

Construction and instrumentation of waste rock test covers at Whistle Mine, Ontario, Canada

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ABSTRACT: Inco Ltd. is currently in the process of decommissioning the Whistle Mine site located in northern Ontario, Canada. Closure of the mine site includes relocation of waste rock from two waste rock piles into an open pit, and construction of an engineered dry cover system over the potentially acid-generating waste material. The final contoured surface of the backfilled pit will have a 20% slope. Site-specific field information is required on the construction feasibility and potential performance of dry cover systems prior to finalizing the design of the full-scale cover system.

Three experimental dry cover systems were constructed over acid-generating waste rock at Whistle Mine in the fall of 2000. Each test cover plot has a different barrier layer overlain by a protective layer of non-compacted soil. The three barrier layers being evaluated are a geosynthetic clay liner (GCL), a compacted sand-bentonite mixture, and a compacted local silt/trace clay material. A monitoring system was installed to evaluate field performance of the test covers, which includes continuous monitoring of climatic parameters, gaseous oxygen / carbon dioxide concentrations and moisture / temperature conditions within the cover and waste materials. The quantity of net percolation through each test cover is also being monitored. A waste rock platform with a 20% slope was constructed to support the test cover systems, as well as a seepage collection system to prevent contamination of the local groundwater system.

This paper describes the construction of the test cover plots, the waste rock platform and seepage collection system, and installation of the field performance monitoring equipment.

1 INTRODUCTION

Inco Limited, Ontario Division (Inco) has finalized the design of the closure works for the Whistle Mine site. The Whistle Mine site is located approximately 30 km north of Sudbury, Ontario, Canada (Fig. 1). A closure plan for the mine site was reviewed and approved by the Ministry of Northern Development and Mines, Ontario in 1998. The closure plan includes relocation of waste rock from two waste rock piles and all acid-generating waste rock used for the various site roads into the pit. The final surface of the filled pit will be contoured once all of the designated materials have been placed, and will possess a constant 20% slope as a result of the natural relief adjacent to the pit. An engineered soil cover system will subsequently be constructed over the backfilled waste material, covering a surface area of approximately 9.7 ha.

The cover will be a critical aspect of the work, as it must be an effective barrier against oxygen diffusion, water infiltration, and deep tree-root penetration over the long term for maximum environmental protection. Field information is required on the construction feasibility and potential performance of alternate dry cover sys-

tems prior to finalizing the design of the full-scale cover system.

A test cover program for acid-generating waste rock was initiated at Whistle Mine in the fall of 2000. Three test cover plots with alternate designs, each approximately 12 m wide and 24 m long, were constructed on a waste rock platform with a 20% slope. A seepage collection system was installed at the study site to prevent potential acidic drainage from the waste rock platform from entering the local groundwater system. Monitoring equipment, including automated net percolation collection and monitoring systems (i.e. lysimeters), was installed to evaluate the field performance of the various test covers for a minimum of two years.

This paper describes the construction of the test cover plots and the waste rock platform / seepage collection system, as well as installation of the field performance monitoring equipment. Issues related to construction of the various barrier layers in a full-scale application are also discussed.



Figure 1. Location of Whistle Mine in Ontario, Canada.

2 BACKGROUND

2.1 Mine history / site description

The Whistle Mine orebody, which was originally discovered in 1897, was developed as an open pit mine in 1988. Mining and the production of waste rock at Whistle Mine occurred between 1988-1991 and 1994-1998. Approximately 6.4 million tonnes of waste rock was produced during these periods and stored in two surface stockpiles adjacent to the pit. The waste rock is composed of approximately 80% mafic norite, which has an average sulphide content of 3% (DeVos et al. 1997). The mine site is currently being decommissioned, which includes relocation of all waste rock to the open pit. Backfilling of the open pit should be completed in early 2002.

The mine site is part of the Post Creek watershed, an area of approximately 5400 ha, which drains into Lake Wanapitei, only 3 km east of the mine. The area immediately surrounding the mine site is undeveloped wilderness. Bedrock outcrops are frequent and typically form hills that rise up to 50 m above the surrounding areas (DeVos et al. 1997). A thin discontinuous blanket of glacial till covers the bedrock. Whistle Mine is situated in a semi-arid environment; the mean annual precipitation and potential evaporation for the region is approximately 870 mm and 520 mm, respectively. Approximately 30% of the annual precipitation occurs as snow.

