LONG TERM ACID ROCK DRAINAGE (ARD) MANAGEMENT AT PT FREEPORT INDONESIA[1]

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Abstract. Freeport Indonesia currently operates a 760,000 t/d open pit mine that will operate until 2015, with the resulting placement of approximately 2,750 Mt of overburden rock.

Laboratory column tests, 500-tonne test pads, and industrial-scale dump trials have been highly successful in gaining an understanding of ARD evolution, metal release kinetics, and the development of key design specifications for long-term ARD control through limestone blending and limestone covers at the Grasberg Open Pit Mine.

Ongoing work will focus on evaluating and monitoring the effectiveness of limestone blending and limestone covers as an integral part of life-of-mine overburden management practices.

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Introduction

The Grasberg open pit Cu and Au mine is operated by PT Freeport Indonesia (PTFI) and located in the high equatorial mountains of the Indonesian province of Papua (Fig. 1). The climate is alpine/sub-alpine with little seasonal variation in temperature or rainfall. Temperature ranges from 2°C to 14°C and annual rainfall in the mining area is about 4,000 to 5,000 mm.

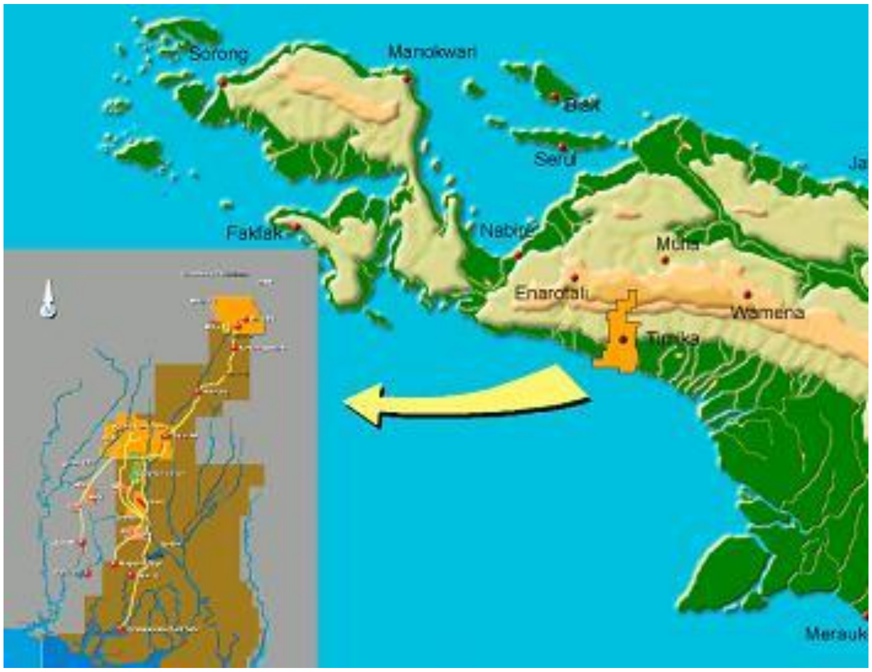

Figure 1. Map of PT Freeport Indonesia Contract of Work Area

Daily mining rates are currently 760,000 t/d of which, approximately 200,000 t/d is ore. Open pit mining will continue until 2015 and will result in the placement of approximately 2.75 billion tonnes of overburden rock. An Overburden Management Plan (PT. Freeport Indonesia (PTFI), 2004), approved by the Indonesian government, and updated on a regular basis provides both technical guidelines and the management tools necessary to effectively mine overburden rock from the Grasberg open pit and place it in engineered stockpiles with minimal long-term impact to safety, environmental and geotechnical.

Acid Rock Drainage (ARD) management and mitigation is obviously a key aspect of overburden management and has been fully integrated with both short and long-term mining objectives. Ongoing site based research and system monitoring will continue throughout the mining period, and into the open pit closure period to ensure that ARD impacts are fully understood, managed and mitigated.

