Rosemont Copper Project

Review of Alternatives Considered but Dismissed

Report Prepared for

SWCA Environmental Consultants

Report Prepared by

SRK Consulting

Engineers and Scientists

May 7, 2010
Rosemont Copper Project – Review of Alternatives Considered but Dismissed

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1 Introduction

SWCA and Mr. Dale Ortman, P.E. (Ortman, 2009) provided SRK Consulting (U.S.) Inc. (SRK) with a scope of work (SOW) for performing a two-phase evaluation of Alternatives Considered but Dismissed (ACD) for the Environmental Impact Statement (EIS) for the proposed Rosemont Copper Project. The request was made at the behest of the U.S. Forest Service, Coronado National Forest (CNF), which previously reviewed these alternatives and dismissed them for various reasons. The initial Phase I SOW consists of evaluating 16 ACDs for technical and practical feasibility and preparing draft and final reports. The number of ACDs subsequently was reduced to 11 alternatives. Phase 2 consists of a subsequent financial feasibility evaluation for those ACDs (if any) that have the potential to be technically and practically feasible. This report describes the Phase I scope of work.

In accordance with the Phase I SOW, SRK evaluated each ACD for technical and practical feasibility on the basis of expert professional judgment and knowledge of the specific scientific and engineering aspects of the alternative. Additionally, each evaluation included a review of documents pertinent to the ACD and the current Mine Plan of Operations (MPO) (WestLand Resources, 2007).

This report is organized into 14 sections, as follow: Introduction; ACD Technical and Practical Evaluations (11 Sections); Summary, which summarizes the technical and practical feasibility of the alternatives and alternatives for further consideration; and References.

1.1 Base Case Method for Mine Operation

Rosemont has proposed an open pit operation as the main method to mine the oxide ores and sulfide ores (WestLand Resources, 2007). This mining method would involve:

- Mining and placing approximately 1.23 billion tons (Tetra Tech, 2009, p. 19, Table 4.01) of overburden and non-mineralized limestone and other rock types in waste rock dumps on cleared and grubbed areas southeast, east, and northeast of the proposed pit;
- Mining of the approximately 69 million tons of low-grade oxide ore and subsequent placing of the ore on a leach pad, followed by acid leaching and solvent-extraction electrowinning (SX/EW) to produce cathode copper;
- Mining of the 546 million tons sulfide ore by blasting and haulage, followed by crushing, milling, flotation, and production of copper concentrates with silver credits, and molybdenum concentrates;
• Placing of the approximately 546 million tons of dry-stack tailings on a stripped and grubbed tailings disposal area in McCleary and Barrel Canyons, and accomplishing reclamation by an engineered cover;
• Building infrastructure would be used to assist production, including access roads, parking areas, fencing, power lines, process buildings, maintenance shops, and administrative buildings; and
• Shipping 1,328 tons per day of copper and molybdenum concentrates by truck and then truck or rail for further processing.
• Shipping a total of 19,000 tons of copper cathodes by truck and then truck or rail.

The metals of value recovered include copper, molybdenum, and silver.

1.2 ACD Technical and Practical Evaluations

Sections 2 through 12 provide the evaluations of the ACDs. Following the ACD title and author(s), each section contains of the following subsections:

• ACD Description,
• Technical Feasibility,
• Practical Feasibility,
• Consequences,
• Summary, and
• Qualifications of Responsible Personnel
2 Dispose of Tailings and Waste Rock on the West Side of Santa Rita Mountains

The following section on disposing of tailings on the west side of the Santa Rita Mountains instead of on the east side of the mountains was prepared by Corolla K Hoag, R.G. and reviewed by Ken Black, P.Eng.

2.1 ACD Description

The MPO proposes to transport 1.23 billion tons of overburden and non-mineralized waste rock and 546 million tons of dry stack tailings for disposal adjacent to the Open Pit (Tetra Tech, 2009, p. 19, Table 4.01). The waste rock will be transported by 250-ton haul trucks; the tailings material will be placed in Barrel and McCleary canyons using a conveyor and radial stacking system. The transport distance for waste rock is a lateral distance of approximately 7,400 feet from the pit center to the waste rock dump center; the transport distance for tailings is approximately 8,800 feet (Arnold, 2009, p. 3, Updated Summary Table).

This ACD would select an alternate location for disposal of the dry stack tailings and waste rock west of the ridge crest of the Santa Rita Mountains instead. The intent of this ACD is to minimize surface disturbance impacts at the proposed mine area. No change to the production schedule is proposed for this ACD although the change in location would have an effect on operational costs (not evaluated) that may impact the life-of-mine (LOM) reserves. No alternate location was identified by SRK during this brief review, but the over land transport distances would range from approximately 10 to 20 miles. A tunnel from the pit to the west side of the ridge would shorten the haul distance to 3 to 5 miles if material were placed on or adjacent to the mountain fringe.

2.2 Technical Feasibility

The land position on the east side of this range primarily consists of land controlled by the State of Arizona (surface and minerals) with lesser ownership by CNF, private parties, and the U.S. Bureau of Land Management (BLM) in descending order. Finding an alternate location for the tailings and waste rock on the west side of the Santa Rita Mountains is technically feasible. A siting study would need to be performed to identify one or more potential tailings and waste rock dump locations from an engineering perspective, and conceptual engineering designs would need to be prepared. It can be assumed that because of water restrictions the tailings would still be deposited as a dry stack with waste rock used to buttress and protect the outer slopes. The topographic features most ideal for this design of dry stack tailings disposal include gently sloping topography or low-lying areas within a
drainage. Waste rock can be placed on gently to moderately sloping topography and within incised drainages. In addition to performing an engineering options analysis for selecting an alternate tailings location, Rosemont Copper would also need to adhere to state and federal permitting requirements that require an evaluation to identify the environmentally least damaging alternative.

Transporting large quantities of run-of-mine waste rock and tailings material to the selected location west of the ridge crest would require operation of an extensive truck fleet along an existing or potentially new road, operation of a short-haul rail line to a transfer station to transport the waste to the final disposal location, or operation of a large conveyor system with a radial stacker system to place the material in the final location. The construction of a tunnel could shorten the transport distance to 3 to 5 miles and would be technically feasible to construct.

2.3 Practical Feasibility

The amount of waste material to be moved, the large size fractions of the run-of-mine material, and distances involved would exceed the capacity of a large truck fleet to move the waste and tailings material efficiently. Typically, the number and size of trucks required to move ore and waste materials is determined through optimization studies that incorporate the height of the benches, the capacity of the shovel and/or loader bucket, the truck haulage capacity, haulage distances and elevation profile, and the time needed to make a return trip to the shovel. Given the very long haul distances to transport waste rock to the west side of the mountains, the number of trucks required for waste rock disposal would increase significantly over what is planned in the MPO and may include an large fleet of high-tonnage, off-road haulage trucks and large commercial trucks using the highway system. This would, in turn, increase diesel fuel consumption, generate higher dust and air quality emissions, and accelerate the wear on the trucks and tires. Truck disposal of waste and tailings material to an alternate location on the west side of the Santa Rita Mountains is not practically feasible.

Conveyor systems could be designed to transport tailings and crushed waste rock to the distances proposed for an alternate location west of the ridge crest. The main considerations are increased water usage for fugitive dust suppression, increased energy use to crush the run-of-mine waste rock to a consistent size fraction for the conveyor, the increased energy use to convey the material to significantly greater distances, and the greater surface impacts to include the lengthy conveyor and maintenance support access.
Construction of a tunnel through the Santa Rita Mountains to transport material to the west side of the ridge would shorten the transport distance; however, a cost benefit analysis would be required to determine the practicality of this alternative.

2.4 Consequences

The consequences of locating the tailings disposal on the west side of the Santa Rita Mountains include the following:

- The relocation would have no impact on the 69 million tons of oxide materials proposed for heap leaching adjacent to the Open Pit.
- Relocated waste materials would have no impact on the size of the surface footprint of the tailings and/or waste rock facilities unless the resulting operational costs are excessive and significantly decrease the life-of-mine (LOM) reserves.
- The impacted surface area will increase owing to the increased distance of the conveyor system and companion maintenance road(s).
- Fugitive dust related to the conveyor system and maintenance vehicles will increase owing to the increased travel distances along a longer conveyor route.
- Water usage will increase to support dust suppression on the conveyor system and companion maintenance roads (if they are all-weather graded dirt roads).
- Electric energy use and related emissions will increase owing to the increased conveyor distances and the need to crush the run-of-mine waste rock to a more uniform size fraction.
- Tailings and waste rock would not be visible on the east side of the ridge crest or from State Route 83 (SR83) resulting in an improvement in the viewshed.
- Tailings and waste rock would be visible from the west side of the ridge crest and from Interstate-19 (I-19) resulting in a degradation of the current viewshed.

2.5 Summary

The land ownership on the west side of the mountains is a mix of private, county, state, and federal with associated restrictions and permitting requirements. An alternate disposal site for tailings and/or waste rock material west of the ridge crest of the Santa Rita Mountains could be identified through an industry standard siting evaluation. Increased water and fuel usage, increased dust and air quality pollutants, and a degradation of the viewshed are expected outcomes. No reduction to the footprint of the facilities will be generated other than those caused by excessive costs and a decrease in the LOM material that can be economically extracted, processed, and transported to the final disposal location. In SRK’s opinion, this ACD, although potentially technically feasible, is not a practical alternative.
2.6 Qualifications of Responsible Personnel

The author of this section, Corolla Hoag, R.G., M.Sc. has a degree in economic geology and has worked for more than 23 years in the exploration, mine development, and consulting industry. The discussion in this section was based on general observances and knowledge gained at mining operations where the author has worked including Cyprus Copperstone, Cyprus Tohono, BHP Copper San Manuel Operations, BHP Copper Florence Project, Phelps Dodge (now Freeport-McMoRan) Sierrita, and conclusions from SRK mine planning and/or optimization studies at ASARCO Ray Complex, ASARCO Mission Complex, and Silver Bell Mining.
3  Mechanical Conveyance of Ore to Rail Head

The following section on mechanical conveyance of “ore” to a railhead was prepared by Kenneth P. Black, P. Eng. (Mining) and John Kline, B.S., M.A.O.M..

3.1 ACD Description

The base case in the Rosemont MPO is to crush and concentrate ore minerals on site and ship the copper sulfide and molybdenum sulfide concentrates for off-site smelting via commercial trucks. This proposed ACD reviews using other mechanical conveyances to ship ore and concentrates off site. The intent is to reduce the footprint of plant facilities on the mine site and to reduce traffic on the nearby highways. This proposed alternative evaluated two aspects of mechanical conveyance of ore to the Port of Tucson railhead for shipment to an off-site location for crushing and processing to prepare concentrates, and subsequent shipment to smelter markets within or outside the state of Arizona. Additionally the evaluation includes the conveyance of concentrates to the railhead at the Port of Tucson. It is believed the intent of the ACD is really to address copper concentrate shipments and not ore primarily because of the technical difficulties in mechanical conveyance of ore off the mine site. These difficulties will be addressed in the next section.

3.2 Technical Feasibility

This section will discuss the technical feasibility of transporting materials from the proposed mine site by truck haulage, rail haulage, conveyor haulage, and slurry pipeline. No economic consequences are discussed or included. A summary of the technical feasibility of each method is provided in Table 1.

The Port of Tucson is located in a federally designated foreign trade zone in south Tucson (near Interstate-10 and S. Kolb Road) and consists of railroad interchange facilities to provide on/off loading from rail cars to and from highway transport vehicles. The Port of Tucson is a Union Pacific terminal for freight forwarding to and from Mexico. The term “Port” in this case refers to a point of entry and exit and not to a location for ocean transport via large ships. A SRK inquiry to the Port of Tucson on whether concentrates would be accepted for transport generated the response that the Port of Tucson has previously accepted and shipped bagged copper concentrates for shipment. To SRK’s knowledge the only nearby ship ports with rail and ocean transport capabilities that will accept concentrates are in Guaymas Sonora, Mexico and in Vancouver, Washington; concentrates are not accepted in Long Beach, California or Corpus Christy, Texas because of environmental restrictions.
Method 1: Truck Haulage

Mined ore cannot be shipped via truck or conveyor without crushing and resizing the run-of-mine material. Run-of-mine ore would exceed highway truck capacity in size. The need to crush the run-of-mine ore, to facilitate conveyance in a highway vehicle, means that the crushing and conveying facilities would not change from the planned size stated in the MPO. The haul truck fleet would not be reduced either. The balance of this discussion, therefore, will include only transportation of concentrates.

Truck haulage of copper and molybdenum concentrates by common carrier is the normal transportation method in Arizona and is the base case in the Rosemont MPO. The truck haulage method is used by ASARCO Mission to take copper concentrates to the ASARCO Hayden smelter for processing and by the Freeport-McMoRan’s Bagdad and Sierrita operations to take their concentrates to the Freeport-McMoRan smelter at Miami, Arizona. Prior to the cessation of operation in early 2009, BHP Copper’s Pinto Valley Operation shipped concentrates via commercial truck to the rail transload facility in San Manuel, Arizona for final processing overseas.

Method 2: Rail Haulage

Rail haulage of ore is currently used at ASARCO Ray Complex to transport sulfide ore from a primary crusher at Ray Mine via ASARCO’s Copper Basin Railway to the company’s mill, concentrator, and smelter facilities located at Hayden approximately 20 miles away. The available siding area limits the train to approximately 40 cars. Rail haulage of ore was previously used at the BHP Copper San Manuel Mine to take sulfide ore from the primary crusher at the mine to the company’s mill/concentrator and smelter located 7 miles to the south at the town of San Manuel. At Rosemont, rail haulage of ore is technically feasible assuming a mill-concentrator can be secured elsewhere to process the sulfide ore. This method would require a short-line rail spur and siding area to be built at the proposed plant facilities (and potential receiving facilities) for transporting ore for off-site processing.

