The Remediation of the Hollinger Tailings Stack – A Case Study in Government Response to a Problem

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Abstract
From 1909 to 1968, the Hollinger Mine produced over 53 millions tons of gold tailings stored in a structure referred to as the Hollinger Tailings Stack. Covering some 190 hectares, up to 25 metres deep, with over 600,000 cubic metres of ponded waters and no spillway, the stack placed at risk some 150 mobile homes located at the toe of the structure. Preliminary assessments of the structure's stability rated the site to be a high hazard. In 1992, the Ontario Ministry of Northern Development and Mines (MNDM) declared the tailings site to be abandoned and requested that the City of Timmins declare the site to be an emergency. These declarations permitted the Crown to enter the property and carry out much needed remediation work over a period of two years. This paper will present in detail the approach used by the MNDM to solve both the legal and technical problems associated with the remediation of the site. Geotechnical analyses and hydrologic modeling results are discussed as well as construction and revegetation techniques used by the contractors. In 1996 and 2000, policy and regulations were amended to enable the Crown to be better equipped to deal with such emergencies and to prevent similar problems from re-occurring in the future.

Keywords: Hollinger Mine, gold tailings reclamation, physical stability assessment, mine hazard, public safety

Introduction

In the spring of 1990, an unattended tailings dam in northern Ontario failed, taking out a section of a provincial highway and costing the Province several million dollars to repair and rehabilitate the area. The Matachewan incident heightened the interest of the Crown and resulted in the commissioning of a province-wide study in late 1990 of the risks and potential liabilities associated with unattended tailings sites (Golder, 1991). The Hollinger site, located in the City of Timmins, in the province of Ontario, Canada, was identified as part of this effort. Follow-up inspection work completed in the summer of 1991 confirmed the hazardous potential of the site.

The slopes of the stack were showing severe erosional scars in a number of areas. As well, the high phreatic line, constantly recharged by the large ponds on top of the stack, was causing the toe of the slope to erode, undercutting the slope and causing the surface to slump further and migrate towards the crest of the stack (see Figure 1).

Figure 1 – Severe slope erosion and sloughage

To complicate matters further, the stack had no water discharge structure resulting in the impoundment of approximately 600,000 m^3 of water in five large ponds. In several areas, the edge of the ponds was creeping towards the crest increasing the risk that the ponds would eventually overflow the crest, releasing large quantities of water and tailings into the surrounding environment.

At risk from such an event was a residential trailer park, shown on Figure 2, located immediately at the toe of the 20 to 25 metres tall stack. There were no doubts that a failure towards the trailer park would have disastrous consequences. This realization forced the Province to assess further the situation with a view of solving this problem as quickly as possible.

Figure 2 – Aerial view of stack and trailer park

Site Ownership

Under the Mining Act (Ontario, 1990), the Crown is authorized to enter any mining premise for the purpose of carrying out an inspection to verify compliance with the Mining Act and its regulations. If a problem is observed, the Ministry will usually attempt to work with the owner of the property if known. In this case, the owner was not known and a title search was initiated in September of 1991. Unfortunately, the search revealed several potential owners with no clearly defined responsibility for the site. One owner in particular had most of the surface rights but had died leaving the property to his children. However, it was also clear that the mineral rights had no ownership. To resolve this impasse, the Crown contacted every potential owner, instructing them to make their legal position clear within 30 days. None of the potential owners admitted ownership or responsibility. To complicate matters further, the tailings had been optioned off to an Australian company as part of a re-processing venture. This company had entered bankruptcy and no longer had a local presence. The Crown was therefore forced to proceed to the next step – declare the property abandoned and initiate rehabilitative measures while examining other legal avenues.

Preliminary Field Work

The Crown carried out some preliminary field work during the winter of 1991-92. The stack was surveyed and a geotechnical investigation was performed to determine the properties of the tailings and the site conditions. The field work indicated that the tailings were loose to very loose in density, saturated to near-surface and with average SPT (Standard Penetration Test) blowcount values of 5 below the phreatic line and 8 above. The site stratigraphy, shown in Figure 3, is as follows, tailings overlying a thin seam of sand, peat, and inorganic clays of low plasticity to non-plastic silts. The hydraulic conductivity was estimated at $1x10^{-5}$ to $1x10^{-6}$ cm/sec, corresponding to fine sands and silts. The friction angle of the tailings was estimated at 35 to 40 degrees.

