Rosemont Copper Company
Filtered Tailings Dry Stacks
Current State of Practice
Final Report

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Appendix A Tailings Dry Stack Global Experience
1.0 Summary

Most of the world's concentrators or milling operations use conventional tailings processes which result in tailings impoundments. These impoundments store tailings slurry that typically arrives at the impoundment with solids contents ranging between 25% and 60% depending on the degree of thickening that is carried out prior to deposition. These engineered impoundments require construction and maintenance to insure structural integrity for the retention structures. In addition, these facilities must be designed and constructed to manage large quantities of water.

As the mining industry is increasingly scrutinized on its stewardship of the natural environment, beneficial use of available water resources as well as a commitment to alternatives beyond impoundments is often sought. The amount of water that is "lost" to the voids in the stored tailings, to seeps, or through evaporation from the tailings impoundments is something being increasingly viewed by critical regulatory and public eyes that insist on evaluating whether there are viable alternatives for any given proposed mining development. This pressure to seek alternative tailings management approaches exists today and the future will likely only see these pressures intensified.

Conventional tailings impoundments remain the primary alternative for the majority of operating and proposed mines around the world. These facilities are developed using tailings slurries from the milling process. However, with advances in dewatering technologies over the past few decades, tailings slurry is actually only part of a continuum of tailings "states" available to the modern tailings designer. Development of large capacity vacuum and pressure filter technology has presented the opportunity for storing tailings in an unsaturated state, rather than as conventional slurry or in a paste consistency associated with thickened tailings. For the minority set of projects that can use a non-slurried tailings alternative to optimize use of available water and to streamline permitting and/or operating conditions, filtered tailings are often an excellent alternative.

Filtered tailings are transported by conveyor or truck and placed, spread and compacted to form an unsaturated, dense and stable tailings stack (often termed a "dry stack"). Dry stack facilities don't typically require a dam for a retention structure and as such no associated tailings pond. Each project needs to assess the potential applicability for filtered tailings based upon technical, economical, and regulatory constraints. Experience shows the most applicable projects are those that have one or more of the following attributes:

1. Are located in arid regions, where water conservation is crucial (e.g. Western Australia, Southwest United States, much of Africa, many regions of South America including Chile)

2. Have flow sheets where economic recovery (commodity or process agent(s)) is enhanced by tailings filtration

3. Are located in areas where very high seismicity precludes some forms of conventional tailings impoundments

4. Are located in cold regions, where water handling is very difficult in winter
5. Have topographic considerations that exclude conventional dam construction and/or viable storage to dam material volume ratios

6. The operating and/or closure liability of a conventional tailings impoundment are in excess of the incremental increase to develop a dry stack

7. Are located in areas where construction materials for conventional dams do not exist or are very expensive to supply.

Moreover, filtered tailings stacks generally require a smaller footprint for tailings storage (e.g. much lower bulking factor), are easier to reclaim, and can have lower long-term (closure) liability in terms of potential environmental impact.

Filtered tailings (dry stacks), although new to many mining jurisdictions, are becoming more common both for operating mines and for projects in the evaluation stage (e.g. feasibility). The upper bound, in terms of operating throughput to date, is approximately 20,000 tpd and most operating dry stacks are developed for mines with a throughput less than 10,000 tpd. Dewatered tailings systems may have less application for operations where tailings ponds must serve dual roles as not only solids storage but as water storage reservoirs as well. This is particularly true in temperate climates where water balances must be managed to store annual snowmelt runoff or seasonal period of high precipitation to provide water for year round operation.

Filtered tailings are not a panacea for the mining industry for tailings management. However, under a growing number of site and regulatory conditions, filtering offers a real alternative for tailings management that is consistent with the expectations of the mining industry, its regulators, and the public in general. In the past few years, the capacity of filtration units has increased and unit cost for filtering tailings has commensurately decreased. However, economic considerations rarely indicate a preference for dry stacked tailings facilities over conventional slurry impoundments. As the method becomes more common, the economics will continue to improve.
2.0 Tailings Continuum

Figure 2.1 shows the continuum of water contents available for tailings management and includes the standard industry nomenclature. Decreasing water content increases placement expense because hauling or conveying is required rather than pumping. However, as the water content decreases, the tailings are able to be placed in self-supporting structures such as stacks.

Filtered tailings are typically taken to be the dry cake stage. Dry cake material has enough moisture to allow the majority of pore spaces to be water filled (70-85% saturation) but not so much as to preclude optimal compaction of the material.
3.0 Literature Database

3.1 General

On a global basis, conventional tailings facilities (e.g. slurry tailings direct from mill into a tailings impoundment) make up a vast majority of all existing tailings facilities. In terms of dewatered tailings, there are a similar number of thickened/surface paste tailings facilities to filtered tailings facilities in worldwide operations. There is, however, an intriguing dichotomy between available information about paste/thickened tailings and filtered tailings.

