produced during the closure design phase for surface water quantity and quality in a lowland setting and a vegetative cover in an upland setting are shown in Tables 1 and 2. We have focused on the key activities for that area, and who is responsible for what, where, and when. Developing this table at the closure design stage then sets up for the production of an OMM manual and identifies key areas where the design may need to accommodate some operational or monitoring activities.

Table 1 shows an example of a marsh that is in its first season of operation since construction was completed. Such a recently constructed landform will require the maximum amount of monitoring, maintenance, and operation effort that a landform would require, as the early stages are when most adjustments and optimizations must be made.

Table 1. Example Operation, Maintenance, and Monitoring Summary Table for a Recently Constructed Marsh

<table>
<thead>
<tr>
<th>Activity</th>
<th>Action</th>
<th>Personnel Responsible</th>
<th>Schedule (Maximum Required)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MONITORING</td>
<td>Water levels</td>
<td>Datalogger</td>
<td>Collect and analyze bi-weekly, May to October</td>
</tr>
<tr>
<td></td>
<td>Water quality</td>
<td>Grab sample</td>
<td>Collected and analyzed monthly, May to October</td>
</tr>
<tr>
<td></td>
<td>Specific research monitoring</td>
<td>As determined by researchers</td>
<td>As determined by researchers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>University Researchers and students</td>
<td></td>
</tr>
</tbody>
</table>


Table 2 shows an example OMM plan for an upland forest that was planted 8 years prior. The forest requires a minimum of monitoring, maintenance, and operation. In the forest’s first few years, it received much more attention in order to put it on the correct trajectory towards becoming an upland mixed-wood forest, and needs less attention now to keep it on that trajectory.

Table 2. Example Operation, Maintenance, and Monitoring Summary Table for an Upland Forest

<table>
<thead>
<tr>
<th>Activity</th>
<th>Action</th>
<th>Personnel Responsible</th>
<th>Schedule (Minimum Required)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MONITORING</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check coverage percentage</td>
<td>Field survey</td>
<td>Landscape Operator or other assigned personnel</td>
<td>Collected and analyzed once yearly during summer season</td>
</tr>
<tr>
<td>List of vegetative species present</td>
<td>Field Survey</td>
<td>Landscape Operator or other assigned personnel</td>
<td>Collected and analyzed once yearly during summer season</td>
</tr>
<tr>
<td>Soil Quality</td>
<td>Dig soil quality pit</td>
<td>Landscape Operator or other assigned personnel</td>
<td>Collected and analyzed once yearly during summer season</td>
</tr>
<tr>
<td>Erosion</td>
<td>Field Survey</td>
<td>Landscape Operator or other assigned personnel</td>
<td>Once yearly and after severe rain storms</td>
</tr>
<tr>
<td><strong>MAINTENANCE</strong></td>
<td>Weed control</td>
<td>Pulling weeds, applying control chemicals, etc.</td>
<td>Area owner or other assigned personnel</td>
</tr>
<tr>
<td>Maintain access</td>
<td>Repair boardwalk/walkway</td>
<td>Area owner or other assigned personnel</td>
<td>As needed</td>
</tr>
<tr>
<td><strong>MAINTENANCE</strong></td>
<td>Repairing outlets</td>
<td>Fix any beaver damage/damage from high flow events etc.</td>
<td>Area owner or other assigned personnel</td>
</tr>
<tr>
<td><strong>OPERATION</strong></td>
<td>Maintain Water Balance</td>
<td>Adjust stop logs and pumping activity</td>
<td>Landscape Operator or other assigned personnel</td>
</tr>
<tr>
<td>Protection from wildlife</td>
<td>Add fences to keep wildlife out, wrap base of seedlings, etc.</td>
<td>Area owner or other assigned personnel</td>
<td>As needed</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------------------------------------------------------</td>
<td>---------------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td><strong>OPERATION</strong></td>
<td><strong>Maintain vegetative cover</strong></td>
<td><strong>Seed and plant</strong></td>
<td><strong>Re-seed or plant if needed as shown by monitoring</strong></td>
</tr>
<tr>
<td>Prevent erosion</td>
<td>Add erosion mats or other means to prevent erosion</td>
<td>Landscape Operator or other assigned personnel</td>
<td>As needed according to monitoring</td>
</tr>
</tbody>
</table>

