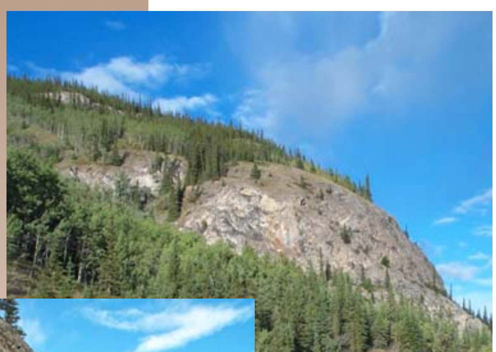
Deloitte & Touche

Faro Mine Complex Lime Supply Review

2007/08 Task 20a - FINAL



Prepared for

Deloitte and Touche Inc.

On behalf of

Faro Mine Closure Planning Office

Prepared by

SRK Consulting
Engineers and Scientists

Project Reference Number
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October 2008

Faro Mine Complex

Lime Supply Review

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Executive Summary

SRK has completed a study that explores potential cost savings associated with the development of local limestone deposits to produce lime of a quality suitable for water treatment and the relocation of tailings and/or waste rock versus the cost of lime delivery from distant sources, such as Edmonton. The study assumed that limestone deposits which are geochemically suitable for the intended purpose are available within 50 km of the Faro Mine Complex, and that a new road 5-km long would be required to provide access from existing roads.

Given the uncertainty regarding the final closure plan, two main production rates were considered in the cost comparison: a “minimum” rate based only on water treatment and a “maximum” rate based on water treatment plus the relocation of all of the tailings and a portion of the waste rock.

Financial modelling has shown that it is economically viable to operate a calcining plant on site at Faro for the required quantities of quicklime. This is based on the assumption that quarried limestone would be used for amendment in the relocation scenarios and quicklime for water treatment.

The following points outline the option that appears to be most cost-competitive:

- Establish a local limestone quarry with a mining contractor at a rate of about 5,000 t/d;
- Haul the limestone to the Faro mine site and establish a limestone run-of-mine stockpile;
- Set up a crushing and screening plant at the Faro mine site to process the limestone as required for relocations and calcining; and
- Establish a coal-fired calcining plant to produce quicklime.

In order to provide more accurate costs, additional studies should address the following:

- Assess the differences in mining costs associated with a larger, experienced non-local mining contractor and representative contractors from the local communities;
- Identify sources of suitable coal or alternative fuels for firing a calcining plant;
- Assess the comparative cost of the various energy alternatives related to calcining;
- Identify the environmental issues associated with the operation of a calcining plant, including greenhouse gas emissions;
- Explore local markets for quicklime to offset the calcining costs for Faro;
- Explore the opportunities for local private companies to do some or all of this work; and
- Once the limestone source is identified, complete neutralization testing using this limestone for a range of waste and tailings samples and then determine water treatment requirements.

* * *

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Table of Contents

List of Tables

List of Figures

List of Appendices

1 Introduction

Acid rock drainage and water quality issues drive many aspects of site remediation and closure of the Faro Mine Complex. Lime products will play an important, long-term role in the water treatment at Faro and, depending on the selected closure plan details, may also be used in large quantities in conjunction with the potential relocation of tailings and/or waste rock. As a consequence of these factors, the cost of lime will be a very significant part of the short and long-term costs of site remediation and closure.

In view of these costs, and the presence of numerous limestone deposits in the Faro region, Deloitte and Touche (Deloitte), on behalf of the Faro Project Management Team (FPMT), commissioned SRK Consulting (SRK) to assess the potential cost savings associated with the development of local limestone deposits to produce lime of a quality suitable for the requirements noted above. The cost comparison was to be based on local Yukon production assuming there is a limestone source within 50km of the Faro Mine Complex, versus the cost of lime delivery from distant sources, such as Edmonton.

This report summarizes the results of the conceptual study and provides “scoping-level” costs associated with the provision of lime (limestone, quicklime and slaked lime) that can be used for site remediation and closure at the Faro Mine Complex (Faro). Scoping level costs are considered to have an accuracy of +/- 40%.

2 Background

2.1 Closure Scenarios

SRK (2008a) identified six closure scenarios for Faro. These are summarised in Table 2.1.

Table 2.1: Summary of Faro Closure Scenarios

Combination	Faro	Tailings	Vangorda/Grum
Physical Stabilization 1	Upgrade Faro Creek Diversion	Stabilize in Place	Stabilize Current Situation
Physical Stabilization 2	Upgrade Faro Creek Diversion	Stabilize in Place	Vangorda Pit Backfill
Relocate Tailings & Stabilize Mine Areas 1	Upgrade Faro Creek Diversion	Complete Relocation	Stabilize Current Situation
Relocate Tailings & Stabilize Mine Areas 2	Upgrade Faro Creek Diversion	Complete Relocation	Vangorda Pit Backfill
Partially Relocate Tailings & Stabilize Mine Areas 1	Upgrade Faro Creek Diversion	Partial Relocation	Stabilize Current Situation
Partially Relocate Tailings & Stabilize Mine Areas 2	Upgrade Faro Creek Diversion	Partial Relocation	Vangorda Pit Backfill

Each of these scenarios requires different quantities of lime products. In addition, each scenario consists of two phases. Phase 1 is the “closure” phase in which waste rock stockpile and tailings dams are either relocated and/or rehabilitated. Phase 2, the “post-closure” phase, consists primarily of management of the existing infrastructure.

The lime requirements during the closure (Phase 1) period are for the neutralisation of relocated acidic material and for water treatment, whereas the post-closure (Phase 2) period requires lime for water treatment only.

2.2 Definitions

2.2.1 Types of Lime

“Lime” is a generic term that only embraces the manufactured forms of lime – quicklime (CaO) and hydrated lime ($Ca(OH)_2$). It does not include limestone or calcite ($CaCO_3$) or the other carbonates [dolomite ($CaMg(CO_3)_2$)] which are often incorrectly referred to as “lime”. More detailed definitions of lime are included in Appendix A.

2.2.2 Quicklime

Quicklime is a solid produced from the calcination of limestone in kilns at temperatures of 1100°C to 1300°C.

Quicklime rapidly absorbs carbon dioxide from the air and, over time, is completely converted back to calcium carbonate. It is highly caustic and requires special handling precautions.

2.2.3 Hydrated Lime

The strict definition of hydrated lime is generally taken as follows:

A dry powder obtained by treating quicklime with sufficient water to satisfy its chemical affinity for water under the conditions of its hydration.

Hydrated lime is less caustic than quicklime but still highly alkaline.

In general, hydrated lime is used in the lime treatment process because it does not require slaking and has a high availability. However, in the quantities required for Faro, it would not be economic to transport hydrated lime from the supplier to the mine site.

2.2.4 Slaked Lime

The term "slaking" applies to the process of combining varying proportions of water and quicklime to yield widely varying degrees of consistency in a slurry or paste form. In the lime industry, the term "hydration" refers to the production of a dry, finely powdered, hydrated lime. Less water is used in commercial hydration than in slaking. It is difficult to control the slaking process because of the highly exothermic nature of the reaction. The temperature at which slaking occurs affects the reactivity of the slaked lime slurry, as does the water ratio at which slaking occurs.

2.2.5 Limestone

Limestone is a naturally occurring calcite ($CaCO_3$) that is the raw ingredient for the manufacture of quicklime and hydrated lime. The limestone rock often contains significant quantities of $MgCO_3$ and is then referred to as dolomite. Dolomite which is less reactive than calcite would, therefore, need to have low magnesium content to be useable.

It is less reactive than quicklime and hydrated lime and has the capacity to increase pH to about 8.3, whereas quicklime or slaked lime can achieve higher levels of pH[1]. In this context, limestone is suitable for acid neutralisation but other lime products would be required for metal chelation[2].

In the context of the requirements for Faro, raw limestone alone would not be sufficient to meet the needs of the closure program, however, limestone used in conjunction with either quicklime or hydrated lime may meet the requirements.

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[1] pH is a measure of the level of acidity, where a low pH is acidic and a high pH is alkaline. Neutral pH (mid-way between acid and alkaline) is 7.0. Pure water has a pH of 7.0 whereas drinking water has a pH in the range of 5 to 8.

[2] Metal chelation is the process of removing metal ions (dissolved metal salts) from solution. In this case, the solution is water. Raw limestone is sufficiently reactive to neutralise acids, however it is unable to remove the dissolved metal ions from the water. Quicklime is better suited to this task as it can achieve a higher pH which is necessary to achieve precipitation of the metals.

3 Lime Requirements

3.1 Introduction

SRK (2008b) estimated the annual lime requirements for each phase of the six closure scenarios.