Rail haulage is an effective way to move bulk materials such as concentrates. Binding materials are applied to reduce wind-blown losses from uncovered rail cars but some losses still occur. The transportation of concentrates to the Port of Tucson is technically feasible by rail haulage, but requires installation of a rail spur to the site (with attendant surface disturbance) and installation of rail loading facility adjacent to the mill/concentrator and other plant facilities.
Method 3: Conveyor Haulage

Conveyors were evaluated as a mode of transporting materials. This approach allows for the conveyance of crushed ore and concentrates along the 12-mile access corridor from the mine to a railhead near Exit 281 on I-10 and directly loading the ore onto 100-car rail trains. As mentioned previously, this method is not technically feasible without processing the ore through a crushing circuit to reduce the size of the run-of-mine material. Additionally direct loading is not technically feasible as each car would likely be filled in less than 2 minutes but it would take longer yet to shunt the rail cars into position for loading. Additional facilities including storage bins would need to be constructed at the railhead on the north side of I-10 or at the Port of Tucson to control automated loading of all cars. The mechanical conveyance of ore to the Port of Tucson is not technically viable.

Conveyors are can be an effective method to transport coarse to fine-grained materials and will be used to transport the dewatered, dry stack tailings at Rosemont (primarily coarse sand to silt size). Concentrates are the final recovered residue from the crushing, grinding, and flotation circuit and the particles are typically silt to ash size. Operation of a conveyor with direct loading capabilities at a railhead or the Port of Tucson is not technically feasible. Construction and operation of additional facilities to control automatic loading would be required.

Method 4: Slurry Pipeline

Slurry pipelines are a common means of transporting products including copper concentrates. The Escondida Mine in Chilean Andes pumps copper concentrate approximately 100 miles to Antofagasto, a port city on the coast of Chile. Antamina mine in Peru has a similar production rate and it slurries the concentrates by a 187-mile pipeline to the Pacific coast where the concentrates are filtered prior to loading onto a ship. (Xstrata Copper, 2009). At the terminus of the pipeline, the slurried concentrate would be dewatered in a filter plant and dried to 8 percent moisture content for rail car shipment or containerized ocean transport shipment to a smelter facility. The concentrates would be stockpiled in a covered building prior to loading the material on rail cars for shipment to smelters. Water treatment may be required before returning the clarified water via pipeline back to the proposed mine site.

This method requires the off-site construction of: a plant to receive and filter/dewater the concentrates, a pump station to recycle the water, concentrate storage building(s), pond(s) for water impoundment prior to pumping back to the mine site, and a transload facility for loading of rail cars. The net result is two pump lines are required, namely one to send and one to receive the liquids. The slurrying of concentrates in a solid/liquid phase and their subsequent transport over long distances is common industry practice especially for mining.
facilities that are at a significant distance from the smelter/refinery complex. It is technically feasible assuming off-site dewatering, water treatment/pumping, and transload facilities can be constructed and operated.

**Table 1  Technical feasibility of the ore and concentrate haulage**

<table>
<thead>
<tr>
<th>Method</th>
<th>Material</th>
<th>Technically Practical?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck Haulage</td>
<td>Ore</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Concentrate</td>
<td>Yes</td>
</tr>
<tr>
<td>Rail Haulage</td>
<td>Ore</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Concentrate</td>
<td>Yes</td>
</tr>
<tr>
<td>Conveyor Haulage</td>
<td>Ore</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Concentrate</td>
<td>Yes</td>
</tr>
<tr>
<td>Slurry Pipeline</td>
<td>Ore</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Concentrate</td>
<td>Yes</td>
</tr>
</tbody>
</table>

3.3 **Practical Feasibility**

This section discusses the practical feasibility of conveying concentrates to the Port of Tucson for transload into rail cars. The transport of ore is only addressed for the Rail Haulage method, as it is the only method that is technically feasible for the transportation of ore. Many of the methods of conveyance are technically feasible but not practically feasible as discussed below.

**Method 1: Truck Haulage**

Truck haulage of copper and molybdenum concentrates by common carrier is practically feasible and the base case in the Rosemont MPO.

**Method 2: Rail Haulage**

Construction of a rail spur to transport copper and molybdenum ore or concentrates to the Port of Tucson rail facility is technically feasible, but is considered impractical here. Construction of a rail spur would require obtaining a right-of-way, building a railway siding and loading facility at or near the mine, and would add to the environmental impacts. The addition of a rail spur would result in substantial land disturbance.
Method 3: Conveyor Haulage

It is common for coarse materials to be transported over long distances by conveyors. The longest conveyor system in the world transports phosphate from a mine in Western Sahara 62 miles to a Moroccan port (Wikipedia, 2008). The transport of fine-grained concentrates from the proposed Rosemont processing plant to a storage facility adjacent to the Southern Pacific rail line at Exit 281 is impracticable. The concentrate would have to be filtered and dried to a reasonable moisture content to be conveyed. Windblown loss related to the drying process and the small particle size of the concentrate is difficult to prevent and manage. Normal conveyor covers are not currently designed to handle these small particle sizes on a practical level; no example could be found where this method is used. New and innovative equipment would have to be developed. Further, the potential environmental degradation caused by the windblown concentrate, coupled with the long distance of conveyance, make this option impracticable. For these reasons, this method would not be practically feasible.

Method 4: Slurry Pipeline

Slurry pipelines are a common means of transporting copper concentrates where other options are not practical. Operation of a slurry pipeline introduces risk to the environment owing to the potential for loss of the slurry from pipeline breakage or damage. An off-site facility near the proposed mine site or Tucson would need to be identified for the construction of the required concentrate filtration plant, water treatment plant, water recycling pump station, and transload facilities. If a suitable site could be identified and permitted, this alternative would be practically feasible.

3.4 Consequences

As previously discussed, the transportation of run-of-mine ore is not a viable alternative. The discussion of consequences will be limited to alternate transportation methods for concentrates.

- Alternate means of transporting concentrates may result in increased energy and water consumption for fugitive dust control.
- Risk of environmental damage may be increased due to spillage, wind-blown dust, and/or pipeline failures.
- Rights-of-way will be required to allow construction of the proposed alternatives.
- The alignment of the proposed alternatives may cross state trust land, private land, riparian areas, and waters of the U.S., the environmental impacts of which have not been evaluated.
• An increase disturbance area in another location for the construction of a concentrate filtration plant, water treatment plant, water recycling, pump station and transload facility.

3.5 Summary

The various mechanical conveyances for ore and concentrates have been evaluated. The conveyance of ore off site by various mechanical means is not technically or practically feasible due to the sheer volume and size of the material to be transported to other facilities for treatment.

Alternatives for the conveyances of concentrates from the mine using rail haulage are technically feasible from an engineering perspective assuming direct, automated load of concentrates from conveyor. However, some alternative alignments may not be viable owing land ownership or environmental aspects relating to alignment.

3.6 Qualifications

Kenneth Black, P.Eng. has a degree in mining engineering and has worked for 35 years in the mining industry as a mine manager and project manager; additionally he has technical expertise in the branches of mining related to environmental permitting and mining operations. His specific work experience includes:

• Mine manager of an open pit operation;
• Permitting and technical design for the Crandon Project;
• Permitting and environmental manager at numerous operating sites;
• Environmental assessment reviews of numerous mines in North America and South America; and
• Closure Manager of BHP Billiton’s sites in Canada.

John Kline, BS, M.A.O.M., has a degree in chemistry and has worked for 35 years in the copper mining industry as technical manager, environmental permitting, operations managers, and project manager. His specific work in the field of mechanical conveyance of ore and/or concentrates includes:

• Project Manager to facilitate and transport 400,000 of copper concentrates to and from the Port of Guaymas, Sonora, Mexico.
• Experience with evaluation and permitting of rail transload facilities in Arizona and Mexico.
• Health, Safety, and Environmental Manager at Pinto Valley and San Manuel Operations where truck haulage and rail transload facilities were used to transport copper concentrates to the Port of Guaymas for final processing.

4 Use In Situ Leaching in Lieu of Open Pit Mining

The following section on using in situ leaching instead of open pit mining was prepared by John T. Kline, B.S., M.A.O.M., and Corolla K Hoag, R.G.

4.1 ACD Description

The proposed ACD would consist of in situ leaching of the oxide and sulfide copper mineralization by a weak sulfuric acid solution followed by solvent-extraction and electrowinning (SX/EW) of the recovered copper with copper cathode as the final product. Cathode would be shipped to market by truck followed by truck or rail.

Infrastructure would include a series of injection and recovery wells, a network of solution pipelines, process ponds for raffinate and pregnant leach solution (PLS), a SX/EW plant, administration buildings, maintenance and warehouse buildings, power lines, fencing, surface roads, and parking areas.

4.2 Technical Feasibility

The use of an in situ mining technique as an alternative to open pit mining requires a review of several critical concepts. These include:

• The definition of in situ leaching versus in place leaching,
• The definition of oxide ore versus sulfide ore,
• Where in situ leaching has been used or tried,
• The material property of the material to be leached,
• The regional geologic setting, and
• Potential permitting requirements.

Definitions

“In situ” is Latin for “in place” and has been used to define two different types of mining: in situ and “in place.” In situ mining refers to the recovery of the metals without any significant disturbance of the rock matrix. Essentially, the rock matrix is in its native form and is accessed by drilling and leaching methods. Leach solutions, generally a weak sulfuric acid solution, are pumped into the ground via an injection well and subsequently travel though the
fractures in the rock and dissolve the minerals. Recovery wells fitted with downhole pumps are installed to recover the metal-bearing solutions. With reference to copper \textit{in situ} leaching, the copper-bearing solutions are pumped to a SX/EW plant where the copper is extracted and then electrically plated as copper cathode.

“In place” leaching refers to leaching of the metals in ground that has been disturbed by previous mining methods. This would include: leaching of pit walls where stress-relief has occurred due to blasting and mining operations, the walls of underground mine workings where the rock has been stress-relieved by blasting, and ore bodies that have been previously mined by underground block caving techniques. “In place” is often used instead of \textit{in situ}. In this review, the author believes the intent of the alternative is to review \textit{in situ} mining and not “in place” mining, with the goal of mitigating surface disturbance.

It is also necessary to understand the various ore types. “Oxide” may refer to several types of soluble copper minerals such as copper-bearing iron and manganese oxides, chrysocolla (a copper silicate mineral), cuprite (cuprous oxide), and chalcocite (a soluble copper sulfide mineral). The primary “oxide” mineral in the Rosemont ore is chrysocolla, but the ore also may contain a small amount of chalcocite. Some of the copper “oxide” minerals are less readily soluble than others. Chrysocolla is readily soluble but chalcocite copper, for example, is only partially released in the presence of ferric iron and weak sulfuric acid. The oxide ore will not generally contain any soluble amounts of silver or molybdenum.

“Sulfide” generally refers to copper sulfide minerals that are not readily soluble in a weak sulfuric acid solution. The copper sulfide minerals at Rosemont are chalcopyrite, bornite, and molybdenite. All of the molybdenum and silver content is contained in the sulfide minerals (WLR Consulting, 2007, p. 10, 21).

There are a number of Arizona mining operations using “in place” copper mining and pilot testing of “\textit{in situ}” mining has occurred at several locations. The materials leached are primarily quartz monzonite or other igneous host rock, porphyritic intrusive rock. There is no record of any recovery of molybdenum or silver from these types of mining methods, as will be explained in Section 2.1.3. Examples of the mines where “in place” and \textit{in situ} leaching have been attempted are listed in Table 2.

In all of the tests and in all cases listed in Table 2, the criteria for success was the ability to pass a leach solution through the target ore with suitable rock chemistry and hydraulic conductivities and recover the copper in a manner consistent with permit requirements under the Arizona Department of Environmental Quality’s (ADEQ’s) Aquifer Protection Permit program. In the case of the Florence Project it also was necessary to meet the requirements of
a U.S. Environmental Protection Agency (EPA) Class III well system, as regulated under the Safe Drinking Water Act. The goal of both regulations is to prevent degradation to drinking water sources of the U.S. This means the facility operator must demonstrate to the agencies that in situ leach solutions will not migrate beyond the leaching facility. The Florence Project is the only Class III copper leach system approved to date by the EPA. The other “in place” leach systems listed in Table 1 are considered Class V leach systems. The distinction is that Class III wells apply leach fluid under pressure and the fluid is recovered in nearby pumping wells. Hydraulic control of the leach solution is by injection and pumping. Class V wells utilize open pits, underground mine workings, and well systems for recovery. Hydraulic control is maintained by solutions migrating into previously mined areas.

Testing has also occurred on sulfide mineralization. These include:

- Laboratory column and bench-scale leaching tests, and
- Injection and pumping tests for flow characterization.

In situ leaching of copper oxide mineralization is technically feasible if the host rock has low carbonate content that is sufficiently fractured and has high hydraulic conductivity. Additional certain site characteristics must be met to ensure hydraulic control of the injected solutions is maintained. Insufficient aquifer testing and fracture studies have been performed at Rosemont to assess the technical feasibility of in situ leaching on copper oxide mineralization. In general it is not technically feasible to perform in-situ leaching on sulfide mineralization owing to the low hydraulic conductivity typical of sulfide zones in these types of deposits.