The Grasberg Deposit

The limestone hosted, Grasberg porphyry Cu/Au deposit, also referred to as the Grasberg Igneous Complex (GIC), is a cone shape deposit, which had an elliptical surface expression measuring approximately 2.3km by 1.7km at the 4,100m elevation, with the cone narrowing to about 900m in diameter at the 3,000m level, which is the approximate ultimate pit depth. Copper is primarily in the form of chalcopyrite with some bornite. Below the 3,000m level, the deposit will be mined by underground block-caving methods once open pit mining is completed in 2015. The floor of the Grasberg open pit is currently 500m below the original topography and 1.0 to 1.2 km in diameter at the top. Surface water entering the open pit is drained through the pit floor to a series of underground dewatering drifts and directed to the mill for use as process water.

The current overburden mining rate is approximately 550,000 t/d at a stripping ratio of 2:5. This will continue until 2007 at which time the mining rate will decline. Overburden placement at the Grasberg mine currently occurs adjacent to final pit limits within the Carstenszweide and the West Grasberg, which includes Wanagon Valley and Lower Wanagon (Fig. 2). As of mid-2005 some 1,250 million tonnes of overburden had been mined from the Grasberg. Starting in late 2003, a portion of the overburden has been placed in Lower Wanagon, below the Wanagon Valley using a conveying and stacking system. The total volume of overburden rock to be produced from the Grasberg open pit will be approximately 2.75 billion tonnes.

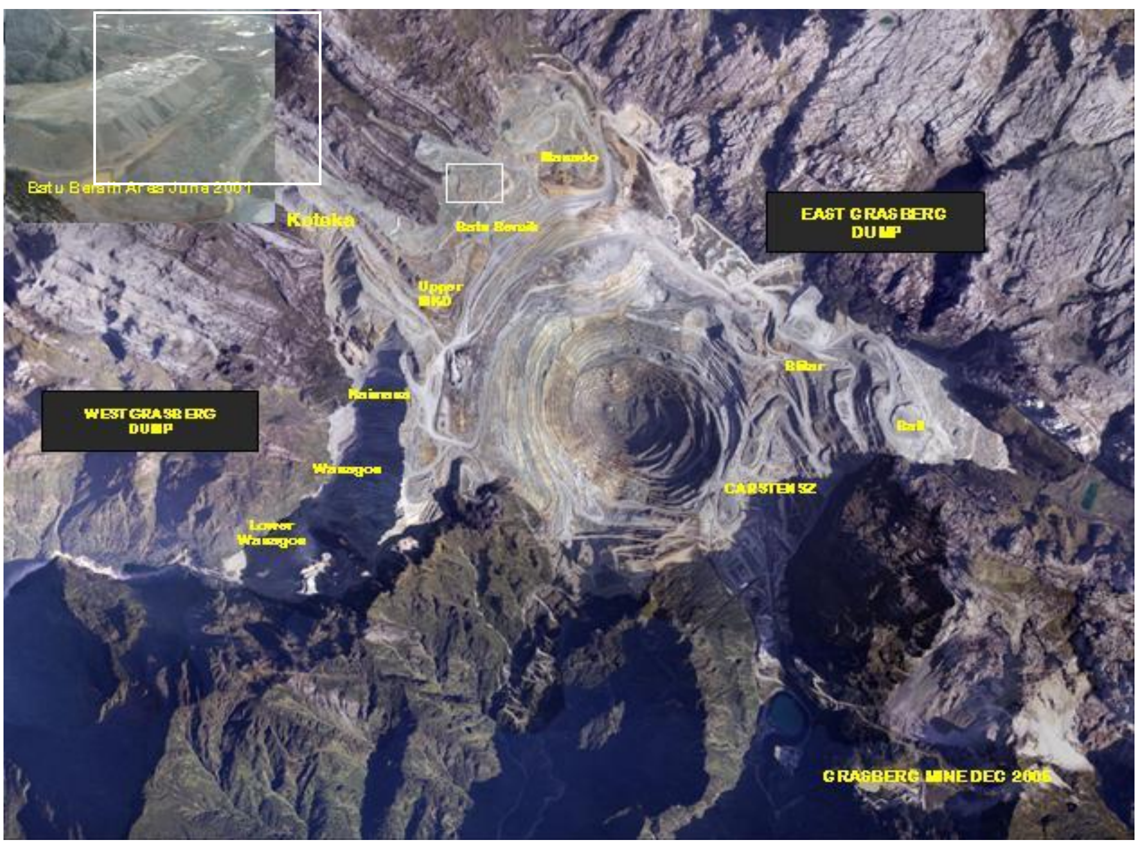

Figure 2: Overburden placement layout around the Grasberg Open Pit Mine and dump trial location (inset)