Calculations were provided for the use of quicklime and hydrated lime at Faro. In general, quicklime would be used for the waste rock and tailings amendment while slaked lime (derived from either quicklime or hydrated lime) would be used in the water treatment process. The slaked lime is preferred for water treatment because the flowrate (dosing) of the slaked lime slurry is easier than for dry quicklime powder.

In addition to the work performed by SRK (2008b), it was determined that crushed limestone could be used in the waste relocation component of the program to reduce the requirement for processed lime. This determination is based on the assumption that the limestone demand will be equal to the total lime demand. The limestone is expected to buffer the porewater of the relocated waste rock and/or tailings to between 6.5 and 7.0. Within this pH range, the free acid and acidity associated with most metals (e.g. ferric iron, copper etc.) will be removed. However, the zinc will only be partially removed and will therefore need to be captured in water treatment. The amount of zinc that will remain in solution will depend on the starting condition of the materials to be amended. For a high acidity, low pH material, most of the acidity would be removed. For a low acidity, high pH material, a smaller proportion of the acidity would be removed. Consequently, the residual acidity (as Zn) that would need to be captured in the water treatment will vary, but would be small in comparison to other loads and is not likely to have a significant impact on the cost of treatment. Nonetheless, a complete assessment would require this to be factored into the evaluation. At present, insufficient information is available to enable a complete assessment to be done.

The various lime/limestone supply options that may be suitable for Faro are shown in Figure 3.1.

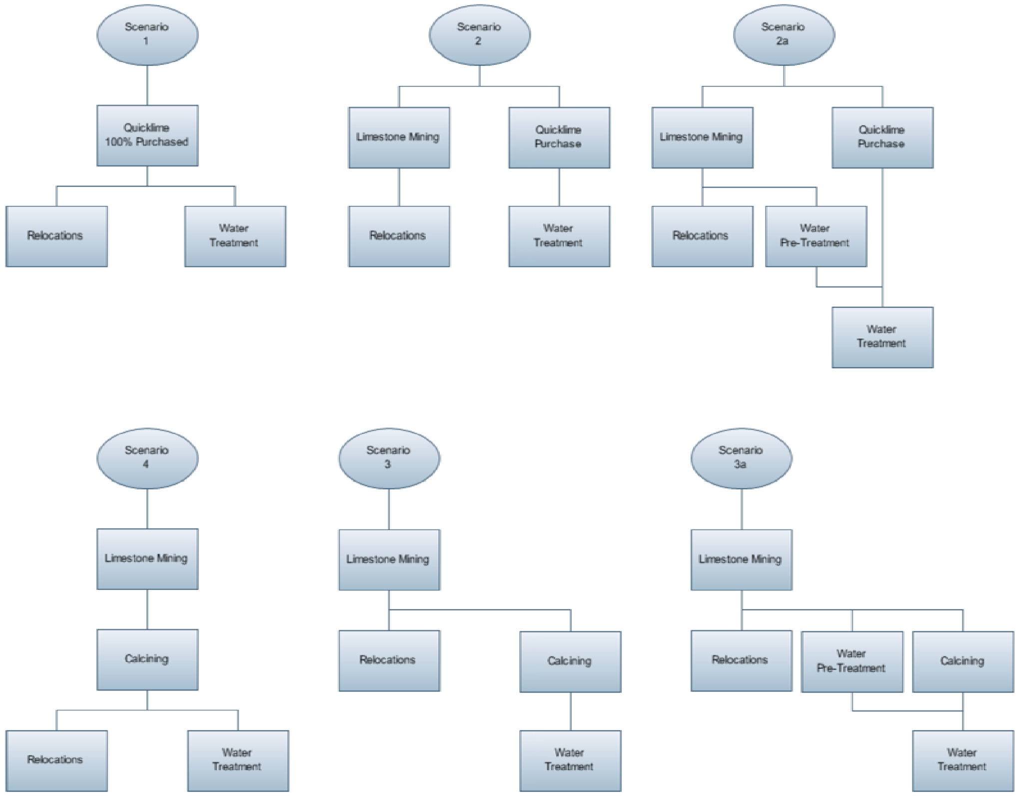

Figure 3.1: Options for Supply of Lime Products

3.2 Quicklime Estimates

The yearly lime requirements for quicklime are present in Table 3.1.

Table 3.1: Estimated Quicklime (CaO) Requirements by Scenario

Combination	Relocations	Water Treatment		Yearly Lime Requirements	
				Closure	**Post-Closure**
	Lime Required (tonnes)	**Minimum[1] (tonnes/yr)**	**Maximum[2] (tonnes/yr)**	**Years 1 to 15[3] (tonnes/yr)**	**Years 16 and Up[4] (tonnes/yr)**
Physical Stabilization 1	48,200	790	8,410	**8,000**	**4,600**
Physical Stabilization 2	61,200	710	7,900	**8,000**	**4,400**
Relocate Tailings & Stabilize Mine Areas 1	453,600	510	5,760	**33,000**	**3,200**
Relocate Tailings & Stabilize Mine Areas 2	466,600	430	5,250	**34,000**	**2,900**
Partially Relocate Tailings & Stabilize Mine Areas 1	219,700	670	7,610	**19,000**	**4,200**
Partially Relocate Tailings & Stabilize Mine Areas 2	232,700	590	7,100	**19,000**	**3,900**

1. Minimum annual lime required based on the current average loadings with maximum expected cover thickness.
2. Maximum annual lime required based on future worst case loadings with minimum expected cover thickness.
3. Lime Requirements during closure period, assumed to be 15 years for this study (= Lime for Relocations + Average water treatment lime demand).
4. Post-Closure: Lime Requirements = Average water treatment requirement.

3.3 Slaked Lime Estimates

The yearly lime requirements for hydrated lime are present in Table 3.2.

Table 3.2: Estimated Hydrated Lime ($Ca(OH)_2$) Requirements by Scenario

Combination				Yearly Lime Requirements	
	Closure	**Post-Closure**		**Closure**	**Post-Closure**
	Lime Required (tonnes)	**Minimum[1] (tonnes/yr)**	**Maximum[2] (tonnes/yr)**	**Years 1 to 15[3] (tonnes/yr)**	**Years 16 and Up[4] (tonnes/yr)**
Physical Stabilization 1	61,700	1,010	10,760	**10,000**	**5,900**
Physical Stabilization 2	78,300	900	10,110	**11,000**	**5,600**
Relocate Tailings & Stabilize Mine Areas 1	580,400	650	7,370	**43,000**	**4,100**
Relocate Tailings & Stabilize Mine Areas 2	597,000	550	6,710	**43,000**	**3,700**
Partially Relocate Tailings & Stabilize Mine Areas 1	281,100	860	9,740	**24,000**	**5,300**
Partially Relocate Tailings & Stabilize Mine Areas 2	297,800	760	9,080	**25,000**	**5,000**

1. Minimum annual lime required based on the current average loadings with maximum expected cover thickness.
2. Maximum annual lime required based on future worst case loadings with minimum expected cover thickness.
3. Lime Requirements during closure period, assumed to be 15 years for this study (= Lime for Relocations + Average water treatment lime demand).
4. Post-Closure: Lime Requirements = Average water treatment requirement.

The six closure scenarios (Table 3.3) were consolidated into three options with approximately similar lime requirements (Table 4.1). These were used to evaluate the supply options. Option 1 was selected as being representative of the minimum quicklime requirements and Option 2 as being representative of the maximum quicklime requirements.

Table 3.3: Consolidation of Closure Scenarios (Quicklime Requirements)

Option	Quicklime Requirements								
	Closure (Yr 1 - 15)			Post Closure (Yr 16 - 35)			Total (Yr 1 - 35)		
	A	B	Total	A	B	Total	A	B	Total
	t/yr	t/yr	t/yr	t/yr	t/yr	t/yr	t	t	t
1	3,600	4,600	8,200	-	4,600	4,600	54,000	161,000	215,000
2	31,000	3,200	34,200	-	3,200	3,200	465,000	112,000	577,000
3	15,000	4,200	19,200	-	4,200	4,200	225,000	147,000	372,000

A = Relocations
B = Water Treatment

The hydrated lime requirements are about 30% higher than the quicklime and the limestone requirements are about double the quicklime requirements. Limestone will only be used in the relocations component of closure, i.e. the relocation of waste rock and/or tailings.

4 Supply of Limestone and Lime

Due to the relatively remote location of Faro, there is no economic benefit in transporting hydrated lime or slaked lime to the site as both of these products are derived from quicklime by adding water. Additional freight charges would be incurred as a result of transporting water in addition to the quicklime component of both of these products. Therefore, the economic benefit is in the use of quicklime and limestone as the basic products.

