

Field Performance Monitoring of a Cover System with Geosynthetic Layers, Case Study – Franklin Waste Rock Pile, Sydney NS

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ABSTRACT

Enterprise Cape Breton Corporation (ECBC) implemented a remediation program for the Franklin coal mine located near Sydney, Nova Scotia. Waste rock generated from the Franklin mine and four other mines in close proximity, all of which operated from 1885 to 1959, were consolidated into the Franklin waste rock pile (WRP). The waste rock is acid generating with the potential to continue to generate acid rock drainage (ARD) for an extended period. A dry cover system was constructed over the Franklin WRP in the fall of 2010 with the overall objective to minimize detrimental impacts of the mine waste on the receiving environment in the short-term and facilitate recovery of the environment disturbed by mining over the long-term.

The Franklin WRP cover system consists of a geotextile fabric, engineered 60 mil high density polyethylene (HDPE) geomembrane, a geocomposite drainage layer (GDL), and 600 mm of glacial till. Instrumentation was installed during construction of the cover system to facilitate evaluation of its performance over time under site-specific climatic conditions. The primary objective of the monitoring program is to develop a database of cover system moisture and thermal field responses, as well as internal WRP dynamics and groundwater conditions within the WRP footprint, for eventual calibration of a soil-plant-atmosphere numerical model and groundwater flow and contaminant transport model.

The WRP performance monitoring system is detailed within this paper along with preliminary performance of the cover system to include a simple water balance.

Key Words: acidic drainage, high-density polyethylene, geocomposite drainage layer, composite cover

INTRODUCTION

The application of a dry cover system over reactive waste rock is a common technique for preventing and controlling acid mine drainage following closure of a mine waste storage facility. Dry covers can be simple or complex, ranging from a single layer of earthen material to several layers of different material types, including native soils, non-reactive tailings and/or waste rock, geosynthetic materials, and oxygen consuming organic materials. Cover system field monitoring is an essential and necessary method for evaluating performance of cover systems and provides a direct method of verifying the design of the cover system. Field performance monitoring can be implemented during the design stage with test cover plots (e.g. Aubertin et al., 1997; O’Kane et al. 1998a, 1998b), or following construction of the full-scale cover (e.g. MEND 2.22.4a,b; O’Kane et al. 1998c). Direct measurement of field performance of a cover system is the best method for demonstrating performance to stakeholders and developing further understanding for long-term cover system performance.

The primary purpose of cover systems is to minimize any deleterious impact of the mine waste on the receiving environment in the short-term and to facilitate recovery of the environment disturbed by mining over the long-term. The impact of a waste storage facility on the receiving environment will depend on the nature of the site, climate, characteristics of the waste, local hydrogeology, and the ability of the cover system design to limit the release of contaminants of concern from the underlying waste. As a result, one

of the design objectives of a cover system for waste storage facilities is to limit percolation of water into the underlying waste (O’Kane and Barbour 2003). This is generally achieved through the use of a low permeability layer and/or a moisture store-and-release layer (MEND 2.21.4a). Subsequently, net percolation (NP) from the base of the cover system into the underlying waste material is a key measure of cover system performance.

Even though NP is a critical cover system performance monitoring parameter, a monitoring program should be designed to measure the various components that influence the performance of a cover system. These components are shown schematically in Figure 1 and are comprised primarily of the elements of the water balance, oxygen flux, and climate. MEND BC.03 provides a detailed overview of field performance monitoring for cover systems. In terms of field performance monitoring for a full-scale cover system, a recommended minimum level of monitoring would include meteorological monitoring, such as determination of the potential evaporation (PE) and site-specific precipitation, cover material moisture storage changes, watershed or catchment area surface runoff, vegetation, and erosion (MEND 2.21.4b).

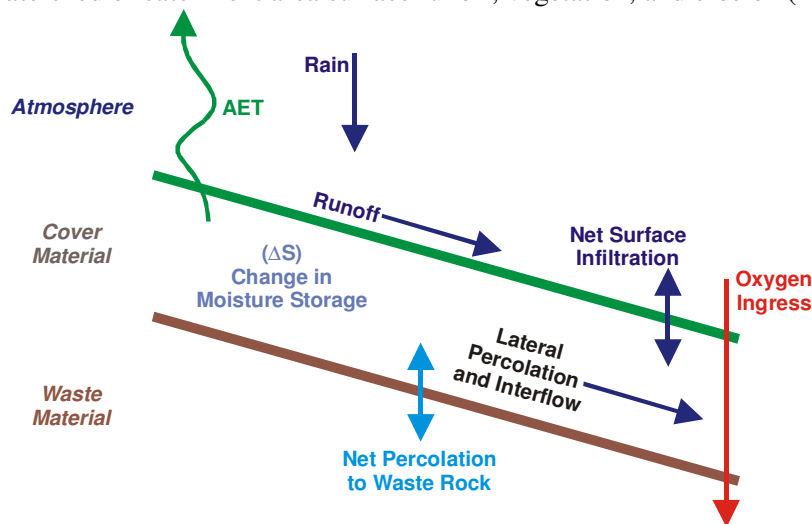


Figure 1. Components that influence the performance of a cover system.

Field performance monitoring programs, which focus on water quality analyses of seepage discharged from the waste storage facility, empirically describe a waste storage facility through monitoring of its cumulative effect at the base. This approach has two major disadvantages. The first is that it may take tens if not hundreds of years before a considerable change is measured inside or downstream of the waste storage facility due to, for example, drain-down effects, complete oxidation of sulphidic minerals, and/or mixing with groundwater. The second disadvantage is that without additional forms of monitoring, there will not be sufficient information to explain the results if they do not meet expectations. Therefore, this monitoring approach on its own does not provide enough information for understanding and predicting performance of a cover system placed on the waste storage facility to mitigate ARD (O’Kane 2011).