4.3 Practical Feasibility

This section will discuss the practical feasibility of in situ leaching of the oxide and sulfide ores. This discusses the use of in situ technology based upon similar conditions tested at other Arizona sites and the specific ore characteristics of the Rosemont mineralization. A review of available Rosemont data finds no mention of downhole permeability testing of the oxide ore body as distinct from the sulfide ore body, so some assumptions necessarily are based upon knowledge of similar ore bodies tested elsewhere in Arizona.

Leaching of the in situ mineralization requires that the ore can be contacted efficiently by the leach solutions and that the mineral of interest will dissolve with the lixiviant used. (Lixiviant refers to the characteristics of the solubilizing fluids.) The ability to wet the ores is measured by permeability testing and an examination of the cores drilled through the ore body. In Arizona, only sulfuric acid is used when applied to the ore in dilute solutions. Laboratory
tests have tried ammonium hydroxide, sulfur dioxide, and other exotic solutions. As a general statement, only sulfuric acids solutions have been found suitable to recover copper.

To understand how flow passes through the ore and how the material properties affect leaching and recovery, a simplified example of typical layering of an ore body is presented in Table 2 along with permeability characteristics generally found in these rock types.

Permeability varies widely by rock type but typically decreases by orders of magnitude with increasing depth and consolidation of the rock. Examples from the authors’ experience are at Cyprus Tohono and BHP Billiton Florence. The overburden conglomerate unit will have permeabilities in the 9.7 x 10^{-4} to 4.8 x 10^{-1} centimeters per second (cm/sec) range. Oxide ores will have permeabilities in the 9.7x10^{-6} to 9.7x10^{-5} cm/sec range. The sulfide units will have significantly lower permeability. At the proposed Rosemont Copper Mine, the hydraulic conductivity values measured in short-duration pump tests in four pit characterization wells (PC-1 through PC-4) ranged from 3.6x10^{-7} to 1.6 x 10^{-3} cm/sec (Errol L. Montgomery & Associates, 2009, Table 3). The formations tested include basin-fill formation, Willow Canyon Formation, Glance Conglomerate, and the Epitaph Formation.

**Table 2**  Examples of in place and in situ leaching operations in Arizona

<table>
<thead>
<tr>
<th>Mine</th>
<th>Location</th>
<th>Operation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercator Minerals (formerly Cyprus Minerals) Mineral Park Mine</td>
<td>Wickenburg, Maricopa Co, Arizona</td>
<td>In place leaching of pit walls and near pit (copper in chalcocite)</td>
<td>NRC, 1995, p. 68</td>
</tr>
<tr>
<td>BHP Billiton Miami Operations</td>
<td>Gila Co., Arizona</td>
<td>In place leaching of block-caved ore (copper in chalcocite)</td>
<td>U.S. Congress, 1988, Table 6-7, p. 125</td>
</tr>
<tr>
<td>BHP Billiton San Manuel Mine</td>
<td>Pinal Co., Arizona</td>
<td>In place leaching of block-caved oxide ore in an active underground mine; In situ leaching of the oxide zone ore (copper in chrysocolla in porphyry matrix) in the open pit during open pit operations and after open pit mining was completed</td>
<td>U.S. Congress, 1988, Table 6-7, p. 125 Wiley, Ramey, and Rex, 1994</td>
</tr>
</tbody>
</table>
Table 3  Typical rock types and generalized permeability

<table>
<thead>
<tr>
<th>Rock Type/Mineralization Zone</th>
<th>General Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overburden conglomerate unit</td>
<td>High permeability</td>
</tr>
<tr>
<td>Oxide ore</td>
<td>Low to moderate permeability</td>
</tr>
<tr>
<td>Sulfide ore</td>
<td>Very low to extremely low permeability</td>
</tr>
</tbody>
</table>

The reason for the wide range of hydraulic conductivity values is the way the ore bodies were formed and subsequently altered, fractured, weathered, eroded, and redeposited as basin-fill conglomerate. As the intrusive magma pushed its way up from the magma chamber, copper and iron sulfides associated with hydrothermal fluids were deposited in veinlets and grain-size particles in the rock. Acid gasses associated with the magma subsequently attacked the original copper and iron sulfide minerals in the presence of oxygen and ultimately formed the oxidized chrysocolla. As the acidic copper-bearing solutions retreated downward deoxidation occurred, and in the absence of oxygen, copper minerals (cuprite, chalcocite) formed at a deeper level, leaving residual iron oxides and hydroxides behind in the altered, fractured, and weathered oxide zone. Later, material eroded from nearby mountains covered the deposits with poorly cemented conglomerate. The net result is that water can readily pass through the conglomerate owing to its interconnected pore spaces and lack of consolidation, less so through the oxide ore, and generally not at all or very poorly through the sulfide ores due to its tightness.
Hydrothermal alteration, weathering, and intense post-deposit fracturing can naturally open the sulfide zone and produce a network of closely spaced fractures that allow even distribution and recovery of leach solutions; the rock behavior in this case performs as an “equivalent porous media” with good interconnection between the pores and fractures independent of specific fault zones. Leaching of competent rock that lacks such a comprehensive fracture network tends to direct the leach solutions continually along specific fractures or fault zones, which does not allow thorough penetration away from the specific fault or fracture zone. This fracture-flow distribution of leach solutions does not allow equal contact with the copper oxides and copper sulfides on fractures away from the predominant fracture system and consequently reduces copper recovery.

Attempts to open ores by hydrofracturing techniques have been tried at other projects in an effort to increase permeability and flow-through of injected fluids. Hydrofracturing, typically used in the petroleum industry, is a method whereby very high pressure is applied down a well bore to create fractures that are kept open by injected sand or other materials (propants). In the late 1970s Project Sloop (Anonymous, 1967, p. 66-67) considered the use of a nuclear device at the deposit at Safford, but was stopped by the Salt 2 agreement with the Soviet Union. In essence, all attempts to increase permeability of sulfide ores have failed.

The solubility of the minerals themselves also is a major consideration. The sulfide minerals are greatly insoluble in the presence of sulfuric acid solutions. A minimal amount of chalcopyrite may be solubilized, but the mineral is disseminated in the ore along fractures typically sealed with quartz and the solution cannot readily access the copper mineralization. Molybdenum and silver are essentially non-soluble in the weak sulfuric acid solutions. The net result is the sulfide ores cannot be contacted efficiently by leach solution in low permeability rock materials, and even when contacted, the copper is minimally solubilized, and the silver and molybdenum are not recovered at all.

The Rosemont oxide ore, although not specifically tested for hydraulic conductivity, may have sufficient solubility within the ore matrix (in the presence of leaching solutions) to consider in situ leaching methods. The oxide-mineralized rock, however, is an acid-consuming ore and of very low grade at 0.18 percent total copper (WestLand Resources, 2007, p. 12) so may provide insufficient copper recovery values. If attempted, this in situ leaching would be on ore of substantially lower grade than other copper ores leached either “in place” or in situ in Arizona. “In place” or in situ ore grades at the Florence, Tohono, or Miami copper deposits are in the 0.3 percent or greater total copper concentration range.

Lastly, the regional hydrologic setting must be addressed for permitting reasons. The only permitted in situ greenfields facility is the Florence Project (ADEQ, 1997; USEPA, 1997) just
northwest of the Town of Florence, Arizona. This permit was authorized on the basis of the favorable site-specific characteristics and the regional hydrology, and the permit required an aquifer exemption. Favorable site conditions at the Florence project included an extensive overlying and confining clay layer that did not allow solutions to migrate upward into the overlying conglomerate unit and area water resources. A demonstration was made through modeling and a pilot field test that injection and recovery wells would be able to maintain hydraulic control of the leach fluids and remediate the residual leach solution upon the end of leaching. The regional hydrology gradient in conjunction with the well field design provided control of the solution flow.

At Rosemont, the deposit has a relatively thin oxide zone (approximately 50-75 feet thick) with faulted blocks that have been downthrown to the east along steeply dipping faults (see Figure 1). The oxide and sulfide zones are buried by basin-fill formations that extend to a depth of approximately 1,500 feet below surface. The authors could find no mention of any confining layer in the basin-fill formations to restrict the leached zone and protect the overlying aquifer. If Rosemont were to attempt leaching of the oxide ores by in situ leaching, the leach solutions may migrate vertically into the overlying conglomerate unit as the least tensor when the pressure is applied downhole is upward. Additionally, migration could occur laterally away from the basin-fill bounded fault blocks into the conglomerate. Furthermore, the rock matrix is acid consuming and may self-seal due to the formation of gypsum (calcium sulfate). It also appears from the description of regional geology (WLR Consulting, Inc., 2007, p. 19) that solution flow would be impacted by faults and cracks (redirecting the solution to barren rock, for example), thereby reducing the ability of leach solution to dissolve the copper silicates.

From a practical standpoint, new technology would need to be developed to facilitate the use of in-situ leaching of the Rosemont ore body because of the low hydraulic conductivity. The acid consuming nature of the ore body makes it likely that even if the rock could be fractured to increase hydraulic conductivity, the fractures would be blocked by precipitates. For these reasons, it would not be practically feasible to perform in-situ leaching on the Rosemont ore body.
4.4 Consequences

- No significant excavations or milling/grinding of the ore to fine grain size would be required, thus there would be no tailings, or overburden piles.
- The physical plant footprint would be smaller than a crushing, milling, and concentrating operation.
- The copper oxide mineralization may be recoverable by in situ methods, but the oxide zone is only 10 percent of the identified copper resource based on the stated reserves and a portion of the oxide zone may be above the water table.
- It is highly unlikely that the Rosemont sulfide mineralization could be leached effectively using in situ leach methods owing to the low permeability of the sulfide zone and the inability of the leach solutions to contact the sulfide mineralization. Recovery of copper would be extremely low due to the low solubility of the dominant copper sulfide minerals – chalcopyrite and bornite.
- Copper recovery, in what is expected to be a fracture-flow dominated system, will be low owing to the inability of the leach solutions to sweep effectively and thoroughly throughout the entire ore deposit.
- The molybdenum and silver mineralization in the sulfide ores could not be recovered by this extraction method.
- Permitting under the Safe Drinking Water Act would require a Class III well permit and an aquifer exemption permit but would likely be difficult owing to the specifics of the regional and local hydrology.
4.5 **Summary**

The *in situ* leaching works well in heavily fractured rock in which copper oxide and soluble copper sulfides are deposited along fractures, there is a very short distance (on the scale of inches) to the nearest fracture, the oxide zone represents a significant proportion of the deposit, and the leach solutions can evenly penetrate the mass of the rock to dissolve the contained copper. Environmental control is best maintained where there are no abrupt changes in the elevation of the ore deposit (across fault blocks for example) and there is an overlying confining unit to protect and separate the local and regional aquifers. These physical conditions are lacking at the Rosemont Copper deposit.

Use of the *in situ* leaching method at Rosemont would result in the loss of salable copper, silver, and molybdenum from the sulfide ores. Copper recovery from the oxide ore would be low, and it would be difficult to control inadvertent migration of leach solutions into the permeable basin-fill formations.

The *in situ* leach method has been considered as an alternative method, but in the authors’ opinion it should be dismissed. This conclusion is based upon personal experience with *in situ* and “in place” copper leaching operations in Arizona and knowledge of prior work performed in both laboratory and field leaching tests of similar ore types.

4.6 **Qualifications of Responsible Personnel**

John Kline, B.S, M.A.O.M., has a degree in chemistry and has worked for 35 years in the copper mining industry as a technical, environmental permitting, operations, and project manager. His specific work in the field of in situ leaching includes:

- Technical development of “in place” leaching at Cyprus Tohono;
- Conducted joint studies underground at the Tohono mine with U.S. Bureau of Mines personnel on fracture flow modeling and measurement in the porphyry deposit;
- Managed an underground injection test at the Tohono Mine; and
- Project Manager at BHP Copper Florence in situ leach project where he supervised the site scientific and technical investigations and pilot leach test, and obtained permitting for the site.
- Review of closure-related site characterization investigations at San Manuel Mine (geochemical field and laboratory test work, hydrogeological and geochemical modeling) performed by environmental consulting firm in support of an APP application for mine closure.
Corolla K Hoag, M.S., R.G., has a degree in economic geology and has worked for more than 20 years in the copper mining and environmental consulting industry. Her specific work in the field of in situ leaching includes:

- Geological site characterization and copper resource delineation at the BHP Copper Florence in situ leach project including detailed evaluation of the geology, mineral oxidation zones, fracture characterization, and the distribution of copper mineralization on fracture surfaces;
- Evaluation of scientific and technical results of the Florence in situ pilot leach test;
- Environmental support for Aquifer Protection Permit (APP) and Underground Injection Control permits at Florence in situ leach project.
- Geological characterization (mapping, drilling, and laboratory leaching tests) of the in situ and “in place” leaching zones at the BHP Copper San Manuel Operations for site closure investigations, geochemical, hydrogeological, and geotechnical modeling, and preparation of Arizona’s first APP application for the closure of a major copper mining and processing operation. On-going post-closure compliance monitoring of the San Manuel Operation including water quality trend analysis for impacted waters in a closed, in situ copper leaching operation.
5 Use High-temperature/High-pressure Leaching for Ore Processing

The following section on using high-temperature/high-pressure leaching for ore processing was prepared by John T. Kline, B.S., M.A.O.M..