ARD Management Strategies

The key Overburden Management objectives related to ARD management will ensure that throughout the operation, closure and beyond:

- Limestone rock mined as overburden will be used effectively to mitigate ARD and ensure stockpile geotechnical stability; and
- Heavy sulfide zone material, a high pyrite "skin" around the intrusive complex, will be selectively mined and segregated to facilitate ARD collection.
- ARD formation will be mitigated, collected and/or treated to minimize impacts to surface water and groundwater quality;

PFTI has incorporated into its strategies an approach to ARD management that considers applicable regulatory and environmental practices, the large scope and scale of the Grasberg open pit mining operation, and the unique challenges presented by the physical, topographical and geological location. Extensive research has been completed or is currently underway to:

Confirm the overburden geochemical and geotechnical characteristics;

- Categorize the potential for acid generation within all overburden rock types; and
- Assess acid generation mitigation options through long-term full-scale test stockpiles and laboratory column tests.

In 1996 PTFI initiated unprecedented overburden ARD generation investigations that ranged from laboratory scale tests (leach columns), to 500-tonne field test pads (Menado), instrumented full-scale stockpile studies (Batu Bersih) and in-situ characterizations of weathered overburden during re-mining (Menado autopsy) of overburden stockpiles as the ultimate pit limits were extended. The results of these investigations have been used to:

- Evaluate stockpile geochemistry;
- Define scale-up factors to quantify the acid generation and metal leaching rates of the overburden;
- Estimate current and future potential ARD generation (including ARD kinetics and key oxidation and release rate data for geochemical modeling); and
- Identify control options.

Standard ARD characterization test work was used to classify the geochemical overburden types on the basis of ARD and metal leaching potential and ARD risk. A simplified color coding system of green (acid consuming or non-acid generating), blue (1 – 35 kg H_2SO_4/t acid generation) and red (greater than 35 kg H_2SO_4/t) is used to facilitate mine planning and overburden placement. The acid generating capacity and kinetics predicted from Net Acid Producing Potential (NAPP), Net Acid Generation (NAG) and mineralogy data are compared with the time evolution of acid and metal loads released from laboratory columns, field test pads and trial stockpiles to predict potential acid generation and to correlate field measurements against previous predictions for ARD evolution.

In late 2004, results from the Batu Bersih trial stockpile research confirmed that the ARD kinetics observed in laboratory leach columns and the Menado leach pads were consistent with what could be measured in a full-scale stockpile (Miller.S, 2004). Excavation of the Batu Bersih trial stockpile produced the following key findings:

- Internal limestone layers placed by truck dumping at a natural angle of repose are ineffective for ARD control and may in fact accelerate ARD generation by promoting oxygen transfer within the stockpile (Fig. 3).

Figure 3: Exposure showing oxidized face zone and convective venting from a sloping coarse layer which appeared to have accelerated oxygen transfer within the stockpile.

- Horizontal limestone covers, comprised of coarse run-of-mine limestone, of approximately 2 m in thickness resulted in a downward neutralization rate of about 0.2 – 0.5 m/year.
- Weathered limestone, with a significant component of fines, results in a lower infiltration rate, restricting downward seepage, and providing a less effective cover. Interestingly, the weathered limestone does not provide a sufficiently impervious cover to reduce infiltration to zero (Fig. 4).
- Trials involving limestone blending prior to placement, for example using a conveyor and stacker system confirmed that limestone blending can provide effective and long term ARD oxidation control (Fig. 5). The critical criterion being to ensure that the relatively coarse limestone is appropriately mixed with the relatively finer sulfide minerals.

