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Monitoring after mine remediation – planning considerations and lessons learned in northern Canada

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Abstract

As most mines leave waste deposited on site, there is a need to monitor the mine site long after mine closure. Through remediating a number of abandoned mine sites in the Northwest Territories, Canada, the Northern Contaminated Sites Programme has identified some key considerations and lessons learned for planning mine closure and monitoring. The most important consideration is to scope out monitoring requirements at the remediation planning stage, alongside developing remediation objectives for each mine site component and/or waste stream. This ensures: a better evaluation of remedial options; expectations of regulators and stakeholders are managed properly; and risks and liabilities are identified and mitigated appropriately. This also helps to define a monitoring end point. This paper also discusses other lessons learned and monitoring considerations such as defining the main drivers for short and long-term monitoring, considerations for scope and frequency of monitoring, and other considerations such as health and safety and site infrastructure, third party factors, adaptive management, and documentation and institutional controls.

1 Introduction

At the early stages of a mine, there is now a lot of focus placed on mine closure planning and reclamation/remediation. However, it is often not until remediation is near completion that full scoping and consideration of post-closure monitoring requirements are analysed. This can be a risky management decision as there will likely be challenges in residual risk acceptance by stakeholders, especially land managers/owners as well as local communities/Aboriginal groups. Their expectations need to be identified early in the process, addressed in developing objectives in the remediation planning stage, and managed throughout the life of a mine to ensure final acceptance of the completed remediation.

The monitoring considerations and lessons learned discussed in this paper have stemmed mostly from Indian and Northern Affairs Canada's (INAC's) Northwest Territories (NWT) Contaminants and Remediation Directorate (CARD). CARD is currently managing over 30 contaminated sites in the NWT, at various stages of remediation. There are five remediated mines of which four are in long-term monitoring and one only has a short-term monitoring component. There are also two mines in Nunavut and three in the Yukon that are also in long-term monitoring that were considered in developing this paper. Many of these sites became the Government of Canada's responsibility after private owners relinquished their properties according to the legislation of the day, or when companies went bankrupt. The properties then reverted to the Crown, and as representative of the Crown, INAC became custodian of these properties and related remediation activities.

The Government of Canada recognises that not only is it important to remediate federal contaminated sites, it is also necessary to prevent them from occurring in the future. Today, there is a suite of legislation and policies protecting the North, committing to pollution prevention and the "polluter pays" principle. This ensures that new mining operations do not leave a legacy of environmental and human health hazards or a financial liability for the Canadian taxpayer.

For the most up-to-date information on contaminated sites in the NWT, including some of the case studies reference, please visit the following website: http://www.ainc-inac.gc.ca/ai/scr/nt/cnt/index-eng.asp.

2 Main drivers for long-term monitoring

The main driver for long-term monitoring requirements is legal/regulatory requirements. These are often a combination of national and provincial/territorial acts and regulations; however there are guidelines or protocols that are often relevant as well. These drivers are not usually very prescriptive in terms of requirements but more performance based, such as preventing impacts to fish and fish habitat, protecting a certain water source, minimising impacts to wildlife etc., with the expectation that the monitoring plan will determine how best to reach those objectives.

For the Northwest Territories of Canada, the most relevant legal/regulatory requirements could include, but are not limited to; NWT Waters Act and Regulations, Mackenzie Valley Resource Management Act and Regulations, Arctic Pollution and Prevention Act, NWT Mine Health and Safety Act, Fisheries Act, Canadian Environmental Protection Act, and other acts depending on the type of mine involved such as the Metal Mining Effluent Regulations, or Nuclear Safety and Control Act. There might be other requirements addressed in the appropriate Comprehensive Land Claim Agreement (CLCA) or through cooperation agreements with Aboriginal governments or claimant groups.