In terms of composite covers, which include a geomembrane layer, water and oxygen can move through the geomembrane by diffusion, but the transmission rates are very low. In general the hydraulic conductivity corresponding to water diffusion is on the order of 10^{-12} to 10^{-15} cm/s (Giroud and Bonaparte 1989). Considering that geomembranes are perceived as being essentially impervious when devoid of defects, performance monitoring programs are traditionally focused on water quality analyses of seepage discharged from the waste storage facility. However; this rationale is somewhat flawed in that NP alone does not provide an understanding of the actual cover system performance. For example Ayres et al. (2004) highlighted the importance of the growth medium in providing protection to a low flux barrier layer against physical, chemical and biological processes. An improperly designed growth medium layer

may not adequately protect the barrier layer, leading to possible changes in its performance INAP (2003). As well as providing protection to the barrier layer, the growth medium should provide for a stable landform and the establishment of sustainable vegetation (MEND 2.21.4a). This is particularly important in composite cover systems where geosynthetics are placed within earthen layers. Cover systems that include a geomembrane typically include a granular or geosynthetic drainage layer (geocomposite drainage layer, GDL) to increase slope stability through limiting pore-water pressures. Holding to the conceptual idea that the geosynthetic layers will perform as intended, the longevity of the geosynthetics and subsequent long-term performance of the cover system will be a function of the performance of the growth medium. The initial performance of the growth medium and geosynthetics layers will change as a result of physical, chemical, and biological processes, and result in long-term performance.

SITE BACKGROUND

The reclaimed Franklin WRP is located at the former Franklin mine site in Bras d'Or, N.S, Canada. As part of the Franklin Group of Properties remediation program, approximately 187,000 m³ of historic coal waste materials (waste rock) from the Franklin mine site and other nearby sites (Colonial No. 1, Colonial No. 4 and the Atlantic Mine Sites) were removed, relocated and consolidated in the Franklin WRP. The consolidated waste rock is currently acidic with the potential to continue to generate ARD (Phase 2010).

The Franklin WRP is sloped at a 4:1 (H:V) surface gradient and has a relatively small surface plateau at its apex. A perimeter ditch, which is divided into two flow directions, collects runoff from the landform surface with runoff generated in two surface water catchments. Runoff generated from the south catchment is directed southeast to the sediment pond adjacent to the eastern side of the pile, while runoff from the north catchment is directed north and then east towards the sediment pond. The WRP landform is approximately 2.5 ha with the south and north catchment approximately 1.05 and 1.45 ha, respectively.

The cover system was constructed between June 2010 and November 2010. The WRP was reclaimed with a geotextile fabric, HDPE geomembrane, GDL, and 600 mm of imported glacial till to serve as a growth medium (see Figure 2). The till consists of approximately 19% gravel, 57% sand, and 24% silt and clay size particles, based on the Unified Soil Classification System. In addition, two 150 mm HDPE riser pipes or exhaust 'vents' were installed through the cover and HDPE on the top of the WRP to provide for degassing.

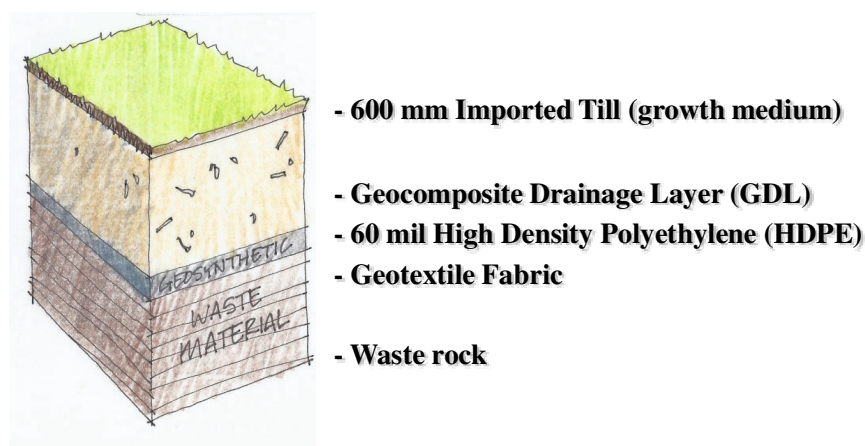


Figure 2. Franklin WRP cover system design.

A multi-phase, multi-discipline monitoring program was implemented in support of evaluating the performance of the reclaimed Franklin WRP and to achieve the following objectives:

- Obtain a water balance for the site, and more specifically, for the cover system itself.
- Identify and characterize key mechanisms and processes that control performance.
- Track the evolution of cover performance in response to site-specific physical, chemical and biological processes.
- Obtain a representative set of field performance monitoring data to calibrate a soil-plant-atmosphere numerical model and ultimately predictions of long-term cover performance.
- Link a groundwater contaminant transport numerical model to a soil-plant-atmosphere numerical model for predictions of impacts of contaminant release from the WRP on the receiving environment.
- Develop confidence with all stakeholders with respect to closure performance of the WRP.

RECLAIMED WASTE ROCK PILE - PERFORMANCE MONITORING SYSTEM

The Franklin WRP performance monitoring system includes a meteorological station, a v-notch weir for measuring runoff flows and interflow, four automated stations for measuring *in situ* moisture and pore-gas concentrations above and below the cover system. In addition, three systems were installed to allow for monitoring of the WRP internal conditions. The instrumentation, shown in Figure 3, was installed and commissioned as of October 24, 2010, with the exception of the weir data acquisition system (DAS), which was installed by ECBC in March 2011. OKC (2011) provides a complete record of installation.