For paste/thickened tailings there has been a steady stream of publications (far outnumbering actual projects where the methods have been applied) and even an annual specialty conference. Each year since the late 1990s, there is an international conference on paste and thickened tailings where presentations focus on potential advances more than actual case studies. There are more than 200 publications on paste/thickened tailings including several guidebooks.

Filtered tailings have simply not had the attention other paste/thickened tailings have had yet there are a similar number of actual operating mines using filtered tailings. There are few publications on filtered tailings and they are rarely mentioned in conference proceedings.

3.2 Technical Publications

As noted above, there are very few publications on filtered tailings. Davies and Rice (2001), remains one of the only technical publications on the subject. A few websites listed below also make note of filtered tailings:

- www.tailings.info
- www.infomine.com
- www.onemine.org

3.3 Regulatory Publications

Some of the most thorough discussion on filtered tailings comes from regulatory sources. While such sources often lag behind state-of-practice, in the case of filtered tailings, some jurisdictions are certainly demonstrating leadership in publicizing the technology.

The Yukon Government (http://www.geology.gov.yk.ca/pdf/MPERG_2003_2.pdf) provides a document entitled *Examination of Revegetation Methodologies for Dry Stack Tailings in Northern Environments*. The most thorough and impressive regulatory summary on dry stacks is provided by the US EPA, Region 10, Mining Source Handbook.
4.0 Filtered Tailings Basics

4.1 General

The extraction of minerals is essential to our present standard of living. Although overall impacts of mining may be lower than those of other land uses, such as agriculture and municipalities, mining can have significant impacts within a given locality on water availability for other uses. Large volumes of water are used for extraction and concentration of metals and non-metal minerals. One of the largest losses of water in the process is through tailings management.

As for any other form of tailings management, there are a number of issues that require careful consideration prior to selecting filtered tailings for a given project. Ultimately, these considerations are economic (capital, operating and closure liability) but require individual attention during the prefeasibility and feasibility stages of the project.

4.2 Why Filtered Tailings?

Whether filtered tailings are a candidate for a given project can depend on a number of factors both economic and technical. These could include such items as regulatory process considerations, structural/geotechnical components, water recovery or other technical requirements at the site.

There are geotechnical advantages of filtered tailings. A review of an instability database for conventional slurry tailings impoundments for the past 30 years shows approximately 2 to 5 tailings dam failure incidents per year.

The most common failure incidents for slurry tailings impoundments are physical instability (including static and dynamic liquefaction) and water management issues (including lack of freeboard and seepage phenomena). Filtered tailings placed in dry stacks are essentially immune to geotechnical "failure" and can be readily designed to withstand static and seismic forces. The unsaturated tailings mass is extremely resistant to saturation and seepage is governed by unsaturated hydraulic conductivities. Moreover, far less is required of foundation conditions as the unsaturated, largely dilatant tailings within a dry stack are not susceptible to static liquefaction or catastrophic breaching by an impounded pond should the foundation move creating substantive shear strains in the tailings mass.

Often one of the main reasons to select dry stacked filtered tailings as a management option is the recovery of water for process water supply. This is particularly important in arid environments where water is an extremely valuable resource. Filtering the tailings removes the most water from the tailings for recycle when compared with other tailings technologies. This recovery of water has a cost benefit to the project, which offsets the capital and operating cost of the tailings system. It should be noted, that water surcharge storage needs to be factored into the design of a filtered tailings system. Depending upon the application this can be a small water supply reservoir or tank. Where water is relatively scarce, either year round or seasonally due to extreme cold, sending immense quantities of water to quasi-permanent storage in the voids of a conventional impoundment can severely hamper project feasibility. By reclaiming the bulk of the process water in or near the mill, far more efficient recycle is achieved.
One of the main advantages of dry stack tailings is the ease of progressive reclamation and closure of the facility. The facility can often be developed to start reclamation very early in the project life cycle. This can have many advantages in the control of fugitive dust, in the use of reclamation materials as they become available, and in the short and long-term environmental impacts of the project. Progressive reclamation often includes covers and re-vegetation of the tailings slopes and surface as part of the annual operating cycle.

4.3 What is Involved?

Pressure filters consisting of horizontally or vertically stacked plates, and vacuum filters consisting of drums and horizontal belts are the most common filtration plant configurations. Pressure filtration can be carried out on a much wider spectrum of materials.

The nature of the tailings material is important when considering filtration. Not only is the gradation of the tailings important, but the mineralogy is as well. In particular, high percentages of <74 µm clay minerals (i.e. not just clay-sized but also with clay mineralogy) tend to hinder effective filtration. Furthermore, substances such as residual bitumen (e.g. oil sands tailings) can create special difficulties for a filtration plant.