2.2 Dry cover systems

The application of a dry cover system over reactive waste rock is becoming a common technique for preventing and controlling acid rock drainage following clo-

sure of a mine site or waste storage facility (MEND 2001). The objectives of dry cover systems are to minimize the influx of water and provide an oxygen diffusion barrier to minimize the influx of oxygen. Apart from these functions, dry covers are expected to be resistant to erosion and provide support for vegetation. Dry covers can be simple or complex, ranging from a single layer of earthen material to several layers of different material types, including non-reactive tailings and/or waste rock, geosynthetic materials, and oxygen consuming organic materials (MEND 2001).

In general, the design of a dry cover system for acid-generating waste rock must consider the performance of the dry cover on both horizontal and sloped surfaces, the internal hydraulic and geochemical performance of the waste material, and the potential influence of basal flow (MEND 2001).

2.3 Study objectives

The objectives of the Whistle Mine test cover program are:

- 1 To evaluate the “relative” field performance of three different test cover plots in response to varying site climatic conditions, as well as the “absolute” field performance of each test cover compared to a control (i.e. uncovered) test plot;
- 2 To collect accurate field performance data for calibration and subsequent validation of numerical models used for cover design; and
- 3 To evaluate cover construction techniques and in particular, gain some insight into potential quality assurance / quality control (QA/QC) difficulties associated with construction of the barrier layer.

3 DESIGN OF TEST COVER PLOTS

Three test cover systems are being evaluated in this study for potential placement over the backfilled open pit at Whistle Mine (Fig. 2). Each test cover system has a barrier layer to limit the ingress of atmospheric oxygen and meteoric water. The barrier layer for Test Plot #1 is a geosynthetic clay liner (GCL). Test Plot #2 has a 0.45 m thick sand-bentonite mixture barrier layer, which has a sodium bentonite content of 8% on a dry mass basis. Test Plot #3 has a 0.60 m thick barrier layer of a silt/trace clay material, obtained from a nearby borrow pit.

Each of the test cover systems has a 0.9 m thick layer of relatively well-graded material over the barrier layer. This layer protects the integrity of the barrier layer and provides a medium for the growth of vegetation. In addition, this layer will reduce the percolation of meteoric waters to the underlying waste through storage and release of moisture to the atmosphere as a result of evapotranspiration.

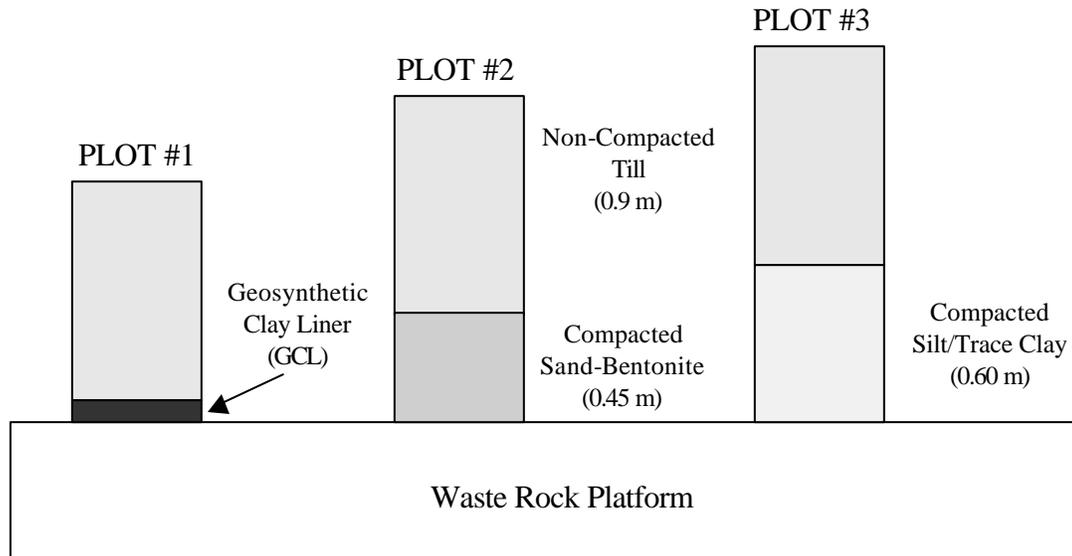


Figure 2. Schematic diagram of the Whistle Mine waste rock test cover plots.