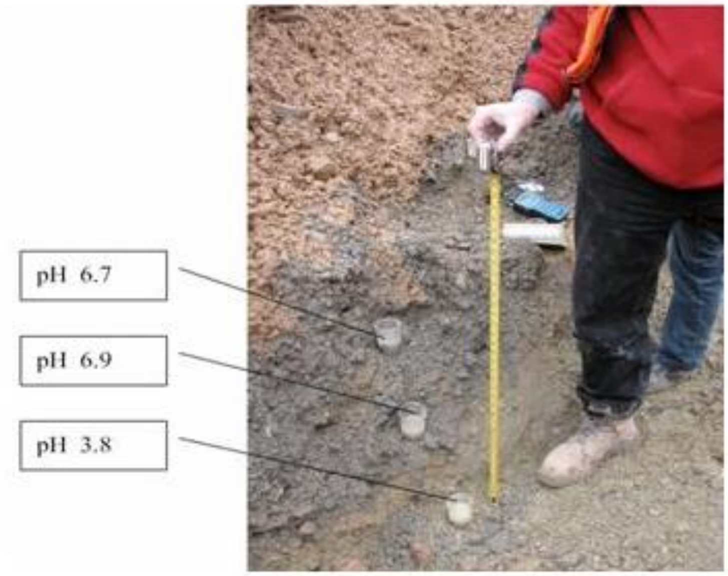

Figure 4: Excavation in Pad 1 showing a weathered limestone cover (brown layer), over a 0.5 m thick grey reaction layer, migrating downwards into an acid generating blue waste

Figure 5: Limestone blended face zone of Panel 7

The findings from the 500-tonne Menado test pads and the full scale Batu Bersih trials confirm that Grasberg overburden material is highly reactive as recorded by the rapid temperature increases within the stockpile (indicative of sulfate oxidation) within the first year, rapid increases in leachate sulfate content through the first 2-3 years, followed by a long-term increase in leachate pH (Miller.S et al, 2003a). Leachate chemistry (sulfate and Cu concentrations) appears to pass through a maximum in less than 24 months, and then enters a long-term decline (Fig. 6 and 7).

Subsequent covering with limestone results in alkaline infiltration, which promotes the formation of armoring layers resulting in the progressive, but accelerated, shut down of ARD generation in the underlying layers of acid generating overburden (Miller.S et al, 2003b). Results to date suggest that zones of partially blended or unblended red and blue coded waste may not be a long-term concern.