Determining the most cost-effective manner to obtain a filtered product consistent with the geomechanical requirements of the tailings can be a challenge. It is important to anticipate mineralogical and grind changes that could occur over the life of the project. The candidate filtering system(s) must be able to readily expand/contract with future changes at the mine while minimizing economical impact.

4.4 Geotechnical Considerations

The strength, moisture retention, and hydraulic conductivity characteristics of the tailings need to be established. The saturated behavior of the tailings should be determined in order to appropriately evaluate the unsaturated tailings behavior. The other important geomechanical characteristic to determine is the moisture-density nature of the tailings. The unsaturated moisture-density relationship indicates in-situ density expectation as well as the sensitivity of the available degree of compaction for a given moisture content. From a compaction perspective, the filtered tailings have an optimal degree of saturation, usually between 60 and 80%.

Filtered tailings can be placed in a relatively dense state meaning that more solids per unit volume can be achieved. This allows a more aggressive use of available land, limits the storage facility footprint and allows the use of areas with lower quality foundation conditions (from the standpoint of hydraulic containment) when compared to conventional impoundments.

4.5 Environmental Stewardship

Issues related to the environmental impacts from tailings dams were first seriously introduced in the 1970’s in relation to uranium tailings. However, environmental issues related to mining have received attention for centuries. For example, public concerns about the effects of acid rock drainage (ARD) have existed for roughly 1,000 years in Norway. Today, environmental issues are growing in importance as
attention has largely turned from mine economics and physical stability of tailings dam to their potential chemical effects and contaminant transport mechanisms. Recent physical failures such as Merriespruit, South Africa in 1994 and Omai, Guyana in 1995 and Los Frailes in Spain in 1998 illustrates this issue with most of the media reports highlighting the real or perceived environmental impacts of the failures.

Dry stacked tailings facilities have potential environmental advantages over impounded slurried tailings largely because physical failures of tailings cannot occur. Moreover, leachate development is limited due to the very low seepage rates possible. Even though the hydraulic conductivity (unsaturated permeability) is very low, dry stacks do have the potential for oxidation and therefore can have unanticipated leachate issues. Leachate may be limited in quantity but the concentrations could be high. Full geochemical characterization of the tailings in their filtered state is essential to determine the potential effect.

Fugitive dusting, both during operation and upon closure, is a concern with dry stacks, particularly in arid environments. Progressive reclamation is an effective method to address this concern. Other methods that can be used include compaction, active management such as binders or wetting agents, agglomeration or other operational measures.

4.6 Tailings Management

The design of a tailings dry stack needs to be compatible with how the stack can be practically constructed using conventional haulage and placement equipment. Other than the capital and operating costs of the filtering process, the economics of dry stack management is the most important component of filtered tailings viability. Haul distance, placement strategy and compactive effort as well as closure and reclamation requirements can increase the unit cost of a dry stack facility in comparison with a slurried impoundment.

There are two methods in common use for transport of the filtered tailings to the tailings storage facility, either by conveyors or trucks. Placement in the facility can be by a conveyor radial stacker system, trucks or a combination of both depending upon the application and the design criteria.

The main issue associated with the placement of the filtered tailings by truck is usually trafficability. The filtered tailings are generally produced at or slightly above the optimum moisture content for compaction as determined in laboratory compaction tests (Proctor Tests). Construction/operating plans are required to avoid trafficability problems, especially in wetter environments because trafficability drops as moisture content rises. In addition, in high seismic areas there is often a design requirement to compact the tailings to a higher density in at least the perimeter “structural” component of the facility. This requirement increases the need for construction quality control. It is the authors’ experience that the degree of compaction required for assured and efficient trafficability is often higher than the compaction required to achieve design densities.

Dry stack designs often incorporate placement zones for “summer/good weather” placement (dry, non-freezing conditions) and “winter/bad weather” placement (wet, or freezing conditions) with summer placement being focused on the structural zones. Again, this is especially true for facilities planned for wetter or colder climates were seasonal fluctuations are significant and predictable.
The key is to consider the environment and the design criteria and develop a flexible operating plan to achieve them. The design should also clearly identify what contingency(s) will be in place if the filtering process experiences short-term disruptions.

4.7 Water Management

Surface water, particularly concentrated runoff, should not be permitted to be routed towards a dry stack and catchment of precipitation on the stack must be actively managed. Surface runoff within the overall catchment containing the dry stack, will probably include perimeter ditches or under-stack flow through drains designed for an appropriate hydrological event(s). “On stack” water should be managed by routing flows to engineered channels and limited slope lengths/gradients to keep erosion potential at a minimum.

Site development for a dry stack normally consists of the construction of surface and groundwater control systems. There are normally two systems:

1. A collection and diversion system for non-contact water (i.e. natural surface water and groundwater from the surrounding catchment area that has not come into contact with the tailings). This system usually consists of ditches to divert surface runoff around the site and if necessary, a groundwater cut-off and drainage system. The cut-off system can range from simple ditches to sophisticated cut-off walls depending upon site conditions.

