Abstract

The Mt. Whaleback iron ore mine is located in the Hamersley Iron Province in the northwestern corner (Pilbara Region) of Australia and situated adjacent to Newman, Western Australia (WA), approximately 1,200 km north-northeast of Perth. Development of the Mt. Whaleback mine commenced in 1968. Ultimately, some 3.5 billion tonnes of overburden will be mined and located into Overburden Storage Areas (OSA) in and around the final pit. Waste movement within the life of mine plan includes mining of unmineralised Banded Iron Formation (BIF), Mt. Whaleback Shale, Mt. McRae Shale, Mt. Sylvia Formation, and parts of the Wittenoom and Jeerinah Formation. All of these units, with the exception of the BIFs, contain zones with varying amounts of sulphides and carbon, hereinafter referred to as ‘reactive shale’. Reactive shale at Mt. Whaleback has the potential to self-heat and can react with some explosives, resulting in spontaneous explosion. Furthermore, with respect to the focus of this paper, sulphide rich zones also have the potential to generate acid rock drainage (ARD).

This paper will focus on the approach undertaken at Mt. Whaleback with respect to management of overburden storage areas (OSAs). A review of 12 years of large-scale cover system field trial performance monitoring data is presented in light of its (i.e. the cover system) application to closure of OSA containing reactive shale. The field response and predictive modelling completed to gain further understanding for long-term performance of the cover systems is also be presented. Finally, application of the optimum cover system and landform evaluated as part of the large-scale field trials is demonstrated through presentation and discussion of Mt. Whaleback’s plan for closure of the W40 North OSA.

1 Introduction

The Mt. Whaleback iron ore mine is located in the Hamersley Iron Province in the northwestern corner (Pilbara Region) of Australia and situated adjacent to Newman, Western Australia (WA), approximately 1,200 km north-northeast of Perth (Figure 1). Development of the Mt. Whaleback mine commenced in 1968. The mine currently produces approximately 18 million wet tonnes of saleable product and 53 million tonnes of waste material annually. Ultimately, some 3.3 billion tonnes of waste rock will be mined and located into overburden storage areas (OSAs) in and around the final pit.
The OSAs contain unoxidised waste rocks, which possess varying amounts of carbonaceous matter and sulphide minerals. Approximately 15% of the waste rocks contain elevated levels of carbon and sulphides, with negligible carbonates, and are referred to as ‘reactive shales’ (Waters and O’Kane, 2003). The nodular zone of the Mt. McRae Shale has sulphide values greater than 20% by weight. The oxidised waste rocks at Mt. Whaleback are geochemically similar and deficient in pyrite as well as carbonates (Campbell, 1996), and are classified as ‘inert’. The reactive material is potentially acid forming (PAF) (Porterfield et al, 2003), with certain components also being prone to spontaneous combustion (Waters and O’Kane, 2003).

The climate of the Pilbara region is semi-arid, tropical with a mean annual rainfall of approximately 320 mm. There are two distinct seasons, a hot, wet summer (December to April), and the rest of the year, which is more temperate and generally experiences low rainfall conditions. Rainfall generally occurs in high intensity, short duration events, usually associated with cyclonic events in the summer months. The annual potential evaporation typically exceeds 3,000 mm. (O’Kane et al., 1998, 1999, 2000).

2 Background

Porterfield et al. (2003) summarise the acid rock drainage (ARD) management strategy for the Mt. Whaleback operation. A key component of the ARD management strategy is research into the application of dry cover systems. The dry cover systems research program was initiated in 1996, and is currently in progress. The objective of the research program is to evaluate the effectiveness of dry cover systems at the Mt. Whaleback site (as well as at satellite ore-bodies) to buffer rainfall incident to the OSA surface, such that seepage into and through OSAs is minimal; thus providing an at source control of ARD.

The two principal objectives of a cover system are to control the ingress of oxygen to the underlying reactive mine waste and/or to control infiltration of meteoric waters to the underlying waste. Additional objectives include: control of consolidation and differential settlement; oxygen consumption (i.e. organic cover materials); reaction inhibition (i.e. incorporate limestone at the surface which does not prevent oxidation but can control the rate of acid generation); control of upward capillary movement of process water constituents/oxidation products; and to provide a growth medium for revegetation.