There is a large variety of other information sources that would be relevant to determining long-term monitoring requirements or best practices for a site in Canada. Some of these include, but are not limited to:

- Mine Environment Neutral Drainage Programme through Natural Resources Canada (MEND, 2011); the Mining Association of Canada, if there are acid rock drainage or acid generating tailings issues.
- National Orphaned/Abandoned Mines Initiative for best practices on addressing abandoned mines (NAOMI, 2010).
- Dam Safety Association – Dam Safety Guidelines (CDA, 2007) - if dams remain on site post-remediation.
- Mining Association of Canada for best practices in operating mines (MAC, 2011).

For further information, the associated website links are included in the reference section.

Other policies and directions for abandoned mine sites in the NWT include, but are not limited to:

- INAC Mine Site Reclamation Policy (INAC, 2002) – includes long-term monitoring considerations for each site component.
- INAC Mine Site Reclamation Guidelines for the Northwest Territories.

For federal contaminated sites (mines or otherwise), a federal approach to Contaminated Sites (CSMWG, 1999) documents the process to assess and prioritise contaminated sites. Long-term monitoring is listed as the last step in the recognised 10-step process as shown in Table 1.

Table 1 The 10 step process through the federal contaminated sites action plan (FCSAP) as per the federal approach to contaminated sites

Step 1	Identify suspect sites	Step 6	Reclassify the site using Canadian Council of Ministers of the Environment (CCME) national classification system
Step 2	Historical review	Step 7	Develop remediation/risk management strategy
Step 3	Initial testing programme	Step 8	Implement remediation/risk management strategy
Step 4	Classify contaminated site using the CCME national classification system	Step 9	Confirmatory sampling and final reporting
Step 5	Detailed testing programme	Step 10	Long-term monitoring - if required, ensures remediation and long-term risk-management goals are achieved

The underlying driver for all of these monitoring requirements is to manage the residual risks on site after remediation has been completed. Remediation plans for mine sites are site-specific and therefore no set protocol can be established for all sites. Rather, guidance for certain site components or elements is applicable.

3 Planning for a monitoring end point

Once the regulatory and policy requirements are understood, then a monitoring plan can be scoped and developed with greater certainty. However, from the experience gained at several sites in the NWT, it is recommended that this be done in conjunction with the development of a Remediation Plan.

Setting remediation objectives for each site component (such as waste rock piles, tailings containment areas, waste disposal facilities, roads, borrow areas, etc.) is key to developing a good remediation plan, but also to help set the final monitoring endpoint. If a remediation objective is quantifiable or clearly defined, then it is easier to determine whether that objective is met, and therefore monitoring that site component should no longer be required. It is also important to clearly define each site component so there is a shared understanding with regulators and other stakeholders of what each component or bundled components encompass, and what is outside of the scope defined. Otherwise, during final implementation of the remediation plan, there is a risk of scope creep or drift.

Rather than planning for remediation, projects should be planning for final site closure. If the expectation is that the residual liabilities will be taken over by third party or the land owner (if leasing), then defining final acceptance criteria is crucial in the planning stages of the project. These are often left to the end of a project when sign-off is requested, which leaves little opportunity to modify the work competed to meet these criteria. If the residual liability continues to rest with the custodian of the site, then this is also important to clearly identify up front as this would affect which remediation options are best suited to the situation.

If the remediation options analysis suggests leaving a certain waste in place or risk managing certain site aspects, then the full cost accounting of doing so should be compared to the cost of a more complete liability reduction. Some of the cost considerations to address the residual risk/liability include, but are not limited to, costs associated with: accessing the site (especially for remote sites), monitoring, operations and maintenance, communication, community engagement, reporting, retaining liability, programme overhead etc. Some monitoring set-up costs that are often overlooked include surveying costs, including setting up permanent survey marker(s), as well as instrumentation installation during remediation phase and maintenance into the long-term. There are also costs to decommission any monitoring instrumentation or wells at the end of the monitoring phase.