2. An interception and collection system for contact surface water, and any impacted groundwater or seepage that may result from the dry stack. This system usually consists of an underdrain system that may have finger drains, toe drains, drainage blankets, French drains, collection sumps or ponds. Water collected in the ponds or sumps is typically reused in process or pumped to a water treatment plant depending upon the site water balance. Liners for the facilities can also be components of the interception and collection system depending upon predicted seepage impacts and regulatory requirements.

4.8 Reclamation/Closure Issues

Dry stack facilities can be developed to closely approximate their desired closure configuration with a plan to manage surface runoff. The tailings can be progressively reclaimed in many instances. In all cases, a closure cover material is required to resist runoff erosion, prevent dusting and to create an appropriate growth media for project reclamation.

The lack of a tailings pond, very low (if any) appreciable seepage from the unsaturated tailings mass and general high degree of structural integrity allows dry stacks to present the owner/operator with a comparably straightforward and predictable facility closure in comparison with most conventional impoundments.
5.0 Global Operating Experience

5.1 Overview

There are a growing number of dry stack facilities. At the same time there is likely not any one of those operations that can point to an overall operating economic advantage to the practice. However, for at least three of the operating dry stack projects, the increased operating cost was sufficiently negated by other factors including regulatory issues and closure/liability costs.

The majority of the dry stacks are either in colder climates (e.g. Greens Creek, Alaska, Raglan, Quebec) or in arid environments (e.g. La Coipa, Chile). The La Coipa facility, developing at more than 15,000 tonnes/day, is one of the largest operating dry stacks. The La Coipa facility is located in a high seismic region with designed, and confirmed, structural integrity.

5.2 Global Database

AMEC developed a global database in the late 1990s for tailings facilities and included dewatered tailings in this database. One of the types of dewatered tailings included was filtered dry stacks. Portions of this database are updated regularly but the dry stack portion was specifically revisited in the development of this summary document. A database of filtered surface tailings projects is included in Appendix A.

There is a challenge in developing and maintaining a database such as that excerpted in Appendix A for filtered dry stacks. The challenge is really two-fold:

1. Many of the projects using filtered tailings are new and have proprietary systems and/or operating issues owners are not anxious to have published

2. Few owners are documenting their projects in terms of case histories even where there are no issues mentioned in item one above.

The database presented in Appendix A does not claim to be globally exhaustive but it is believed to be the most thorough practically available. Effort was made to assure the information was both current and accurate but actual operating conditions may vary from the available/published information. One advantage AMEC has in this regard is that we are involved in more filtered tailings dry stacks as designers than any other group.

5.3 Case Examples

5.3.1 Raglan - Canada

The tailings disposal concept implemented at Raglan involves deposition of filtered tailings. The nickel-copper concentrate production started in December 1997, with commercial production levels reached in April 1998 at a nominal mill feed of 2,400 tonnes/day. The tailings disposal operation started as a demonstration project basis, and was converted to the permanent operational mode in the winter 2000/2001. Details of the project are listed below:
Xstrata-SMRQ – Owner/Operator

Started in 1998-1999

Approximately 2400 tpd, current geological reserves stand at over 19 million tonnes, averaging 2.82% nickel and 0.77% copper

Open pit and U/G

Thickener - 30 m diameter

Filtration Plant - Svedala pressure filtration

Transport System - 35 tonne trucks (mainly)

Placement System - Dozer and compactor

Target Moisture - pressure filtered to optimum moisture content.

The Raglan site is located within the Canadian Arctic region, with the mean annual air temperature probably in the order of -8° or -9° C and mean annual precipitation in the order of 500 mm.

Approximately 700,000 tonnes/year of tailings are deposited over the estimated remaining life of the mine of about 15 years, with the possibility of increasing the production rate and/or the length of mine life. Tailings solids comprise about 70% silt sizes. Immediately prior to filtering, the tailings stream is thickened, with thickener underflow at 60-65% solids. Filtered tailings are loaded on trucks, hauled to Tailings Repository, dumped, spread and compacted to form a stable stack with 5H:1V side slopes. Tailings solids, having sulphide sulphur content of 6-8%, are reactive. Loading of the filtered tailings on trucks and the tailings repository are shown on Figure 5.1 below:
5.3.2 La Coipa - Chile

Compañía Mantos de Oro (MDO), wholly owned as of December 2007 by Kinross Gold Corporation, own and operate the La Coipa gold and silver mine near Copiapó, Chile. The processing facilities treat approximately 15,000-16,000 tonnes of ore per day. Mercury is also a common constituent in the ore body. The mine is located in Chile's Region III, in the Atacama Desert area of the Chilean Andes, roughly 130 km from Copiapó.