It is difficult and usually not economically feasible in arid and semi-arid climates to construct a cover system that contains a layer that remains highly saturated thereby reducing oxygen transport. The cover system will be subjected to extended dry periods and therefore the effect of evapotranspiration will be significant. However, subjecting the cover system to evaporative demands can be beneficial in arid and semi-arid climates, and result in a reduction of infiltration to the underlying sulphidic waste material. A homogeneous upper cover surface layer with a well-graded texture and possessing sufficient storage capacity can be used to retain water during rainfall events. Subsequent to the increase in moisture storage in the well-graded layer, it would release a significant portion of pore water to the atmosphere by evapotranspiration during
extended dry periods, thereby reducing the net infiltration across the cover system. The principal objective is to control acidic and/or metaliferous drainage by preventing moisture movement into and through the waste material. A cover system with the above objectives is often referred to as a 'moisture store-and-release' cover system.

3 Characterisation and management of overburden at Mt. Whaleback

3.1 Material characterisation

Three waste materials have been identified at Mt. Whaleback: Banded Iron Formation (BIF), PAF and inert. The BIF is the dominant waste rock type consisting primarily of alternating bands of quartz and hematite (Porterfield et al., 2003). The run-of-mine BIF material can be dumped in benches up to 80 m high and the inert material can be dumped in 20 m high benches. These materials can be used to encapsulate the PAF material to prevent adverse effects of this reactive material (Sommerville and Heyes, 2009).

The PAF material is primarily a part of the Mt. McRae Shale Formation, the Jeerinah Shale Formation and the Whaleback-Fault Shale member of the Brockman Iron Formation (Porterfield et al., 2003). There are two major effects of the PAF material at Mt. Whaleback; spontaneous combustion and potential generation of ARD. Spontaneous combustion can result in in-pit fires and high temperature in blast holes, which increase the risk of premature detonation. This is managed by characterisation and use of high temperature explosives in identified areas. PAF (pyritic material) prevents successful revegetation and discharges of water to the surrounding environment. This characterisation has an environmental effect and is also against mining lease approvals where the aim is to hand back the leasehold to the State “free of all encumbrances” (Sommerville and Heyes, 2009).

3.2 Geochemistry

All of the waste rock types at Mt. Whaleback, excluding some sections of Mt. McRae Shale, have a very low acid neutralizing capacity (ANC). The BIF material, for example, typically has an ANC value of 5 kg $\text{H}_2\text{SO}_4$/t. Geochemical data of the Mt. Whaleback waste rock suggests a low to very low buffering capacity. The BIF, Whaleback Shale, Jeerinah Dolerite and Mt. McRae Upper Shale have all been classified as non-acid forming (NAF) materials. The Jeerinah Shale is considered to have a low ARD risk and is expected to have long-term ARD or revegetation problems when co-disposed with these non-acid forming materials (NAF) materials (Porterfield et al., 2003).

The Mt. McRae Upper Shale (low ANC zones), Mt. McRae Nodule Shale, Mt. McRae Lower Shale, Mt. McRae Lower Chert and Whaleback Fault Shale have been classified as highly reactive PAF material. During investigations by the site, the role of bacteria in the oxidation of the Nodule Shale sulphides was studied. These investigations concluded that bacterial activity is not the limiting factor for pyrite oxidation and acid generation in the Mt. McRae Shale. Instead, it was expected that transport and availability of oxygen at the mineral surfaces are the limiting factors (Porterfield et al., 2003).

The nodular zone of the Mt. McRae Shale unit is considered the major geochemical issue on site, as it is one of the highly reactive PAF materials capable of generating ARD. If air movement is left unrestricted within the OSA stockpiles, coupled with the low ANC properties of the waste rock, the Mt. McRae Shale PAF materials will have a significant impact on the overall stockpile geochemistry (Porterfield et al., 2003).