4.1 Limestone Quarry

Preliminary investigations have identified several potential sources of limestone are within a reasonable distance from Faro (SRK, 2006). These are shown in Figure 4.1, though there may well be other sources worthy of consideration in the region. Further investigation would be required to determine the most suitable source for the Faro requirements but available data suggests there are suitable sources.

The limestone product could be utilised according to the following scenarios:

1. Provide limestone to blend with the waste rock when it is relocated.
2. SRK (2008b) calculated the quantity of quicklime required for relocations. However, if the intent is to provide a neutral pH, then 100% limestone would work; if the intent is to remove metals such as zinc, then the target would be to achieve a pH of 9 to 9.5 which would result in a high proportion of quicklime being required.
3. Provide limestone to blend with the waste rock when it is relocated (as described above); and provide feedstock for an on-site calcining plant that would produce quicklime.

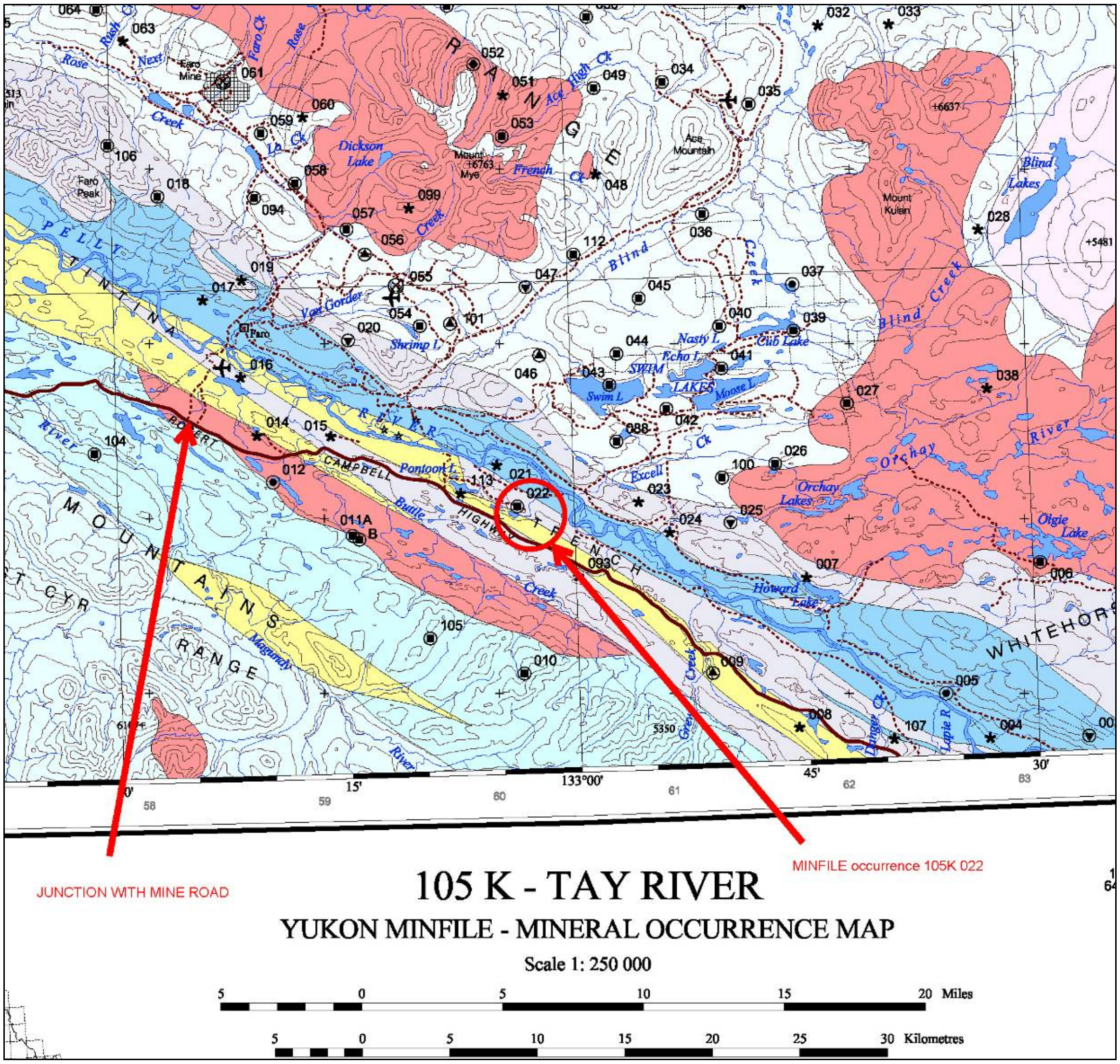

Figure 4.1: Sources of Local Limestone (SRK, 2006)

4.1.1 Production Options and Costs

The annual quantities of limestone required for the Faro closure are relatively small for an operating quarry. There are three scenarios for operating a limestone quarry to meet the needs of the Faro closure program:

1. *Mine and Stockpile (single phase)*
   This is likely to be the most cost effective option. Mining contractors would carry out the mining and stockpiling over a period of about one year and produce sufficient limestone to meet the expected needs of the closure program. The limestone would be stockpiled as uncrushed, run-of-mine material. This option would produce a stockpile of about 1.2 million tonnes (700,000 m^3). The limestone would be crushed and screened on an "as-required" basis on-site at Faro.

   The estimated cost is about $8.00/t mined.

2. *Mine and Stockpile (multiple phase)*
   Under this scenario, the mining contractors will mine and stockpile smaller quantities and, as a result, will need to remobilise on several occasions during the course of the closure program. This is likely to be a higher cost option due to the cost of remobilising to site, however potential weathering of the limestone will be less of an issue.

   The estimated cost is about $12.00/t mined.

3. *Mine Continuously*
   A small fleet could be efficiently utilised and managed by local contractors so that limestone is mined on an as-required basis. This is likely to be the highest cost option due mostly to the ownership costs of the mining fleet. This option may be advantageous if the local communities were to carry out the mining, haulage and crushing.

   The estimated cost is about $15.00/t mined.

SRK believes that the most cost-effective scenario would be to mine and stockpile the required quantities at the commencement of the closure program (the single phase option). The stockpiled limestone would be crushed and screened on an “as-required” basis during the course of the closure program. If crushed limestone is to be stockpiled, then provision for weather protection may be required.

Prior to blending with waste rock or tailings, the limestone would be ground to 100 percent less than 1 mm.

The cost to produce limestone, inclusive of mining, haulage and crushing, in a single campaign of mining and hauling, is shown in Table 4.1. The cost of mining and hauling on a continuous basis (with significantly lower daily volumes), could be about twice the cost of the single phase mining campaign. No allowance has been made for mining royalties, as it has been assumed that mining for reclamation purposes would be exempt.

Table 4.1: Unit Rates – Limestone Supply

Item	**Units**	**Unit Price or Amount**	**Unit Price per tonne**
Mining Subtotal	$/t		8.00
Haulage	$/t-km	0.40	
Haul Distance	km	30.0	
Haulage Subtotal	$/t		12.00
Crushing Subtotal	$/t		7.00
Total	**$/t**		**27.00**

4.1.2 Access Road

Our experience in northern projects indicates a well formed, unsealed access road made from local materials with minimum excavation would cost about $600,000 per km. Therefore, a 5-km access road from the quarry area to the main highway would cost about $3.0 million.

4.2 Lime Supply

In terms of neutralisation potential, it is more cost effective to transport quicklime than hydrated lime or slaked lime, because hydrated lime and slaked lime are both made from quick lime by adding water; therefore, the additional transport cost is incurred in the transport of water.

Two supply options were explored. The results are shown in Table 4.2.

Table 4.2: Unit Rates – Lime Supply

Supplier	UoM	Supply	Transport	Total
Graymont Ltd. Tacoma, WA, USA	$/t	$165.35	$184.64	$349.99
Chemical Lime Co. Langley, BC, Canada	$/t	$178.29	$239.06	$417.35

Graymont Ltd (www.graymont.com) has the contract to supply quicklime to Faro and currently provides about 640 tonnes per annum. The quicklime is transported in bulk in modified sea-containers that are owned by Faro. The containers are barged from Tacoma to Skagway and then taken by truck to the Faro Mine. The containers are pneumatically unloaded into silos. The international freight incurs a customs & brokerage charge of about $10.00 per tonne.

The transport strategy for the Chemical Lime Company (www.chemicallime.com) is to haul the quicklime by rail from the plant at Langley, BC, to the terminal at Topley, BC, where it is hauled in bulk lime trucks to the Faro Mine. The truck would be pneumatically unloaded into silos. The transport cost for the Chemical Lime Company assumes delivery of all lime between May and September each year. The company notes that the road transport cost could be significantly reduced by delivering lime throughout the year and, if necessary, storing it in a purpose-built shed on site.