Different methodologies were used to determine the design thickness of the various test cover layers. Laboratory and numerical modeling investigations were completed in order to determine the optimum thickness for the barrier layers in Test Plots #2 and #3 (KP 1998). The GCL being evaluated in this study is Bentomat[®] ST, which is a prefabricated product consisting of a layer of sodium bentonite (<0.1 m thick) between woven and non-woven geotextiles needle-punched together. Although preliminary cover design modeling results showed a 0.5 m thick protective layer was adequate for the Whistle Mine test cover systems, the design thickness of this layer was increased to 0.9 m to provide greater protection for the barrier layers against deep-root penetration and freeze-thaw effects (KP 1998).

Saturated-unsaturated flow numerical modeling was completed for this project in order to determine the optimum dimensions for the cover test plots. The software package SEEP/W (Geo-Slope International 1995) was configured for steady-state, two-dimensional seepage and used for all simulations. A critical component in the design of the cover dimensions was to ensure that the cover was large enough so that any potential flow around the test plots would not be intercepted by the lysimeter. In addition, the cover had to be large enough so that lateral moisture movement under the cover due to liquid and vapour gradients or slope effects would be minimized. The final dimensions of the cover that met these criteria had a top surface of approximately 24 m long and 12 m wide with 2H:1V side-slopes.

A waste rock platform located in an undisturbed area was required for this study because of the on-going open pit backfilling operation. A continuous 20% slope at the existing waste rock piles would not be available for the duration of the test cover project. A seepage collection system was also designed for this project to prevent potential acidic drainage from the waste rock platform from entering the local groundwater system. A

fourth test plot with no cover (Test Plot #4) was also established on the platform.

4 CONSTRUCTION OF STUDY COMPONENTS

Construction of the Whistle Mine test cover plots and associated infrastructure occurred in September and October 2000. Figures 3 and 4 show the major components of the test cover project. The study site is located in a cleared area on the Whistle Mine property. OKC (2001) provide complete details on the construction of the various study components. A summary of the construction details is provided below.

4.1 Seepage collection system

The seepage collection system has two components; namely, the waste rock containment area and the seepage collection pond. The waste rock containment area has a length and width of approximately 90 m and 45 m, respectively, and a slope of about 1.7% from the north to south perimeter. The south perimeter of the containment area is also the north perimeter of a lined pond, which collects all surface runoff and seepage from the containment area. The waste rock containment area is comprised of an earthen foundation, a 0.3 m thick sand sub-base layer, a geosynthetic liner and finally, an overlying sand drainage layer. The geosynthetic liner consisted of one 20-mil thick panel of low-liner density polyethylene (LLDPE). A 0.3 m containment berm was constructed around the perimeter to ensure all runoff and seepage from the area reports to the seepage collection pond. The sand drainage layer was a minimum thickness of 0.5 m to protect the liner from damage during placement of the waste rock.