3.3 Management strategy

The potential for acid formation by pyritic materials, such as those in the waste rock, has the most impact on the planning and management of OSAs. Currently, Mt. Whaleback operations manage the PAF materials by encapsulating the pyritic materials using a minimum of 5 m of inert material. Encapsulation minimises percolation and leakage to the environment. The size of the cell should target maximum covering before the wet season (Sommerville and Heyes, 2009). Prior to the 1990s, ARD was not identified as an issue because of low annual rainfall and high evaporation rates experienced at the site. Following heavy rainfall in 1995 (204 mm in February), acidic runoff from the OSAs was detected entering Whaleback Creek. Detailed site investigations and consultation with Government regulatory authorities resulted in construction of a
permanent retention facility. The ARD dam (wall length 1,000 m, capacity 821 Million Litres (ML)) was constructed in late 1996 to prevent movement of ARD off-site (Porterfield et al., 2003).

Since 1996, numerous projects have been undertaken to manage the ARD at Mt. Whaleback. These include:

- Establishment of the Acid Rock Drainage Control Group committee;
- Development of a short, medium and long term strategy;
- Geochemical characterisation of all rock types;
- Tracer studies to confirm flow pathways and water sources;
- Modifications to the ARD dam to increase storage capacity and evaporative surface area;
- Research into dry cover systems as part of a closure strategy; and
- Implementation of closure solutions.

An integrated ARD management plan was formulated and approved to affect the strategy and to satisfy governmental requirements. This management plan (Acid Rock Drainage Control Group, 1998) was implemented to provide a systematic approach to the efforts to manage ARD and to provide mechanisms for review, modification and improvement. The ARD management plan is further enhanced with a comprehensive monitoring system, as well as an annual water modelling and contingency program. Water monitoring consists of surface, alluvial and groundwater sites, both outside and within the Mt. Whaleback pit, with specified schedules for sampling and analyses. These frequencies are modified by triggering events such as containment levels or by emergency system activation, such as cyclone alert levels (Porterfield et al., 2003).

4 Cover system design

O’Kane et al. (1998, 1999, and 2000) summarise the cover system design, construction of field trials, and installation of the field performance monitoring systems. However, the information is summarised here for clarity.

4.1 Physical characterisation of Banded Iron Formation (BIF) material

The run-of-mine BIF oxidised material represents the most promising cover material at the site. A field-sampling program completed in October 1996 included collection of 27 bulk samples (material <300 mm) in 200 litre drums. The samples and locations were chosen to represent BIF material that had been placed in OSAs, as well as material from within the open pit, that had been drilled and blasted, but not yet hauled to an OSA.

Particle size distribution (PSD) analysis for the bulk samples was completed. Typical PSD curves for the BIF cover material as well as the Mt. McRae Shale waste rock (see Waters and O’Kane, 2003, for description of the Mt. McRae shale) are shown in Figure 2. The materials are generally coarse in texture and relatively well-graded, and while being physically similar are geochemically dissimilar (Porterfield et al, 2003).
Moisture retention curve (MRC) and saturated hydraulic conductivity ($k_{sat}$) testing using large-scale (30 cm diameter) laboratory testing apparatus was completed on representative samples that were chosen based on a review of the PSD data. The large-scale apparatus ensured that as much of the material as possible was included as part of the test (larger sized particles up to material <75 mm), such that a minimal amount of correction for over-size material was required to the MRCs measured in the laboratory. The samples chosen for testing represented the coarse, fine, and intermediate textured BIF material. The drying portion (i.e. increasing matric suction) of the MRC is shown in Figure 3. The BIF cover material has a distinctive low air entry value with a gradual decrease in the slope of the MRC near the residual suction, as shown in Figure 3. The $k_{sat}$ measured in the laboratory was in the range of $5 \times 10^{-2}$ cm/s, although this value was lower (approximately 1.5 orders of magnitude) for higher density conditions typical of compacted haul truck traffic surfaces.
4.2 Soil-atmosphere cover system design modelling

Preliminary soil-atmosphere cover system design modelling completed to assist with design of cover system field trials (test plots) concluded that a 2 m BIF cover thickness would be sufficient at preventing high rates of net percolation based on the 30-year maximum annual rainfall (≈ 500 mm) for bare surface conditions (i.e. no vegetation). The soil-atmosphere modelling predicted that net percolation rates much less than 1% of annual rainfall would result from a single year rainfall of 500 mm. Although numerous simulations were completed during this preliminary modelling, the occurrence of multiple extreme rainfall years and the resultant performance of the cover systems were not considered at this stage of the project.