5.1 ACD Description

The proposed alternative is the use of high-temperature/high-pressure leaching for on-site processing of oxide and sulfide ores. The leaching would be followed by solubilization by a weak sulfuric acid solution and treatment of the copper-bearing solutions by SX/EW methods. The recovered copper would be in the form of copper cathode as the final site product. Cathode would be shipped to market by truck followed by truck or rail. This alternative would replace conventional smelting and electro-refining that is described in the MPO as the selected processing method for sulfide ore.

Infrastructure requirements for the open pit operation proposed by Rosemont (WestLand Resources, 2007, p. 30-33) are summarized in Section 1.1 of this report. Infrastructure requirements for a high-temperature/high-pressure leaching alternative would include:

- A facility for milling of the ore to the proper size suitable for high temperature/high pressure leaching;
- A facility designed to covert the minerals by temperature/pressure leaching;
- A facility for leaching the ores;
- A facility for separation of the leached copper from the leached tailings;
- A facility for tailings disposal;
- A SX/EW plant, administration buildings, maintenance shops, power lines, fencing, surface roads, and parking areas.

The facility to convert the minerals would be an enclosed vessel, with off-gas scrubbers to capture any potential releases of sulfur dioxide emissions. The vessel would be heated with natural gas to a temperature of 250–260°C. The ore would be in the vessel for several minutes, and oxygen or air would be added at pressures of greater than one atmosphere. The treated ore would be placed in an agitated leach vessel where acid solutions would be added. The leached ore then would be separated from the leach liquors in a series of thickeners, after which the pregnant leach liquor would be sent on to the SX/EW circuit.

The physical plant footprint for this alternative would be similar to the crushing/milling operation proposed in the MPO (WestLand Resources, 2007, p. 9).
5.2 Technical Feasibility

The oxide ores at Rosemont are already oxidized and any treatment by oxidation (high temperatures) and pressure is not necessary. The net result on the oxide ores is that leaching on heap leach pads using a weak sulfuric acid followed by SW/EW processing into copper cathode is all the processing that is needed.

The sulfide ore is materially different in mineralization. The sulfide mineralization at Rosemont is a mixture of chalcopyrite, chalcocite, and bornite, and the ore grade is relatively low (WestLand Resources, 2007, p. 12) at 0.47 percent total copper, 0.015 percent total molybdenum, and 0.12 ounces per ton silver.

The ore would have to be reduced to a size where the surfaces could be oxidized and the treated ores leached. Crushing and milling, to make concentrates as proposed in the MPO, would be required; however, the physical size of the ore particles would have to be reduced to a dramatically smaller size than required for production of concentrate.

There is no record of bulk or milled copper ore being treated by high temperature/high pressure leaching. The scale of treating all ore in this manner is technically infeasible because the facilities to do so do not exist.

Although this evaluation found no technical equivalent to this alternative in current or past use in the copper industry for processing low-grade copper ores, low- and high-pressure leaching coupled with medium to high temperatures has been used in Arizona in a number of process types on copper concentrates (Moore, 1985; Marsden and others, 2007; Cole and Wilmot, 2009). Treating copper concentrates rather than copper ore would reduce the volume of the material to be treated by a factor of 20 to 40.

The current process used at operations in Arizona and world-wide reduces the sulfide ore in size and creates a copper concentrate prior to treatment by any of the pressure oxidation methods presently in use.

A roast leach process is one example of a high-temperature process used on copper concentrates. During the period 1988–1990, fluid bed roasting of copper concentrates followed by leaching was conducted on copper concentrates from the Cyprus Bagdad and Cyprus Sierrita mines. The processing was done at the Cyprus Tohono mine. The concentrates were treated by forming a slurry with water, which was injected into the fluid bed roasters. The process was initiated with natural gas until the exothermic reaction reached temperatures of 700–705°C. The sulfur dioxide off gasses were passed through a reactor and converted into sulfuric acid. The roasted copper concentrate (calcine) was leached with
raffinate from the SX/EW circuit, and the resultant copper-bearing solution was converted into copper cathode. This is one example where an attempt was made to process the concentrates on site and avoid shipping the concentrate to an off-site smelting facility. Although the process did recover copper, the overall copper recovery was lower than smelting and refining, and all contained precious metals were lost in the process. It did not recover any secondary metals either, such as molybdenum. No one uses the method currently in the copper industry.

Stoichiometrically, approximately 1.54 kilograms of weak sulfuric acid are produced per kilogram of copper produced by the SX/EW method. The production of weak sulfuric acid is ideal if the operation has run-of-mine oxide ore that is being leached on a heap or dump leach facility. The locally generated acid is consumed and used on-site and the need to transport acid to the site from a local smelter or other third-party acid producer is eliminated or reduced.

The net results of a roast leach process are lower recovery of copper than by smelting and loss of molybdenum and silver credits. Most waters in Arizona have some, typically low, level of chloride. The chloride will react with any solubilized silver, causing the silver to precipitate. The silver precipitate eventually reports to the tailings as silver chloride. The silver is not recovered in the process. The molybdenum is not recovered.

More recently Freeport-McMoRan has processed copper concentrates by medium-pressure/high-temperature leaching to recover copper from chalcopyrite, chalcocite, and covellite (Marsden and others, 2007; Cole and Wilmot, 2009). The concentrate is ground to a superfine grind (80 percent passing 7 microns) at an energy consumption of 68-kilowatt hours per ton. Copper recovery was 97.5 percent in the tests. The concentrates were treated at a temperature of 260°C.

The process is technically feasible on the right types of concentrate – that is, the copper-bearing minerals must be copper sulfides such as chalcocite or chalcopyrite. Chalcopyrite is the dominant copper sulfide mineral at Rosemont so this process method is technically feasible. Separate off-site treatment, however, would be required to recover the molybdenum and silver content in the residual autoclave sludges. The operator must also have a heap leach facility to recover copper from the oxide ore and to consume the excess acid that will be produced through the SX/EW process.

### 5.3 Practical Feasibility

The sulfide ore would have to be milled (ground) to a super-fine mesh size in order to expose the mineral surfaces to the leaching process. The ores would have to be heated in pressure
vessels to a temperature exceeding 260°C. The process would require off-gas scrubbers, and because the copper from the sulfide would be solubilized, a substantial load of weak acid will be generated through the SX/EW circuit during the mine life. This evaluation has not attempted to calculate the energy requirements to process ore by high pressure/high temperature leaching.

Since oxide ores will be leached by weak acid for only 6 years at Rosemont, this additional acid, which will produced over the LOM, must be neutralized by some method over the LOM or sold to an off-site third party. Some form of neutralizing circuit would be required, and that would require a source of lime either from on site or off site. The significant imbalance between the amounts of sulfide concentrates on site to treat by pressure leaching versus the amount of run-of-mine oxide heap leach ore to consume the excess acid is the primary factor that makes this alternative impractical.

5.4 Consequences

- The proposed alternative would have no impact on processing the oxide ores because they are already in an oxidized state;
- There is no current process in use to recover copper, silver, and molybdenum from copper sulfide ores by this method. The process would have to be developed and evaluated.
- Feasible methods do exist using this alternative to recover copper from copper concentrates, but silver and molybdenum would not be recovered;
- The alternative would not result in less mining, handling, energy, and labor costs or personnel or facility requirements relative to the MPO;
- The footprint of the open pit and tailings facilities would not be reduced relative to the those proposed in the MPO unless the processing costs negatively affected the LOM reserves and plan;
- The footprint of the plant facilities would not be reduced;
- The process plant would be substantial in size, require sophisticated off-gas controls, and would result in no less tailings than generated by the conventional processes proposed by Rosemont;
- A new natural gas line, not currently included in the MPO, would need to be brought to the project site, possibly resulting in an additional utility alignment/corridor;
- Fumes, sulfur dioxide off-gasses, and excess acid will be generated through the SX/EW circuit that will need to be mitigated, handled, and disposed;
- Additional permits would be needed to address the off-gasses and excess acid;
- The surplus weak acid generated through the SX/EW circuit would have to be addressed after Year 6 due to limited availability of Rosemont oxide leach ore;
• The process would require substantially more electrical energy than conventional milling and flotation;
• Off-site shipment of weak acid would occur via truck or rail transport if acid use on the heap leach pad was not sufficient to consume the excess acid.
• Off-site shipments of concentrate would be eliminated; and
• Off-site shipments of copper cathodes would be increased.

5.5 Summary

There is no current or proposed method found in the literature or current industry practice to process sulfide ores by low or high pressure or medium-temperature leaching. High-temperature pressure leaching of concentrates is used at number of copper mining operations world-wide as a replacement for conventional smelting and refining methods – especially in operations that have an optimal balance of sulfide and oxide ore to treat or other markets available to dispose of the excess acid that is produced. Rosemont currently does not have the optimal balance of oxide heap leach ore and sulfide concentrate pressure-leach ore to use all the excess acid that would be generated. The acid would need to be neutralized and disposed of on-site or sold to third parties who would commit to purchasing all of the excess acid.

Although not fully evaluated, the energy consumption to grind the ore and to provide the heat needed for conversion temperatures are expected to be too high use this method in a commercial application.

5.6 Qualifications of Responsible Personnel

The author of this section, John Kline, BS, M.A.O.M., has a degree in chemistry and has worked for 35 years in the copper mining industry as technical manager, environmental permitting, operations managers, and project manager. His specific work in the field of copper concentrate processing includes:

• Operations Manager at the Cyprus Tohono Fluid Bed Roast Leach Acid Plant.
• Technical Service Manager with experience in process evaluation and various copper technologies.
• Chief Metallurgist at Hecla Mining Company, Lakeshore Mines, which process copper sulfide and oxide ores by leaching, concentrating, roasting/leaching, and SX/EW.
• Developed methods for the recovery of silver and copper from calcined leached tailings.
6 Modify the Mine Operating Life

The section on modifying the mine operating life was prepared by SRK technical staff under the supervision of Corolla K Hoag, R.G. The section was reviewed by John T. Kline, B.S., M.A.O.M..

6.1 ACD Description

This alternative considers modifying the mine life [Life of Mine (LOM)] by lengthening or shortening the number of years taken to mine and process the same volume of ore\(^1\) cited in the MPO (WestLand Resources, 2007, p. 9). The present LOM is 20 years with a mill through-put of approximately 75,000 tons per day. This alternative evaluation considers doubling the mine life to 40 years, and halving the mine life to 10 years. Both modifications would affect multiple aspects of mining and production: personnel, mining, processing, infrastructure, equipment, operations, on- and off-site vehicular traffic, and the timing of reclamation and closure.

Neither modification would affect the ultimate size of the open pit, waste rock dumps, or tailings piles unless changes in operating or capital costs affect the LOM reserves. Nor would either modification affect the total volume of water used or the ultimate viewshed. The technical and practical feasibility of modifying the LOM are discussed in Sections 6.2 and 6.3. Consequences of modifying the mine life are discussed in Section 6.4.

6.2 Technical Feasibility

Lengthening the LOM would entail operations over a longer period of time. It would require a smaller plant size, a reduced rate of production, reduced staffing, and reduced on- and off-site vehicular traffic on a daily basis. Shortening the LOM would involve a shorter operational time period. It would require a larger plant size, a greater rate of production, increased staffing, and greater vehicular traffic on a daily basis. The trade off is not 1:1. Doubling the mine life, for example, does not reduce plant size, infrastructure, or production rate by one-half. Halving the mine life does not increase the plant size, infrastructure, or

\(^1\) The project will produce more than 230 million pounds of copper per year for 20 years. Average annual production of molybdenum and silver will be 5 million pounds and 3.5 million ounces, respectively.
production rate by a factor of two. The standard engineering rule of thumb for such changes in scale is a ratio of 1:1.6 that is increased or decreased from the base case.

Lengthening the LOM from 20 to 40 years would reduce operational conditions only by a factor of 1.6. In particular, conditions such as blasting and on- and off-site vehicular traffic, although minimized, would continue for 40 years. In actuality, emissions would go up with a longer mine life because trucks would haul smaller loads over a longer time period, which would require more truck trips. Further, mine operational related impacts would be spread out over a longer period.

Mines are impacted by environmental and safety factors including rain, wind, and the risk of safety incidents. A longer LOM increases the risk of rain damage, erosion, and wind damage and dust due to high winds. It also means that equipment gets older and more subject to failure. Regulatory impacts due to changing regulations can impact the compliance requirements as the mine life is extended. Markets conditions can change. There is also a reliance that concentrate shipments to markets are fixed, but as mine life is extended, the processing facilities, ports used to ship the concentrate, and off shore country political conditions can change.

Shortening the LOM from 20 to 10 years would require a considerable increase in the scale of the mining operation, the plant size and daily mill throughput, the number of personnel, mining and processing equipment, on- and off-highway vehicular traffic, and ancillary facilities. The mine footprint would be enlarged to accommodate these increases. Space required for the mining and milling operations would increase as well as the number of roads required for haulage, vehicular access, and deliveries on and off site. For example, a greater number of haul trucks entering and exiting the open pit would require more haul roads and different haul road routing to maintain safe and efficient traffic flow. Daily blasting would increase. The shortening of LOM time would increase noise, traffic, and air impacts on a daily basis.

Modifying the LOM for a facility comparable in size to Rosemont is technically feasible.