The approximate elevation of the mill and ancillary facilities is 3850 m above mean sea level. The climatic conditions are typical of Atacama Desert mountain-region conditions. Annual precipitation is roughly 50 mm with essentially this entire amount falling in the winter months (May – September) in the form of snow. Freezing temperatures occur throughout the year.

Leach tailings are processed in a vacuum filtration plant then conveyed to the tailings storage area. The tailings storage area consists of a main deposit, the Rahco, and an auxiliary deposit, the Rakito. The Rahco deposit is developed in an upslope direction by placing compacted lifts of conveyed tailings. Individual lifts average 20 to 30 m in thickness though Zone 3 was just over 30 m thick. The overall facility, which approximately parallels original topography, is up to 70 m thick. Individual lifts include an inwardly sloping “bench” which creates a zero lift thickness at the intersection with the natural ground. Each lift creates an inter-ramp slope (step-in) to create the overall slope angle prescribed by geotechnical design. The Rakito deposit, on the other hand, is developed as a top-down facility that allows the
unsaturated tailings to “flow” along roughly repose angle slopes that are buttressed at the toe by earlier tailings and a dyke structure called the “Retaining Wall.” The Rakito deposit is intended to be used exclusively for periods of Rahco system upset. When the vacuum plant is down, the tailings are stored in surge tanks. The frequency of use of the Rakito was reduced substantially after about 2001 through careful operating procedures.

The approximate design criterion for the vacuum plant was to achieve a water content of less than 25% (where water content is defined as weight of water as a percentage of the dry weight of solids).

- Owner/Operator – Kinross
- Nominal 17,000 tpd silver/gold
- Open Pit mine
- Two thickeners
- Vacuum belt filtration
- Conveyed and stacked using Rahco stacker and dozer spreading
- World’s largest dry stack
- Target moisture content - vacuum filtered to 2% over optimum moisture content but the extreme dry climate makes the difference. Note the appearance of the La Coipa filtrate on the belt shown on Figure 5.2 in comparison to the Raglan material shown being loaded in the truck on Figure 5.1 above.
5.3.3 Greens Creek – United States

Greens Creek is an underground polymetallic mine, which produces approximately 2,000 tons per day of ore. The mine is located on Admiralty Island, Alaska located adjacent to the Admiralty Island National
Monument and is currently 100% owned and operated by Hecla Mining Company through a joint venture arrangement. The site is located in an area of high rainfall and high seismicity.

The tailings are de-watered at the mill using pressure filters and either used underground as cemented backfill or placed on surface in dry stacks. The tailings consisting of between 73% and 96% by weight passing the No. 200 sieve are delivered to the surface tailings facility by truck at or close to optimum standard Proctor moisture content (approximately 15%). The tailings are spread into cells and compacted.

Construction of the original tailings facility commenced in 1988 with construction of a surface water collection system, finger drains, and drainage blankets to collect contact water. The key to success is the operating plan developed to allow successful placement of moisture sensitive material in a high rainfall environment. A dry stack tailings cell is shown on Figure 5.3.

5.3.4 El Sauzal - Mexico

Minas de la Alta Pimería, S.A. de C.V. (MAPSA), a subsidiary of Goldcorp, Inc. (formerly owned by Glamis Gold, Inc.), own and operate the El Sauzal project. The El Sauzal project is an oxide gold deposit in the Batopilas/Urique Mining District, in a remote area of southwestern Chihuahua State about 450 km south of the United States/Mexico border and 15 km east of the Sinaloa State line.
The mine is between elevations of 500 m and 750 m in steep terrain above the Urique River. The ore body is being mined using open pit methods, with a target mill throughput rate of 5,300 tonnes per day (tpd). Mill tailings are currently vacuum filtered and transported by conveyor to a temporary stockpile and hauled by trucks for placement in the dry stack facility down gradient of the plant site.

The climate of El Sauzal is classified as temperate sub-humid, with wet, warm summers and a mean annual temperature of 18°C. Mean annual precipitation at the site is about 800 mm, concentrated in the months of June through July. On average, 250 mm of this precipitation occurs in the month of July, the wettest month of the year. In an average year, precipitation occurs 55 days per year. Mean annual evaporation is about 2,400 mm.

The dry stack tailings facility is sited below the mill facility and lies in a valley setting with steep, rugged topography as shown on Figure 5.4. Key components of the dry stack facility include an up gradient storm water diversion/retention dam, the dry stack storage area with an underdrain system located in the major drainages, a rockfill starter dam and a lower sedimentation pond. The dry stack geometry includes a down gradient zone of compacted tailings faced with rockfill and the up gradient zone of tailings being placed with enough compaction to provide adequate access for haulage equipment.

The approximate design criterion for the filter plant was to achieve moisture contents about 15 to 20 percent (weight of water divided by weight of solids). The filtered tailings are then transported by conveyor to a tailings stockpile below the filter plant. The tailings are subsequently transported by truck for placement, drying to near optimum moisture content and compaction within the impoundment in an unsaturated, dense, and stable tailings stack (dry stack).