5 Construction and monitoring of TP#1 and TP#2

Two 1 ha field test plots were constructed in February 1997 on a relatively horizontal surface to verify the results predicted by the soil-atmosphere model. The test plots (TP) were constructed with common operational considerations. Test Plot #1 (TP#1) had a cover thickness of 2 m, while two lifts of material were placed during construction of Test Plot #2 (TP#2) to achieve a 4 m cover layer thickness. The undulating surface created by ‘paddock’ dumping was not levelled in order to maintain short surface run-off paths during the life of the test plots. TP #1 and TP#2 were left as “bare surface” field trials in order to develop a conservative estimate of cover system performance at the site. In other words, no topsoil was applied, and the field trials were not seeded. Hence, moisture is only ‘removed’ from the cover profile through evaporation (i.e. there is no transpiration component).

A field performance monitoring system was installed to measure actual evaporation, potential evaporation, rainfall, net percolation (large-scale lysimeters), and in situ temperature and moisture (suction and volumetric water content) conditions at TP#1 and TP#2. The in situ monitoring profiles included sensors installed into the overlying BIF cover material, as well as underlying reactive shale (Figure 4).

The large-scale lysimeters consist of large HDPE tanks (2 m in diameter and 2.5 m deep) that were installed below the original waste rock surface prior to the placement of the cover material. A piezometer was installed into the centre of the lysimeter for manual measurements. The water level is checked in the
piezometer on a monthly basis. If there is a rainfall event, the water level is checked immediately following the event and frequently after that. After the water level is measured, the water is pumped out of the lysimeter.

Figure 5 shows the annual rainfall recorded at the field trial area since monitoring commenced in 1997. The data is presented for 12 month periods from October to September in order to straddle the wet season when the large majority of rainfall occurs. During the first year of monitoring after construction of TP#1 and TP#2, the site experienced weather conditions similar to the average annual rainfall. During the second and third years, however, extreme weather events occurred at the site, which resulted in 727 mm rain recorded during the period from October 1998 to September 1999, and 1,162 mm during the October 1999 to September 2000 monitoring period. The subsequent four years (October 2001 to September 2004) were also well above average in terms of rainfall recorded at the field trial area as 548 mm, 382 mm, 453 mm, and 485 mm of rainfall was recorded, respectively. The average annual rainfall for the October to September period for the twelve years of monitoring data is 474 mm. On a calendar year basis, this equates to 486 mm on average, which is well above the long-term site average of approximately 320 mm, despite there being several years during the twelve year period where rainfall was less than average.

Figure 6 shows the change in the volume of water stored during the entire monitoring period, up to and including September 2009, for both TP#1 and TP#2. The volume of water is an estimation of the ‘depth’ of water if the solid, air and water components of the cover profile were separated. For example, if a volumetric water content of 0.20 was measured in a 1.0 m thick cover material profile with a porosity of 0.30, the ‘depths’ of soil, air and water would be 700 mm, 100 mm and 200 mm, respectively. The data shown in Figure 6 are based on in situ volumetric water content sensors installed throughout the cover profiles.

![Figure 4 Test plot instrumentation showing Bowen ratio monitoring system (a), automated soil monitoring system (b), and meteorological station (c).](image-url)
Figure 5  Annual rainfall recorded at the cover system field trial area and net percolation measured at TP#1

Figure 6  Cumulative change in water storage at TP#1 and TP#2 since the onset of monitoring

The annual change in storage at TP#1 changes substantially in response to rainfall, illustrating the cover system’s ability to store and release moisture as evaporation. The total volume of moisture in the profile remained unchanged after the first year of monitoring at TP#1. However, for the subsequent to extreme wet years, as well as the following four above average, and the next five years, at the end of each wet season
there was an additional 20 to 40 mm of water in the 2 m cover profile at TP#1. It was not until the below average rainfall years recorded in 2006-07 and 2007-08 where moisture conditions with the TP#1 profile were reduced to near that which was recorded in July 1997 (i.e. the start of the cover monitoring program).