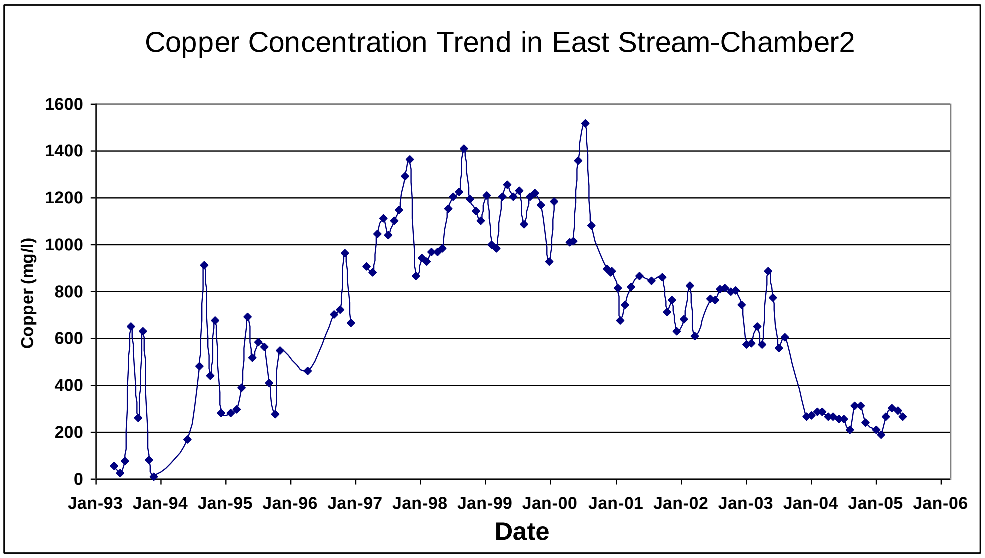

Figure 6: Historical Copper Concentration in East Stream

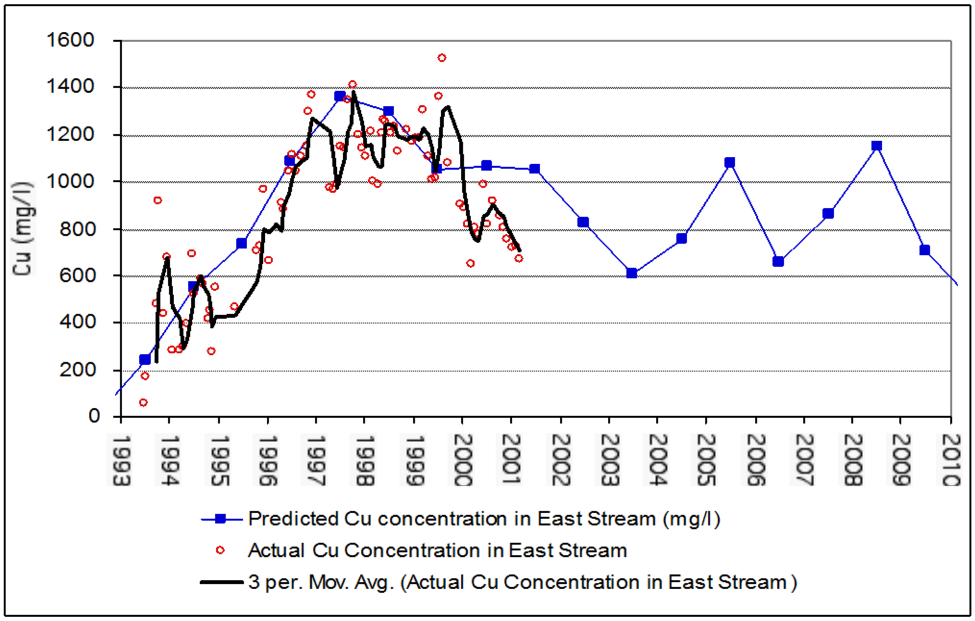

Figure 7: Predicted Cu concentration in East Stream vs . Actual Cu concentration

Observations and measurements made during the post-mortem sampling of the Batu Bersih trial and the findings of investigations carried out previously, have provided important long-term knowledge toward the ongoing ARD management program for Grasberg. The results of research efforts and ongoing monitoring indicate that using a combination of overburden segregation (including limestone management), overburden blending and stockpile covering (also referred to as capping) is the most effective approach for minimizing and managing the generation of ARD from the Grasberg open pit overburden stockpiles, in the short and long-term (Neale.A, 2003). Results from ongoing column and test pad programs indicate that less rigorous design and operational specifications than previously envisaged may be appropriate for dump re-sloping, cover construction and limestone blending.

Current status of ARD Mitigation Strategies

The results of research efforts and ongoing monitoring indicate that using a combination of overburden segregation (including limestone management), overburden blending and stockpile covering (also referred to as capping) is the most effective approach for minimizing the generation of ARD from the Grasberg open pit overburden stockpiles, in the short and long-term.

Overburden segregation:

Overburden segregation is one of the strategies applied in the early stages of stockpile development to minimize the generation of ARD. All overburden is classified according to geotechnical and geochemical characteristics prior to loading on to haul trucks. Based on this classification, once loaded, the overburden rock is directed to specific stockpile locations.

Segregation, as one of the primary ARD control measures for Grasberg overburden management, identifies and manages the placement of materials based on the potential to generate or consume acid. Of particular concern is the high acid generating potential of the Heavy Sulfide Zone (HSZ) which will contribute approximately 100 million tonnes, or approximately 8%, of the overburden generated from the Grasberg Open Pit. The high sulfide content of the HSZ, the high acid generating potential, and the understanding that no placement system will completely avoid the generation of some ARD, dictates that HSZ material should be placed in a confined volume in a location in the West Grasberg Stockpile that will ensure that any ARD generated from the HSZ will flow into the existing ARD capture systems, and be transported to the mill area for lime neutralization. Once the HSZ has been placed, an alkaline cover of either limestone of lime will be placed over the HSZ overburden, with the objective of armoring the HSZ particles and preventing further ARD generation. Results of ongoing cover trials will be used to refine the limestone cover design in terms of required depth of cover, and the most appropriate materials to be placed in the cover. The current overburden management plan ensures that HSZ overburden is not placed in the Carstenzweide, Lower Wanagon or Wanagon Basin overburden management areas.

Overburden blending:

Blending and/or layering of potentially acid forming overburden with acid neutralizing overburden allows alkalinity (in solution) to infiltrate the stockpile, and form armoring layers around reactive sulfide surfaces, effectively isolating the reactive sulfides from water and atmospheric oxygen. Blending is an effective technique to minimize sulfide oxidation as demonstrated in the laboratory column experiments, the 500-tonne test pads and confirmed in the full scale Batu Bersih stockpile trials. Blending is specifically implemented in the development of the Lower Wanagon overburden stockpile to ensure that minimal ARD is generated thus avoiding the need to install an ARD capture and treat system downstream of the Lower Wanagon Overburden Stockpiles.