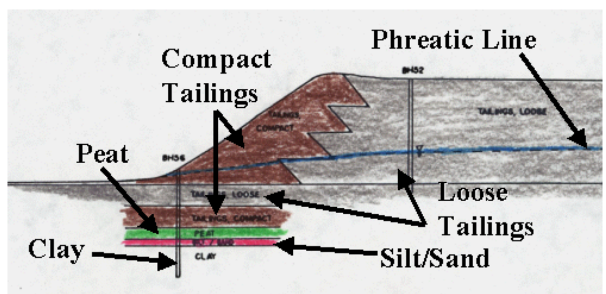

Figure 3- Soils/tailings stratigraphy at the site

Physical Stability Analysis

Static and pseudo-static analyses were carried out on the site on the highest section of the dam, closest to the trailer park. Data from the federal government in Ottawa indicated a ground acceleration of 0.065g horizontal and 0.043g vertical for a 1000-year seismic event. The static factor of safety (FOS) of the site was assessed at between 1.1 and 1.2, which was barely adequate. The pseudo-static FOS was estimated at less than 0.9. In addition, opinions from selected seismic/geotechnical experts assessed the seismic (dynamic) stability to be inadequate with liquefaction estimated at around 0.05g with the toe of the slope to be the most susceptible to liquefaction due to inadequate confinement. Their primary recommendation was unanimous - remove the ponded water from the top of the stack.

Action Plan and Rehabilitation Measures

The Crown decided to implement the following measures (see Figure 4):

1) Drain the ponded water using a permanent spillway on the east side and a set of internal ditches
2) Construct a rockfill toe berm and drainage network to shore up the eroded slopes
3) Re-slope the west and south-west sections to a more stable configuration
4) Re-vegetate the stack to reduce erosion, stabilize the tailings and provide wildlife habitat

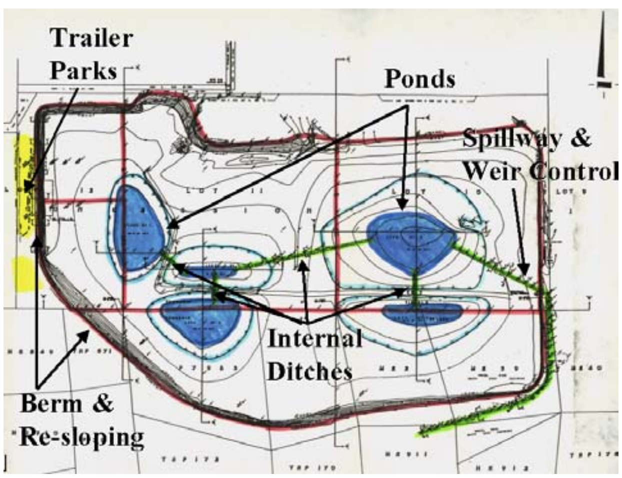

Figure 4 – Proposed rehabilitation measures for the site

To protect its investment, the Crown would place liens on the site. Any owner would have to remove these liens prior to selling the tailings to anyone else.

Spillway Design

The spillway was located on the far east side of the stack, where the elevation difference between the stack and the surrounding topography was the smallest. This layout would result in the lowest excavation cost possible.

The hydraulic response of the stack was modeled using HYMO (commercial hydrologic modeler and storm runoff simulation software). For the analysis, a spillway having side slopes of 3 to 1 horizontal to vertical (3H:1V) and a base width of 2.0m was selected. It was felt that ditch slopes no steeper than this could be used in tailings. Two design storms were modeled, the Regional Design Storm, referred to as the "Timmins Storm" and the PMP or Probable Maximum Precipitation. The results of the modeling are in Table 1.

Table 1 – Hydrological Modeling Results of the Spillway

Rain Event	Timmins Storm	PMP
Precipitation	193mm in 12 hours	491mm in 12 hours
Peak Flow at Weir (m^3/sec)	4.1	8.8
Peak Flow Velocity (m/sec)	-	2.8
Peak Rise in Spillway (m)	2.5	2.9

The results indicated that the spillway would be able to handle the flows. To reduce the impact of downstream flooding during a severe storm event, it was decided to put a control structure (weir) within the spillway. This control structure would delay the peak of the outflow sufficiently such that the spillway would contribute no more than 5% of the total downstream flow. In spite of these efforts, downstream flooding would be inevitable should such severe event occur due to a combination of rather flat topography, poor natural drainage, and drainage restrictions at road culvert crossings.