If this full cost evaluation of remediation options is completed up front, then for smaller remote mine sites or advanced exploration sites, a different remediation option might be more cost effective and/or selected in the remediation planning stages. A small incremental cost of fully addressing the site liability could in some cases be easily offset by programme cost savings in the longer term. Examples of options that might warrant this type of further analysis include shipping certain materials off-site for disposal versus landfilling on site; installing permanent seals for mine openings versus more temporary seals; and consolidating waste across several sites into one landfill or waste disposal area versus having multiple waste facilities to manage.

From our experience, the selection of remediation options needs to involve the most affected stakeholders of the project. In the North, this includes Aboriginal groups and/or governments as well as the communities most affected by the original mining operation. Stakeholders need to be heard and have their concerns validated in the planning stages of a project, or they will not accept that the site is remediated even when it meets policy and regulatory requirements for a remediated site. This is a situation INAC faces for the case of Rayrock Mine, a remediated uranium mine as described in Case Study 1 below. This was the first mine site remediated in the territory under INAC’s custodianship and has therefore provided numerous lessons learned which have helped to inform future projects as well as the overall Contaminated Sites Programme.

Case Study 1: Rayrock Mine

Rayrock Mine was an underground uranium mine operated from 1957 to 1959, and located 74 km northwest of Behchoko, accessible by winter road and aircraft. During operations at Rayrock Mine, approximately 70,000 tonnes of ore were processed, yielding 207 tonnes of uranium concentrate. Radioactive tailings were deposited on land and partly flowed into three small lakes. In 1959, two tailings basins contained

70,903 tonnes of radioactive tailings that had the potential to leach materials. The mine was also a potential source of radioactivity, through radon gas emissions from mine openings and ventilation shafts.

The site was remediated in 1996 and 1997, following several site assessments. This included sealing all mine openings and ventilation shafts, relocating radioactive material from the dump to the tailings piles and capping the tailings with a thick layer of silt-clay, followed by re-vegetation. Since then, the site has been monitored annually as part of the long-term monitoring programme, generally performing well, with minor maintenance being carried out as required.

In the mid 1990s the current concepts of consultation were not widely understood, or interpreted through Section 35 of the Constitution Act and other court cases, and therefore the remediation plan for the site was developed by INAC and Public Works and Government Services Canada (PWGSC) with minimal aboriginal and community engagement. This lack of early involvement on this project has led to an ongoing perceived risk that is much greater than the residual post-remediation risk. There are also some site elements that were not addressed to the satisfaction of the community that could have fed into the initial planning, rather than potentially addressing after the work has been completed, obviously at much greater cost.

4 Foundations/considerations for scope and frequency of monitoring

INAC's first remediation projects consisted mostly of the Intermediate Distant Early Warning (DEW) Line sites across the North. Building from work by the Department of National Defence (DND), INAC developed the Abandoned Military Site Remediation Protocol (AMSRP – INAC, 2009) with an associated monitoring protocol was developed, as these sites are all very similar in nature and extent of contamination. Remediation criteria within the protocol were developed using a contaminant source and pathway targeted approach, consistent with CCME's Tier 3 method (which describes how to develop clean-up criteria based on a site-specific risk assessment and management, CCME, 2008). The monitoring requirement for these sites is focussed on the engineered structures that remain, such as landfills. Although not mine sites, these protocols have set the tone in the North for stakeholder expectations of monitoring other contaminated sites such as mine sites.

Monitoring protocols for mine sites are more difficult to define, as many of the environmental issues are site-specific. Although the nature and extent of contamination are rarely the same, for some mine components a certain level of guidance is appropriate. From project experience to date, the most effective means of developing a monitoring plan for the site is to look at each site component or area of concern individually, and determine the monitoring needs at that level. Once all the components are pulled together, then some overall monitoring efficiencies as well as broader monitoring requirements can be pulled into the plan. This bottom-up approach, with subsequent top-down review, ensures that all the risks that need to be managed, are being monitored appropriately.