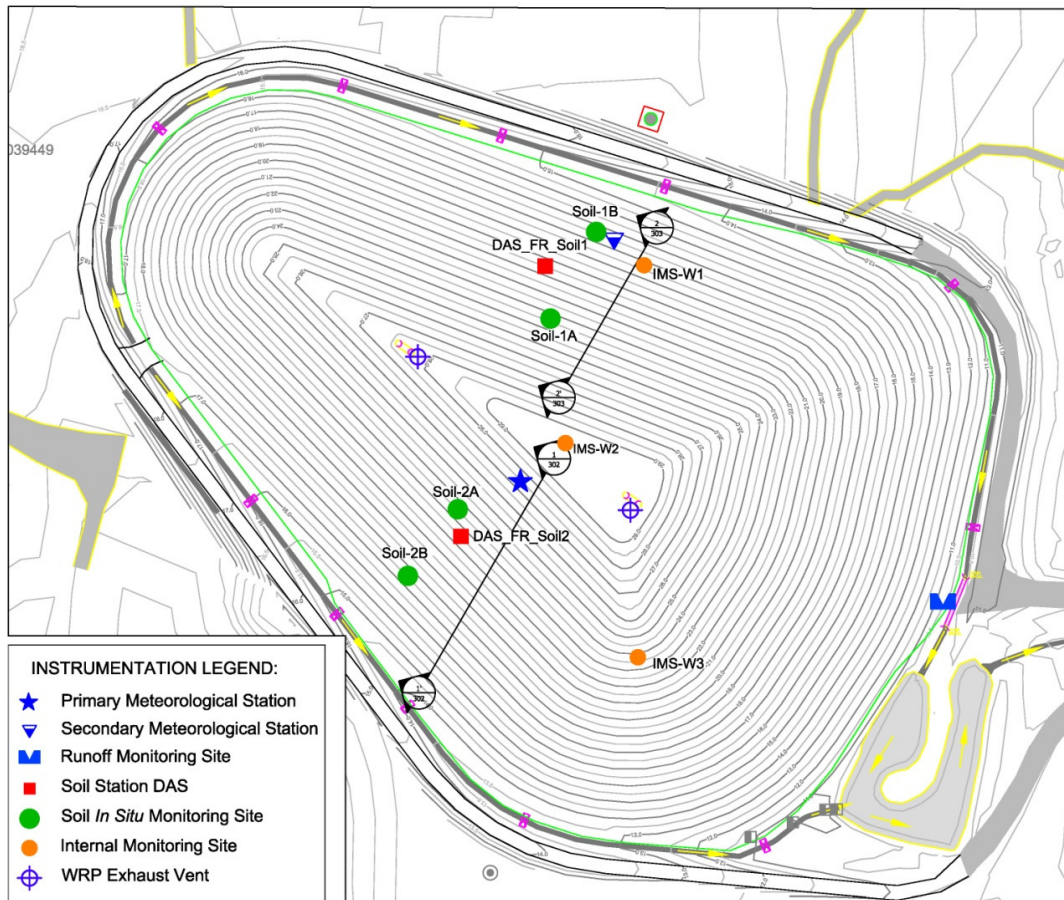


Figure 3. Location of monitoring stations on the reclaimed Franklin WRP cover system.

A fundamental design feature of a field performance monitoring system is that the presence of the monitoring system components and installation procedures must not influence the data being collected. To ensure the monitoring system did not compromise the HDPE layer all instrumentation and sensor leads

were passed through a PVC pipe which was sealed to the HDPE with a boot assembly. The inside of the pipe was then sealed with an epoxy resin to mitigate gas and water fluxes across the cover system.

Meteorological Station

A fully-automated meteorological station was installed near the crest on the south slope. The station measures air temperature, relative humidity, wind speed and direction, net radiation, rainfall, barometric pressure and snowpack depth. Sufficient monitoring is in place to allow potential (or theoretical maximum) rates of evaporation from the cover surface to be determined using the Penman (1948) method. Given the anticipated differences in incident solar radiation, an additional net radiometer was installed at a north slope monitoring location.

***In situ* Moisture Conditions**

Thermal conductivity (TC) and time domain reflectometry (TDR) sensors were installed into a trench excavated into the waste rock and cover profile to measure matric suction/temperature and volumetric water content, respectively. The TC sensors were calibrated from 0.1 to 293,000 kPa prior to installation, while material-specific calibration curves were developed for the TDR sensors in order to obtain absolute values of volumetric water content for determining changes in water storage within the cover profile. The waste rock and cover material backfill was placed in lifts and compacted with the excavator bucket and by tracking the excavator across the surface. The use of traffic compaction was utilized to create a similar density condition to the surrounding *in situ* material, which was compacted in a similar manner during placement and earthworks activities. The methodology selected for backfilling the sensor trench was based on the *in situ* water content of the cover material and waste rock. Sufficient *in situ* water existed in the backfill materials to adequately reduce negative pore-water pressures to allow for the till to form around the sensors creating intimate contact with the *in situ* material. Typically, at water contents below the plastic limit, sensors are installed in an undisturbed face within the excavation to minimize sensor damage while providing the required *in situ* conditions.

Cover system performance will be different along the slope profile of the WRP as a result of higher surface runoff and lateral diversion of subsurface waters on the slopes. In addition, slope aspect will have an influence on cover system performance due to differences in incident solar radiation and resulting snowpack formation and melting period, rates of evapotranspiration, and vegetation development. To accommodate for the variety in moisture dynamics, four (4) “soil monitoring stations” were strategically positioned across the WRP to develop a thorough understanding for the cover system moisture regimes on a temporal and spatial basis.

The TC and TDR sensors were installed at the same depth in close proximity to one another in the cover and waste rock profile to enable development of ‘field’ moisture retentions curves (MRC), and field hydraulic conductivity functions (k-functions). The field measured MRC and k-function is a parameter input to the soil-plant-atmosphere numerical model, which will ultimately be utilized for simulating measured field performance. Figure 4 is a schematic of a soil monitoring station located on the Franklin WRP.