The spillway design required rip rap armouring to a water depth of 3 metres to prevent scour. The remainder of the spillway was vegetated. The spillway would be lined with a geotextile to separate the tailings from the 0.35m thick sand and gravel filter which in turn would be covered with a 0.45m thick rip rap layer (see Figure 5).

Rock Berm & Re-sloping Design

A decision was made to construct a rock berm at the toe of the west and south-west slopes of the stack. This 1.6 km structure would enhance the stability of the re-sloped surface first by its physical mass but also by acting as a free draining filter even during the cold winter months, thus lowering the phreatic line and preventing it from daylighting. This structure was built with rockfill extracted from a nearby quarry.

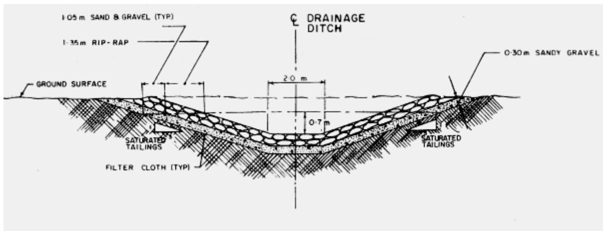

Figure 5 – Spillway cross-section

The rock berm contained a 2.5m wide crest width for constructability and side slopes of 1H:1. The height of the berm ranged from 1.5m at the south-west end to almost 5m at the corner where the west slope joins the south-west slope. As part of the design, a thick non-woven geotextile was specified between the berm and the tailings. Re-sloping was done on both the west and south-west slopes. Due to the proximity of the trailer park to the west slope, re-sloping was limited to 3H:1V. On the south-west slope where space limitation was not a factor, the slope was further reduced to 3.75H:1V. It should be noted that a 3H:1V slope is generally accepted as the steepest slope practicable that will easily maintain a vegetation cover and minimize erosion.

The selected slope was modeled for slope stability. The static FOS increased from 1.1 to 2.0. The pseudo-static FOS for the 1000-year seismic event increased from 0.9 to 1.6 assuming no liquefaction. Under a worse case scenario, assuming that the tailings would partially liquefy coupled with an elevated phreatic line, the pseudo-static FOS was reduced to 0.98, which is marginally stable (see Figure 6). Overall, it was believed that the rock berm and re-sloping design would provide a reasonable cost-effective solution to the problem.

Legal and Regulatory Permitting Work

While the *Mining Act* provides a mechanism for the Ministry or its agent to enter mining properties for the purpose of inspection or study, it did not in 1992 provide a way for the Ministry to do rehabilitative work under emergency conditions. For this to happen, the City of Timmins was asked to declare an emergency due to the potential impacts on the trailer homes under the *Emergency Plan Act of Ontario*. As well, the government is subject to the Ontario Environmental Assessment Act. Because there was no time to carry out a full environmental assessment, an exemption from the Ontario Ministry of the Environment (MOE) was requested and granted. In addition, various permits were secured including a Permit to Take Water from the MOE for removing water from the top of the stack.

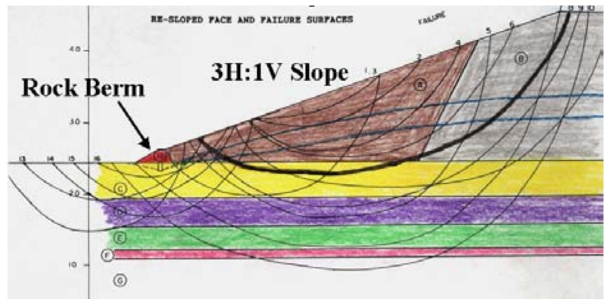

Figure 6 – Re-sloped cross-section

Construction Work

The Crown started construction work in November 1992. The contractor installed two pumps to transfer approximately 385,000 m^3 of water off the stack while constructing the spillway and internal ditches. This emergency work was completed in January 1993 and on January 13, 1993, the Declaration of Emergency was lifted. To reduce costs to the Crown, competitive bidding was used at all stages of the rehabilitation work and the cost for this part of the work was $470,000.