Alternative supply/transport scenarios may also include the use of Mega Bags. These are made from woven polypropylene and have a capacity up to two tonnes. Various styles of top and bottom opening bags are available. (www.megatharo.co.za).

4.3 Using Limestone to Offset Lime Requirements

There may be opportunity to use limestone in the water treatment process if the water (that requires treatment) is sufficiently acidic. In this scenario, the water would be pre-treated with finely ground limestone. The pre-treated water would then be treated in a conventional treatment system. (Refer to Scenarios 2a and 3a in Figure 3.1) This would require verification through testing to determine reaction rates and efficiencies.

Crushed limestone could also be used in the waste/tailings relocation component of the work by blending with relocated waste or tailings. The blended limestone would neutralise the acidity of the waste/tailings.

Approximately 1.78 kilograms of limestone would be required to achieve the same neutralisation potential as one kilogram of quicklime. Table 4.3 shows the cost saving that could be realised with limestone substitution, using a conversion factor of 2.0 kg limestone to replace 1.0 kg of quicklime.

Table 4.3: Limestone Offset

Quicklime	Limestone	Unit Cost
350	**27**	**$/t**
	2.00	<<<Offset factor
100%	0%	$350
80%	20%	$291
60%	40%	$232
40%	60%	$172
20%	80%	$113
0%	100%	$54

4.4 Other Considerations

4.4.1 Calcining

The benefits of establishing a calcining plant on site are marginal, at best, if the sole purpose is to provide quicklime for water treatment. The economics become more favourable if the quicklime is also used for relocation. However, if limestone is suitable for the relocation, then limestone is significantly more cost effective than quicklime.

In addition, production of quicklime from limestone is an energy intensive process that is best done closer to energy sources (diesel, oil, used motor oil, pulverized coal, natural gas, etc.). It is also a relatively sophisticated technical process requiring careful control. Operating a technical manufacturing process at a site, like Faro, may add significant incremental costs for training.

An alternative justification for a calcining plant could be based on providing quicklime to other mining and remediation operations in the region. Although SRK has not undertaken a market survey, there are sites would benefit from cheaper, locally produced quicklime. The possible market may include the following:

- Alexco Resource Corp. (www.alexcoresource.com), operator of the Keno Hill Silver Mines would require quicklime for the processing plant and for their remediation program.
- Sherwood Copper Corp. (www.sherwoodcopper.com), operator of the Minto Copper Mine would also require quicklime for the processing plant and possibly for their remediation program.

- North American Tungsten Corp. Ltd. (www.northamericantungsten.com), operator of the Cantung Tungsten Mine, may require quicklime processing and remediation.
- Other consumers in the Whitehorse township are likely to be users of quicklime.

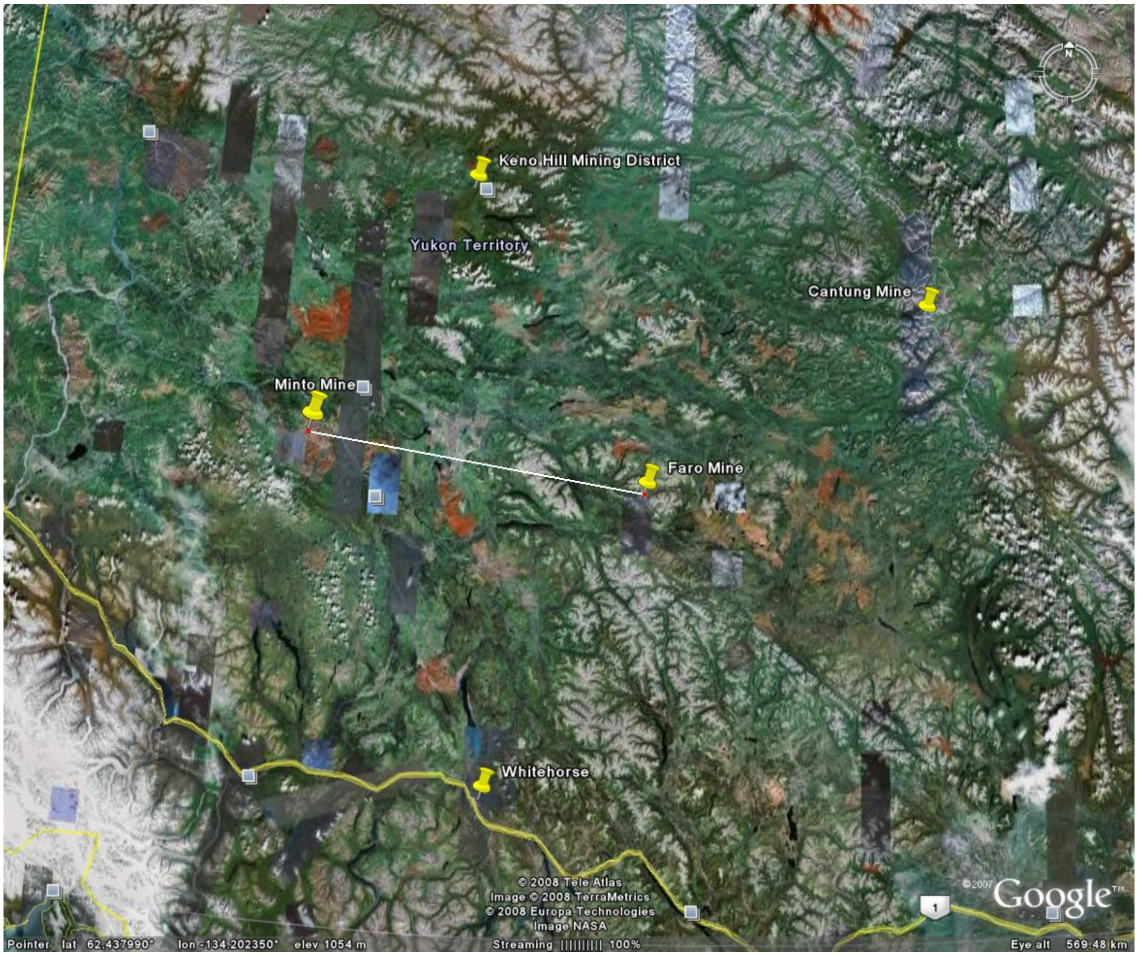

Figure 4.2: Location Map Showing Potential Users of Quicklime (200 km line)

4.4.2 Application of Lime & Limestone in the Remediation Process

The two main applications for lime in the Faro remediation process are in water treatment and relocation of waste rock. Due to the nature of the water treatment process, lime (quicklime or hydrated lime) is the most suitable product; limestone, as a substitute for lime, has a lower neutralisation potential and, therefore, makes the water treatment process less efficient.

The substitution of limestone for lime in the relocation program is a more cost effective option.

4.5 Handling and Storage of Lime

The preference is generally to use bagged lime where the daily requirements are small. The handling and storage operations are relatively uncomplicated, requiring manual labour and simple mechanical aids to suit the volumes being handled.

When the daily requirement is large, then it becomes more efficient to use bulk lime in either quick or hydrated form. The lime is handled by mechanical or pneumatic conveying systems that discharge to weather-tight bins or silos.

4.5.1 Bagged Lime

Bagged lime is usually delivered loose or palletised for shipment and is generally handled by hand-truck or fork-lift truck to storage. Lime is usually removed from the bag by hoisting the bag and bottom dumping the contents into a hopper/feeder.

Precautions

The storage bags must be covered to prevent rain from wetting the bags. Hydrated lime is normally packed in multi-wall paper bags which are not resistant to free water or humid air. Quicklime is also packaged in multi-wall paper bags, however one or more of the plies is moisture-proofed. The moisture-proofing will be resistant to humid air but generally not effective in its resistance to rain.

The reaction of quicklime with water generates heat and will be sufficient to cause the bags to rupture. For this reason, quicklime storage must be water resistant. In addition, quicklime should not be stored adjacent to flammable materials.

Quicklime will deteriorate in storage much more quickly than hydrated lime. In ideal conditions, bagged quicklime may be stored for as long as six months, but in general should not be stored for longer than three months.

4.5.2 Bulk Lime

Bulk lime offers considerable savings over bagged lime, but only if the demand is sufficient. The savings are realised in the initial purchased price (no bag required) and also in the reduced labour costs involved with handling and storage. Delivery of bulk lime is made by a variety of trucks, rail cars or barges.

Truck Shipment

Dump trucks and pneumatic (blower) trucks are commonly used for bulk lime shipments. The dump trucks must be covered with a waterproof tarpaulin. The pneumatic truck is becoming popular due to its simplicity and speed of delivery and unloading. Provision must be made with the pneumatic truck for filtration of the lime dust from the discharge air.