**LESSONS LEARNED DURING THE OMM PHASE**

To conclude, we present some key lessons learned from various mining projects during the OMM phase which may benefit future projects:

- An OMM Manual for a post closure landscape is similar to that of any operating facility such as a tailings facility, which are commonplace in the industry. (Crossely et al. 2011).
- Methods to heighten the chance of the landform’s success in operations include:
  - Operations and maintenance team should work together with the construction team, and have some involvement at the design and construction stage to see that achievable operation goals are clearly set (McKenna 2002).
  - Including in the design contracts and budget that operation and maintenance visits will be required.
  - Assigning a dedicated monitoring team with clear goals, procedures and data recording responsibilities.
  - Keeping naming conventions consistent throughout the entire design, construction, and operation process. When giving names to different areas or sampling spots within the project site (for example, BH19 or South Outlet), set the names in the design and do not change or duplicate them throughout the process.
- Once construction has been completed, our experience is that fixes to the site are more difficult than anticipated, even for a relatively simple issue.
  - For example, if more material is needed after construction is completed, site and material access can become major barriers.
  - If larger fixes are required, such as retro-fitting pipes or pumps or re-contouring, there is a risk that some of the reclamation that has been completed will have to be destroyed in order for equipment to re-enter the site and carry out the fixes.
  - It is more efficient time-wise and budget-wise to ensure that if these types of fixes may be required, access is maintained and it is planned for during the construction process. Access can be designed to be easily reclaimed in the future when no longer needed.
- A date to cease monitoring must be chosen based on the type of landform and its goals and should be included within the design and conceptual OMM process. Monitoring typically will decrease with time and cease at relinquishment unless the new custodian wishes to do long-term monitoring in support of a regional adaptive management program.
• Data from monitoring must be mindfully managed to ensure that once it is collected, it is being analyzed and used as the basis for operation and maintenance decisions. The data should be analyzed on a schedule so the real conclusion about the landform can be developed and management decisions made. For example, if data analysis for a landscape shows poor water quality, but no action has been carried out to assess the problems and mitigate them, it is likely that this condition will continue to worsen.

• Data and data management are important aspects of operations, monitoring, and maintenance, and some specific data lessons learned include:
  o Data collection and analysis should be undertaken early in the design phase to make adaptive management decisions.
  o Data should be recorded in an organized, project-specific, easy to navigate database.
  o The database should be backed up in another location.
  o Specific people or groups should be assigned specific tasks and methods documented for consistency.

NEW INNOVATIONS

There are numerous tools and emerging technologies available to enhance monitoring capabilities. Along with the current state of practice monitoring, such as water quality and level monitoring, soil surveys, vegetation surveys, wildlife surveys, etc., some recent innovative examples that have proved useful on constructed closure landforms include:

• Static cameras
• Video cameras with remote feed
• Multispectral satellite and aircraft mounted imagery
• LiDAR survey and radar satellite imagery for settlement
• Instruments and gauges – remote feed, manual visits.

These innovations may allow less expensive, more expansive data collection that is easy to organize. Development of methods of remote monitoring of reclaimed mine sites lags behind some other uses of these technologies.

Other bright lights in the industry where new innovations are being used for OMM are:

• Dominion Diamond Corporation/Rio Tinto Grizzly bear monitoring in the NWT, where bear hair samples are collected and submitted for DNA analysis to build up a database to follow bear population over time (MAC 2014).
• Vale’s Voisey’s Bay operation in Newfoundland and Labrador, where they track water quality data in real-time and the data is available to the public (Yukon Government 2012).
Figure 2. New Innovations in Landscape Monitoring

It is likely in the future that there will be less of a “boots on the ground” approach, and more use of remote sensing (although the importance of field visits must not be forgotten). Though the use of drones to collect information has not yet been tested, there is room for such innovation in the future. All of these new possible technologies still require good data management to be effective.

CONCLUSION

The benefits of developing an OMM manual in tandem with the construction design will reduce the risk of retro-fitting, fixes post-construction, access and accessibility issues, etc. Developing an OMM plan and doing so early in design will benefit mines on the path to closure and relinquishment by saving money, frustration, and time, and levels of effort. The operations, maintenance, and monitoring phases of a landform reclamation project carry just as much importance as the earlier steps of reclamation, and cannot be ignored until the last minute.

REFERENCES


