MINE CLOSURE AND DECOMMISSIONING

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ABSTRACT

With society's increasing understanding and awareness of the fragile nature of our environment, attention to and scrutiny of mining operations is understandable and warranted. The realization of the potential long-term impacts and effects resulting primarily from the wastes generated during a mine's operation focuses attention not only on the mine operation itself but particularly on the post-mining legacy.

This paper presents and discusses issues, schedules and costs of the closure and decommissioning program and draws particularly on the experience of Rio Algom Limited in the recent closure of several uranium mines in Elliot Lake, Canada.

INTRODUCTION

As with most activities, mining operations normally have a well-defined life, from exploration and discovery, through permitting, development, operation to eventual closure.

Mining operations tend to be short-lived, average twenty years and the mining life cycle has been well understood and accepted as a natural consequence of extracting a valued mineral from a finite orebody. Historically mining companies came and went and mines opened and closed without attracting a great deal of attention.

However, over the past twenty years, as society's expectations and environmental awareness have increased, the whole life cycle of mining has been subjected to increasing levels of attention and scrutiny.

This attention resulting primarily from the realization of the potential harmful effects of mining operation's discharges in both the short and long term together with the often significant social impacts of such operations on the immediate and broader communities.

Today, all phases of a mine's life received a high level of attention and review, with a great deal of the focus on the tail-end of the process, namely mine closure, decommissioning and long-term care.

POST-OPERATIONAL REQUIREMENTS

This paper addresses the process, programs, issues, schedule and costs of this 'tail-end' phase of mining.

The overall schedule/timeline of the typical mining operation of today can be considered as five principal mine-life phases, namely:

1. Exploration and discovery. Often this early activity will take several years, perhaps on average ten years.

2. Exploitation. This is the period where the discovery becomes a mine and takes in feasibility studies, financing, planning, design, permitting and then construction. Again a lengthy period of up to ten years.

3. Mining operations. The real mining activity occupies a relatively short period between the pre-mining and post-mining activities. An average mine life can be considered as twenty years.

4. Closure and decommissioning. This phase encompasses the decommissioning permitting requirements, environmental assessment process, actual site reclamation and performance demonstration and will possibly take the same length of time as the mining operation phase, i.e., fifteen to twenty years.

5. Long-term care. When the site is fully reclaimed, stable and self-sustaining, there will still be a need for some level of maintenance, care and monitoring. This need will likely last for 10s, 100s or even 1000s of years.

Hence, in the overall life span and period of potential impact of the mining activity, the actual mine operation occupies a relatively short period, while the tail-end/post operational phases (4 and 5) are of a much longer duration.
When considering mine operations, it is quickly apparent that, as opposed to a short term activity designed to generate certain valuable minerals, in fact mines are actually much more generators of large quantities of long-lasting wastes, perhaps in quantities exceeding the recovered minerals by 100 times, or more! Also, the waste does not go away but has to be managed for the long term.

The process, activities and social impacts related to mine closure and decommissioning are long lasting and demanding, necessitating considerable technical effort together with a high level of social conscience and understanding both of which translate to potential areas of risk and high costs.

The above three points are considered significant and critical, identifying the true importance to a mining project's fundamental viability of proper management of this 'post-closure' phase.

THE CLOSURE

The overall process of mine closure can be considered in the following six stages:

1. Closure decision. At some point, a decision is made to cease operations and close the operation. The decision is based on either exhaustion of the orebody or changing market conditions which make the operation no longer economic or a combination of both.

2. Plan preparation and submission. Although a preliminary closure plan will likely have been prepared early in the mine operation, as the possible closure date approaches, additional efforts will be needed to review and reconsider it and this effort will further increase once a closure decision has been made.

Once prepared, the plan must be submitted for regulatory and public approval.

3. Plan review and approval. Once submitted, there follows a period of review, discussion, communication and revision of the plan. This phase may be long but will eventually lead to acceptance and approval of a plan and authorization to proceed.

4. Decommissioning. Actual decommissioning activities will be required once plan approval is obtained. These activities will address facilities and issues related to each of the three areas of the mine operation, namely underground workings or pit, surface administration, servicing and processing facilities and lastly, waste management.

The objectives throughout are to assure, as a minimum, long-term public safety and health together with no significant adverse environmental impacts.