Rail Cars

When transporting by rail, most bulk lime is shipped in covered hopper cars with a bottom discharge gate. Generally, the lime is discharged to an undertrack hopper, then by screw conveyor and bucket elevator to plant storage. Railcars may also be unloaded with pneumatic conveying systems.

Barges

The lowest cost means of transporting large quantities of bulk lime is by covered hopper barges on inland navigable water ways. The most common method for unloading barges is by clamshell bucket.

The quantities of lime required for barges to be most cost effective are far in excess of the quantities required at Faro.

4.5.3 Bulk Storage

Since quicklime and hydrated lime are not corrosive, conventional steel or concrete bins can be used for storage. The caveat is that the storage units must be weather tight because quicklime will react with moisture in the atmosphere. The moist popular storage system for bulk lime is the steel silo with cone bottom.

5 Lime Slaking and Slurry Handling

SRK (2008b) defined the Faro lime requirements as tonnes of quicklime or hydrated (dry) lime. The current understanding is that there is no requirement to have both products available on site. The advantage of slaked lime (and hydrated lime) is that general handling is easier than for quicklime.

5.1 Methods of Slaking

Although quicklime can be produced as a pebble-sized product, the slaking process is significantly more efficient if the quicklime is finely powdered.

There are two methods of slaking:

1. Batch; and
2. Continuous.

5.1.1 Batch Slaking

Simple batch slaking can be achieved by hand-mixing quicklime and water in a trough. Larger quantities can be produced by using a mechanical mixing device that has been specifically designed for slaking.

5.1.2 Continuous Slaking

There are three types of continuous slakers:

1. The *paste slaker* operates at a minimum water to lime ratio and produces a very think paste;
2. The *detention slaker* uses a greater water to lime ratio and can produce a slurry ranging from 10% solids to about 25% solids; and
3. The *ball mill-type slaker* provides all of the slaked products to the treatment process, without producing a grit discharge.

Most continuous slakers can handle a particle size up to about 50 mm, although they tend to be more efficient at sizes less than 25 mm.

5.2 Cost of Slaking Plants

- A 450 tonne silo with a slaking plant rated at 1.5 tonnes per hour would cost about $1.22 million.
- A 1,500 tonne silo with a slaking plant rated at 5.0 tonnes per hour would cost about $2.25 million.

6 Economic Considerations

Financial models were set up to explore the various combinations of quicklime supply, calcining, limestone mining, waste material relocations, water treatment and minimum/maximum requirements.

A summary of the results is shown in Table 6.1. The details are provided in Appendix B. As this is a scoping study, the results should be interpreted as indicative rather than absolute. The Base Case is "Quicklime Supplied with No Limestone Mining".

Two calcining options were explored: coal-fired and propane-fired. The coal-fired calcining plant is about 30% cheaper than the propane fired calcining plant due to the lower cost of coal.

The results show the following:

- Locally mined limestone is a cost effective substitute for quicklime in the material relocations.
- "Rapid" single phase mining and "Slow" single phase mining cost about the same, even though the mining cost for the rapid mining is about half of that for slow mining. This occurs as a result of the net present value (NPV) calculation discounting the "slow" mining costs over a longer period, thus reducing their "present value". Contractor mining has been assumed; therefore no capital costs have been included.
- The cost of "Limestone Mining with Quicklime Purchase" is about the same as "Limestone Mining with Calcining (Coal)." However, this analysis does not consider the additional risks associated with operating a calcining plant.

In each option, provision has been made for a lime silo and slaking plant, with replacement occurring in Year 16.

Table 6.1: Economic Analysis – Summary

Option / Scenario / Mining Rate	**Net Present Cost (3%) ($000s)**	
	Minimum Requirement	**Maximum Requirement**
Option 1 – Quicklime Purchased (No Local Calcining)		
100 % Quicklime (Relocations & Water Treatment)	52,605	156,260
Quicklime (Water treatment) Local Limestone (Relocations)		
Rapid Mining (5000 tpd)	39,884	46,718
Slow Mining (500 tpd)	41,603	61,521
Option 2 – Coal Fired Calcining Plant (100% Local Limestone)		
100 % Quicklime (Relocations & Water Treatment)		
Rapid Mining (5000 tpd)	23,565	41,833
Slow Mining (500 tpd)	25,284	56,636
Quicklime (Water treatment) Local Limestone (Relocations)		
Rapid Mining (5000 tpd)	20,451	19,984
Slow Mining (500 tpd)	22,170	34,787

7 Findings and Suggestions

The following findings were derived from the study:

- The cheapest supplier of quicklime is the one currently used by Faro: Graymont Ltd. of Tacoma, Washington. The current cost to Faro is about CAD$350 per tonne (based on a cost of US$317.39 per Imperial ton and a CAD$ at par), so currency fluctuations could lead to significant changes in the cost of quicklime.
- Limestone can be economically substituted for quicklime in the relocation of waste rock and or tailings. The cost of limestone is about $27 per tonne whereas the current cost of quicklime delivered to site is about $350 per tonne. Some additional water treatment will be required if metal chelation is to be achieved.
- “Rapid” mining and “Slow” mining have about the same NPV in the minimum requirements scenario, even though the mining cost for the rapid mining is about half of that for slow mining. The difference between the two mining rates is highlighted in the maximum requirements scenario, where rapid mining is about ten percent cheaper. Contractor mining has been assumed; therefore no capital costs have been included.
- The coal fired calcining plant is about 30% cheaper to operate than the propane fired calcining plant.

However, in the context of the comparison of the cost of locally produced lime versus imported quicklime, the principal finding is as follows:

- Financial modelling has shown that it is economically viable to operate a calcining plant on site at Faro for the required quantities of quicklime. This is based on the assumption that quarried limestone would be used for amendment in the relocation scenarios and quicklime for water treatment.

The economics of operating the calcining plant are driven, in part, by the production rate of the limestone quarry. In general, a quarry operating at a high production rate (e.g. 5,000 tonnes per day) will deliver limestone at a lower unit cost than a quarry operating at a low production rate (e.g. 500 tonnes per day). In addition, the duration of the quarrying program will also impact on the unit cost of limestone as a result of the fixed costs (mobilisation, demobilisation, rehabilitation, etc.) being amortised over the quantity of material produced. For example, 5,000 tonnes per day for one year will have a higher unit rate than 5,000 tonnes per day for ten years.

Therefore, if limestone is not needed for relocations, then the unit cost of limestone for calcining will certainly increase. In this case, the final cost of locally produced quicklime is still expected to be cheaper than the current cost of quicklime.

Based on these findings, the approach to local lime production that warrants consideration is as follows:

- Establish a local limestone quarry with mining carried out by a contractor at a rate of about 5,000 tonnes per day. The required quantity of limestone (for a 35 year period) will be mined in less than 12 months.
- Haul the limestone to the Faro mine site and establish a limestone run-of-mine stockpile.
- Set up a crushing and screening plant at Faro to process the limestone as required for the relocations.
- Establish a calcining plant to produce quicklime for water treatment and as a supplement for the relocations.
- Set up a slaking plant to provide slaked lime for the water treatment plant(s).

This option is preferred for the following reasons:

- The use of limestone for relocations is significantly cheaper than quicklime.
- Limestone mining is a relatively low risk operation.
- The NPV of the coal-fired calcining option is cheaper than purchasing the quicklime from the current supplier.

The results of this study should be viewed as indicative rather than absolute due the broad nature of the review and the level of accuracy (± 40%).

8 Additional Studies

Although there are benefits in establishing a local limestone quarry to reduce the need for quicklime, there are still a number of additional studies that would need to be undertaken if this study option is pursued further. These are outlined below.

- Carry out a trade-off study between “rapid” mining and “slow” mining. The results of the current study show that these options have about the same NPV, however there are social factors that have not been included in this study, such as mining by a local contractor, that may make the “slow” mining options more attractive. In addition, mining by a local contractor will incur some capital costs, and possibly training, that need to be included in the evaluation.
- Carry out a trade-off study between mining/coal-calcining and quicklime purchase. The current financial analysis shows these options to be similar in cost. The trade-off study should include consideration for supply of quicklime to other local users.
- Carry out a trade-off study for calcining that compares the cost of the various energy alternatives.
- Evaluate the environmental issues associated with the operation of a calcining plant.
- As calcining of lime is a major source of carbon dioxide, a review of greenhouse gas emissions should be conducted in conjunction with other Faro studies.
- Evaluate the potential for local markets for quicklime beyond the quicklime requirements of Faro.
- The next level of study should explore the opportunities for local private companies to do some or all of this work.