- Owner/Operator – MAPSA (Goldcorp, Inc.)
- Nominal 5,300 tpd gold
- Open Pit mine
- Vacuum belt filtration
- Conveyed and stacked in temporary area
- Trucked, processed and placed in compacted and uncompacted areas within the impoundment
5.3.5 Alamo Dorado - Mexico

Minera Corner Bay S.A. de C.V. (Corner Bay) as of June 2005 is a wholly owned subsidiary of Pan American Silver Corporation. The Alamo Dorado project is an open pit silver-gold deposit located near the town of Alamos, Sonora, Mexico. The project site is located approximately 67 km southeast of the town of Alamos in Sonora, Mexico. The general site area is near the border with the State of Sinaloa.

The approximate elevation of the mill and dry stack facilities is 350m above mean sea level. The project climate is transitional between the tropical climates further south and the subtropical desert lands typical of the Pacific Coast of Baja California. Annual mean temperature at the site is approximately 26°C. Precipitation at the Alamo Dorado site is bi-seasonal with an average annual rainfall of approximately 800 mm per year. Most of the rainfall occurs in the form of summer tropical cyclonic storms during the months of July, August, and September with June and October marking the beginning and end of the rainy season. There is a secondary, minor rainy season in the winter, with precipitation occurring primarily in December and January. The spring months, from February through May typically have little or no rainfall.
The project includes a conventional mill to process silver and gold ores from open pit mining operations. The planned mill throughput rate is about 4,000 tonnes per day. Mill tailings are processed in a vacuum filtration plant using two 160 m² belt filters and transported by conveyor and truck to the dry stack tailings facility adjacent to the plant site. The general arrangement of the site is shown on Figure 5.5.

The dry stack tailings disposal facility lies on rugged topography with several ridges and drainages. The tailings facility will be constructed in 3 phases capable of storing 4.5, 9, and 14 million tonnes of tailings, respectively. An underdrain system was constructed within the existing drainages in the tailings impoundment area to capture any fluids that may drain from the placed dry stack tailings. The underdrain system flows to the northwest at low gradients for collection in the geomembrane-lined underdrain pond located southwest of the toe dam.

The approximate design criterion for the filter plant was to achieve moisture contents about 20 to 25 percent (weight of water divided by weight of solids). The filtered tailings are then transported by conveyor to a tailings stockpile within the adjacent impoundment area. The tailings are subsequently transported by truck for placement, drying to near optimum moisture content and compaction within the impoundment in an unsaturated, dense, and stable tailings stack (dry stack).

The dry stack tailings impoundment covers an area of approximately 39 hectares with maximum plan dimensions of approximately 900 m east-west and 800 m north-south. Tailings containment on the north and south sides of the impoundment is provided by natural hillsides. The stability of the impoundment is enhanced with the construction of containment embankments at the upper (east) and lower (west) ends of the impoundment. In addition, select portions of the dry stack tailings are placed to minimum compacted levels for added strength and stability. The impoundment includes the north and south toe dams, north and south rock berms, impoundment underdrain system, and underdrain pond.

- Owner/Operator – Pan American Silver Corporation
- Nominal 4,000 tpd silver/gold
- Open Pit mine
- Vacuum belt filtration (two 160 m² vacuum belt filters)
- Conveyed and stacked in temporary area
- Trucked, processed and placed in compacted and uncompacted areas within the impoundment
5.3.6 Pogo – Alaska

The Pogo project is a joint venture between Teck-Cominco Limited subsidiary Teck-Pogo inc. and subsidiaries of Sumitomo Metal Mining and Sumitomo Corp. The mine lies in the rolling hills of the Tanana uplands, 145 km southeast of Fairbanks as shown on Figure 5.6 below.
Based upon 2006 projections, the mine will operate for approximately ten years, treating ore at a rate of approximately 2,500 tpd. The ore will be beneficiated on site to recover gold through gravity, and flotation/concentrate leach processes. Roughly, 50% of the tailings produced will be thickened and mixed with cement to form paste and placed underground as backfill. The remaining tailings will pressure filtered and placed in a tailings and waste rock storage facility called the Dry Stack. A diversion ditch has been constructed to control and divert surface runoff from the catchment basin in which the mine facilities is located. A water treatment system has also been constructed to collect and treat water prior to permitted discharge.

Due to the lack of an assured geographic setting to provide a conventional tailings pond, an innovative solution was utilized to store surface tailings and waste rock.