Special consideration needs to be made for monitoring waste rock and tailings that are potentially acid generating (PAG). The scope and timing would need to reflect the oxidation levels at time of cover, type of cover, water balance, permafrost conditions and overall neutralisation potential. Mine Environment Neutral Drainage (MEND) Programme through Natural Resources Canada (MEND, 2011) provides technical guidance on many of these PAG complex issues.

4.1 INAC mine site reclamation guidelines

The INAC Mine Site Reclamation Guidelines (INAC, 2007) were produced to support INAC's Mine Site Reclamation Policy, and are currently under review as there are plans to consolidate these with the regional regulatory boards (Mackenzie Valley Land and Water Board and regional panels) as a combined guideline. Currently, the guidelines provide a phased approach to long-term monitoring. At the end of the first five years of monitoring, for example, it is recommended that a Performance Assessment Report be completed. It is important to clearly identify to regulators and other stakeholders at what stages or time intervals all of the monitoring data will be compiled and evaluated, as a means to re-evaluate the residual environmental and human health risks at the site. This makes the decision-making process more transparent and therefore more defensible.

Beyond the phased approach, the INAC Mine Site Reclamation Guidelines also list for each mine site component, what long-term monitoring considerations should be taken into account. For example, for remediated mine openings, some long-term monitoring considerations would include, but are not limited to: physical deterioration or subsidence, discharge of mine water, use of thermisters to monitor permafrost ingression, and mine flooding levels or associated passive treatment systems.

4.2 Phased approach to decision-making on monitoring requirements

Although there are numerous guidelines associated with mine site reclamation, there is very little specific direction for long-term monitoring requirements. As such, the INAC landfill monitoring protocol for abandoned military sites as per the AMSRP described earlier is used as an example of how mine components can be broken down and analysed in terms of scope and frequency of monitoring as per Table 2. A similar protocol could be followed for a landfill at a mine site as well, and the phased approach can be used for any engineered structure such as a tailings cap, waste rock pile or other major earthworks component.

Table 2 Phased approach to landfill monitoring as per AMSRP

Monitoring Stage/Phase	Year(s)/ Frequency	Scope of Monitoring
Baseline	0	Baseline geochemical monitoring, including geochemical characterisation of soil conditions and groundwater quality adjacent to landfills.
Phase I: Confirm thermal equilibrium and physical stability	Year 1, 3, and 5 post-remediation	Landfill – visual (erosion features, settlement, seepage, vegetation stress, liner & overall cap integrity), groundwater and thermal (freezeback)
		Natural environment – including wildlife sightings and use, revegetation, as well as traditional use of the site
	Year 3 and 5	Groundwater / leachate
Phase I: Evaluation	Year 5*	Confirm thermal equilibrium achieved and landfill and area are physically stable
Phase II: Verification of equilibrium conditions	Depends on Phase I evaluation; Years 7, 10, 15, 25	Same scope as Phase I, or modified based on Phase I results
Phase II: Re-evaluation of the monitoring programme	~Year 25	To be carried out prior to initiating Phase III. It is difficult to predict beyond 25 years how world events and improvements in technology may impact monitoring requirements.
Phase III: Monitoring for long term issues	Years 25+	Monitoring for long term issues such as liner integrity, permafrost stability, and significant storm events

* Note: for Phase I, a five-year term was selected on the basis that ground-temperature thermal regimes at these sites would require three to five years to reach equilibrium. It is anticipated that, if there is settlement or erosion within the initial years following remediation, it is likely attributable to construction quality. Changes after the first three to five years are more likely attributable to changes in the site conditions (i.e. warmer temperatures, changes in surface water drainage patterns). The Phase I monitoring programme may be extended, if required.

It is important that project stakeholders are aware of a general monitoring timeline and process for determining future monitoring needs. If this is not provided early on, then the commitment to complete long-term monitoring often leads to the assumption that monitoring would be completed annually in perpetuity. This would be a costly implication, as would the alternative of ongoing risk communication to stakeholders rationalising why a different approach may be proposed. If the expectations of when all of the monitoring data will be re-evaluated and analysed are discussed early on, this will provides greater confidence in the approach and will likely lead to greater community/stakeholder support.