Once the limestone source is identified, neutralization testing should be completed using the source limestone for a range of waste and tailings samples. The equilibrated solutions would then be analysed to determine residual zinc solution concentrations. Splits of the samples would also be subjected to leach extraction tests to determine the initial conditions. The relationship between initial and equilibrated conditions would then be used to determine water treatment requirements.

This report, "**Faro Mine Complex - Lime Supply Review, 2007/08 Task 20a - FINAL",** was prepared by SRK Consulting (Canada) Inc.

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Appendices

Appendix A
Definitions

Types of Lime

"Lime" is a generic term that only embraces the manufactured forms of lime – quicklime and hydrated lime. It does not include limestone or the other carbonates which are often incorrectly referred to as "lime".

The basic formulas involved in the production of quicklime and hydrated lime are as follows:

Limestone + Heat	→	Quicklime + Carbon Dioxide
Quicklime + Water	→	Hydrated Lime + Heat

Quicklime

Quicklime is produced from the calcination of limestone in kilns at temperatures of 1100°C to 1300°C. Quicklime consists primarily of the oxides of calcium and magnesium, which are the two principal elements in limestone.

There are three broad classifications for quicklime.

1. *High calcium quicklime*.
   The primary constituent is calcium oxide (CaO) and magnesium oxide (MgO), if any, usually comprises less than five percent.

$CaCO_3$ + Heat	→	CaO + CO_2 (gas)
High calcium limestone		High calcium quicklime

2. *Dolomitic quicklime*
   Contains about 35 to 40 percent magnesium oxide.

$CaCO_3 . MgCO_3$ + Heat	→	CaO . MgO + $2CO_2$ (gas)
Dolomitic limestone		Dolomitic quicklime

3. *Magnesian quicklime*
   Contains 5 to 35 percent magnesium oxide and is relatively rare in North America.

Quicklime is available in a wide range of sizes, from lump/pebble sizes down to a pulverised lime powder.

Quicklime rapidly absorbs carbon dioxide from the air and, over time, is completely converted back to calcium carbonate.

Quicklime is highly caustic and requires special handling precautions.

Hydrated Lime

The strict definition of hydrated lime is generally taken as follows:

> *A dry powder obtained by treating quicklime with sufficient water to satisfy its chemical affinity for water under the conditions of its hydration.*

The chemical formula of hydrated lime generally reflects the composition of the quicklime from which it was derived as well as the method of hydration. There are three types of hydrated lime:

1. *High calcium hydrate*
   Derived from a high calcium quicklime, containing 68 to 74 percent calcium oxide and 23 to 24 percent water in chemical combination with the calcium oxide. The correct name for this product is calcium hydroxide.

   $$CaO + H_2O \rightarrow Ca(OH)_2 + \text{Heat}$$

   High calcium hydrate

2. *Type N Dolomitic hydrate*
   A Dolomitic quicklime will produce a Dolomitic hydrate. Under normal atmospheric pressure, the calcium oxide fraction of the Dolomitic quicklime completely hydrates, whereas only a small amount (5 to 20%) of the magnesium oxides hydrates. The composition of a typical or Type N Dolomitic hydrate will be about 46 to 48% CaO, 33 to 34% MgO and 15 to 17% H_2O in a chemical combination with the calcium oxide.

   $$CaO \,.\, MgO + H_2O \text{ @ 1 atm pressure} \rightarrow Ca(OH)_2 \,.\, MgO + \text{Heat}$$

   Type N dolomitic hydrate

3. *Type S Dolomitic hydrate.*
   A dolomitic lime that has been hydrated under pressure. The pressure hydration results in almost all (>92%) of the oxides being hydrated.

   $$CaO \,.\, MgO + 2H_2O \rightarrow Ca(OH)_2 \,.\, Mg(OH)_2 + \text{Heat}$$

   Type S dolomitic hydrate

Hydrated lime is less caustic than quicklime but still highly alkaline.

In general, hydrated lime is used in the HDS treatment process, because it does not require slaking prior to use. However, in the quantities required for Faro, it would not be economic to transport hydrated lime from the supplier to the mine site.

Slaked Lime

The term "slaking" applies to the process of combining varying proportions of water and quicklime to yield widely varying degrees of consistency. In the lime industry, the term "hydration" refers to the production of a dry, finely powdered, hydrated lime. Less water is used in commercial hydration than in slaking. Slaking results in the generation of heat and requires accurate control to ensure a consistent, reactive product is generated. Poor slaking can lead to low reagent inefficiencies (i.e. that not all of the quicklime is converted and chemically available for reaction).

In general, hydrated lime is dry product produced by commercial operators whereas slaked lime is a slurry or paste that is produced on-site by the consumer from quicklime. Slaked lime is less caustic than quicklime and hydrated lime but is still highly alkaline.

Limestone

Limestone is a naturally occurring calcite ($CaCO_3$) that is the raw ingredient for the manufacture of quicklime and hydrated lime. In addition, the limestone rock often contains $MgCO_3$, (referred to as dolomite) which is less reactive than calcite. Also, neutralization by dolomite results in high dissolved solids concentrations because the magnesium sulphate that is formed is more soluble than calcium sulphate (or gypsum). (Note that dolomite, when converted to quicklime, is significantly less effective for water treatment because the magnesium results in a higher dissolved solids in the treated effluent and it precipitates as a hydroxide at lower pH than calcium.). Therefore the local limestone sources would need to have low magnesium ($MgCO_3$) content to be useable.

It is less reactive that quicklime and hydrated lime and has the capacity to increase pH to about 8.3.

In the context of the requirements for Faro, raw limestone alone would not be sufficient to meet the needs of the closure program, however limestone used in conjunction with either quicklime or hydrated lime may meet the requirements.

Appendix B
Economic Analysis

Economica Analysis - Option 1 / Scenario A

	Units	Total or Avg	Closure (Yr 1 - 15) Relocation	Closure (Yr 1 - 15) Water Treat	Post Closure (Yr 16 - 35) Relocation	Post Closure (Yr 16 - 35) Water Treat
Option 1 - Quicklime Supplied (No calcining)						
Scenario A - Minimum Requirements						
100% Quicklime (Purchased)						
No Limestone Mining (therefore no calcining)						
Quantities						
Limestone	t	-	-	-	-	-
Quicklime	t	215,000	3,600	4,600	-	4,600
Operating Costs						
Limestone Mining & Hauling	$/t		-	-	-	-
Limestone Crushing	$/t		-	-	-	-
Quicklime	$/t		350	350	350	350
Slaking	$/t		-	10	-	10
Limestone Mining & Hauling	$000's					
Limestone Crushing	$000's					
Quicklime	$000's		1,260	1,610		1,610
Slaking	$000's			46		46
Operating Costs	**$000's**		**1,260**	**1,656**	**-**	**1,656**
	$/t		350	360	-	360
Capital Costs						
…	$000's					
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**1,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	52,605	15,042	20,989	-	16,574
Limestone (Relocations) & Quicklime (Water Treatment)						
Single Phase "Rapid" Mining (5,000 t/d) - Crushing as req'd						
Quantities						
Limestone	t	108,000	7,200		-	
Quicklime	t	161,000		4,600		4,600
Operating Costs						
Limestone Mining & Hauling	$/t		20		20	
Limestone Crushing	$/t		7		7	
Quicklime	$/t			350		350
Slaking	$/t			10		10
Limestone Mining & Hauling	$000's		144	-	-	-
Limestone Crushing	$000's		50	-	-	-
Quicklime	$000's		-	1,610	-	1,610
Slaking	$000's			46		46
Operating Costs	**$000's**		**194**	**1,656**	**-**	**1,656**
	$/t		27	360	-	360
Capital Costs						
…	$000's					
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**1,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	39,884	2,321	20,989	-	16,574
Single Phase "Slow" Mining (~500 t/d) - Crushing as req'd						
Quantities						
Limestone	t	108,000	7,200		-	
Quicklime	t	161,000		4,600		4,600
Operating Costs						
Limestone Mining & Hauling	$/t		40		40	
Limestone Crushing	$/t		7		7	
Quicklime	$/t			350		350
Slaking	$/t			10		10
Limestone Mining & Hauling	$000's		288	-	-	-
Limestone Crushing	$000's		50	-	-	-
Quicklime	$000's		-	1,610	-	1,610
Slaking	$000's			46		46
Operating Costs	**$000's**		**338**	**1,656**	**-**	**1,656**
	$/t		47	360	-	360
Capital Costs						
…	$000's					
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**1,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	41,603	4,040	20,989	-	16,574