6.3 Practical Feasibility

Mine scheduling is largely dependent on the type and grade of material available from each of the deposits (Sullivan, 1989, p. 142). Sequencing of mining is generally achieved with specialized mining software and optimization techniques. Optimization programming (see for example, Zuckerburg and others, 2007) is used to derive the most practicable LOM given the mining bench height, ratio of overburden to ore; the size and capacity of the loading and hauling fleet, and the throughput capacity of the mill. The techniques take into consideration
the life of the mining and milling equipment, and it is not practical to expect such equipment would last 40 years if the mine life were lengthened. If the mine life were shortened to 10 years, the usefulness of the equipment and processing facilities would not be fully realized.

In addition, extending the LOM to decrease the tonnage rate produced on a daily basis would result in a decrease in haul truck sizes with less haulage capacity per truck. Smaller trucks, however, are less efficient with respect to emissions and dust due to the tire footprint.

Optimizing the mine schedule is routinely done to take advantage of improvement when new equipment is purchased or equipment technology is improved. Doubling the LOM or halving the LOM with the resultant change in scheduling over the base case is not typically done in the industry. This alternative is not practically feasible because the optimization typically performed as part of the mine planning determined that the most practical mine operating life is the one described in the MPO.

6.4 Consequences
Numerous consequences would result from modifying the mine life by either shortening or lengthening it. As a single example, the consequences to of on- and off-side vehicular traffic are shown in Table 4.

<table>
<thead>
<tr>
<th>Trips</th>
<th>Proposed LOM¹</th>
<th>Shortened LOM²</th>
<th>Lengthened LOM²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 years</td>
<td>10 years</td>
<td>40 years</td>
</tr>
<tr>
<td>Approximate Number</td>
<td>Per Week</td>
<td>Per Day</td>
<td>Approximate Number</td>
</tr>
<tr>
<td>Personnel round-trip travel to and from the plant (assumes 5-person van pools)</td>
<td>434</td>
<td>61</td>
<td>695</td>
</tr>
<tr>
<td>Shipments to and from the plant</td>
<td>582</td>
<td>88</td>
<td>931</td>
</tr>
</tbody>
</table>

² Source: Calculated by SRK Consulting, Inc., December 2009, from data in MPO Table 6.

Note: Numbers have been rounded and are approximate.

Additional consequences from lengthening or shortening the LOM are listed below.

Lengthening the LOM:

- Blast would continue an additional 20 years;
• Daily blasting frequency would be reduced;
• On- and off-highway vehicle traffic would continue at a lower level for a longer period;
• Employment time would be extended an additional 20 years.
• Fewer employees would be required per day over the life of mine (Table 4).
• Fewer shipments of sulfuric acid would be required on an annual basis;
• Shipment of sulfuric acid would continue for 40 years;
• Equipment aging may increase safety and environmental risk;
• Expected timeline to complete closure and reclamation activities would be extended;
• Regulations may change; and
• Country conditions where the concentrate processing is planned may change.

Shortening the LOM:

• The mine footprint would be enlarged to accommodate increased activity;
• Blasting would be carried out only for 10 years;
• Daily blasting frequency would be increased;
• On- and off-highway vehicular traffic related to mining and processing activities would last only 10 years;
• On- and off-highway vehicle traffic related to mining and processing activities would be increased;
• More shipments of sulfuric acid would be required on an annual basis; and
• More employees would be required, increasing related vehicular traffic;
• The expected timeline to complete closure and reclamation activities would be shortened.

6.5 Summary

The life of the mine could be shortened or lengthened. Such changes would (1) reduce the length of time that mining activities are carried out but increase the activity, or (2) reduce the mining activity by spreading it out over a longer period of time. Modifying the LOM in the manner proposed in this ACD would not reduce impacts and may increase them. These types of alternatives are not a standard practice in the mining industry. Rather than using an arbitrary production schedule, mine-planning professionals use optimization programs to determine the most favorable life of mine using inputs from all of the conditions associated with the mine, such as infrastructure requirements and considerations of ore type, grade, and occurrence. For these and other reasons, while the alternative is technically feasible it is not practically feasible.
6.6 Qualifications of Responsible Personnel

Comments included in this discussion are general in nature and are based on observations by the authors and reviewers at mine operations around Arizona and elsewhere in the industry. Reviewers include Corolla K Hoag, M.S., R.G. and John T. Kline, B.S., M.A.O.M., each with more than 23 and 35 years in the mining industry, respectively.
7 Suspend Mining during Certain Environmental Conditions

This section on suspending mining during certain environmental conditions was prepared by SRK technical staff under the supervision of Corolla K Hoag, R.G.

7.1 ACD Description

The proposed ACD would restrict mining operations to day only or night only. This alternative would lengthen the LOM and was discussed in Section 6 in the description of doubling the LOM.

The ACD also proposes to suspend mining during certain environmental conditions such as high winds, extreme drought, or excellent visibility. The intent of this alternative is apparently intended to reduce or eliminate fugitive dust created by mining and processing activities. Fugitive dust emissions may occur during mining and mineral processing operations.

7.2 Technical Feasibility

It is technically feasible to operate a mine on a 12-hour schedule (day only or night only) or to suspend mining operations during periods of extreme weather conditions.

7.3 Practical Feasibility

It is not practically feasible to operate a mine on a 12-hour schedule or to suspend mining operations for most environmental conditions. It is practically feasible to suspend some operations at the mine site for certain extreme environmental conditions, and this is done as a standard industry practice. Selected examples are provided below.

1. It is not practically feasible to operate a mine on a 12-hour schedule. Mining and milling operations are continuous-flow processes that are not amenable to being shut down half of each day (12-hour scheduling). For that reason it is an industry standard practice to operate an open pit mine and the associated processing facilities on a 24-hour-per-day schedule, 365 days per year. Operating on a 12-hour schedule would double the life of the mine. Such a change in scale would not lessen impacts and may increase them. (See Section 6—Modify the Mine Operating Life.)

2. It is not practically feasible to suspend mining during prolonged environmental conditions such as an extreme drought. The length of such a suspension would be unknown. Mine
staffing would be problematic, as would purchasing of equipment and supplies, meeting delivery schedules, mine and equipment maintenance, upkeep of infrastructure, and so on.

3. It is not practically feasible to suspend mining during high winds, in most instances. [Exceptions are described in Item 4, below.] A Class I or Class II air quality permit, required by the ADEQ, will establish air-quality standards for the facility. The permit class will depend upon the potential and magnitude of emissions from point sources, as determined by pre-application ambient particulate and meteorological monitoring and air-impact analyses. For normal operating conditions, dust at the mine site will be addressed by physical, engineering, and operational controls, as follows:

Roads

- Dust will be suppressed by wetting the road surfaces using a fleet of appropriately sized water trucks with up to 30,000-gallon tank capacities (WestLand Resources, 2007, p. 11).

Tailings (WestLand Resources, 2007, pp. 74-75)

- Waste-rock buttresses will break up air flow and reduce large areas of tailings to exposure to windy conditions.
- The moisture content of the tailings delivered to the dry stack area will be between 10 and 15 percent, sufficient to ensure that dust is not generated on the belts or in the stacking operation.
- Tailings will be stacked in an irregular pattern, breaking up air flow patterns.
- The use of dozers, trippers and mobile conveyors will reduce the use of wheeled vehicles.
- Lack of size segregation during tailings placement may reduce the likelihood for dust to become airborne.
- Binder material and agglomeration chemicals may be used to bind smaller particles so they do not become airborne.
- Water application may be used to suppress dust if it becomes necessary to control dust from limited areas of the tailings.

Mill Site

- Dust will be controlled in the crushing area with a wet scrubber dust collection system (WestLand Resources, 2007, p. 18).
- Dust in the coarse ore stockpile reclaim area will be controlled with a wet scrubber dust collection system similar to that in the crushing circuit (WestLand Resources, 2007, p. 18).
- Water sprays will be used for dust control at the primary crusher dump pocket (WestLand Resources, 2007, p. 75).
- Wet scrubbers will be used in the primary crushing building and crushed-ore stockpile building and tunnels (WestLand Resources, 2007, p. 75).
- The crushed-ore stockpile and concentrate loadout will be covered to control dust (WestLand Resources, 2007, p. 75).

4. It is practically feasible to suspend selected operations temporarily during high winds to comply with air-quality permit requirements. This is a standard industry practice.

5. It is practically feasible to suspend selected operations temporarily during extreme weather conditions to protect worker health and/or safety and the environment. These are standard industry practices. Specific directives typically are contained in mine Health and Safety Plans. For example, haul trucks do not drive into and out of the open pit during periods of torrential rain when the roads are wet and dangerous, and blasting is suspended during electrical thunderstorms. A run-of-mine stockpile, located near the primary crusher, will be used throughout the mine's life to provide flexibility in handling such short-term operating disruptions in the sulfide ore crushing and conveying system (WestLand Resources, 2007, p. 12).

6. It is practically feasible to limit blasting to daylight hours, typically between 9:00 am and 4:00 pm (WestLand Resources, 2007, p. 13).

7.4 Consequences

The principal consequence of limiting mining to 12 hours per day is to double the life of mine. Specific consequences are discussed in Section 6, under Shortening the Mine Life. The consequences of suspending mining during extreme environmental conditions are listed below:

- Unsafe operating conditions would be avoided.
- Dust emissions would be reduced.
- Air quality standards would be met.
- Processing could be disrupted.
- Scheduling could be adversely impacted.
- Employee schedules could be adversely impacted.
7.5 Summary

It is technically feasible to operate the mine on a day-only or night-only schedule. Operating on a 12-hour schedule would double the mine life and is discussed in Section 6.

It is technically feasible to halt mining and processing operations temporarily for extreme environmental conditions. It is not practically feasible in most instances to cease mining even temporarily. It is more practical to have in place physical, operational, or engineered controls that will prevent or mitigate adverse effects. However, it is standard industry practice to cease operations temporarily during environmental conditions that involve health and safety issues or damage to the environment.

7.6 Qualifications of Responsible Personnel

The author of this section, Corolla K Hoag, M.S., R.G., has worked in the mining and consulting industry for more than 23 years. The discussion is based on standard industry practices, the observations of SRK technical staff at domestic and foreign mining operations, and the author’s work experience at multiple copper mining operations in Arizona.
8 Use Sea Water for Mining and Ore Processing

The following section was prepared by John T. Kline, B.S., M.A.O.M.

8.1 ACD Description

Rosemont Copper plans on using approximately 3,800 gallons per minute (gpm) for industrial operations with a maximum of 5,000 gpm used during peak periods. The evaluation will address the technical and practical feasibility of supplying treated sea water for use in mining and processing operations at Rosemont Copper instead of the planned use of local groundwater.

8.2 Technical Feasibility

Sea water in its native state contains about 35,000 parts per million (ppm) of salt. In comparison, ground water contains generally less than 1,000 ppm of total dissolved salts (Anonymous, 2009). Water at the site would be used for dust control, processing, and for potable water. Sea water in its untreated form is corrosive to steel and is not potable. The salts would interfere in the process. Sea water could not be used in its native state for dust control on roads because of possible groundwater contamination. The review will assume sea water is taken from its sources and treated at the coastline prior to pumping to the site.

The use of sea water for industrial and drinking purposes is a well-known technology and has been used for many years. According to the U.S. Geological Survey (Anonymous, 2009), “In 2002, there were about 12,500 desalination plants around the world in 120 countries. Among industrialized countries, the United States is one of the most important users of desalinated waters (6.5%), especially (sic) in California and parts of Florida.”

“In November 2009, Connecticut-based Poseidon Resources Corporation won a key regulatory approval to build a $300 million water desalination plant at Carlsbad, north of San Diego California” (Energy Recovery, Inc., 2008). The plant is designed to produce 50 million gallons of drinking water per day (34,700 gpm) for southern California users. This plant alone will produce approximately 10 times the daily needs of Rosemont.

There are two main processes used to remove salt from sea water, namely, distillation and reverse osmosis (RO) (Ashley, 2009). RO is the more efficient process. This well-known and readily available technology uses filtration of sea water followed by passing the sea water past high-pressure membranes. The salt is separated as highly concentrated brine and returned to the sea. There are some environmental issues associated with this process as the brine may
have impacts on the local environment where the salt is discharged (California Coastal Commission, 2004).

Pumping long distances is also a well-known and commonly used technology. It is done in the oil and gas industry, and water is commonly pumped from its source to its end users through steel, concrete, and high-density polyethylene pipelines.

8.3 Practical Feasibility

The nearest source of sea water is the Gulf of California (Sea of Cortez) located southwest of Tucson, between the mainland of Mexico and Baja Mexico to the west. The approximate distance from the mine site to Puerto Peñasco, which is the closest town on the Gulf, is 250 miles via roads. By dead reckoning, the distance is approximately 165 miles, but this path is across mountain ranges. The pathway crosses private fee lands, Indian Nation lands, and federal lands in the U.S. The pathway in Mexico traverses Mexican federal land and private land, and would cross an international boundary.

The second source option is a location near or surrounding San Diego, California. The approximate distance of the pipeline by dead reckoning is over 430 miles. The pipeline would cross state and federal lands and Indian Nation lands, and traverse two states.

In both cases, the water line would have to be buried some of which would be along rights-of-way for existing roads. The pipeline would also cross through potentially sensitive areas such as archaeological sites, rivers and streams, mountains, town sites, and highways. The water would have to pass through purpose-built pumping stations due to elevation changes, expansion of the line, and line loss due to friction.

Numerous permits would be required and there may be a need to have an international agreement if the water source is from the Gulf of California.

As noted earlier in the Section 8.2, this would be a major undertaking, probably requiring its own EIS. In the opinion of this author, the technology is feasible, but the installation of such a pipeline to transport and maintain the water line is impracticable.