5. Transition phase. On completion of the decommissioning activities, there will follow a period of active management of the site and remaining facilities to achieve a condition of a stable, self-sustaining site requiring a minimum of active operation. This phase necessitates a high degree of monitoring and reporting to demonstrate plan achievement and compliance.

6. Long-term care. It is expected that even after plan achievement has been successfully demonstrated, the remaining facilities will need some level of ongoing care.

ELLIOIT LAKE: A CASE STUDY

Over the past fifteen years, Rio Algom Limited (a Canadian mining company based in Toronto, Canada) has undertaken an extensive and high profile mine reclamation program as it permanently closed, decommissioned and reclaimed nine uranium mine properties in the vicinity of the small community of Elliot Lake. This experience is used to provide actual data on process, schedule, costs and issues related to this important phase of the mine life-cycle.

Operational History: An Overview

Following WWII, there was suddenly a demand for uranium, a mineral previously of little interest or value. As a result, intensive exploration for the radioactive element in North America commenced to meet perceived needs for western security and defense. Many deposits were discovered but possibly the largest was one found just north of Lake Huron in Ontario, Canada in the early 1950s.

In the short years of 1953 to 1959, some twelve underground mines were established and brought into production, each with a production capacity of between 3 and 7000 tons per day. The area at the time of the discovery was rugged and unpopulated and to meet the needs of the mines for workers, a new town was built in the bush, to accommodate some 25,000 people.

Over the past 45+ years, the mining cycle has twice gone from rapid expansion and development to closure and cut-backs. Most recently, as a consequence of several market factors in the 1980s such as the discovery of new, rich uranium deposits around the
world, a reduction in power demand from industry generally and an influx of previously unavailable supplies from the former Soviet block countries, the Elliot Lake mines, though modern and efficient, were unable to compete for new contracts due to the low grade/high cost of their product. This situation led to the closure of all the mines in the area by 1996.

The Mines

The extensive ore body supporting the initial twelve mines comprised a meta-sedimentary, quartzite conglomerate deposit containing on average, 0.1% uranium oxide (ie, 2 lb/ton) and sulphides of 7 to 8%, some 10 to 15 feet thick folded into a syncline and anticline. Mining was underground at depths of 1 to 4,000 feet, accessed by mine shafts. Mining was principally trackless. Primary crushing to -6 " was carried out underground.

Most mines incorporated their own surface processing facilities. The final product, yellowcake (U3O8) was shipped to other facilities for further enrichment.

The waste from the mines comprised almost exclusively tailings which were pumped to the mine's own tailings pond situated close to the operation.

The tailings ponds were generally sited in a natural rock controlled valley with the basin capacity increased through the construction of engineered dams at low points on the basin perimeter. Discharge from the ponds was treated, primarily through the use of lime slurry for pH control.

The largest tailings pond contains some 45 m tonnes of tailings, stored at depths of up to 90 feet (30 m), has an area of 450 acres (200 Ha) with 8 perimeter containment dams, height to 80 feet (25 m).

Mine Operations and Closure: Summary Schedule

1950s: Orebody discovery. Mine development and operations (nine Rio Algom mines). City population 25,000+.

1960s: Drop in demand, mine closures. Rio Algom keeps one mine operational. All other properties retained. City population drops to 6000.

1970s: Renewed interest in uranium for nuclear power generation. New contracts obtained, two mines reopened, operating mines expand. City population rises to 18,000+.

1980s: Rio Algom operates three mines for whole decade. Early realization that mines unlikely to be able to compete on open market, post 1980s. Preparation commences for mine closures and decommissioning. Regulators draft legislation addressing mine closure.

1989: Rio Algom makes decision to close two of its mines within one year.

1990: Rio Algom shuts down two mines. Lays-off 1,500 workers. Prepares and submits applications to undertake mine decommissioning in accordance with new legislation. Public information programs established.

1992: Following two years of discussion and review of plans by regulators, government decides the project warrants a full independent public review. Three member panel appointed.

1992-1996: Public review process proceeds. Rio Algom commences site decommissioning pending government approvals. Rio Algom initiates program to finalize site reclamation for the several (six) historical mines that it still owns and manages in accordance with current-day standards.

1996: Public Review Panel submits its report and recommendations to government; conclusions are generally supportive of Rio Algom's plans. Rio Algom closes last operating mine in Elliot Lake and commences public and government review and approval process for its decommissioning. Government gives approval to the decommissioning plans submitted for the two mines closed in 1990. Government gives approval to the decommissioning plans for the last operating mines, closed in 1996.