5 Management considerations during monitoring phase

5.1 Health and safety & site infrastructure

One of the most important considerations at remote sites like those in the NWT is determining how the monitoring activities can be carried out safely. Some of the more common health and safety hazards for these sites relate to weather issues or delays, lack of remote airstrip maintenance, limited aircraft availability, wildlife encounters and communication challenges (satellites not supporting satellite phones). There are also some residual health and safety hazards on the remediated site that we are monitoring, such as exposure to metal-contaminated soil, however, these are often minimal when compared to safely hazards associated with getting to and from the site. These hazards are present for any activity at these sites and are therefore not limited to the monitoring phase of a project. It is also important to note that such hazards may still exist even after a site has been remediated and is considered “safe”.

To understand the hazards that continue at monitoring sites, there is a need to monitor the site components that would affect the overall risk exposure or likelihood. For example, noting the overall condition of an airstrip, roads, docks or other site infrastructure, as well as looking for signs of wildlife usage (sightings, scat, etc.).

If it was determined that some equipment should remain on site to complete monitoring activities, then the condition and maintenance records would also need to be considered. For some of our sites, we maintain all-terrain vehicles (ATVs)/boats on site and occasionally fly in a mechanic, whereas on sites with easier access, we might fly in a small ATV or zodiac to ensure the equipment is safe to use. These types of decisions need to be made on a site-specific basis as each site has a unique suite of issues.

Other potential “assets” that may be left on site to support monitoring and potentially future maintenance or emergency response would include such things as storage buildings, pumps, and/or other equipment or materials. Many of these “assets”, however, create a site attractant for the general public and by doing so add to the site issues, and therefore can become a liability. A building that was left at a DEW line site for example, was quickly taken over by hunters who would leave garbage behind, windows were then smashed by vandals, and soon there were also issues of mould, making the building inhospitable. However, during a severe snow storm, this building would still be very valuable as an emergency shelter. Therefore it is critical that the risks and benefits of leaving these kinds of “assets” on site be fully evaluated (and documented!) during the remediation planning stages.

5.2 Third party factors

From our project experience to date, monitoring of site use post-remediation is also required. This includes reviews of regulatory applications for use of the site, as well as submissions to regulators etc., to ensure that any monitoring anomalies or concerns can be attributed to a remediation quality issue or whether there are new contaminant or impact sources that need to be considered.

For many abandoned mine sites in the NWT, there are often exploration companies that are interested in the mineral rights of these properties, and this likelihood is expected to increase with increased commodity prices. In some cases, this renewed interest can create complications during remediation, if the operations are concurrent or there is a limited resource on site, such as borrow materials. However, in some cases, having a third party on site has led to logistical efficiencies, especially at the monitoring phase of a project as described in Case Study 2: Discovery Mine below. In the NWT, however, how historical environmental liabilities will be addressed if a new full scale mining operation was undertaken and overlapped one of these legacy abandoned mines is yet to be determined. Unlike in Ontario or Quebec, there have been no full scale re-use of mining infrastructure, such as tailings ponds etc. However, for United Keno Hill Mine (UKHM) in the Yukon a mine operator has taken on the historical liability in exchange for being able to extract resources on the property.

Case Study 2: Discovery Mine

Discovery Mine was an abandoned gold mine located approximately 80 km northeast of Yellowknife, and operated from 1949 to 1969. At shut-down, approximately 1.1 million tonnes of acid-generating tailings containing mercury had been spread over 32 hectares of land and 3.7 hectares of lake sediment above the low water level. There was also asbestos, lead-based paint, old buildings, mine structures, unsealed mine openings and soils containing hydrocarbons on site that posed health and/or safety risks.