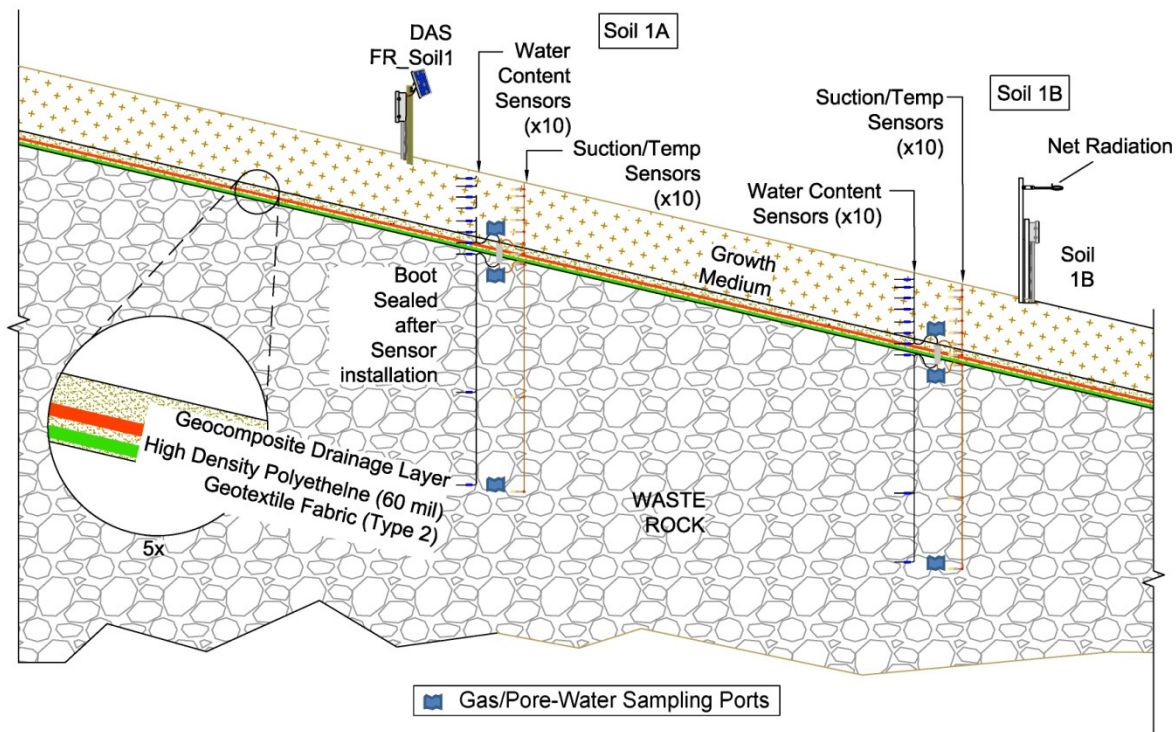


Figure 4. Schematic of the Franklin WRP soil monitoring station.

Internal Monitoring System

The characteristics of ARD that develop, such as low pH and elevated concentrations of dissolved elements, are influenced by, but not limited to, the *in situ* moisture content and the ingress of meteoric water, as well as transport of gases (e.g. oxygen) across the cover system (exiting and entering the waste material). The mass or load of contaminants released from the WRP to the receiving environment will be a function of cover system performance (i.e. NP), change in water storage within the waste facility/material, characteristics of the waste and the concentration of solutes within the seepage. Hence, monitoring of internal WRP conditions is critical for predicting impacts to the receiving environment.

One of the design objectives of the cover system and HDPE layer in particular is to limit oxygen fluxes into the underlying reactive waste rock. The migration of oxygen to the underlying waste will be minimized by maintaining the integrity of the HDPE layer. Gas can move across the cover system by diffusion and advection processes. Diffusion is the movement of molecules or ions from a region of higher concentration to one of lower concentration as a result of random Brownian movement. An advective process is one in which oxygen may be carried along with air or water moving through a WRP.

Respiration through a WRP will largely be influenced by the dynamic interaction between internal and external pressure and temperature conditions. The reaction of oxygen with sulphide minerals releases heat, as does the reaction of carbonate minerals with acidity. An increase in gas temperature causes it to expand and become less dense and when the gas becomes warm enough and light enough in relation to the external conditions, it will start to rise (Phillip et al. 2009). Changes in oxygen and carbon dioxide content can also affect the density of the pore-gas and can lead to the same effect as temperature change (Hockley et al. 2009). For example, oxygen is one of the heavier components of air, so its depletion within the pore-gas tends to make it lighter.

The two potential pathways for oxygen ingress into the Franklin WRP would include diffusion across the cover layer and respiration (i.e. advection) through defects in the HDPE layer and exhaust vents located on the upper surface. In order to develop an understanding of pore-gas dynamics within the WRP three Internal Monitoring Systems (IMSS) were installed in the Franklin WRP to allow for:

- Automated monitoring of pore-gas pressure and temperature.
- Manual monitoring of ground water levels and pore-gas concentration.
- Collection of pore-water for geochemical analysis.

The IMS consists of a well, instrumented with four temperature probes and continuous multi-channel tubing (CMT). The CMT is a polyethylene tube segmented into seven (7) channels, which allows for sampling along the profile at isolated depths. Sampling ports were installed at each of the soil monitoring stations to allow for collection of pore-water and/or pore-gas samples within the cover profile and within the waste rock approximately 0.1 m and 2.0 m below the HDPE layer. In addition, differential pressure is monitored within the exhaust vent to evaluate gas fluxes from the structures.

Internal Monitoring System

There are a variety of ways of estimating NP depending on the range of data that is available for the site. A methodology that incorporates several monitoring methods of estimating NP is advantageous in that a more comprehensive understanding of cover system performance can be developed (Meiers et al. 2009). NP from the base of the reclaimed Franklin WRP cover system will be:

- Estimated utilizing measured components of the water balance and *in situ* hydraulic gradients (analytical method).
- Simulated using soil-plant-atmosphere numerical models that have been calibrated to measured field responses.
- Estimated using a conservative tracer.

Analytical Method

A simple water balance can be completed for a cover system using the performance monitoring data collected at the site. The water balance for a sloping cover system consists of the following components (also see Figure 1):

$$PPT = R + AET + NP + \Delta S + LP \quad [1]$$

where: PPT is precipitation, R is surface runoff, ΔS is the change in water storage within the cover material, AET is the actual evapotranspiration, and LP is lateral percolation or interflow. NP is then back-calculated as the residual based on measurements or estimates of the other components of the water balance. It is essential that as many components of the water balance are measured as possible because NP rates are often a small component of the water balance, particularly in the case cover systems that include an HDPE layer. ECBC has procured an Eddy covariance (EC) system, which will be rotated between the Franklin site and three other waste storage facilities to provide direct measurements of AET. Utilization of an EC system to measure AET is “best practice” because it allows for all but one component of the cover system water balance to be measured for the monitoring program. In the absence of an EC system, analytical estimates of AET can be developed based on components of the water balance, hydraulic gradients, and meteorological parameters.

Numerical Model Simulations

Field monitoring of cover system performance provides a data set for calibration of simulation models. The minimum level of field monitoring required for calibration of the numerical model includes meteorological monitoring of precipitation along with sufficient monitoring to estimate PE, changes in cover water storage, and surface runoff. It is important to monitor over multiple years in order to observe

cover performance for a range of climatic conditions, thus increasing confidence with the numerical simulations.

In general, numerical models used in cover design are one or two dimensional finite element models that predict pressure head (suction) and temperature profiles in the cover profile in response to climatic forcing (such as evaporation). A key feature of these models is the ability to predict AET based on PE, vegetation parameters and soil suction. Parameters required by the model include climate data to characterize the soil-atmosphere boundary condition, material properties (particularly the functional relationships between volumetric water content and hydraulic conductivity as a function of suction), and vegetation characteristics (rooting depth/distribution and leaf area).