8.4 Consequences

- The water line would cross through potentially sensitive areas such as archaeological sites, rivers and streams, town sites, and highways;
- The water line would have to be buried;
- Numerous permits would be required;
- Brine disposal would be necessary at the treatment plant in Mexico or California;
• A determination would need to be made regarding legal ownership of the water rights; and
• International agreements may be required.

8.5 Summary

The production of water for mining and processing from seawater is possible because it is a commonly used technology. The large distances required to pump the treated water are substantial and the net result is that the alternative is impracticable due to the legal and environmental impacts that would be caused by the water treatment plant, the residual brine, and the transport pipeline.

8.6 Qualifications of Responsible Personnel

The author of this section John Kline B.S., M.A.O.M., has a degree in chemistry and has worked for 35 years in the copper mining industry as technical manager, environmental permitting, operations managers, and Project manager. His specific work in the field of water management and treatment includes:

• Manager of Plant Operations, where he was responsible for operation and maintenance of a 14,000 gpm water production system;
• Manager of an Environmental Water Testing Laboratory;
• Technical Manager where he conducted test on mine solutions treatment by ion exchange and reverse osmosis; and
• Manger of an In Situ Copper Mining Leach Project in which a membrane filtration system was designed to treat mine water effluents.
9 Use Reclaimed Water for Mining and Ore Processing

This alternative was prepared by SRK Consulting technical staff under the supervision of Corolla K Hoag.

9.1 ACD Description

Rosemont requires approximately 3,800 gpm (6,000 acre feet per year (af/yr) of fresh water for mining and processing operations (Stantec Consulting, 2009, p. 1). (One acre foot equals 325,851 gallons.) The company plans to acquire a water supply from the Santa Cruz basin to the west of the project site, from the aquifer within the Upper Santa Cruz sub-basin of the Tucson Active Management Area groundwater basin (WestLand Resources, 2007, p. 42.) By purchasing and recharging water from the Central Arizona Project Rosemont has committed to offset total project pumping by 105 percent (WestLand Resources, 2007, p. 42.)

This alternative proposes to use reclaimed water for mining and ore processing operations. Two types of water that may be discharged by a wastewater treatment plant are effluent and reclaimed water. Effluent is wastewater that has been treated to at least the minimum standards for discharge to the environment per Arizona Pollutant Discharge Elimination System (AZPDES). Reclaim water is effluent that has undergone additional treatment that makes it suitable for irrigation of turf, ornamental landscaping, and orchards and vineyards. In Arizona there are different classes of reclaimed water, depending on the level of treatment. For example, the reclaimed water produced by the City of Tucson is Class A reclaimed water. Class A water is required for reuse applications where there is a relatively high risk of human exposure to potential pathogens.

The proposed alternative advocates using reclaimed water from Tucson, Green Valley, and other communities in Pima County rather than pumping groundwater for mining use. This would require construction of water lines from the wastewater treatment plants directly to the proposed mine site or to a consolidated pump station and then to the mine. In addition, a filtration plant would have to be built at the mine site or somewhere along the pipeline. The alternative assumes that excess capacity is available for purchase from the providers.

9.2 Technical Feasibility

The use of reclaimed water for mining and processing at the proposed Rosemont Copper Mine would require transporting the water from the wastewater treatment plants where it is generated to the mine site. This would require either road transport by truck or the construction of pipelines, both of which methods are technically feasible. If sufficient water
could be purchased from the City of Tucson or some combination of municipalities, pipeline(s) could be constructed to deliver the reclaimed water to the mine.

The use of reclaimed water is technically feasibly and well suited for mining and processing operations—especially for the milling and concentrating facilities. Many mines in Arizona, such as the BHP Billiton Pinto Valley Mine and Freeport-McMoRan Bagdad Mine, use water from their on-site wastewater treatment plants in their mill and concentrator facilities. The gray water typically comprises a small volume of the water needed. The majority of reclaimed water used at a mine site is pumped back from reclaimed-water ponds on conventional tailings facilities.

9.3 Practical Feasibility

Insufficient availability of reclaimed water on an assured, continuing basis during Rosemont’s LOM from one or more wastewater treatment plants is the primary limitation on the practical feasibility of this ACD. Existing long-term contracts with private parties typically secure the reclaimed water for reuse within the communities that generate the water. As of 2007, the Green Valley wastewater treatment plant did not have a reclaimed delivery system for Green Valley effluent (Huckelberry, C.H., 2007, Long-Term Green Valley Water Supply: Memorandum to the Pima County Board of Supervisors, October 2, 2007, 5 p., 2 appendices.) The Tucson Water reclaimed water delivery system does not extend to that area.

If sufficient water could be purchased, transporting this volume of water would require continual, round-the-clock operation of a large fleet of commercial water trucks (semi-trucks with approximately 9,000 gal container capacity or 500 trucks/day), which would not be practically feasible. The only practical method to transport the required volume would be to construct a pipeline from a pumping station in Tucson, which is the only potential source with sufficient capacity. The length of pipeline would approach 50 miles; the pipeline would cross private, state, and federal land, and would require extensive permitting to construct and operate. This alternative is practically feasible provided sufficient reclaimed water is available on a continuing basis.

9.4 Consequences

- The use of reclaimed water for mining and processing operations at the Rosemont mine is unlikely to cause any difficulties in those operations;
- Potable groundwater would not be withdrawn from the groundwater aquifer in the Upper Santa Cruz Basin.
- Reclaimed water for the mine would be diverted from other uses, such as turf irrigation, municipal use, and agriculture; and
• Pipelines would be required to transport water from the source(s) to the proposed mine (distances up to 50 miles).

9.5 Summary

While technically feasible, the practical feasibility of using reclaimed water at the Rosemont mine is completely dependent on available excess capacity.

9.6 Qualifications of Responsible Personnel

This section was prepared by technical staff of SRK Consulting, Inc., Tucson office, under the direct supervision of Corolla K Hoag, R.G. The information was compiled from publicly available data and is based on the observation of SRK technical staff at various domestic and foreign mining operations.
10 Use Microbial Leaching for Ore Processing

The following section on using microbial leaching for ore processing was prepared by John T. Kline, B.S., M.A.O.M.

10.1 ACD Description

Rosemont has proposed to mine oxide and sulfide ores in an open pit operation. Sulfide copper recovery would be via a milling/concentration circuit; oxide copper would be recovered via a heap leach and SX/EW operation. The Rosemont deposit was formed by a quartz monzonite magma body intruding a relatively high-lime content host rock, namely the Horquilla Limestone, Colina Limestone, and Epitaph Formation (Tetra Tech, 2007, p. 8). The mineralization is characterized by finely disseminated and vein-controlled bornite, chalcopyrite, sphalerite, molybdenite, and pyrite; silver occurs in minor quantities associated with the molybdenite3 (Tetra Tech, 2007, p. 9). The pyrite content in the intrusive and sedimentary host rocks is low compared to other southwest porphyry deposits.

An alternative has been proposed to use microbial leaching for ore processing of all ore materials. The proposed alternative would eliminate the steps needed to mill and concentrate the sulfide ore. Copper and molybdenum concentrates would not be produced and the resulting tailings disposal facility would not be needed. Under this proposed alternative the following operational methods would be used:

- Oxide and sulfide ores would either be blasted or crushed to a suitable size, or placed on the lined heap leach pad as run-of-mine ore (i.e., not crushed).
- The heap leach materials would be inoculated with *Thiobacillus* species or other bacteria to facilitate the oxidation and leaching of sulfide minerals. Inoculation would not be necessary for the oxide copper ores.
- Leaching would be via application of acidic solutions most likely from the solvent extraction circuit after inoculation of the ores with the appropriate strain(s) of *Thiobacillus*.
- Piping, connected to low-pressure blowers, would be installed to pump air into the heap leach pad at the base of the heap to assist in oxidation and to maintain the required heat conditions within the heap.
- Copper would be recovered from the pregnant leach solution (PLS) via the solvent extraction-electrowinning (SX/EW) circuit and shipped to market as copper cathode.
- Lined inoculum, raffinate, and PLS ponds would be constructed to culture the bacteria and store the process solutions.
10.2 Technical Feasibility

The use of microbial leaching on Rosemont sulfide ores is dependent on the mineralogy of the ore and the potential leaching conditions. Heap leaching of sulfide ores is done widely around the world on low-grade sulfide ore containing chalcopyrite, chalcocite, and other sulfide copper minerals. Local, Arizona examples with varying levels of success include:

- BHP Billiton Pinto Valley mine near Miami,
- Freeport-McMoRan Bagdad mine near Bagdad,
- Freeport-McMoRan Morenci mine near Morenci,
- Freeport-McMoRan Sierrita mine near Green Valley, and
- ASARCO Ray mine near Hayden.

A substantial amount of laboratory and pilot test work has been done over the past decades to determine how to enhance the heap leach recovery of copper from primary sulfide minerals like chalcopyrite. Robertson and others (2005, p. 473) reported that 80 percent of the world copper resources, including resources in Chile, Peru, and Australia, consist of low-grade chalcopyrite mineralization for which the grade is too low to mill and concentrate and for which the mineralization cannot be processed in any other way than by heap leaching. Low copper recovery and long recovery times have been operational challenges for heap leaching of these sulfide minerals.

*Thiobacillus* aid in the leaching by electomotively converting the iron in solution from a reduced oxidation state (ferrous) to the oxidized form (ferric). The ferric sulfate then attacks the surface of the copper minerals and releases the copper into solution. The ferric iron is reduced back to ferrous state during the release of the copper into solution. The *Thiobacillus* then cycle the ferrous iron back to ferric and the process continues.

There are several environmental factors that allow the bacteria to assist in leaching the chalcopyrite sulfide ores. These are:

- The ore must have sufficient quantities of associated iron sulfide (pyrite) to release the iron as ferric iron, which then assists in dissolution of the copper minerals (Breed and others, 2000).
- The temperature of the ore, once the reaction starts, must remain in a suitable range to allow the bacterial to survive and grow. If the temperature gets too warm or cold the reaction will slow or cease entirely. Bioleaching of chalcopyrite generally requires higher heap temperatures than required for leaching chalcocite, which can be achieved at ambient temperatures (Robertson and others, 2005, p. 474).
• The copper minerals must be contacted by the leach solution. If the mineral is encapsulated within the rock matrix or by a quartz vein, or is an area where flow bypasses the mineral surfaces, recovery of the copper will be lower or nonexistent.
• Chalcopyrite dissolves slowly, so leach times are on the order of months to years.
• Oxygen must be available to the mineral surface, and air flow is needed to maintain the core temperatures of the heap leach, so leach pad engineering is a key issue (Burkhalter and others, 2002, p. 5).
• Forced air has been used at several sites to ensure good availability of oxygen (Schlitt, 2006).

Once a leach system is employed, leach fluids become entrained in the heap and discharge by gravity to a solution collection pond or sump. Rainfall impacts the off-flow of the heap leach, so when the rainy season occurs, more outflow will generally occur for several weeks to months. Although the use of drip irrigation will reduce water use over the sprinkler method, a substantial amount of water still will be tied up in the leaching process. The end of the mine life will leave millions of gallons of draindown solutions that will need to be handled and remediated. This is true of all of the leach operations currently in use around the world.

In essence, microbial leaching of the Rosemont sulfide ore requires that the copper sulfides be exposed to the bacteria and be contacted by the leach solutions, that the heap be kept at the right oxygen and heat conditions, and that the bacteria are not killed by too much/too little water or acid. If all the operational conditions can be met, bacterial leaching of copper from chalcopyrite can be technically feasible.

10.3 Practical Feasibility

The author could find no metallurgical test work conducted on Rosemont materials to evaluate the practical feasibility of this option. Selected, limiting factors that impact the practicality of this proposed alternative include:

• The pyrite levels in the ore appear to be lower than those found in other southwest copper porphyry deposits. Pyrite is a contributor to successful microbial leaching.
• The matrix of the ore is in limestone, which would result in buffering of the ore to a higher-than-desired pH and likely would impede leaching. Precipitation of gypsum (calcium sulfate), resulting from sulfuric acid in contact with limestone (calcium carbonate) may cause the leach solutions to “blind off” and not contact all rock materials evenly or thoroughly.
• The minerals are finely disseminated in the ore matrix (Tetra Tech, 2007, p. 9), so exposure to the leach solution will be retarded unless the ore is crushed, which then exposes more lime to the acidic solutions.
• No molybdenum or silver would be recovered by the microbial leaching and processing of ores.
• The heap leach pad would be about 10 times the size of the oxide leach pad and would require engineered placement of the ore and surge ponds sufficiently large to hold major storm events.
• In order to expose the mineral surfaces, blasting may need to be enhanced to limit the ore size or the ore particles, or crushing may be required.
• Overall copper recovery will be lower than milling and concentrating.
• Leach times will take months to years to attain a modest level of recovery

Once a leach system is employed, significant volumes of leach fluids become entrained in the heap and must be drained and remediated at the end of mine life, which is extended owing to the slow recovery of the copper. Draindown of entrained solutions will also occur in the planned oxide heap leach facility, but the scale is substantially larger owing to the larger quantities of sulfide ore.

The lack of microbial leaching test work conducted on Rosemont materials makes it impossible to determine the practical feasibility of this alternative at this time.