Phase I of remediation was completed from 1998 to 2000, with the major accomplishment being the capping of tailings with clay and rock. Phase II remediation, completed in 2008, included sealing mine openings, decommissioning all site buildings, addressing contaminated soil, stabilising the borrow pit, and removing hazardous waste. Short-term monitoring began in 2000 and has been conducted every year since to ensure conditions are improving. Results of the monitoring programme have been positive (Golder, 2011).

Third Party Factors: Part of the success of the monitoring programme is that Tyhee NWT Corp. is currently in the advanced exploration stage for its Yellowknife Gold Project immediately adjacent to the remediated site, and has been very cooperative in supporting the monitoring programme. For monitoring activities at a remote abandoned mine site such as Discovery Mine, having a camp nearby or a mechanic who can fix ATVs/boats required for monitoring purposes simplifies the logistics of planning and implementing a monitoring programme. It can also greatly reduce the health and safety risks of travelling to and from the site as there is emergency shelter when needed.

Adaptive Management: After the first phase of remediation, permafrost degradation and discharge issues arose in the borrow pit, from which the silty-clay borrow material was extracted for use in the tailings cap. Two solutions were proposed: an engineered fixed-schedule approach (rip rap armouring, wood chips etc.) or a modified natural adaptive management approach (separation dykes, interim water treatment and revegetation/stabilisation). The latter option was selected and implemented over several years at an overall 50% lower cost and with site aesthetics that are more acceptable to project stakeholders. However, it required INAC to be able to respond quickly in order to maintain water licence discharge criteria (Cassie et al., 2007).

5.3 Adaptive management

For a monitoring plan to be successful there needs to be an understanding that if the monitoring results produce results that are not expected, that further investigation and/or maintenance may be required. The ideal situation would be to have a monitoring programme where the trigger points for escalating actions levels are clearly defined. However, there are usually unforeseen events or results that could influence actions. It is therefore important to understand the failure risks for any engineering structures on site, such as a dam failure. Quantifying the risk level of this potential risk event would then help influence how early actions would need to be taken versus waiting for the next phase of monitoring plan review. It is important to be prepared to respond to emergency or high risk situations very quickly, in terms of planning, communication and notifications, as well as procurement of contractors to complete the work.

5.4 Documentation and institutional controls

For a monitoring project to be successful, all of the key relevant project documentation must be easily accessible. This would include documentation of key project decisions so that these decisions can be easily defended into the future, rather than guessing as to why a certain aspect of the site was remediated one way and another a different way.

There should also be a system in place to ensure that the remediated works such as tailings caps, waste rock covers, landfills, dams and drainage features etc. are protected. As INAC has a dual mandate of supporting mineral exploration as well as addressing abandoned mine sites, we are currently in the process of determining a land management system process by which to reserve the remediated abandoned mine property. This allows INAC to clearly identify any future site use restrictions, along with referencing a suite of associated information reports, which would inform regulators (which includes INAC as a responsible minister) to ensure this happens. As a site moves through the various phases of monitoring, there is often a large turnover in human resources and associated corporate knowledge. It is therefore not practical to assume someone who was involved in the original project will still be around when questions are raised 20 years later. Most filing systems set a lifecycle end date for each file, yet these documents need to be maintained in some cases in perpetuity. Therefore, information management systems and timelines need to reviewed and modified in order to manage key information from these long-term monitoring programmes.

6 Summary

The Northern Contaminated Sites Programme has remediated a number of mine sites in the NWT and as a result has identified some key considerations and lessons learned for planning mine closure and monitoring. The most important consideration is to scope out monitoring requirements at the remediation planning stage, alongside developing remediation objectives for each mine site component and/or waste stream with the project stakeholders, especially regulators and affected communities. This ensures: a better evaluation of remedial options; expectations of regulators and stakeholders are managed properly; and risks and liabilities are identified and mitigated appropriately. This also helps to define a monitoring end point. Other monitoring considerations were also discussed, such as scope and frequency of monitoring, health and safety and site infrastructure, third party factors, adaptive management, and documentation and institutional controls.

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