Prediction of long-term cover system performance due to varying climatic conditions, geometry, and material properties would be completed using the field calibrated model. In addition, models calibrated to measured performance would be a tool to enhance ones understanding of post construction defects in the HDPE layer. This would be accomplished by calibrating the model to measured performance and then substituting the pressure condition measured at the base of the HDPE layer to the base of the geocomposite drainage layer (i.e. remove the HDPE layer from the numerical simulation). Outcomes based on the aforementioned numerical simulations will provide stakeholders with an understanding of potential liabilities and adverse impacts to the receiving environment associated with various HDPE layer performance scenarios.

Conservative Tracer

Two conservative tracers were applied at the IMS sites to validate NP rates estimated through the analytical method and numerical simulations. Deuterium (D) and chloride (as sodium chloride, NaCl) were applied in September 2010. The tracers were applied to the waste rock surface on a 5 m by 5 m area centered on each CMT monitoring well prior to placement of the HDPE cover layer. Water for the tracer tests was spiked to produce the required concentrations of deuterium and chloride. The delta D for the tracer is approximately +1,500‰ compared to background delta D (-100‰) in pore-water.

As changes in the isotopic signature and Cl concentration would be primarily due to advection, the migration of the tracers within the waste rock can be used to estimate a NP rate between the time of applying the tracers and sampling for their migration. Samples will be analyzed for concentrations of D and Cl using mass spectrometry and ion chromatography. Given that the D will equilibrate with water-vapour in the waste rock, sampling for D through the CMT can occur in the vapour or water phase, depending on the *in situ* moisture conditions at the depth of sampling. Given that it is anticipated that the flux of water across the HDPE layer will be low, sampling for D will occur annually with the first sampling period in September 2011. Sampling for Cl would only occur if the cover system was exhumed exposing the underlying waste rock.

Runoff and Interflow

A zero-height V-notch weir structure was constructed to allow for measurement of flows in the perimeter ditch generated from the north WRP catchment. Sensors are used to automatically record the water level (stage) in the weir and temperature and conductivity of discharge waters. Given that the cover system HDPE layer extends into and underlies the perimeter ditch, both runoff and interflow volumes are channelled through the weir.

COVER SYSTEM PERFORMANCE MONITORING

Substantial amounts of data are collected from the Franklin WRP cover performance monitoring system. Preliminary trends in performance monitoring data are presented in the section to address the objectives of this paper.

Atmospheric Gas Flux to the WRP

Pore-Gas Concentration Measurements

Concentrations of O₂ and CO₂ were measured at the soil monitoring stations and IMS monitoring sites within the cover profile and underlying waste rock. During the oxidation of sulphide minerals, atmospheric O₂ (20.9% concentration) is consumed and CO₂ (0.03% concentration in atmospheric air) is produced when acidic pore-water generated as a result of the sulphide oxidation reacts with carbonates in the system.

Figure 5 presents pore-gas O₂ and CO₂ concentrations measured across the cover material and waste rock profile. The pore-gas concentrations were collected on May 7, 2011 (approximately 8 months following construction) and include data from the Soil-1B and IMS-W1 location. The O₂ pore-gas concentration was 20.7 % at a depth of 40 cm within the growth medium and then decreases to 0.3 % immediately below the cover layer. O₂ concentrations decrease along the waste rock profile from 0.3% to 0.1% to a depth of 4.7 m. The CO₂ concentration is 1.5 % at 40 cm and increases to approximately 16% in the waste rock.

Prior to covering the WRP atmospheric O₂ was able to enter the upper waste rock profile via several mechanisms, including diffusion, barometric pumping, wind action, volume displacement during infiltration, and with infiltrating water containing dissolved oxygen. Subsequently, the pore-gas concentrations presented within this paper may be in part due to oxygen that entered the waste rock prior to cover placement and O₂ transport across the cover system. Continued monitoring of pore-gas concentrations in the cover and waste rock profile will be a key set of data for developing an understanding for the O₂ flux across the cover profile.

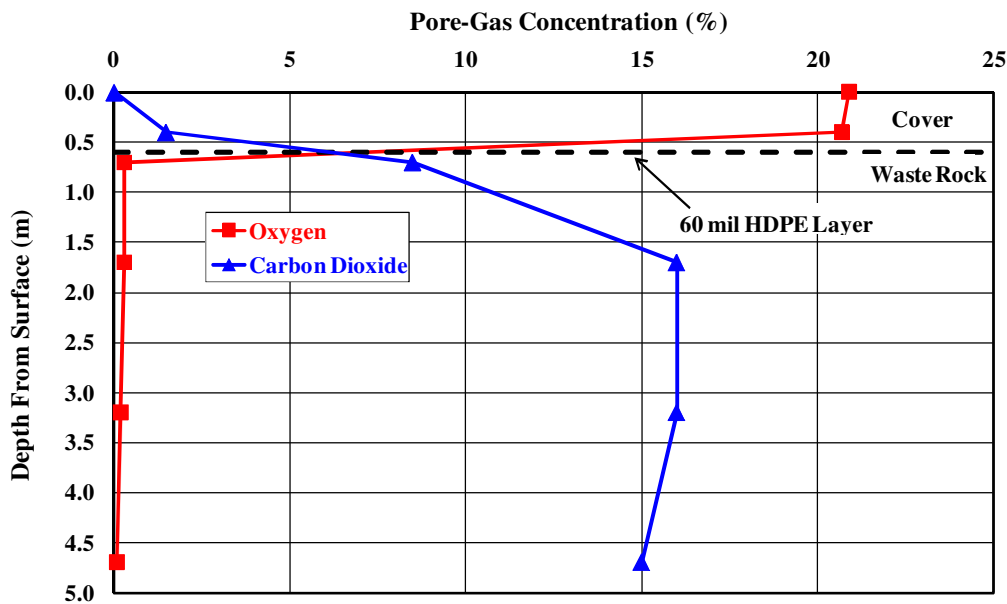


Figure 5. O₂ and CO₂ pore-gas concentrations measured across the cover/waste material interface and the underlying waste rock.

Barometric Pumping

Oscillations in barometric pressure are both diurnal, corresponding to daily heating and cooling of the atmosphere, and seasonal, resulting from the passage of weather fronts. When the barometric pressure rises, fresh surface O₂ enriched air is driven into the soil; however, when the barometric pressure drops, soil air vents upward into the atmosphere. The total movement of soil air is dependent primarily on the

magnitude and period of the pressure oscillations, the soil permeability to air and cover homogeneity, and depth to an impermeable boundary.