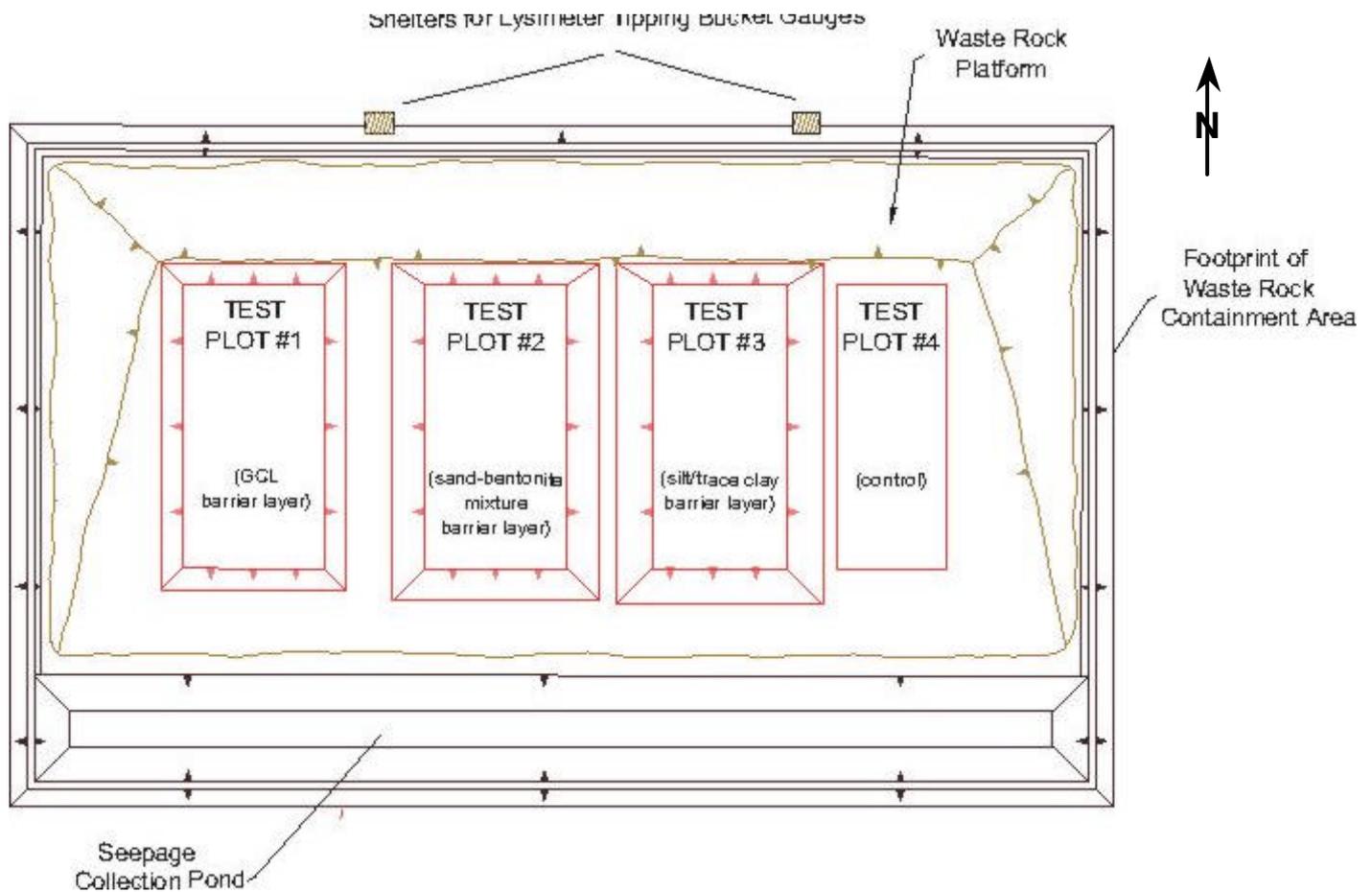


Figure 3. Plan view of the major components of the Whistle Mine test cover project (after OKC 2001).

The seepage collection pond is located immediately south of the containment area and has a length of 90 m and width of 10 m. The pond is 1.5 m deep and was designed to retain runoff from the 24-hour design storm event with a 1:100 year return period (113 mm), assuming the pond is less than one-third full prior to the storm event. One 30-mil thick panel of LLDPE was installed to provide containment of runoff and seepage waters.

4.2 Waste rock platform

A platform of waste rock with a 20% slope was required to support the three test cover plots and one control test plot. This resulted in the waste rock platform having a footprint of approximately 85 m by 40 m and a height of 6.0 m. The volume of waste rock in the platform is approximately 12,000 m³.

The waste rock platform was constructed in three stages. The first stage involved placing and grading a single lift of waste rock, with an average thickness of 0.5 m, up to the design elevation of the bottom of the lysimeter tanks. Once the lysimeter tanks and drainage pipes were installed, waste rock haulage to the test area resumed and subsequent placement in 0.5 m thick lifts. The third and final stage consisted of placing and grading waste rock to achieve the desired final elevation of the 20% slope. Four 50-ton haul trucks were used to place waste rock in the containment area, and a D8N and D3 bulldozer were used for rough and final grading, respectively. The surface of the 5H:1V slope was compacted with an 84" wide smooth-drum vibratory roller to provide a smooth foundation for the test plots. Waste rock samples were collected throughout construction for geotechnical and/or geochemical laboratory testing.

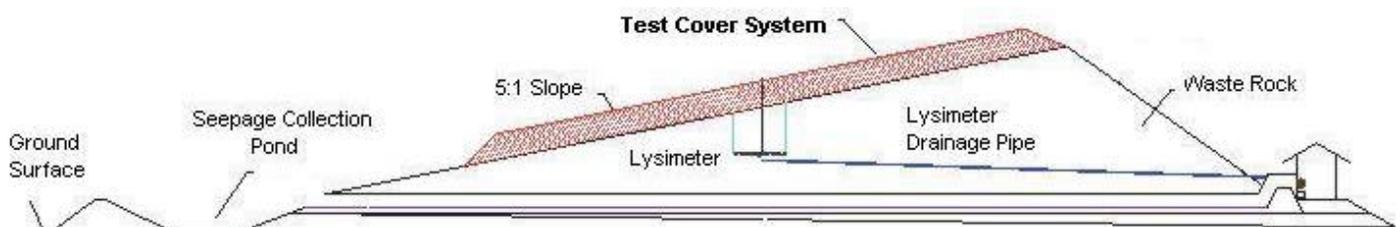


Figure 4. Cross-section of the major components of the Whistle Mine test cover project (after OKC 2001).