1997: Rio Algom initiates process to place the historical properties under a government licence similar to that obtained for the recently operating mines.

2000: Substantial completion achieved in decommissioning all nine mining properties in Elliot Lake. Efforts now focus on transition phase issues and long-term management.

Particular Issues

Elliot Lake had an interesting and possibly unique position in the recent history of mine closure for several reasons.

Firstly, during the 1980s industry and government focussed attention on methods and technologies for long-term, environmentally responsible management of mine wastes. The Elliot Lake area was particularly
challenging as their ore and wastes contained both radioactive elements and acid bearing sulphide minerals. This at a time when there was little precedence in implementation of either of these technologies.

Secondly, although the principle federal regulator for the uranium mine operations and their closure was well defined, it was quickly apparent that there were several other federal agencies with possible interests or mandate together with provincial agencies who were the principle regulators for all base-metal mines. How to accommodate, provide input from and respond to all these agencies was another issue to be addressed.

Thirdly, the final closure of the four recently operating mines would lead to layoffs of over 2,500 mine employees with possibly an equal number of indirect positions within the community. The sole reason for the city's existence had been mining which would suddenly come to an end. The social and economic impacts of the mine closures would be significant on a national scale.

Lastly, with the anticipation of long-term site needs and ongoing costs, regulations were being formulated requiring mining companies to accept all responsibility for their sites and make adequate financial provision to do this. This relatively new expectation necessitated careful and detailed consideration of all possible site needs and the development of the plans to accomplish these ongoing responsibilities. Site monitoring, reporting and compliance achievement comprised fundamental needs going forward.

In finalizing the plans for closure management of the tailings, advantage was taken of the experience and research going on worldwide, particularly in Canada with respect to acid-generating materials. Where practical within existing site restraints, it was decided to decommission (permanently manage) the tailings which were deposited in natural, bedrock controlled valleys under a water cover. Engineered, low permeability dams were constructed where necessary on the basin perimeter to meet the storage volume needs. Water cover was a viable solution in this low populated region of Canada as a result of it's topographic, geological and climatic conditions.

This solution ensured long-term stable containment of the material and the water cover provided not only a level of shielding from radiation, but more importantly, virtually eliminated any further oxidation and therefore, acid generation of the wastes. Also, it was expected that soon after flooding of the tailings areas, excess surface water would be able to be discharged without treatment as it would naturally meet discharge criteria. As a result, four recently operating storage areas, containing some 80 M tonnes (80%) in total of radioactive and acid-generating tailings were decommissioned in this way.

Three historic tailings areas which had been inactive for 30+ years were sited in locations which were impractical or would not support a water-cover closure solution. For these areas, containing in total some 20 mT of material, stable containment would be assured through a combination of natural topography and the construction of engineered dams. Surface stabilization of the tailings would be provided through self-sustaining vegetation cover either directly on the tailings or through the provision of a cover and growing medium. In these three cases however, long-term effluent treatment will be necessary until natural stabilization of the site occurs.

How to sensibly and rationally deal with the many regulatory agencies with potential mandates for the closure work proposed was very satisfactorily resolved through the initiative of the principle regulator with support of the other agencies and the company. A 'one-window' approach was initiated where all requirements and issues would be addressed to and through the principle regulator whilst at the same time, copies of any and all correspondence and documentation was issued to each of the other agencies. In this way, a Joint Review Group (JRG) was established comprising representatives of each agency with interest or mandate in the closure programs being proposed and undertaken. This formally recognized group undertook to review and present comments on the plans prepared by Rio Algom to the lead agency who in turn would consolidate and rationalize them before forwarding them to Rio Algom. The JRG would equally participate in all meetings, site tours, presentations and progress reviews. The effectiveness and viability of the JRG approach improved with time as each of the representatives obtained comfort and confidence that all issues would be addressed satisfactorily in this way.

The social and economic impacts of the mine closures would obviously be severe and significant and were recognized as a major issue to be managed at a very early stage in the process. The mining company put in place wide-ranging programs designed to either assist employees obtain alternative employment or provide them with early retirement options. Programs included retraining, certification, career counseling, résumé and interview skills, job search and follow-up, family counseling, financial planning, etc. These programs were jointly funded by the company and government and were generally seen as successful.