Figure 6 shows the difference in air pressure measured between the barometric pressure (atmosphere) and air pressure at the base of the exhaust vent located at the top of the WRP in February 2011. Changes in barometric pressure are also included in Figure 6 for the monitoring period. An upward and downward advective flux is defined by a negative and positive differential pressure, respectively. The trend in differential pressure indicates a predominately upward flux from the WRP vent, with the differential pressure fluctuating from approximately -0.015 to 0.04 kPa for the monitoring period.

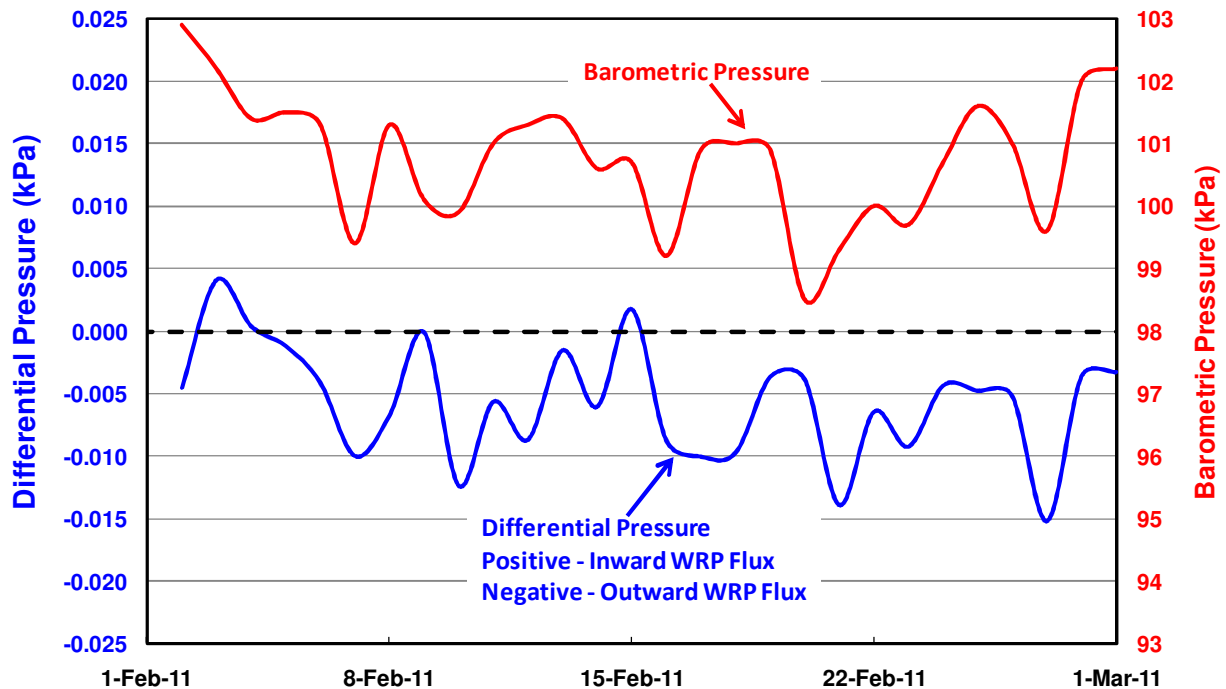


Figure 6. Changes in differential pressure measured across the WRP exhaust vent in relation to changes in barometric pressure.

The changes in differential pressure to some extent replicate the change in barometric pressure, suggesting that the cover system is susceptible to barometric pumping. For example, an increase in barometric pressure tends to result in a more positive trend in the differential pressure. In general, the advective flux is upward out of the WRP. Barometric pumping, in terms of a homogeneous cover system, is typically not a significant factor influencing WRP respiration; however, it is more pronounced in conditions where flow is concentrated, such as that which would occur through exhaust vents on a cover system with a HDPE layer.

Further insight into dump respiration will be gained following an analysis of the dynamic interaction between internal and external temperature conditions and changes in oxygen and carbon dioxide content. This will be achieved through data collected at the IMS locations in terms of internal temperature, pressure, and gas concentrations along the waste rock profile. It is anticipated that the flow dynamics may change over time and become more pronounced as the relatively fine textured waste rock drains, consolidates and develops structure.

Water Balance for the WRP

A water balance has been developed for the cover system for the September 2011 to January 2012 period. Since the value of NP is a small component of the water balance for a low flux cover system the analytical method, numerical simulations, and conservative tracer will be utilized to develop accurate estimates. These estimates will be developed following the development of an extensive database for field performance monitoring data. For this monitoring period NP through the cover system is assumed to be zero. PPT is comprised of both rainfall and snow water equivalent. ΔS is calculated based on the volume of water in the cover profile at the start and end of the monitoring period. LP or interflow and surface runoff from the cover system can be estimated based on data collected by the weir. Finally, AET from the cover system is not directly measured at the site, but can be back-calculated from the water balance equation.

Figure 7 shows the water balance fluxes for the cover system. A total AET of 124 mm (24% of total precipitation) was calculated for the cover system using the water balance equation. The amount of PE, which is a theoretical maximum assuming free water on the surface at all times, was 144 mm based on the Penman method and climate data collected at the site. The estimated AET was 86% of the calculated PE, which is reasonable given the *in situ* pore-water pressure, site climatic conditions and vegetation. Total runoff and interflow was 351 mm or 67% of PPT. Total runoff and interflow was 351 mm or 67% of PPT.