The Dry Stack is a facility where tailings that have been pressure filtered to a moisture content of about 15% are placed into one of two areas used for either winter or summer placement. In the summer period, assumed to be not more than four months, tailings are placed in lifts and compacted in the shell area, and
provide a structural shell for the dry stack. The other disposal area includes the general placement area, which is the catchment upstream of the starter berm and tailings shell. This area is used for tailings storage year-round, but exclusively during winter months when snow and ice could potentially affect the placement and compaction of these materials. The general placement area is constructed to promote lateral drainage of surface runoff into the flow-through drains. During operation of the mine, tailings and mineralized development rock are co-disposed in the general placement area of the dry stack such that the rock is encapsulated by tailings. The purpose of encapsulating the rock is to prevent preferential seepage paths and to significantly reduce the potential oxidation of any remnant sulphide minerals in the rock. The Dry Stack start-up facilities were constructed during the winter months from November 2004 to February 2005. The Pogo Dry Stack Facility is shown on Figure 5.7 below:
6.0 Report Closure

This paper has been prepared by AMEC for the exclusive use by Rosemont Copper and M3 Technologies for the Rosemont Copper Project. The data shown in this paper is of a preliminary nature and may not contain sufficient information for the purpose of other parties or for other uses. AMEC is not responsible for any conclusions or recommendations that may be made by others.
7.0 References


Appendix A

Tailings Dry Stack Global Experience
<table>
<thead>
<tr>
<th>Mine</th>
<th>Location</th>
<th>Ore Type</th>
<th>Production tpd</th>
<th>Dewatering Technology</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaal Reef</td>
<td>South Africa</td>
<td>Gold/uranium</td>
<td>10,000</td>
<td>Vacuum Belt</td>
<td></td>
</tr>
<tr>
<td>Randfontein Estates</td>
<td>South Africa</td>
<td>Gold/uranium</td>
<td>10,000</td>
<td>Vacuum Belt</td>
<td></td>
</tr>
<tr>
<td>Chingola</td>
<td>Zambia</td>
<td>Copper</td>
<td>24,000</td>
<td>Vacuum Belt</td>
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</tr>
<tr>
<td>El Sauzal</td>
<td>Chihuahua, Mexico</td>
<td>Silver/gold</td>
<td>5,300</td>
<td>vacuum belt</td>
<td></td>
</tr>
<tr>
<td>Alamo Dorado</td>
<td>Sonora, Mexico</td>
<td>Silver/gold</td>
<td>3,500</td>
<td>vacuum belt</td>
<td></td>
</tr>
<tr>
<td>Spinifex Ridge</td>
<td>Australia</td>
<td>Molybdenum</td>
<td>140,000</td>
<td>vacuum belt</td>
<td>Project is under construction. Freeze tailings solid in permafrost area.</td>
</tr>
<tr>
<td>La Coipa</td>
<td>Chile</td>
<td>Tailings/Dewatering</td>
<td>16,000</td>
<td>HB filter</td>
<td>12 - 100 m². Includes rinse cycle to recover cyanide. Gold leach washing. Vacuum belt filters</td>
</tr>
<tr>
<td>Greens Creek</td>
<td>Alaska, USA</td>
<td>Ag/Zn/Au</td>
<td>1,500</td>
<td>Pressure Filters</td>
<td>Placed with trucks</td>
</tr>
<tr>
<td>Raglan</td>
<td>Quebec, Canada</td>
<td>Lead/Zinc</td>
<td>2,000</td>
<td>Pressure Filters, plate and frame type</td>
<td>Under construction. Freeze tailings solid in permafrost area.</td>
</tr>
<tr>
<td>Pogo</td>
<td>Alaska, USA</td>
<td>Gold</td>
<td>2,500</td>
<td>Belt</td>
<td></td>
</tr>
<tr>
<td>Mantos Blanco</td>
<td>Chile</td>
<td>Copper</td>
<td>4,000</td>
<td>Vacuum Belt/ HB filter</td>
<td>3 - 100 m²</td>
</tr>
<tr>
<td>Geocamines</td>
<td>Zaire</td>
<td>Copper</td>
<td>5,000</td>
<td>Vacuum Belt</td>
<td></td>
</tr>
<tr>
<td>Wallsend Mt. Th.</td>
<td>Australia</td>
<td>Coal</td>
<td></td>
<td>Belt press, filter</td>
<td></td>
</tr>
<tr>
<td>Alcoa</td>
<td>Australia</td>
<td>Alumina</td>
<td>35,500</td>
<td>Thickening to 50%</td>
<td>Bauxite residue, underdrained to 62%, dozer spreading to 68-70%</td>
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<tr>
<td>Nabalco</td>
<td>Australia</td>
<td>Alumina</td>
<td>5000</td>
<td>Thickening to 46%</td>
<td>CTD over conventional deposit, dried to 60 or 70% by 'tilting'</td>
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<tr>
<td>Nixon Fork</td>
<td>Alaska, USA</td>
<td>Gold</td>
<td>150</td>
<td>Drum filter</td>
<td>Tailings place with trucks</td>
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<tr>
<td>Eskay Creek</td>
<td>BC Canada</td>
<td>Copper</td>
<td>300</td>
<td>Pressure filter</td>
<td>16 chamber, 300 litre, 9.75 m² (1.0 x 1.0 m frame) pressure filter</td>
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<tr>
<td>Lihir Island</td>
<td>Papua New Guinea</td>
<td>Gold</td>
<td>est. 7,500</td>
<td>Filter plant</td>
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<tr>
<td>Mantos de Oro</td>
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<td>Gold</td>
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<td>Filter plant</td>
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<tr>
<td>TVX Gold</td>
<td>Montana, USA</td>
<td>Gold</td>
<td>15,000</td>
<td>Vacuum disk filters</td>
<td></td>
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<tr>
<td>Bwana</td>
<td>Zambia</td>
<td>Copper</td>
<td></td>
<td>Filter</td>
<td>2 units - 145 m²</td>
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<tr>
<td>Blue Diamond</td>
<td>USA</td>
<td>Sand &amp; Gravel</td>
<td></td>
<td>Filter</td>
<td></td>
</tr>
<tr>
<td>Blue Star</td>
<td>USA</td>
<td>Sand &amp; Gravel</td>
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<td>Filter</td>
<td></td>
</tr>
<tr>
<td>A.J. Dean</td>
<td>USA</td>
<td>Sand &amp; Gravel</td>
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<td>Filter</td>
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<tr>
<td>Owl Rock</td>
<td>USA</td>
<td>Sand &amp; Gravel</td>
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<td>Filter</td>
<td></td>
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<tr>
<td>Vulcan Material</td>
<td>USA</td>
<td>Sand &amp; Gravel</td>
<td></td>
<td>Filter</td>
<td></td>
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## SUMMARY OF FILTERED SURFACE TAILING PROJECTS