10.4 Consequences

The consequences of using microbial leaching to process sulfide ore in lieu of crushing, milling, flotation, and concentration of the sulfide ore include:

• Loss of silver and molybdenum metal recovery.
• The recovery of copper through the proposed ACD will be lower than that in crushing, milling, flotation, and concentration.
• Exposure of finely disseminate copper sulfides to the bacteria and to the leach solution will be retarded unless the ore is crushed, which then exposes more lime to the acidic solutions.
• Tailings disposal would be eliminated.
• The footprint taken up by heap the heap leach pads, SX/EW process plant, and process ponds will increase beyond what is proposed in the current MPO.
• The time to get the copper to market as product is increased due to the long leach times to dissolve the copper metal from the leach ore.
• The operation of the Rosemont life of mine will be extended due to slow leach kinetics and dealing with fluids generating as part of closure drain down and storm events.
• Solutions entrained in the heap leach pad and impacted by storm event will have to be managed and remediated for a substantial period (many years) after ore mining is no longer feasible.

10.5 Summary

Microbial leaching is done around the world as a normal course of business to extract copper from chalcocite and chalcopyrite sulfide material. Mines use the technique where the sulfide ore grade is too low to concentrate, and other methods of processing low-grade chalcopyrite are not economically feasible. Microbial leaching may be technically feasible, but is not likely to be practical in the case of Rosemont ores owing to the following conditions:

• The copper is located as finely disseminated minerals in an acid-consuming host rock matrix;
• Molybdenum and silver credits will be completely lost;
• Pyrite concentrations may be too low to fully assist the microbial leaching kinetics; and
• Lower copper recovery is expected than from the milling, flotation, and concentrating method.
• Tailings disposal would be eliminated.
• The footprint taken up by heap the heap leach pads, SX/EW process plant, and process ponds will increase beyond what is proposed in the current MPO.

10.6 Qualifications of Responsible Personnel

The author of this section, John Kline BS, M.A.O.M., has a degree in chemistry and has worked for 35 years in the copper mining industry as technical manager, environmental permitting manager, operations manager, and Project manager. His specific work in the field of copper concentrate processing and leaching includes:

• Technical Service Manager with experience in process evaluation and various copper technologies;
• Chief Metallurgist at Hecla Mining Company Lakeshore mines, which process copper sulfide and oxide ores by leaching, concentrating, roasting/leaching, SX/EW;
• Consulted on numerous leaching projects involving heap and dump leaching;
• Directed laboratory leach studies on heap and dump leach projects on ores from Arizona and elsewhere around the world’ and
• Managed permitting activities on several ore leach projects.
11 Replace Internal Combustion Engines with Electric Motors

The following section on replacing internal combustion engines with electric motors was prepared by John T. Kline, B.S., M.A.O.M.

11.1 ACD Description

The proposed alternative is to replace internal combustion engines with electric motors, presumably on mobile and fixed equipment and other mine equipment wherever feasible and practicable, in order to reduce local green house gas emissions (GHG).

Rosemont plans to drill blast holes with diesel or electric powered rotary rigs. Electrically powered shovels with 60 cubic foot dippers will perform the bulk of the ore and waste rock loading into the haul trucks. The loading would be augmented by use of two diesel-powered 33 cubic yard frontend loaders. The ore would be transported via haul truck to the crusher or waste pile as needed (WestLand Resources, 2007, p. 14). The type of haul truck to be used was not noted in the MPO (WestLand Resources, 2007). Rosemont was considering diesel-powered units with either mechanical or electrical drive.

The haul trucks would transport the ore from the open pit to a crusher located near the east pit rim. Crushed ore would then be transported by electrically powered overland conveyor to the crushed-ore storage pile. The ore then travels into the mill by electric operated conveyors (WestLand Resources, 2007, p. 13).

Oxide ore would be transported by the haul trucks to the leach pads and placed in 30-foot lifts. Crawler dozers would spread and rip the ore to promote infiltration of the leach solutions. All pumping from the various leach and environmental collection ponds would be by electrically operated pumps. The sulfide ore feeders, conveyor systems, and processing systems inside the SX/EW and mill circuits are electrically operated and controlled.

It is believed the intent of the proposed ACD is to limit GHG, including carbon dioxide, nitrogen oxides, and sulfur dioxides. The table below lists those pieces of operating equipment that could release green house gases (GHG).

Rosemont was in the process of conducting pre-air quality application air monitoring to determine whether it needed an Arizona Class I or Class 2 air quality permit. This required a study of the local air shed to estimate the emissions inventory, in order to determine whether
the proposed operation would comply with all state and federal air quality requirements (WestLand Resources, 2007, pp. 72 and 73).

Table 5  Equipment that could release greenhouse gases

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Planned Equipment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shovels</td>
<td>Electrically operated</td>
<td>Minimal to no GHG</td>
</tr>
<tr>
<td>Haul trucks</td>
<td>Diesel powered with either mechanical or electrical drives</td>
<td>Decision on unit not finalized as of the 2007 draft MPO. A trolley system was being investigated by Rosemont (WestLand Resources, 2007, p. 14)</td>
</tr>
<tr>
<td>Front end loaders</td>
<td>Diesel powered</td>
<td></td>
</tr>
<tr>
<td>Crawler dozers</td>
<td>Diesel powered</td>
<td></td>
</tr>
<tr>
<td>Front end loaders</td>
<td>Diesel powered</td>
<td></td>
</tr>
<tr>
<td>Backup generators</td>
<td>Diesel powered</td>
<td></td>
</tr>
<tr>
<td>Pickup trucks</td>
<td>Gasoline powered</td>
<td>For on-site transportation</td>
</tr>
<tr>
<td>Drill rigs-blast hole</td>
<td>Diesel or electrically powered</td>
<td>Decision on unit not finalized as of the 2007 draft MPO (WestLand Resources, 2007, p. 14)</td>
</tr>
<tr>
<td>Motor graders</td>
<td>Diesel powered</td>
<td></td>
</tr>
<tr>
<td>Water trucks</td>
<td>Diesel or gasoline powered</td>
<td>Fuel depends on size of truck</td>
</tr>
</tbody>
</table>

Source: Compiled by SRK Consulting, Inc.

Non-road diesel emissions are regulated under federal law. Tier 1–3 standards are met by changes in engine designs that were phased in over the period 2000–2008 (DieselNet, 2009, p. 1). Rosemont will have to demonstrate compliance with state and federal air quality regulations to obtain an operating air quality permit.

11.2 Technical Feasibility

Rosemont has indicated in the draft MPO (Westland Resources, 2007) that it will consider several possible methods of reduction in emissions. These include:

- Diesel-powered haul trucks with either mechanical or electrical drives,
- Selected electrically powered blast hole drill rigs, and/or
- Haul trucks partially operated on an electric trolley system.

The technology for recent haul truck design includes electrically assisted drives. Liebherr, which began in the business in 1949, introduced the first 218-ton diesel-electric truck for the mining industry in 1982, and in 1998 Liebherr introduced what was at the time the world’s largest ac drive diesel-electric truck (Yernberg, 2000). Caterpillar electric drive made its most
recent debut at MINExpo 2008, Sept. 22-24 in Las Vegas, Nevada (Curfman, 2008; Anonymous, 2008). The move from all-mechanical to electric-assisted drives is a well-known technology. These systems are used widely on a broad range of haul trucks.

Likewise, trolley systems are also technically feasible and have been used where conditions allow (Brown and others, 2001). These units are designed so that they can switch from diesel of electrical trolley, depending upon location and conditions.

Backup generators are used to supply power needed for critical systems where safety, operational, or environmental damage could occur in a power outage. These systems may be attached to the operational plants or located remotely at collection sumps. They, by need, operate in the absence of supplied power. They operate on diesel fuel. The units are included in the air quality permits and are accompanied by an estimated amount of annual operating hours, which are included in the air quality modeling. These generators are operated on an as-needed basis when there is a loss of supplied power. They are also operated during test cycles to assure they are available when needed.

Other mobile equipment that moves from location to location on a frequent basis includes:

- Motor graders
- Crawler dozers
- Water trucks

These units are used widely around the property on pit roads, plant road, access and utility corridors. This author found no examples where these types of unit are electrically powered.

Rosemont proposes to install its crusher near the pit. There are examples where locating the crusher within the pit coupled with conveyors systems to feed the mill have been used (Dowall and Linde, 1993). Truck travel has been offset by near-pit or overland conveyor systems at locations in Arizona that include Cyprus Tohono, Freeport Sierrita, and Freeport Morenci. The goal was to limit truck travel and time to transport the ore.

### 11.3 Practical Feasibility

Several methods have been used locally in Arizona and internationally to reduce GHG emissions.

Substitution of electrical systems for diesel powered back up units is impractical as the diesel generators are stand-alone systems and operate only when the electrical grid or on-site electrical systems are inoperable. The impact on air quality is minimal due to the limited time
of operation. Generally, the air quality permit will include restrictions on hours of operation of these units.

Electrically assisted motor drives on haul trucks are commonly used in the industry. These units are designed to reduce carbon emission and meet Tier II EPA Guidelines (DieselNet, 2009). The in-pit shovels planned by Rosemont are stated to be electrically powered units. These units produce no significant on site green house gases. Water trucks and wagons, and motor graders must be able to move over large geographic areas and it is not practical to have electrical tethers tied to them due to the distances.

Pickup trucks and maintenance vehicles could be replaced with battery-powered units such as golf carts; however, this is not practical due to the safety exposure of the drivers, who must conduct their work over large areas and in proximity to large mobile equipment.

Trolley systems and in-pit crushing systems are used practically in the mining industry; however, the use of the systems is site specific depending on elevation, distances traveled, safety considerations, and slope stability.

11.4 Consequences

Replacement of mechanically driven haul trucks, outside pit primary crusher with an in-pit crusher, and other mobile equipment will offset GHG emission on site. This offset is diminished by the additional installation of electrical power line, poles, and trolley systems that will require relocation when the pit enlarges. Likewise, an in-pit crushing system may reduce haul truck travel, but will require movement of the crushing facility periodically. Safety is also a considered factor due to installation of in-pit cables, overhead lines, and contact of trolley lines with nonhaul equipment by personnel and in-pit traffic.

11.5 Summary

Rosemont has indicated it will consider the use of electrical systems as part of its final determination of equipment mix and air quality studies as a method to offset GHG emissions. The final MPO should include a discussion of the results of these studies and the logic of the proposed choices. The net result is that the final choice will depend on mine design, safety considerations, and air quality impacts.

11.6 Qualifications of Responsible Personnel

The author of this section John Kline B.S. M.A.O.M., has a degree in Chemistry and has worked for 35 years in the copper mining industry as technical manager, environmental permitting manager, operations manager, and project manager. Specifically, he has been
responsible for mine and plant evaluations, mine and plant site power management, power reduction studies, air quality permitting, and operational management.
12 **Reconstruct the McCleary Drainage Features at Closure**

The following section on tailing relocation to reconstruct the original McCleary drainage at closure was prepared by Dave L. Bentel, Pr. Eng and Clara Balasko, P.E.

12.1 **ACD Description**

This section describes the alternative of removing tailings solids from the McCleary Drainage during Phase II of the project. The base case used for this alternative was the Phased Tailings Alternative presented by AMEC (2009).

AMEC (2009, p. 16 and Drawing No. 600-CI-906) indicates that mine tailings will be placed in the McCleary Canyon drainage during Phase II of the Dry Stack Tailings Storage Facility (TSF). Phase II will commence in Year 12 and continue through the completion of the project in Year 20.

In the final configuration the Phase II Dry Stack TSF, the tailings will cover approximately 7,300 ft of the length of McCleary Canyon wash. The tailings will be stacked to an elevation of 5,237.5 feet above mean sea level (ft amsl) at the end of operations and will attain a maximum height of 587.5 ft at the midpoint of the TSF eastern boundary as shown on Figure 2. This height is the vertical difference between the ground elevation at the embankment toe and the final tailings surface elevation, as this defines the extent of tailings that requires removal.

As part of the site closure, this ACD proposes that the tailings placed in McCleary Canyon would be excavated and relocated to re-establish the natural drainage. The goal is to provide a low-maintenance alternative that minimizes potential downstream watershed impacts by providing the maximum surface water flow-through. Activities that would be involved in the implementation of this ACD are:

- Excavation and relocation of the tailings that overlie the McCleary Canyon drainage;
- Construction of flow protection within the channel and floodplain; and
- Reestablishment of McCleary Canyon drainage upstream of the plant site.

Two potential tailings removal scenarios have been evaluated.

Scenario 1 incorporates removal of the minimum amount of tailings necessary to allow “potential maximum through-flow function,” assuming that the through-flow generated in
upstream catchment areas is routed towards the northwest corner of the TSF (at the area of lowest TSF embankment height), and then into an approximately 150 feet wide channel section constructed by excavating at maximum 3:1 (H:V) side slopes, and removing the previously stored tailings along the approximate route shown on Figure 2 (black dotted and solid lines). [Note: The 150 feet wide base width is an estimate of the width required to route peak flows generated during the Probable Maximum Flood, and is based on designed profiles for the diversion channel (AMEC, 2009, Drawing No. 600-CI-940)]. Flows would be conveyed in the channel toward the midpoint of the remaining eastern embankment, and then down the eastern embankment slope via an engineered spillway with appropriate armor, erosion protection and energy dissipation features.

Figure 2  Tailings removal area in McCleary Canyon drainage and adjacent areas: Scenario 1
Under Scenario 1, the volume of tailings requiring removal is estimated at around 150 million tons. This estimate is based on formation of a channel profile that is 6,550 feet long with a starting base elevation of 4,900 ft amsl and an end base elevation of 4,834 ft amsl (i.e., 1% slope from west to east), resulting in an average excavation depth of 370 feet along the length of the channel. The estimated volume of tailings requiring removal for this Scenario 1 is around 100 million cubic yards, or about 150 million tons (at 110 pound per cubic foot dry density). This represents about 60 percent of the dry stacked tailings stored on Phase II.