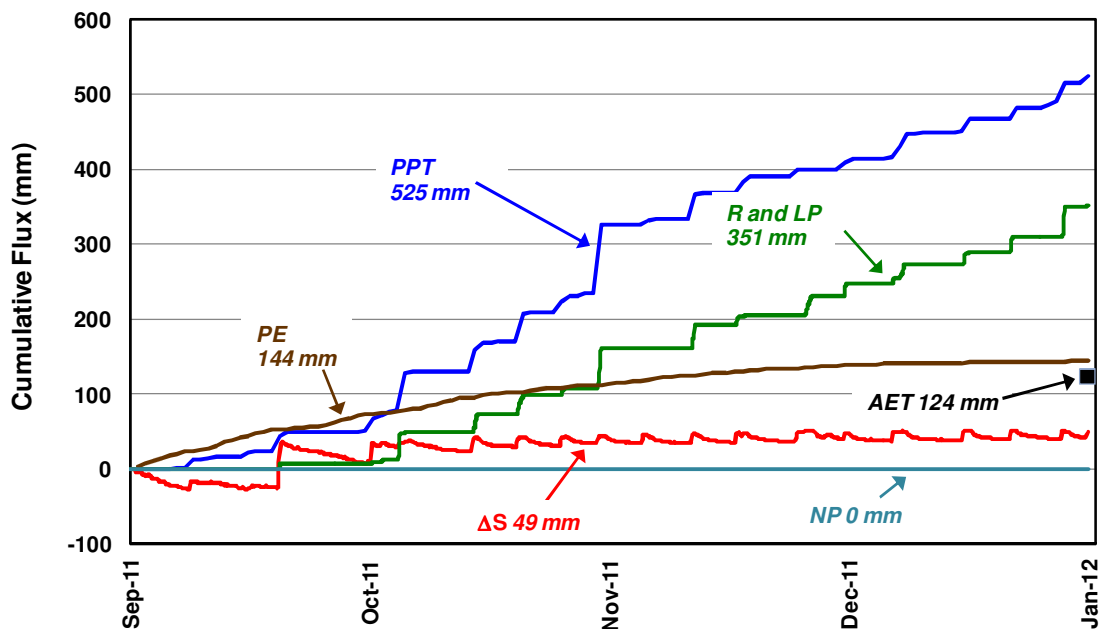


Figure 7. Water balance for the WRP cover system.

Figure 8 is a 2-D contour of the volumetric water content profile measured at Soil-2A. A decrease in the cover profile volumetric water contents occur over the summer period in response to atmospheric forcing (i.e. evapotranspiration). Figure 8 shows that the cover profile in general remains near saturated, while the GDL is 'drained' throughout the monitoring period. The drained condition within the GDL establishes a zero pressure condition at the base of the growth medium layer. Subsequently, flow into the GDL is limited to when the growth medium layer meets field capacity. It is anticipated that interflow is a relatively small component of the water balance at this stage in the monitoring program based on the short duration of weir discharge events (see Figure 7) and drained condition in the GDL.

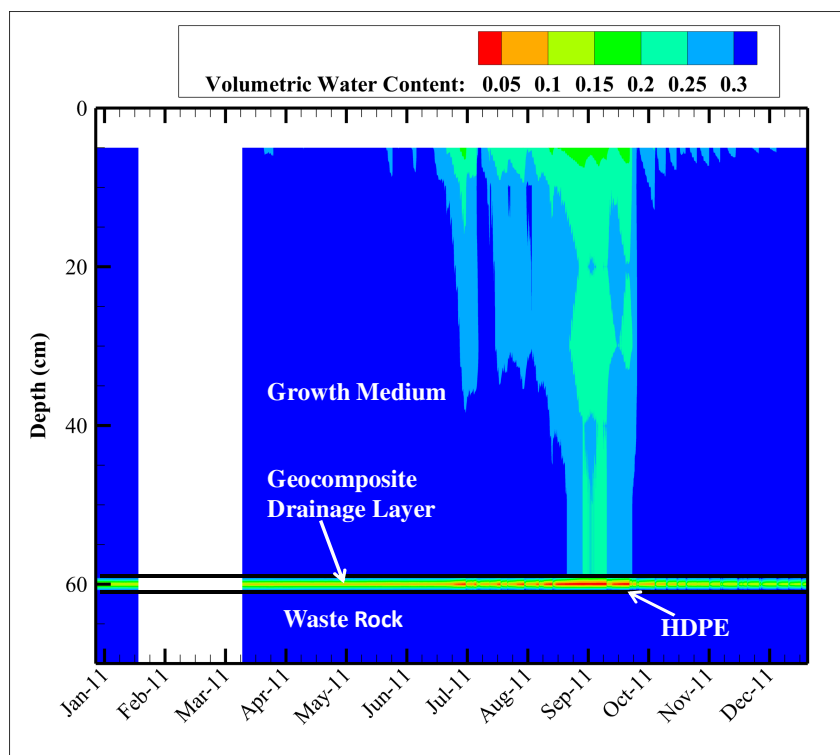


Figure 8. 2-D contour of the Soil-2B water content profile.

The growth medium will initially exhibit a relatively low as-built saturated hydraulic conductivity. Following wet-dry and freeze-thaw cycles the hydraulic conductivity of the cover system will increase to a post-construction condition (Benson et al. 2007; Meiers et al. 2006). The increase in saturated hydraulic conductivity of the growth medium layer may allow for greater volumes of meteoric water to infiltrate the cover surface and access the GDL. GDL is a drained system limiting the buildup of positive pore-water pressures, which is a positive performance monitoring aspect.

Continued monitoring of moisture conditions in the cover profile will allow for the GDL to be evaluated and an understanding for the hydraulic performance of cover system water dynamics to be developed. Inspection of the GDL for potential clogging due to the migration of fines and root penetration will occur through visual observations and *in situ* measurements of hydraulic conductivity. Assuming that the permeability (vertical flow) and transmissivity (lateral flow) of the GDL is adequate to dissipate pore-water pressures landform stability would not be compromised.

SUMMARY

Construction of the Franklin WRP cover system occurred between June 2010 and November 2010. The cover system is composed of geotextile fabric, engineered 60 mil HDPE geomembrane, geocomposite drainage layer, and 600 mm of glacial till. A monitoring system was installed to assess field performance of the cover system during all seasons of the year. The system includes continuous monitoring of various climatic parameters, runoff and interflow, gaseous oxygen and carbon dioxide concentrations, pore-gas pressure, and moisture / temperature conditions within the cover and waste material. The system allows for determination of a water balance for the site and advective and diffusive oxygen fluxes to the underlying waste rock.

A preliminary review of key sets of field performance monitoring data would suggest that WRP respiration, at the moment, is influenced by barometric pumping. The GDL is a drained system limiting the buildup of positive pore-water pressures, which is a positive performance monitoring aspect. On-

going monitoring of the Franklin WRP will provide a unique dataset for the assessment of cover system performance under site-specific climatic conditions and an understanding for the field performance of geosynthetic layers placed within dry cover systems.