<table>
<thead>
<tr>
<th>Mine</th>
<th>Location</th>
<th>Ore Type</th>
<th>Production tpd</th>
<th>Dewatering Technology</th>
<th>Comments</th>
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<tbody>
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<td><strong>OPERATING MINES</strong></td>
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<tr>
<td>Redwater</td>
<td>Alberta, Canada</td>
<td>gypsum</td>
<td></td>
<td>HB filter</td>
<td>Two large belt filters (75 m³) &amp; pan filter</td>
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<tr>
<td>J.C.I.</td>
<td>South Africa</td>
<td>uranium leach</td>
<td></td>
<td>HB filter</td>
<td>1 - 120 m³</td>
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<tr>
<td>Grooteguluk</td>
<td>South Africa</td>
<td>Coal Fines</td>
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<td>HB filter</td>
<td>3 - 100 m³</td>
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<tr>
<td>WMC</td>
<td>Australia</td>
<td>Gold plant</td>
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<td>filter</td>
<td>3 - 100 m³</td>
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<tr>
<td>Australian Iron &amp; Steel</td>
<td>Australia</td>
<td>Coal Fines</td>
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<td>filter</td>
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<tr>
<td>C.S.B.P.</td>
<td>Australia</td>
<td>Phosphoric</td>
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<td>HB filter</td>
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<td>Namhae Chemicals</td>
<td>Korea</td>
<td>Phosphoric acid</td>
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<td>HB filter</td>
<td>2 - 110 m³</td>
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<td>Isador Durancol</td>
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<td>ZCCM</td>
<td>Zambia</td>
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<td>Steep Rock Calcite</td>
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<td>Alwinski Potash</td>
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<td>1 - 24 m³ Mod 9360</td>
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<td>Sigeo</td>
<td>Indiana, USA</td>
<td>FDG gypsum</td>
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<td>HB filter</td>
<td>3 - 30 m³ Mod 3M30</td>
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<td>HB filter</td>
<td>2 - 72 m³ Mod 3.2M72</td>
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<td><strong>FEASIBILITY STUDIES</strong></td>
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<tr>
<td>Ok Tedi</td>
<td>Papua New Guinea</td>
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<td>90,000</td>
<td>Vacuum Belt</td>
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<tr>
<td>ElZOK Lake</td>
<td>NWT Canada</td>
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<td>Volcan</td>
<td>Peru</td>
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<td>Mineral Ridge</td>
<td>Nevada, USA</td>
<td>gold</td>
<td>1500</td>
<td>unknown at this time</td>
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<td>Aqua Rica</td>
<td>Brazil</td>
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<td>Peru</td>
<td>Copper-</td>
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<td>unknown at this time</td>
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<tr>
<td>Inco Mine</td>
<td>New Caledonia</td>
<td>nickel</td>
<td></td>
<td></td>
<td>Design stage. Placing tailings back in pit.</td>
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<tr>
<td><strong>CLOSED MINES</strong></td>
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<td>2,000</td>
<td>Pressure disc?</td>
<td></td>
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