4.3 Test cover plot construction

The waste rock test cover plots at Whistle Mine were constructed in a similar manner, with the exception of the barrier layers. The protective layer in each test cover, which consisted of a well-graded soil material obtained from a nearby borrow pit, was placed in a single, 0.9 m thick non-compacted lift following construction of the barrier layer. A 25-ton haul truck and a D3 bulldozer were used to haul, place and grade the protective layer material. Heavy equipment was not allowed to operate directly on the barrier layer in order to protect its integrity.

A seed mixture was applied to the surface of each test cover, including the control test plot, following construction of the protective cover layer and installation of the near surface field monitoring equipment. A truck-mounted hydroseeder was used to apply the seed mixture to the entire test plot area.

Details related to construction of each barrier layer are provided below.

4.3.1 Test plot #1 barrier (GCL)

The GCL was shipped from the factory to the site in two rolls, each 38 m long by 4.5 m wide. Each roll was hauled to the top of the waste rock platform with a fork-lift, and subsequently unrolled and placed directly on the prepared smooth waste rock surface. A small anchor trench, approximately 0.2 m deep, was excavated along the entire north perimeter of the test plot to prevent the GCL from moving during placement of the overlying protective layer material. A strip of sodium bentonite was placed along all overlapping seams to provide a watertight seal at these locations.

4.3.2 Test plot #2 barrier (sand-bentonite mixture)

The sand-bentonite mixture being evaluated in this study consists of relatively uniform sand with a bentonite content of 8% on a dry mass basis. The bentonite used in the mixture is Envirogel[®] 12, which was supplied by Wyo-Ben, Inc. out of Montana, USA. This product is a granular sodium bentonite containing particles ranging in size from fine sand to clay. The bentonite was delivered to the test site in 3000 lb canvas bags on semi-trailer flatbed units.

Construction of the compacted sand-bentonite mixture barrier layer was completed in two 0.23 m (9") thick lifts. Slightly different construction techniques were used for each lift. Construction of the first lift involved placing the host material within the footprint of the test plot and subsequently mixing in the bentonite and moisture conditioning the mixture directly on the waste rock platform (Fig. 5). Mixing and moisture conditioning the sand-bentonite mixture for the final lift occurred in a cleared area immediately west of the waste rock platform. The prepared mixture was then hauled, placed and graded on top of the first lift.

The following methodology was applied to both lifts of the barrier layer for mixing, moisture conditioning and compacting the sand-bentonite mixture:

- The bentonite host material was placed and graded, and then bentonite was applied evenly to the lift surface corresponding to the design bentonite content.
- The bentonite was mixed thoroughly into the host material with a pulvi-mixer prior to moisture conditioning.



Figure 5. Moisture conditioning and mixing the first lift of the sand-bentonite mixture barrier layer (from OKC 2001).

- The sand-bentonite mixture was moisture conditioned to achieve a moisture content corresponding to 2% wet of the optimum moisture content (OMC) for the

mixture, based on a standard Proctor compaction test.

- A smooth-drum vibratory roller was used to compact each lift following moisture conditioning.

4.3.3 Test plot #3 barrier (silt/trace clay)

The compacted silt/trace clay barrier layer was constructed in three 0.20 m (8") thick lifts. A loader was used to place and grade the barrier layer material. Each lift was moisture conditioned to achieve a moisture content corresponding to 2% wet of the optimum moisture content (OMC), based on a standard Proctor compaction test. A smooth-drum vibratory roller was used to compact each lift following moisture conditioning.

4.4 Evaluation of test cover construction techniques

Construction techniques used for the test covers were evaluated and assessed as to their potential application for construction of a cover system on the backfilled open pit at Whistle Mine. This component of the study focused on gaining some insight into potential quality assurance / quality control (QA/QC) difficulties associated with construction of the barrier layer. Discussions are provided below on the installation of the GCL and construction of a sand-bentonite mixture barrier layer.

4.4.1 Installation of the GCL

Installation of the GCL barrier layer was a relatively simple task. This was reflected in the brief amount of time required to cover the surface area of the test plot (three hours). The force of gravity (i.e. the 20% slope) played a key role in the simplicity of unrolling and installing the GCL on the waste rock surface. The use of a spreader bar, inserted through the core of the GCL roll, attached to the bucket of an excavator or loader may be required for a full-scale installation. Nevertheless, it is expected a GCL could be installed on the entire surface of the backfilled open pit in a relatively short period of time.