From 2000 to 2004, the volume of water stored within the TP#1 cover profile would increase from approximately 50 mm to >200 mm as a result of wet season rainfall events described above. As a result of the average to lower than average rainfall from 2005 to 2008, the spikes in water storage were much less pronounced, indicating less water entering the cover profile and ultimately lower net percolation from the base. In March 2009, a similar magnitude spike in moisture storage occurred indicating that for the first time in a few years there was a substantial wetting front within the cover profile that may ultimately lead to net percolation, although this will depend on rainfall conditions during the current monitoring period.

Water storage within TP#2 profile increased significantly in response to the large cyclone events beginning in 2000 as moisture infiltrated deeper in the cover profile past a depth of 2 m. The total volume of water stored in the cover profile at the end of each wet season decreased from 2001 to 2004 and then began a sharper decrease with the beginning of average to below average rainfall years in 2005. Since 2008, the volume of water stored within the TP#2 profile has remained near its initial value from the onset of monitoring in 1997. Hence, the influence of the extreme climate conditions in 1998-99 and 1999-00 extended nearly ten years past their occurrence.

Annual net percolation as a percentage of rainfall for the monitoring period is summarised in Table 1 for both TP#1 and TP#2. Net percolation as a percentage of rainfall for each year at TP#1 ranged from a 0.0% (for monitoring years 1, and 7 through 12) to 15.2% for monitoring year 6 (i.e. 2002-03). It is noteworthy that the highest annual net percolation rate did not occur during the wettest rainfall year, which is a function of the time required for net percolation to report to the base of the lysimeter. In addition, it is hypothesised that if the years following the extreme rainfall recorded in 1999-00 had been drier, then not nearly as much net percolation would have reported during the subsequent years.

No net percolation has been recorded in the 4 m cover system field trial (i.e. TP #2), as summarised in Table 1.

**Table 1  Summary of annual net percolation amounts and rates as a percentage of rainfall since commencing monitoring of the TP#1 and TP#2 cover system field trials**

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall (mm)</th>
<th>Test Plot #1</th>
<th>Test Plot #2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>mm (%age of rainfall)</td>
<td>mm (%age of rainfall)</td>
</tr>
<tr>
<td>1997-98</td>
<td>294</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>1998-99</td>
<td>727</td>
<td>18 (2.5%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>1999-00</td>
<td>1162</td>
<td>103 (8.9%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>2000-01</td>
<td>548</td>
<td>64 (11.7%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>2001-02</td>
<td>382</td>
<td>34 (8.9%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>2002-03</td>
<td>453</td>
<td>69 (15.2%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>2003-04</td>
<td>485</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>2004-05</td>
<td>312</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>2005-06</td>
<td>437</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>2006-07</td>
<td>275</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>2007-08</td>
<td>241</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>2008-09</td>
<td>378</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Average</td>
<td>474</td>
<td>24 (5.0%)</td>
<td>0 (0.0%)</td>
</tr>
</tbody>
</table>
6 Long-term performance of TP#1 and TP#2

Soil-atmosphere modelling was completed for TP#1 and TP#2 in 2010 to provide further understanding for long-term performance of the cover systems. The objectives were to simulate the measured field responses in order to obtain a set of calibrated hydraulic properties for the cover and waste rock materials and to evaluate cover performance over varying scenarios over a 100-year period using this calibrated model. The scenarios used in this study included the impact of vegetation and climate change on the performance of the cover systems. The vegetation scenarios included the use of “dense” and “sparse” vegetation scenarios, as well as the base case scenario where the surface is left bare. The climate change scenarios included wetter and drier climates (374 mm/yr and 243 mm/yr averages), as well as the base case 100-year climate (historical 337 mm/yr average). The key performance criterion for the cover system was the resulting net percolation rate from the cover system into the underlying waste rock.