Performance evaluation to date for the Lower Wanagon overburden stockpile following a placement of at least 20 million tonnes of blended overburden, has shown that measurable acid generation within the Lower Wanagon stockpile has not occurred, and in the short to medium term is not expected to occur. This is due to the relatively high acid neutralizing capacity of the blended materials, due to the specific assignment of limestone to this stockpile in ratio with the potential acid generating of the other overburden rock types. Drainage from this stockpile will be monitored during the active mining period, and through the closure period, as a feedback control mechanism, to verify that the blending programs are in fact being effective.

Limestone covering:

Limestone covers provide a mechanism for continually adding alkalinity to reduce ARD generation through neutralization and mineral armoring processes, as well as enhance geotechnical stability.

Based on the results from site specific laboratory test work in conjunction with full scale field trials (Fig. 8) PTFI will place a 3-5m limestone cover over final stockpile surfaces as they become available over the life of the mine (Neale.A, 2003). The cover is expected to provide an adequate source of alkalinity for ARD neutralization and sufficient alkalinity for armoring of any residual reactive overburden. Stockpiles in which it is deemed that there is sufficient limestone blending to avoid ARD formation in stockpile, a limestone cover will not be required.

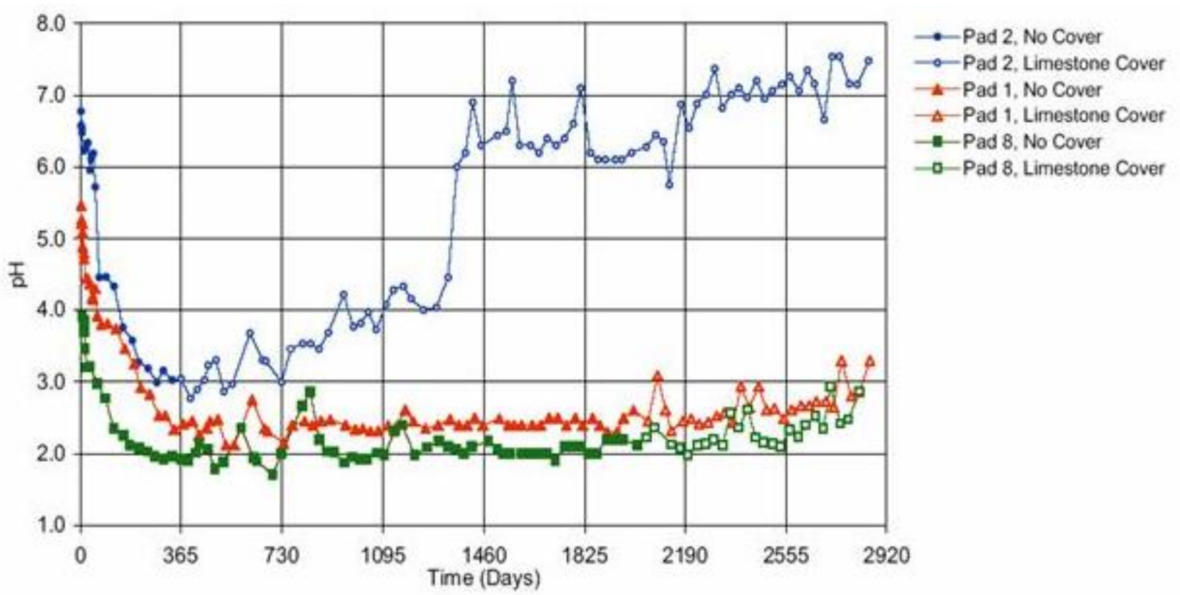

Figure 8: Limestone cover performance at Menado test pads as indicated by pH measurement from various pad types.

ARD collection and treatment:

The acid rock drainage currently generated from the West Grasberg and Upper Wanagon overburden stockpiles is collected through surface water drainage channels, vertical and horizontal pipelines and drifts and directed to the mill where it is neutralized with lime. From the neutralizing plant, water is directed to the tailings thickener for re-use as mill process water.

Other strategies:

Other strategies are integral to minimizing ARD generation including management of surface water and groundwater drainage which involves re-sloping and erosion control to the final top surfaces of overburden stockpiles at the end of mining to provide for positive drainage and ensure slope stability and control erosion.