REFERENCES

- Aubertin, M., Bussière, B., Barbera, J.-M., Chapuis, R.P., Monzon, M., and Aachib, M. 1997. Construction and instrumentation of *in situ* test plots to evaluate covers built with clean tailings. In Proceedings of the Fourth International Conference on Acid Rock Drainage, Vancouver, BC, May 31-June 6, pp. 715-730.
- Ayers, B., O’Kane, M., and Barbour, S. 2004. Issues for consideration when designing a growth medium layer for a reactive mine waste cover system. Tailings and mine waste '04, Taylor and Francis, London, 161–164.
- Benson, C.H., Sawangsuriya, A., Trzebiatowski, B., and Albright, W.H. 2007. Postconstruction changes in the hydraulic properties of water balance cover soils. Journal of Geotechnical and Geoenvironmental Engineering. 133(4): 349-359
- Benson, C. 2000. Liners and covers for waste containment. Proceedings of Fourth Kansai Intl. Geotechnical Forum. Kyoto, Japan.
- Brennecke, D. and Corser, P. 1998. Performance Issues Related to Geosynthetic Liners at Monticello, Utah, Proc. Tailings and Mine Waste '98, Balkema, Rotterdam, 351-360.
- Darilek, G., Laine, D., Parra, J. 1989. The Electrical Leak Location Method for Geomembrane Liners: Development and Applications, Geosynthetics '89, Industrial Fabrics Assoc. Intl., St. Paul, Minnesota, USA, 456-466.
- Giroud, J.P., and Bonaparte, R. 1989. Leakage Through Liners Constructed with Geomembranes – Part 1. Geomembrane Liners, Geotextiles and Geomembranes, Vol. 8, Elsevier Science, England, pp 27-67.
- Hockley, D., W. Kuit and M. Phillip. 2009. Sullivan Mine fatalities incident: Key Conclusions and Implications for Other Sites. In: Securing the Future and 8th ICARD, June 22-27, 2009, Skelleftea, Sweden.
- International Network for Acid Prevention (INAP). 2003. Evaluation of the long-term performance of dry cover systems, final report. Prepared by O’Kane Consultants Inc., rpt. no. 684-02, March.
- Meiers, G., O’Kane, M. and Barbour, S. L. 2009. Measuring net percolation rates for waste storage facility cover systems. In Proceedings 2009, 62nd Canadian Geotechnical Conference, Halifax, Nova Scotia, September 20-24
- Meiers, G.P., Barbour, S.L., Qualizza, C.V. 2006. The use of *in situ* measurement of hydraulic conductivity to provide an understanding of cover system performance over time. In Proceedings of the 7th International Conference for Acid Rock Drainage, St. Louis, MO, USA, March 26-30, pp. 1259-1272.
- MEND 2.21.4a. 2004. Design, construction and performance monitoring of cover systems for waste rock and tailings. Canadian Mine Environment Neutral Drainage Program, Project 2.21.4, Volume 1, July.
- MEND 2.21.4b. 2004. Design, construction and performance monitoring of cover systems for waste rock and tailings. Canadian Mine Environment Neutral Drainage Program, Project 2.21.4, Volume 4, July.
- MEND BC.03. 2000. 7th Annual BC MIEM – MEND 2000 Metal Leaching / ARD Workshop (Dry Covers, Predicting Solubility Constraints, Research and New Developments), Vancouver, BC, Canada. November.
- MEND 2.22.4a. 1999. Construction and instrumentation of a multi-layer cover Les Terrains Aurifères. February.
- MEND 2.22.4b. 1999. Field performance of the Les Terrains Aurifères composite dry covers. April.

- O'Kane, M. 2011. State-of-the-art performance monitoring of cover systems – Moving from point scale to macro scale approaches. 7th Australian Workshop on Acid and Metalliferous Drainage (AMD), Darwin, NT, 21-24 June 2011
- O'Kane, M., and Barbour, S. L. 2003. Predicting field performance of Lysimeters used to evaluate cover systems for mine waste. In Proceedings Sixth International Conference on Acid Rock Drainage, pp 327-339 (Cairns).
- O'Kane, M., Porterfield, D., Haug, M.D., and Endersby, M. 1998a. The design and implementation of the field test plots at BHP Iron Ore, Mt. Whaleback – a soil cover system for an arid climate. In Proceedings, 1998 SME Annual Meeting & Exhibit, Orlando, Florida, March 9-11.
- O'Kane, M., Stoicescu, J., Januszewski, S., Mchaina, D.M., and Haug, M.D. 1998b. Design of field test plots for a sloped waste rock surface. In Proceedings, 15th National Meeting of the American Society for Surface Mining and Reclamation, St. Louis, MO, May 16-21, pp. 368-378.
- O'Kane, M., Wilson, G.W., and Barbour, S.L. 1998c. Instrumentation and monitoring of an engineered soil cover system for mine waste rock. Canadian Geotechnical Journal, Vol. 35, pp. 828-846.
- OKC (O'Kane Consultants Inc.). 2011. Enterprise Cape Breton Corporation – Record of Installation Report for the Reclaimed Franklin Waste Rock Pile Cover System. Letter Report No. 831/1-02 prepared for ECBC, April.
- Peggs, I.D. 2003. Geomembrane Liner Durability: Contributing Factors and the Status Quo”, 1st United Kingdom Geosynthetics Symposium, UK Chapter of IGS, Invited Keynote Speaker, June 2003.
- Penman, H.L. 1948. Natural evaporation from open water, bare soil and grass. In Proceedings of the Royal Society. (London) Part A. 193: 120-145.
- Phillip, M., D. Hockley, B. Dawson, W. Kuit and M. O'kane. 2009. Sullivan Mine fatalities incident: Technical investigation and findings. In: Securing the Future and 8th ICARD, June 22-27, 2009, Skelleftea, Sweden.
- Phase Geochemistry (Phase). 2010. Review of Available Geochemical Information for the Franklin Waste Rock Pile, Cape Breton, Nova Scotia., memorandum to Enterprise Cape Breton Corporation from Phase, 19 October.
- Rollin, A.L., Marcotte, M., Jacquelin, T., Chaput, L. 1999. Leak Location in Exposed Geomembrane Liners Using an Electrical Leak Detection Technique”, Geosynthetics '99, IFAI, Roseville, MN, pp 615-626.