The field response modelling was divided into two tasks. First, a fully discretised model of each site, one in which each monitored soil depth is simulated with its own unique set of material properties, was simulated. The calibrated model inputs of the discretised model were then compared to determine with increased objectivity the locations of layering within the soil system and to determine generalised material properties for these layers. Generalised models were then completed using the layering and material properties determined from the comparison. Acceptable results attained from the generalised models indicate that the model inputs can be used to provide further understanding for long-term cover performance.

Comparisons of the measured and simulated amounts of water stored within the top 2 m of TP#1 and TP#2 cover profiles are shown in Figures 7 and 8, respectively. The figures show that the generalised models adequately predict the trends and magnitudes of the storage changes measured in the field over the 12-year monitoring period. Comparing the material characteristics calibrated for the discretised field response models indicate that the model profiles can be adequately simulated using the same set of material properties to represent the cover and underlying waste rock. Hence, the calibration field response models of TP#1 and TP#2 were repeated using generic model configurations to demonstrate that the simulations can be simplified.

Figure 7  Comparison of field and simulated cover water volumes for TP#1
7 Implications of current and future performance

7.1 Evaluation of predicted long-term performance

The field response model calibrated to TP#1 conditions was used to gain further understanding for long-term performance of the 2 m cover system at Mt. Whaleback. The model used the TP#1 generalised cover system and the “historic” 100-year climate database. The historic climate database was estimated from regional historic climate data, which had a 100-year average annual rainfall of 337 mm.

The probability of rainfall and net percolation exceeding different values for any given year are shown in Figure 9. On average, just over 1% of rainfall (5 mm) was predicted to report as net percolation for each year. However, as shown in Figure 9, only 45% of the years register any net percolation with the largest two events (141 mm and 146 mm) representing 57% of the total net percolation occurring during the 100-year period.

The results shown in Figure 9 assume bare surface conditions and any runoff predicted by the model reports as surface runoff exiting the landform (i.e. no ponding). Assuming any runoff predicted by the model would pond, and thus be available for surface infiltration or evaporation, increases the 100-year average annual net percolation to approximately 11 mm (~ 3% of the 100-year average annual rainfall of 337 mm).
8 Application of cover system and landform design

In 2003 Mt. Whaleback initiated research on additional field trials combined with landform design evaluation as part of final surface contouring of the W29 OSA. The objective was to trial an alternate surface contour to the hummocky block dumped surface implemented at TP #1 and TP#2, as well as begin monitoring to assist with understanding the influence on vegetation to cover system performance at the site.

Reactive carbonaceous shale was encapsulated in W29, and the two lifts of ROM BIF material was placed on the surface, resulting in a total of approximately 4 m of cover material. The surface of each lift was ripped in perpendicular directions to minimise the potential for segregation and thus preferential ‘macro’ pore flow during high rainfall events. This phenomenon was observed during an extreme event at TP #1 during the 1999-2000 monitoring year.

The top of W29 was delineated into catchment areas ranging from approximately 1/3 to 1/2 of a hectares by bunds that were constructed from additional loads of ROM BIF material. Prior to a catchment area being ‘close out’ with the final bund, topsoil with a nominal thickness of 10 cm was placed in the area. This landform approach allowed for topsoil to be placed and seeding to occur in a much more practical manner as compared to that implemented at TP#1 and TP#2. The different catchment areas on W29 were seeded with different seed mixtures, ranging from cover crops to native seed mixes of grasses and shrubs. A total of nine catchment areas were established, including a control area. Monitoring similar to that established at TP#1 and TP#2 was installed (save for the large-scale lysimeters), and has been ongoing since 2003 in two of the catchment areas on W29 seeded with native species. These are referred to as Test Plot #4 (TP #4) and Test Plot #5 (TP #5).