It should be noted that construction work on tailings is generally only feasible during winter when the cold temperatures freeze the ground sufficiently to permit large equipment to work on it, particularly in the area where the ponds were located. There were several instances where the contractor had to stop work for a few days to let the ground freeze. Figure 7 shows the construction of the main spillway.

The next phase of the work was the construction of the rock berm. This work was done during the winter of 1993 and 94. To reduce costs, a small rock quarry was developed approximately 2km from the site. A permit from the Ministry of Natural resources was obtained prior to opening the quarry. After grubbing, the geotextile was laid on the ground along the berm's alignment and rockfill was placed in 0.5m lifts and compacted. Approximately 30,000 m^3 of rockfill was required to build the structure at a total cost of $460,000.

Figure 7 – Main spillway construction

The last phase of the work was done during the fall of 1994. The contractor mobilized a large equipment fleet for the re-sloping work. Several bulldozers, excavators and trucks were used to cut, push, excavate and haul tailings from the stack to reduce the slope on the west and south-west sides (see Figure 8). A geotextile was placed against the upstream slope of the rock berm and the tailings were pushed against it. Compaction of the tails was done using the bulldozing equipment and verified by independent testing. Several rock-lined trenches were built to allow the rock berm to drain into the nearby drainage system to remove water from the toe of the stack and ensure long-term stability.

After re-sloping the stack sides, the contractor installed silt fences because the re-vegetation work was delayed until the spring of 1995. Table 2 presents the seed and fertilizer mix used for the re-vegetation work. This mix was spread over 143 hectares after the site had been prepared. Total cost to re-slope and revegetate the slopes and the rock berm base area was $313,000.

Figures 9 and 10 show the completed work. Total cost was $1.76M spent over three years including $120,000 for field work, engineering and site supervision services.

Figure 8 – Re-sloping work

Table 2 – Seed and Fertilizer Specifications for the Hollinger Stack

Seed Mix	Application Rate (kg/ha)
Cereal rye	60
Creeping red fescue	40
Timothy	20
Canada bluegrass	20
Birdsfoot trefoil	10
Alsike clover	10
Fertilizer Mix	**(kg/ha)**
5-20-20	450
0-0-60	160

Figure 9 – Revegetated west slope

<u>Follow-up Work</u>

Follow-up inspections have shown that the rehabilitation work done on the stack was successful. The volume of ponded water has been reduced considerably and the west and south-west sides of the stack appear to have a sustainable vegetative cover. Recent inspections have since shown the south side, where no remedial work was carried out, is now in need of repair, having deteriorated somewhat from the 93/94 era.

Figure 10: Completed main spillway

The Hollinger reclamation work caused the Province of Ontario to re-examine some of its policies and legislation. The emergency powers of the Crown were expanded to better address such eventualities.

In 1996, a provincial policy statement was created which stated that "no development will be permitted on lands located on or adjacent to former mine sites unless rehabilitative measures to address and mitigate known or suspected hazards are underway or have been completed" (Ontario, 1997). This new policy should prevent the kind of unrestricted development that took place adjacent to the Hollinger stack, where a private party was allowed to develop a residential area immediately adjacent to a mine hazard.

Since the completion of the rehabilitation work, the site has a new alternate land use somewhat more compatible with a former waste storage site. A wood waste storage dump has been developed on the north-west side of the stack. As well, the stack is now used by a miniature flying aircraft club who have built a small runway for their hobby.

Conclusions

The Hollinger Stack is a good example of what can happen when former mine sites are essentially abandoned and alternate non-mining related land uses are developed in that area. In particular, the complex issue of tailings ownership presents challenges. Although typically associated with the mineral rights holder, tailings are stored on surface and affect the surface rights. When mineral rights and surface rights holders are different, ownership of the tailings can be further complicated. In addition, tailings can and are frequently sold or optioned off as a chattel, separate from the mineral or surface rights. At this point, the legal agreements, which are not located within the title documents for the property, are required in order for the Crown to verify who is the real owner.

At the time, in spite of supporting legislation, the process to initiate emergency action was complex and cumbersome. However, the legislative and policy changes introduced by the Province demonstrate the government's determination to respond to real problems. The current emergency provisions should greatly assist the Crown in handling similar problems in the future.

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