Economica Analysis - Option 1 / Scenario B

	Units	Total or Avg	Closure (Yr 1 - 15) Relocation	Closure (Yr 1 - 15) Water Treat	Post Closure (Yr 16 - 35) Relocation	Post Closure (Yr 16 - 35) Water Treat
Option 1 - Quicklime Supplied (No calcining)						
Scenario B - Maximum Requirements						
100% Quicklime (Purchased)						
No Limestone Mining						
Quantities						
Limestone	t	-	-	-	-	-
Quicklime	t	577,000	31,000	3,200	-	3,200
Operating Costs						
Limestone Mining & Hauling	$/t		-	-	-	-
Limestone Crushing	$/t		-	-	-	-
Quicklime	$/t		350	350		350
Slaking	$/t		-	10	-	10
Limestone Mining & Hauling	$000's					
Limestone Crushing	$000's					
Quicklime	$000's		10,850	1,120		1,120
Slaking	$000's			32		32
Operating Costs	**$000's**		**10,850**	**1,152**	**-**	**1,152**
	$/t		350	360	-	360
Capital Costs						
…	$000's					
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**1,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	156,260	129,527	14,973	-	11,761
Limestone (Relocations) & Quicklime (Water Treatment)						
Single Phase "Rapid" Mining (5,000 t/d) - Crushing as req'd						
Quantities						
Limestone	t	930,000	62,000		-	
Quicklime	t	112,000		3,200		3,200
Operating Costs						
Limestone Mining & Hauling	$/t		20		20	
Limestone Crushing	$/t		7		7	
Quicklime	$/t			350		350
Slaking	$/t			10		10
Limestone Mining & Hauling	$000's		1,240	-	-	-
Limestone Crushing	$000's		434	-	-	-
Quicklime	$000's		-	1,120	-	1,120
Slaking	$000's			32		32
Operating Costs	**$000's**		**1,674**	**1,152**	**-**	**1,152**
	$/t		27	360	-	360
Capital Costs						
…	$000's					
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**1,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	46,718	19,984	14,973	-	11,761
Single Phase "Slow" Mining (~500 t/d) - Crushing as req'd						
Quantities						
Limestone	t	930,000	62,000		-	
Quicklime	t	112,000		3,200		3,200
Operating Costs						
Limestone Mining	$/t		40		40	
Limestone Crushing	$/t		7		7	
Quicklime	$/t			350		350
Slaking	$/t			10		10
Limestone Mining	$000's		2,480	-	-	-
Limestone Crushing	$000's		434	-	-	-
Quicklime	$000's		-	1,120	-	1,120
Slaking	$000's			32		32
Operating Costs	**$000's**		**2,914**	**1,152**	**-**	**1,152**
	$/t		47	360	-	360
Capital Costs						
…	$000's					
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**1,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	61,521	34,787	14,973	-	11,761

Economica Analysis - Option 2 / Scenario A

	Units	Total or Avg	Closure (Yr 1 - 15) Relocation	Closure (Yr 1 - 15) Water Treat	Post Closure (Yr 16 - 35) Relocation	Post Closure (Yr 16 - 35) Water Treat
Option 2 - Calcining Plant - Propane						
Scenario A - Minimum Requirements						
100% Quicklime (Purchased)						
No Limestone Mining (threfore no calcining)						
Quantities						
Limestone	t	-	-	-	-	-
Quicklime	t	215,000	3,600	4,600	-	4,600
Operating Costs						
Limestone Mining & Hauling	$/t		-	-	-	-
Limestone Crushing	$/t		-	-	-	-
Quicklime	$/t		350	350	350	350
Slaking	$/t		-	10	-	10
Limestone Mining & Hauling	$000's					
Limestone Crushing	$000's					
Quicklime	$000's		1,260	1,610		1,610
Slaking	$000's			46		46
Operating Costs	**$000's**		**1,260**	**1,656**	**-**	**1,656**
	$/t		350	360	-	360
Capital Costs						
…	$000's					
Calcining Plant	$000's			-		
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**1,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	52,605	15,042	20,989	-	16,574
Limestone (Relocations) & Quicklime (Water Treatment)						
Single Phase "Rapid" Mining (5,000 t/d) - Crushing as req'd						
Quantities						
Limestone	t	108,000	7,200		-	
Quicklime	t	161,000		4,600		4,600
Operating Costs						
Limestone Mining & Hauling	$/t		20		20	
Limestone Crushing	$/t		7		7	
Quicklime - Calcining Plant	$/t		728	728	728	728
Slaking	$/t			10		10
Limestone Mining & Hauling	$000's		144	-	-	-
Limestone Crushing	$000's		50	-	-	-
Quicklime - Calcining Plant	$000's		-	3,351	-	3,351
Slaking	$000's			46		46
Operating Costs	**$000's**		**194**	**3,397**	**-**	**3,397**
	$/t		27	738	-	738
Capital Costs						
…	$000's					
Quicklime - Calcining Plant	$000's			8,000		
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**9,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	85,285	2,321	49,769	-	33,196
Single Phase "Slow" Mining (~500 t/d) - Crushing as req'd						
Quantities						
Limestone	t	108,000	7,200		-	
Quicklime	t	161,000		4,600		4,600
Operating Costs						
Limestone Mining & Hauling	$/t		40		40	
Limestone Crushing	$/t		7		7	
Quicklime - Calcining Plant	$/t		728	728	728	728
Slaking	$/t			10		10
Limestone Mining & Hauling	$000's		288	-	-	-
Limestone Crushing	$000's		50	-	-	-
Quicklime - Calcining Plant	$000's		-	3,351	-	3,351
Slaking	$000's			46		46
Operating Costs	**$000's**		**338**	**3,397**	**-**	**3,397**
	$/t		47	738	-	738
Capital Costs						
…	$000's					
Quicklime - Calcining Plant	$000's			8,000		
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**9,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	87,004	4,040	49,769	-	33,196

Economica Analysis - Option 2 / Scenario B

	Units	Total or Avg	Closure (Yr 1 - 15) Relocation	Closure (Yr 1 - 15) Water Treat	Post Closure (Yr 16 - 35) Relocation	Post Closure (Yr 16 - 35) Water Treat
Option 2 - Calcining Plant - Propane						
Scenario B - Maximum Requirements						
100% Quicklime (Purchased)						
No Limestone Mining (threfore no calcining)						
Quantities						
Limestone	t	-	-	-	-	-
Quicklime	t	577,000	31,000	3,200	-	3,200
Operating Costs						
Limestone Mining & Hauling	$/t		-	-	-	-
Limestone Crushing	$/t		-	-	-	-
Quicklime	$/t		350	350		350
Slaking	$/t		-	10	-	10
Limestone Mining & Hauling	$000's					
Limestone Crushing	$000's					
Quicklime	$000's		10,850	1,120		1,120
Slaking	$000's			32		32
Operating Costs	**$000's**		**10,850**	**1,152**	**-**	**1,152**
	$/t		350	360	-	360
Capital Costs						
…	$000's					
Quicklime - Calcining Plant	$000's					
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**1,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	156,260	129,527	14,973	-	11,761
Limestone (Relocations) & Quicklime (Water Treatment)						
Single Phase "Rapid" Mining (5,000 t/d) - Crushing as req'd						
Quantities						
Limestone	t	930,000	62,000		-	
Quicklime	t	112,000		3,200		3,200
Operating Costs						
Limestone Mining & Hauling	$/t		20		20	
Limestone Crushing	$/t		7		7	
Quicklime - Calcining Plant	$/t		479	479	479	479
Slaking	$/t			10		10
Limestone Mining & Hauling	$000's		1,240	-	-	-
Limestone Crushing	$000's		434	-	-	-
Quicklime - Calcining Plant	$000's		-	1,534	-	1,534
Slaking	$000's			32		32
Operating Costs	**$000's**		**1,674**	**1,566**	**-**	**1,566**
	$/t		27	489	-	489
Capital Costs						
…	$000's					
Quicklime - Calcining Plant	$000's			11,000		
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**12,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	66,609	19,984	30,913	-	15,713
Single Phase "Slow" Mining (~500 t/d) - Crushing as req'd						
Quantities						
Limestone	t	930,000	62,000		-	
Quicklime	t	112,000		3,200		3,200
Operating Costs						
Limestone Mining	$/t		40		40	
Limestone Crushing	$/t		7		7	
Quicklime - Calcining Plant	$/t		479	479	479	479
Slaking	$/t			10		10
Limestone Mining	$000's		2,480	-	-	-
Limestone Crushing	$000's		434	-	-	-
Quicklime - Calcining Plant	$000's		-	1,534	-	1,534
Slaking	$000's			32		32
Operating Costs	**$000's**		**2,914**	**1,566**	**-**	**1,566**
	$/t		47	489	-	489
Capital Costs						
…	$000's					
Quicklime - Calcining Plant	$000's			11,000		
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**12,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	81,412	34,787	30,913	-	15,713