Construction of the W29 landform and cover system provided the opportunity for Mt. Whaleback to further enhance closure planning for the site as a result of the understanding with respect to the dynamic behaviour of climate and the resultant impacts on cover system performance at TP #1 and TP#2. In 2009, the lessons learned at TP #1, TP #2, TP #4, and TP #5 were incorporated into the design of the landform and cover
system the W40 North OSA. This OSA is currently being constructed with the landform design implemented in 2010.

The closure plan of the W40 North OSA includes the use of a “store-and-release” cover system, similar to those evaluated at TP#4 and TP#5. Individual catchment areas, delineated by interior bund walls, are included as part of the final cover system design to provide control of runoff during extreme weather events, while allowing a relatively flat surface to be maintained. The latter condition more readily allows for placement of topsoil for reclamation of the OSA. The size of the catchment areas, slope of the surface within the catchment area, the bund wall heights, and orientation of the bund walls in relation to the sloping surface of the landform were designed using a 1:1,000 year return period 24-hr storm event. A set of design guidelines were developed based on these criteria, which were then used to develop the final landform. The objective was to provide the planning and operations team at Mt. Whaleback with a landform design that was flexible enough to construct with the large-scale mining equipment on site (within the design guidelines), yet sufficiently robust so that the percolation rates and conditions measured over the past 12 years and TP#1 and TP #2 could be achieved for the W40 North OSA cover system as a whole.

8 Summary

The data presented for the twelve-year monitoring period demonstrates the potential for success of the ‘moisture store and release’ type cover system at the Mt. Whaleback site. Improved understanding in performance of the moisture store and release ARD control cover system trials is a direct benefit from the current field performance-monitoring program. Key factors controlling performance will continue to be developed and understood through continued monitoring of the bare surface and vegetated cover system field trials.

The following are key lessons learned from the Mt. Whaleback ARD control cover system field trials.

1. The importance of field performance monitoring over an extended time frame is clearly illustrated by the Mt. Whaleback cover system monitoring database. The cover system has responded differently for each year of the twelve-year monitoring period with respect to changes in moisture storage and net percolation.

2. Re-visiting the soil-atmosphere cover design model is fundamental because it allows for development of a calibrated model, which can be used for developing further understanding for long-term performance. The calibrated model also provides the opportunity to highlight aspects of cover system performance that require further investigation and research, as well as predict future performance of the cover systems undergoing potential climate change conditions and revegetation.

3. Net percolation measured over the twelve-year period did not agree with the net percolation predicted by soil-atmosphere cover design modelling completed prior to construction of the field trials. The difference between the climate years modelled beforehand, and the climate conditions during the monitoring period are clearly a significant reason for the difference between the predicted and measured performance, as well as the development of preferential flow paths from material segregation during construction.

4. Transpiration is a key aspect of long-term performance of a store and release cover system. In general, bare surface conditions (i.e. no vegetation) can control net percolation to very low rates for average climate conditions, or even moderately above average rainfall conditions. However, for extreme wet conditions, or successive years of wetter than average conditions, transpiration is required to control net percolation to very low rates (i.e. less than 1%).

5. Research on transpiration rates and rooting characteristics of native grasses and shrubs is required to ensure that defensible predictions of long-term performance can be developed for store and release cover systems. Although not within the scope of this paper, research on the benefits due to the presence of vegetation (and this transpiration) on performance of the cover system is in progress as part of additional cover system field trials established in 2003 at Mt. Whaleback.

6. Mt. Whaleback is in the process placing the measured and predicted performance of the cover system for OSAs into context with seepage characteristics (flow and storage) and geochemistry.
within the OSAs. In effect, ‘linking’ cover system performance to surface water and groundwater impacts at the site. Discussion on this aspect of closure planning for the site is not within the scope of this paper.

7. There is no unique set of input conditions to a field calibrated model. However, the moisture retention and saturated hydraulic conductivity properties developed from field data and during model calibration for this project were different than those developed in the laboratory beforehand. The difference between the laboratory material properties and those developed based on field conditions highlights the need to validate laboratory results in the field, because it is difficult if not impossible to properly replicate field conditions in the laboratory. There are physical, biological, and chemical processes that impact on as-built performance, which generally cannot be simulated in the laboratory.

References