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To assist the community address the significant adverse economic impacts of the mine closures, again the government and mining company combined to develop programs which would ease the community through the difficult transition phase from a mining community to possibly provide an alternative strategy for assuring the future viability of the city. Through the provision of significant funding from the government and the early establishment of a program to market Elliot Lake as a ‘retirement living’ community by the mining company, the city has survived and is in a stable situation with over 14,000 residents today, perhaps 50% of these, new to the city since mining ceased.

And lastly, as a result of the timing of the Elliot Lake mining closures being at the lead-end of the recent interest by society in this inevitable consequence of mining, Rio Algom has had to consider and develop a policy to address the many and varied issues related to how their closed mines in Elliot Lake, and mines in general, will be operated, and managed, retaining responsibility for the ongoing needs of the non-operational sites after the mines have closed. This entails decisions on company site organization, in-house and contract work scope, relationships with community and government, financial assurance issues, long-term land management and the roles of the company, community and society going forward.

Next, we should consider in some detail the several aspects and phases of a mine closure program with particular reference to cost and timeframe.

### Plan Preparation and Approvals

For the Rio Algom, Elliot Lake case, plan preparation commenced in the early 1980s and continued for about ten years. The plan addressed all aspects of the mine facility and site from underground operations to effluent treatment, asset disposal to tailings management. As in all such circumstances, some level of environmental assessment is now required. The initial plan and decommissioning application submission, prepared with the assistance of several reputable consultants and comprising a large quantity of studies and documents was issued to the government for review in 1990/1991. There followed a six year review which included an independent public review panel and public hearings leading to the eventual approval of the plan in 1997.

This aspect of the closure program is long and costly, representing up to 15% of the total decommissioning budget.

### Decommissioning

The actual site activities required to implement the approved decommissioning plan must address each aspect of the particular mine facility. For Elliot Lake, these included the underground workings, surface structures and facilities and tailings management.

In our case, the underground workings were cleaned to ensure any and all potentially hazardous materials (eg, oils and greases, explosives, paints and solvents, chemicals, garbage, etc.) were collected and brought to surface for proper disposal. At the same time, potential assets (mobile and stationary equipment, pumps, electrical switchgear, voltage equipment, etc.) were identified, cleaned and hoisted to surface.

As no alternative future use could be identified for any of the surface facilities, these were dismantled or demolished and disposed of, openings to underground were permanently sealed, the whole site was cleaned, regraded and revegetated.

In the tailings areas, additional containment dams were built, as necessary, or raised; tailings were relocated also where necessary; and precipitation was impounded to achieve the flooded configuration selected in the plan.

These direct decommissioning works are capital intensive and were executed by experienced and competent contractors quickly (two or three years).

These direct activities will likely account in total for 30 to 40% of the decommissioning budget, with,

- 5% for underground evacuation and shaft closure
- 10% for site demolition and site rehabilitation
- 20% for tailings management
- 35% in total

### Transition Phase/Ongoing Costs

During and following the decommissioning activities, the site and remaining facilities need ongoing care, maintenance, some level of operation together with monitoring and reporting. Also, other costs continue to be incurred related to licensing fees, taxes, insurances.

This termination phase will likely last over ten years before it is possible to demonstrate to all stakeholders satisfaction that the plan has been fully and satisfactorily executed. This is the case in Elliot Lake where a transition phase of ten to fifteen years following full implementation of the plan is anticipated.
As a result, there are considerable costs to this phase of the closure program, possibly 50% of the total decommissioning budget.

Long-term Care

Beyond the transition phase, although there will be some level of site care, maintenance and monitoring required, the extent of intervention is likely to be substantially reduced. As a result, the annual cost of such care and maintenance is expected to be low, but ongoing. How this care will be provided and financed will likely vary from site to site but the cost must not be neglected in preparing the overall closure budget.

CONCLUSIONS

The experience gained through the mine closures of Elliot Lake has been substantial and provides a useful reference for similar work elsewhere.

The lessons learned are many and include:

• Expect the closure process to be long. This gives rise to issues of continuity and knowledge transfer for the mining company and regulators.

• A detailed and comprehensive closure plan should be established early in the mine which should clearly define end land-use plans and acceptance criteria. Review and approval by all regulators and stakeholders is needed.

• Progressive rehabilitation will always prove worthwhile and cost effective.

• Establish (actively) good public relations throughout the operating period and maintain this during the closure program.

• Work with the regulators.

• Keep informed on industry developments, standards and expectations.

• Plan your closure team carefully and provide the necessary incentive packages to keep the key people.

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