Economica Analysis - Option 3 / Scenario A

	Units	Total or Avg	Closure (Yr 1 - 15) Relocation	Closure (Yr 1 - 15) Water Treat	Post Closure (Yr 16 - 35) Relocation	Post Closure (Yr 16 - 35) Water Treat
Option 3 - Calcining Plant - Coal						
Scenario A - Minimum Requirements						
100% Quicklime (Calcined Locally)						
Single Phase "Rapid" Mining (5,000 t/d) - Crushing as req'd						
Quantities						
Limestone	t	430,000	7,200	9,200	-	9,200
Quicklime	t	215,000	3,600	4,600	-	4,600
Operating Costs						
Limestone Mining & Hauling	$/t		20		20	
Limestone Crushing	$/t		7		7	
Quicklime - Calcining Plant	$/t		72	72	72	72
Slaking	$/t		-	10	-	10
Limestone Mining & Hauling	$000's		144	-	-	-
Limestone Crushing	$000's		50	-	-	-
Quicklime - Calcining Plant	$000's		261	333	-	333
Slaking	$000's			46		46
Operating Costs	**$000's**		**455**	**379**	**-**	**379**
	$/t		63	82	-	82
Capital Costs						
…	$000's					
Calcining Plant	$000's			8,000		
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**9,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	23,565	5,435	13,748	-	4,382
Single Phase "Slow" Mining (~500 t/d) - Crushing as req'd						
Quantities						
Limestone	t	430,000	7,200	9,200	-	9,200
Quicklime	t	215,000	3,600	4,600	-	4,600
Operating Costs						
Limestone Mining & Hauling	$/t		40		40	
Limestone Crushing	$/t		7		7	
Quicklime - Calcining Plant	$/t		72	72	72	72
Slaking	$/t			10		10
Limestone Mining & Hauling	$000's		288	-	-	-
Limestone Crushing	$000's		50	-	-	-
Quicklime - Calcining Plant	$000's		261	333	-	333
Slaking	$000's			46		46
Operating Costs	**$000's**		**599**	**379**	**-**	**379**
	$/t		83	82	-	82
Capital Costs						
…	$000's					
Quicklime - Calcining Plant	$000's			8,000		
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**9,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	25,284	7,154	13,748	-	4,382
Limestone (Relocations) & Quicklime (Water Treatment)						
Single Phase "Rapid" Mining (5,000 t/d) - Crushing as req'd						
Quantities						
Limestone	t	108,000	7,200		-	
Quicklime	t	161,000		4,600		4,600
Operating Costs						
Limestone Mining & Hauling	$/t		20		20	
Limestone Crushing	$/t		7		7	
Quicklime - Calcining Plant	$/t		72	72	72	72
Slaking	$/t			10		10
Limestone Mining & Hauling	$000's		144	-	-	-
Limestone Crushing	$000's		50	-	-	-
Quicklime - Calcining Plant	$000's		-	333	-	333
Slaking	$000's			46		46
Operating Costs	**$000's**		**194**	**379**	**-**	**379**
	$/t		27	82	-	82
Capital Costs						
…	$000's					
Quicklime - Calcining Plant	$000's			8,000		
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**9,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	20,451	2,321	13,748	-	4,382
Single Phase "Slow" Mining (~500 t/d) - Crushing as req'd						
Quantities						
Limestone	t	108,000	7,200		-	
Quicklime	t	161,000		4,600		4,600
Operating Costs						
Limestone Mining & Hauling	$/t		40		40	
Limestone Crushing	$/t		7		7	
Quicklime - Calcining Plant	$/t		72	72	72	72
Slaking	$/t			10		10
Limestone Mining & Hauling	$000's		288	-	-	-
Limestone Crushing	$000's		50	-	-	-
Quicklime - Calcining Plant	$000's		-	333	-	333
Slaking	$000's			46		46
Operating Costs	**$000's**		**338**	**379**	**-**	**379**
	$/t		47	82	-	82
Capital Costs						
…	$000's					
Quicklime - Calcining Plant	$000's			8,000		
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**9,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	22,170	4,040	13,748	-	4,382

Economica Analysis - Option 3 / Scenario B

	Units	Total or Avg	Closure (Yr 1 - 15) Relocation	Closure (Yr 1 - 15) Water Treat	Post Closure (Yr 16 - 35) Relocation	Post Closure (Yr 16 - 35) Water Treat
Option 3 - Calcining Plant - Coal						
Scenario B - Maximum Requirements						
100% Quicklime (Calcined Locally)						
Single Phase "Rapid" Mining (5,000 t/d) - Crushing as req'd						
Quantities						
Limestone	t	1,154,000	62,000	6,400	-	6,400
Quicklime	t	577,000	31,000	3,200	-	3,200
Operating Costs						
Limestone Mining & Hauling	$/t		20		20	
Limestone Crushing	$/t		7		7	
Quicklime	$/t		44	44	44	44
Slaking	$/t		-	10	-	10
Limestone Mining & Hauling	$000's		1,240	-	-	-
Limestone Crushing	$000's		434	-	-	-
Quicklime	$000's		1,355	140		140
Slaking	$000's			32		32
Operating Costs	**$000's**		**3,029**	**172**	**-**	**172**
	$/t		98	54	-	54
Capital Costs						
…	$000's					
Quicklime - Calcining Plant	$000's					
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**1,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	41,833	36,160	3,272	-	2,401

	Units	Total or Avg	Closure Relocation	Closure Water Treat	Post Closure Relocation	Post Closure Water Treat
Single Phase "Slow" Mining (~500 t/d) - Crushing as req'd						
Quantities						
Limestone	t	1,154,000	62,000	6,400	-	6,400
Quicklime	t	577,000	31,000	3,200	-	3,200
Operating Costs						
Limestone Mining & Hauling	$/t		40		40	
Limestone Crushing	$/t		7		7	
Quicklime	$/t		44	44	44	44
Slaking	$/t			10		10
Limestone Mining & Hauling	$000's		2,480	-	-	-
Limestone Crushing	$000's		434	-	-	-
Quicklime	$000's		1,355	140		140
Slaking	$000's			32		32
Operating Costs	**$000's**		**4,269**	**172**	**-**	**172**
	$/t		138	54	-	54
Capital Costs						
…	$000's					
Quicklime - Calcining Plant	$000's					
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**1,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	56,636	50,963	3,272	-	2,401

	Units	Total or Avg	Closure Relocation	Closure Water Treat	Post Closure Relocation	Post Closure Water Treat
Limestone (Relocations) & Quicklime (Water Treatment)						
Single Phase "Rapid" Mining (5,000 t/d) - Crushing as req'd						
Quantities						
Limestone	t	930,000	62,000		-	
Quicklime	t	112,000		3,200		3,200
Operating Costs						
Limestone Mining & Hauling	$/t		20		20	
Limestone Crushing	$/t		7		7	
Quicklime - Calcining Plant	$/t		44	44	44	44
Slaking	$/t			10		10
Limestone Mining & Hauling	$000's		1,240	-	-	-
Limestone Crushing	$000's		434	-	-	-
Quicklime - Calcining Plant	$000's		-	140	-	140
Slaking	$000's			32		32
Operating Costs	**$000's**		**1,674**	**172**	**-**	**172**
	$/t		27	54	-	54
Capital Costs						
…	$000's					
Quicklime - Calcining Plant	$000's			11,000		
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**12,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	36,657	19,984	14,272	-	2,401

	Units	Total or Avg	Closure Relocation	Closure Water Treat	Post Closure Relocation	Post Closure Water Treat
Single Phase "Slow" Mining (~500 t/d) - Crushing as req'd						
Quantities						
Limestone	t	930,000	62,000		-	
Quicklime	t	112,000		3,200		3,200
Operating Costs						
Limestone Mining	$/t		40		40	
Limestone Crushing	$/t		7		7	
Quicklime - Calcining Plant	$/t		44	44	44	44
Slaking	$/t			10		10
Limestone Mining	$000's		2,480	-	-	-
Limestone Crushing	$000's		434	-	-	-
Quicklime - Calcining Plant	$000's		-	140	-	140
Slaking	$000's			32		32
Operating Costs	**$000's**		**2,914**	**172**	**-**	**172**
	$/t		47	54	-	54
Capital Costs						
…	$000's					
Quicklime - Calcining Plant	$000's			11,000		
Slaking Plant	$000's			1,220		1,220
Capital Costs	**$000's**		**-**	**12,220**	**-**	**1,220**
Timeline						
Period	years		15	15	20	20
NPV	3%	51,460	34,787	14,272	-	2,401