The GCL was installed directly on the surface of the waste rock platform following compaction of the 20% slope. Compaction of the waste rock surface provided a relatively smooth foundation for the GCL. However, a visual inspection of the GCL following installation revealed that puncturing of the GCL could potentially occur during placement of the non-compacted cover material. This issue must be addressed if GCL is to be used in the design of the full-scale waste rock cover system. It is anticipated that a geotextile, installed between the GCL and underlying waste rock, would provide the necessary cushioning to prevent puncturing of the GCL.

4.4.2 Construction of sand-bentonite barrier layer

The sand-bentonite mixture for the barrier layer in Test Plot #2 was prepared using an in-situ or field batch technique. The primary reason for preparing the mixture adjacent to the waste rock platform for the second lift was due to space constraints on the platform and concerns for the safety of equipment operators. However, this would not be an issue for construction on the back-filled open pit. In summary, both techniques would be suitable for full-scale cover system construction.

Another technique that has been used at other sites for preparation of sand-bentonite mixtures involves the use of a pug mill or batch plant. The bentonite host material, along with appropriate quantities of bentonite and water, are mixed in the batch plant and subsequently transferred to a stockpile or directly to haul trucks via a conveyor belt. This technique as well as the in-situ or field batch technique generally produce a similar product; however, due to differences in rotation speed, batch plant mixing may not produce as well of a mixed product. Precipitation can affect both techniques; however, batch plant mixers have more difficulty working in moist conditions because of their lack of drying capability.

The key criteria for placing and compacting the sand-bentonite mixture material, as well as the silt/trace clay material, was moisture content, as opposed to dry density. One of the design objectives of the Whistle Mine test cover systems is to reduce the ingress of atmospheric oxygen to the underlying waste rock by maintaining the barrier layer at or near saturation. Therefore, placing and compacting the barrier layer materials above the OMC, as opposed to below or at the OMC, benefits this particular cover system design objective. In addition, a minimum saturated hydraulic conductivity will occur wet of the OMC for typical silt/trace clay soils and sand-bentonite mixtures (see Lambe 1958, Mitchell et al. 1965, Haug & Wong 1992). Nonetheless, the dry density of each compacted lift achieved in the field was between 90 and 95% of the standard Proctor maximum density.

5 INSTALLATION OF FIELD PERFORMANCE MONITORING SYSTEM

A monitoring system was installed in order to evaluate the field performance of the various test covers constructed on Whistle Mine acid-generating waste rock. The objectives of the field performance monitoring system are to:

- 1 Develop an understanding for key processes and characteristics that control performance;
- 2 Obtain a water balance for each of the test cover systems and the control test plot;

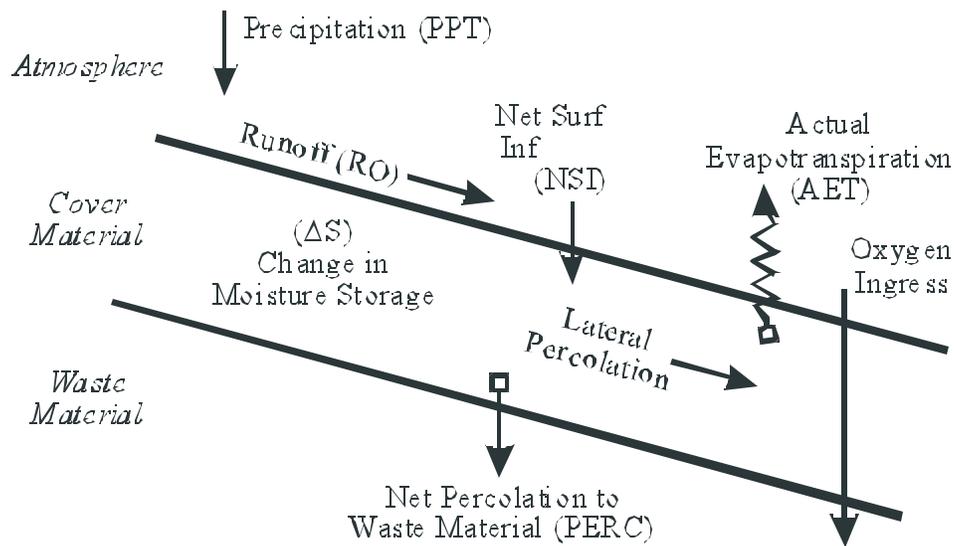


Figure 6. Parameters affecting the field performance of a sloped cover system (from MEND 2001).