Figure 3  Tailings removal area in McCleary Canyon drainage and adjacent areas: Scenario 2

Scenario 2 assumes removal of tailings to the existing elevations of McCleary Creek bed, also to a minimum base width of 150 feet, 3:1 side slopes, and construction of adequate armor and erosion protection features (Figure 3, black dotted and solid lines). Similar calculations to
those performed for Scenario 1 reveal that about 235 million tons of tailings would require removal (or just over 90 percent of the dry stacked tailings stored on Phase II).

12.2 Technical Feasibility

The technical feasibility of tailings removal and slope/channel/spillway erosion protection are discussed below.

Tailings Removal

Potential methods for successfully removing previously stored copper tailings in either Scenario 1 or 2 include:

- Mechanical excavation (via scraper, backhoe), relocation (via truck) and lift placement within a pre-constructed containment facility; and
- High-pressure water jetting using remotely controlled “monitor guns” that causes shear failure and reconstitution into a slurry form that is typically transported via agitation and pumping and placed in a pre-constructed storage facility.

The choice of which method to use is dependent to a high degree on the dry density of the tailings at the time removal is required. The dry density (in pounds per cubic foot or pcf) is the mass of the tailings solids (in pounds) divided by the total volume that the tailings occupy at any point in time (in cubic feet). The dry density is an indicator of tailings materials’ strength and resistance to shear forces, similar to those applied by mechanical excavation or high pressure water jetting.

For tailings with relatively high dry density, such as dry stacked tailings, mechanical excavation and removal is technically feasible, depending on the moisture content at the time of removal, and the propensity for the tailings to liquefy (and consequently lose strength) under anticipated field conditions at the time of removal.

For these tailings, reconstitution as a slurry via high pressure water jetting would also be technically feasible, depending on the thickness of cut being attempted. The relatively high dry density of the dry stacked tailings would require high breakout power and the cuts to be limited to a relatively low height because of monitor gun breakout power limitations.

When necessary, tailings can be moved to expand a mine operation where tailings or stockpiles impinge on the area to be developed, to remediate environmental degradation, to meet safety or other reclamation requirements, or to provide a beneficial post-mining land
use. In addition, tailings are occasionally reprocessed owing to improvement in technology that allows recovery of the residual mineral resources at lower cut-off grades; this has been done at several gold mines in South Africa where the value of the residual gold justified the cost to reprocess the historic tailings.

Selected tailings removal and erosion protection projects are summarized in Table 3. Included are the methods used to remove tailings and the approximate total tons of material removed.

Erosion Protection

The excavated slopes will require long-term protection against erosion. This will require installation of an adequate cover to the exposed tailings slopes such as a 2 to 3 feet thick layer of suitably graded, durable, geochemically neutral rock “rip-rap.” The channel section and spillway for Scenario 1 will require similar protection with additional subbase preparation (e.g., additional compaction, low permeability liner). In addition the spillway section will require energy dissipation features as well as downstream sediment control facilities during construction and post-construction maintenance periods at a minimum. A representative example of previously implemented slope protection for regraded closed copper tailings slopes is the closed San Manuel TFS.

At this stage no representative examples of channels or spillways excavated into dry stacked tailings exist, however, the only other major technical risk identified with this construction is differential settlement of the channel/spillway bases, resulting in poor drainage and formation of potentially wet depressions along the channel/spillway routes. This is why low permeability liner may be required. In addition, planning for longer periods of post-construction maintenance will be necessary to ensure that ponding related to differential settlement can be addressed to assure that flows are not permanently detained along the channel/spillway routes.

If the tailings densities are maintained at around 110 pcf, differential settlement is not anticipated to be significant.

There are three on-site options for final location of the relocated McCleary Canyon tailings – all of which are technically feasible. If one or more of these alternatives are recommended for additional consideration, these would need to be reviewed in more depth to assess the practical feasibility and potential consequences of each one. These options include:

- Partial backfill of the open pit,
- Relocation to a new tailings facility, and
• Expansion of the current facility.

12.3 Practical Feasibility

The practical feasibility of implementing either Scenario 1 (mechanical removal) or Scenario 2 (reconstituting as slurry and pumping) is dependent on the availability of an adequate storage repository for long-term containment and stabilization of the removed tailings. However, reconstituting the tailings as a slurry would require (at a minimum) about 200,000 acre feet of water for Scenario 1 and about 325,000 acre feet for Scenario 2, both based on an assumed solids:water ratio of 35:65. Due to the low availability of make-up water supply, a major objective of the dry stacking method of tailings deposition is to optimize water recycling and usage. Planned utilization of the water required for re-slurrying the tailing is not practically feasible because of the large additional water requirement that may not be available.

Further, it is not practically feasible to consider removal of the tailings due to the significantly high proportion of placed tailings that would potentially require double handling (i.e., 60 to 90 percent of placed tailings).

Assuming the tailings are excavated and relocated at the same rate they are placed (75,000 tons per day), it will take approximately 9 years to relocate the tailings. This would be in addition to the 3 years (Tetra Tech, 2007, p. 44) currently estimated for the demolition and closure of the mining facilities. From a practical point of view, as well as from the industry standard of “design for closure,” it is in the operator’s best interest to place the tailings during operation in their final location so as to reduce the time of closure and minimize the ultimate footprint of surface disturbance. A closer look at the final location options shows that only the “Partial backfill of the open pit” option requires that the mine operator wait until closure to place the tailings. If either of the other cases were chosen, standard industry practice dictates that the operator would chose to place tailings in the final location during operation.

12.4 Consequences

If the majority of the tailings are removed the concurrent reclamation included in the MPO (WestLand, 2007, pg. 76-78) would not be required for the Phase II Dry Stack tailings design and operation.

The closure timeframe would be extended by the time required to remove and relocate the tailing, and by the time required to close the final removed tailings repository, approximately 9 years. These extensions will require an appropriate increase in currently planned reclamation activities and water consumption requirements (e.g., for dust control).
With the lack of concurrent reclamation of the side slopes and the 9 additional years of closure, there would be a major increase in water consumption for dust control.

If the tailings were slurried for relocation purposes, there would be a large requirement of water, 200,000 to 325,000 af.

The ACD would potentially increase the footprint of disturbance because the tailings would be placed in one location and then relocated to a second facility.

Free-flow conditions within McCleary Canyon would allow native flora to reestablish itself and for wildlife to utilize the canyon; and

Free-flow conditions within the canyon will increase flow velocities, which will make erosion protection to prevent undercutting of the tailings in the future more difficult.

12.5 Summary

Relocation of the dry stacked tailings at a dry density of 110 pcf is technically feasible by conventional mechanical excavation/relocation/placement methods and high-pressure water jetting/reconstitution as slurry/pumping methods.

Long-term stabilization of the excavated profiles is technically feasible using conventional engineered surface amendments such as rock armor (rip-rap) and energy dissipation features.

Removal by either method is considered practically unfeasible because of:

- The significant quantities of tailings requiring removal;
- The significant volume of water required for jetting;
- The lack of an approved disposal area for additional tailings waste disposal.

In addition, current industry practice is to “design for closure” so that the mine waste materials (tailings, waste rock dumps) will not have to be double-handled at closure to achieve reclamation and safety requirements. Therefore, a tailings designer would not intentionally place tailings material in a temporary storage location if it were known in advance that the tailings would need to be relocated at closure.

Scenario 1 geometry may be achievable by operational storage of about half of the Phase II tonnage in McCleary Creek Canyon and the rest in an additional impoundment (e.g., Schofield Canyon).
12.6 Qualifications of Responsible Personnel

Dave L. Bentel has a B.S. in civil engineering and is a registered engineer (South Africa) with more than 30 years’ experience in engineering and environmental permitting services, and financial estimating services for mining facilities. His areas of specialization include:

- Process fluid and stormwater management facilities,
- Tailings disposal facilities,
- Tailings recovery and re-treatment facilities,
- Heap leach facilities, and
- Open pit and waste rock disposal facilities.
Table 6  Tailings relocation and erosion stabilization projects

<table>
<thead>
<tr>
<th>Company/Name</th>
<th>Location</th>
<th>Tonnage (short tons)</th>
<th>Reason</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHP Billiton Miami No. 2 Tailings</td>
<td>Miami, Arizona</td>
<td>38 million tons</td>
<td>Part of closure reclamation program. Historic tailings were reprocessed to recover copper sulfides and oxides and re-deposited in an abandoned open pit. The former tailings area was covered and re-vegetated.</td>
<td>ADEQ, 2009, APP Draft Permit No. P-101356, p. 2</td>
</tr>
<tr>
<td>Monticello Mill Tailings Site</td>
<td>San Juan Co., Utah</td>
<td>2.54 million cy</td>
<td>Tailings were moved from 1992 to 1999 to remEDIATE environmental degradation.</td>
<td>DOE, 2007. p. 11</td>
</tr>
<tr>
<td>Sherridon Orphan Mine</td>
<td>Manitoba, Canada</td>
<td>&lt;8.21 million tons of material (in progress – will be completed in 2012)</td>
<td>In order to control acid generation from the sulfide tailings, a portion of them were relocated to ensure they would be submerged under a minimum of 1.5m of water.</td>
<td>Ramsey and Martin, 2009, p. 627</td>
</tr>
<tr>
<td>Climax Molybdenum Co. Climax Mine</td>
<td>Climax, Colorado</td>
<td>NA</td>
<td>Conversion of a tailings impoundment to a freshwater reservoir in the Eagle River Valley to develop post-mine beneficial water resources.</td>
<td>Romig, Cupp, and Ford, 1999</td>
</tr>
<tr>
<td>Belle Eldridge Mine (Historic)</td>
<td>Deadwood, South Dakota</td>
<td>3,300 cy</td>
<td>Remediation of breached, historic high-sulfur tailings that were contributing metals by wind and fluvial dispersal to streambed sediments. Tailings were removed from drainage and near mill foundation, 1999 to 2000, to a new impoundment.</td>
<td>Webb, Davis, Johnson, Porter, 2002</td>
</tr>
</tbody>
</table>

Source: Compiled by SRK Consulting
13 Summary

Alternate methods have been suggested for mining and processing ore, modifying the mine life, and disposal of tailings and waste rock at the proposed Rosemont Copper Mine. These methods were proposed with the intention of reducing the footprint of the proposed facilities, reducing the volume of mine wastes, and/or eliminating the disposal of mine wastes (waste rock dumps, tailings) on site.

Table 6 in Section 13.1 provides a summary of alternatives that in SRK’s professional opinion and industry experience are not technically or practically feasible at this time at the Rosemont operation. These alternatives are not feasible alternatives to the base case methods presented in the Rosemont MPO.

Section 13.2 provides a summary of alternatives that in SRK’s professional opinion and industry experience may be technically and practically feasible at the proposed Rosemont operation. Additional review of the associated capital and/or operating costs may be necessary to assess the ultimate feasibility of these alternatives owing to potential negative impacts on the LOM plan.

13.1 Technical and Practical Feasibility of Alternatives

Table 7 summarizes the technical and practical feasibility of the alternatives evaluated in this report.
Table 7  Summary of technical and practical feasibility of alternatives

<table>
<thead>
<tr>
<th>Report Section</th>
<th>Alternatives</th>
<th>Feasibility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Technical</td>
</tr>
<tr>
<td>2</td>
<td>Dispose of Tailings and Waste Rock on the West Side of Santa Rita Mountains</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Mechanical Conveyance of Ore to Rail Head</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Use in-situ Mining in Lieu of Open Pit Mining</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>Use High-temperature/High-pressure Leaching for Ore Processing</td>
<td>Yes³</td>
</tr>
<tr>
<td>6</td>
<td>Modify the Mine Operating Life</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>Suspend Mining during Certain Environmental Conditions</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>Use Sea Water for Mining and Ore Processing</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>Use Reclaimed Water for Mining and Ore Processing</td>
<td>Yes</td>
</tr>
<tr>
<td>10</td>
<td>Use Microbial Leaching for Ore Processing</td>
<td>Yes</td>
</tr>
<tr>
<td>11</td>
<td>Replace Internal Combustion Engines with Electric Motors</td>
<td>Yes</td>
</tr>
<tr>
<td>12</td>
<td>Reconstruct the McCleary Drainage Features at Closure</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Uncertain feasibility indicates insufficient data to make a determination.

13.2 Alternatives for Final Consideration
Two alternatives were found to be both practically and technically feasible: Using reclaimed water for mining and ore processing and replacing diesel engines with electric motors. Both alternatives, however, are practically feasible only with meeting specific requirements. 

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² This alternative is technically feasible for some methods of transportation of ore and concentrates.
³ This alternative is technically feasible for certain copper sulfide concentrates.
⁴ This alternative is practically feasible for selected equipment only.
14 References


_____ 2009, Aquifer Protection Permit No. 101546: Draft permit for the BHP Copper Inc. Miami Unit, 37 p.


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Gavin, Nicole Ewing; Dotson, Karen; Chavez, Kathy; and others, 2009, City of Tucson and Pima County Reclaimed Water Technical Paper, report prepared as part of the City/County Water and Wastewater Study, Phase II, 30 p.


_____ 1997, Class III in-situ production of copper— Permit No. AZ396000001: issued to the BHP Copper Inc. Florence Project, June 1, 1997, 32 p.