The key function of the re-sloping of the flat surfaces of the stockpiles is to allow for surface runoff. Where necessary, all large plateau areas of the overburden stockpiles will be regraded towards a central drainage ditch. In general, re-grading of the flat surfaces will minimize ponding and/or infiltration and will provide a margin of safety against any small long-term settlement of the overburden stockpiles.

The long-term surface water control plan and diversion system will direct water away from the open pit, and around the remaining facilities. Maximizing the amount of water that can be collected and diverted around the overburden stockpiles will minimize water infiltration, which in tern minimizes contact with products of sulfide oxidation, and reduce the volume of runoff that will require capture and treatment. Therefore, the closure measures will involve the engineering and placement of surface water flow control structures, such as rock lined drainage channels, drop structures to transport water from one level to the next, and controlled discharge points to avoid plugging and resulting increase in pore pressures within the stockpiles.

Slumping, mass movement, external and internal (piping) erosion can cause physical instability of the overburden stockpiles. Identified long-term failure modes include the possible instability of the Lower Wanagon stockpile as a result of very high seismic loading or significant pore pressures in the embankment, risk of liquefaction of the Carstenzweide foundation, and the influence of the block cave mines, post-closure of the Grasberg. These issues are being addressed through controlled overburden loading, buttressing of stockpiles toes against natural topography, stockpile geometry, and ensuring the inclusion of adequate coarse material to avoid pore pressure build-up.

Conclusions

Implementation of the selected ARD mitigation strategies has shown positive results to date. Preliminary performance evaluation shows that acid generation at Lower Wanagon in the short to medium term is not expected and is less probable in long term providing the acquired knowledge and OBM practice are consistent. This result suggests the effectiveness of the stacker blended placement of OBS at current ANC:NAG ratio into the Lower Wanagon to ensure a minimal ARD generation in the Lower Wanagon stockpile.

Approximately of 2.75 billion tonnes of overburden will be generated from Grasberg Open Pit Mine through the year 2015 and at least 85% will be placed in the West Grasberg area. Most of this overburden will be placed in the Upper Wanagon and Lower Wanagon areas and of this amount approximately 30% of the overburden placed will be acid consuming limestone. The limestone surplus is expected to be adequate for limestone capping of the remaining stockpiles, providing a source of alkalinity for ARD neutralization and the armoring of any reactive overburden which have already been placed. Systems have been installed to capture and treat the existing ARD.

Other strategies that are integral to managing ARD include the placement of a 3-5 meter deep limestone cover, diversion of surface water away from the stockpiles, and management of groundwater drainage. It is critical that strategies continue to be developed that will make maximum use of the available limestone for ARD control. Appropriate overburden control and closure procedures are being developed and implemented through appropriate segregation and blending, groundwater collection, surface water drainage and surface stability and erosion control to ultimately provide the most reliable and feasible mechanisms for minimizing any possible long term impacts.

Ongoing work will focus on evaluating and monitoring the effectiveness of limestone blending and limestone covers to ensure that the current strategy provides assurance for meeting the long-term geotechnical and geochemical objectives as an integral part of life-of-mine overburden management practices.

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References

Neale, A. (2003). "Overview of the ARD Management Program at PT Freeport Indonesia Operations in Papua Province, Indonesia. In *Proceedings of Sixth International Conference on Acid Rock Drainage (ICARD 2003). Cairns, Queensland, Australia.*

Miller S. D, Andrina J. and Richards. D (2003a). "Overburden Geochemistry and ARD Scale-Up investigations at the Grasberg Mine, Papua Province, Indonesia." In *Proceedings of Sixth International Conference on Acid Rock Drainage (ICARD 2003). Cairns, Queensland, Australia.*

Miller S. D,, Smart R. St., Andrina J. and Richards. D (2003b). "Evaluation of Limestone Covers and Blends for Long Term ARD Control at the Grasberg Mine, Papua Province, Indonesia." In *Proceedings of Sixth International Conference on Acid Rock Drainage (ICARD 2003). Cairns, Queensland, Australia.*

Miller S (2004), *Site Visit Report December 2004.*

PT. Freeport Indonesia (PTFI) (2004), *Overburden Management Plan 2004. Report prepared in November 2004.*