- 3 Develop credibility and confidence with respect to performance of the proposed cover system from a closure perspective; and
- 4 Develop a database with which to calibrate the cover system design using numerical modelling tools.

The test cover field monitoring program was designed to quantify as many parameters as possible influencing the performance of a sloped cover system (Fig. 6). The critical parameters being measured are the net percolation of meteoric water and the ingress of atmospheric oxygen into the underlying waste material. Net percolation is a component of the water balance for the cover system, and is related to the other water balance components as follows:

$$\text{PERC} = \Delta S + D_r + \text{NSI} \quad (1)$$

$$\text{NSI} = \text{PPT} - \text{AET} - \text{RO} \quad (2)$$

where PERC = net percolation into the waste material; ΔS = change in moisture storage within the cover layers; D_r = lateral drainage or percolation within the cover layers; NSI = net surface infiltration; PPT = precipitation; AET = actual evapotranspiration; and RO = runoff.

Table 1 summarizes the field instrumentation that was installed in each of the test plots in the fall of 2000. OKC (2001) provide complete details on the installation of the various field monitoring components. Installation of the major monitoring components is summarized below.

Table 1. Summary of field instrumentation installed in the Whistle Mine waste rock test cover plots.

Instrumentation (parameters measured)	Test Plot #1 – GCL barrier	Test Plot #2 – Sand-bentonite barrier	Test Plot #3 – Silt/trace clay barrier	Test Plot #4 – Control
Lysimeter (net percolation)	1 – at base of cover	1 – at base of cover	1 – at base of cover	1 – at surface
Campbell Scientific 229-L thermal conductivity sensor (matric suction & temperature)	7 – in N/C layer 2 – in waste rock	7 – in N/C layer 4 – in barrier layer 2 – in waste rock	7 – in N/C layer 4 – in barrier layer 2 – in waste rock	4 – in waste rock
Campbell Scientific CS615-L frequency domain reflectometer (volumetric water content)	7 – in N/C layer 2 – in waste rock	7 – in N/C layer 4 – in barrier layer 2 – in waste rock	7 – in N/C layer 4 – in barrier layer 2 – in waste rock	4 – in waste rock
Gas sampling port (O_2 & CO_2 gas concentrations)	1 – above barrier in N/C layer 1 – below barrier in waste rock 1 – at depth in waste rock	1 – above barrier in N/C layer 1 – below barrier in waste rock 1 – at depth in waste rock	1 – above barrier in N/C layer 1 – below barrier in waste rock 1 – at depth in waste rock	3 – in waste rock
Surface runoff and sub-surface collection & monitoring systems	Preliminary work completed in 2000 (installation to be completed at a later date)			NA
Meteorological station – installed on Test Plot #2 (air temperature, relative humidity, wind speed & direction, net radiation, barometric pressure, rainfall and snowfall)				

5.1 Net percolation collection & monitoring system

A net percolation collection and monitoring system (lysimeter) was installed at each test plot for monitoring the quantity and quality of percolating water through each test plot. Each lysimeter is comprised of a net percolation collection tank, in-situ moisture monitoring system, underdrain system and a net percolation monitoring system. Installation of each of these components is described briefly below.

The net percolation collection tank, which is the main component of the lysimeter, consists of a large vertical storage tank. Two-dimensional saturated-unsaturated flow numerical modeling was carried out to determine the optimum tank dimensions and tank position within the test plot, based on design criteria outlined in Bews et al. (1997). The results of steady-state simulations utilizing SEEP/W (Geo-Slope International 1995) dictated the installation of 2.4 m diameter tanks, 2.3 m high, at approximately the centre point of each test plot. Figure 7 shows the location of the four lysimeter tanks. The top of the lysimeter tanks, which were cut to have a 20% slope, were positioned immediately below the waste rock / barrier layer interface. A thin layer of drainage sand (<0.1 m) was placed in the bottom of each tank prior to backfilling with waste rock. Samples of the drainage sand and waste rock backfill were collected for future laboratory characterization.

An in-situ moisture monitoring system was installed in each of the net percolation collection tanks for monitoring temporal and spatial changes in moisture storage in the waste rock backfill. The in-situ moisture monitoring system selected for this project is the Diviner 2000, a product manufactured and distributed by Sentek Pty Ltd. of Adelaide, Australia. The Diviner

2000 consists of one sensor on a shaft with an automatic depth sensor (i.e. the probe) and pre-installed access tubes. Insertion of the probe into an access tube provides an immediate profile of soil moisture as a function of depth.

The underdrain component of the lysimeter consists of a 51 mm diameter PVC pipe that extends from the base of the net percolation collection tank to a point just above the monitoring system. The underdrain pipes have a downward slope ranging between 1% and 2% to allow gravity flow of net percolation waters from the tanks. Portions of the underdrain pipes were covered with insulation to minimize the potential for freezing of percolating waters draining during the winter months. A water trap oxygen barrier was installed at the end of each underdrain pipe to prevent oxygen from entering the underdrain system and oxidizing the waste material in the net percolation collection tank. Ethylene glycol was placed in the oxygen barrier, as opposed to water, to prevent freezing of the oxygen barrier during the winter months. The solution in the water trap oxygen barrier can be changed-out at any time with distilled water to facilitate the collection of representative seepage waters for chemical analysis.

The lysimeter monitoring systems are comprised of a flow meter to automatically record the time and quantity of water discharged from each net percolation collection tank, and a sample bucket to collect net percolation waters for chemical analysis. The flow meter is simply a tipping bucket rain gauge, connected to an automated data acquisition system (DAS). The flow meters and sample buckets are housed in sheds located at the north perimeter of the test plot area.



Figure 7. Looking northwest at the Whistle Mine test plot area showing the location of the four lysimeter tanks (from OKC 2001).

5.2 In-situ moisture / temperature sensors

Sensors to measure in-situ matric suction, temperature and volumetric water content in the test cover materials and waste rock were installed in all four plots. Model 229 thermal conductivity sensors, supplied by Campbell Scientific Canada Corporation, were selected for monitoring in-situ matric suction and temperature in the various test plot materials. Model CS615 frequency domain reflectometer (FDR) probes, also supplied by Campbell Scientific Canada Corporation, were installed to measure in-situ volumetric water content in the various test plot materials. Where possible, these sensors were installed into the face of undisturbed material.

These sensors were installed in a single instrumentation nest located approximately 1.5 m up-gradient of each lysimeter tank. Sensors installed in Test Plots #1 and #2 were connected to an automated DAS located on Test Plot #2, while sensors installed in Test Plots #3 and #4 were connected to an automated DAS located on Test Plot #3. Each DAS consists of a datalogger and multiplexer, housed in an environmentally sealed enclosure, powered by a rechargeable battery / solar panel system. In-situ moisture and temperature measurements are currently being collected every six hours.

5.3 Gaseous O₂/CO₂ monitoring system

Three sampling ports were installed within the three test cover systems; one 0.05 m above the barrier layer, one 0.05 m below the barrier layer, and one about 0.6 m below the barrier layer. Data collected from the sampling ports just above and below the barrier layers will be used to assess the effectiveness of the barrier layers in reducing the ingress of atmospheric oxygen to the underlying waste material. Three sampling ports were also installed at various depths within the waste rock of the control test plot.

The sampling ports were connected to a gas analyzing system, which consist of an O₂/CO₂ analyzer, a 12-point sequencer and a condensate trap panel. The gaseous concentration analyzer is capable of measuring O₂ and CO₂ concentrations in the range of 0 – 25% and 0 – 10%, respectively. The O₂/CO₂ analyzer and 12-point sequencer were connected to a DAS to automatically record gas concentrations every twelve hours.

6 SUMMARY AND CONCLUSIONS

The construction and instrumentation of experimental dry cover systems for acid-generating waste rock at Whistle Mine in Ontario, Canada were reviewed. Three cover system alternatives were constructed on a specially designed waste rock platform possessing a 20% slope. Each test cover system has a barrier layer to limit the ingress of atmospheric oxygen and meteoric water, and an overlying non-compacted layer to protect the integrity of the barrier layer and provide a medium for the growth of vegetation. The barrier layers being evaluated in this

study are a geosynthetic clay liner (GCL), a 0.45 m thick compacted sand-bentonite mixture and a 0.6 m compacted silt/trace clay material. Techniques used to construct each of the barrier layers were assessed in terms of their potential application for construction of the full-scale cover system.

A state-of-the-art monitoring system was installed to assess field performance of the test cover systems during all seasons of the year. The system includes continuous monitoring of various climatic parameters, gaseous oxygen / carbon dioxide concentrations and moisture / temperature conditions within the cover and waste materials, and the quantity of net percolation through each test cover.

Collection of test plot field data commenced in November 2000. Data collected over the next two years will be used for calibration and subsequent validation of numerical models used for cover design. The field calibrated model will be a key tool for determining the optimum cover design for the Whistle Mine backfilled open pit.

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